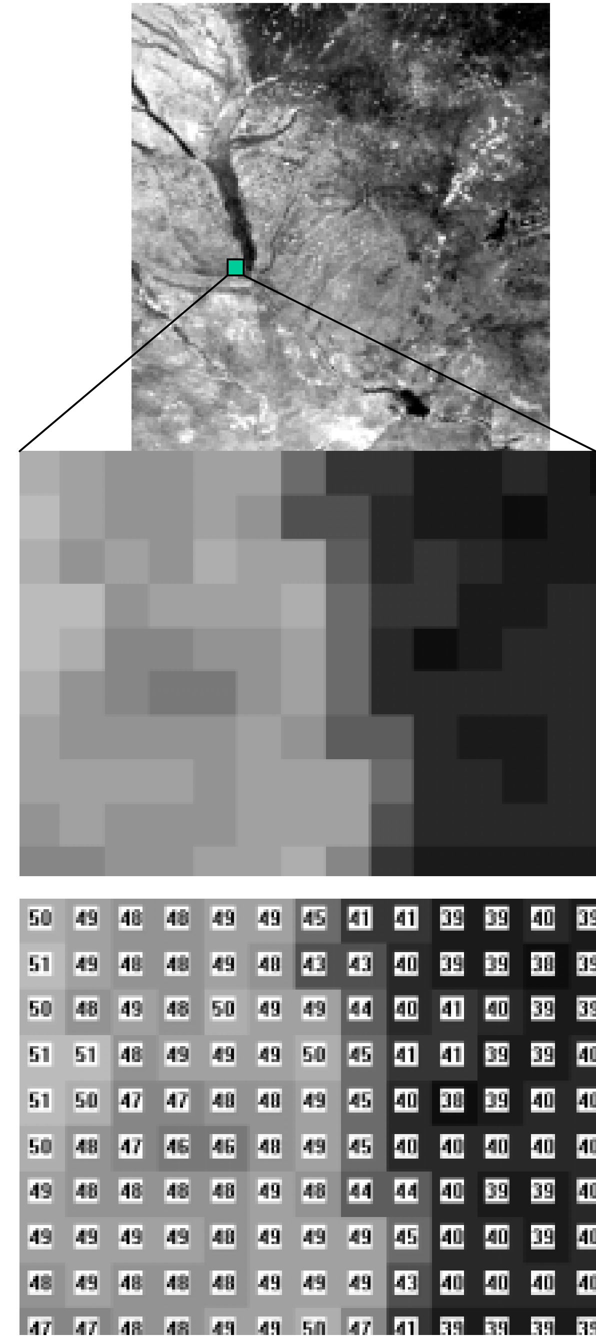
Basics of image processing

What will you learn?

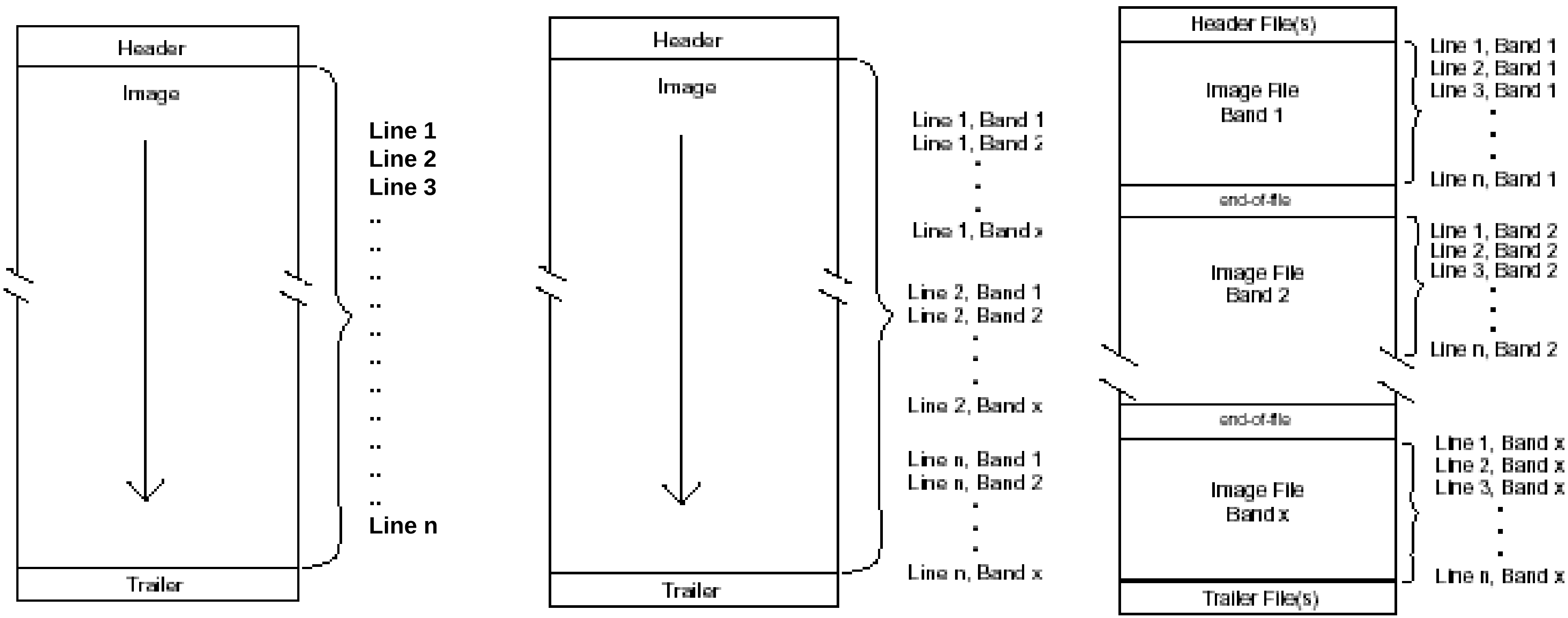
- importing image data to your RS processing/GIS software
- radiometric image correction
- geometric image correction (georeferencing and geo-coding)
- basic image enhancement
  - contrast enhancement
  - spatial enhancement
- single band image classification
  - density slicing

RS data characteristics

- RS data are not photos - they are images at best
- each image element (pixel) is described by a meaningful digital number (DN)
- DN reflects radiation value measured by a radiometer
- data files are binary, i.e. we cannot see DNs using a normal ASCII file editor
- DN for a single pixel can be written using 8 to 24 bits depending on range of DNs obtained from the radiometer
- we do image processing on DNs, but “translate” them into colors for visual interpretation
- RS data comes in various formats, not always compatible with the format your RS processing software uses



RS data formats



single band file

BIL
(band interleaved by line)

BSQ
(band sequential)

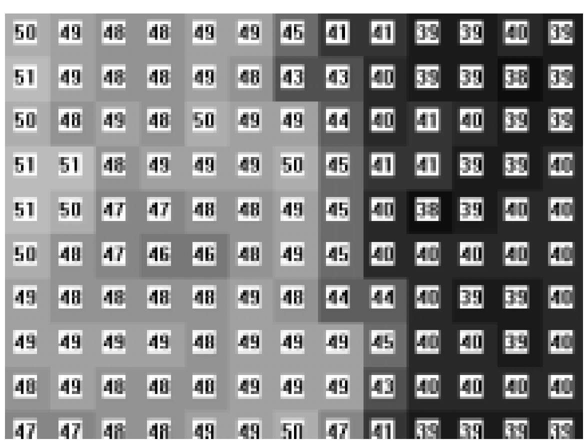
Usually, there are sequential pixel data only.
No information on row and column, no information when row changes.
Header is sometimes an independent file.

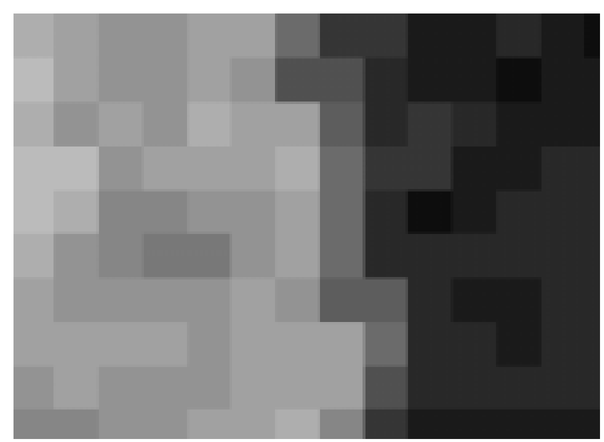
Importing RS data

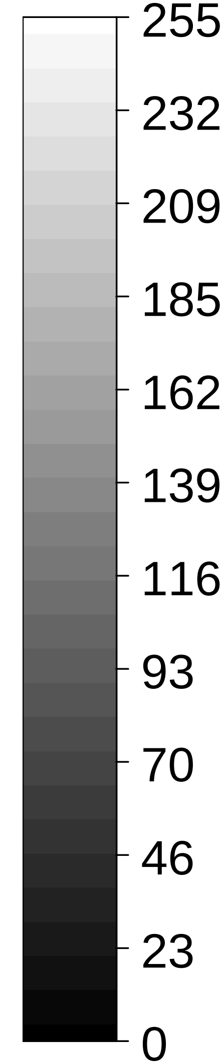
- **importing usually done by build in filters**
  - if we know the raw file format, and if there is a proper filter in our RS software
- **importing single band general raster**
  - you have to know: number of rows, number of columns, number of bytes per pixel
  - best check: nrow * ncol * nbytes per pixel = size of the file in bytes
- **importing multiple band general raster**
  - have to know: number of rows, number of columns, number of bytes per pixel, number of bands, interleaving format
  - best check: nrow * ncol * nbytes per pixel * nbands = size of the file in bytes
  - interleaving formats: BIL (band interleaved by line), BSQ (band sequential), BIP (pixel interleaved)

Displaying RS data

- RS data are Digital Numbers,
- one band is usually written using 1 byte per pixel, i.e. values between 0 and 255
- monitors usually display 256 shades of grey (i.e. different levels of brightness of white)
- In the process of displaying a single band image, brightness of the screen pixel corresponding to the image pixel is adjusted according to its DN value



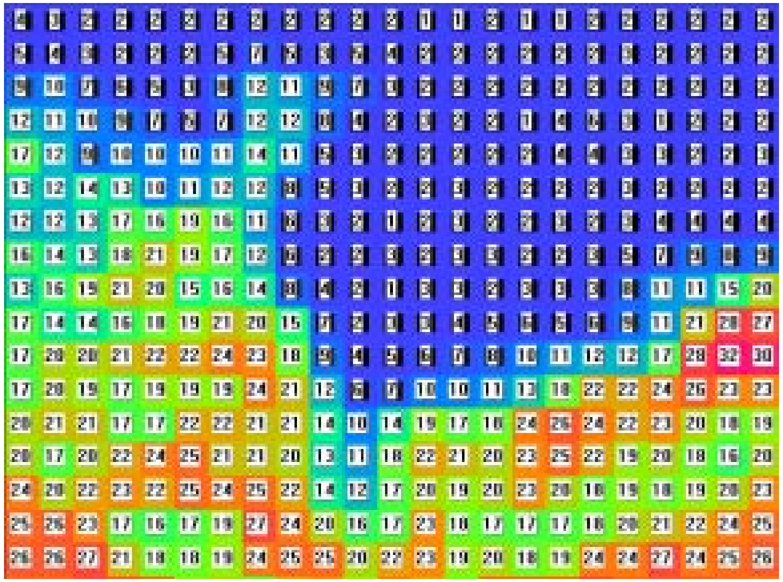


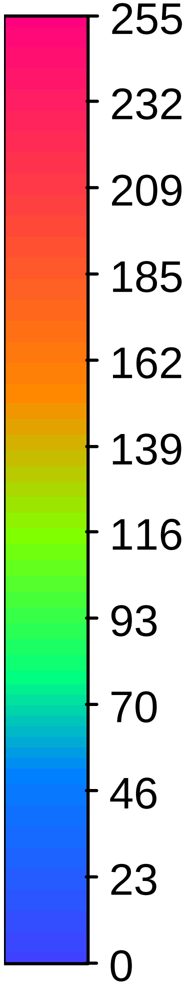


Displaying RS data

- **if DNs have wider range than 0-255, or if different colour scheme than greyscale is to be used - LOOKUP TABLE (or representation) is applied**

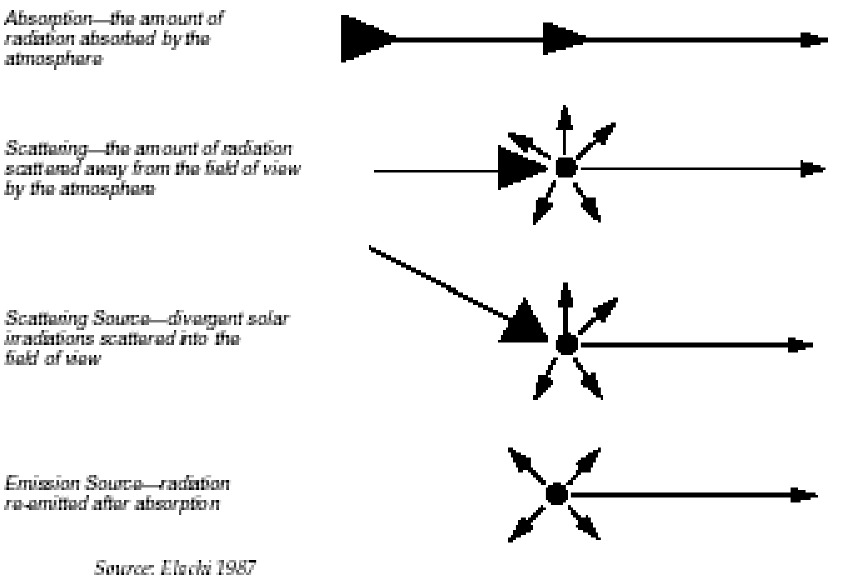
- **Lookup table tells the computer, what colour to use to represent given DN value**





Multiple band images are displayed in a different way. More about it later.

Radiometric corrections



- there is a difference between top of the atmosphere (TOA) radiation and ground level radiation - due to absorption and scattering in the atmosphere

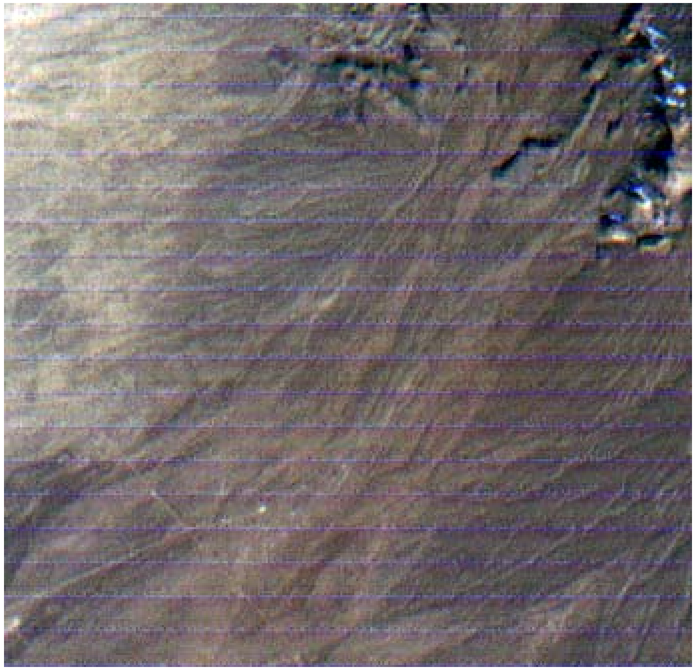
- sensors are sometimes faulty/, what results in dropped lines or pixels

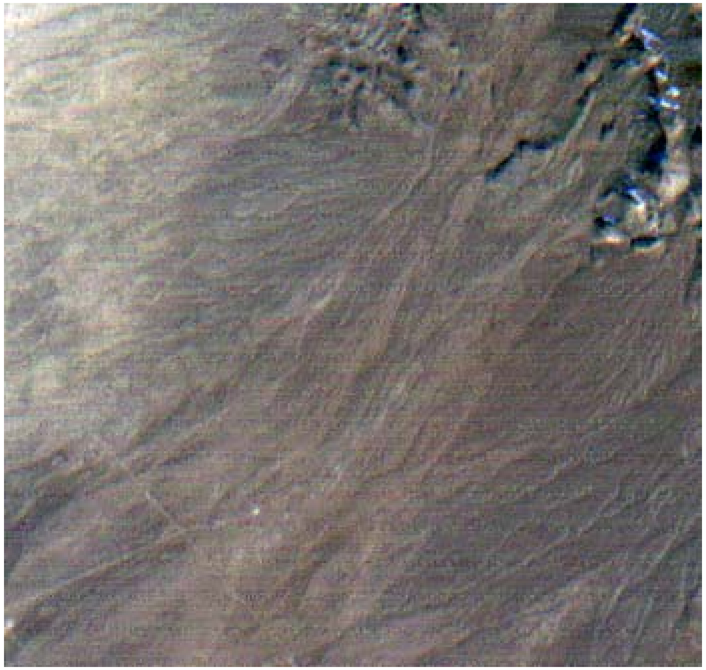
- TM data often exhibits “sixth-line striping” resulting from difference in sensitivities of sensors in the array

radiometric correction procedure eliminates these effects

Radiometric corrections

Striping

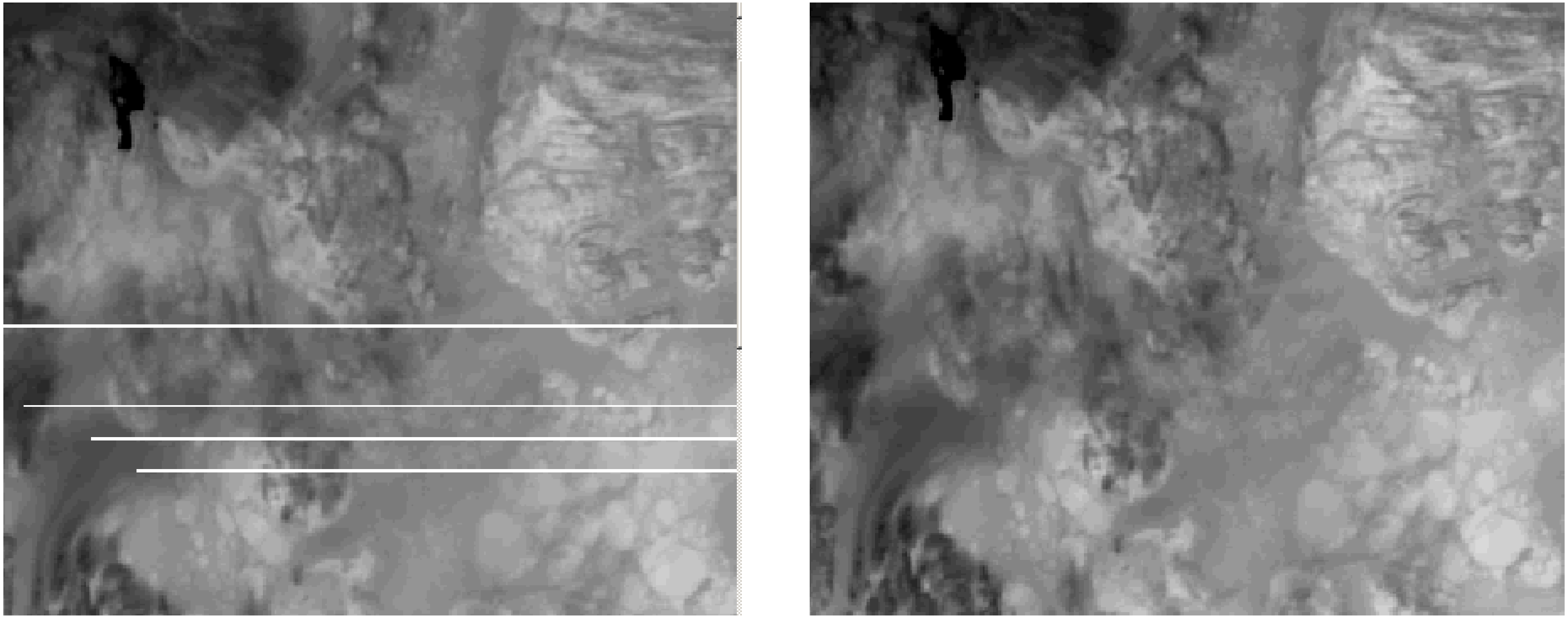




DNs of bad lines are adjusted so as histogram of the bad line matches that of the good lines

Radiometric corrections

Dropped lines



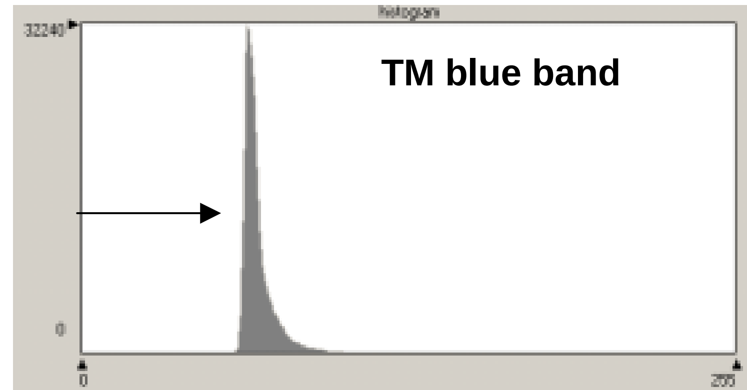
DNs of bad lines are obtained as average of the neighbouring DNs

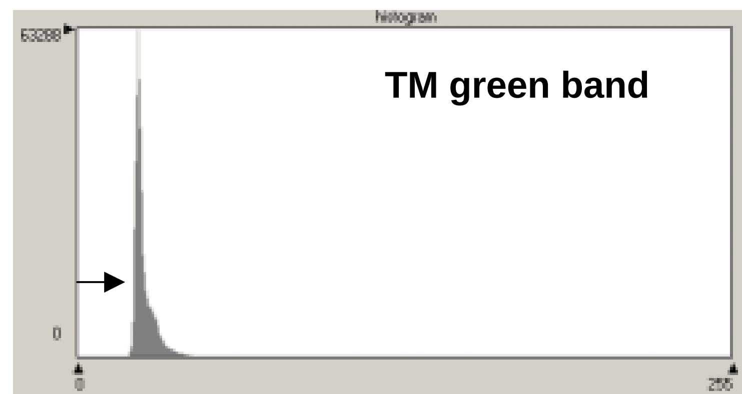
Radiometric corrections

Atmospheric effects correction

Atmospheric scattering causes an addititve effect, i.e. TOA radiation is higher than at ground level

Shorter wavelenghts are affected stronger





Methods

- **dark pixel subtraction**
- **radiance to reflectance conversion**
- **linear regressions between bands**
- **atmospheric modelling**

Important when quantitative calculations are performed, can be ignored for most qualitative applications

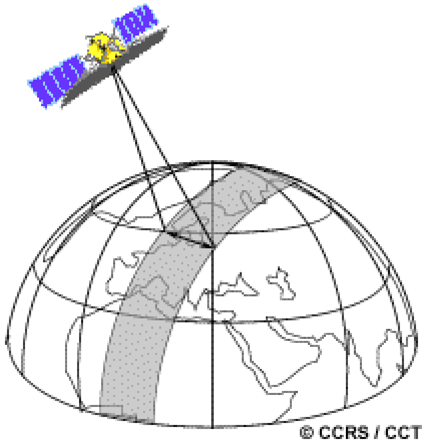
Georeferencing and geometric corrections

- **RS data has geographical meaning (i.e. pixels correspond to a given place on Earth)**
- **geometry of the raw image does correspond neither to the real geometry of the area nor to that used to represent that area in maps**

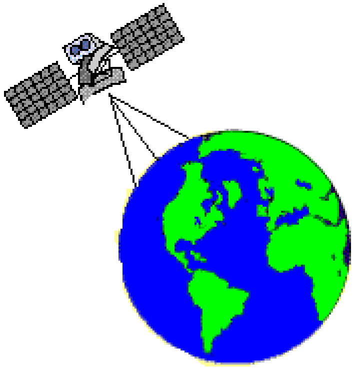
Aim of georeferencing: to make RS data compatible with other spatial data (maps, ground measurements etc.) in a GIS system

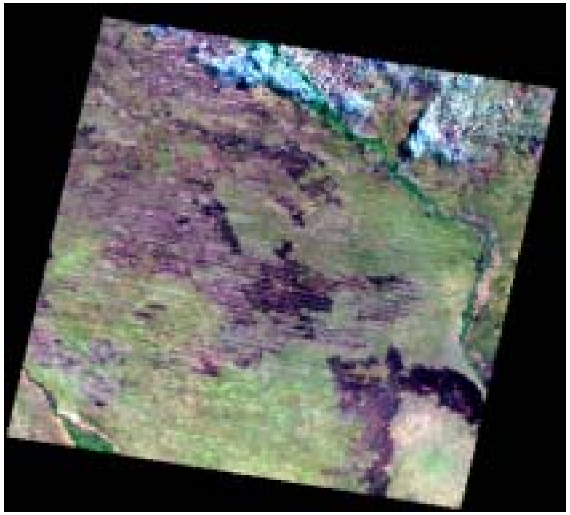
Georeferencing and geometric corrections

- RS data are affected by geometric distortions due to
  - sensor geometry,
  - platform instabilities,
  - earth rotation,
  - earth curvature etc.

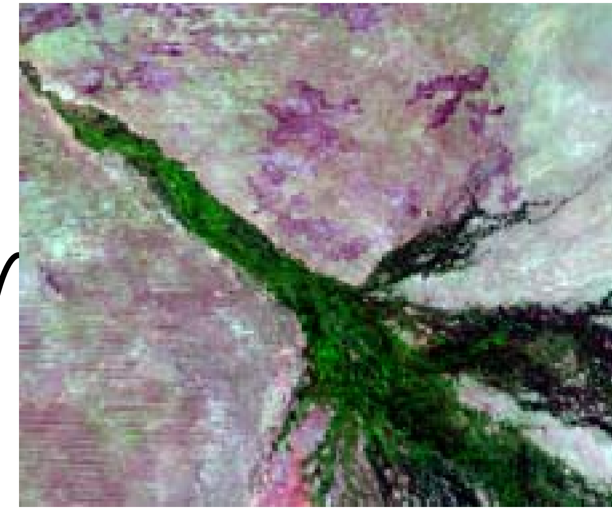


- Some of these distortions are corrected by image supplier, others have to be corrected by referencing images to exisiting maps or other images.

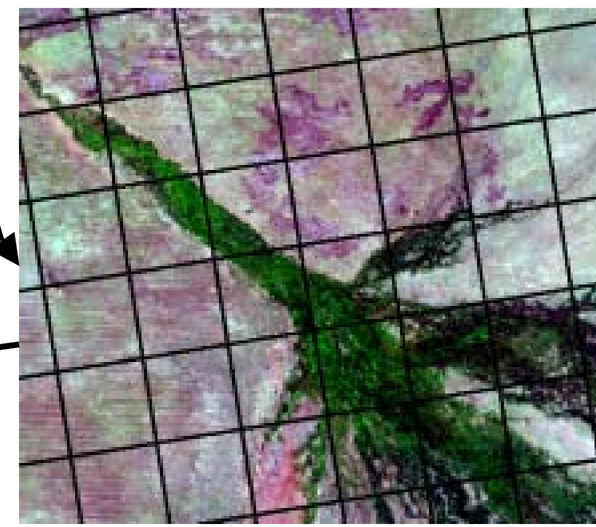


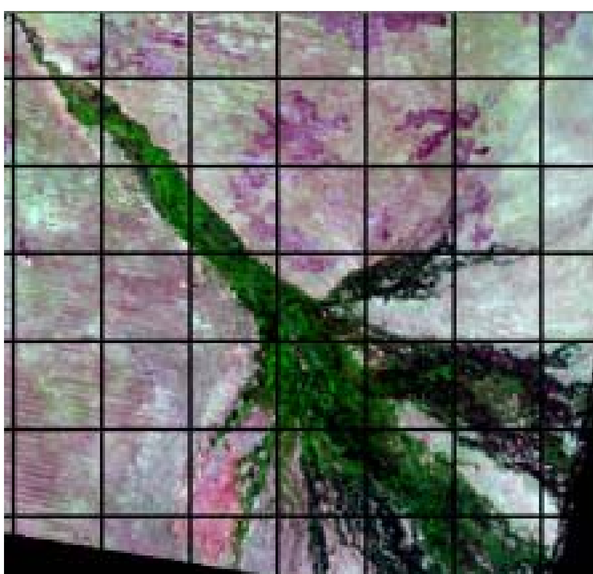


Georeferencing and geometric correction



- **image georeferencing or calibration**
  - defining geographic coordinates without changing the geometry and DNs of the image





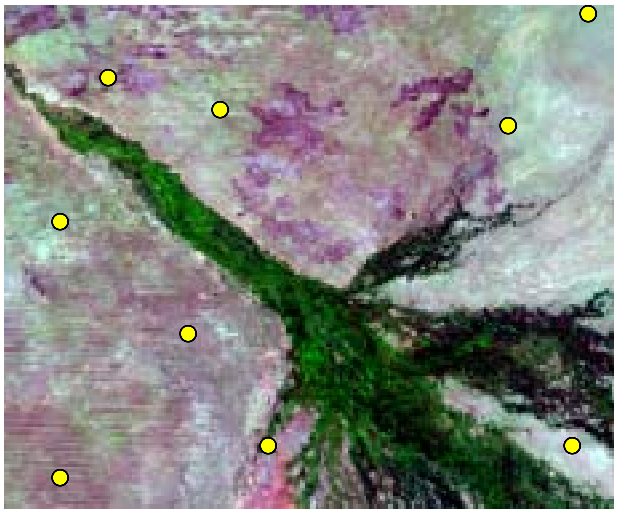
- **image geo-coding or geometric correction**
  - adjusting the geometry of the image to a given geometry, may involve change of DNs

Image georeferencing
(a.k.a calibration, registration, rectification)

defining (geographic) coordinates for each pixel in the image

two steps:

- **attaching coordinates to a few known pixels in the image**
- **defining the formula (coordinate transform) that allows for calculating coordinates for the remaining pixels**



xcoord,ycoord = f(row,col)

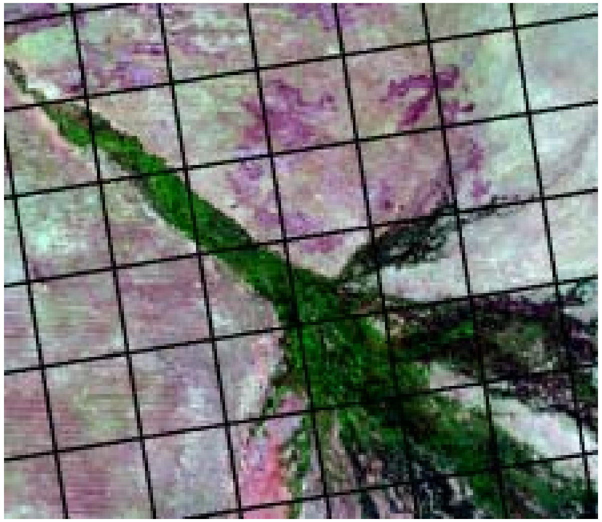


Image georeferencing

(a.k.a calibration, registration, rectification)

<u>**attaching coordinates to a few points in the image**</u>

- **georeferencing corners (linear transformation only)**
  - **coordinates known from satellite position data and geometry of the imaging system, and data has been corrected already for some geometry errors, coordinates of corners often included in image header (e.g. for TM images)**

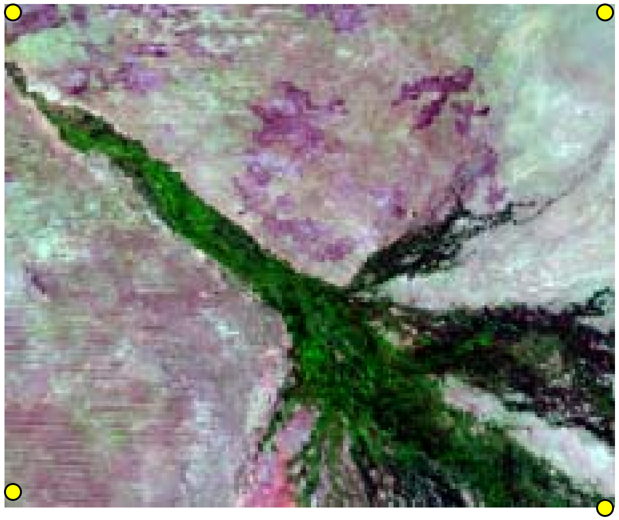
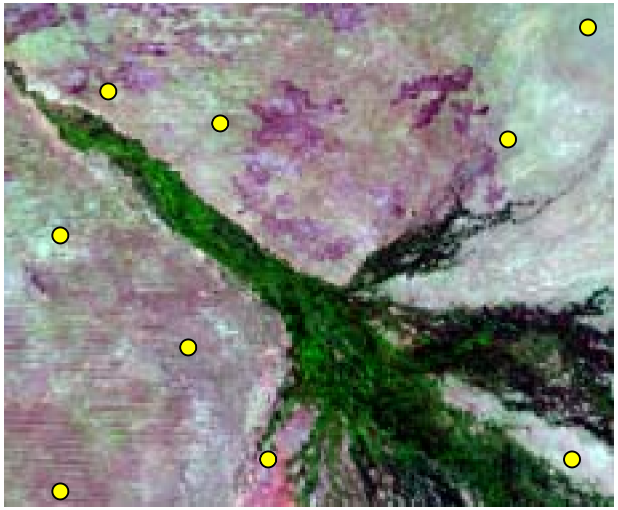


Image georeferencing
(a.k.a calibration, registration, rectification)

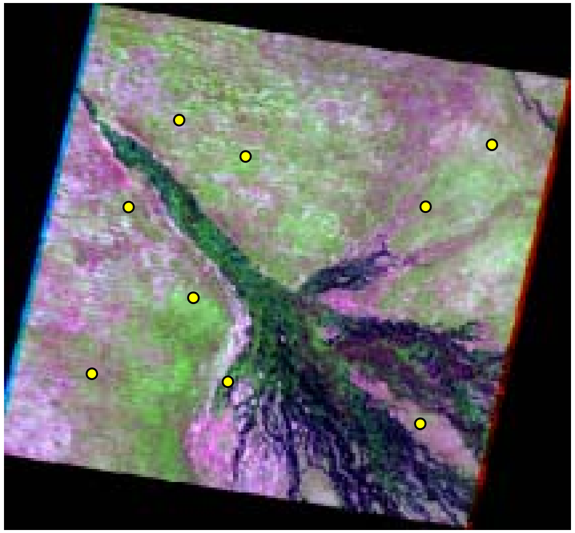
<u>attaching coordinates to a few points in the image</u>

- **georeferencing using ground control points (GCP) (a.k.a image-to-map registration)**
- **georeferencing using image-to-image registration**

raw image



georeferenced image



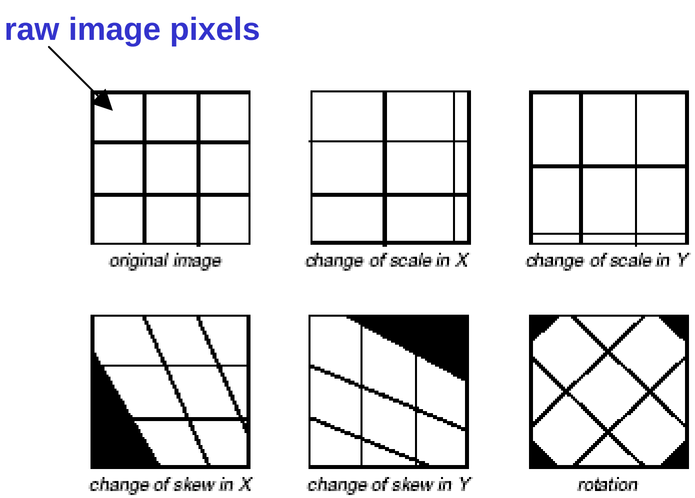
http://glcf.umiacs.umd.edu

tip: GCPs should be distributed evenly throughout the image. For a TM scene - 15-30 points.

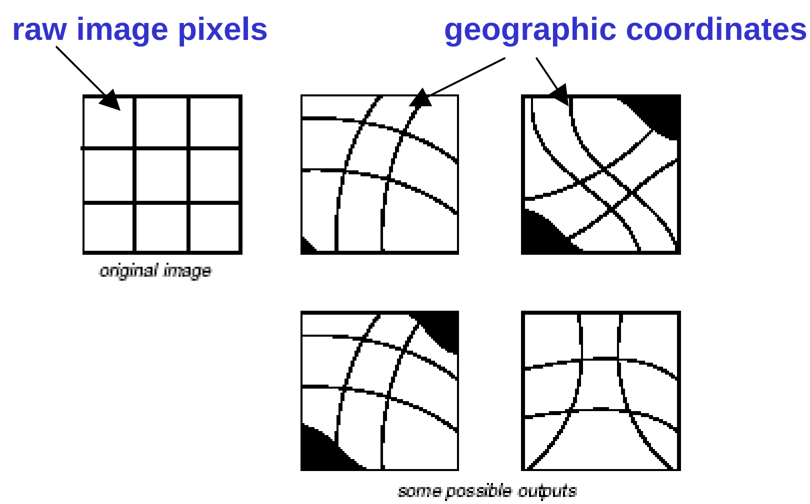
Image georeferencing

Defining the coordinate transform

- **affine (linear):** **xcoord = A * row + B * col + C**
- **polynomial:** **xcoord = A * row² + B * row + C * col² + D * col + E * row * col + F**



affine (linear)

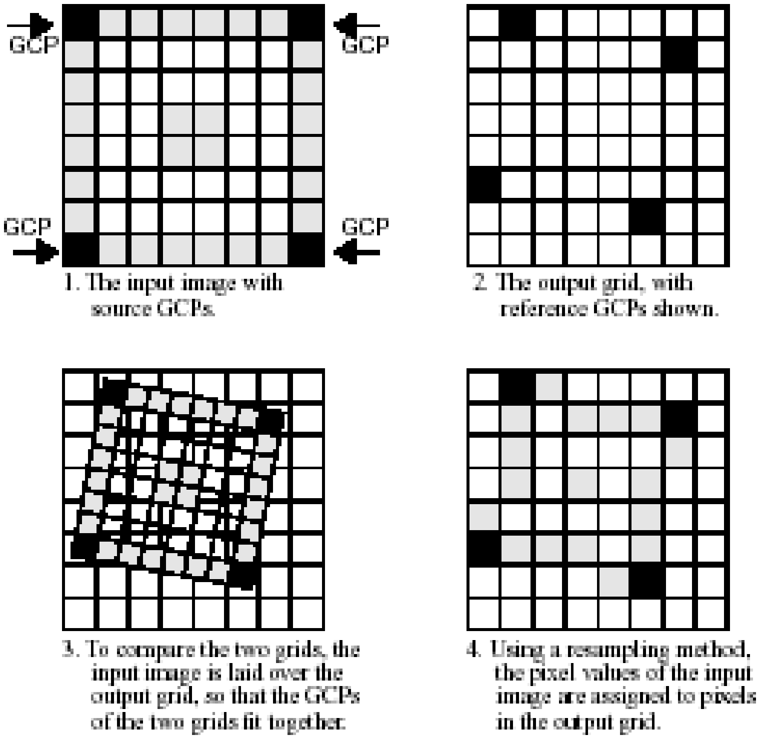


polynomial

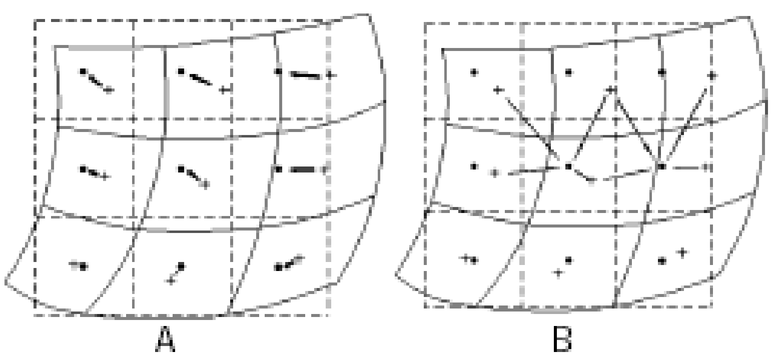
tip: for satellite images - degree not higher than 2, preferably 1

Image geometric correction
(a.k.a geo-coding)

- identification of target grid (pixel size, image extents and projection)
- defining resampling method:
  - nearest neighbour - for images
  - bilinear and bicubic - for DEM data, but not for images, because it changes DNs



1. The input image with source GCPs.
2. The output grid, with reference GCPs shown.
3. To compare the two grids, the input image is laid over the output grid, so that the GCPs of the two grids fit together.
4. Using a resampling method, the pixel values of the input image are assigned to pixels in the output grid.



nearest neighbour bilinear interpolation

Image enhancement

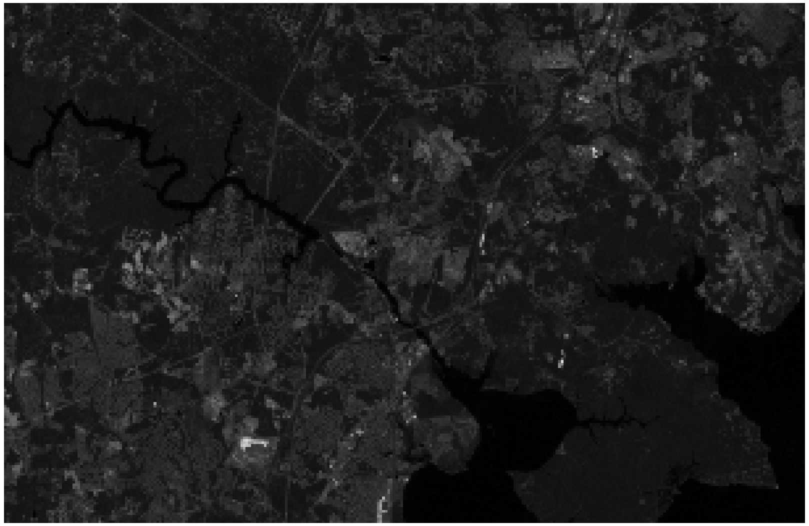
Aim: making an image better interpretable for a particular application

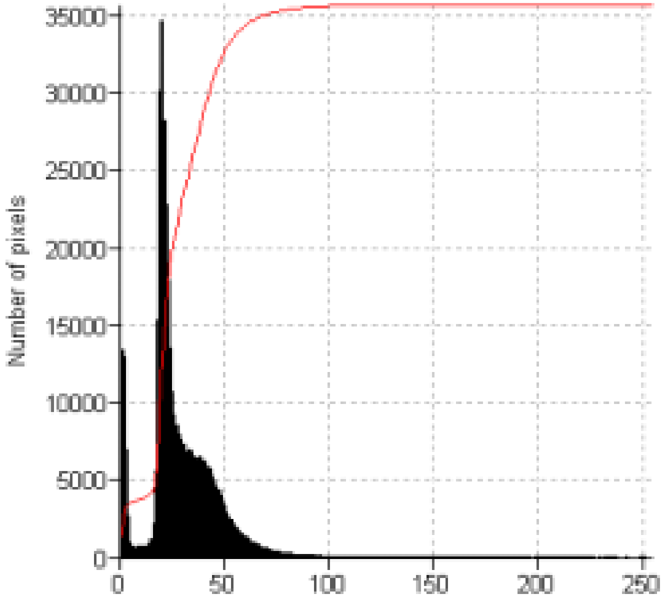
- **contrast enhancement**
  - **linear stretching**
  - **histogram equalization**
  - **piecewise stretching**
- **spatial enhancement**
  - **low pass filter**
  - **high pass filters**
    - **directional filters**
    - **non-directional**

tip: two ways of stretching - for display only (no change in DNs), and in file (DNs change)

Image enhancement - stretching

Raw image





Linear stretch

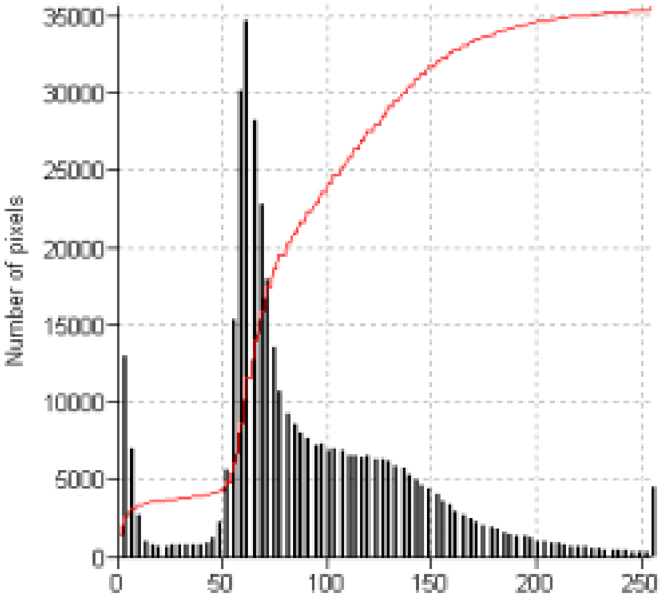
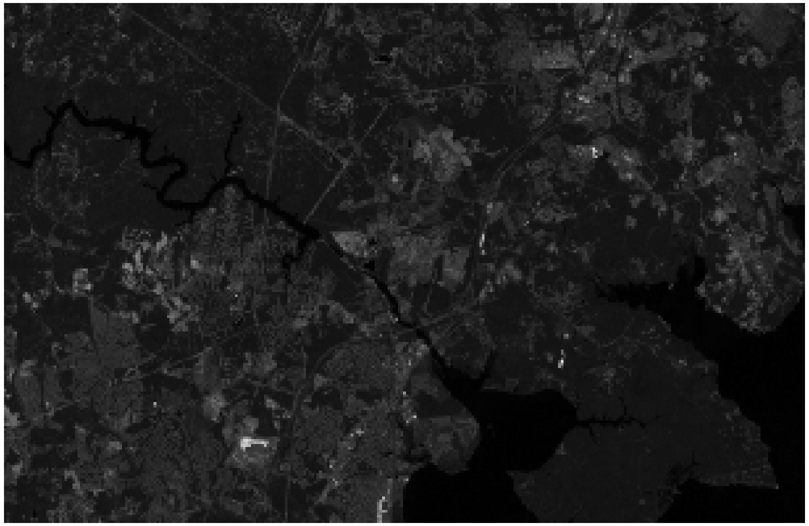
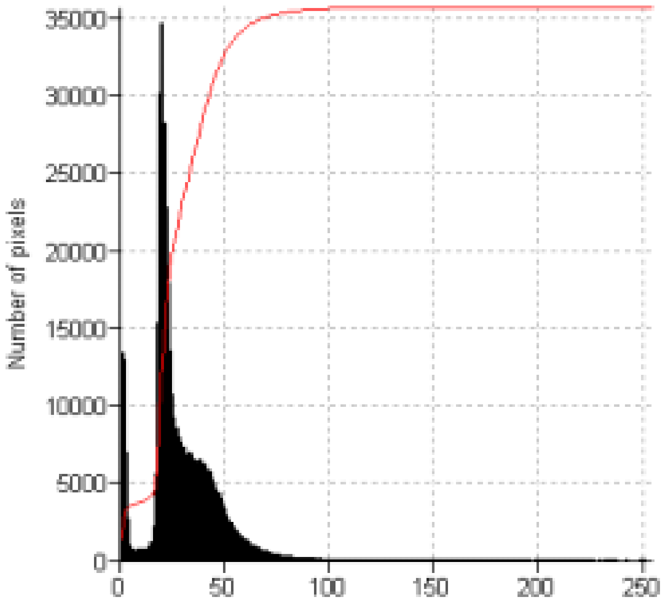


Image enhancement - stretching

Raw image





Histogram equalization stretch

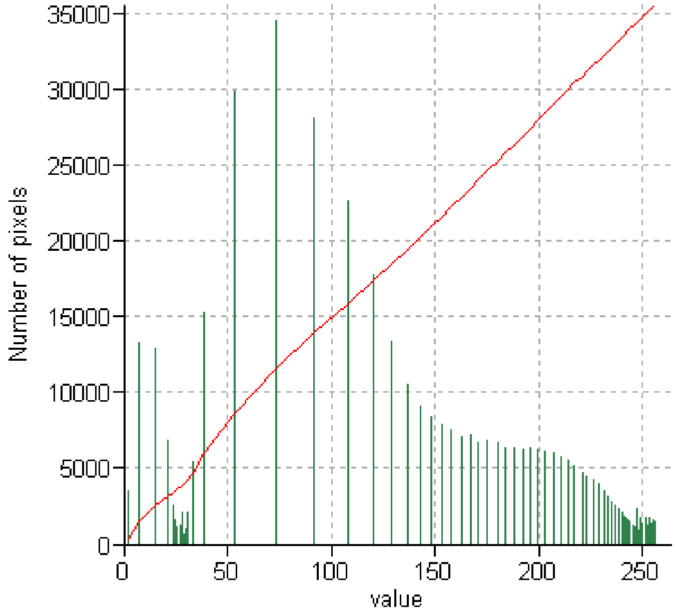
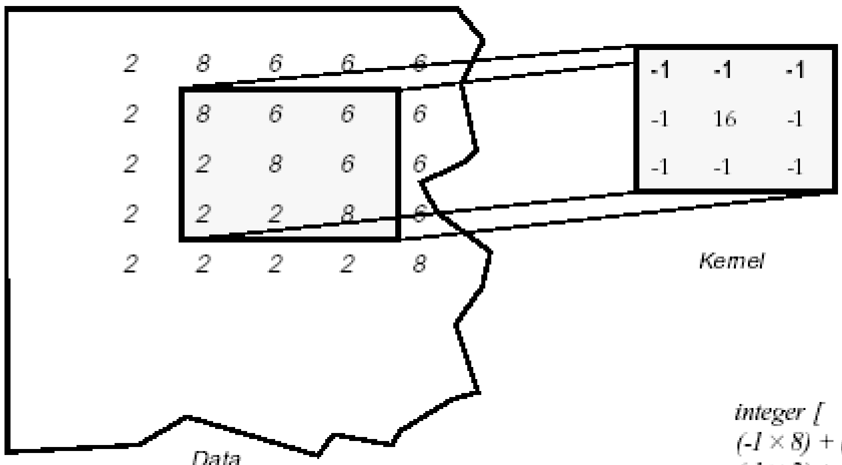


Image enhancement - filtering



integer [
$(-1 \times 8) + (-1 \times 6) + (-1 \times 6) +$
$(-1 \times 2) + (16 \times 8) + (-1 \times 6) +$
$(-1 \times 2) + (-1 \times 2) + (-1 \times 8) : (-1 + -1 + -1 + -1 + 16 + -1 + -1 + -1 + -1)]$

$= int\ [(128-40) / (16-8)]$

$= int\ (88 / 8) = int\ (11) = 11$

Filtering - how does it work?

- **For each pixel in the image**
  - **DN values are multiplied by corresponding values of the “superimposed” kernel**
  - **these values are summed**
  - **the sum is divided by the sum of kernel values**

Image enhancement - filtering

Filtering - what does it do?

- **Low pass kernel - image smoothing**

1	1	1
1	1	1
1	1	1

BEFORE

204	200	197
201	106	209
198	200	210

AFTER

204	200	197
201	190	209
198	200	210

BEFORE

64	60	57
61	125	69
58	60	70

AFTER

64	60	57
61	72	69
58	60	70

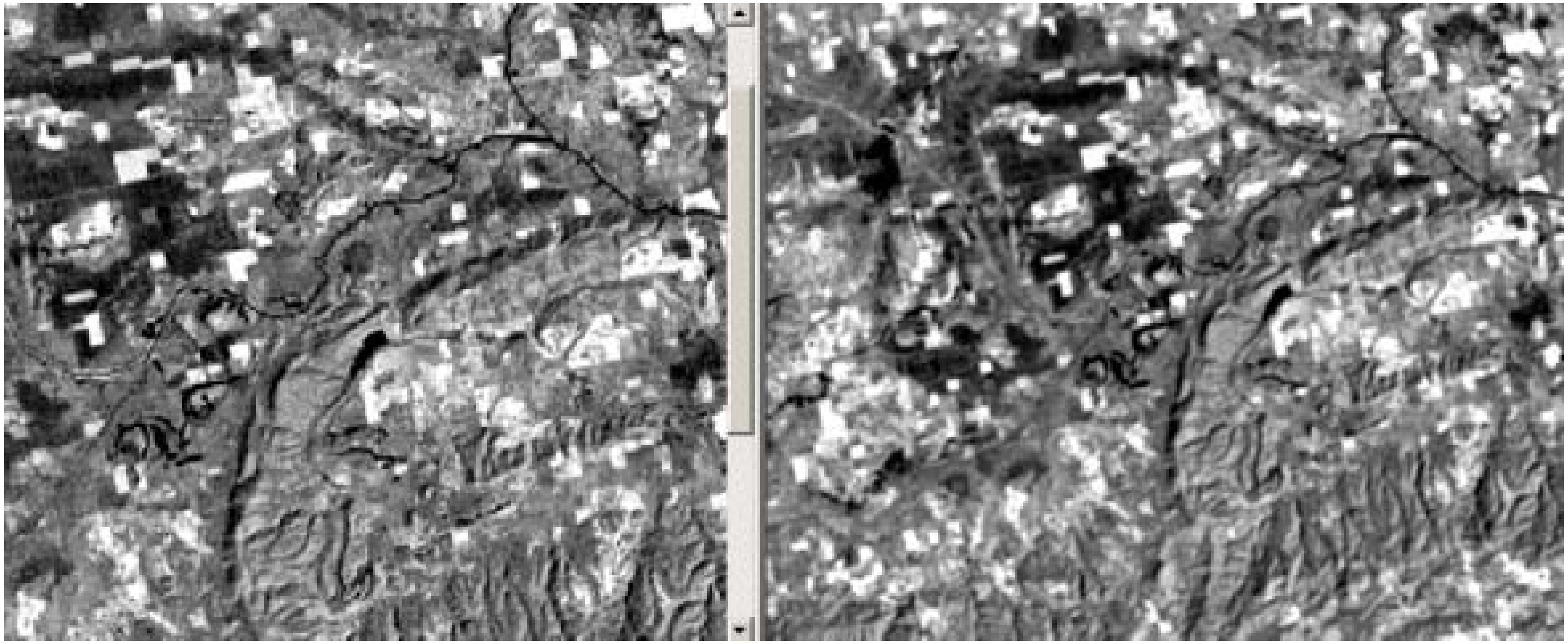


Image enhancement - filtering

Filtering - what does it do?

- **High pass kernel - image sharpening - e.g. edge enhancement**

-1	-1	-1
-1	16	-1
-1	-1	-1

BEFORE			AFTER		
204	200	197	204	200	197
201	106	209	201	9	209
198	200	210	198	200	210

BEFORE			AFTER		
64	60	57	64	60	57
61	125	69	61	187	69
58	60	70	58	60	70

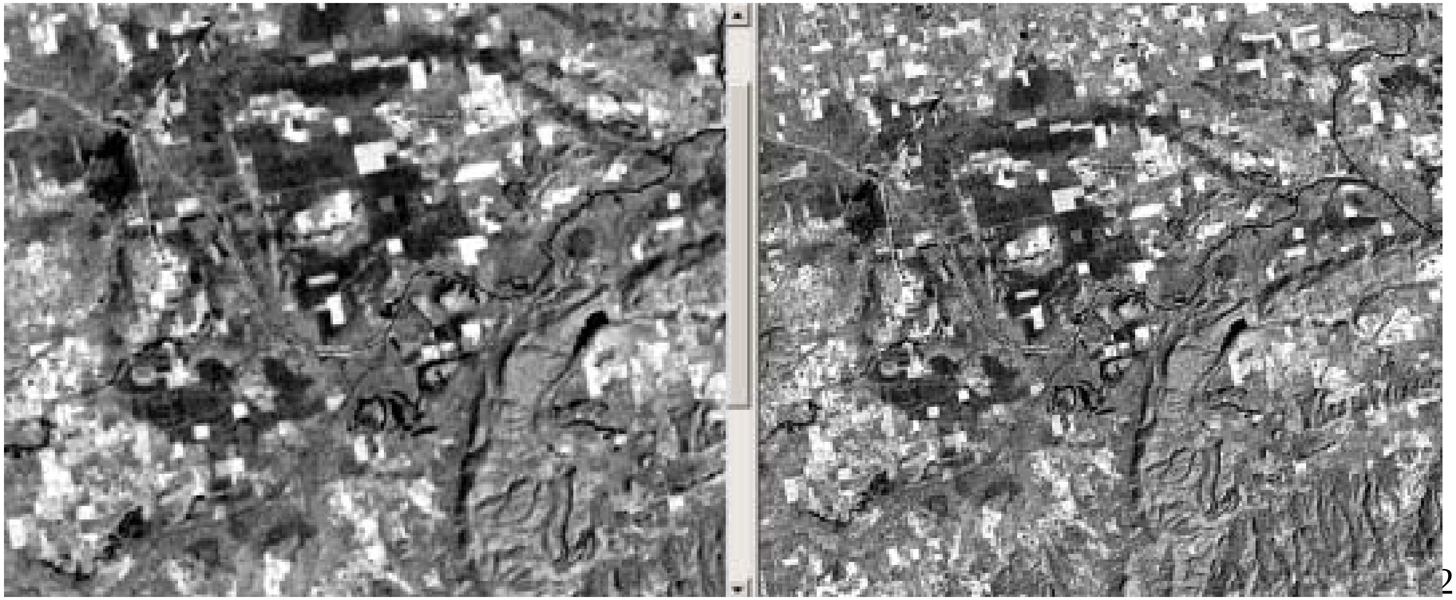


Image enhancement - filtering

Filtering - what does it do?

- **High pass kernel - edge detection**

-1	-1	-1
-1	8	-1
-1	-1	-1

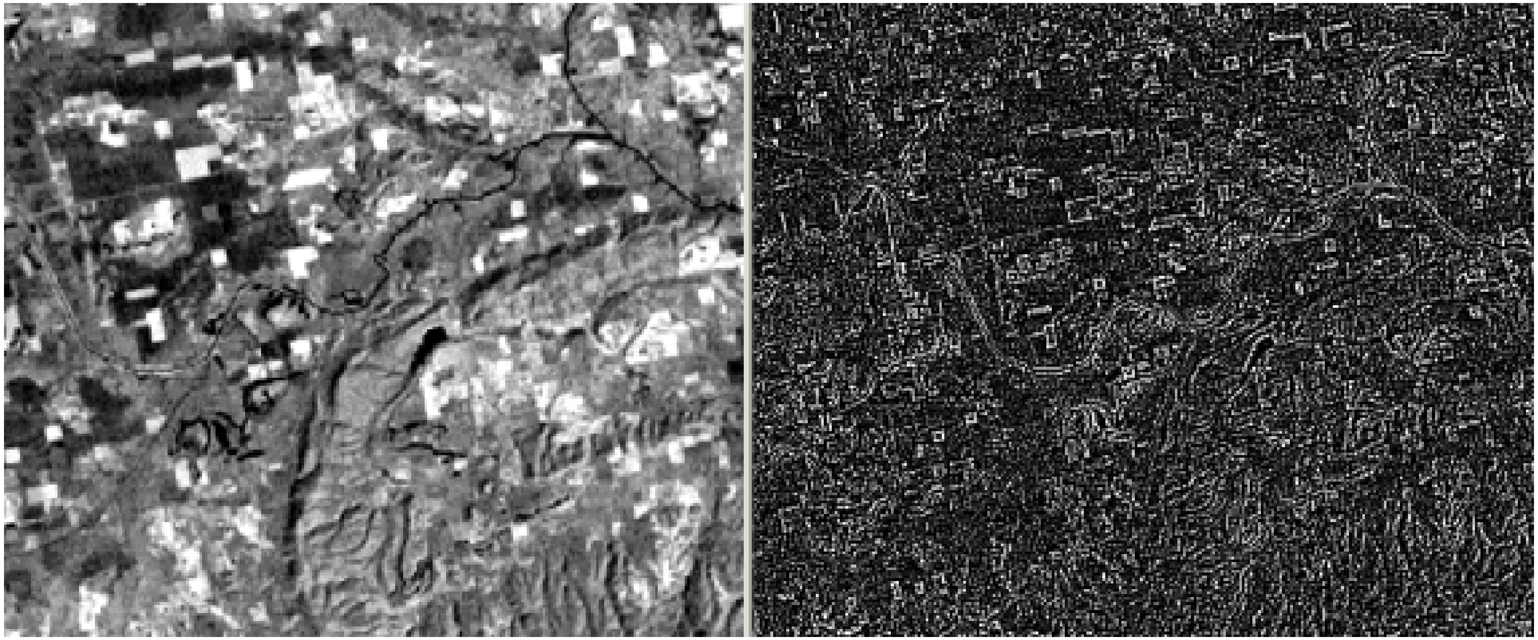


Image enhancement - filtering

Filtering - what does it do?

- **Directional filters - directional edge detection**

$$
\begin{matrix} -1 & 2 & -1 \\ -1 & 2 & -1 \\ -1 & 2 & -1 \end{matrix}
$$

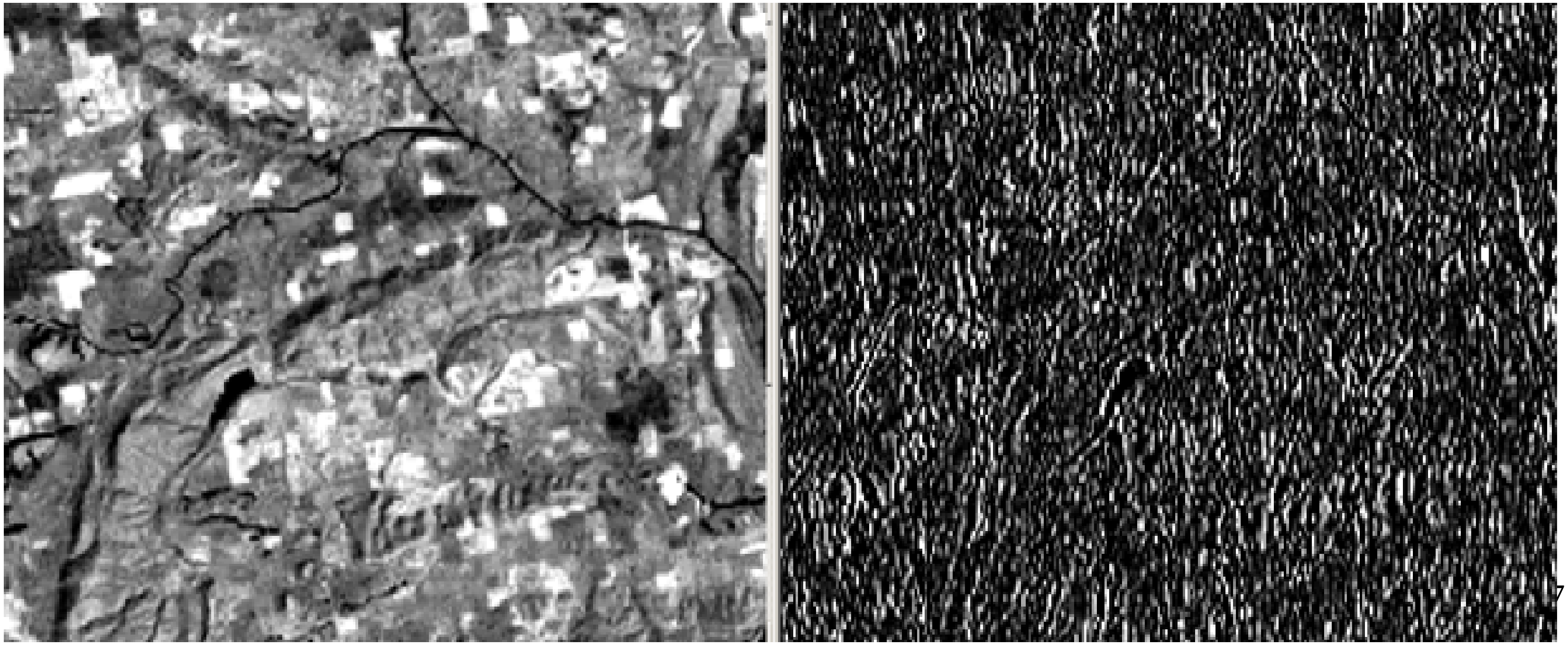
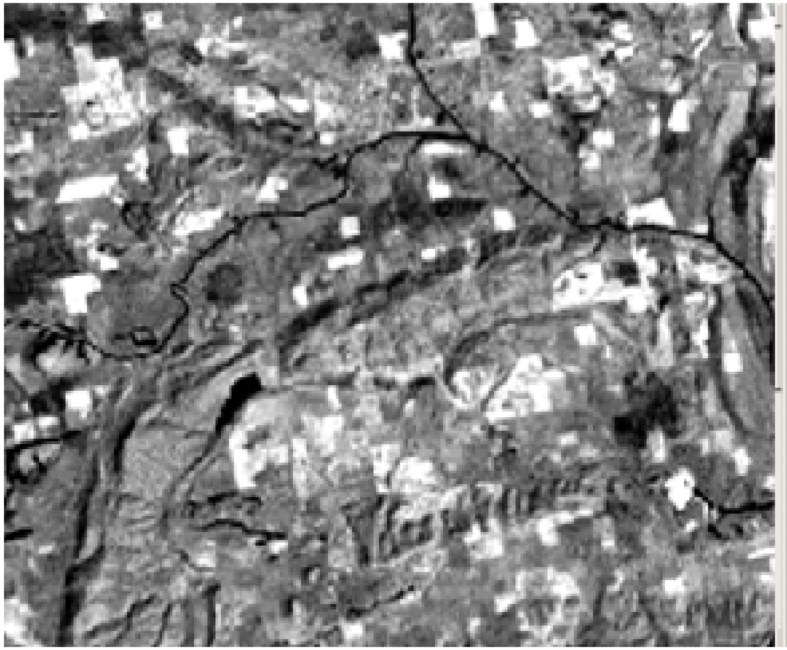


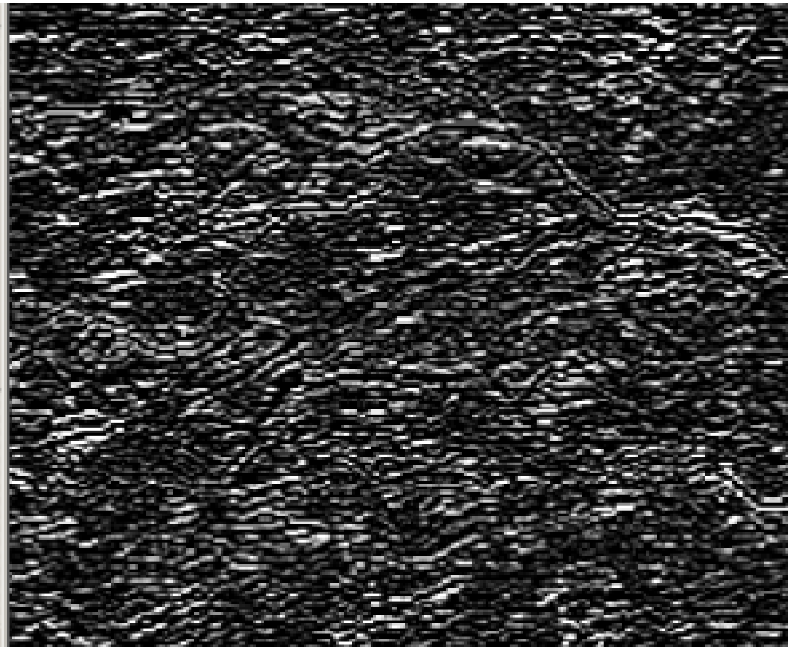
Image enhancement - filtering

Filtering - what does it do?

- **Directional filters - directional edge detection**

$$\begin{matrix} -1 & -1 & -1 \\ 2 & 2 & 2 \\ -1 & -1 & -1 \end{matrix}$$

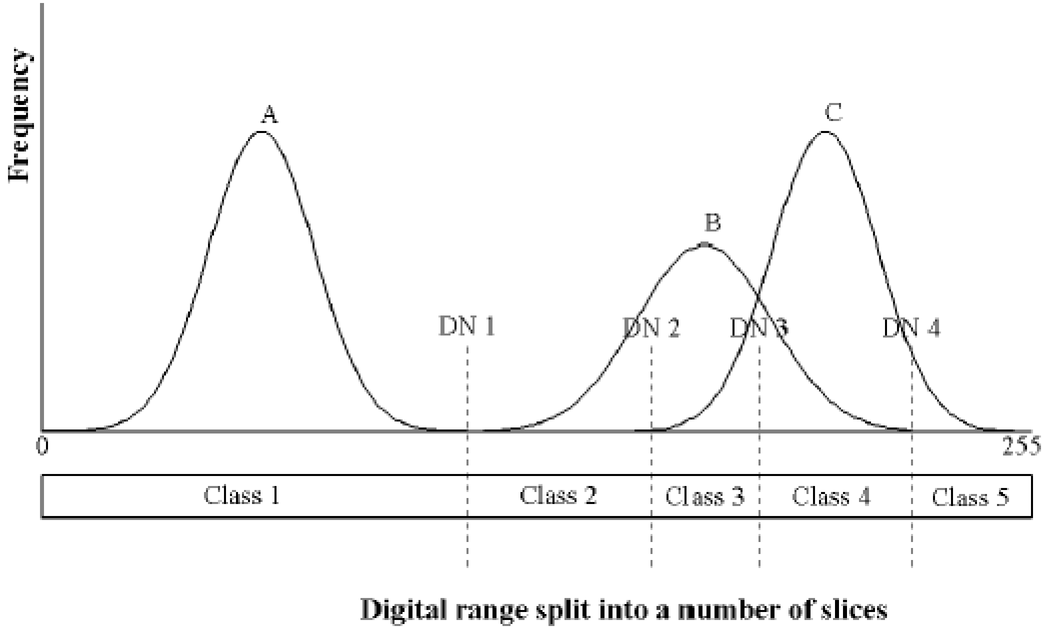




Single image classification: density slicing

Density slicing - what is it?

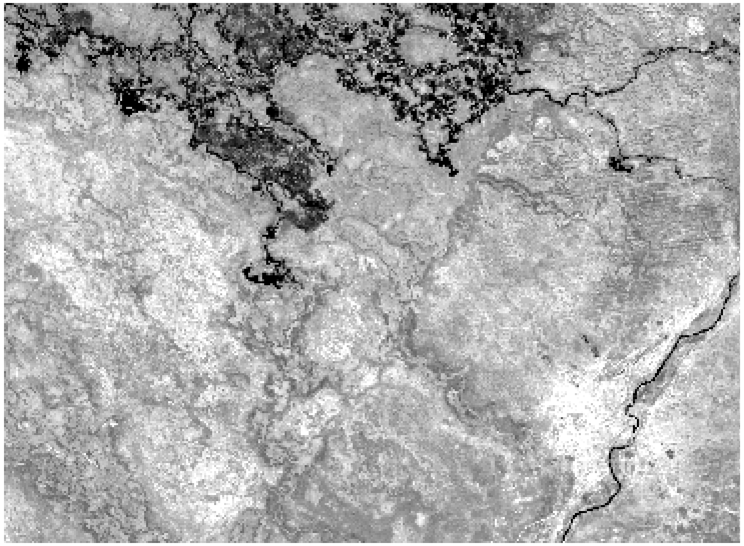
- **DNs of a single band are divided into a number of user-defined intervals or slices.**
- **the number of slices and boundaries between them depend on type of land covers of the area.**
- **obtained map is displayed as thematic map (i.e. pixels are no longer characterized by DNs, but by class names, e.g. water, snow, dense vegetation)**

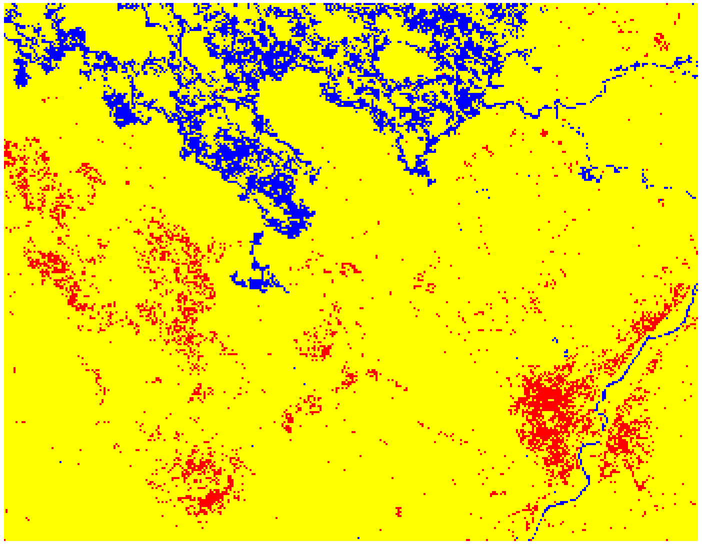


Single image classification: density slicing

Density slicing - what does it do?

- **Basic way of classifying single band images**
- **only classes that strongly differ in spectral response**





three classes: water, vegetation, bare soil