

## MODULE – 2 LECTURE NOTES – 2

### SPATIAL AND SPECTRAL RESOLUTIONS

#### 1. Introduction

In general, the resolution is the minimum distance between two objects that can be distinguished in the image. Objects closer than the resolution appear as a single object in the image. However, in remote sensing the term resolution is used to represent the resolving power, which includes not only the capability to identify the presence of two objects, but also their properties. In qualitative terms resolution is the amount of details that can be observed in an image. Thus an image that shows finer details is said to be of finer resolution compared to the image that shows coarser details. Four types of resolutions are defined for the remote sensing systems.

- Spatial resolution
- Spectral resolution
- Temporal resolution
- Radiometric resolution

This lecture covers the spatial and spectral resolutions in detail.

#### 2. Spatial resolution

A digital image consists of an array of pixels. Each pixel contains information about a small area on the land surface, which is considered as a single object.

Spatial resolution is a measure of the area or size of the smallest dimension on the Earth's surface over which an independent measurement can be made by the sensor.

It is expressed by the size of the pixel on the ground in meters. Fig.1 shows the examples of a coarse resolution image and a fine resolution image.

Coarse Spatial Resolution



Fine Spatial Resolution



Fig.1 Examples of a coarse resolution and a fine resolution image

A measure of size of pixel is given by the Instantaneous Field of View (IFOV). The IFOV is the angular cone of visibility of the sensor, or the area on the Earth's surface that is seen at one particular moment of time. IFOV is dependent on the altitude of the sensor above the ground level and the viewing angle of the sensor.

A narrow viewing angle produces a smaller IFOV as shown in Fig. 2. It can be seen that viewing angle  $\beta$  being greater than the viewing angle  $\alpha$ ,  $\text{IFOV}_\beta$  is greater than  $\text{IFOV}_\alpha$ . IFOV also increases with altitude of the sensor as shown in Fig. 2.  $\text{IFOV}_\beta$  and  $\text{IFOV}_\alpha$  of the sensor at smaller altitude are less compared to those of the higher altitude sensor.

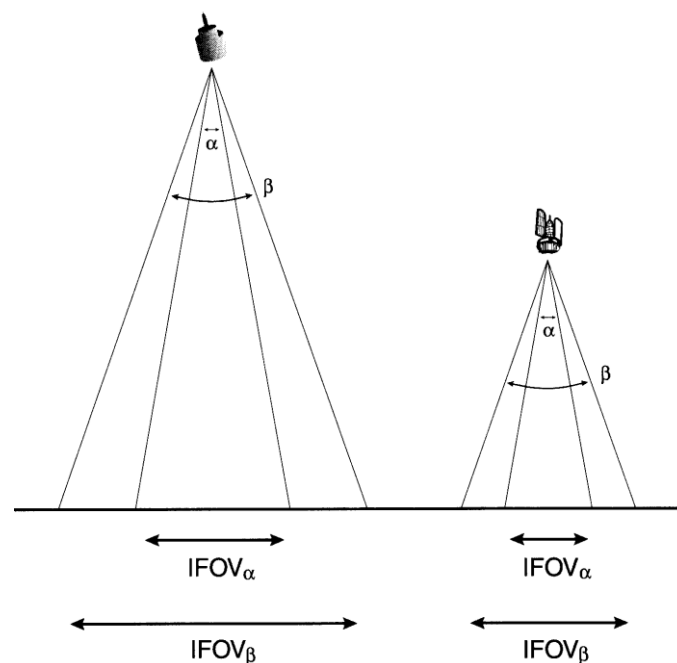


Fig.2. IFOV variation with angle of view and altitude of the sensor

The size of the area viewed on the ground can be obtained by multiplying the IFOV (in radians) by the distance from the ground to the sensor. This area on the ground is called the ground resolution or ground resolution cell. It is also referred as the spatial resolution of the remote sensing system.

For a homogeneous feature to be detected, its size generally has to be equal to or larger than the resolution cell. If more than one feature is present within the IFOV or ground resolution cell, the signal response recorded includes a mixture of the signals from all the features. When the average brightness of all features in that resolution cell is recorded, any one particular feature among them may not be detectable. However, smaller features may sometimes be detectable if their reflectance dominates within a particular resolution cell allowing sub-pixel or resolution cell detection.

Fig. 3 gives an example of how the identification of a feature (a house in this case) varies with spatial resolution. In the example, for the 30m resolution image, the signature from the “house” dominates for the cell and hence the entire cell is classified as “house”. On the other hand, in the fine resolution images, the shape and the spatial extent of the feature is better captured. In the 5m resolution image, along the boundary of the feature, some of the cells that are partially covered under the feature are classified as “house” based on the dominance of the signals from the feature. In the very fine resolution image, the feature shape and the spatial extent is more precisely identified.

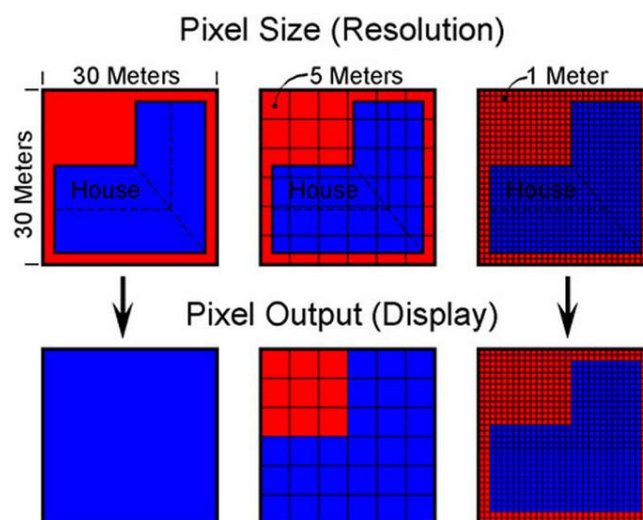


Fig. 3. Schematic representation of feature identification at different spatial resolutions

(Source: <http://www.satimagingcorp.com/> )

Based on the spatial resolution, satellite systems can be classified as follows.

- Low resolution systems
- Medium resolution systems
- High resolution systems
- Very high resolution systems

Remote sensing systems with spatial resolution more than 1km are generally considered as low resolution systems. MODIS and AVHRR are some of the very low resolution sensors used in the satellite remote sensing. When the spatial resolution is 100m – 1km, such systems are considered as moderate resolution systems. IRS WiFS (188m), band 6 i.e., thermal infrared band, of the Landsat TM (120m), and bands 1-7 of MODIS having resolution 250-500m come under this class. Remote sensing systems with spatial resolution approximately in the range 5-100m are classified as high resolution systems. Landsat ETM<sup>+</sup> (30m), IRS LISS-III (23m MSS and 6m Panchromatic) and AWiFS (56-70m), SPOT 5(2.5-5m Panchromatic) are some of the high resolution sensors. Very high resolution systems are those which provide less than 5m spatial resolution. GeoEye (0.45m for Panchromatic and 1.65m for MSS), IKONOS (0.8-1m Panchromatic), and Quickbird (2.4-2.8 m) are examples of very high resolution systems.

Fig. 4 shows how an area looks like in images of different spatial resolution, how much information can be retrieved from each and the scale of application of these images.

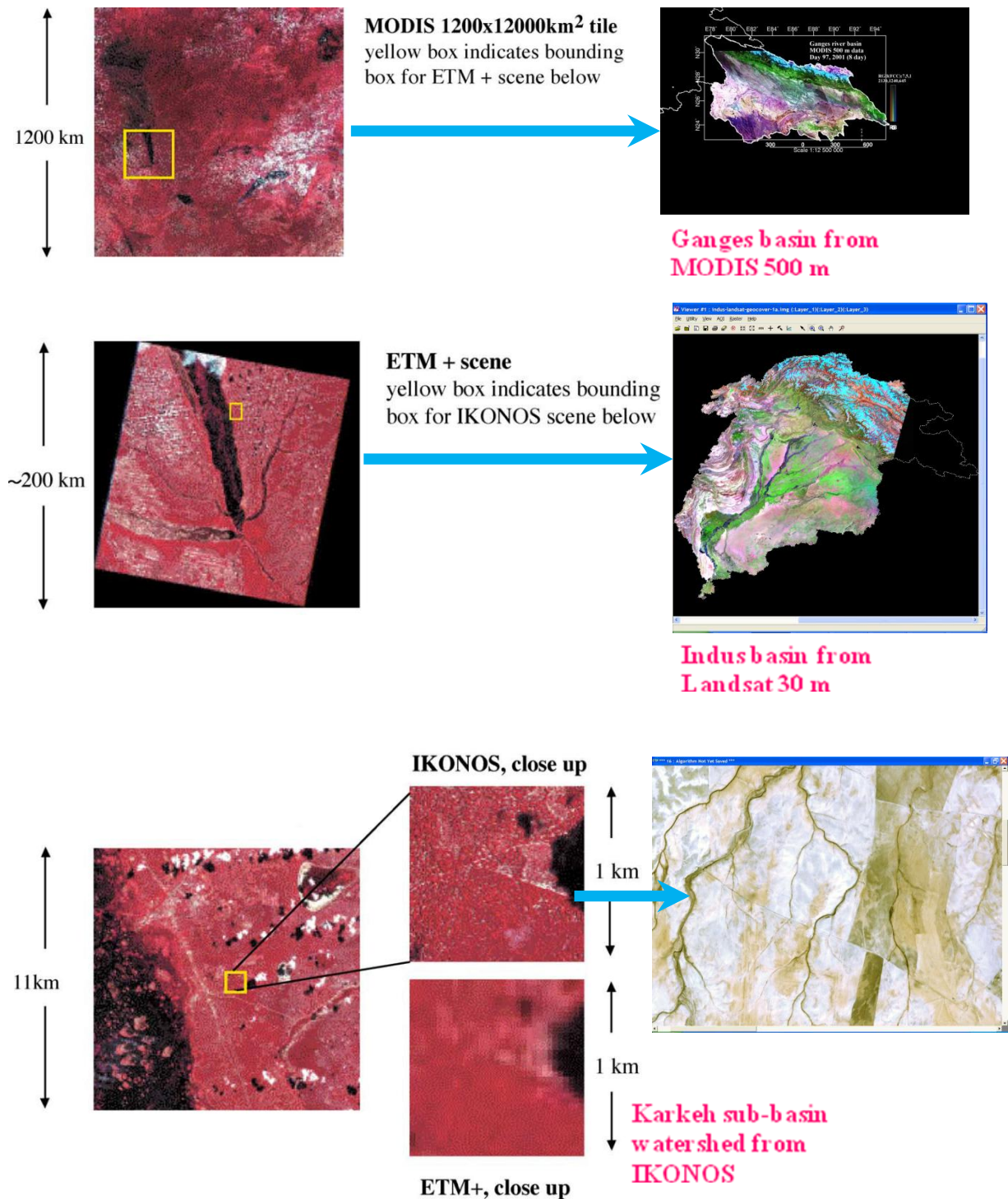


Fig.4. False color composite image (red = 850 nm, blue = 650 nm, blue = 555 nm) of MODIS, ETM+ and IKONOS imagery (Courtesy: Morisette et al., 2002)

The ratio of distance on an image or map, to actual ground distance is referred to as scale.

If we have a map with a scale of 1:100,000, an object of 1cm length on the map would actually be an object 100,000cm (1km) long on the ground. Maps or images with small "map-to-ground ratios" are referred to as small scale (e.g. 1:100,000), and those with larger ratios (e.g. 1:5,000) are called large scale. Thus, large scale maps/images provide finer spatial resolution compared to small scale maps/images.

### 3. Spectral resolution

Spectral resolution represents the spectral band width of the filter and the sensitiveness of the detector. The spectral resolution may be defined as the ability of a sensor to define fine wavelength intervals or the ability of a sensor to resolve the energy received in a spectral bandwidth to characterize different constituents of earth surface. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band.

Many remote sensing systems are multi-spectral, that record energy over separate wavelength ranges at various spectral resolutions. For example IRS LISS-III uses 4 bands: 0.52-0.59 (green), 0.62-0.68 (red), 0.77-0.86 (near IR) and 1.55-1.70 (mid-IR). The Aqua/Terra MODIS instruments use 36 spectral bands, including three in the visible spectrum. Recent development is the hyper-spectral sensors, which detect hundreds of very narrow spectral bands. Figure 5 shows the hypothetical representation of remote sensing systems with different spectral resolution. The first representation shows the DN values obtained over 9 pixels using imagery captured in a single band. Similarly, the second and third representations depict the DN values obtained in 3 and 6 bands using the respective sensors. If the area imaged is say  $A \text{ km}^2$ , the same area is being viewed using 1, 3 and 6 number of bands.

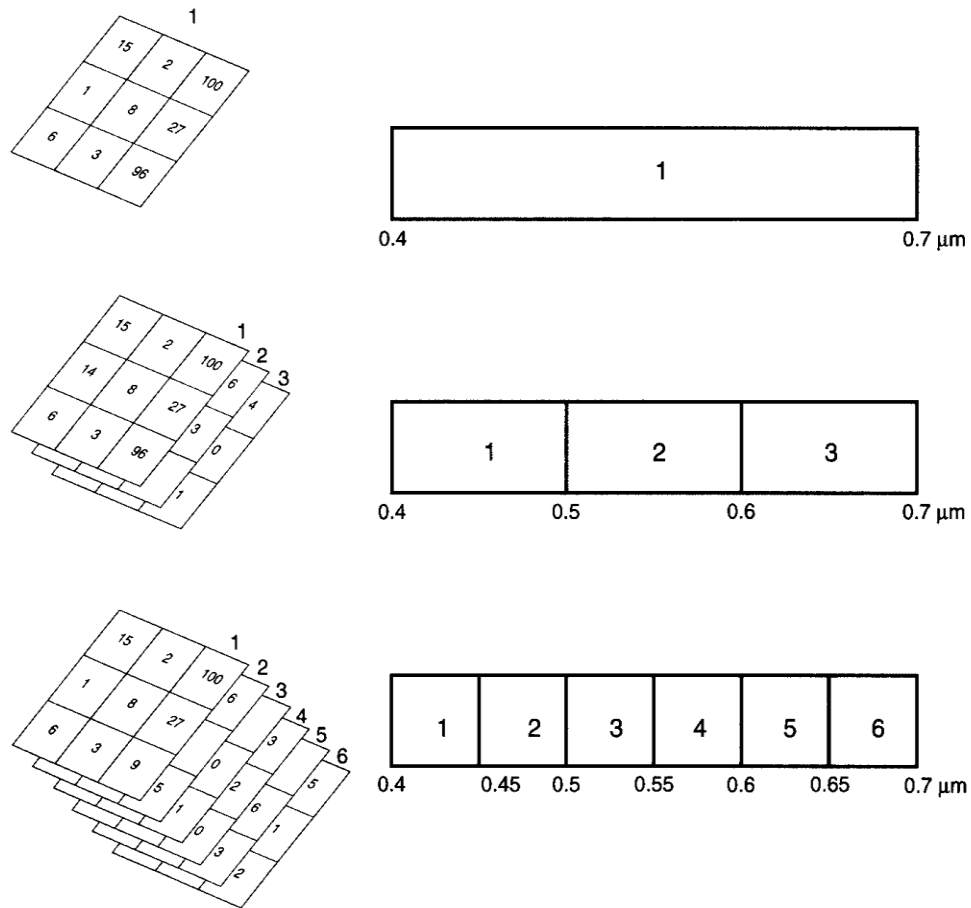


Fig. 5. Hypothetical representation of remote sensing systems with different spectral resolution (Source: Gibson, 2000)

Generally surface features can be better distinguished from multiple narrow bands, than from a single wide band.

For example, in Fig. 6, using the broad wavelength band 1, the features A and B cannot be differentiated. However, the spectral reflectance values of the two features are different in the narrow bands 2 and 3. Thus, a multi-spectral image involving bands 2 and 3 can be used to differentiate the features A and B.

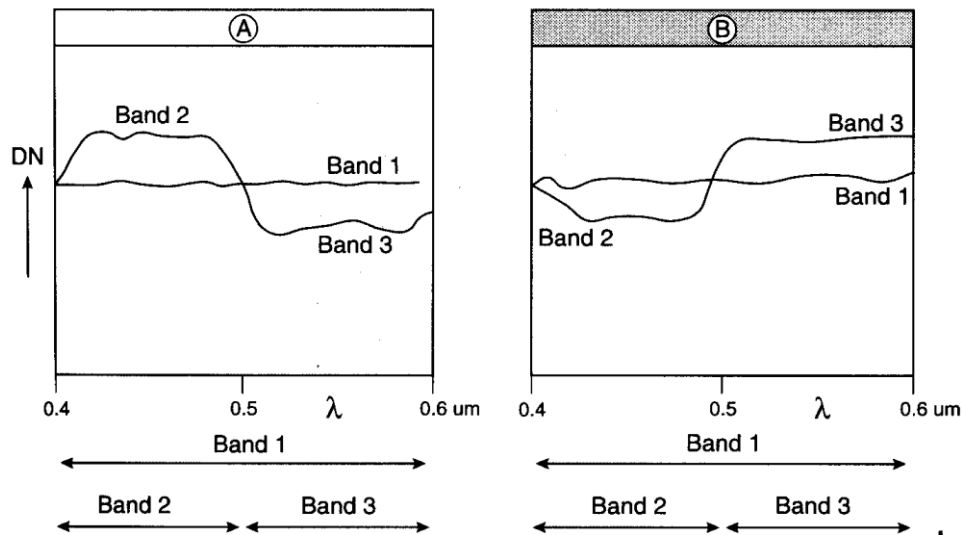


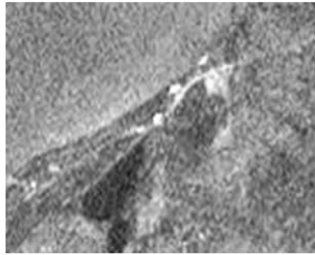
Fig.6. Two different surfaces (A and B) are indistinguishable on a single band but can be differentiated in 2 narrow bands

In remote sensing, different features are identified from the image by comparing their responses over different distinct spectral bands. Broad classes, such as water and vegetation, can be easily separated using very broad wavelength ranges like visible and near-infrared. However, for more specific classes viz., vegetation type, rock classification etc, much finer wavelength ranges and hence finer spectral resolution are required. For example, Fig. 7 shows the difference in the spectral responses of an area in different bands of the Landsat TM image.

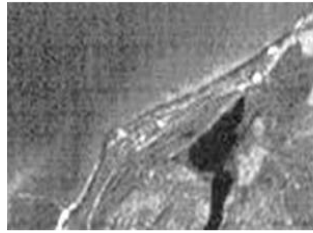
Fig.8 shows a panchromatic image and Fig.9 and 10 show Landsat TM images taken in different spectral bands. The figures clearly indicate how different bands and their combinations help to extract different information.



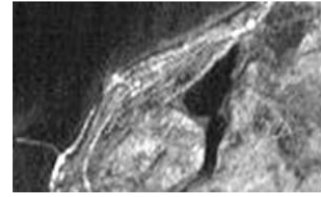
TM Band 1  
0.45–0.52  $\mu\text{m}$   
(blue)



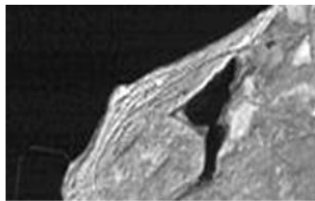
TM Band 2  
0.52–0.60  $\mu\text{m}$   
(green)



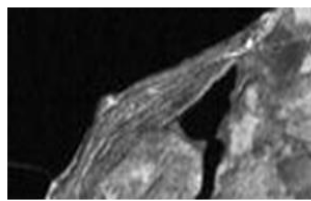
TM Band 3  
0.63–0.69  $\mu\text{m}$   
(red)



TM Band 4  
0.76–0.90  $\mu\text{m}$   
(near-infrared)



TM Band 5  
1.55–1.75  $\mu\text{m}$   
(mid-infrared)



TM Band 6  
10.4–12.5  $\mu\text{m}$   
(thermal-infrared)



TM Band 7  
2.08–2.35  $\mu\text{m}$   
(mid-infrared)

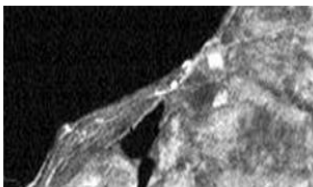


Fig.7 Landsat TM images of an area recorded in different spectral bands



Fig.8. A coarse resolution panchromatic image- Minimum information is visible from the image

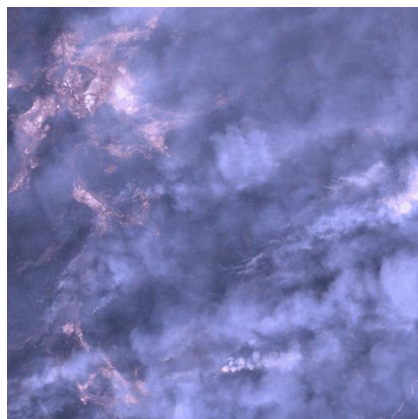


Fig. 9. Landsat TM (321) showing forest fire in Yellowstone NP- The smoke cover obstructs the ground view

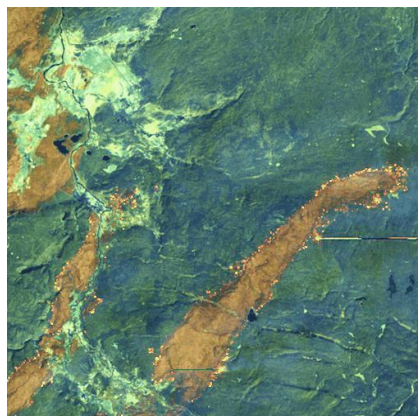


Fig. 10. Landsat TM (754) showing forest fire in Yellowstone NP

## **Bibliography / Further Reading**

1. Gibson P.J (2000) “Introductory Remote Sensing- Principles and Concepts”  
Routledge, London.
2. Morisette, J.T, Privette, J. L, Justice, C. O [2002], A framework for the validation of  
MODIS Land products. Remote Sensing of Environment, 83 (2-Jan), 77-96.