UNIT : 5

DATA PRODUCTS AND INTERPRETATION

Syllabus :

Photographic and digital products - Types, levels and open source satellite data products - selection and procurement of data - Visual Interpretation: basic elements and interpretation keys - Digital Interpretation - Concepts of image rectification, Image enhancement and Image classification.

Visual Interpretation:

Image interpretation of remote sensing data is to extract qualitative and quantitative information from the photograph.

It involves identification of various objects on the terrain which may be natural or artificial consists of points, lines or polygons.

In the beginning when digital images and computerised classification were not available the aerial photographs were analyzed only by visual interpretation.

Accuracy of the interpretation depends on the training, experience, scale of photograph, geographic location of the study area, associated map, ground observation data etc.

After the availability of satellite images, the data were categorized in two processing methods.

Analogue aerial photographs
Digital satellite images

In image some objects may be readily identifiable while other may not.

The detail to which an image can be analyzed depends on the resolution and scale of the image.

Visual interpretation involves visual analysis of aerial photographs and satellite images.

Visual image interpretation is the process of identifying features seen on the images by an analyst and communication of information obtained from these images to others for evaluating their significance

⇒ Elements of Visuals Interpretation :

Interpretation of aerial photographs and images are different because of three important aspects:

The protrayal of features from an overhead often unfamiliar, perspective.

The frequent use of wavelengths outside of the visible portion of the spectrum.

The depiction of the earth's surface at unfamiliar scales.

Eight fundamental elements are used in the interpretation of remote sensing images. They are

Tone (color)
Texture
size
shape
Pattern
shadow
site
Association

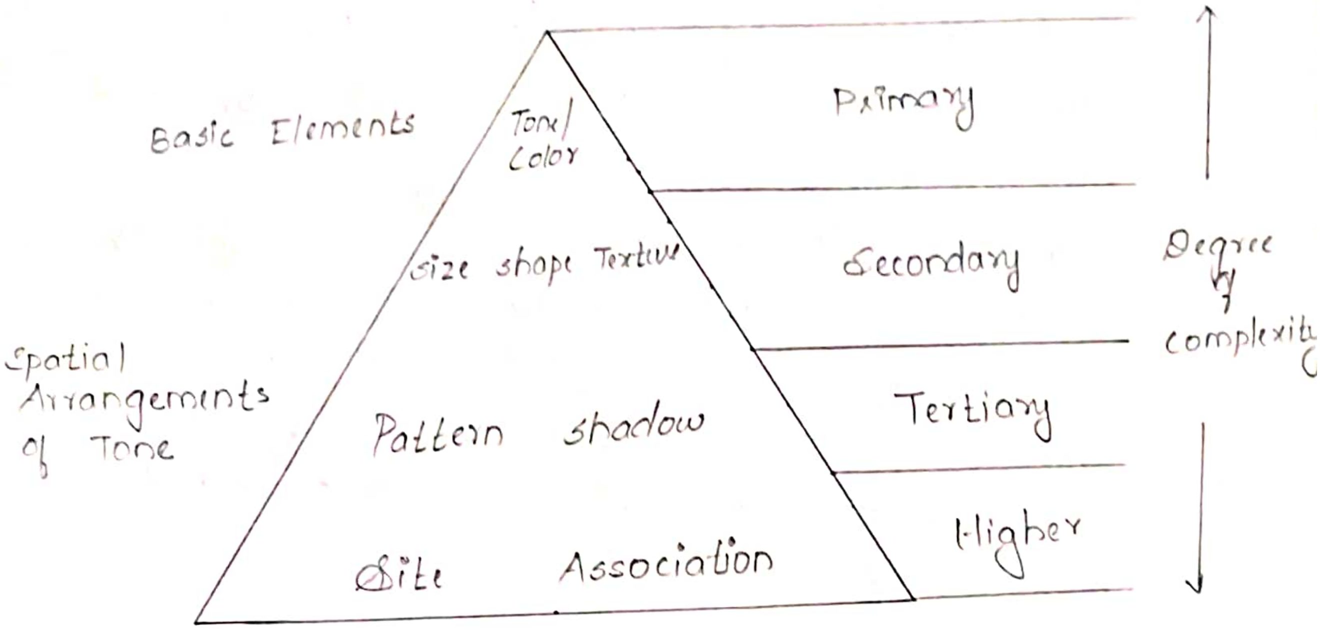

Fig: Ordering of image elements in image interpretation

(i) Tone (or) Color:

Tone is the relative brightness of grey level on black and white image or color image.

Tone is the measure of the intensity of the reflected or emitted radiation of the objects of the terrain.

Lower reflected objects appear relatively dark and higher reflected objects appear bright.

Rivers does not reflect in NIR region: thus appear black and the vegetation reflects much thus appears bright.

False color composite (FCC) using NIR, red and green are most preferred combination for visual interpretation.

(ii) Texture:

Texture refers to the frequency of tonal variation in an image.

Texture is produced by an aggregate unit of features which may be too small.

It depends on shape, size, pattern and shadow of terrain features.

Texture is always scale or resolution dependent.

Same reflected objects may have difference in texture helps in their identification.

Smooth texture refers to less tonal vibration and rough texture refers to abrupt tonal vibration in an image.

(iii) Pattern:

Pattern refers to the spatial arrangements of the object.

Objects both natural and manmade have a pattern which aids in their recognition.

The repetition of certain general form or relationship in tones and textures creates a pattern.

(iv) Size:

Size of objects on images is important to assess the size of a target relative to other objects in the scene, as well as the absolute size to aid in the interpretation of that target.

The most measured parameters are length, width, perimeter, area and occasionally volume.

(v) Shape:

Shape refers to the general form, configuration, or outline of an individual object.

Shape is one of the most important single factors for recognizing object from an image.

Generally regular shapes, squares, rectangles, circles are signs of man-made objects. Eg: Buildings, roads etc.

Whereas irregular shapes, with no distinct geometrical patterns are signs of a natural environment. Eg: River, Forest.

(vi) Shadow:

Shadow is a helpful element in image interpretation. It also creates difficulties for some objects in their identification in the image.

Knowing the time of photography, we can estimate the solar elevation which helps in height estimation of objects.

Shadow is also useful for enhancing or identifying topography and landforms particularly in radar image.

(vii) Association:

Association refers to the occurence of certain features in relation to other objects in the imagery.

In urban area a smooth vegetation pattern generally refers to a playground or grass land not agricultural land.

(viii) Site:

Site refers to topographic or geographic location. It is also an important element in image interpretation when objects are not clearly identified using the previous elements.

A very high reflectance feature in the Himalayan valley may be snow or cloud but in kerala it is not snow.

⇒ Int pretation Keys:

The criterion for identification of an object with interpretation elements is called an interpretation key.

It provides guidance about the correct identification of features or conditions on the images.

There are eight interpretation keys are available namely,

- Size
- Shape
- Shadow
- Tone
- Colour
- Texture
- Pattern
- Association

For agricultural and tree species identification a number of keys have been employed based on location and season.

Besides these, the time the photograph is taken, film type and photo scale should be considered while developing interpretation keys.

Interpretation keys for forestry mapping is given in the below table.

There are two types of keys: Selective key and Elimination key.

Selective key: It is also called reference key which contains numerous examples images with supporting text.

Elimination Key: It is also called dichotomous keys where the interpreter makes a series of choices between two alternatives and progressively eliminates all but one possible answer.

Species	Crown shape	Edge of crown	Tone	Pattern	Texture
Cedar	Conical with sharp spear	Circular and sharp	Dark	spotted grain	Hard and Coarse
Cypress	Conical with round crown	Circular but not sharp	Dark but lighter than cedar	Spotted	Hard and Fine
Pine	Cylindrical with shape-less crown	Circular but unclear	Light and unclear	Irregularly spotted	soft but coarse
Larch	Conical with unclear crown	Circular with unclear edge	Lighter than cypress	Spotted	soft and Fine
Fir / Spruce	Conical with wide crown	Circular with zig zag edge	Dark and clear	Irregular	coarse
Deciduous	Irregular shapes	Unclear	Lighter	Irregular	Coarse

Digital Interpretation:

Digital interpretation facilitates quantitative analysis of digital data with the help of computers to extract information about the earth surface.

Digital interpretation is popularly known as Image Processing.

Image processing deals with image correction, image enhancement, and information extraction.

Image correction means to correct the errors in digital image.

Errors are resulted due to two reasons

When errors are resulted due to defect in sensor is called radiometric error.

When errors are resulted due to earth rotation, space craft velocity, atmospheric attenuation is called geometric error.

Both radiometric and geometric errors in images are reduced through different techniques with the help of computer.

Image enhancement deals with manipulation of data for improving its quality for interpretation.

Through different image enhancement technique contrast is improved in digital image.

After image correction and enhancement informations are extracted from the digital image which is the ultimate goal of the interpreter.

In information extraction, spectral values of pixels are analyzed through computer to identify objects on the earth surface.

In this way, different features of earth are recognised and classified.

The field knowledge and other sources of information also helps in recognition and classification process.

⇒ Concept of Image Rectification/correction:

Image rectification is a transformation process used to project images onto a common image plane.

Image rectification is used in computer stereo vision to simplify the problem of finding matching points between images.

It is also used in geographic information systems to merge images taken from multiple perspective into a common map co-ordinate system.

In GIS this is done by matching ground control points (GCP) in the mapping system to points in the image.

Primary difficulties in the process are,

When the accuracy of the map points are not well known.

When the images lack clearly identifiable points to correspond to the maps

The maps that are used with rectified images are non-topographical.

However the images may contain distortion from terrain.

Image orthorectification additionally removes these effects.

There are two types of correction are available to remove the distortion in the images.

Radiometric correction
Geometric correction

> Radiometric Correction:

Radiometric correction is to avoid radiometric errors or distortions.

When the emitted or reflected electromagnetic energy is observed by a sensor does not coincide with energy emitted or reflected from the same object observed from a short distance.

This is due to sun's azimuth and elevation, atomphospheric conditions etc.

Therefore inorder to obtain the real reflectance those radiometric distortions must be corrected.

Radiometric correction is classified in to following three types

Radiometric correction of effects due to sensor sensitivity

Radiometric correction for sun angle and topography.

Atmospheric correction.

> Geometric Correction:

Geometric correction is undertaken to avoid geometric distortions from an image.

It is achieved by establishing the relationship between the image co-ordinate system and the geographic co-ordinate system.

The relationship is established by using calibration data of the sensor, measured data of position and attitude, ground control points, atmospheric condition etc.

The steps to follow for geometric correction are

Input Image
↓
Selection of Method
↓
Determination of Parameters
↓
Accuracy Check
↓
Interpolation and Resampling
↓
Output Image

Fig: Flow of Geometric correction

There are three types of geometric correction namely,

- systematic correction
- Non-systematic correction
- Combined Method.

Systematic Correction ⇒ When the geometric reference data are measured, the geometric distortion can be systematically or theoretically avoided.

Non-systematic correction ⇒ Polynomials to transform from a geographic coordinate system to an image co-ordinate system or vice versa will be determined using the least square method.

Combined Method ⇒ Firstly the systematic correction is applied then the residual errors will be reduced using low order polynomials.

Usually the goal of geometric correction is to obtain an error within plus or minus one pixel of its true position.

Concept of Image Enhancement :

Image enhancement is a method which improve the contrast and edge information of the input image.

Widely used remote sensing applications such as mapping, classification, soil moisture detection etc require high quality images.

To meet the increasing need for higher quality images, image enhancement method is used.

Images provided by remote sensing devices have to be enhanced by special methods instead of standard enhancement methods.

Remote sensing image enhancement techniques should improve the visibility, contrast and edge informations of the image while preserving the original reflectance values.

Most of the enhancement methods are based on histogram modification and transform based methods.

Histogram modification based methods aim to modify the histogram of the input image to obtain a more uniform distribution.

Transform based methods apply a certain transform to the input image and enhance the image in transform domain followed by the inverse transform.

Visual comparisons as well as quantitative comparisons have been carried out for different enhancement methods.

Image enhancement methods can be divided into two main groups as direct and indirect methods.

Direct methods aim to enhance the images by using a defined contrast measure, while the indirect methods try to improve the dynamic range of the images without a contrast measure.

In direct methods, contrast measurements can be global or local.

The indirect methods can be divided into two sub categories as histogram modification based methods and transform domain methods.

The simplest histogram modification method is Histogram Equalization.

In this method, the histogram distribution of the input image is aimed to have uniform distribution.

The HE based enhanced images generally suffer from undersaturation which results in poor quality images.

To fix this problem, more efficient histogram modification methods have been proposed.

Transform domain based image enhancement methods use certain transformations to decompose the image into subbands and improve the contrast by modifying specific components.

The quality of remote sensing images depends upon numerous factors such as noise, illumination or equipment conditions during acquisition procedure.

The data obtained by optic sensors are degraded by atmospheric effects and instrumental noises, namely thermal noise, quantization noise and shot noise which cause corruption in spectral bands by varying degrees.

These degradations reduce the contrast in the resulting images and can highly affect human perception or the accuracy of computer assisted applications.

Thus contrast enhancement besides noise removal, constitute a primary step for various applications of remote sensing image processing for better information representation and visual perception.

Concept of Image Classification:

Image classification is the process of assigning land cover classes to pixels. For eg: classes include water, forest, agriculture etc.

The three main types of image classification techniques in remote sensing are

- Unsupervised image classification
- Supervised image classification
- Object based image analysis.

⇒ Unsupervised Classification:

In this method, it first groups pixels into clusters based on their properties.

Then it is classified each cluster with a land cover class.

There are two basic steps are involved for unsupervised classification. They are,

Generate clusters
Assign classes

The first step is to create clusters by using image clustering algorithms namely,

K - Means
ISO Data

After picking a clustering algorithm, the number of groups that wants to be generated was identified

The next step is to manually assign land cover classes to each cluster.

⇒ Supervised Classification:

In supervised classification, representative samples has to be selected for each land cover classes

The software then uses these training sites and applies them to the entire image.

The three basic steps involved in supervised classification are,

Select training areas
Generate signature file
Classify.

For supervised image classification

First create training samples

Then add training sites representative in the entire image.

Continue creating training samples until each class have representative samples.

In turn, this would generate a signature file, which stores all training samples' spectral information.

Finally the last step would be to use the signature file to run a classification.

In the final step classification algorithm has to be picked such as,

- Minimum Likelihood
- Minimum Distance
- Principal components
- support vector Machine (SVM)
- ISO cluster.

⇒ Object Based Image Analysis (OBIA)

Supervised and Unsupervised classification is pixel based.

But object based image classification groups pixels into representative vector shapes with size and geometry.

The steps to perform object based image classification are,

Perform multiresolution segmentation
Select training areas
Define statistics
Classify

OBIA segments an image by grouping pixels. It doesn't create single pixels. Instead it generates objects with different geometrices.

The two most common segmentation algorithms are,

Multi resolution segmentation in ecognition.
The segment mean shift tool in ArcGIS Pro.

In OBIA classification, different methods can be used to classify objects. namely,

> Shape:

If buildings has to be classified a shape statistic such as rectangular fit can be used.

> Texture:

Texture is the homogeneity of an object.
Eg: Water is mostly homogeneous because it's mostly dark blue.
But forests have shadows and are a mix of green and blue.

> Spectral:

The mean value of spectral properties such as near-infrared, short-wave infrared, red, green or blue can be used.

> Geographic context:

Objects have proximity and distance relationship between neighbors.

> Nearest Neighbor classification:

It is similar to supervised classification.

After multi resolution segmentation, the user identifies sample sites for each land cover class.

Next statistics are defined to classify image objects.

Finally the nearest neighbor classifies objects based on their resemblance to the training sites and the defined statistics.

Photographic and Digital Products:

Photographic and digital products play crucial role in remote sensing, offering diverse data outputs.

Traditional aerial photography provides high resolution images for detailed analysis.

Digital products such as multispectral and hyper spectral imagery, enhance the ability to capture and analyze specific wavelengths, aiding applications like vegetation health assessment and mineral identification.

Additionally, LIDAR technology generates precise elevation data, contributing to 3D modeling and terrain analysis in remote sensing applications.

⇒ Photographic Products

* **Orthophotos** : Aerial images corrected for distortions, providing accurate representations of the earth's surface.
It is very important for accurate mapping and spatial analysis.

* **Stereoscopic Imagery** : A pair of overlapping images captured from different perspectives, allowing analysts to perceive the terrain in 3D.
It is used for feature identification and measurement.

* **Photogrammetric Products** : Derived from photogrammetry and it includes point clouds which represent 3D co-ordinates of surface points and digital elevation models (DEMs) for topographic mapping.

* **Mosaics** : Stitched together from multiple images. It provide a seamless and comprehensive view of large areas.
They are useful for regional planning and land cover assessment.

⇒ * Digital Products

* **Digital Orthophotos** : These are directly captured by digital sensors, offer high spatial resolution and accurate georeferencing.
They are essential for GIS applications.

* Satellite Imagery : Digital sensors aboard satellites capture data for various purposes, including monitoring land cover changes, assessing environmental conditions and supporting disaster management.

* Hyperspectral Imagery : These sensors capture a wide range of spectral bands enabling detailed analysis of surface materials.

This is valuable for tasks like mineral identification and environmental monitoring.

* LiDAR Data : Light Detection and Ranging technology uses laser pulses to measure distances creating highly accurate elevation models.

LiDAR is crucial for terrain modeling and assessing canopy structure.

* RADAR Imagery : Synthetic Aperture Radar (SAR) on satellites provides all weather, day and night imaging.

It is used for applications like detecting land cover changes, monitoring agriculture and assessing deforestation.

* Digital Terrain Models : Similar to DEM, DTM represents the bare Earth's surface without any vegetation or human-made structures, providing valuable information for various applications.

The integration of these products into Geographic Information systems (GIS) enhances their usability, allowing for advanced spatial analysis, decision making and monitoring of Earth's surface over time.

The transition to digital technologies has significantly improved the efficiency and accuracy of remote sensing processes.

Types, Levels and Open Source Satellite Data Products

Satellite data products encompass a diverse range of information captured by Earth Observation satellites.

⇒ Types of Satellite Data:

* Optical Imagery: Captures visible and infrared light, providing high-resolution images for applications like land cover mapping and change detection

* Radar Imagery (SAR): Utilizes radar signals to create images, offering all-weather and day and night capabilities.
SAR is valuable for terrain mapping, monitoring vegetation and disaster response.

* Hyperspectral Imagery: captures a wide range of spectral bands, enabling detailed analysis of material composition.
Useful for agriculture, environmental monitoring and mineral exploration.

* Thermal Infrared Imagery: Measures thermal radiation, allowing the assessment of surface temperatures

Applied in agriculture, urban heat island studies and environmental monitoring

* Multispectral Imagery: Captures data in multiple bands, often including visible and near infrared spectra. Beneficial for vegetation health assessment and land cover classification.

⇒ Levels of Satellite Data:

* Level 0 (Raw data): Unprocessed data as received directly from the satellite.
* Level 1 (Radiometrically corrected): Calibration for radiometric distortions, providing pixel values in physical units.
* Level 2 (Geometrically corrected): Radiometrically corrected data with additional geometric corrections for accurate spatial representation.
* Level 3 (Geophysical Parameters): Derived products such as vegetation indices, land surface temperature or atmospheric parameters.

⇒ Open Source Satellite Data Products:

* Sentinel Data (ESA): Part of the copernicus program, sentinel-1 (SAR) and sentinel-2 (optical) data are freely accessible.
* LANDSAT Data (USGS/NASA): Landsat satellites provide multispectral and thermal data. Landsat imagery is widely used for land cover monitoring

* MODIS (NASA): Moderate Resolution Imaging spectroradiometer provides global coverage and is used for climate studies, land cover mapping and monitoring.

* Copernicus Open Access Hub: Offers access to various Copernicus Sentinel satellite Data including optical and SAR data.

* USGS Earth Explorer: Provides access to a variety of satellite data, including Landsat, Sentinel and others.

* NOAA CLASS: The comprehensive Large Array-data Stewardship System (CLASS) offers access to NOAA satellite data.

* Google Earth Engine: While not a source itself, it provides a platform for accessing and analyzing various satellite datasets.

Open source satellite data facilitates research, monitoring and analysis, supporting a wide range of applications from environmental studies to disaster response.

Selection and Procurement of Data:

Selection and procuring data in remote sensing involves a systematic process to ensure that the acquired information aligns with the objectives of a particular project.

The step by step is given below,

* Define Project Objectives:

Clearly articulate the goals and objectives of remote sensing project.

Specify the type of information needed, the spatial and temporal resolution required and any specific variables of interest.

* Identify Area of Interest (AOI):

Clearly define the geographic area you intend to study or monitor.

* Research Available Sensors and Satellites:

Identify satellites or sensors that offer data relevant to your AOI and objectives.

Consider factors like spatial resolution, spectral bands, revisit frequency and sensor characteristics.

* Consider Temporal Requirements:

Determine the required temporal frequency for data acquisition.

Some applications may need frequent revisits while others may focus on seasonal or annual data.

* Assess Data Sources:

Explore open access repositories (Eg: NASA Earthdata, USGS Earth Explorer), commericial satellite providers, or data sharing initiatives (eg: Copernicus).

Understand the types of data each source provides and their data distribution policies.

* Evaluate Data Quality:

Check the data and quality assessments provided by data providers.

* Assess factors such as cloud cover, atmospheric conditions and the accuracy of the sensor

* Consider Spatial Resolution:

Choose data with an appropriate spatial resolution based on the scale of study.

High resolution data is suitable for detailed analysis, while coarser resolution may suffice for ~~bore~~ broader regional assessments.

* Review Historical Data:

Investigate the availability of historical data to analyze temporal bands or changes over time.

* Budget and Cost Analysis:

Evaluate the costs associated with data acquisition, including any subscription fees, licensing costs or processing charges.

Consider budget constraints and explore free or lower cost data options if available.

* Check Data Format and Compatibity:

Ensure that the selected data format is compatible with your analysis tools or software.

Consider preprocessing requirements and the availability of data in the desired format. (Eg: GeoTIFF, Net CDF).

* Legal and Ethical Considerations:

Understand the licensing agreements, terms of use and any legal restrictions associated with the data.

Ensure compliance with regulations and ethical considerations related to data use

* Engage with Data Providers:

Communicate with data providers to address specific inquires, clarify any uncertainties and establish a reliable channel for onging support:

* Data Access and Delivery:

Verify the accessibility of the selected data and the distribution ~~of~~ mechanism

consider the ease of download, availability of APIs. or cloud based access options.

By systematically going through these steps ~~you can match make~~ informed decisions during the selection and procurement of remote sensing data is made.

It also ensure that the data acquired is suitable for the project objectives and requirements.