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Assignment - 4

Roll No. 48

1.) Describe the different types of image resolutions. Describe IFOV, swaths & Nadir with illustrations.

⇒ Image resolution refers to the level of detail & clarity in an image. It describes the ability of a remote sensing system to record & display fine details of ground features.

The different types of image resolutions are as follows:-

1.) Spatial resolution:-

It refers to the size of smallest features that can be detected in an image, it is typically measured as the ground are represented by the pixel. This type of resolution determines how much detail can be seen in an image. Higher spatial resolution allows finer details to be distinguished.

11.) Spectral resolution:-

It refers to the number & width of spectral bands a sensor can detect. Spectral resolution describes the ability of a sensor to distinguish different parts of the electromagnetic spectrum. Higher spectral resolution means more numerous & narrower bands allowing for better discrimination between different types of surface materials.

111) Radiometric resolution:-

It refers to the ability to detect small differences in radiation intensity. Typically, it is measured in number of bits (eg. 8 bit, 12 bit). Higher radiometric resolution allows detection of subtle difference in reflectance/emittance.

IV.) Temporal resolution:- It refers to how frequently a sensor can image the same area. This is typically measured in days. Higher temporal resolution allows more frequent monitoring of an area.

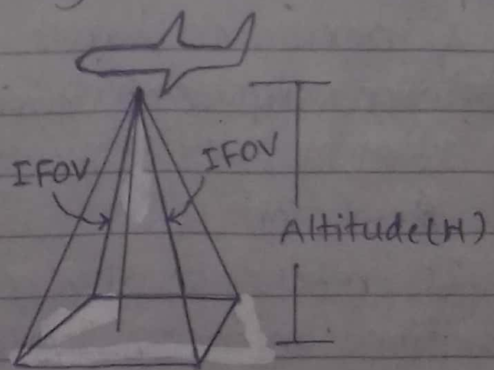
- IFOV :-

Instantaneous field of view (IFOV) refers to the angular cone of visibility of a remote sensing instrument. It is the angle through which a detector is sensitive to radiation.

- IFOV is a key parameter for determining spatial resolution.

Illustration :-

Imagine a cone extending from the sensor on plane to ground. Here, the apex of cone is sensor & the base of cone represents the area on ground that the sensor can see at any given instant. The base area is typically square or rectangular & represents a single pixel in an image.



Example :-

If a satellite has an IFOV of 0.5 milliradians & it is orbiting at an altitude of 500km, the ground footprint (D) can be calculated as;

$D = \text{Altitude} \times \text{IFOV}$
$= 500\ \text{km} \times 0.5\ \text{milliradians}$
$= 500{,}000 \times 0.0005$
$= 200\text{m}.$

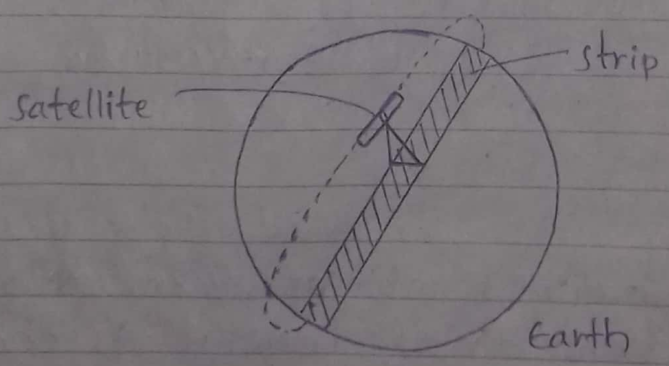
Thus, the sensor captures an area of 250 meters in diameter on the ground at any instant.

- Swath:-

The swath is the strip of the Earth surface from which data is collected by a side looking remote sensing system.

Illustration:-

picture a satellite orbiting Earth. Below it there is a long strip on earth surface. This strip represents the total area imaged during one pass of satellite. The width of this strip is swath width.



Example:-

For a satellite with an altitude of 700km & a IFOV that results in a swath width of 100km as the satellite moves along its orbit, it continuously captures data across this 100km width strip.

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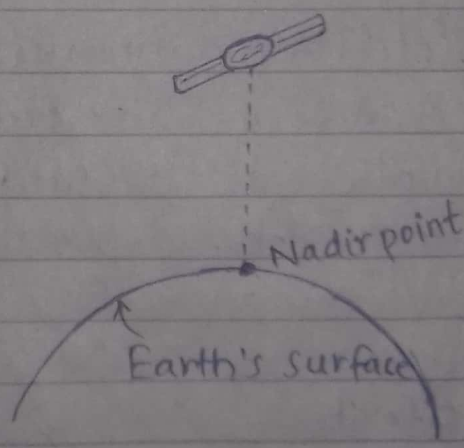
- Nadir :-

Nadir refers to the point on the ground directly beneath the satellite or sensor platform. It is the point where a vertical line from the sensor would intersect the Earth surface.

Illustration :-

Draw a straight line from the satellite directly down to the Earth's surface perpendicular to the Earth's surface. The point where this line touches the Earth is the Nadir point.



Example :-

A satellite in orbit at 800km altitude has it's Nadir point directly below it. As the satellite moves along its orbit the Nadir point traces a line on the Earth's surface. This line is crucial for calibrating satellite data & understanding the geometry of the imagery.

2.) Differentiate between photogrammetry & LIDAR technology? How DEM/DTM can be generated in photogrammetric process?

⇒ photogrammetry:-

It is the science of making measurements from photographs. It is used to recover the exact positions of surface points.

LIDAR (Light Detection & Ranging):-

LIDAR is a remote sensing technology that uses laser light to measure distances & create high resolution maps of the Earth's surface.

Differences between photogrammetry & LIDAR technology:-

photogrammetry	LIDAR Technology
1.) It is the science of making measurements from photographs especially for recovering the exact positions of surface points.	1.) It is a remote sensing technology that measures distances by illuminating the target with laser light & analyzing the reflected light.
II.) It uses passive sensors (cameras) to capture reflected light.	II.) LIDAR uses active sensors (lasers) to measure distances.
III.) It provides high resolution images & 3D models with color & texture.	III.) It produces detailed 3D point clouds representing surface geometry.
IV.) It offers lower accuracy for elevation data.	IV.) It generally offers higher accuracy for elevation data.

v.) Data acquired using optical cameras (aerial or terrestial).	v.) Data acquired using Laser sensors (airborne or terrestial).
vi.) High resolution depending on camera quality.	vi.) Very high resolution (centimeter level accuracy).
vii.) Time consuming.	vii.) Faster processing with advanced software.
viii.) Cheap	viii.) Expensive due to equipments.
ix.) Affected by weather & lighting conditions.	ix.) Less affected (cannot work in heavy fog or rain).
x.) Applications:- archeology, 3D modelling, mapping.	x.) Applications:- Topographic mapping, forestry, urban planning, agriculture.

- Digital Elevation models (DEM) & Digital Terrain models (DTM) are representation of the Earth's surface in digital format. These are the critical products derived from photogrammetric process in GIS.

• Data Acquistion:-

- Aerial photography:- capture overlapping aerial photographs using cameras mounted on aircraft or drones. The overlap (typically 60-80%) ensures that every point on the ground is visible in multiple images.

- Ground control points (GCPs) :- Identify & measure accurate coordinates of GCPs in the field to help georeference the aerial images.

- Image preprocessing:-
- Radiometric correction:- Adjust the images for variations in lighting & sensor sensitivity.

- Geometric correctness:- Correct distortions caused by camera angle, lens distortion & topography.

- Dense point cloud Generation:-
- Stereo Matching:- Use algorithms to match corresponding pixels in overlapping images & generate a dense point cloud. Each point in the cloud represents a specific location on the ground.

- Dense Reconstruction:-
Enhance the point cloud by increasing the density of points improving the level of detail.

- DEM/DTM Extraction:-
- DEM creation:- Extract elevation information from the dense point cloud. The DEM represents the bare ground surface including all natural & man-made features. Apply filtering techniques to remove non-ground points (eg. buildings vegetation) if needed.

- DTM creation:- Further process the DEM to remove all above

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ground objects resulting in a model that represents the terrain's surface without any features. Use ground classification algorithms to identify & retain only ground points.

Interpolation:- Use interpolation techniques (eg. Inverse Distance Weighting (IDW), Kriging) to convert the point cloud into a continuous raster grid where each cell represents an elevation value.

Example Workflow:-

i.) Capture overlapping aerial images using a drone equipped with a high resolution camera.
ii.) Import images into photogrammetric software (eg. Agisoft, metashape).
iii.) Align images using tie points & perform bundle block adjustment.
iv.) Generate a dense point cloud from the aligned images.
v.) Classify the point clould to identify ground points & remove non-ground features.
vi.) Interpolate the classified point cloud to create a continuous DEM/DTM.
vii.) Validate the accuracy using GCPs & perform necessary corrections.
viii.) Export the DEM/DTM for use in GIS analysis & applications.

By following these steps, GIS professional can generate accurate & detailed DEMs & DTMs from aerial imagery, providing valuable elevation data for a wide range of applications such as terrain analysis, hydrological modeling & urban planning.

3.) Explain common image processing functions with illustrations. Differentiate between supervised & unsupervised classification.

⇒ Image processing functions are :-

i.) Histogram :-

It is a graphical representation of distribution of pixel values in an image. It is used to access brighness & contrast of image to identify problems like noise or saturation.

ii.) Histogram Equalization:-

It is a technique that aims to improve contrast in an image by stretching out histogram.

iii.) Image filtering:-

It is a process that applies mathematical function to remove noise, enhance edges or blur images.

- low pass filtering:- removes high frequency noise.
  - used in smoothing of images.

- High pass filtering:- removes low frequency noise.
  - used in sharpening of images.

iv.) Edge Detection:-

It is a technique that identifies edges of objects & it is used for segmentation & object recognition.

v.) Image segmentation:- It is a process that divides an image into multiple regions. It is used for object recognition & analysis.

vi) Image classification:-

It is a process that assign labels to pixels in an image.

Difference between supervised & unsupervised classification are:-

- Supervised classification:- It is a technique in remote sensing where set of training data is used to classify pixels in a image.

- unsupervised classification:- It is a technique in remote sensing where the classification algorithm automatically groups pixels with similar spectral properties into clusters.

Supervised classification	Unsupervised classification
i.) classification guided by known training sample.	i.) Classification without predefined training data.
ii.) Requires labelled training data for each class.	ii.) No labelled training data required.
iii.) Involves training the classifier using labelled samples	iii.) Uses clustering algorithms to group pixels.
iv.) Requires user to select	iv.) minimal user intervention

training samples.	during classification.
v.) Prior knowledge of class identities is needed.	v.) classes are discovered from data patterns.
vi.) Often results in higher accuracy due to training.	vi.) May have lower accuracy due to lack of training.
vii.) Effective for identifying specific classes.	vii.) Suitable for exploratory data analysis.
viii.) Less flexible as predefined classes are used.	viii.) more flexible as classes are generated dynamically.
ix.) potentially more complex due to training process.	ix.) Generally simpler as it relies on clustering.
x.) Requires expertise.	x.) Doesn't require expertise.
xi.) Processing time is slow.	xi.) Processing time is typically faster.
xii.) eg. Support vector machine	xii.) eg. K-means clustering

4.) What are image enhancement technique? Describe the importance of spatial filtering in image enhancement.

⇒ Image enhancement techniques in Geographic Information systems (GIS) are used to improve the visual interpretation

& analysis of satellite or aerial imagery. These techniques help to highlight specific features, remove noise & enhance the overall quality of the images
Here are some common image enhancement techniques are:-

1.) Contrast Enhancement:-
- Histogram Equalization:- Adjusts the contrast of the image by redistributing the pixel intensity values.

- contrast stretching:- Expands the range of intensity values to cover a wider spectrum.

- Linear & Non-linear stretching:- Applies a linear or non-linear transformation to the pixel values to improve contrast.

II.) Filtering:-
- Spatial filtering:- Uses convolution kernels to emphasize or suppress specific spatial patterns. Includes high-pass filters (for edge enhancement) & low pass filters (for noise reduction).

- Frequency domain filtering:- Applies Fourier Transform to filter out noise or enhance features in the frequency domain.

III.) Edge Enhancement:-
- Sobel, prewitt & canny edge detectors:- Highlight the edges in the image to make features more distinct.

- Laplacian filter :- Emphasizes area of rapid intensity change which often correspond to edges.

iv.) Image fusion :-

Combines information from multiple images or sensors to create a single enhanced image. Techniques includes pan-sharpening, which merges high resolution panchromatic & lower resolution multispectral images.

v.) Image smoothing :-

Reduces noise & small variations using techniques like Gaussian or median filtering.

vi.) Color Enhancement :-

Adjusts the color balance & intensity to improve the visual appeal & distinguish features more easily. Techniques include false-color composites & color stretching.

vii.) Texual Analysis :-

Enhances textual features in the image to distinguish different land cover types or materials.

viii.) Noise Reduction :-

Uses various filters (eg. median, mean) to reduce random noise in the image, improving clarity.

GIS analysis tools like ArcGIS, QGIS & remote sensing software (eg. ENVI, ERDAS image) provide functionalities to perform these enhancements.

Spatial filtering is a crucial technique in image enhancement especially in the context of Geographic Information System (GIS). It involves the manipulation of pixel values based on their spatial context to improve the visual quality of an image & highlight specific features. Here are the some importance of spatial filtering in image enhancement.

- Noise Reduction:-

To reduce random variations in pixel values that do not represent actual features in the image. Low-pass filters (such as mean or Gaussian filters) smooth the image by averaging the pixel values within a specified neighborhood thereby reducing noise.

- Image Enhancement:-

To make the boundaries of features more distinct aiding in feature extraction & interpretation. High-pass filters including sobel, prewitt & laplacian filters enhance edges by highlighting rapid changes in pixel values, making features like roads, boundaries & edges of building more visible.

- Feature extraction:-

To emphasize specific patterns or structures within the image facilitating easier identification

& analysis. Various spatial filters can be applied to highlight linear features (like rivers & roads), circular patterns (like lakes or ponds) or textured areas (like forested regions).

- Texture Analysis:-
To analyze the surface texture of different land cover types for classification & pattern recognition.

- Filters can enhance textual differences in the image helping to distinguish between different types of vegetation, urban areas, water bodies etc.

- Enhacement of specific features:-
To selectively enhance certain features or suppress others based on the analysis requirements custom-designed spatial filters can target specific spatial frequencies or patterns emphasizing features like agricultural fields, urban infrastructure or natural formations.

- Data preprocessing for further Analysis:-
To prepare images for more advanced analyses such as classification, segmentation or change detection. Spatial filtering can standardize image quality, remove artifacts & enhance relevent features, making subsequent analytical processes more accurate & reliable.

- visual Interpretation & presentation :-

To improve the visual appeal & interpretability of images for human analysts. By enhancing contrast edges and textures spatial filtering makes images easier to interpret, which is particularly important for presentations, reports & decision-making.

Spatial filtering plays a pivotal role in enhancing image quality & extracting meaningful information from spatial data in GIS, ultimately supporting better analysis, interpretation & decision making.

5.) Differentiate between photograph & image. calculate the scale factor for an Aerial photo-taken at 2500 meter hight by a camera with a focal length of 88 mm.

photograph	Image
1.) A visual representation captu-red by a camera showing a real world scene as it appeared at a specific moment.	1.) Any visual representation including photographs, satellite images, raster data or any other graphical depiction.
II.) Typically captured from cameras (aerial, drone or ground-based)	II.) Can be obtained from various sources like camera, satellite, sensors.
III.) The data is raster data with values representing light	III.) The data is raster or vector data, where values

intensity.	represent various attributes like elevation, temperature etc.
iv.) Used for visualizing & analyzing real world features.	iv.) Used for spatial analysis, land cover classification, terrian modeling & more.
v.) Represents real world scences or objects.	v.) Represents real or imaginary subjects.
vi.) Originally unedited, but can be post processed.	vi.) can be manipulated from the start.
vii.) High level of realism.	vii.) can be highly realistic or completely abstract.
viii.) Example :- aerial photograph of a city, wedding ceremony picture, wildlife picture of lion.	viii.) Example :- Satellite image showing vegetation indices, CT scan of human body, a computer generated rendering of a 3D model or a geographical representation of data trends.

Given,

Flying height (H) = 2500 meters

Focal length (F) = 88 mm ⇒ 0.088 meters

We know,

$$\text{scale factor} = \frac{\text{Focal length}}{\text{Height above ground}}$$

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$$= \frac{0.088}{2500}$$

$$= \frac{1}{28409.09}$$

$$= 0.0000352 \Rightarrow 3.52\times10^{-5}$$

Also,

Ratio of unit on photo to units on actual ground can be calculated as,

$$\frac{1}{\text{scale factor}}$$

$$= \frac{1}{3.52\times10^{-5}}$$

$$= 28409.09091$$

∴ 1 unit on the photo represents 28409.09091 units on the actual ground.//

6.) What information is contained in a histogram of image data? What is a focal cell in neighborhood operation? Describe with example.

⇒ A histogram of image data is a graphical representation that shows the distribution of pixel intensities in a image.

The information contained in a histogram of a image data are as follows:-

1.) pixel value distribution:-

- It shows how many pixels have a specific intensity value.
- This information is crucial for understanding the

image's brightness & contrast.

ii.) Brightness :-
The overall brightness of the image can be inferred from where the majority of pixel values fall.

iii.) Dynamic Range :-
It reveals the range of pixel values indicating image's brightness & contrast.

iv.) Image Contrast :-
- Shape of histogram indicate the image's contrast.
- Wide histogram indicates high contrast, while narrow histogram suggests low contrast.

v.) Image Noise :-
- Histogram can identify noise in an image.
- Noise appear as spikes or uneven distribution in the histogram.

vi.) color information :-
In color image separate histogram for each color channel (typically RGB) can be used.

vii.) Outliers :-
- Coutrame pixel values or outliers can be detected in histogram

viii.) Image Quality Assessment :-
- By analyzing histogram, we can access overall quality of an

image.

Focal cell in Neighborhood operations:-

- A focal cell is the central cell within a defined neighborhood or moving window used in spatial analysis.
- It is the cell for which the analysis is being performed, & its value is influenced by values of surrounding cell.

Example :- Averaging filter

Imagine 3x3 neighborhood operation applied to a grayscale image. Each pixel in image is assigned an intensity value.

Original Image (3x3 region) :-

100	102	103
101	105	106
104	107	108

In case of the focal cell is 105.

Applying averaging filter:-

$$\text{New value} = \frac{100+102+103+101+105+106+104+107+108}{9}$$

$$= 104$$

So, after applying the filter, the focal cell (priviously 105) will be updated to 104. //

7.) Describe relief displacement with illustrations. The relief displace--ment for a tower is 2.5mm, & the radial distance from center of the photo to the top of the tower is 55mm. If the flying height is 1250m above the base of the tower, find the height of the tower.

⇒ Relief displacement is the apparent displacement of objects on an aerial photograph or satellite image due to the relief, or elevation of the Earth's surface.

- Relief displacement is a phenomena in aerial photography where tall objects appears to "learn" away from the center of the photography. This effect is more pronoun--ced for objects father from the center of image.

- This displacement can cause objects to appear closer to or from camera than they actually are.
- Relief displacement is most noticeable for all tall objects, such as buildings and mountains.
- The amount of displacement is proportional to the height of object & the distance between the camera & the object.

- The relief displacement (d) can be calculated using:

$$d = \frac{h \cdot r}{H}$$

where, h = height of the object above the datum (eg. ground level).

r = radial distance from the Nadir to the object's base.

H = height of the camera above the datum.

Given,

Relief displacement (d) = 2.5mm

Radial distance (r) = 55mm

Flying height (H) = 1250 m

Height of tower (h) = ?

we know that,

$$d = \frac{(r \times h)}{H}$$

Then, $h = \frac{(d \times H)}{r}$

$$= \frac{2.5\,mm \times 1250\,m}{55\,mmm}$$

$$= \frac{0.0025\,m \times 1250\,m}{0.055\,m}$$

$$= 56.82\,m$$

Hence, Height of tower (h) = 56.82m

8.) What are airborne radars? How does it differ from space-borne radars?

⇒ Airborne Radars :-

These are the radar systems mounted on aircraft or other flying platforms like drones, heli--copters. They typically operates at altitude ranging from few hundred meters to above 20km above Earth's surface. They are often used for military reconnaissance, weather monitoring, environment studies. They provide localized & detailed coverage of specific area.

key characteristics:-

i.) High resolution
- Due to lower altitude, they can capture finer details.

ii.) flexibility:-
- can be deployed quickly to specific areas.

iii.) Limited coverage:-
- can only cover a small area at a time.

iv.) cost effective for small areas:-
- Compared to spaceborne radars, they are cost-effective.

- Spaceborne Radars:-
- These are radar systems mounted on satellites orbiting the earth. They operate at altitude much higher, typically hundreds of kilometers from the earth's surface. They provide global or near global coverage. They are often used for global weather monitoring, climate studies, tracking environmental changes etc.

key characteristics:-

i.) wide coverage
ii.) consistent data
iii.) High cost
iv.) Limited resolution.

Airborne Radars	Spaceborne Radars
i.) operate at lower altitude (a few kilometers to tens of kilometers) image with limited coverage area per flight.	i.) operate at much higher altitudes (hundreds to thousands of kilometers & provide broad global coverage.
ii.) They can be deployed for specific localized missions.	ii.) They can continuously monitor large areas over extended periods.
iii.) Typically offer higher spatial resolution due to their closer proximity to the earth's surface.	iii.) Provide wider coverage but may have lower resolution compared to airborne radars.
iv.) This makes them ideal for detail mapping & localized studies.	iv.) Advances in technology, however have significantly improve the resolution of modern spaceborne radars.
v.) more flexible & can be deployed quickly to different locations as needed. They can be used for specific time-sensitive missions such as disaster response.	v.) Provide consist long-term data collection over large areas. They are less flexible in terms of immediate redeployment but offer valuable time-series data for monitoring change over time.

vi.) Generally less expensive to deploy & maintain. They are accessible for a wide range of users including military, government agencies & provide companies.	vi.) Higher initial cost for satellite development, launch & operation. However, they provide cost-effective solutions for large scale long-term monitoring & research.
vii.) Can be affected by atmospheric conditions such as weather, urbulence & altitude variations. Eg. Synthetic Aperture Radar (SAR) on Aircraft.	vii.) Operate above the atmosphere reducing the impact of weather or atmospheric interference on radar signals. Eg. Sentinel-1 satellite

9.) How is Hyperspectral image different from multispectral image? Explain with illustration.

⇒ Hyperspectral image & multispectral images are both types of remote sensing imagery that capture information about the Earth's surface.

- Hyperspectral images are composed of hundreds of narrow, continuous bands. It is used for detailed material identification like vegetation, minerals & other materials. It has narrow bandwidth. Often 10-20 nm or less. The volume of data is larger with high spectral resolution.

- Multispectral images are composed of few bands (typically 3-10 bands), it has broader bandwidth, often covering

50-100nm each. The volume of data is smaller with smaller/lower spectral resolution. It is generally used for land cover classification, broad vegetation studies.

Hyperspectral image	Multispectral Image
i.) many bands (100-200) with narrow contiguous wavelength ranges.	i.) for bands (3-10) with broad wavelength ranges.
ii.) Higher spectral resolution, capturing finer details within the spectrum.	ii.) Lower spectral resolution, capturing broader segments of the spectrum.
iii.) Generates large volume of data requiring more processing power & storage.	iii.) Generates less data, easier to process & store.
iv.) Suitable for detail analysis & precise identification of materials & conditions.	iv.) Suitable for general applications where broad spectral information is sufficient.
v.) visible to Near-infrared spectrum (100+ bands).	v.) visible spectrum (3 bands) Blue, Green & Red.
vi.) Applications:- material identification, precision agriculture, environmental monitoring & medical imaging etc.	vi.) Applications:- vegetation monitoring, land use classification & environmental monitoring etc.

picture of 3D cube for hyperspectral & multispectral image is shown below :-

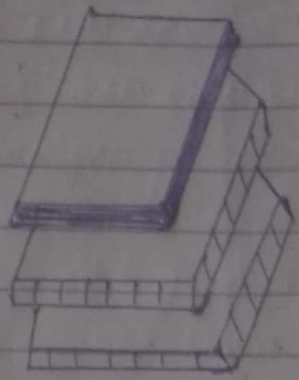

fig. Multispectral

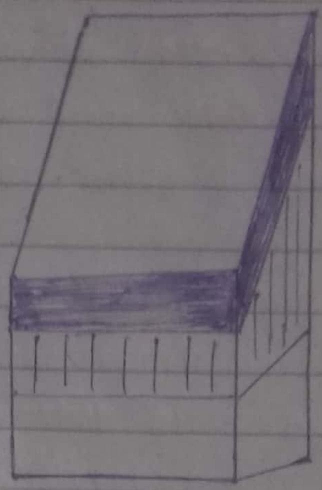

fig. Hyperspectral

- Hyperspectral images have many more spectral bands than multispectral images that allows for more detailed analysis of spectral properties of materials on the Earth's surface.

- Hyperspectral images are typically more expensive to acquire & process than multispectral images.

- Hyperspectral & multispectral images are both important tools for remote sensing.//