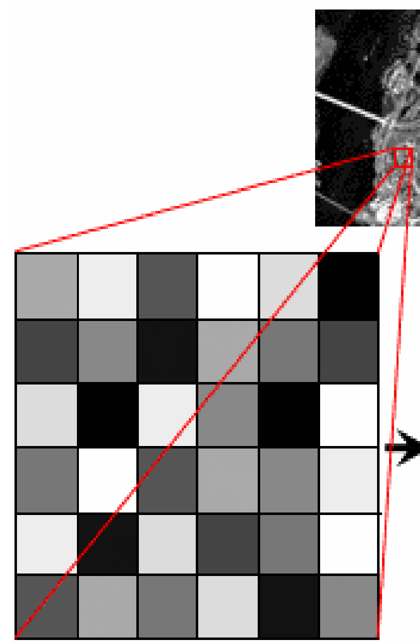
Content

Characteristics of digital Images

- Electromagnetic energy may be detected either photographically (**analog image**) or electronically (**digital image-Raster data**).
- The **photographic process** uses chemical reactions on the surface of light-sensitive film to detect and record energy variations(e.g. x-ray films, infrared films and films used in ordinary photography).
- In **Digital images,** The image is represented and displayed in a **digital format** by subdividing the image into small equal-sized and shaped areas, called picture elements or **pixels**, and representing the brightness of each area with a numeric value or **digital number (DN).**
- If a photograph is scanned, the scanner subdivides it into pixels with each pixel assigned a digital number representing its relative brightness. Then the computer displays each digital value as different brightness levels.
- **Satellite Sensors** that record electromagnetic energy, electronically record the energy as an array of numbers in digital format right from the start. Sensors separate data into narrow wavelength ranges and store it in several **channels** , referred to as **bands.**
- **The data from one band** can only be represented as different shades of black and white depending on the relative brightness (i.e. the digital value) of each pixel in the band. **Data from three bands** can be represented in **RGB** to form a colored image. In TM Lansat, bands **3,2,1** used as RGB produce a **natural color image** because the wave lengths of these bands cover the visible light range. Any other three bands used in RGB will produce a **false color image.**



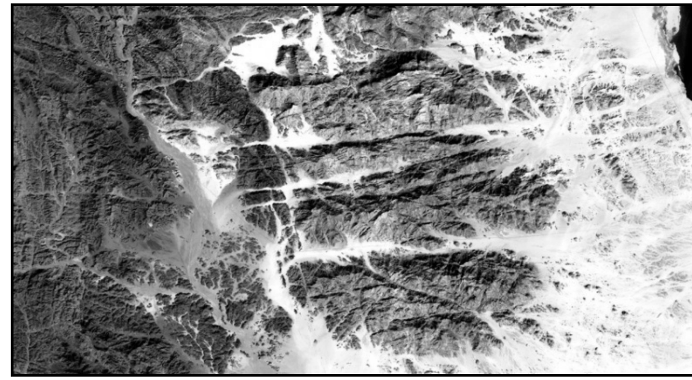
170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

- **Digital image is an array of numbers. These numbers represent the spatial distribution of a certain parameter.**

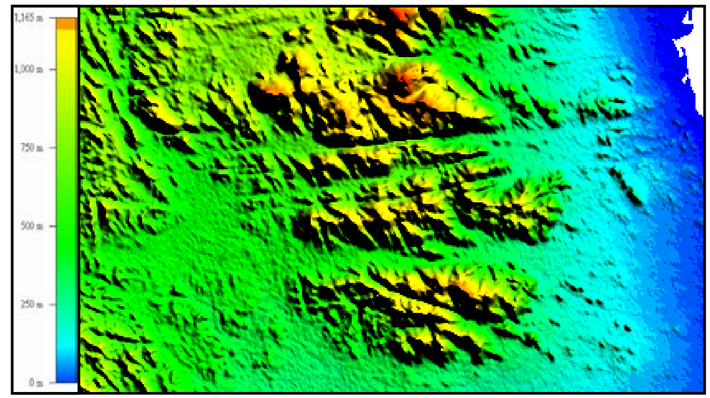
- **In Passive remote systems** (e.g. Landsat and spot satellites) this parameter is the reflectivity of the electromagnetic waves. It is recorded as digital numbers (DN values) that represent the reflectance or brightness of each pixel. In this case **each pixel** has **x, y, z** values (**coordinates and reflectance as DN value**)

- **In active remote sensing systems** the parameter depends on the type of waves created by the sensing system and sent to the earth's surface.

- In **DEM** data (Digital Elevation Data) the parameter recorded is the "**two way time**" of the **radar** wave (as in SRTM data and the ASTER GDEM data of the Aster Satellite) or the **laser** waves (as in Lidar data). Then the "two way time" is transformed to elevations. In this case, each pixel has x,y,z values **(coordinates and elevation value as DN value).**



Landsat image. DN values represent brightness of each pixel



DEM data. DN values represent The elevation of each pixel

- **The parameter** could be reflectivity of EM radiation, emissivity, temperature, or a parameter such as topographical elevation, geomagnetic field or even any other computed parameter.

- **Digital number (DN)** is representing the intensity of a parameter for each pixel. **The physical meaning of DNs depends on the source of the image.**

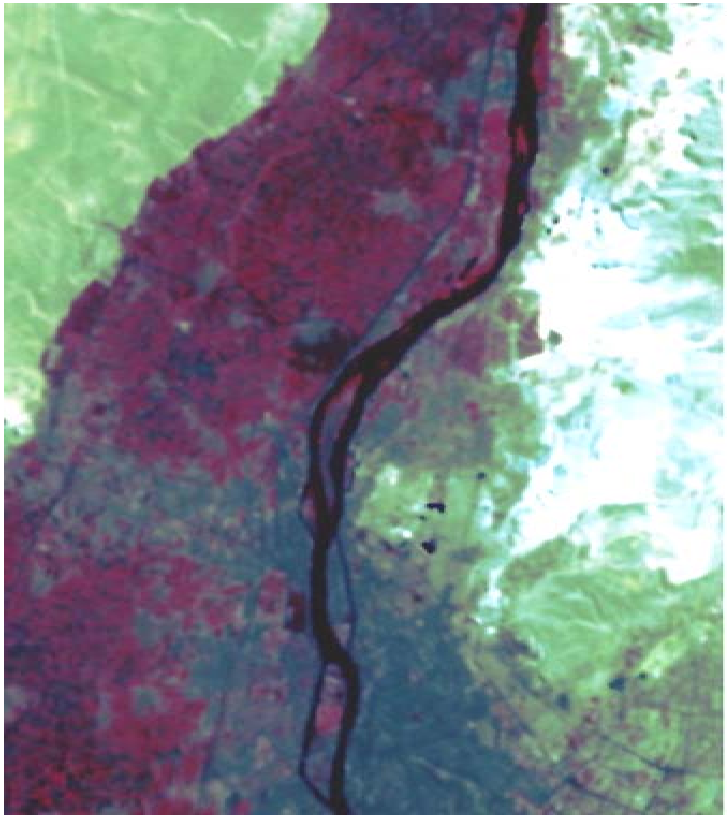
- **Pixel** is a unit area which composed the digital image.

Sensor resolution

In general, *resolution* is the smallest interval can be measured by an instrument. It can be taken as a measure for the quality of an instrument or a product.

1. **Spatial resolution of a sensor implies the area on the ground which fills the instantaneous Field of View (IFOV) of the sensor. It is represented by the distance on the ground surface that represent the width of one image pixel (the ground width of the pixel).**
2. **Spectral resolution describes the ability of a sensor to define fine wavelength intervals. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band. It can be considered as the number of bands in an image.**
3. **Radiometric resolution means the degree of sensitivity of a sensor to variation in radiation intensity (brightness). The radiometric resolution stands for the ability of a digital sensor to distinguish between grey-scale values while acquiring an image. Sensors that can store images in 8 bit resolution has 256 (=2^8) levels of brightness and produce images of better details than sensors that store images in 4 bit resolution (16 levels=2^4).**
4. **Temporal resolution refers to the repetitiveness of observation over an area, and is equal to the time interval between successive observations. It is the time required for revisiting the same area of the Earth.**

1-Spatial resolution

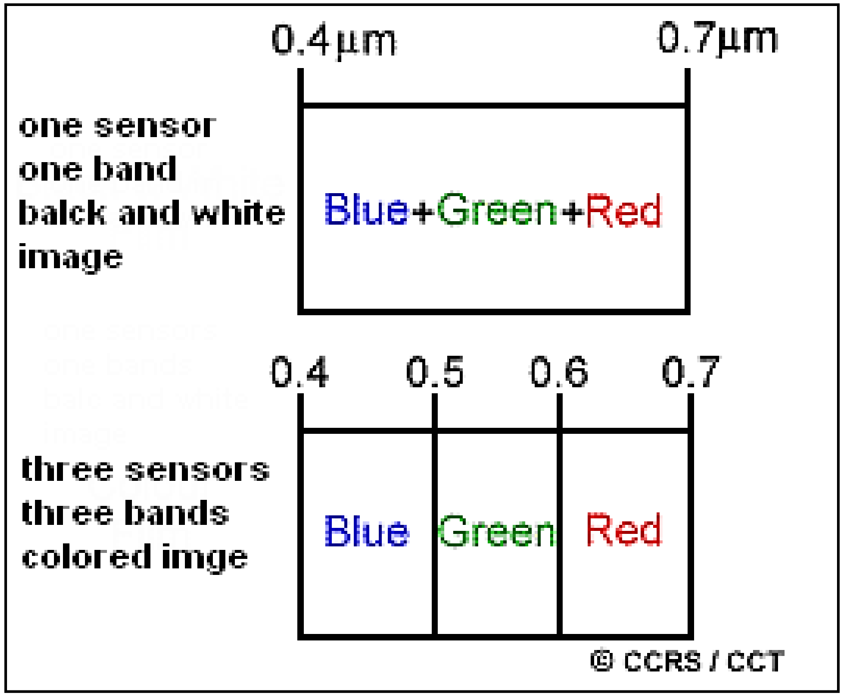


Multispectral (TM) image,
band combination 7,4,2
30 m/pixel resolution.

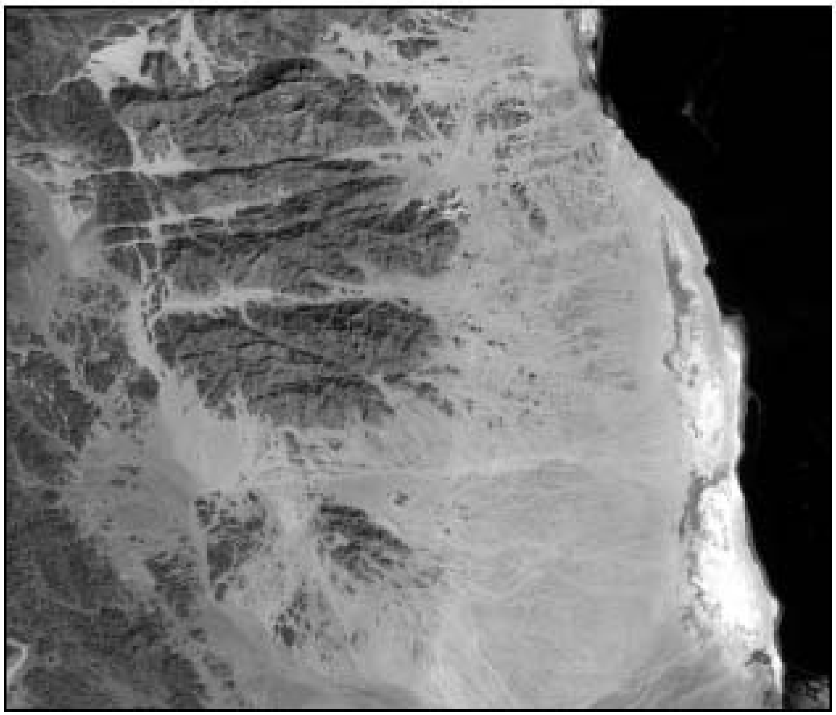
SPOT image
Panchromatic
10 m/pixel resolution

2-Spectral resolution

- If we used a digital sensor of a range (0.4 – 0.7 µm) the produced image will be one band in black and white.
- If we used three digital sensors of wave length ranges as illustrated in the figure, we will get reflectance values for the blue, green and red wave lengths in three bands. These can be combined together to obtain a colored image.
- MSS landsat-1 has 4 bands
- TM landsat-5 has 7 bands
- ETM landsat-7 has 9 bands
- ETM landsat-8 has 11 bands
- Spot-5 has 4 bands
- i.e landsat has higher spectral resolution than spot.
- Hypersectral sensors can produce hundreds of bands.



- The reflectivity of the same body is different in the different bands.
- This property is used to produce false color images of different band combinations and band ratios that are important in the detection of the different rock types in the image.



Band 3
Wave length = 0.63 - 0.69 µm

Band 7
Wave length = 2.09 - 2.35 µm

Characteristics of Most popular satellite images

Satellite Type		Number of bands	Spatial Resolution m/pixel	Temporal Resolution (days)	Scene size (in Km)
Landsat -1 to 3	MSS	4	60	18	about 185 X 185
Landsat -5	TM	7	30	16	
Landsat -7	ETM	9	15	16	
Landsat -8	ETM	11	15	16	
Spot -4 (Panchromatic-multispectral)		1 Panchromatic 4 Multispectral	10 20	1 - 4	60 X 60
Spot -5		1 Panchromatic	5	2 to 3	60 X 60
		1 Panchromatic	2.5		
		4 Multispectral	10		
Spot -6		1 Panchromatic	1.5	1-3	
		4 Multispectral	6		
Aster (14 bands)		3 bands	15	16	60 X 60
		6 bands	30		
		5 bands	90		

Satellite Type	Number of Bands	Spatial Resolution m/pixel	Temporal Resolution (days)	Scene size (in Km)
GeoEye-1	1 Panchromatic	About: 2 upto 0.5	1 to 3	15.2 X 15.3
	4 or 8 Multi spectral			
Quickbird	1 Panchromatic		1 to 3	About 18 X 18
	4 or 8 Multi spectral			
Worldview -2	1 Panchromatic		1 to 3	About 16 X 16
	4 or 8 Multi spectral			

Digital Image Processing

Most of the common image processing functions available in image analysis systems can be categorized into the following four categories:

I- Pre-processing

II- Image Enhancement

III- Image Transformation
(band ratioing and principal components analysis)

IV- Image Classification and Analysis
(supervised and unsupervised classification)

I- Pre-processing

- Pre-processing steps involve those operations that are normally required prior to the main data analysis and extraction of information, and are generally grouped as **radiometric and geometric corrections.**
- There are several corrections must be done on the raw data images before it can be used. The pre-processing steps are:

1- Radiometric correction: is necessary to correct variations in scene illumination and atmospheric conditions. Scattering of radiation occurs as it passes through and interacts with the atmosphere. This will produce noise in the recorded image that must be corrected.

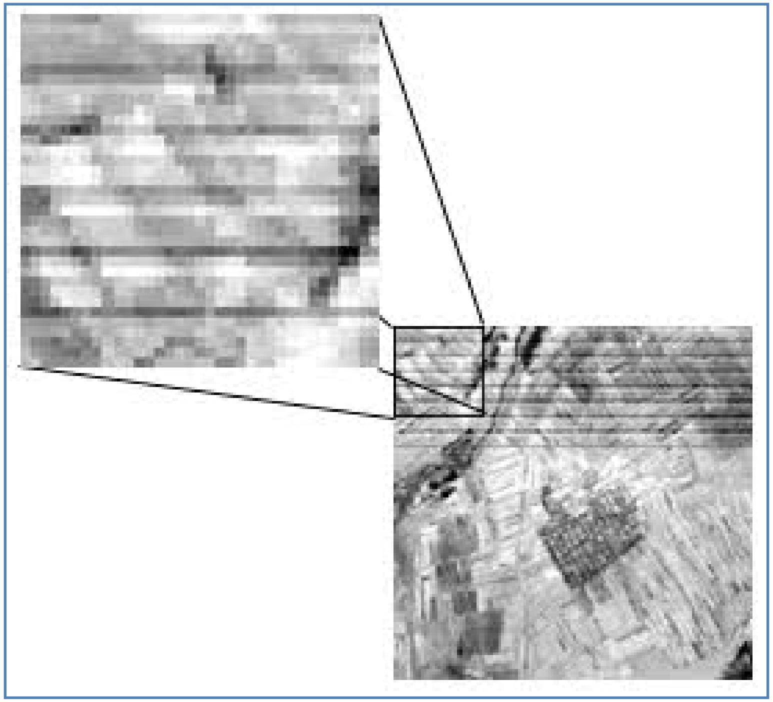
2- Geometric correction: All remote sensing imagery are subject to inherited geometric distortions due to problems with sensor optics; motion of the scanning system; altitude, attitude, and velocity of the system; terrain relief; and curvature and rotation of the Earth. Geometric corrections are to correct these distortions, so that the image will be as close as possible to the real world.

3- Mosaicking to mosaic two or more images from a single sensor into one image.

4- Destriping to correct for sensor noise (e.g. **striping** and **dropped lines**).

5- Image registration (rectification) is to define the coordinates for the image to be used. If the image is supplied without coordinates, it must be registered based on points of known coordinates (control points) from a map or another registered image.

The effect of Stripping noise in satellite image



All satellite images can be ordered corrected to the level you want.
If the image is not radiometrically and geometrically corrected , all these corrections must be applied on the image (in the ENVI software) before any further processing and interpretation..

II- Image enhancement

- **Enhancement of digital images:** are mathematical processes allows us to treat the digital pixel values in an image to make it better to view, easier for visual interpretation and understanding.
- The simplest type of enhancement is a **linear contrast stretch.** This involves identifying the lower and upper bounds from the **image histogram** representing the brightness values that comprise an image (usually the minimum and maximum brightness values in the image, DN values) and applying a transformation to stretch this range to fill the full range from 0 to 255.
- As an example, the minimum value (occupied by actual data) in the histogram is 84 and the maximum value is 153. These 70 levels occupy less than one-third of the full 256 levels available. A linear stretch uniformly expands this small range to cover the full range of values from 0 to 255. This enhances the contrast in the image with light toned areas appearing lighter and dark areas appearing darker, making visual interpretation much easier.

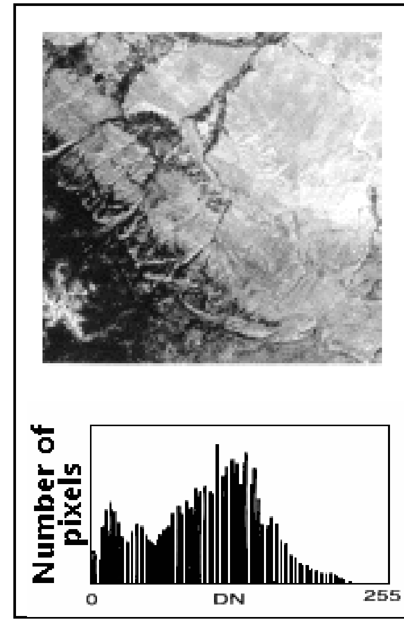
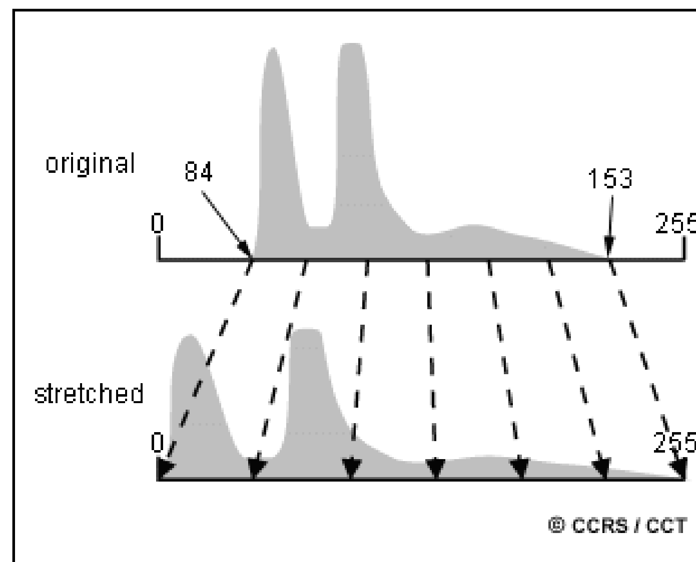
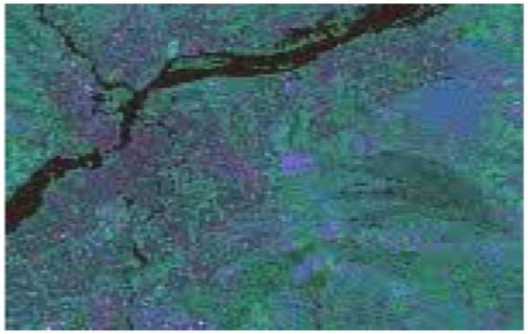


Image histogram



- The following images illustrates the effect of linear contrast stretch on the original image (left) and the enhanced image (right).



Original image

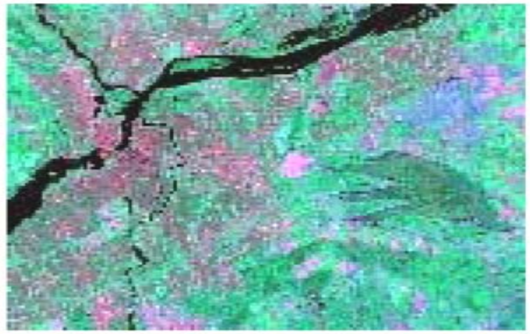
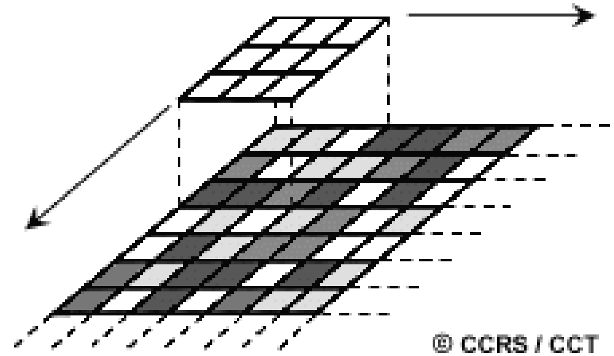


Image with Linear contrast stretch enhancement



Spatial filtering window

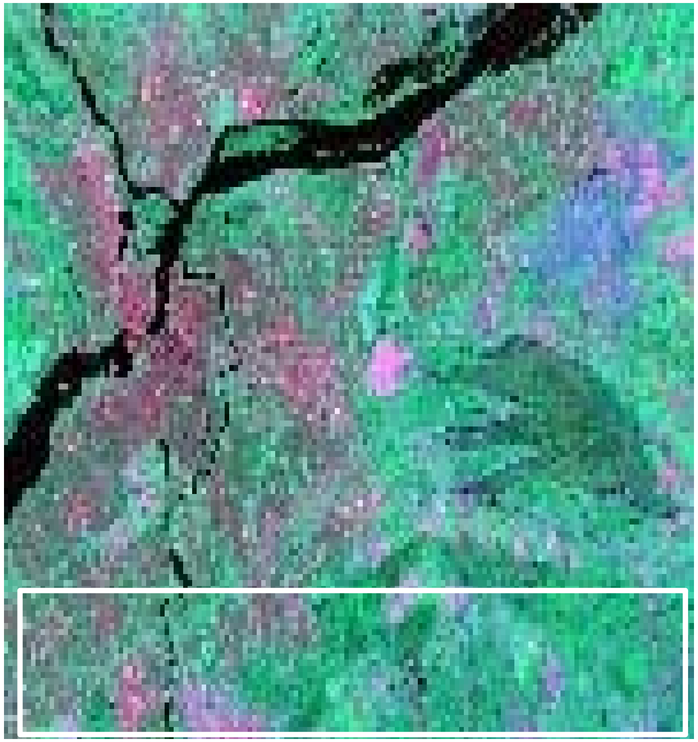
Spatial filtering: It is an important tool in image enhancement. Spatial filters are designed to **highlight or suppress specific features** in an image based on their **spatial frequency**. Spatial frequency refers to the frequency of the variations in tone that appear in an image. **"Rough"** textured areas of an image, where the changes in tone are abrupt over a small area, have high spatial frequencies, while **"smooth"** areas with little variation in tone over several pixels, have low spatial frequencies.

filtering procedure involves moving a 'window' of a few pixels in dimension (e.g. 3x3, 5x5, etc.) over each pixel in the image, applying **a mathematical calculation** using the pixel values under that window, and replacing the DN of the central pixel with the new value. The window is moved one pixel at a time along both the row and column dimensions and the calculation is repeated until the entire image has been filtered and a "new" image with new DN values has been generated.

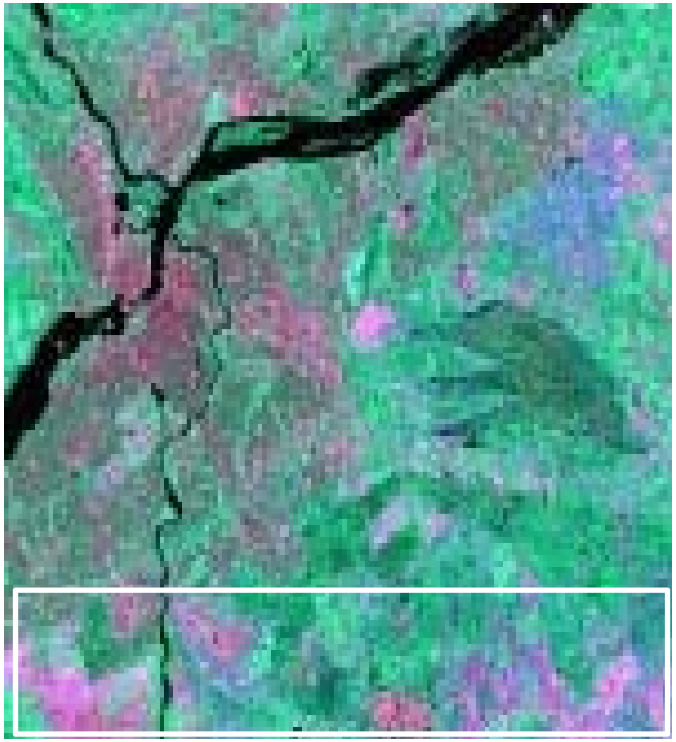
Different Filters are designed to **enhance or suppress** different types of features based on the equations of calculations used. There are two types of such filters:

1- Low-pass filters: are designed to emphasize larger, homogeneous areas of similar tone and **reduce the smaller detail** in an image. Thus, low-pass filters generally serve to smooth the appearance of an image.

2- High-pass filters: do the opposite and serve to **sharpen the appearance** of fine detail in an image

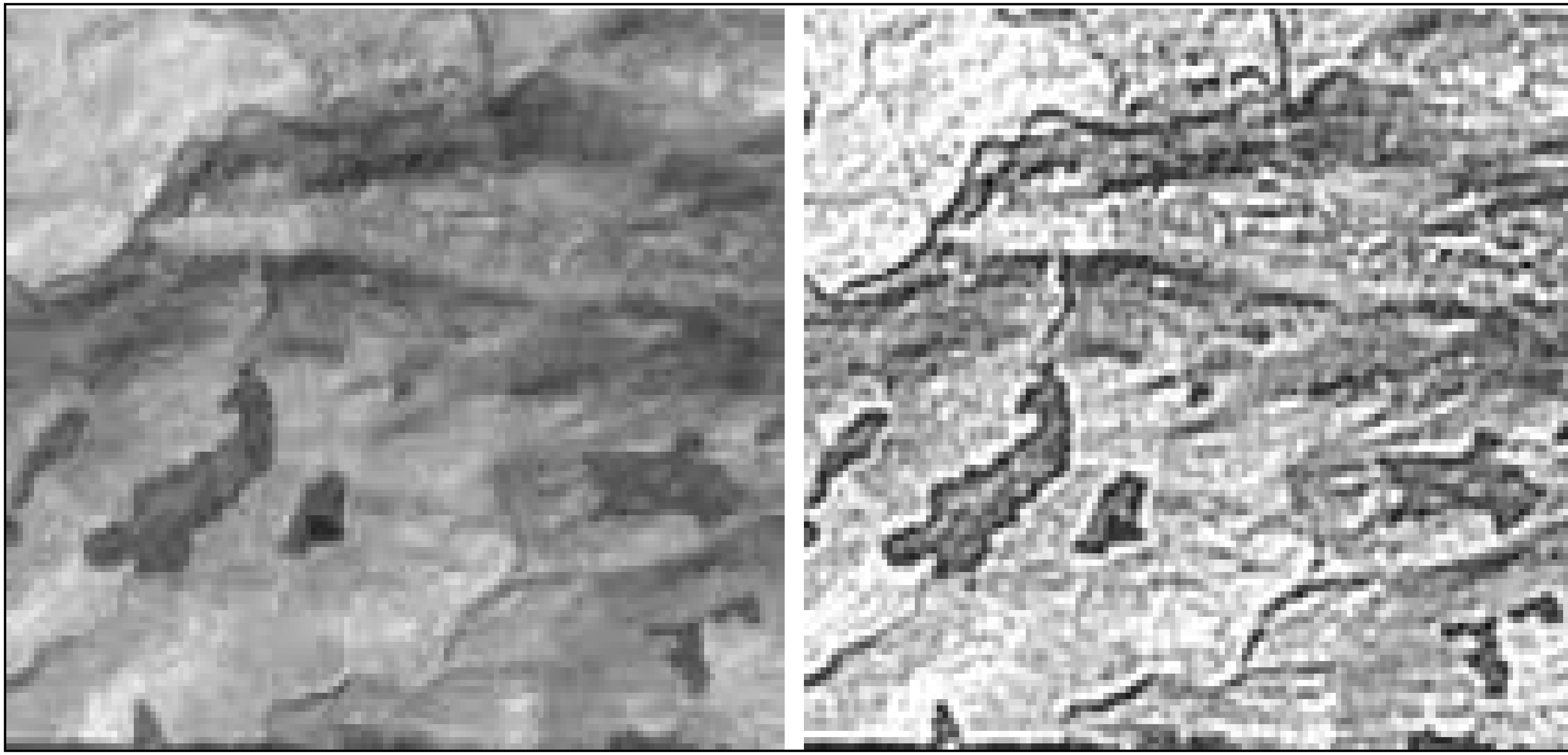


Before



After

Low-pass filter

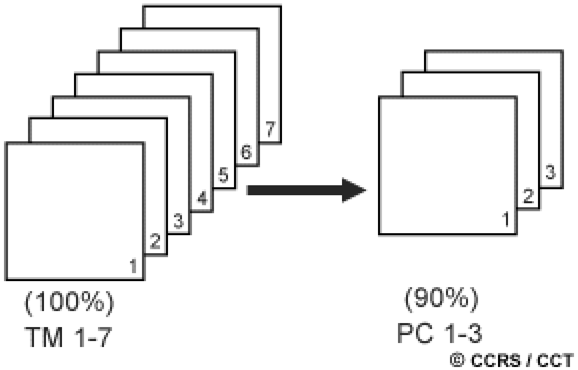


Before **After**

High-pass filter

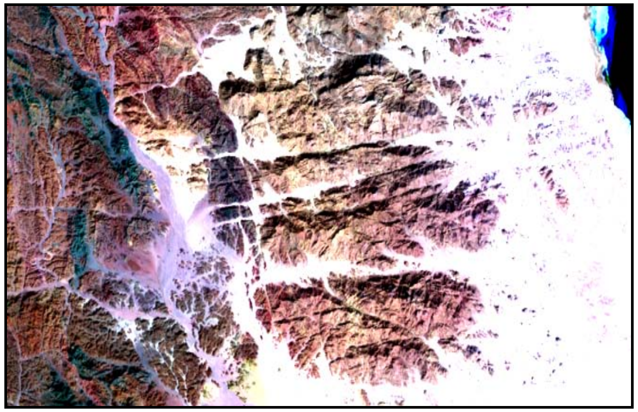
III- Image transformations

- Image transformations usually involve combined processing of data from multiple spectral bands. Arithmetic operations (i.e. subtraction, addition, multiplication, division) are performed to combine and transform the original bands into "new“ images which better display or highlight certain features in the scene.
- These operations include various methods of **spectral or band ratioing, and** procedures of **principal components analysis.**
- Image division or **spectral ratioing** is one of the most common transforms applied to image data. Image ratioing serves to **highlight small variations** in the spectral responses of various surface covers. By ratioing the data from two different spectral bands, the resultant image enhances variations in the reflectance.
- **Principal components analysis:** This process attempts to **maximize (statistically) the amount of variations** from the original bands into the least number of new components through complex statistical procedures.

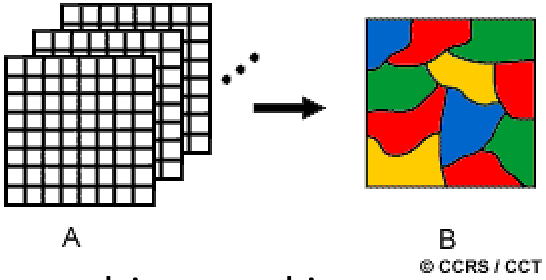


- As an example, the seven bands of TM data may be transformed such that the first three principal components contain over 90 percent of the information in the original seven bands.

IV- Image classification and analysis



- These operations are used to digitally identify and classify pixels in the data. Classification is usually performed on multi-channel data sets (A) and this process assigns each pixel in an image to a particular class (as in B), based on statistical characteristics of the pixel brightness values (DN values).



- Image classification is based on processes of data clustering. **Data clustering** is a mathematical process of classification of any type of data into classes; the data in each class are equal or close together in their value.
- **Image classification (spectral clustering)** is classifying pixels of a multispectral image into discrete classes based on the value of pixel reflectance or digital number (DN).
- There are two main basis of image classification. The first is based on **statistical methodology** only. The second is based on **user-defined training classes** (user-defined small areas defined by the user and used by the software as a base for classification).
- There are two main types of image classification, namely **supervised and unsupervised classification.**

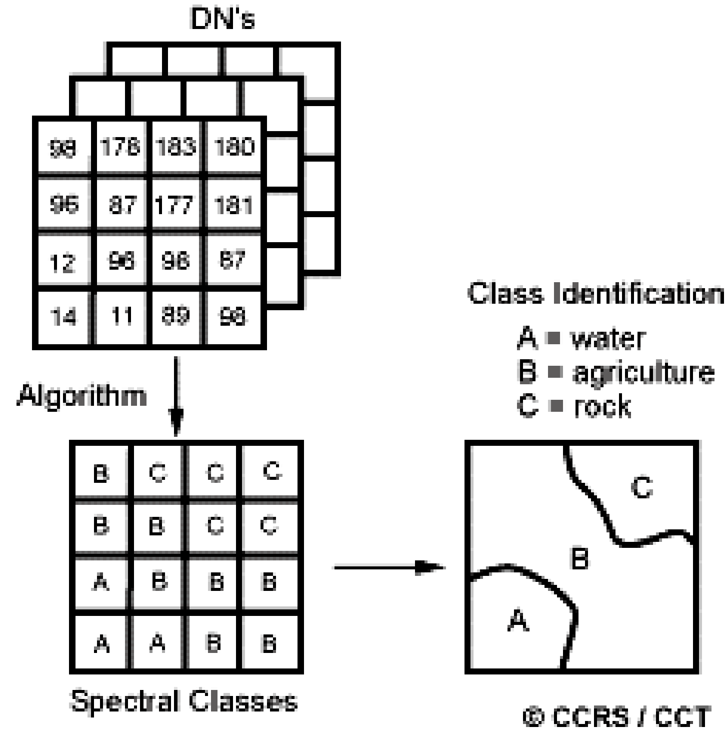
1- Unsupervised Classification:

The classification process is totally based on mathematical operations called **clustering algorithms,** that are used to determine the natural (statistical) groupings of pixels.

Usually, the user specifies how many groups or clusters or classes are to be used in the classification process.

To choose the number of classes, it is better to be based on pre-existing knowledge about the number of rock units (classes) in the area under study, otherwise, the number of classes can be chosen arbitrary.

The resulted classes must be examined and revaluated to determine the efficiency of the classification process. If the result is not satisfactory, the user must repeat the classification process using a suitable number of classes.



Two methods of unsupervised classification are available:

1- ISODATA Classification.

2- K-Means Classification.

The difference between them is the **clustering algorithm** used.

2- <u>Supervised classification</u>:

the process is based on the determination of homogeneous representative small areas in the imagery that represent the different rock types and other features of interest (information classes). These samples are referred to as **training areas (region of interest, ROI).** The software uses these training areas as a base for separation and classification of the different pixels into the pre-defined classes.

Some popular supervised classification methods available in ENVI are:

1- Parallelepiped Classification.
2- Minimum Distance Classification.
3- Mahalanobis Distance Classification.
4- Maximum Likelihood Classification.
5- Binary Encoding Classification.
6- Spectral Angle Mapper Classification.
7- Spectral Information Divergence Classification.

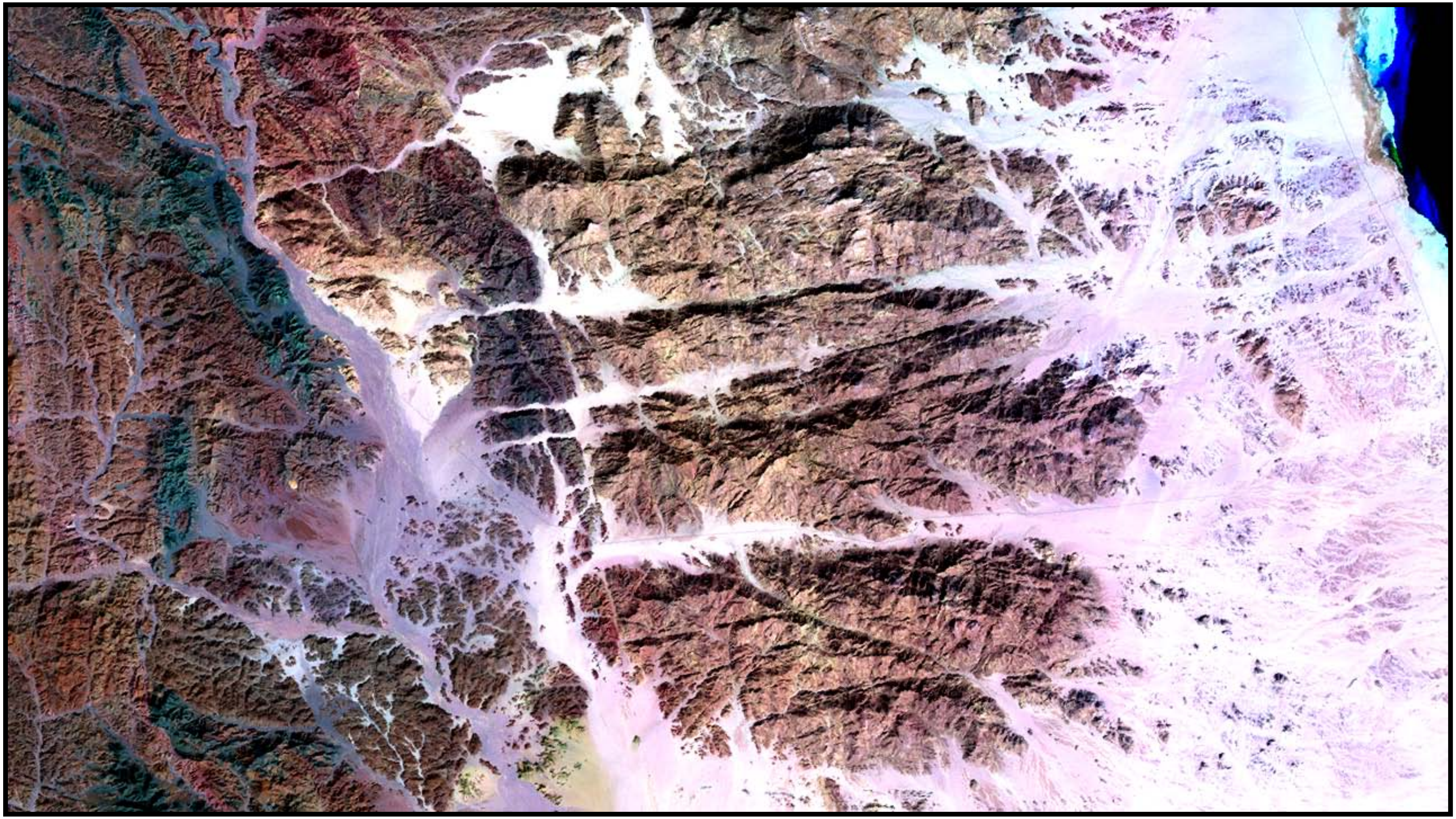
- Some of these supervised classification methods (no.1, 2, 3, 4, 5) are based on the **training classes (region of interest, RIO)**. The difference between them is the algorithm used in the clustering calculation. Methods (6, 7) are based on what is known as **“spectral library”**. These libraries are available in ENVI and represent the reflectance of minerals, rocks or vegetation types that can be used for minerals, rocks, or vegetation detection and classification.

Data Integration and Analysis

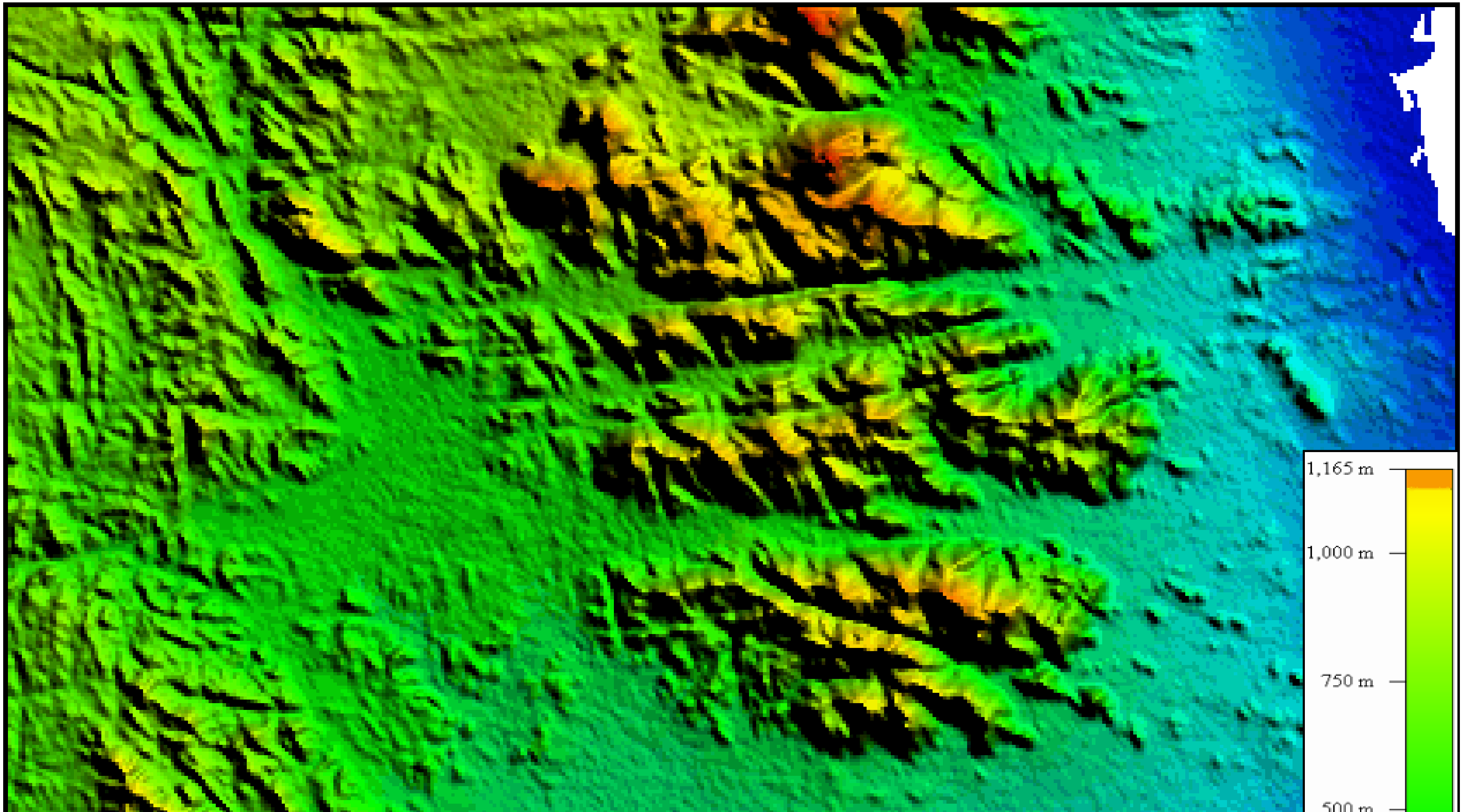
- Most of the data available in digital format from different sensors, can be integrated together and used for better interpretation and analysis.
- **Data integration** fundamentally involves the **fusion or merging** of data from multiple sources in an effort to extract better information (e.g. increase the spatial resolution of the image).
- **Merging** of data is the process that includes the mixing of data of a certain pixel in different images of **multitemporal, multiresolution, multisensor, or multi-data** types together to produce an new image of better understanding using complex algorithms.
- **Multitemporal data integration** is generally used in Multitemporal change detection (the changes that occur in the land surface along a period of time).
- An excellent example of **multisensor data fusion** is the combination of multispectral optical data with radar imagery. The optical data provide detailed discriminating between rock units types, while the radar imagery highlights the structural detail in the image.

- The merging of data of a **higher spatial resolution** with data of lower resolution can significantly sharpen the spatial detail in an image and enhance the discrimination of features. As an example, the merging of false color TM image (28.5 m resolution) with the monochromatic band 8 of ETM data (14.25 m resolution) produce a new false color image of 14.25 m resolution. Also, the same data can be merged on spot image of 10 m or 5 m resolution to get a new image of better resolution.

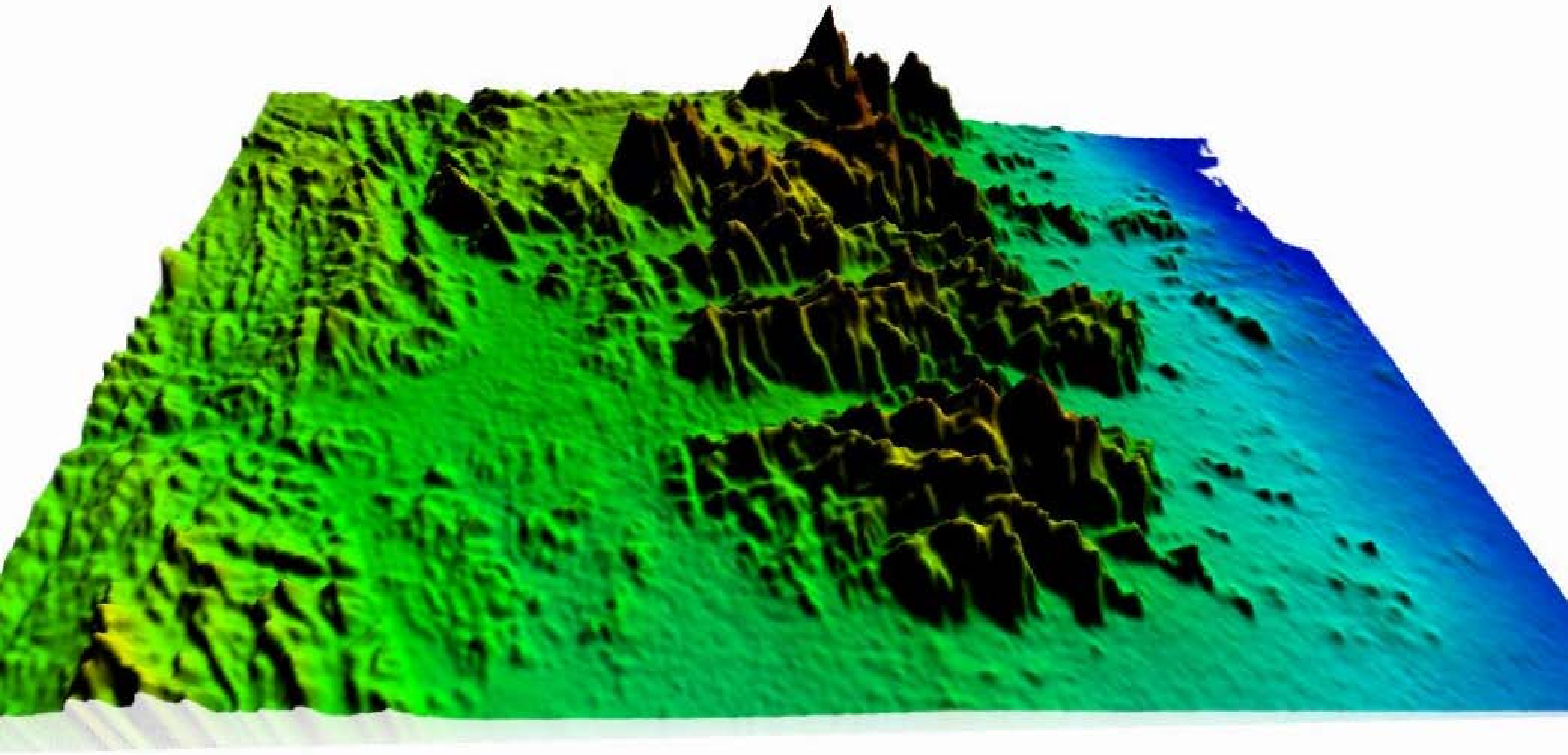
- An example of data integration of **multi-data** types is the integration of TM landsat image with Digital Elevation data (DEM data). This can produce 3D model of the TM image as shown in the following slides.



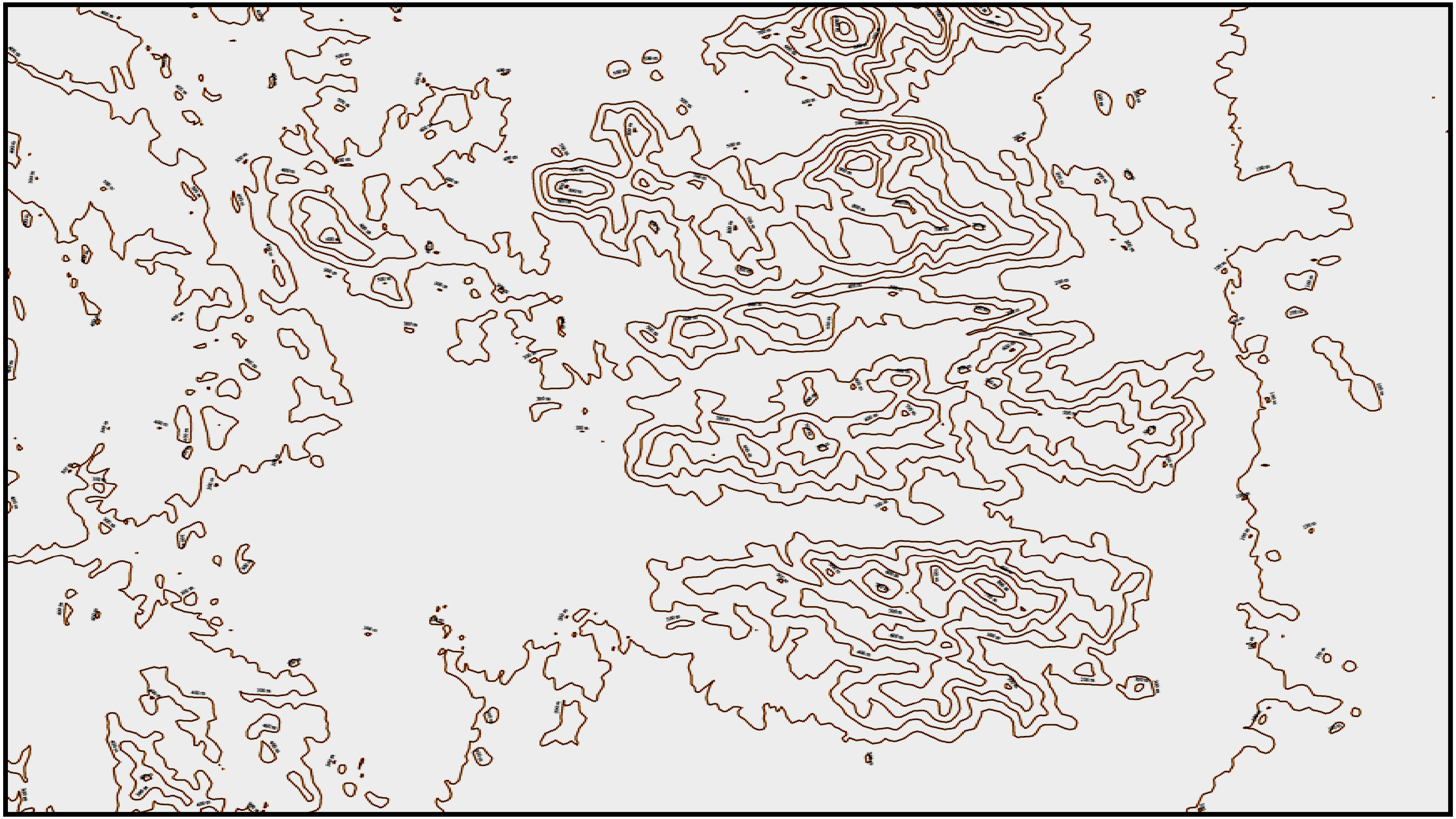
false color TM landsat image of band combination 7,4,2



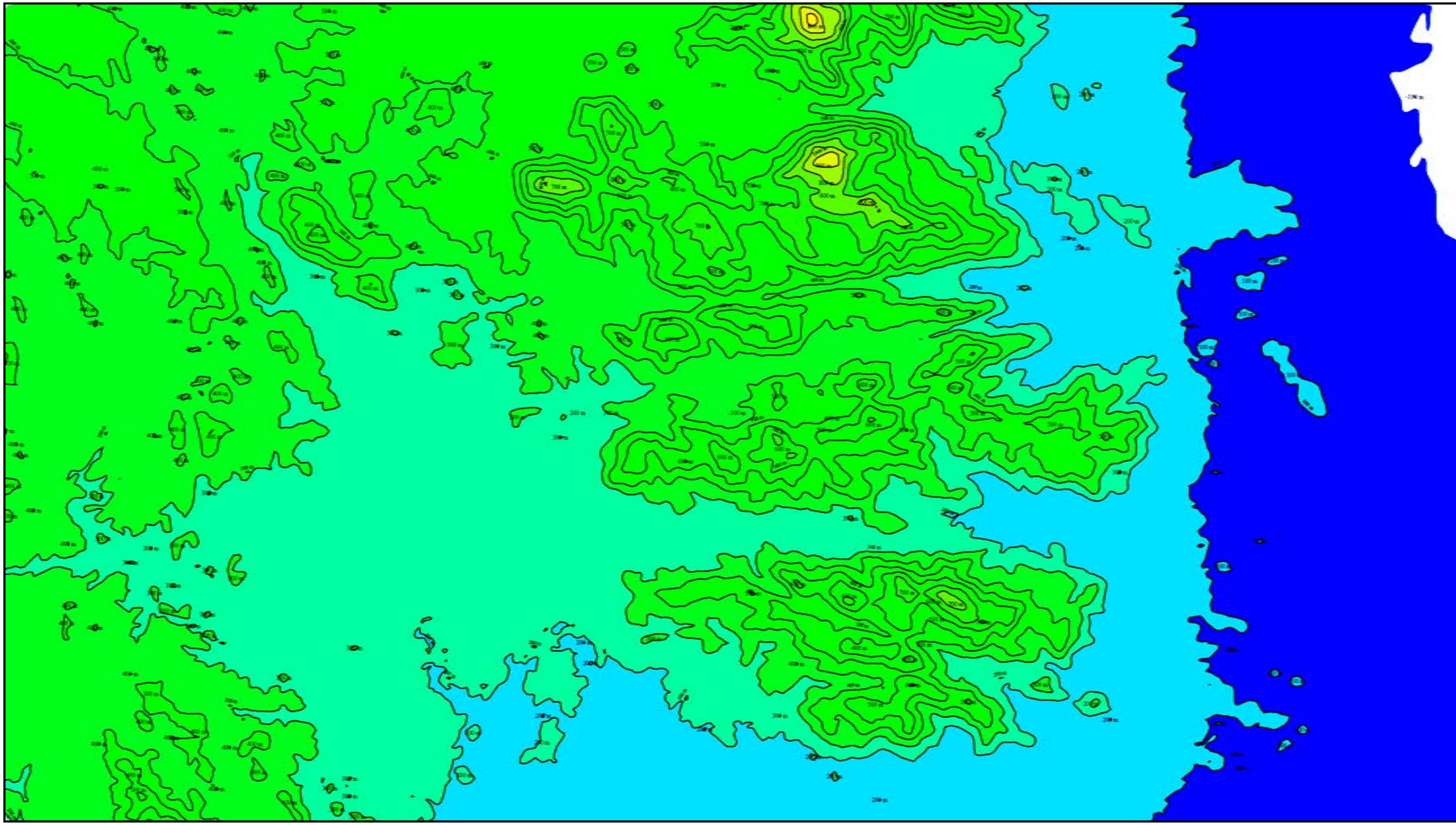
<u>Shaded relief model</u> based on the Digital Elevation (DEM) Data of the same area in the previous slide



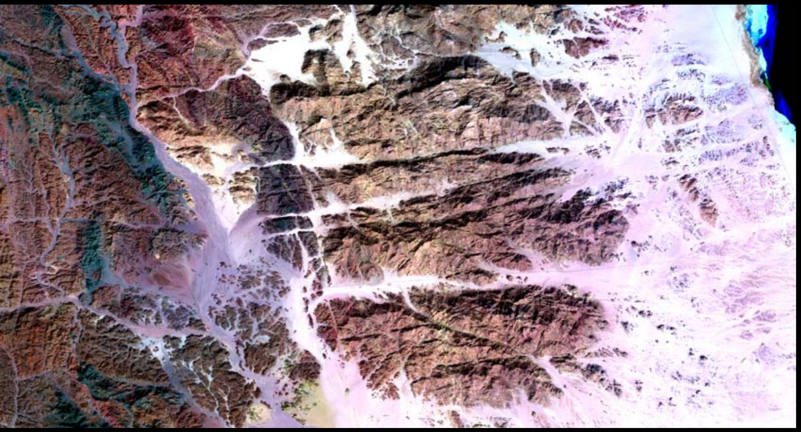
3D model based on the Digital Elevation (DEM) Data
of the same area in the previous slide

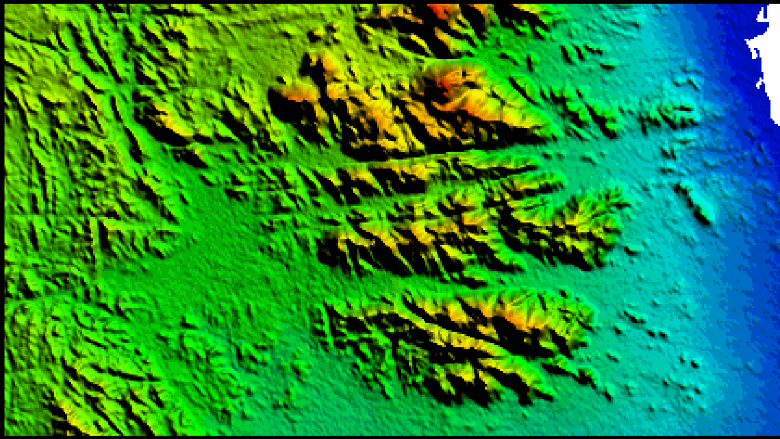


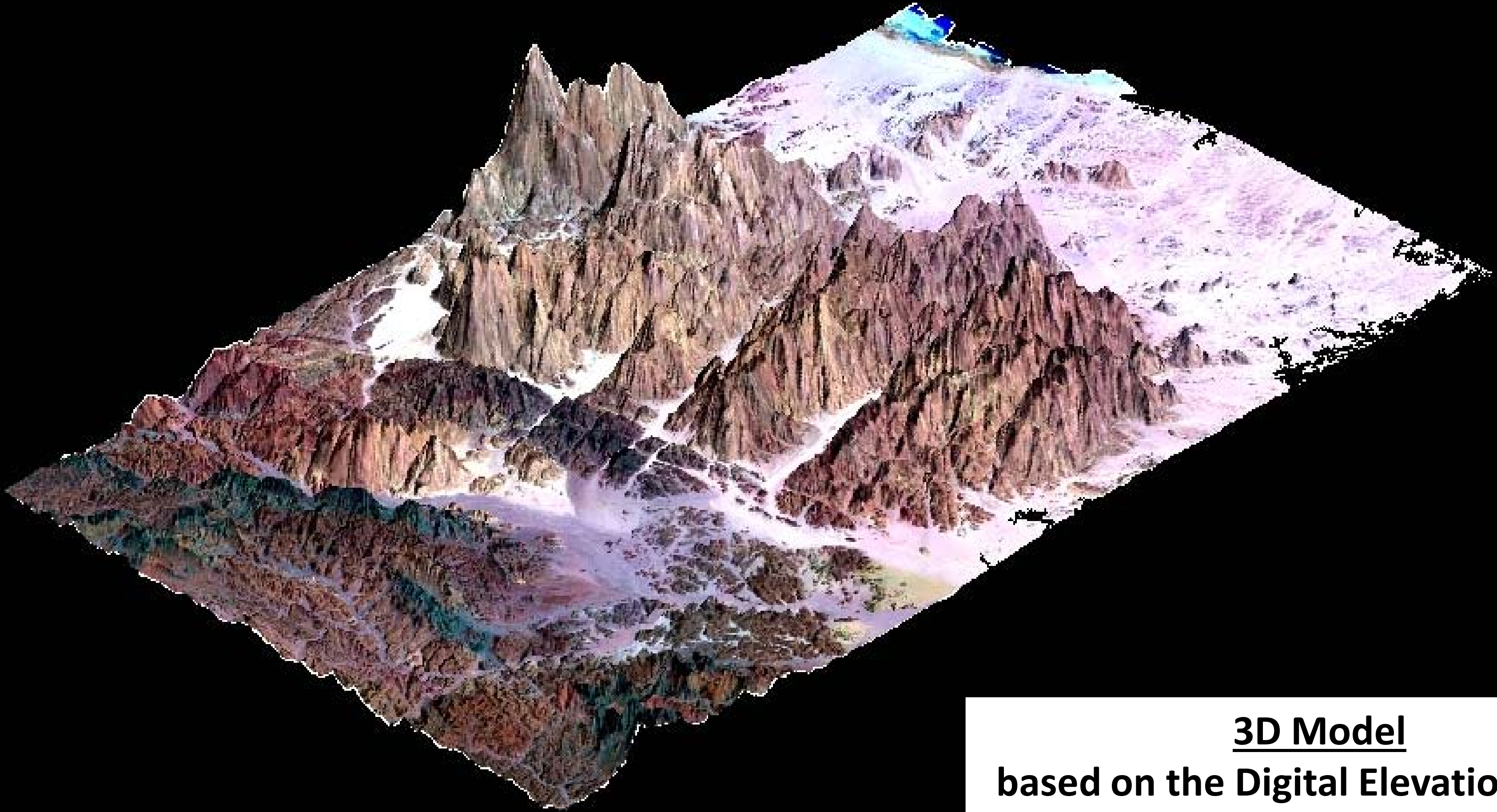
<u>Topographic contour map</u> **based on the Digital Elevation (DEM) Data of the same area in the previous slide**



<u>Topographic contour map</u> **with color shades based on the Digital Elevation (DEM) Dataof the same area in the previous slide**

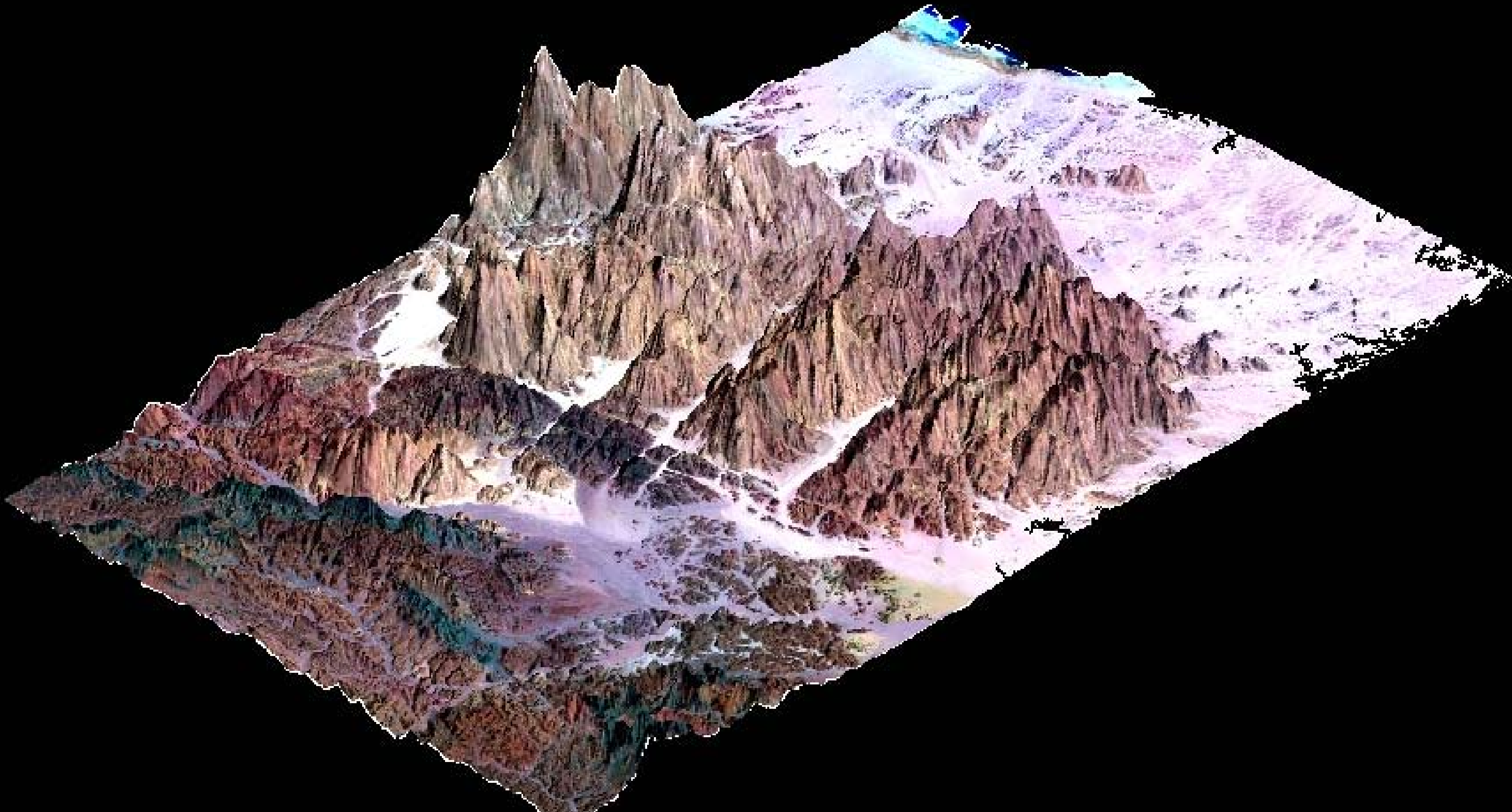






<u>3D Model</u>

based on the Digital Elevation (DEM) Data and TM landsat (7,4,2)



Elements of Visual Interpretation

The visual elements that can be used in image interpretation can be summarized as following:

1- Tone and color: refers to the relative brightness or color of objects in an image. Some rock types may have certain tones and colors in certain band ratios.

2- Shape: refers to the general form, structure, or outline of individual objects. Straight edge shapes typically represent urban or agricultural (field) targets, while natural features, such as forest edges, are generally more irregular in shape

3- Pattern: refers to the spatial arrangement of visibly discernible objects, e.g. the regular arrangement of houses blocks in towns.

4- Texture: refers to the arrangement and frequency of tonal variation in particular areas of an image. Sedimentary, igneous and metamorphic rocks are of different textures on the image.

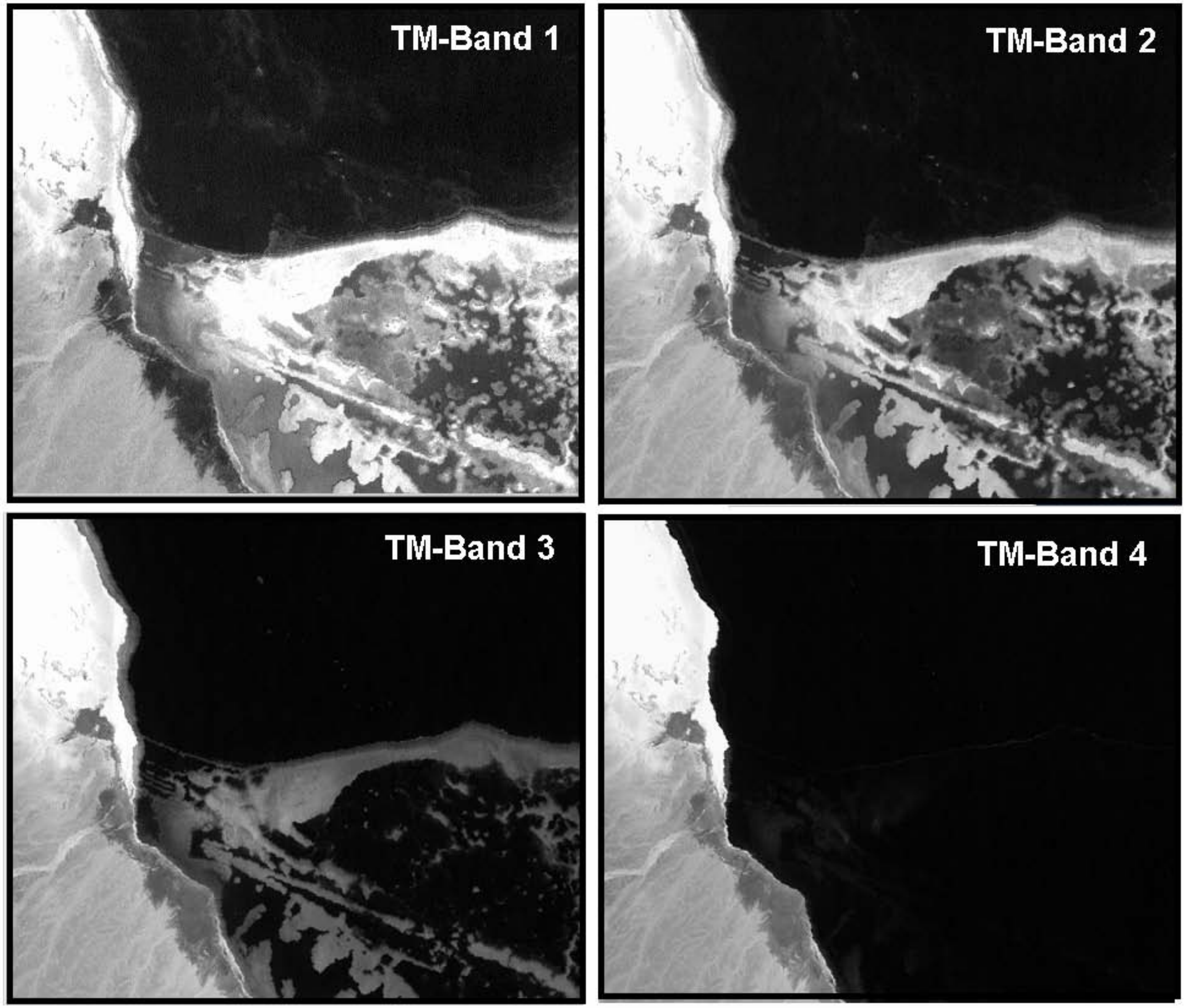
5- Shadow: provides an idea of the profile and relative height of a target or targets

6- Rock Associations: may provide information to facilitate identification and interpretation. Certain rock types usually occur together in the terrain, e.g. in an ophiolitic association it is expected to find serpentine, metagabbro and metavolcanics.

Characteristics of TM Bands

Band	EMS	Band characteristics
1	Blue light	illuminates material in shadows better than longer wavelengths; penetrates clear water better than other colors; absorbed by chlorophyll, so plants don't show up very brightly in this band; useful for soil/vegetation discrimination, forest type mapping, and identifying man-made features
2	Green light	penetrates clear water fairly well, gives excellent contrast between clear and turbid (muddy) water; helps find oil on the surface of water; reflects more green light than any other visible color; man-made features are still visible
3	Red light	limited water penetration; reflects well from dead foliage, but not well from live foliage with chlorophyll; useful for identifying vegetation types, soils, and urban (city and town) features
4	Near IR (NIR)	good for mapping shorelines; very good at detecting and analyzing vegetation
5	Shortwave IR (SWIR)	limited cloud penetration; provides good contrast between different types of vegetation; useful for measuring the moisture content of soil and vegetation; helps differentiate between snow and clouds
6	Thermal IR	useful to observe temperature and its effects, such as daily and seasonal variations; useful to identify some vegetation density, moisture, and cover type;
7	Another SWIR	limited cloud penetration; provides good contrast between different types of vegetation and rocks; useful for measuring the moisture content of soil and vegetation; helps differentiate between snow and clouds

The Red Sea coast at the southern part of Egypt. The mass occurring at the southeastern part of the image is a coral reef below the water surface. Notice its variable degrees of reflectance in bands 1,2 & 3 and its absence in band 4. Band 4 has almost no penetration for water bodies.
Width of the image is about 11 km.



Some useful band combinations

R, G, B	Potential Information Content
4,3,2	The standard "false color" composite. Vegetation appears in shades of red, urban areas are cyan blue, and soils vary from dark to light browns. Ice, snow and clouds are white or light cyan. Coniferous trees will appear darker red than hardwoods. This is a very popular band combination and is useful for vegetation studies, monitoring drainage and soil patterns and various stages of crop growth. Generally, deep red hues indicate broad leaf and/or healthier vegetation while lighter reds signify grasslands or sparsely vegetated areas. Densely populated urban areas are shown in light blue. This TM band combination gives results similar to traditional color infrared aerial photography.
3,2,1	The "natural color" band combination. Because the visible bands are used in this combination, ground features appear in colors similar to their appearance to the human visual system, healthy vegetation is green, recently cleared fields are very light, unhealthy vegetation is brown and yellow, roads are gray, and shorelines are white. This band combination provides the most water penetration and superior sediment and bathymetric information. It is also used for urban studies. Cleared and sparsely vegetated areas are not as easily detected here as in the 4 5 1 or 4 3 2 combination. Clouds and snow appear white and are difficult to distinguish. Also note that vegetation types are not as easily distinguished as the 4 5 1 combination. The 3 2 1 combination does not distinguish shallow water from soil as well as the 7 5 3 combination does.

7,4,2	This combination provides a "natural-like" rendition, while also penetrating atmospheric particles and smoke. Healthy vegetation will be a bright green and can saturate in seasons of heavy growth, grasslands will appear green, pink areas represent barren soil, oranges and browns represent sparsely vegetated areas. Dry vegetation will be orange and water will be blue. Sands, soils and minerals are highlighted in a multitude of colors. This band combination provides striking imagery for desert regions. It is useful for geological, agricultural and wetland studies. If there were any fires in this image they would appear red. This combination is used in the fire management applications for post-fire analysis of burned and non burned forested areas. Urban areas appear in varying shades of magenta. Grasslands appear as light green. The light-green spots inside the city indicate grassy land cover - parks, cemeteries, golf courses. Olive-green to bright-green hues normally indicate forested areas with coniferous forest being darker green than deciduous.
4,5,1	Healthy vegetation appears in shades of reds, browns, oranges and yellows. Soils may be in greens and browns, urban features are white, cyan and gray, bright blue areas represent recently clearcut areas and reddish areas show new vegetation growth, probably sparse grasslands. Clear, deep water will be very dark in this combination, if the water is shallow or contains sediments it would appear as shades of lighter blue. For vegetation studies, the addition of the Mid-IR band increases sensitivity of detecting various stages of plant growth or stress; however care must be taken in interpretation if acquisition closely follows precipitation. Use of TM 4 and TM 5 shows high reflectance in healthy vegetated areas. It is helpful to compare flooded areas and red vegetated areas with the corresponding colors in the 3 2 1 combination to assure correct interpretation. This is not a good band combination for studying cultural features such as roads and runways.

4,5,3	This combination of near-IR (Band 4), mid-IR (Band 5) and red (Band 3) offers added definition of land-water boundaries and highlights subtle details not readily apparent in the visible bands alone. Inland lakes and streams can be located with greater precision when more infrared bands are used. With this band combination, vegetation type and condition show as variations of hues (browns, greens and oranges), as well as in tone. The 4,5,3 combination demonstrates moisture differences and is useful for analysis of soil and vegetation conditions. Generally, the wetter the soil, the darker it appears, because of the infrared absorption capabilities of water.
7,5,3	This band combination also provides a "natural-like" rendition while also penetrating atmospheric particles, smoke and haze. Vegetation appears in shades of dark and light green during the growing season, urban features are white, gray, cyan or purple, sands, soils and minerals appear in a variety of colors. The almost complete absorption of Mid-IR bands in water, ice and snow provides well defined coast lines and highlighted sources of water within the image. Snow and ice appear as dark blue, water is black or dark blue. Hot surfaces such as forest fires and volcano calderas saturate the Mid-IR bands and appear in shades of red or yellow. One particular application for this combination is monitoring forest fires. During seasons of little vegetation growth the 7 4 2 combination should be substituted. Flooded areas should look very dark blue or black, compared with the 3 2 1 combination in which shallow flooded regions appear gray and are difficult to distinguish.

5,4,3	**Like the 4 5 1 combination, this combination provides the user with a great amount of information and color contrast. Healthy vegetation is bright green and soils are mauve. While the 7 4 2 combination includes TM 7, which has the geological information, the 5 4 3 combination uses TM 5 which has the most agricultural information. This combination is useful for vegetation studies, and is widely used in the areas of timber management and pest infestation.**
5,4,1	**This will look similar to the 7 4 2 combination in that healthy vegetation will be bright green, except the 5 4 1 combination is better for agricultural studies.**
7,5,4	**This combination involves no visible bands. It provides the best atmospheric penetration. Coast lines and shores are well defined. It may be used to find textural and moisture characteristics of soils. Vegetation appears blue. If the user prefers green vegetation, a 7 4 5 combination should be substituted. This band combination can be useful for geological studies.**
5,3,1	**This combination display topographic textures while 7 3 1 may display differences in rock types.**

N.B.:
Some of the figures and photos used in this lecture are used after previous iteratures for the purpose of teaching for students.