6^{th} SEMESTER (MAJOR)

PAPER 604: PRINCIPLES AND APPLICATION OF REMOTE SENSING, GIS AND GPS

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CONCEPT OF RESOLUTION

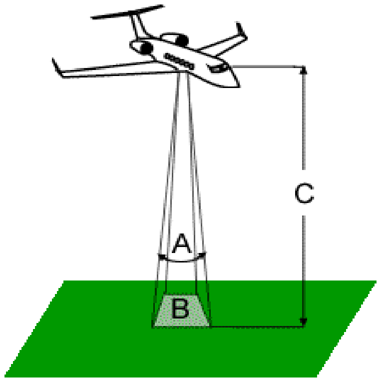
The resolution of an image refers to the potential detail provided by the imagery. Resolution is defined as the ability of the system to deliver the information at the smallest discretely separable quantity in terms of distance (spatial), wavelength band of EMR (spectral), time (temporal) and/or radiation quantity (radiometric).

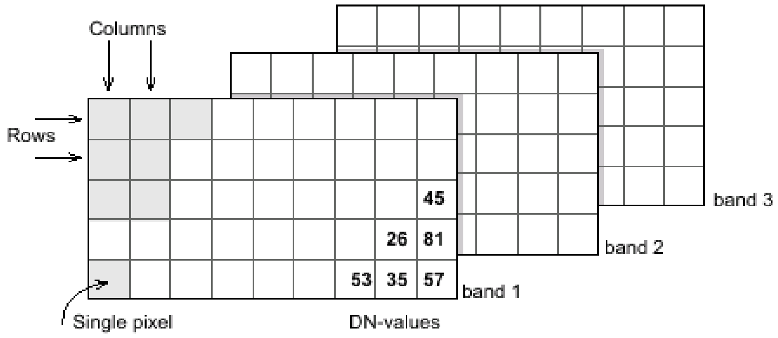
In remote sensing we refer to the four types of resolution:

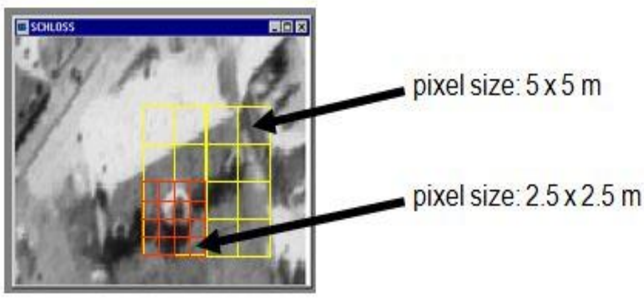
- Spatial (what area and how detailed);
- Spectral (what colors-bands);
- Radiometric (color depth);
- Temporal (time of day/season/year).

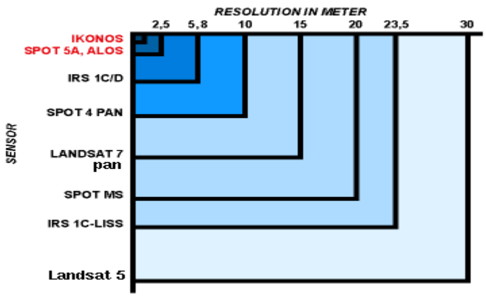
Spatial Resolution: It refers to the size of the smallest feature that can be detected by a satellite sensor or displayed in a satellite image. It describes how much detail in a photographic image is visible to the human eye. The ability to "resolve" or separate, small details is one way of describing what we call spatial resolution. It is usually presented as a single value representing the length of one side of a square. The spatial resolution of images acquired by satellite sensor systems is usually expressed in meters. For example, a spatial resolution of 250m means that one pixel represents an area 250 by 250 meters on the ground. Spatial resolution of the sensor also refers to the size of the smallest possible feature that can be detected. Spatial resolution of passive sensors depends primarily on their Instantaneous Field of View (IFOV). The IFOV is the angular cone of visibility of the sensor (A) and determines the area on the Earth's surface which is "seen" from a given altitude at one particular moment in time (B). The size of the area viewed is determined by multiplying the IFOV by the distance from the ground to the sensor (C). This area on the ground is called the resolution cell and determines a sensor's maximum spatial resolution. Most remote sensing images are composed of a matrix of picture elements, or pixels, which are the smallest units of an image. Image pixels are normally square and represent a certain area on an image. It is important to distinguish between pixel size and spatial resolution - they are not interchangeable. If a sensor has a spatial resolution of 20 metres and an image from that sensor is displayed at full resolution, each pixel represents an area of 20m x 20m on the ground. In this case the pixel size and resolution are the same. Images where only large features are visible are said to have coarse or low resolution**.** In fine or high resolution images, small objects can be detected. Military sensors for example, are designed to view as much detail as possible, and therefore have very fine resolution. Commercial satellites provide imagery with resolutions varying from a few metres to several kilometres. Generally speaking, the finer the resolution, the less total ground area can be seen.

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



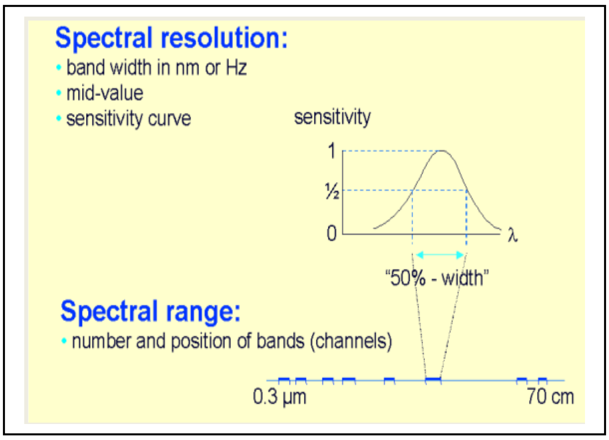




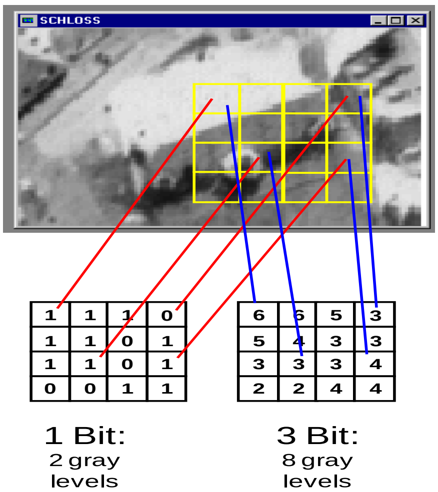


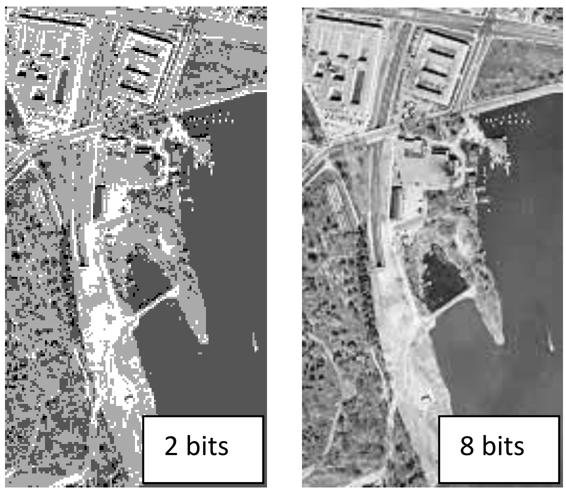
Spectral Resolution: It refers to the ability of a satellite sensor to measure specific wavelengths of the electromagnetic spectrum (red, green, blue, NIR, MIR, thermal etc). Certain spectral bands (or combinations) are good for identifying specific ground features. Different classes of features and details in an image can often be distinguished by comparing their responses over distinct wavelength ranges. Broad classes, such as water and vegetation, can usually be separated using very broad wavelength ranges - the visible and near infrared. Other more specific classes, such as different rock types, may not be easily distinguishable using either of these broad wavelength ranges and would require comparison at much finer wavelength ranges to separate them. Thus, we would require a sensor with higher spectral resolution. Spectral resolution describes the ability of a sensor to define fine wavelength intervals. The finer the spectral resolution, the narrower the wavelengths range for a particular channel or band. Many remote sensing systems record energy over several separate wavelength ranges at various spectral resolutions. These are referred to as multi-spectral sensors and will be described in some detail in following sections. Advanced multi-spectral sensors called hyperspectral sensors, detect hundreds of very narrow spectral bands throughout the visible, near infrared, and mid-infrared portions of the electromagnetic spectrum. Their very high spectral resolution facilitates fine discrimination between different targets based on their spectral response in each of the narrow bands.

- Panchromatic- 1 band (black & white)
- Color – 3 bands (RGB)
- Multispectral- 4+ bands (RGBNIR)
- Hyperspectral- hundreds of bands



Radiometric Resolution: While the arrangement of pixels describes the spatial structure of an image, the radiometric characteristics describe the actual information content in an image. Every time an image is acquired on film or by a sensor, its sensitivity to the magnitude of the electromagnetic energy determines the radiometric resolution. The radiometric resolution of an imaging system describes its ability to discriminate very slight differences in energy. The finer the radiometric resolution of a sensor the more sensitive it is to detecting small differences in reflected or emitted energy. Imagery data are represented by positive digital numbers which vary from 0 to (one less than) a selected power of 2. This range corresponds to the number of bits used for coding numbers in binary format. Each bit records an exponent of power 2 (e.g. 1 bit=2^1=2). The maximum number of brightness levels available depends on the number of bits used in representing the energy recorded. Thus, if a sensor used 8 bits to record the data, there would be 2^8=256 digital values available, ranging from 0 to 255. However, if only 4 bits were used, then only 2^4=16 values ranging from 0 to 15 would be available. Thus, the radiometric resolution would be much less. Image data are generally displayed in a range of grey tones, with black representing a digital number of 0 and white representing the maximum value (for example, 255 in 8-bit data). By comparing a 2-bit image with an 8-bit image, we can see that there is a large difference in the level of detail discernible depending on their radiometric resolutions.



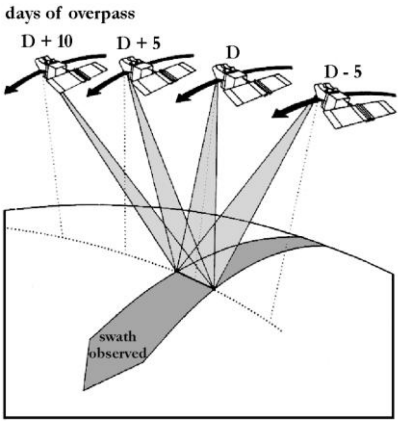


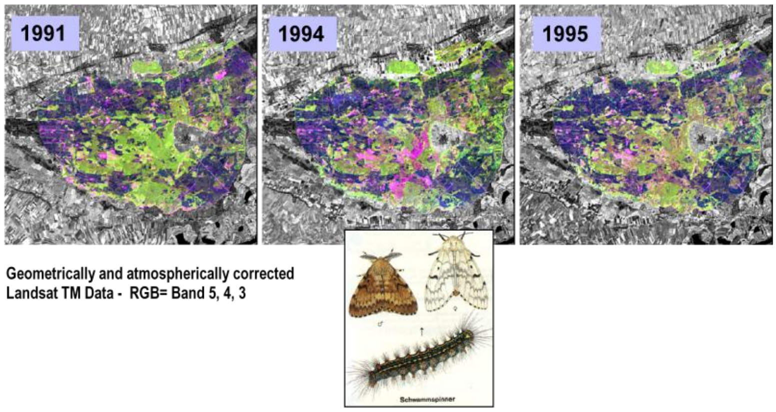
8 bits ↓ 11 bits ↓

1	2	3	4	5	6	7	8	9	10	11	Number of bits
2	4	8	16	32	64	128	256	512	1024	2048	Maximum Values

Temporal Resolution: The ability to collect imagery of the same area of the Earth's surface at different periods of time is one of the most important elements for applying remote sensing data. Spectral characteristics of features may change over time and these changes can be detected by collecting and comparing multi-temporal imagery. For example, during the growing season, most species of vegetation are in a continual state of change and our ability to monitor those subtle changes using remote sensing is dependent on when and how frequently we collect imagery. By imaging on a continuing basis at different times we are able to monitor the changes that take place on the Earth's surface, whether they are naturally occurring (such as changes in natural vegetation cover or flooding) or induced by humans (such as urban development or deforestation). The time factor in imaging is important when:

- persistent clouds offer limited clear views of the Earth's surface (often in the tropics)
- short-lived phenomena (floods, oil slicks, etc.) need to be imaged
- multi-temporal comparisons are required (e.g. the spread of a forest disease from one year to the next)
- the changing appearance of a feature over time can be used to distinguish it from near similar features (wheat / maize) It refers to the time between images.





Geometrically and atmospherically corrected Landsat TM Data - RGB= Band 5, 4, 3

Comparison of Landsat Sensors

	Thematic Mapper (TM) Landsat 4 and 5	Enhanced Thematic Mapper Plus (ETM+) Landsat 7	Multispectral Scanner (MSS) Landsat 1-5
Spectral Resolution (µm)	1. 0.45-0.52 (B) 2. 0.52-0.60 (G) 3. 0.63-0.69 (R) 4. 0.76-0.90 (NIR) 5. 1.55-1.75 (MIR) 6. 2.08-2.35 (MIR) 7. 10.4-12.5 (TIR)	1. 0.45-0.52 2. 0.53-0.61 3. 0.63-0.69 4. 0.78-0.90 5. 1.55-1.75 6. 2.09-2.35 7. 10.4-12.5 8. 0.52-0.90 (Pan)	0.5-0.6 (green) 0.6-0.7 (red) 0.7-0.8 (NIR) 0.8-1.1 (NIR)
Spatial Resolution (meter)	30 x 30 120 x 120 (TIR)	15 x 15 (Pan) 30 x 30 60 x 60 (TIR)	79 x 79
Temporal Resolution (revisit in days)	16	16	18
Spatial coverage (km)	185 x 185	183 x 170	185 x 185
Altitude (km)	705	705	915 (Landsat 1,2,3)