1

APPLICATIONS OF REMOTE SENSING

Unit Structure :

After going through this chapter you will be able to understand the following features

1.1 Land Use/Land Cover and Wetland Mapping

1.2 Agriculture and Soil Mapping Applications

1.3 Water Resources Applications

1.4 Urban Planning Applications

1.1 LAND USE/ LAND COVER AND WETLAND MAPPING

In Remote Sensing Land use/Land cover and Wetland Mapping is the study of landscapes and the associated spatial patterns. Mainly Land Use/Land Cover mapping also known as LU/LC are divided into classes. The classes may refer to natural or man-made landscapes such as forest, river, agricultural area, fallow land, urban areas etc.

Often land cover and land use are interchangeable words. However, if we define these terms,

1) **Land Use** - "Land use refers to the purpose the land serves, for example, recreation, wildlife habitat, or agriculture." (Government of Canada, n.d.) Mostly, land use comprises of man-made activities, wherein planned areas such as agriculture and urban areas or places of economic activities are planned as per land use pattern of the given area.

2) **Land Cover** - Land cover on the other hand refers mostly to the natural landscapes such as forest cover, surface water bodies such as lakes, rivers, or land features such as mountains, plateaus and deserts. According to NOAA, "Land cover indicates the physical land type such as forest or open water whereas land use documents how people are using the land." (NOAA, 2021) Land cover is useful in forming a baseline and identifying change detection. In remote sensing, using satellite data change detection analysis is carried out for both land use and land cover.

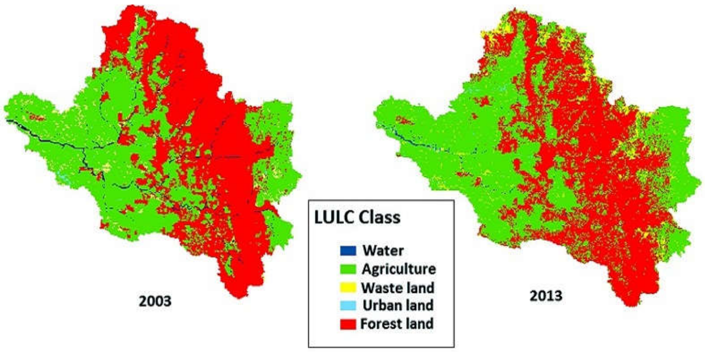
SIGNIFICANCE OF LULC MAPS

According to Geospatial Insight n.d., "Landuse and landcover maps are significant to map, understand and analyze physical and human components and its impact over land during a given time-frame.

The growth of a society totally depends on its social and economical development. This is the basic reason why socio-economic surveys are carried out. This type of survey includes both spatial and non-spatial datasets. LULC maps play a significant and prime role in planning, management and monitoring programmes at local, regional and national levels. This type of information, on one hand, provides a better understanding of land utilization aspects and on the other hand, it plays an important role in the formation of policies and programme required for development planning. For ensuring sustainable development, it is necessary to monitor the on going process on land use/land cover pattern over a period of time. In order to achieve sustainable urban development and to check the haphazard development of towns and cities, it is necessary that authorities associated with the urban development generate such planning models so that every bit of available land can be used in most rational and optimal way. This requires the present and past land use/land cover information of the area. LULC maps also help us to study the changes that are happening in our ecosystem and environment. If we have an inch by inch information about Land Use/Land Cover of the study unit we can make policies and launch programmes to save our environment". (SATPALDA□: Significance of Land Use / Land Cover (LULC) Maps, n.d.)

Using remote sensing techniques LULC maps can be prepared using two methods:

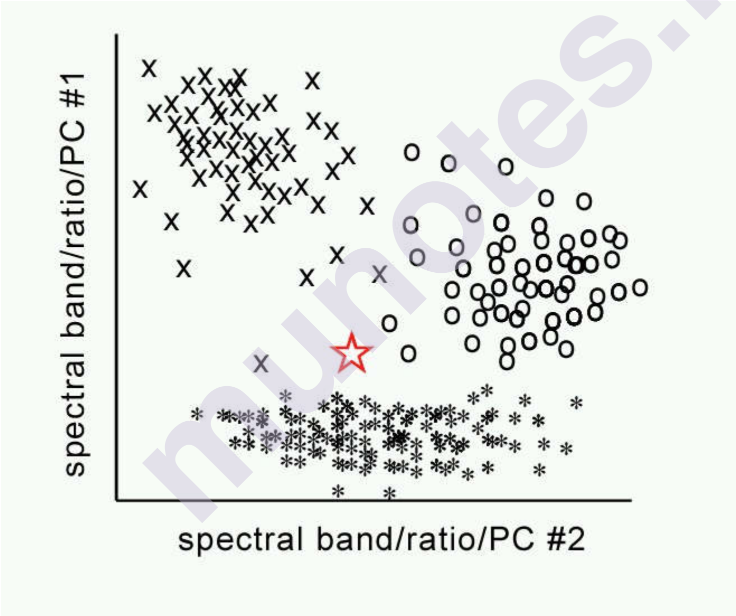
i. **Supervised Classification** - In this type of classification of LULC the user or analyst carries out a diligent or careful selection of samples wherein different categories are chosen. For example, urban areas are chosen and given the number as class 1 then fallow land is chosen and given the number as class 2. Similarly, all land features are classified based on texture, location, pattern, radiometric resolution etc. and supervised classification is carried out.



LU/LC map showing Change detection of same region at different time period (Image Source: Geospatial Insight, n.d.)

ii. **Unsupervised classification** – An unsupervised classification has lesser level of accuracy as compared to supervised classification because in this type of LULC classification land cover is not supervised and hence samples are not indicated. Instead it is a software or computer led classification wherein only based on the elements of LULC classification automatically takes place. Therefore, in unsupervised classification there is no limit to the number of classes that can be obtained. Although this is a more detailed type of classification it may sometimes lead to low accuracy due to erroneous sample selection or mixing of classes.

"The goal of unsupervised classification is to automatically segregate pixels of a remote sensing image into groups of similar spectral character. Classification is done using one of several statistical routines generally called "clustering" where classes of pixels are created based on their shared spectral signatures. Clusters are split and /or merged until further clustering doesn't improve the explanation of the variation in the scene." (Harbor D., Washington and Lee University, n.d.)



(Source: Harbor D., Washington and Lee University, n.d.)

An example of unsupervised classification is given below. It has many classes and each pixel is classified into a class or category. This gives us a more detailed view of the land area and identifies classes based on many techniques such as:

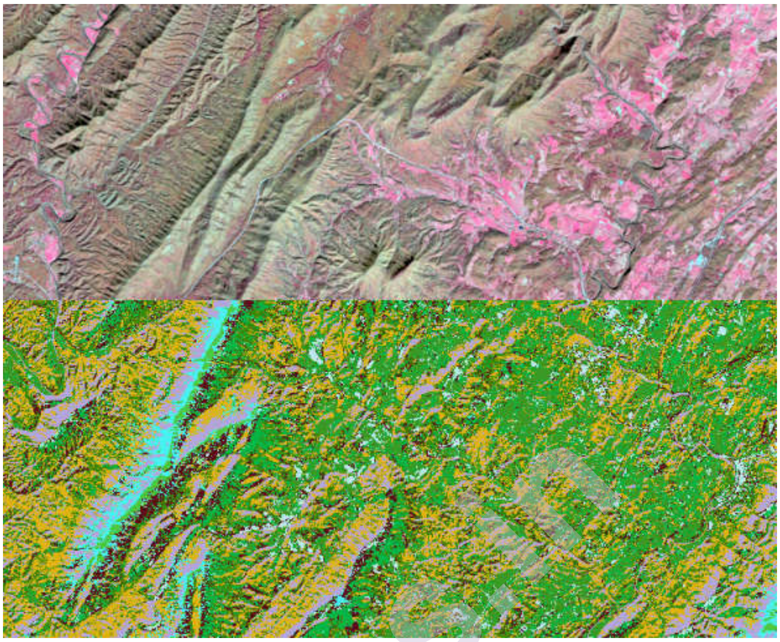
a) ISOCLASS (Using ISO Clusters)

b) Maximum Likelihood

c) Random Trees

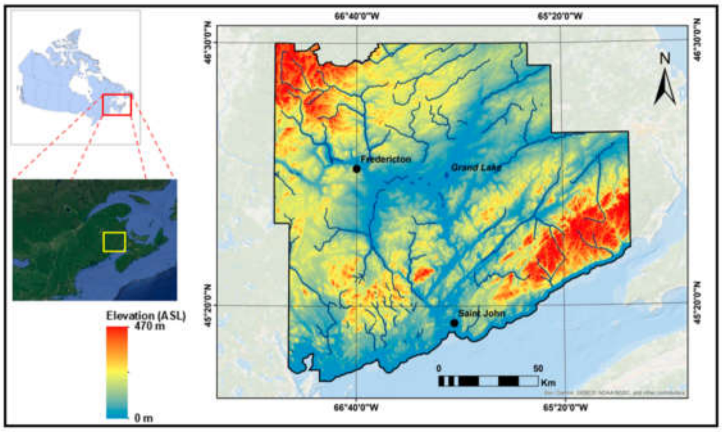
d) Suport Vector Machine

All these methods can be used in a geospatial software such as ArcGIS and the classification can be done using a base map or satellite imagery that is georeferenced. Some of the images used for change detection in remote sensing are LANDSAT, LISS-II etc.



Unsupervised classification (Source: Harbor D., Washington and Lee University, n.d.)

3) **Wetland Mapping** –Wetland mapping is useful for mapping of important ecosystems. It comprises of all the water resources. "Wetlands are defined as lands that are saturated with water long enough to cause the formation of hydric soils and the growth of hydrophytic or water-tolerant plants. Wetlands are found in almost all the regions of the world from the tundra to the tropics and are a critical part of the natural environment. They have high biological diversity and offer critical habitats for numerous flora and fauna species. Wetlands can also provide valuable services to humans such as flood reduction by temporarily storing and gradually releasing stormwater. Wetlands are complex ecological systems that are formed when hydrological, geomorphological, and biological factors work collectively to create the necessary conditions. There are various types of wetlands depending on the regional and local variations in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbances." (LaRocque, n.d.)



Wetland Mapping (Wetland Mapping With Landsat 8 OLI, Sentinel-1, ALOS-1 PALSAR, and LiDAR Data in Southern New Brunswick, Canada, n.d.)

1.2 AGRICULTURE AND SOIL MAPPING APPLICATIONS

Agriculture mapping – Remote sensing is very useful for agriculture and soil mapping. The index used for crop analysis in agricultural mapping is called NDVI. It is an important index to analyze vegetation in general or crops in particular. NDVI stands for Normalized Difference Vegetation Index. NDVI is calculated using the following formula.

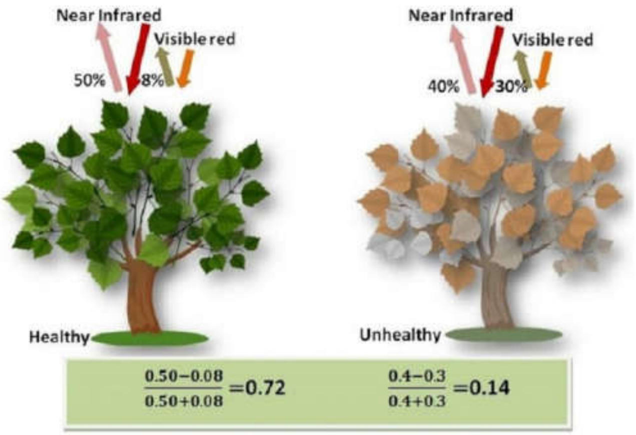
NDVI= (NIR-VIS)/(NIR+VIS)

Wherein, NDVI stands for Normalized Difference Vegetation Index (NDVI)

NIR stands for Near Infrared (NIR)

VIS or RED stands for Visible Spectrum or Red band of the visible spectrum.

NDVI was developed by Compton Tucker,a NASA scientist in 1977. The index identifies healthy green vegetation cover from sickly leaves or damaged crops. It is very useful in studying crop health, predict crop pattern and identify areas that need attention.



Application of remote sensing in Agriculture Mapping: There are numerous applications of remote sensing in agriculture mapping, some of which are listed below:

a) Crop pattern – Satellite images are analyzed using Remote Sensing techniques to identify crop pattern. Based on the reflectivity of crops patterns and types of vegetation are identified. Sometimes drones are also used the agricultural field to take high-resolution photos to better analyze the study region.

b) Forecasting- Forecasting crop production or yield can be done using remote sensing efficiently. The quantity and quality of the crops can be determined using remote sensing techniques.

c) Assessment – Remote sensing as discussed earlier using NDVI can very well assess crop damage. The NDVI can help in identification of sickly crops and protect the healthy plants in time so as to assess the crop damage accurately and minimize damage to ensure good yield.

d) Land mapping and crop estimation – Using remote sensing land pattern can be analyzed and crop yield can be estimated.

e) Weather forecasting – Remote sensing is alsouseful in assessing flood damage or drought damage on crops. This is highly useful in assessing crop growth and crop health.

SOIL MAPPING

Soil mapping is very useful, not only in agriculture but also in other areas such as mining, quarrying activities as well as land-use planning. Using remote sensing techniques soil mapping can be done effectively.

According to Grind GIS, following are the applications of Soil Mapping using Remote Sensing techniques. Following are some applications of remote sensing to analyze soil mapping,

i) **Measurement of soil content** -Soil has diverse contents and components; powerful techniques are required to analyze and study this component. Spatial data is used to determine the content of the soil. In addition to that, multispectral satellite tools are used in mapping and recording the soil content.The spatial data collected from the satellite is then used to make farming-related decisions. Also, the texture of the soil can be predicted using multispectral data.

ii) **Soils maps** - Soil mapping is a vital source of information in creating soil maps. Soil maps are used to show the distribution of the soil, among other surveys.These maps are greatly used in soil/spatial planning, farming, soil evaluation, and similar areas. Moreover, remote sensors are airborne tools, and therefore they can easily be collected and record data related to soil. Therefore, the technique of soil mapping is vital in this field.

iii) Soil survey - In the process of soil survey, the technique of remote sensing is greatly used. Researchers use remote sensors to monitor activities in soils. The spatial data from sensors is then analyzed and recorded to update the survey documents. Also, during other soil-related surveys, remote sensors supplement the tools used in research.

iv) Soil fertilization - Soil fertilization is directly proportional to the yield of the land, and therefore there's a need to study it. Images from the space are used in soil sampling.The soil samples collected by the satellite are analyzed, and the quality of the soil is predicted. Also, since the images are taken from space, the crops and vegetation of a given area are used to decide the soil's quality and fertility.

v) Soil boundary - Soil boundary is a term used to indicate the end of one type of soil and the beginning of another soil. That said, powerful tools such as remote sensors study and analyzed the soil boundaries. Remote sensors are capable of identifying different types of soils. Due to this property, the soil boundary is easily identified.

vi) Soil properties - Soil is a natural component made up of many other properties and components. Thankfully, remote sensors have eased the process of studying properties found in soils.Remote sensors can record and detect the chemical components (Nitrogen, organic carbon, etc.) found in a given soil. The remote sensors analyze the spectral reflectance, and the collected data is used to determine the soil's properties.

vii) Soil science - In soil science, remote sensors are greatly used to map and survey the soil in the study of soils." (Source: Gikunda, A. (2022, March 31). Applications of remote sensing in soil mapping. Grind GIS-GIS and Remote Sensing Blogs, Articles, Tutorials | easy to learn gis, love geography. Retrieved September 13, 2022, from https:// grindgis. com/ remote-sensing/applications-of-remote-sensing-in-soil-mapping)

1.3 WATER RESOURCES APPLICATIONS

According to India Water Portal, "Sustainable management of the available water resource is a challenging task for the new millennium. As stated by the World Water Council, "There is a water crisis today. But the crisis is not having too little water to satisfy our needs. It is crisis of managing water so badly that billions of people and the environment – suffer badly" (World Water Council, 2000). Remote Sensing techniques have been used effectively in integrated development and management of water resources of India (Balakrishnan, 1986). Water has very low spectral reflectance in the visible part of the Electro Magnetic Region (EMR) whereas snow or ice has very high spectral reflectance in visible and near infrared (NIR) part of the EMR. Pure water absorbs nearly all incident energy in both the near infrared and middle infrared (MIR) wavelengths. The low reflectance of water in visible and NIR band has advantage in Remote Sensing as water becomes clearly distinguishable from either vegetation or soil cover throughout the reflective infrared portion.

Total Radiance (R_t) recorded by a Remote Sensing system over a water body is a function of the electromagnetic energy and is given by the equation:

$R_t = R_p + R_s + R_v + R_b$ where, R_p = Atmospheric Path Radiance

R_s = Free-surface Layer Reflectance
R_v = Subsurface Volumetric Reflectance
R_b = Bottom Reflectance

In situ Spectroradiometer measurement of clear water with various levels of clayey and silty soil as suspended sediment shows that the reflectance peak shifts towards longer wavelengths as more suspended sediment is added to the water. Strong chlorophyll a absorption of blue light is observed between wavelengths of 400 and 500 nm and strong chlorophyll a absorption of red light is observed at approximately 675 nm (Lillesand and Kiefer, 2000).

Application of visual and digital Remote Sensing techniques and integration of the remotely sensed data in specific layers through the Geographic Information System (GIS) are used by scientists in management of water resources and prediction of natural water related hazards like flood and drought. Visual Remote Sensing has been extensively used in detection of water pollution, lake eutrophication assessment and estimation of flood damage. The technique of visual image interpretation can be used in variety of ways to help monitor water quantity, quality and geographic distribution of water resources (Lillesand and Kiefer, 2000). In the present paper, various methods of application of Remote Sensing in water quality and water resources management are discussed." (Application of Remote Sensing in Water Quality and Water Resources Management – an Overview, n.d.)

Some major applications of Remote Sensing in Water Resource are as follows:

i) **Assessing water quality** –The impurities in water bodies is captured by remote sensing data by analyzing the spectral reflectivity of the water. However, as it is a complex study with some limitations the results might vary due to the presence of various spectral signatures, water impurities or solar reflectivity.

ii) **Runoff and Hydrological Modelling**–Surface runoff and hydrological modelling can be done using remote sensing. Patterns such as DEM (Digital Elevation Model) Soil erosion are analyzed. (Haralick et al., 1985). Hydrological modeling and GIS has been used in similar studies in small watersheds in India (Hari Prasad et al., 1997).

iii) **Flood and Drought Management**–Remote sensing datasets such as IRS-1C, IRS-1D, IRS-P6, Cartosat-1, Cartosat-2, Radarsat and Earth Resource Satellite (ERS) datasets are used and for flood inundation mapping, estimation of flood damage and infrastructure loss.

Similarly, to predict drought remote sensing is useful especially for analyzing soil moisture pattern.

iv) **Watershed Management**–Multispectral data and baseline data is very useful for watershed management. To analyze the sediment load, water catchment area as well as river basin and associated patterns remote sensing is highly useful.

v) **Irrigation Command Area Management**–Irrigability maps and periodic assessment of Irrigation Command Area Management using remote sensing techniques lead to better crop analysis and prediction and also better irrigation patterns for agricultural lands.

1.4 URBAN PLANNING APPLICATIONS

There are many applications of Remote Sensing in Urban Planning some of them are listed below:

i) **Land use patterns** – In Urban areas a detailed analytical study of Land use pattern is very useful. Town growth and land use patterns can be studied using change detection technique in Remote Sensing and town planning can be analyzed.

ii) **Green zones** – Remote sensing is highly useful to analyze green areas and plan them in urban areas. Identification of fallow using remote sensing land and conversion of land to vegetation cover can be accomplished for urban areas.

iii) **Residential areas** – Using satellite images urban sprawl can be studied in detail to identify if the urban sprawl can be managed or there is need to better plan the residential areas in future.

iv) **Coastal cities** – As discussed previously Remote Sensing is highly useful in prediction of flood and hence it is also useful in monitoring and managing coastal cities or towns.

v) **Disasters** – Some disasters such as fire accidents, droughts or water management can be done using Remote Sensing techniques especially for urban areas if they are having high population density.

vi) **Transport Planning** – Remote sensing is very useful in transport planning of urban areas. Using GIS techniques, satellite images can be used to analyze road networks in a city and identify accident zones, lack of connectivity and areas where there is too much congestion.

1.5 SUMMARY

Remote sensing is defined as a scientific study of studying an area or region using satellite images that are captured remotely, that is to say from a distance or without coming into physical contact of the study area. There are numerous applications of Remote Sensing. Especially with the advancement of technology and availability of resources such as satellites capable of capturing intricate details and high resolution data there is no limit to the usefulness of this field of study.

1.6 CHECK YOUR PROGRESS/ EXERCISE

I. True or False

a) In Remote Sensing Landuse and Landcover are the same.
b) LU/LC maps are highly useful for a spatio-temporal study.
c) Unsupervised classification requires minimum intervention from researcher or remote sensing expert.
d) Supervised classification has higher detail and more number of classes.
e) Cloud cover affects the accuracy of satellite image.

II. Fill in the blanks

i) Connectivity and _______________ is a measure of accident zone analysis in Transport planning:
   a) Road networks
   b) Area
   c) Congestion
   d) None of the above

ii) __________ has low spectral reflectance.
   a) Water, b) Tree Cover, c) Urban dwelling, d) Cloud

iii) In Transport Planning Remote Sensing application Accident zones can be identified using ___________
   a) Urban Sprawl b)Change detection c)Green Zones d)Connectivity

iv) __________ is a method of Unsupervised Classification?
   a) ISOCLASS, b) Random Trees, c) LISS, d) LANDSAT

v) Wetland mapping can be done using_______data:
   a) LiDAR, b) Sentinel-1, c) ALOS-1 PALSAR, d) All of the above

III. Multiple Choice Questions

a. LU/LC maps are highly useful in:
1. Planning
2. Forest cover analysis
3. Transport
4. Green zones

b. Which type of remote sensing technique is used to detect water pollution?
1. Visual Remote Sensing
2. Change Detection
3. Supervised classification
4. Unsupervised classification

c. Water has very low spectral reflectance in the visible part of which of the following:
1. Electro Magnetic Region (EMR)
2. NIR (Near Infrared)
3. Surface Layer
4. Bottom Layer

d. Multispectral data is very useful in analyzing which of the following applications?
1. Flood and Drought Management
2. Watershed Management
3. Land use planning
4. Agriculture planning

e. Compton Tucker, a NASA scientist in 1977 developed which of the following index:
1. NDVI
2. NID
3. ISOCLASS
4. Maximum Likelihood

1.10 ANSWERS TO THE SELF-LEARNING QUESTIONS

Ia. False

Ib. True

Ic. True

Id. True

Ie. True

IIa. Congestion

IIb. Cloud

IIc. Connectivity

IId. ISOCLASS

IIe. All of the above

IIIa. Planning

IIIb. Visual Remote Sensing

IIIc. Electro Magnetic Region (EMR)

IIId. Watershed Management

IIIe. NDVI

1.11 TECHNICAL WORDS AND THEIR MEANING

- **LULC:** The term LULC refers to Land Use Land Cover mapping. Using remote sensing lot techniques LULC maps can be prepared. These maps are highly useful in urban planning, forest monitoring, agriculture planning, urban sprawl studies etc. There are two methods used in Remote Sensing for preparing these maps.

- **DEM:** Digital Elevation Model is a model prepared using Remote Sensing techniques for the study of elevation and associated land features.

- **LADSAT:**LANDSAT data is highly useful in study of land features in Remote Sensing.

- **(R_t):** It refers to Total Radiance which is the total radiance captured over a water body by electromagnetic waves.

1.12 TASK

Download 2 sets of LANDSAT data images (For 2 different years atleast 5 or 10 years apart) from the following website and attempt spatio-temporal change detection analysis to prepare an LULC map using QGIS software.

USGS:https://www.usgs.gov/centers/eros/science/usgs-eros-archive-landsat-archives-landsat-7-enhanced-thematic-mapper-plus-etm

1.13 REFERENCES FOR FURTHER STUDY

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2

HYPERSPECTRAL REMOTE SENSING

Unit Structure :

After going through this chapter you will be able to understand the following features

2.1 OBJECTIVES

By the end of this unit you will be able to –

- Understand the concept of Hyperspectral imaging
- Understand about the data processing techniques in Hyperspectral imaging
- Know about Hyperspectral sensors and classification techniques
- Know about various Hyper-spectral satellite systems

2.2 INTRODUCTION

As discussed earlier remote sensing can be defined as capturing, analyzing and representing data which is collected remotely. This data can be collected via various platforms and techniques. Platforms can be aeroplane or satellites and data capturing equipment can be cameras or sensors. Newest addition to techniques of remote sensing is hyperspectral imaging.

2.3 SUBJECT DISCUSSION

Remote sensing is the process of obtaining information about the earth's surface through measurement and analysis of electromagnetic energy reflected or emitted from terrain using devices called sensors. This process is achieved by launching platforms for sensing, designing the path and orbits, and collecting remotely sensed data, processing the information collected and finally interpreting the results. Newest addition Hyperspectral Imaging is one of the advanced techniques developed in recent years. The technique was developed for in-depth detection of minerals, natural vegetation and objects in physical and man-made environment. Earlier this technique was used by scientists in laboratories as imaging spectroscopy for detecting mineral composition.

2.4 HYPERSPECTRAL IMAGING: HYPERSPECTRAL CONCEPTS, DATA COLLECTION SYSTEMS, NORMALIZATION, CALIBRATION TECHNIQUES

2.4.1 Hyperspectral Concepts :

The process of remote Sensing involves insolation from the source of energy- sun incase of passive remote sensing. The energy falls on the objects of the earth surface. Depending upon the inherent properties of the surface objects a certain amount of energy is reflected back from the earth's objects. (Autade, M.A. GEOGRAPHY, IDOL)This energy is captured through sensors installed in remote sensing equipment- satellites in the form of EM radiation. Electromagnetic radiation covers a large range of wavelengths. In remote sensing the maximum wavelength of EMR is concerned with the radiation from the visible range of EMR (i.e. 0.4 to 0.7 μm), to the radar wavelength region. (Autade, M.A. GEOGRAPHY, IDOL)

Division	Wavelength
Gamma rays	10^{-8} to 10^{-11} cm
X-rays	10^{-6} to 10^{-8} cm
Ultraviolet light	$4*10^{-5}$ to 10^{-6} cm
Visible light	$7.6*10^{-5}$ to $4*10^{-5}$ cm
Infra-red light	10^{-1} to 10^{-5} cm
Microwave	10^{2} to $10^{-1\ cm}$
Radiowaves	10^{2}

Table 2.1 Principal divisions of Electromagnetic Spectrum (Autade, M.A. GEOGRAPHY, IDOL)

Imaging sensors produces data which can be converted into visualized data. This data is spectral in nature, which has Digital numbers(DN). These numbers later on can be converted into spatial data. These data capturing sensors can also be categorized based on the number of spectral bands they can capture and process. For example, Panchromatic sensors -

These sensors can cover all the visible spectrum with gray scale. Multispectral sensors on the other hand can capture visible, thermal as well as microwave spectrum at a time. (Ranade, M.A. GEOGRAPHY, IDOL) For e.g. Landsat Satellite with Multispectral sensor.

Landsat 1–3 MSS	**Landsat 4–5 MSS**	**Wavelength (micrometers)**	**Resolution (meters)**
Band 4 – Green	Band 1 – Green	0.5 – 0.6	60*
Band 5 – Red	Band 2 – Red	0.6 – 0.7	60*
Band 6 – Near Infrared (NIR)	Band 3 – NIR	0.7 – 0.8	60*
Band 7 – NIR	Band 4 – NIR	0.8 – 1.1	60*

Table 2.2 LANDSAT resolution specifications (USGS)

In the above table only four bands (Band 4, 5, 6, and 7) are shown thus only four bands are available for the imaging purpose. With the advancement in the sensors the availability of bands becomes 7 to 8 in Multispectral scanning.

HoweverIf the spectrum is extended with narrow intervals then it becomes Hyperspectral sensors. This sensor focuses on minute details of the spectrum and produces high definition images. Hyperspectral remote sensing systems record 100s of spectral bands of relatively narrow bandwidth simultaneously. The narrow bandwidths can reach upto 5 to 10nm. With such narrow detail capturing the objects on the earth surface are easily identified. This technique is useful specially for change in natural vegetation and minerals, which can not be done with multispectral or panchromatic images. In Multispectral imaging several spectrum bands are created wherein Hyperspectral imaging continuous spectrum is collected. (Figure 2.1) Hyperspectral remote sensing unlike multispectral, breaks the spectral bands into several spectral parts which gives precise results.

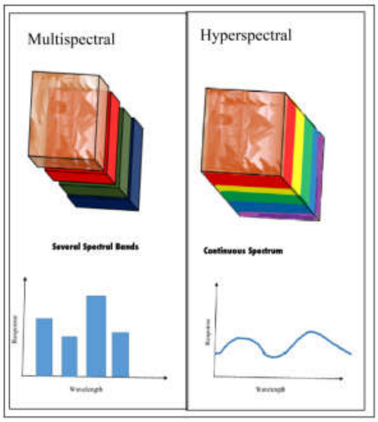

Figure 2.1 Comparison between Multispectral and Hyperspectral Images (Image Recreated from edmundoptics)

Multispectral	Hyperspectral
Separate spectral bands Wide band width Coarse representation of spectral signature Unable to detect minute details Few calibration problems Small data volume	Continuous or no spectral gaps Narrow band width Complete representation of spectral signature Able to detect minute details Calibration is time consuming Large data volume

Table 2.1 Comparison between Multispectral and Hyperspectral Remote sensing (Introduction to Remote Sensing)

2.4.2 Data Collection systems

Hyperspectral imagery is typically collected (and represented) as a data cube with spatial information collected in the X-Y plane, and spectral information represented in the Z-direction. (www.csr.utexas.edu). (Figure 2.2)

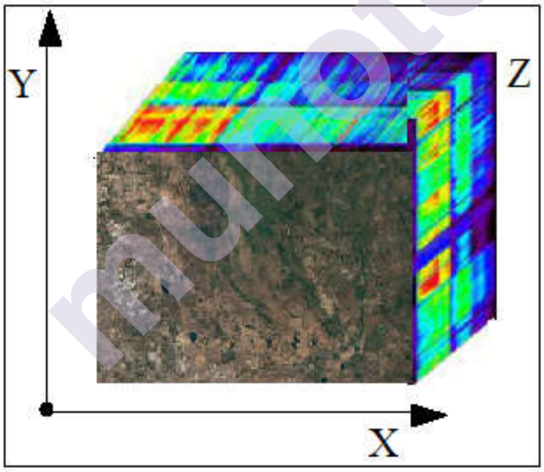

Figure 2.2 Hyperspectral Imagery X-Y plane, and spectral information represented in the Z-direction (Image Recreated)

Spectroscopy

Hyperspectral imaging technique is a combination of spectroscopy and imaging. Spectroscopy means understanding and studying absorption and emission of light -radiation by object. (Figure 2.3)

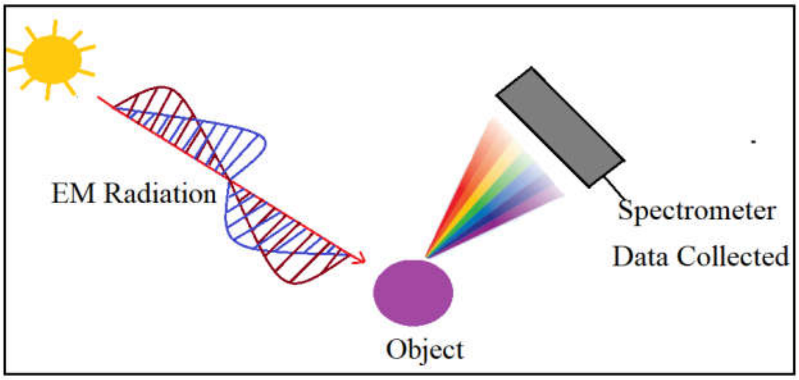

Figure 2.3 Spectrometer collecting Data (Image Recreated from atascientific)

For example, Following are the specifications of Digital Airborne Imaging Spectrometer

Name of the Band	Number of Bands
Visible and Near infra-red (0.4-1.0 microns)	27
Short wave infrared (1.0-1.6 microns)	2
Short wave infrared important for mapping clay minerals (2.0-2.5 microns)	28
Thermal infrared	6

Table 2.2 Specifications of Digital Airborne Imaging Spectrometer

In the above table (Table 2.1) each spectral band is further divided into several bands each observing the reflectance of that particular object. This technique of spectroscopy observes each emission and reflectance of EMR from an object, which can create more clear imagery.

Four parameters to describe the spectrometer's capability :

- Spectral range
- Spectral bandwidth
- Spectral sampling
- Signal-to-noise ratio

Parameters like Spectral range and Spectral bandwidth are crucial when it comes to detection and interpretation of data.

Range of Spectrometers is widespread:

- Ultraviolet (UV)- 0.001 to 0.4 µm
- Visible- 0.4 to 0.7 µm

- Near-infrared (NIR)- 0.7 to 3.0 µm
- Mid-infrared (MIR)- 3.0 to 30 µm (covers thermally emitted energy)
- Far infrared (FIR)- 30 µm to 1 mm

Spectral bandwidth is the width of an individual spectral channel in the spectrometer. (gisresources) Broad bandwidth can collect limited information whereas narrow bandwidth can give acute spectral information.

2.4.3 Calibration and Normalization

Calibration

Size and proper geometry of data is important in spatial data. Geometric scale and measurement of digital image can be varied and biased due to many factors. This can lead to distortion in the final result. Therefore for accurate and reliable results Calibration of geometric measurements is required. Non - collaborated results can compromise on quality of data.

In the atmosphere solar radiation experiences scattering and absorption along with reflection. Where hyperspectral sensors are interested in reflections, scattering and absorption can create error in collected data. Calibration method reduces this error with proper measurement and scale.

Calibration method also converts the sensor's radiance value to surface reflectance values.

Advantages of Calibration spectra are:

- The calibrated data can be compared with the field and spectra of known materials.
- The calibrated data can identify and relate them to chemical and physical properties of materials.

Thus data calibration plays a very important role of rectifying, understanding and relating data with chemical and physical properties of materials of remotely sensed data.

Normalization

Many times data collected in hyperspectral imaging could not be corrected with detailed radiometric correction. In such situations normalization is another option which can be used to create error free data. Normalization technique is used with the help of logs residuals. These log residuals depend upon radiance as well as reflectance in data. Log residuals help to identify topographic and atmospheric noise and produce error free data. Hyperspectral remote sensing data is much larger than multispectral data, thus collecting training samples is difficult. For better results in normalization, an excessive number of samples needs to be taken into consideration, as accuracy of the normalization depends upon the ratio of samples and collected data. Thus many times previously used samples are used to remote error from data. For example reflections and radiation sample data of clouds can be used for interpretation in other dataset. However the procedure is not simple and requires multiple log residuals.

2.5 DATA PROCESSING TECHNIQUES; N-DIMENSIONAL SCATTER PLOTS, SPECIAL ANGLE MAPPING, SPECTRAL MIXTURE ANALYSIS, SPECTRAL MATCHING, MIXTURE TUNED MATCHED FILTERING

2.5.1 N-dimensional scatter plots

N-dimensional scatter plots

Hyperspectral data (or spectra) can be thought of as points in an n-dimensional scatterplot. The data for a given pixel corresponds to a spectral reflectance for that given pixel. The distribution of the hyperspectral data in n-space can be used to estimate the number of spectral endmembers and their pure spectral signatures and to help understand the spectral characteristics of the materials which make up that signature. (www.csr.utexas.edu)

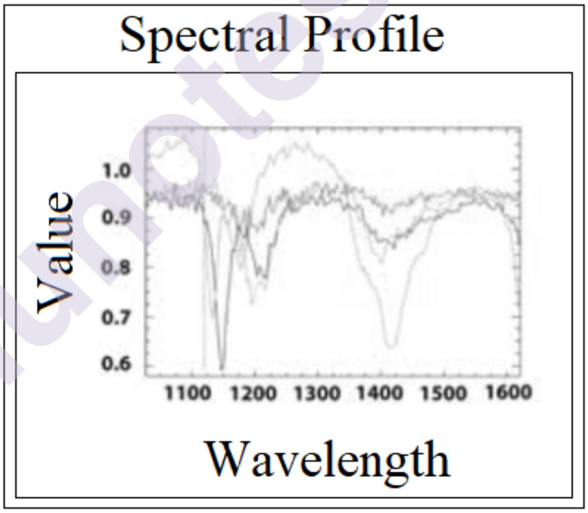

Figure 2.4 Spectral Profile (Image recreated from photonics)

2.5 DATA PROCESSING TECHNIQUES AND CLASSIFICATION TECHNIQUES, SPECTRAL ANGLE MAPPING, SPECTRAL MIXTURE ANALYSIS, SPECTRAL MATCHING, MIXTURE TUNED MATCHED FILTERING

2.5.1 Classification techniques

Images acquired by remote sensing techniques need classification for better interpretation. Image classification is assigning similar spectral signature pixels together, creating a set. This set becomes a class, which can be identified as a feature or an object with visual interpretation. As discussed earlier (Figure 2.2) hyperspectral image is collected in 3 D format. Two dimensions of image and one dimension of spectral information. Thus classifying hyperspectral images needs special classification techniques. (Figure 2. 5)

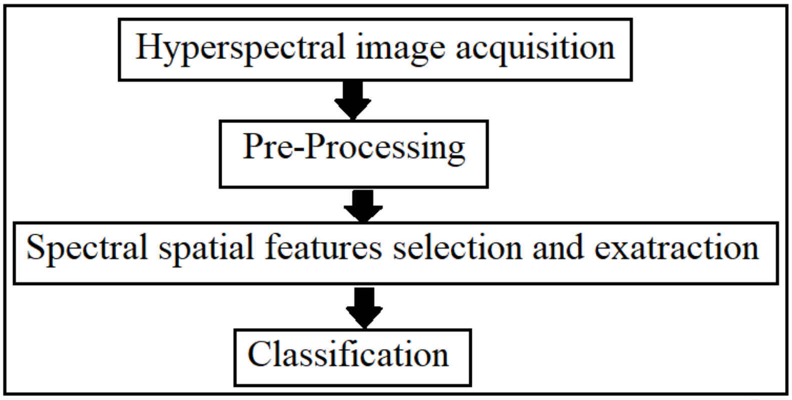

Figure 2.5 Hyperspectral image classification process (Image recreated from intechopen)

1. Unsupervised classification

In unsupervised classification machine or algorithm makes decisions on how to club and which pixels to club together as a class. The decision depends upon statistical methods like mean, Standard deviation of spectral information. This method is further divided into Principal component analysis and Independent component analysis. Principal Component Analysis is a method which reduces dimensionality. In other words using statistical methods such as standardization, covariance matrix large data sets are broken into smaller data sets as they are easier to explore.

Independent component analysis successfully executes the independence of the components with higher-order statistics, and is relatively more suitable to encounter high dimensionality of HS images. (Gogineni and Chaturvedi)

2. Supervised classification

Using predetermined sample signatures and processing images for separating class sets is called supervised classification. Predetermined classes such as land use, agriculture, various resources can be used as samples to classify data sets. Supervised classification can be done using methods like maximum likelihood and nearest neighbor classifier.

The maximum likelihood classifier assumes that the statistics for each class in each band are normally distributed and estimates the probability that a given pixel belongs to a certain specific class. Nearest Neighbor classifier operates on majority voting rule, presumes that all the neighbors make equal contributions to the classification of the testing point. (Gogineni and Chaturvedi)

2.5.2 Spectral angle mapping

Spectral angle mapping uses a method called Spectral Angle Mapper or SAM. It is an automated method of classification of hyperspectral images. It uses predetermined training classes from ASCII files and spectral libraries. To apply SAM the data needs to be converted into reflectance data which is equivalent to spectral libraries. This method calculates spectral angle between image spectrum and reference spectrum. (Figure 2.6)

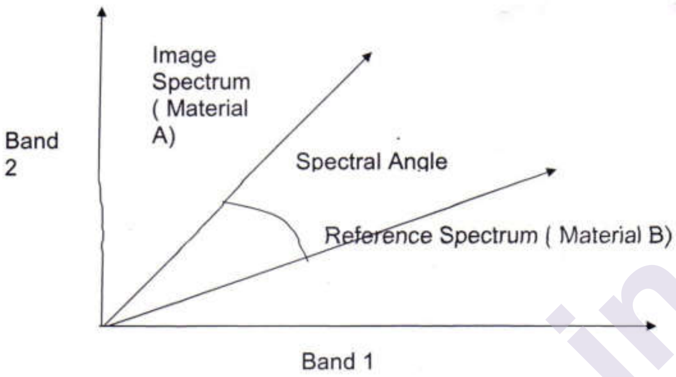

Figure 2.6 2D scatter plot of an image spectrum and library spectrum in a two-band image

For every reference spectrum SAM computes spectral angle for each image pixel. Basically it compares image spectra to individual spectra. SAM procedure can be concluded in Figure 2.7.

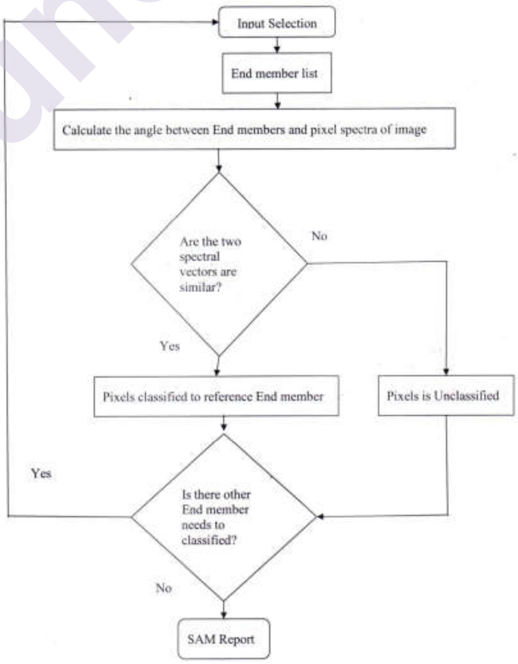

Figure 2.7 SAM procedure (Image recreated from Gogineni and Chaturvedi)

2.5.3 Spectral Mixing

Data captured by an imaging spectrometer interacts with a variety of factors. Image pixels contain a volume of total reflected energy from materials. Spatial mixing of materials in the area represented by a single pixel results in spectrally mixed reflected signals For example, features like shadow which may reflect a signal in pixels, are mixed with the dark end of the spectrum for the accurate results. When a satellite captures an image , depending on its resolution, the pixel carries a lot of information as it is a big patch on ground. (Figure 2.8) Pixels are considered mixed in this scenario. Thus spectral mixing and unmixing becomes necessary for proper interpretation.

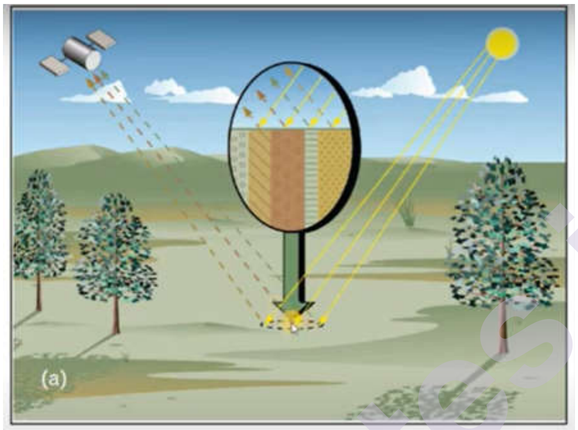

Figure 2.8 A single pixel results in spectrally mixed reflected signals
(Image Referred from Middlebury Remote Sensing)

Spectral library plays an important role in spectral mixing as mixing is done with reference to its library contents. There are various methods of spectral mixing modeling, like Mathematical modeling, Geometric modeling.

In mathematical modeling the observed spectrum [a vector] is considered to be the product of multiplying the mixing library of pure endmember spectra [a matrix] by the end member abundance [a vector]. The geometric mixing model provides an alternate intuitive means to understand spectral mixing. Mixed pixels are visualized as points in n-dimensional scatter-plot space [spectral space], where n is the number of bands. (gisresources)

2.5.4 Spectral Matching

The availability of abundant spectral data from laboratory and field-based spectro-radiometry and hyperspectral imagery has led to the development of diverse spectral databases that are utilized in varied applications. This repository of spectral signatures are called spectral libraries. (Shanmugam and Perumal) These spectral libraries matched with ground verification details to verify the objects.

Spectral matching techniques are well suited for automation due to their ability to map data from different sensors coupled with the reduced need for additional data about the study area.(Figure 2.9) This process is called spectral matching. (Parshakov 2012) This technique can be further classified into:

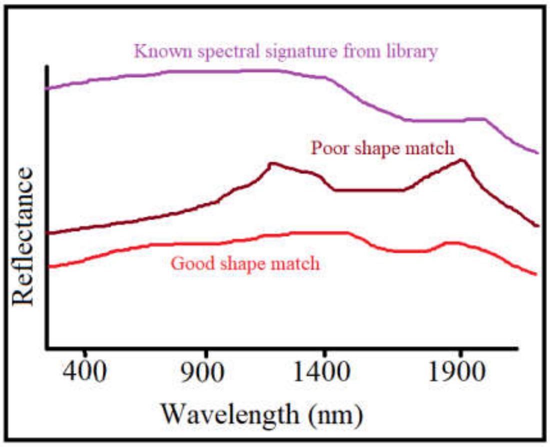

Figure 2.9 Spectral Matching (Image recreated from gcs-docs.s3.amazonaws)

- **Similarity match**

In this match spectra are unknown and they are not available in the present spectral library.

- **Identity match**

In this match it is assumed that spectra are available in the present match and need to identify.

- **Deterministic match**

In the deterministic type, algorithms are based on the geometrical and physical aspects of the unknown and reference spectra. These include the Euclidean Distance Measure (ED),Spectral Angle Mapper (SAM), Spectral Correlation Measure (SCM), Binary Encoding(BE), and Spectral Feature Fitting (SFF) techniques. (Shanmugam and Perumal)

- **Stochastic match**

These algorithms are based on the distributions of the spectral reflectance of target pixels including Spectral InformationDivergence (SID) and Constrained Energy Minimization (CEM). (Shanmugam and Perumal)

2.5.5 Mixture tuned matched filtering

Matched Filtering is a type of unmixing in which only user chosen targets are mapped. (Boardman et al., 1995) Any pixel with a value of 0 or less would be interpreted as background . One problem can occur with Matched Filtering; it can create false positive results. One solution to this problem is to calculate “infeasibility”. Infeasibility is based on both noise and image statistics. Pixels with high infeasibility values are considered as false positives.

One can use Mixture Tuned Matched Filtering (MTMF) to perform Matched Filtering (MF) and to add an infeasibility image to the results. Correctly mapped pixels will have an MF score above the background distribution around zero and a low infeasibility value. (l3harrisgeospatial)

2.6 HYPER-SPECTRAL SATELLITE SYSTEMS: SENSORS, ORBIT CHARACTERISTICS, DESCRIPTION OF SATELLITE SYSTEMS, DATA PROCESSING ASPECTS, APPLICATIONS

2.6.1 Hyper-spectral satellite systems

Over the past few years new technology evolves in the field of remote sensing. Technologies like hyperspectral remote sensing 3D, high dimensional data with hundreds of bands are available.

Hyperspectral sensors

Hyperspectral sensors use image spectroscopy technique to capture an image. These spectrometers can be further divided into:

- **Whiskbroom image spectrometer**

Whiskbroom image spectrometer is an opto-mechanical device and can produce about 200 continuous spectral channels. The moving plane mirror reflects radiation on the spectrometer resulting in a series of reflectance array of information. For example Airborne Visible /Infrared Imaging Spectrometer (AVIRIS)

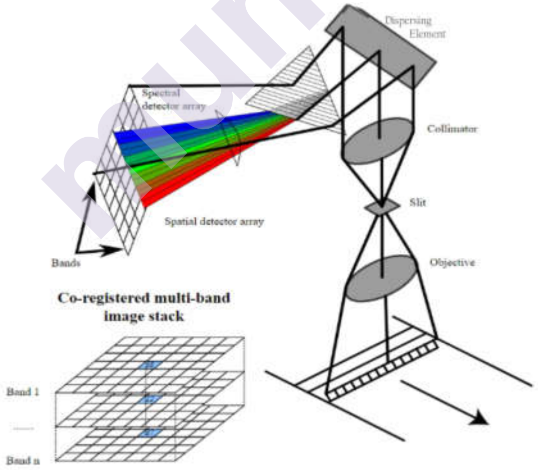

Figure 2.10 Working of image spectrometer (ecological processes.springeropen)

- **Pushbroom image spectrometer**

This spectrometer uses a two dimensional CCD Array of detectors, which is located at the focal plane. This separates the radiation according to wavelength. The scanner works across tracks which determine swath. For example Airborne Imaging Spectrometer (AIS)

Selected Airborne imaging spectrometer systems:

Spaceborne Hyperspectral Imagers

Sensor (Agency)	Number of Bands	Spectral Coverage (nm)	Band Width at FWHM (nm)	GIFOV (mrad) (m)	FOV (deg) (km)	Data Product	Launch Date
NIMS (NASA/JPL)	504	700-5100	10	0.5	20 pixels	Full Cube	flown (extra-terrestrial mission)
VIMS (NASA/JPL)	320	400-5000	15	0.5	70 pixels	Full Cube	flown (extra-terrestrial mission)
UVISI (US MILITARY)	> 200	380 - 900 110-900	1 - 3	(100 - 1000)	(25)	Full Cube	MSX spacecraft (1994)
MODIS (NASA/EOS)	36	415-2130 3750 - 4570 6720 -14240	10 - 500	(250 - 1000)	(2330)	Sub-Cube	EOS AM platform (1998) EOS PM platform (2000)
MERIS (ESA/EOS)	15 (selectable)	400 - 1050	2.5 - 10 (selectable)	(300)	(1450)	Sub-Cube	ESA-POEM 1 AM platform (1998)
PRISM (ESA/EOS)	~ 150 - 200 1 3	450-2350 3800 8000 - 12300	10 - 12 600 1000	(50)	(50)	Full Cube	Design stage
CIS (China)	30 6	VNIR SWIR/MWIR/TIR	20	(402)	90	Full Cube	Design stage
HSI (TRW)	128 256	400 - 1000 900 - 2500	5.00 6.38	(30)	(7.7)	Full Cube	LEO s/c platform (1996)

Table 2.4 Spaceborne Hyperspectral Imagers and Specifications (Hernandez-Baquero)

Airborne Hyperspectral Imagers

Sensor (Agency/Company)IFOV (mrad) (GIFOV (m))	FOV(°) (km)	Data Product	Period of Operation	Data Product	Tentative Launch Date
AAHIS (SAIC)	288	433-832	6.0	Image Cube	since 1994
AHS (Daedalus)	48	440-12700	20 - 1500	Image Cube	since 1994
AIS-1 (NASA/JPL) AIS-2 (NASA/JPL)	128 128	900-2100 1200-2400 800-1600 1200-2400	9.3 10.6	Image Cube Image Cube	1982-1985 1985-1987

AISA (Karelsilva Oy)	286	450-900	1.56 - 9.36	Image Cube	since 1993
AMSS (GEOSCAN)	32 8 6	490-1090 2020-2370 8500-12000	20.0 - 71.0 60.0 550 - 590	Image Cube	since 1985
ARES (Lockheed)	75	2000 - 6300	25.0 - 70.0	Image Cube	since 1985
ASAS (NASA/GSFC) upgraded ASAS	29 62	455 - 873 400 - 1060	15.0 11.5	Image Cube (7 viewing angles) +45(deg)/- 45(deg) Image Cube up to 10 viewing angles) +75(deg)/- 55(deg)	1987 - 1991 since 1992
ASTER Simulator (DAIS 2815) (GER)	1 3 20	700 - 1000 3000 - 5000 8000 - 12000	300.0 600 - 700 200	Image Cube	since 1992
AVIRIS (NASA/JPL)	224	400 - 2450	9.4 - 16.0	Image Cube	since 1987
CASI (Itres Research)	288 up to 15	430 - 870 (nominal)	2.9	Profiles Image	since 1989
CAMODIS (China)	64 24 1 2	400 - 1040 2000 - 2480 3530 - 3940 10500 - 12500	10.0 20.0 410.0 1000.0	Imabe Cube	since 1993
DAIS - 7915 (GER/DLR/JRC)	32 8 32 1 6	498 - 1010 1000 - 1800 70 - 2450 3000 - 5000 8700 - 12300	16.0 100.0 15.0 2000.0 600.0	Full Cube	since 1994
DAIS - 16115 (GER)	76 32 32 6 12 2	400 - 1000 1000 - 1800 2000 - 2500 3000 - 5000 8000 - 12000 400 - 1000	8.0 25.0 16.0 333.0 333.0	Full Cube Stereo	since 1994
DAIS - 3715 (GER)	32 1 2 1 1	360 - 1000 1000 - 2000 2175 - 2350 3000 - 5000 8000 - 12000	20 1000 50 2000 4000	Full Cube	since 1994
FLI/PMI (MONITEQ)	288 8	430 - 805	2.5	Full Cube (Profiles) Sub-Cube	1984 - 1990

GERIS (GER)	24 7 32	400 - 1000 1000 - 2000 2000 - 2500	25.4 120.0 16.5	Full Cube	since 1986
HSI (SAIC)	128	400 - 900	4.3	Full Cube	until 1994
HYDICE (Navel Research Laboratory)	206	400 - 2500	7.6 - 14.9	Full Cube	since 1995
ISM (DES/IAS/OPS)	64 64	800 - 1700 1500 - 3000	12.5 25.0	Full Cube	since 1991
MAS (Daedalus)	9 16 16 9	529 - 969 1395 - 2405 2925 - 5325 8342 - 14521	31 - 55 47 - 57 142 - 151 352 - 517	Full Cube	since 1993
MAIS (China)	32 32 7	450 - 1100 1400 - 2500 8200 - 12200	20 30 400 - 800	Full Cube	1990
MEIS (McDonnell Douglas)	> 200	350 - 900	2.5	Full Cube	since 1992
MISI (RIT)	60 1 1 3 4	400 - 1000 1700 2200 3000-5000 8000-14000	10 50 50 2000 2000	Full Cube	from 1996
MIVIS (Daedalus)	20 8 64 10	433 - 833 1150 - 1550 2000 - 2500 8200 - 127000	20.0 50.0 8.0 400.0/500.0	Full Cube	since 1993
MUSIC (Lockheed)	90 90	2500 - 7000 6000 - 14500	25 - 70 60 - 1400	Full Cube	since 1989
ROSIS (MBB/GKSS/DLR)	84 30	430 - 850	4.0/12.0	Full Cube Sub-Cube	since 1993
RTISR (Surface Optics Corp.)	20 or 30	400 - 700 (900)	7.0 - 14.0 (19.0)	Full Cube	since 1994
SFSI (CCRS)	120	1200 - 2400	10.0	Full Cube Sub-Cube	since 1994
SMIFTS (U. of Hawaii)	75 35	1000 - 5200 3200 - 5200	(100 cm-1) (50 cm-1)	Full Cube	since 1993

TRWIS-A TRWIS-B TRWIS-II TRWIS-III (TRW)	128 90 99 396	430 - 850 430 - 850 1500 - 2500 400 - 2500	3.3 4.8 11.7 5.0/6.25	Full Cube Full Cube Full Cube Full Cube	since 1991 since 1991 since 1991 since 1991
Hybrid VIFIS (U. of Dundee)	30 30	440 - 640 620 - 890	10 - 14 14 - 18	Full Cube	since 1994
WIS-FDU (Hughes SBRC)	64	400 - 1030	10.3	Full Cube	1992
WIS-VNIR (Hughes SBRC)	17 67	400 - 600 600 - 1000	9.6 - 14.4 5.4 - 8.6	Full Cube	1995
WIS-SWIR (Hughes SBRC)	41 45	1000 - 1800 1950 - 2500	20.0 - 37.8 18.0 - 25.0	Full Cube	1995

Table 2.5 Airborne Hyperspectral Imagers and Specifications (Hernandez-Baquero)

2.6.1 Applications Hyperspectral Image Analysis

1. Detecting Minerals and applying Mineral targeting and mapping

3. Detecting soil properties such as moisture, organic content, and salinity

1. 3.To identify Vegetation species (Clark et al., 1995), study plant canopy chemistry (Aber and Martin, 1995), and detect vegetation stress (Merton, 1999).

4. To detect military vehicles under partial vegetation canopy, and other military targets

5. Study of atmospheric parameters like clouds, aerosol conditions and Water vapor

6. In Oceanography: detection of phytoplankton, Investigations of water quality, monitoring coastal erosion.

7. Identifying Spatial distribution of snow cover, surface albedo and snow water equivalent.

8. Oil Spills: Identifying areas affected by wind, waves, and tides, a rapid assessment of the damage.

9. Environmentally sensitive areas can be targeted for protection and cleanup. (gisresources)

2.7 SUMMARY

Remote sensing means data acquisition of EM radiation from various platforms. We understand that Remote sensing data provides excellent geometric, spatial, spectral, radiological and temporal information about earth. With continuous monitoring and analysis, improved technology provides vital information about earth and its systems. Hyperspectral imaging is among the newest and fastest growing remote sensing technology. In this Unit we tried to understand workings and various platforms for Hyperspectral imaging. We also learned about various Hyperspectral sensors.

2.8 CHECK YOUR PROGRESS/ EXERCISE

1. Answer True or False

i. Pushbroom spectrometer uses a two dimensional CCD Array of detectors.

ii. When the spectrum is extended with narrow intervals then it becomes Hyperspectral sensors.

iii. Hyperspectral imaging technique is a combination of remote and imaging.

iv. Hyperspectral imaging is in 3D format.

v. Detection of phytoplankton is one of the applications of Hyperspectral imaging.

2. Answer the following Questions. (MCQ)

i. Hyperspectral remote sensing systems record 100s of spectral bands of relatively____________bandwidth simultaneously

a. Narrow

b. Broad

c. Long

d. Bigger

ii. In________________classification machine or algorithm makes decisions on how to club and which pixels to club together as a class.

a. supervised

b. unsupervised

c. narrow

d. suppressed

iii. _______________ is one of the automated method of classification of hyperspectral images.

a. TMH

b. TWIIE

c. SAM

d. USR

iv. The ______________ data can be compared with the field and spectra of known materials.

a. supervised
b. unsupervised
c. calibrated
d. suppressed

v. ______________ image spectrometer is an opto-mechanical device

a. Pushbroom
b. Whiskbroom
c. Forwardbroom
d. Upbroom

3. Answer the following questions.

1. Write a note on Applications of hyperspectral imaging.
2. State the difference between multispectral and hyperspectral imaging.
3. Explain spectral matching in detail.
4. Write a note on Calibration
5. Write a note on Normalization

2.9 ANSWERS TO THE SELF-LEARNING QUESTIONS

Answer true or False

1. True
2. True
3. False
4. True
5. True

Answer the following Questions.(MCQ)

1. Narrow
2. Unsupervised
3. SAM
4. Calibrated
5. Whiskbroom

2.10 TASK

Write a detailed article on various hyperspectral imaging satellite missions in the world.

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3

AERIAL PHOTOGRAPHY

Unit Structure:

3.1 INTRODUCTION TO AERIAL CAMERA, FACTORS AFFECTING IMAGE QUALITY

3.1.1 Introduction

Photographing from air is basically known as aerial photography. The word 'aerial' derived in early 17th century from Latin word aerial, and Greek word aerios . The term "photography" is derived from two Greek words phosmeaning "light" and graphien meaning "writing" means "writing by light".

Aerial photography comes under the branch of Remote Sensing. Platforms from which remote sensing observations are made are aircraft and satellites as they are the most wide spread and common platforms. Aerial photography is a part of remote sensing and has wide applications in topographical mapping, engineering, environmental science studies and exploration for oil and minerals etc. In the early stages of development, aerial photographs were obtained from balloons and kites but after the invention of aircrafts in 1903 aircrafts are being used widely for aerial photographs.

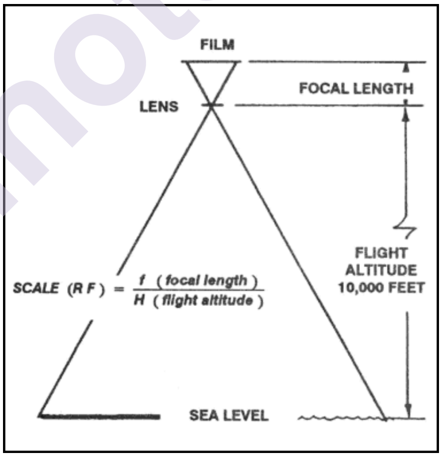
The sun provides the source of energy (electro magnetic radiation or EMR) and the photo sensitive film acts as a sensor to record the images. Diversifications observed in the images of photographs shows the different amount of energy being reflected from the objects as recorded on the film. Nowdays aerial photography also become digital where values of reflected electromagnetic radiation is recorded in digital numbers.

An aerial photograph is any photograph taken from an airborne vehicle (aircraft, drones, balloons, satellites, and so forth). The aerial photograph has many use sinmilitary operations; however, for the purpose of this manual, it will be considered primarily as a map supplement or map substitute.

factors affecting image quality

3.1.2 Factors that influence Aerial Photography Scale

Scale is defined as the ratio of distances between two images on an aerial photograph and the actual distance between the same two points/ objects on the ground, in other words the ratio of/H (where fis the focall ength of the cameralen sand His the flying height above the mean terrain), shown in figure 1. Change in scale from photograph to another is because of the variations in flying height other factors that further affect the scale variations are tilt and relief displacements. Aerial photograph, the image should be of the highest quality. To guarantee good image quality, recent distortion-free cameras are used. Some latest versions of cameras have image motion compensation devices to eliminate or reduce the effects of forward motion. Depending upon there quirements, differentlens/ focallength/ film/ filtercombinations can be taken inuse.



Scale of photograph

Camera/Film/Filter

3.1.3 Combinations Aerial Cameras

Aerial Cameras are special cameras that are built for mapping which have high geometric and radiometric accuracy. Airborne camera are built with exactness and purposely designed to expose a large number of films/photographs in speedy succession with the ultimate in geometric fidelity and quality. Aerial cameras generally have a medium to large format, with good quality lens, a large film magazine, a mount to hold the lens, the camera in a vertical position and a motordrive.

There are various types of aerial cameras such as Aerial mapping camera (single lens), Reconnaissance camera, Strip camera, Panoramic camera, Multi-lenscamera, multi bandaerial cameras, Digital camera.

Aerial Films:

Aerial film is multi layer emulsion laid on a stable anti-halation base. Generally aerial films are available in rolls that has crosss ection of about 10 in chin wide and 200 to 500 ft in length.

Types of Film:

Depending upon the suitability for different purpose and unique situations variety of films are available that are used. Panchromatic and natural color films are the two most commonly utilized films. These two films along with infrared and false colour form the basic media used in aerial photography. As shown below in fig.

Fig: . Types of film photographs

Panchromatic:

Panchromatic, more often termed black and white, is the most commonly encountered film employed for photogrammetry. The sensitive layer consists of silver salt (bromide, chloride, and halide) crystals suspended in a pure gelatine coating which sits atop a plastic base sheet. The emulsion is sensitive to the visible (0.4- to 0.7-μm) portion of the electromagnetic spectrum.

Colour:

Natural colour also known as true colour film.. The multi layer emulsion is sensitive to visible region of electro magnetic spectrum. There are three layers of gelatine containing sensitized dyes, one each for blue (0.4–0.5 μm), green (0.5–0.6 μm), and red (0.6–0.7 μm) light. Green and red layers are also sensitive to blue wave lengths. Visible light waves first pass through and react with the blue layer and then pass through a filter layer which halts further passage of the blue rays. Green and red waves pass through this barrier and sensitize their respective dyes, causing achemical reaction and thus completing the exposure and creating a true colour image.

Infrared:

Current aerial infrared film is offered as two types: black and white in frared and colour in frared. Black and White Infrared have the emulsion sensitive to green (0.54–0.6 µm), red (0.6–0.7 µm), and part of the near infrared (0.7–1.0 µm) portions of the spectrum and renders a gray- scale image.(Fig.)

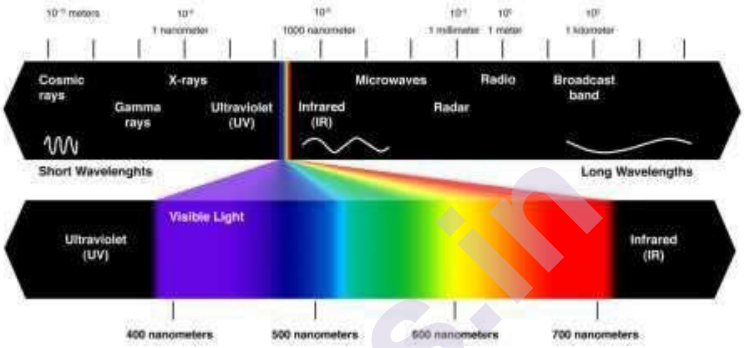


Fig No: . Visible Spectrum

Colour Infrared:

Colour Infrared film is commonly termed as false colour. The multilayer emulsion is sensitive to green (0.5–0.6µm), red (0.6–0.7µm), and part of the near infrared (0.7–1.0µm) portions of the spectrum. A false colour image contains red/pink hues in vegetative areas, with the colour depending upon the degree to which the photosynthetic process is active (Fig:).

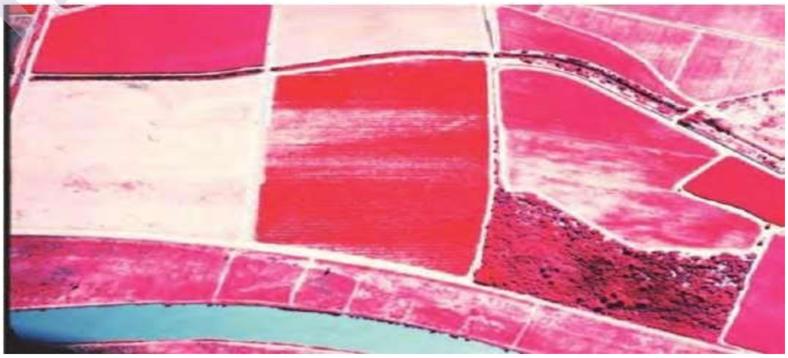


Fig No: . Vegetative areas

Flight Direction:

It is advisable that aerial photography is flown in tiles to cover the chosen area in designated flight line (showninfig). Foreasiness in handling, it is prudent to keep the number of tiles to minimum. The flight direction of the strips/ tiles is there fore kept along the length of the area.

This direction may be any suitable direction along a natural or man-made feature and should be clearly specified. The further transmission process and data collection is shown in fig .

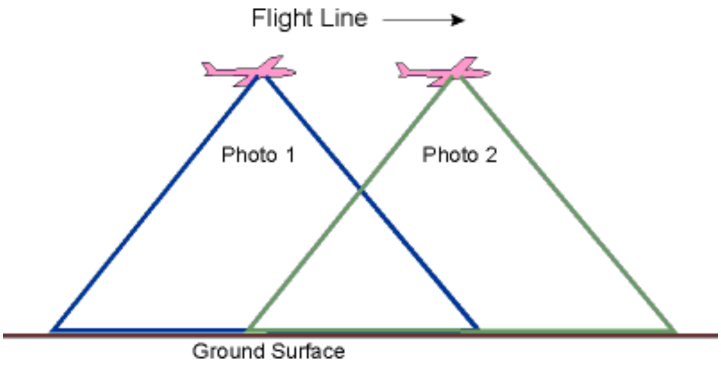


Fig No: . Flight Line

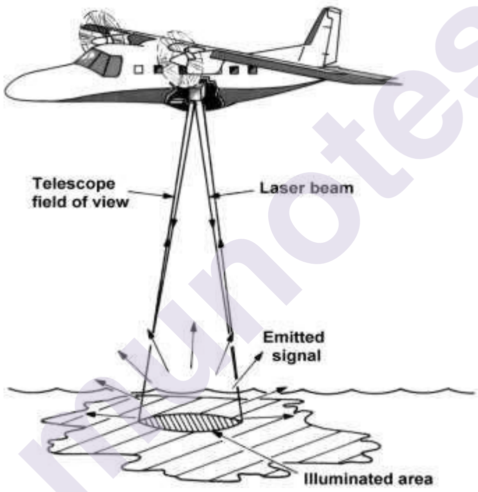


Fig No: . Flight direction and signal receiving process

Time:

The time at which aerial photograph taken is very important, as long, deep shadows tend to doubtful details, whereas undersized/small shadows tendtomark out some details effectively and are generally fruitful in improving the interpretational values of a photograph. Based on experience, aerial photography should be flown when the sun's elevation is 30 degrees above the horizon or three hours before and after the local noontime.

Season:

Factors such as seasonal variations in light reflectance, seasonal changes in the vegetation cover and seasonal changes in climatological factors are the tip points for choosing the suitability of season. The purpose for which aerial photography is flown also dictates the season. For example, for photogrammetric mapping, geological or soil survey purposes, the ground should be as clearly visible as possible.

3.1.3 Atmospheric Conditions

As mentioned before, the presence of particles (smoke or dust) and molecules of gases in the atmosphere tends to reduce contrast because of scattering, especially by the heavier particles; therefore, the best time for photography is when the sky is clear, which normally in India is from November to February. The presence of dust and smoke during the premonsoon summer months and of clouds during the monsoon months forbids aerial photography during theseperiods.

Stereoscopic Coverage:

To examine the Earth's surface in three dimensions, aerial photography is normally flown with a 60 % forward over lap and a 25 % side lap, to provide full coverage of the area (Fig.7a and b).This is an essential requirement from the photogram metric mapping point of view to obtain data both on plan imetry and height susing the stereo scopic principle of observation in 3-Dand measurement techniques with stereo plotting instruments. Stereoscopic viewing also helps in interpretation, as the model is viewed in threed imensions.

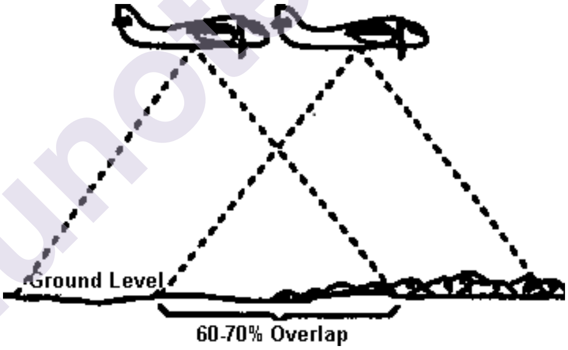


Fig (a) Overlap required to get the full coverage of area

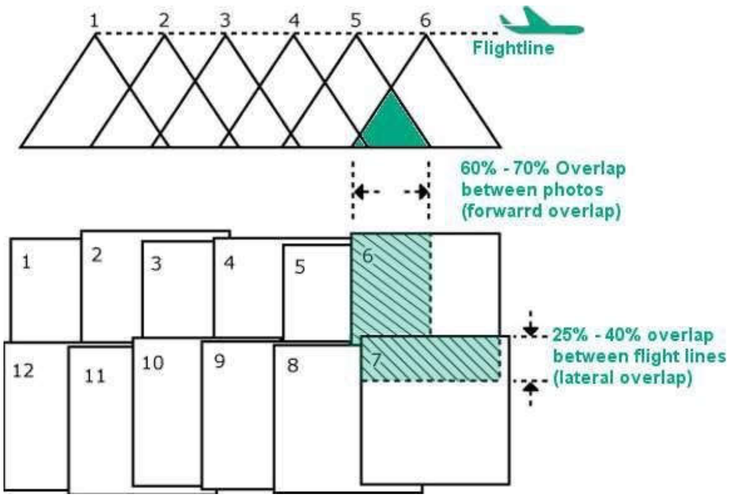


Fig () Overlap required to get the full coverage of area

3.2.1 Types of aerial photographs Photographic resolution and zradiometric Characteristics

Types of aerial photographs

The aerial photographs can be divided into:

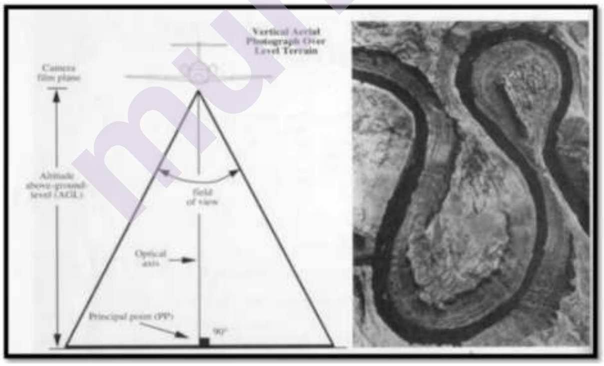
1) On the basis of the direction / position of the axis of the camera
2) On the basis of the angles of coverage and focal length
3) On the basis of the films used in the cameras.

On the basis of the direction / position of the axis of the camera :

1) Vertical
2) Horizontal
3) Oblique
4) Convergent
5) Trimetrogon

Vertical photograph

The axis of the camera is vertically adjusted to take the photographs. The area covered through vertical air photos are often square in shape at the uniform plane. I In simple words. These photographs are taken with an air borne camera aimed vertically downward from the plane.



Horizontal Photographs

The horizontal air photos are also known as Terrestrial air photos. In the production of such air photos, the axis of the camera is horizontal.

Oblique Photographs

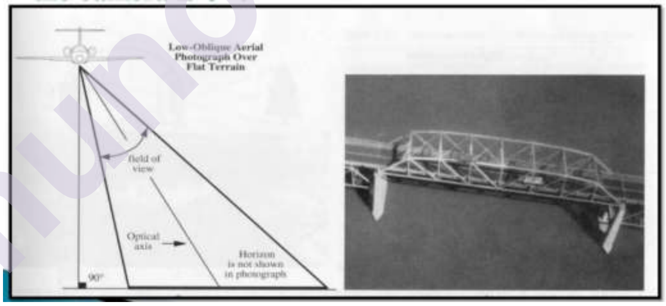
In the oblique air photos, the adjustment of the axis of the camera ranges from the vertical to angular position. The areas covered by oblique air photos assumed the shape of a trapezium. An oblique photograph is divided into two types:

1. Low Oblique Photographs

2. High Oblique Photographs

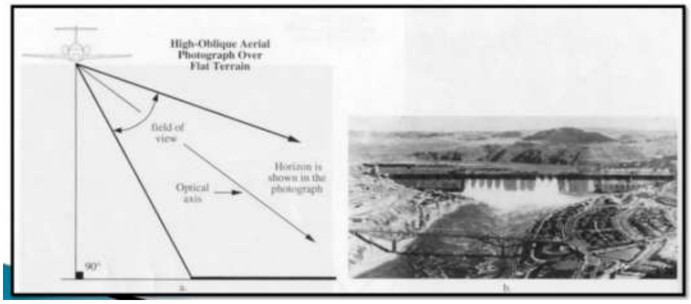
Low Oblique Photographs

One which does not have the horizon showing is called a Low Oblique Photographs and the axis of the camera is 0



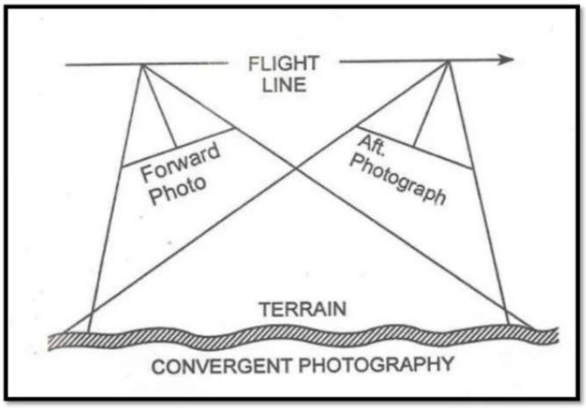
High Oblique Photographs

An oblique photograph showing the horizon is called a High Oblique photographs and the axis of the camera is tilted to 30 to 60



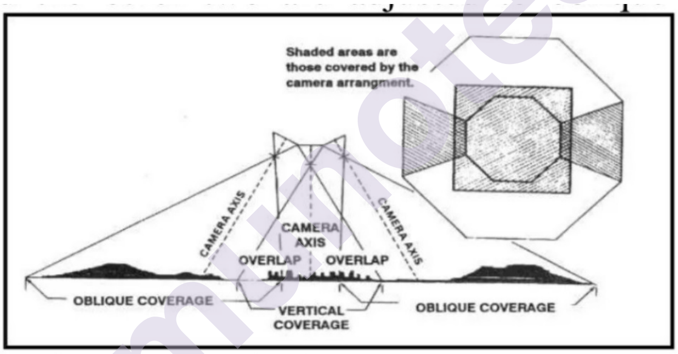
Convergent Photographs

The convergent air photos are also oblique, but an area is simultaneously Photographed by two cameras.



Trimetrogen photographs

In Trimetrogen air photos, three cameras are used simultaneously amongst which the central camera is vertical, and the other two are adjusted to oblique position. The cameras are so fixed that the entire area from right horizon to the left horizon is photographed.



On the basis of the angles of coverage and focal length

The lenses used in the camera, are of the following types according to the angles of coverage and the focal length:

1. Narrow Angle < 60 - More Focal Length
2. Normal Angle 60 - 75
3. Wide Angle 75 - 100
4. Super wide Angle > 100 - Low Focal Length.

On the basis of the films used in the camer as.

On the basis of these category the air photos are divided into three types such as :

1. Black and white.

2. Infrared (IR)

3. Colored

Black and white Photographs

This is also known as PANCHROMATIC. This is most widely used type of aerial photograph. This is mainly used for study of geological mapping. glacial deposit, coastal formation, relief features etc. this films are cheapest and easily available.

Colored Photographs

Colored photography is mainly used for interpretation purpose. There are three colors Yellow Magenta (Blue + Red) and Blue Green when these three colors mixed together colors . This types of photographs for mapping cultivated land environment / vegetation cover, geologs, geomorphology etc.

3.2.2 Arial Photographic resolution

Method 1: By Establishing Relationship Between Photo Distance and Ground Distance :

If additional information like ground distances of two identifiable points in an aerial photograph is available, it is fairly simple to work out the scale of a vertical photograph.

Provided that the corresponding ground distances (Dg) are known for which the distances on an aerial photograph (Dp) are measured. In such cases, the scale of an aerial photograph will be measured as a ratio of the two, i.e. Dp/ Dg.

The distance between two points on an aerial photograph is measured as 2 centimetres. The known distance between the same two points on the ground is 1 km. Compute the scale of the aerial photograph (Sp).

Solution

Sp = Dp: Dg

= 2 cm: 1 km

= 2cm: 1 × 100,000 cm

= 1: 100,000/2 = 50,000 cm

= 1 unit represents 50,000 units

Therefore, Sp = 1: 50,000

Method 2 By Establishing Relationship Between Photo Distance and Map Distance:

As we know, the distances between different points on the ground are not always known. However, if a reliable map is available for the area shown on an aerial photograph, it can be used to determine the photo scale. In other words, the distances between two points identifiable both on a map and the aerial photograph enable us to compute the scale of the aerial photograph (Sp). The relationship between the two distances may be expressed as under: (Photo scale: Map scale) = (Photo distance: Map distance)

We can derive

Photo scale (Sp) = Photo distance (Dp): Map distance (Dm) × Map

scale factor (msf)

The distance measured between two points on a map is 2 cm. The corresponding distance on an aerial photograph is 10 cm. Calculate the scale of the photograph when the scale of the map is 1:50,000.

Solution

Sp = Dp: Dm × msf

Or = 10 cm: 2 cm × 50,000

Or = 10 cm: 100,000 cm

Or = 1: 100,000/10 = 10,000 cm

Or = 1 unit represents 10,000 units

Therefore, Sp = 1: 10,000

Method 3 By Establishing Relationship Between Focal Length (f) and Flying Height (H) of the Aircraft:

If no additional information is available about the relative distances on photograph and ground/map, we can determine the photo-scale provided the information about the focal length of the camera (f) and the flying height of the aircraft (H) are known (Fig. 6.15). The photo scale so determined could be more

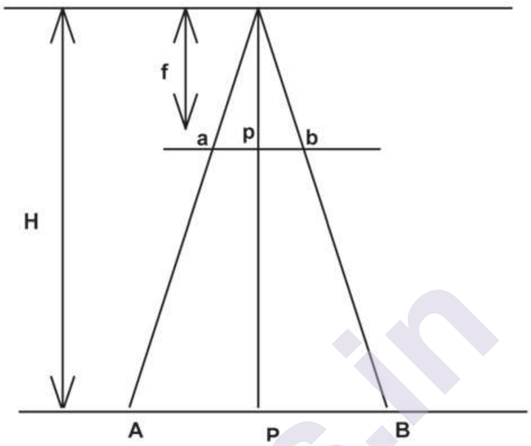


Figure ………. Focal Length of the Camera (f) and Flying Height of the Aircraft (H)

reliable if the given aerial photograph is truly vertical or near vertical and the terrain photographed is flat. The focal length of the camera (f) and the flying height of the aircraft (H) are provided as marginal information on most of the vertical photographs (Box 6.2).

The Fig. 6.15 may be used to derive the photo-scale formula in the following way :

Focal Length (f): Flying Height (H) =

Photo distance (Dp): Ground distance (Dg)

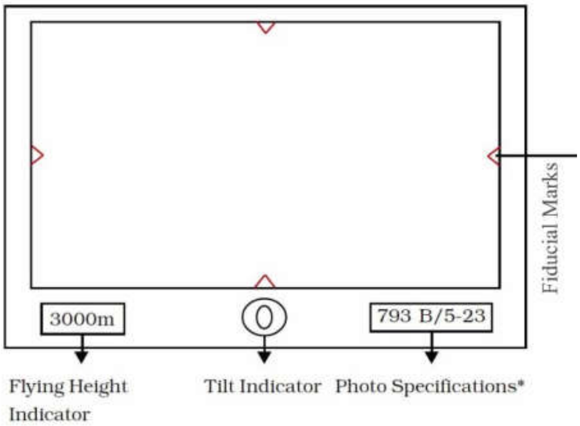
Compute the scale of an aerial photograph when the flying height of the aircraft is 7500m and the focal length of the camera is 15cm.

Sp = f: H

Or Sp = 15 cm : 7,500 × 100 cm

Or Sp = 1: 750,000/15

Therefore, Sp = 1: 50,000



793 is a Photo Specification number maintained by the 73 APFPS Party of the Survey of India. B is the Flying Agency that carried out the present photography (In India three flying agencies are officially permitted to carry out aerial photography. They are the Indian Air Force, the Air Survey Company, Kolkata and the National Remote Sensing Agency, Hydrabad, identified on the aerial photographs as A, B and C respectively), 5 is the strip number and 23 is the photo number in strip 5.

3.3.1 Fundamentals of photogrammetry: Introduction and definition Simple geometry

Fundamentals of photogrammetry

PHOTOGRAMMETRY IS…

A means of obtaining information from aerial photographs

PHOTOGRAMMETRY IS THE SCIENCE

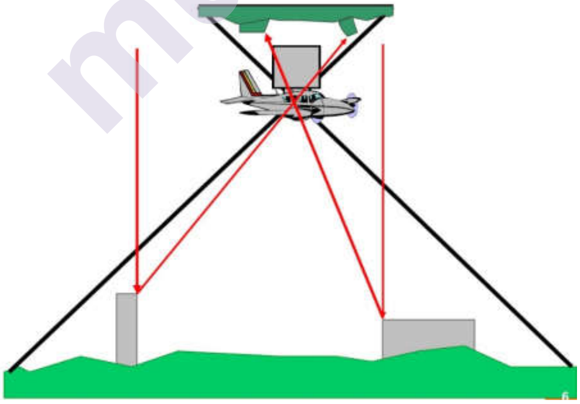


Photo = "Picture",

► Grammetry = "Measurement", therefore

► Photogrammetry = "photo-measurement"

Definition of Photogrammetry:

The art, science, and technology of obtaining information about physical objects and the environment by photographic and electromagnetic images, in order to determine characteristics such as size, shape and position of photographed objects.

WHAT IS PHOTOGRAMMETRY

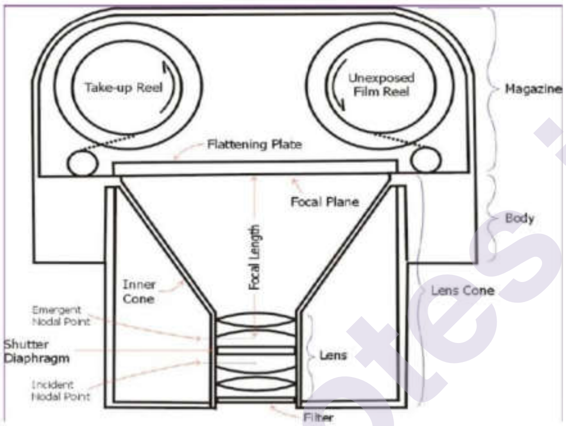
- Photogrammetry is the art and science of making accurate measurements by means of aerial photography:
- Analog photogrammetry (hard-copy photos)
- Digital photogrammetry (digital images)
- Aerial photographs were the first form of remote sensing imagery.
- Differences between photogrammetry and Remote Sensing are that photographs are:
- Black and white (1 band) or color (blue, green, red, and IR)
- Wavelength range of 0.3-1.0 m
- Use cameras
- One type of remote sensing imagery
- Science (or art) of deducing the physical dimensions of objects from measurements on photographs
- Mapping the earth or other bodies in the solar system
- Sometimes used to indirectly measure the geometry of buildings, dams, archeological sites using photographs.
- Sometimes the same principles are applied to digital imagery from satellite-based RS platforms.
- Science (or art) of deducing the physical dimensions of objects from measurements on photographs
- Mapping the earth or other bodies in the solar system
- Sometimes used to indirectly measure the geometry of buildings, dams, archeological sites using photographs.
- Sometimes the same principles are applied to digital imagery from satellite-based RS platforms.

PHOTOGRAMMETRY IS THE TECHNIQUE OF MEASURING OBJECTS (2D OR 3D) FROM PHOTOGRAPHS.

Its most important feature is the fact, that the objects are measured **without being touched**.

Objects are measured without touching.

- It is a Remote sensing technique.
- It is a close-range method of measuring objects.
- It is a 3-dimensional coordinate measuring technique that uses Photographs as the fundamental medium for measurement.
- Modern Photogrammetry also uses radar imaging, radiant electromagnetic energy detection and x-ray imaging – called remote sensing.



Has many uses

Very economical as opposed to on site surveying

The main principle is "TRIANGULATION".

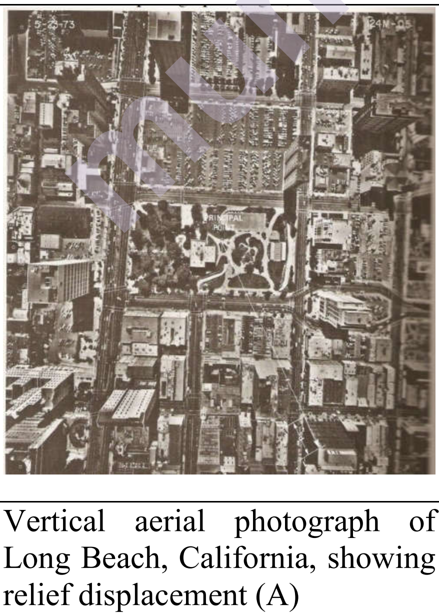
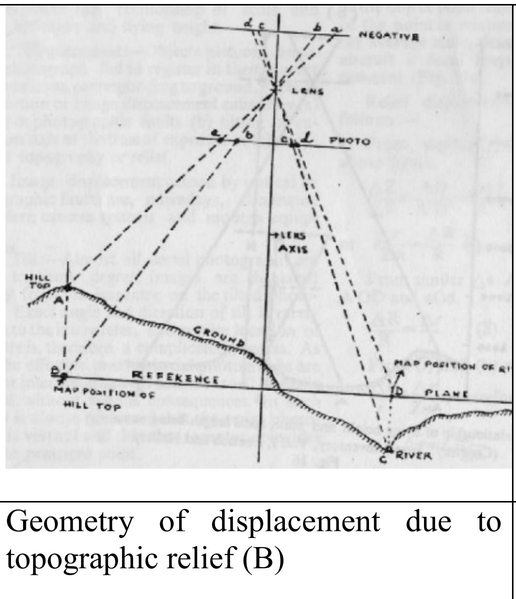
- Eyes use the principle of TRIANGULATION to gauge distance (depth perception).
- TRIAGULATION is also the principle used by theodolites for coordinate measurement.

- By taking photographs from at least two different locations, so-called "lines of sight" can be developed from each camera to points on the object. These lines of sight (sometimes called rays owing to their optical nature) are mathematically intersected to produce the 3-dimensional coordinates of the points of interest.

3.4.1Vertical aerial photograph Relief and tilt displacement Stereoscopy, parallax Equation; flight planning Scale and height determination.

Introduction

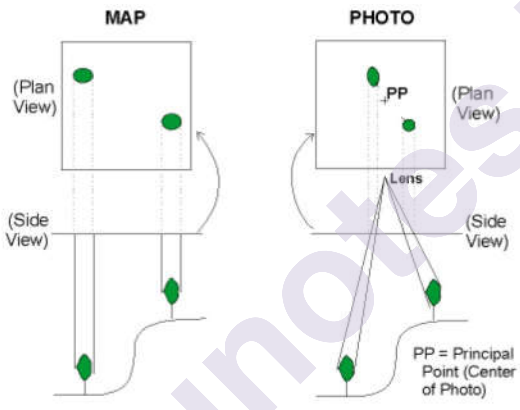
Relief displacement is the radial distance between where an object appears in an image to where it actually should be according to a Planimetric coordinate system. The images of ground positions are shifted or displaced due to terrain relief, in the central projection of an aerial photograph. If a photograph is truly vertical, the displacement of images is in a direction radial from the photograph center. This displacement is called the radial displacement due to relief. Radial displacement due to relief is also responsible for scale differences within any one photograph, and for this reason a photograph is not an accurate map. Relief displacement is caused by differences in relative elevation of objects photographed. All objects that extend above or below a datum plane have their photographic images displaced to a greater or lesser extent. This displacement occurs always along the line which connects the photo point and the nadir and is, therefore termed “radial line displacement”. Or this displacement is always radial with respect to principal point. It increases with increasing height of the feature and the distance from nadir

		
Vertical aerial photograph of Long Beach, California, showing relief displacement (A)	Geometry of displacement due to topographic relief (B)	

shows the geometry of image displacement, where light rays are traced from the terrain through the camera lens and onto the film. Prints made from the film appear as though they were in the position shown by the plane of photographic print in Fig. A. The vertical arrows on the terrain represent objects of various heights located at various distances from the principal point. The light ray reflected from the base of object A intersects the plane of the photographic print at position A, and the ray from the top (or point of the arrow) intersects the print at A'. The distance A-A' is the relief displacement (d) shown in the plan view in Fig. B.

Geometry of relief displacement on a vertical aerial photograph

The effect of relief displacement on a photograph taken over varied terrain. In essence, an increase in the elevation, of a feature causes its position on the photograph to be displaced radically outward from the principal point. Hence, when a vertical feature is photographed, relief displacement causes the top of the feature to lie farther from the photo center than its base. As a result, vertical feature appears to lean away from the center of the photograph. The amount of displacement increases at greater radial distances from the centre and reaches a maximum at the corners of the photograph



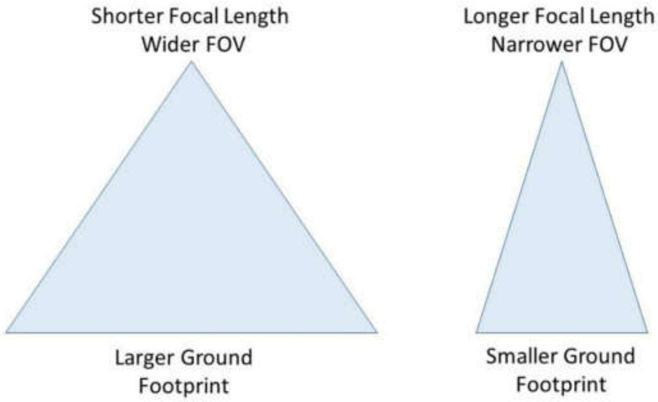
(a) Map (orthographic projection) Constant Scale No relief displacement (b) Photo (perspective projection) varied scale relief displacement

Flight planning Scale and height determination

The scale of an aerial photograph depends on the specific camera characteristics (focal length) and the flying height at which the image was captured. There are several methods for calculating the scale of an aerial photo. Which method you use depends on what information is already known.

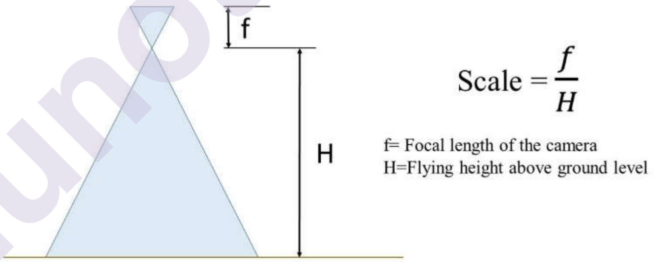
Focal Length and Field of View

The scale of a photograph is determined by the focal length of the camera and the flying height above the ground. The **focal length** is the distance from the middle of the camera lens to the focal plane. Focal length is precisely measured when cameras are calibrated and is typically expressed inn millimeters (mm). The focal length of a lens determines the magnification and the angle of the light ray. The longer the focal length, the greater the magnification of the image. Short focal length lenses cover larger areas. The area captured by a camera is known as the Field of View (FOV), which is typically expressed in degrees. Field of View is a function of the focal length of the lens and the size (sometimes called format) of digital sensors.



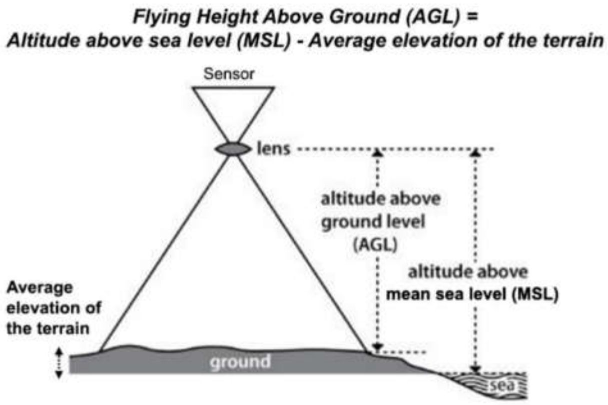
Shorter focal lengths have wider field of views, while longer focal lengths have smaller field of views. There fore a camera lens with a longer focal length will produce an image with a smaller footprint compared to that of a shorter focal length.

The scale of a photo is equal to the ratio between the camera's focal length and the plane's altitude above the ground level (AGL) being photographed. If the focal length and flying altitude above the surface is known, the scale can be calculated using the following formula:



Flying Height Above Ground Level (AGL) vs Above Mean Sea Level (MSL)

In all of the scale calculations, it is important to know the flying height above the surface or above ground level (AGL). Sometime the altitude above sea level or MSL is given and you may need to estimate the average flying height above ground. For example, the GSP on a unmanned aerial vehicle (UAV) may record the altitude or height above sea level and not above ground level (AGL). To estimate the AGL, you will need to determine the average elevation of the terrain and subtract that from altitude above sea level. This will give you the average flying height above ground.



Multiple Choice Questions.

1. The lens used in aerial photogrammetry is having a maximum coverage capacity of _________ (in angles)
   a) 93^0
   b) 63^0
   c) 53^0
   d) 98^0

2. Which of the following is not a type of shutter used in aerial photogrammetry?
   a) Between-the-lens shutter
   b) Louvre shutter
   c) Ideal shutter
   d) Focal plane shutter

3. For placing focal plane, which is used as a reference?
   a) Focal length
   b) Horizon
   c) Azimuth
   d) Collimation marks

4. Focal plane varies while aerial photogrammetry is carried out.
   a) True
   b) False

5. Which among the following surveying methods is meant to be having high precision?

   a) Aerial photogrammetry

   b) Terrestrial photogrammetry

   c) Theodolite surveying

   d) Traverse surveying

6. Vertical photograph coincides with the__________

   a) Direction of line of sight

   b) Direction of lens

   c) Direction of aperture

   d) Direction of gravity

7. How much inclination must be provided in a tilted photograph?

   a) 13˚

   b) 20˚

   c) 3˚

   d) 34˚

8. If the apparent horizon is shown in a photograph, it is low oblique.

   a) True

   b) False

9. Perspective projection is produced from__________

   a) Straight lines radiating a common point

   b) Straight lines radiating different points

   c) Parallel lines radiating a common point

   d) Perpendicular lines radiating a common point

10. Flying height refers to_________

    a) Upper portion of the exposure station

    b) Bottom of the exposure station

    c) Depression of the exposure station

    d) Elevation of the exposure station

Answer

Q. No. 01

Answer: a

Explanation: In general, the lens used in aerial photogrammetry having a minimum coverage area of 63^0 and a maximum coverage area of 93^0. The usage of the coverage angle depends upon the type f land being surveyed and the accuracy needed in output.

Q. No. 02

Answer: c

Explanation: Shutter plays a prominent role in the process of aerial photogrammetry. The speed of shutter must be in such a way that it should function at a speed of 1/100 to 1/1000 second. It is classified as between the lens type, focal plane type, Louvre type.

Q. No. 03

Answer: d

Explanation: Collimation marks can be used as a reference while placing the focal plane. It may place the focal plane at a near distance from nodal plane from which the best possible image can be obtained.

Q. No. 04

Answer: b

Explanation: In the process of aerial photogrammetry, the air-craft is placed at a considerable height so that it can cover a huge area while taking photographs. But the focal plane of the aerial camera is fixed at one location, rather than varying.

Q. No. 05

Answer: a

Explanation: Though terrestrial photogrammetry is having accuracy in the obtained values, aerial photogrammetry is capable of producing precise output when compared to the remaining methods. This accuracy makes it different from the remaining methods and is recommended when high quality works are conducted.

Q. No. 06

Answer: d

Explanation: The aerial photograph consists of a vertical photograph which is made of the camera axis which is made to coincide with the direction of gravity. Optical axis must be first made straight in order to continue further.

Q. No. 07

Answer: c

Explanation: In general, a tilted photograph consists of inclination up to 3˚, which makes it to have an individual tilted scale. It might help in determining the objects which are inclined in the photograph.

Q. No. 08

Answer: b

Explanation: Oblique photograph is used in case of aerial photography, with an intention that the camera axis lies in between horizontal and vertical. High oblique is obtained in case of possessing apparent horizon otherwise it isn't shown.

Q. No. 09

Answer: a

Explanation: The introduction of perspective projection is done by the straight lines radiating a common point and passing through point on the spherical surface. Aerial photogrammetry uses this phenomenon.

Q. No. 10

Answer: d

Explanation: Flying height indicates the elevation of the exposure station above the sea level. Any datum selected can act as a reference so that the flying height can be considered from them.

References

[1] Thomas M. Lillesand and Ralph W. Kiefer: University of Wisconsin-Madison, Third Edition, Remote Sensing and Image Interpretation.

[2] Floyd F. Sabins, Jr., Chevron Oil Field Research Company and University of California, Los Angeles, Second Edition, Remote Sensing: Principles and Interpretation.

[3] Kimerling, A. Jon, Muehrcke, Juliana O. (2005). Map Use Reading Analysis Interpretation, Fifth Edition. JP Publications.

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[5] Wolf, P.R. 1974. Elements of Photogrammetry, McGraw-Hill, Inc.

[6] Pateraki, M.2006. Digital Aerial Cameras. International Summer

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4

APPLICATIONS OF REMOTE SENSING TECHNIQUES IN GEOGRAPHICAL STUDIES

Unit Structure:

4.1 Objectives

4.2 Introduction

4.3 Subject Discussion

4.4 Principles and fundamentals of aerial photo interpretation

4.5 Image analysis Elements, Fundamentals of satellite images analysis: Types of Imagery, Visual image analysis, digital image analysis

4.6 Basic principles of thermal and microwave remote sensing

4.7 Principles of Microwave Remote Sensing

4.8 Summary

4.9 Check your Progress/Exercise

4.10 Answers to Self-Learning Questions

4.11 Technical Words and their meaning

4.12 Tasks

4.13 Reference for further reading/study

4.1 OBJECTIVES

By the end of this unit, you will be able to -

- Know about the principles and fundamentals of aerial photo interpretation
- Explain the elements of image analysis, fundamentals of satellite image analysis
- Learn about the types of imagery, visual image analysis and digital image analysis
- Understand the principles of thermal remote sensing
- Perceive the role of microwave remote sensing

4.2 INTRODUCTION

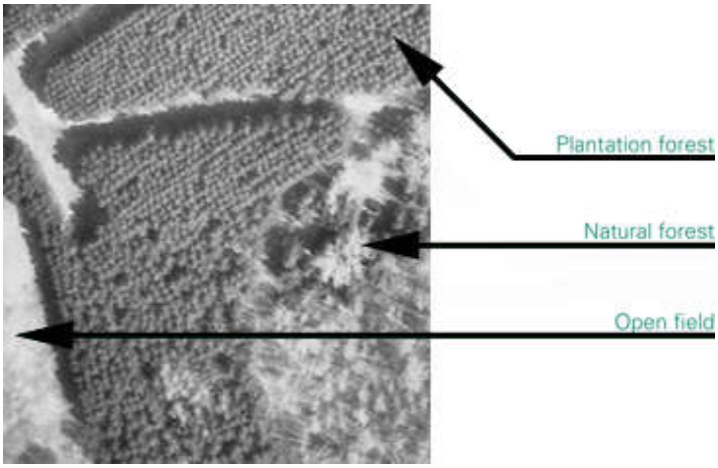
The chapter will deal with aerial photo interpretation and its fundamentals, principles, and elements. Besides, it will also focus on visual and digital image analysis which are fundamentals to aerial photos. It will enhance the knowledge regarding thermal and microwave remote sensing. This chapter will help to provide an insight on the basics of how the aerial photo interpretations and remote sensing is carried out.

4.3 SUBJECT DISCUSSION

Analysis of remote sensing imagery involves the identification of various targets in an image, and those targets may be environmental or artificial features which consist of points, lines, or areas. Targets may be defined in terms of the way they reflect or emit radiation. This radiation is measured and recorded by a sensor, and ultimately is depicted as an image product such as an air photo or a satellite image.What makes interpretation of imagery more difficult than the everyday visual interpretation of our surroundings? For one, we lose our sense of depth when viewing a two-dimensional image, unless we can view it stereoscopically to simulate the third dimension of height. Indeed, interpretation benefits greatly in many applications when images are viewed in stereo, as visualization (and therefore, recognition) of targets is enhanced dramatically. Viewing objects from directly above also provides a very different perspective than what we are familiar with. Combining an unfamiliar perspective with a very different scale and lack of recognizable detail can make even the most familiar object unrecognizable in an image. Finally, we are used to seeing only the visible wavelengths, and the imaging of wavelengths outside of this window is more difficult for us to comprehend.

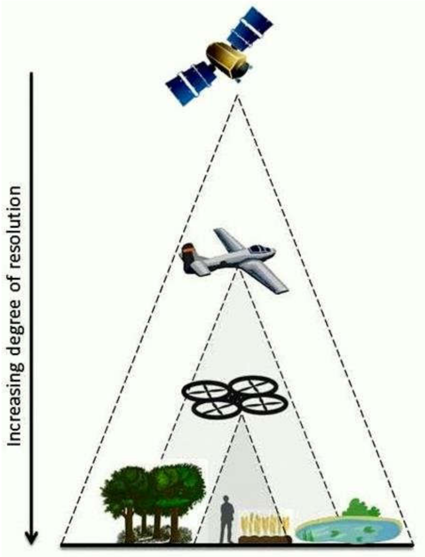
4.4 FUNDAMENTALS OF AERIAL PHOTOGRAPHIC INTERPRETATION

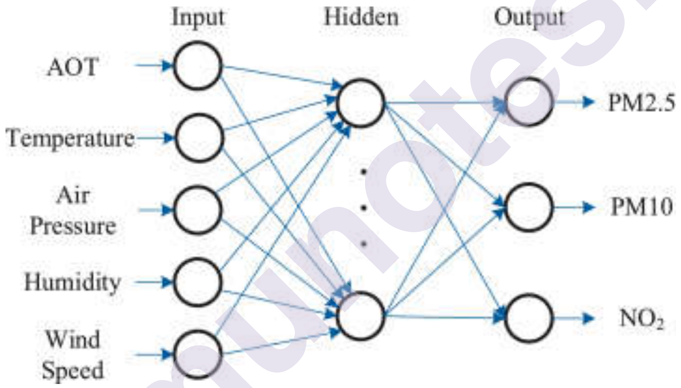
Photo Interpretation: The examination of aerial photographs/images for the purpose of identifying objects and judging their significance.



Source:https://www.nrcan.gc.ca/

Observation & Inference: Observation provides the raw data for interpretation. Inference is the logical process by which observation and interpretation are made.





Source:https://www.nrcan.gc.ca/

4.5 IMAGE ANALYSIS ELEMENTS, FUNDAMENTALS OF SATELLITE IMAGES ANALYSIS: TYPES OF IMAGERY, VISUAL IMAGE ANALYSIS, DIGITAL IMAGE ANALYSIS

Image analysis Elements:

Recognizing targets is the key to interpretation and information extraction. Observing the differences between targets and their backgrounds involves comparing different targets based on any, or all, of the visual elements of tone, shape, size, pattern, texture, shadow, and association. Visual interpretation using these elements is often a part of our daily lives, whether we are conscious of it or not. Examining satellite images on the weather report, or following high speed chases by views from a helicopter are all familiar examples of visual image interpretation. Identifying targets in remotely sensed images based on these visual elements allows us to further interpret and analyse. The nature of each of these interpretation elements is described below, along with an image example of each.

Source:https://www.nrcan.gc.ca/

Tone refers to the relative brightness or colour of objects in an image. Generally, tone is the fundamental element for distinguishing between different targets or features. Variations in tone also allows the elements of shape, texture, and pattern of objects to be distinguished.

Source:https://www.nrcan.gc.ca/

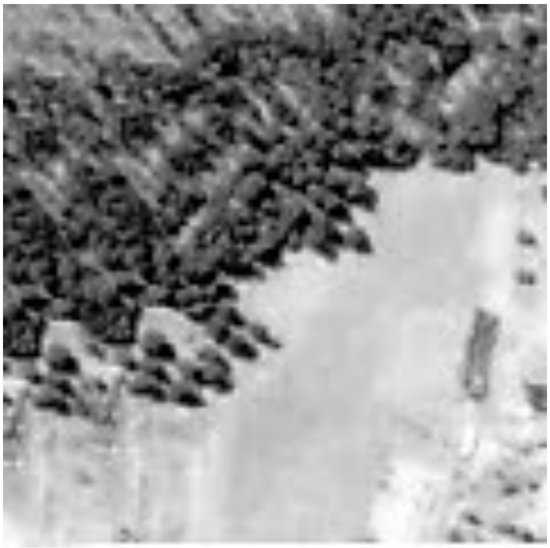
Shape refers to the general form, structure, or outline of individual objects. Shape can be a very distinctive clue for interpretation. Straight edge shapes typically represent urban or agricultural (field) targets, while natural features, such as forest edges, are generally more irregular in shape, except where man has created a road or clear cuts. Farm or crop land irrigated by rotating sprinkler systems would appear as circular shapes.

Source:https://www.nrcan.gc.ca/

Size of objects in an image is a function of scale. It is important to assess the size of a target relative to other objects in a scene, as well as the absolute size, to aid in the interpretation of that target. A quick approximation of target size can direct interpretation to an appropriate result more quickly. For example, if an interpreter had to distinguish zones of land use, and had identified an area with a number of buildings in it, large buildings such as factories or warehouses would suggest commercial property, whereas small buildings would indicate residential use.

Source:https://www.nrcan.gc.ca/

Pattern refers to the spatial arrangement of visibly discernible objects. Typically, an orderly repetition of similar tones and textures will produce a distinctive and ultimately recognizable pattern. Orchards with evenly spaced trees, and urban streets with regularly spaced houses are good examples of pattern.



Source:https://www.nrcan.gc.ca/

Texture refers to the arrangement and frequency of tonal variation in particular areas of an image. Rough textures would consist of a mottled tone where the grey levels change abruptly in a small area, whereas smooth textures would have very little tonal variation. Smooth textures are most often the result of uniform, even surfaces, such as fields, asphalt, or grasslands. A target with a rough surface and irregular structure, such as a forest canopy, results in a rough textured appearance. Texture is one of the most important elements for distinguishing features in radar imagery.

Source:https://www.nrcan.gc.ca/

Shadow is also helpful in interpretation as it may provide an idea of the profile and relative height of a target or targets which may make identification easier. However, shadows can also reduce or eliminate interpretation in their area of influence, since targets within shadows are much less (or not at all) discernible from their surroundings. Shadow is also useful for enhancing or identifying topography and landforms, particularly in radar imagery.

Source:https://www.nrcan.gc.ca/

Association considers the relationship between other recognizable objects or features in proximity to the target of interest. The identification of features that one would expect to associate with other features may provide information to facilitate identification. In the example given above, commercial properties may be associated with proximity to major transportation routes, whereas residential areas would be associated with schools, playgrounds, and sports fields. In our example, a lake is associated with boats, a marina, and adjacent recreational land.

4.5 FUNDAMENTALS OF SATELLITE IMAGES ANALYSIS: TYPES OF IMAGERY, VISUAL IMAGE ANALYSIS, DIGITAL IMAGE ANALYSIS

Remotely sensed satellite data comes in two basic types, passively collected data, and actively collected data.

1. Passive data collection focuses on acquiring intensities of electromagnetic radiation generated by the sun and reflected off the surface of the planet.

2. Active data collection is largely restricted to devices that send and generate a pulse of energy to that is reflected to the satellite to be recorded. Most of the readily available data is passively collected and is limited to energy not absorbed by the Earth's atmosphere.

3. Satellite imagery based on passive reflectivity comes in 4 basic types, which are visible, infrared, multispectral, and hyperspectral.

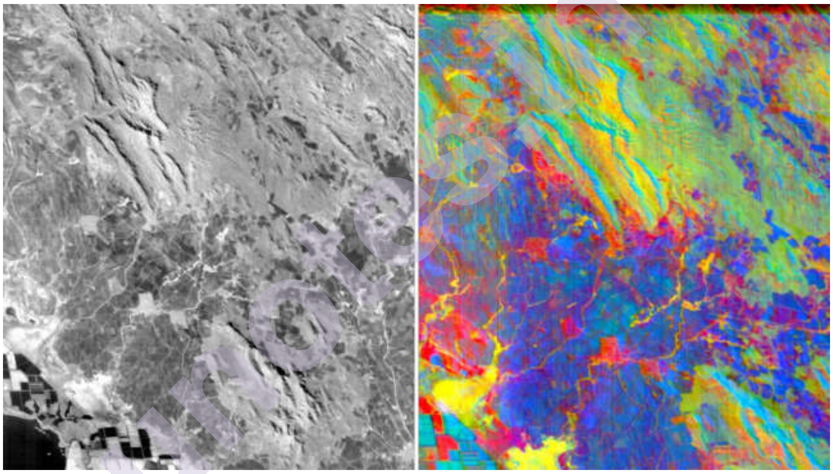
The type and resolution of the data that is collected is generally keyed to the mission of the satellite.

1. Visible data consists of pixels composed of colour values of red, green, and blue to make three bands of data on a raster image.

2. Infrared imagery usually consists of the images that include the visible channels as well as some range of the infra-red spectrum.

Source: https://www.satimagingcorp.com/gallery/quickbird/quickbird-oil-and-gas-near-infrared/

3. Multispectral data include up to 7-12 channels of data



Source: https://www.mdpi.com/2072-4292/14/13/3046/htm

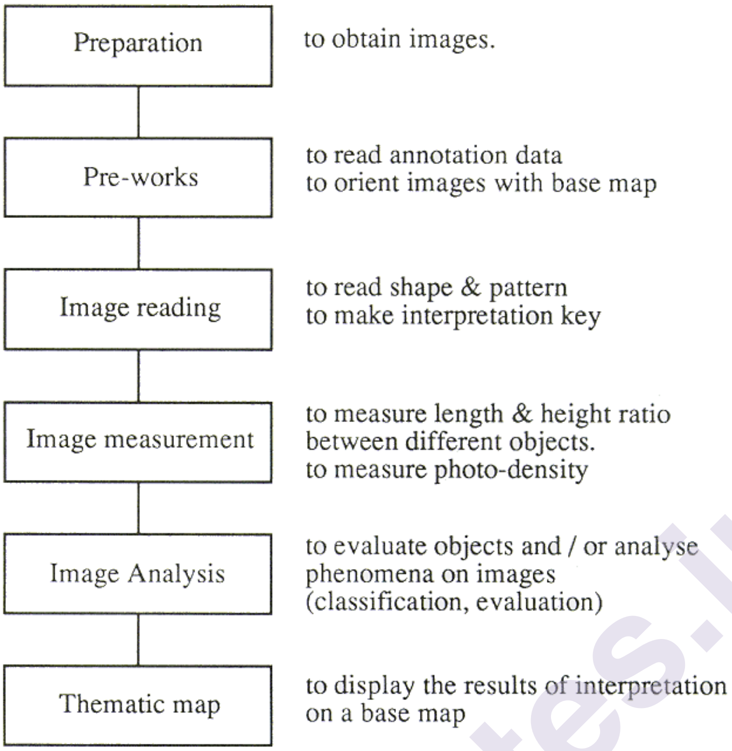
4. Hyperspectral can be up to 50 bands or more of data collected over discrete bandwidths of the electromagnetic spectrum.

How all this data is used goes beyond the scope of this site, but it's worth keeping in mind that there are a range of available products and it may require a great deal of research to determine what type of data is useful in the context of the field-based exercise.

- **Image Interpretation**

Image interpretation is defined as the extraction of qualitative and quantitative information in the form of a map, about the shape, location, structure, function, quality, condition, relationship of and between objects, etc. by using human knowledge or experience. As a narrow definition, "photo-interpretation" is sometimes used as a synonym of image interpretation.

Image interpretation in satellite remote sensing can be made using a single scene of a satellite image, while usually a pair of stereoscopic aerial photographs are used in photo-interpretation to provide stereoscopic vision using, for example, a mirror stereoscope. Such a single photo-interpretation is discriminated from stereo photo-interpretation.



Source: http://sar.kangwon.ac.kr/etc/rs_note/rsnote/cp7/cp7-2.htm

- Image reading is an elemental form of image interpretation. It corresponds to simple identification of objects using such elements as shape, size, pattern, tone, texture, colour, shadow and other associated relationships. Image reading is usually implemented with interpretation keys with respect to each object.

- Image measurement is the extraction of physical quantities, such as length, location, height, density, temperature and so on, by using reference data or calibration data deductively or inductively.

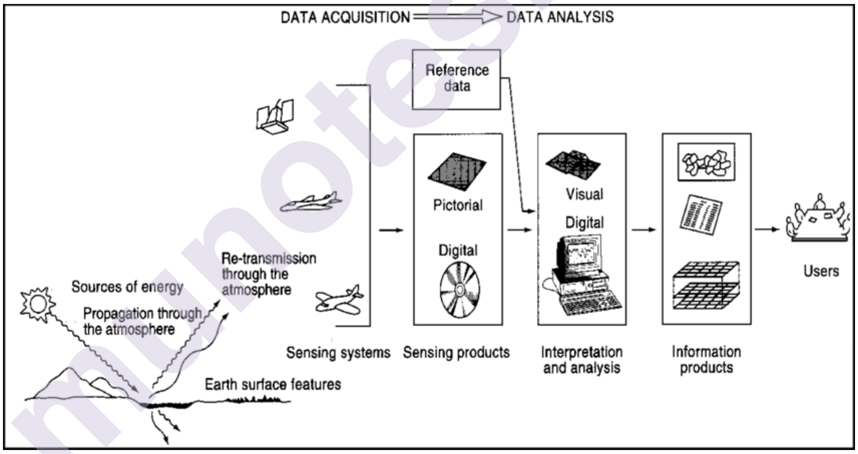
- Image analysis is the understanding of the relationship between interpreted information and the actual status or phenomenon, and to evaluate the situation.Extracted information will be finally represented in a map form called an interpretation map or a thematic map.

Generally, the accuracy of image interpretation is not adequate without some ground investigation. Ground investigations are necessary, first when the keys are established and then when the preliminary map is checked.Analysis of remote sensing imagery involves the identification of various targets in an image, and those targets may be environmental or artificial features which consist of points, lines, or areas. Targets may be defined in terms of the way they reflect or emit radiation. This radiation is measured and recorded by a sensor, and ultimately is depicted as an image product such as an air photo or a satellite image.

- What makes interpretation of imagery more difficult than the everyday visual interpretation of our surroundings? For one, we lose our sense of depth when viewing a two-dimensional image, unless we can view it stereoscopically to simulate the third dimension of height. Indeed, interpretation benefits greatly in many applications when images are viewed in stereo, as visualization (and therefore, recognition) of targets is enhanced dramatically. Viewing objects from directly above also provides a very different perspective than what we are familiar with. Combining an unfamiliar perspective with a very different scale and lack of recognizable detail can make even the most familiar object unrecognizable in an image. Finally, we are used to seeing only the visible wavelengths, and the imaging of wavelengths outside of this window is more difficult for us to comprehend.

Visual Image Analysis:

Images should be analysed evaluated on several levels. Visual analysis is an important step in evaluating an image and understanding its meaning. It is also important to consider textual information provided with the image, the image source and original context of the image, and the technical quality of the image.



Source:https://www.researchgate.net/figure/1-Elements-of-remote-sensing-Lillesand-and-Kiefer-1994_fig1_3298633

Digital Image Analysis:

In today's world of advanced technology where most remote sensing data are recorded in digital format, virtually all image interpretation and analysis involve some element of digital processing. Digital image processing may involve numerous procedures including formatting and correcting of the data, digital enhancement to facilitate better visual interpretation, or even automated classification of targets and features entirely by computer. In order to process remote sensing imagery digitally, the data must be recorded and available in a digital form suitable for storage on a computer tape or disk. Obviously, the other requirement for digital image processing is a computer system, sometimes referred to as an image analysis system, with the appropriate hardware and software to process the data. Several commercially available software systems have been developed specifically for remote sensing image processing and analysis.

For discussion purposes, most of the common image processing functions available in image analysis systems can be categorized into the following four categories:

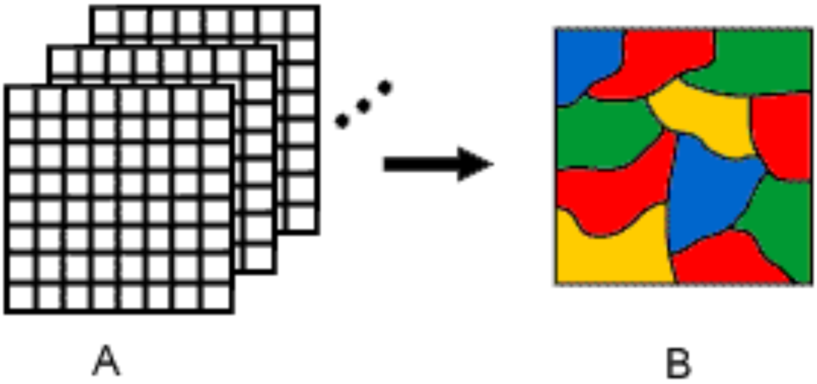
- Pre-processing
- Image Enhancement
- Image Transformation
- Image Classification and Analysis

Pre-processing functions involve those operations that are normally required prior to the main data analysis and extraction of information, and are generally grouped as radiometric or geometric corrections. Radiometric corrections include correcting the data for sensor irregularities and unwanted sensor or atmospheric noise, and converting the data so they accurately represent the reflected or emitted radiation measured by the sensor. Geometric corrections include correcting for geometric distortions due to sensor-Earth geometry variations, and conversion of the data to real world coordinates (e.g. latitude and longitude) on the Earth's surface.

Source:https://www.nrcan.gc.ca/

The objective of the second group of image processing functions grouped under the term of image enhancement, is solely to improve the appearance of the imagery to assist in visual interpretation and analysis. Examples of enhancement functions include contrast stretching to increase the tonal distinction between various features in a scene, and spatial filtering to enhance (or suppress) specific spatial patterns in an image.

Image transformations are operations similar in concept to those for image enhancement. However, unlike image enhancement operations which are normally applied only to a single channel of data at a time, 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. We will look at some of these operations including various methods of spectral or band ratioing, and a procedure called principal components analysis which is used to represent the information more efficiently in multichannel imagery.



Source: https://www.mdpi.com/2072-4292/14/13/3046/htm

Image classification and analysis 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 or theme (B) based on statistical characteristics of the pixel brightness values. There are a variety of approaches taken to perform digital classification. We will briefly describe the two generic approaches which are used most often, namely supervised, and unsupervised classification.

4.6 BASIC PRINCIPLES OF THERMAL AND MICROWAVE REMOTE SENSING

Principles of Thermal Remote Sensing

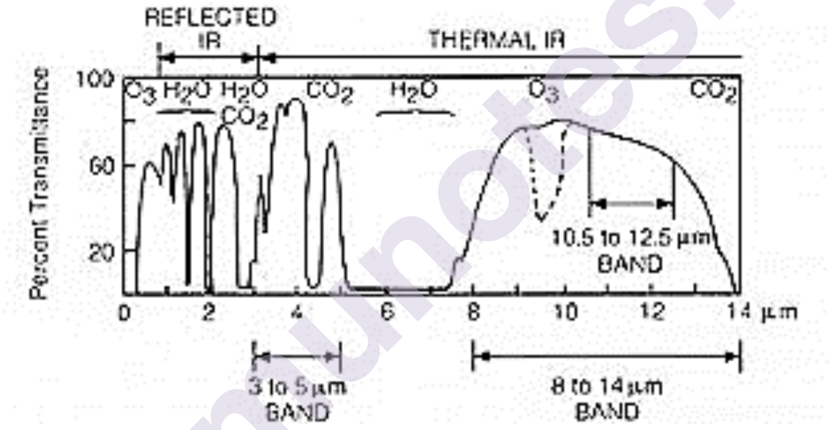
The earth-atmosphere system derives its energy from the sun which being at a very high temperature, radiates maximum energy in the shorter wavelengths (visible, 0.20 to 0.80 mm). The earth-atmosphere system absorbs part of this energy (part due to its reflective properties due to surface albedo, clouds, and other reflectors/scatterers in the atmosphere), which in turn heats it up and raises its temperature. This temperature being in the range of 300 degrees Kelvin, it will emit its own radiation in the longer wavelengths called 'thermal infrared'. The observations in the thermal wavelength of the electromagnetic spectrum (3-35 mm) are generally referred to as thermal remote sensing.

In this region the radiation emitted by the earth due to its thermal state are far more intense than the solar reflected radiation, therefore any sensor operating in this wavelength region would primarily detect the thermal radiative properties of ground material. All materials having a temperature above absolute zero (-273°C or 0°K) both day and night emit Infrared energy Infrared sensing refers to the detection of remote objects by recording the amount of infrared energy emitted from various surfaces as a continuous tone image on photographic film. Thermal IR imagery is usually obtained in the wavelength regions 3 to 5.5mm and from 8 to 14mm because of atmospheric absorption at other wavelengths.

IR Region of the Electromagnetic Spectrum the IR region covers wavelengths from 0.7 to 300mm. The reflected IR region ranges from wavelengths 0.7 to 3 mm and includes the photographic IR band (0.7 to 0.9 mm) that may be detected from IR film. IR radiation at wavelengths 3 to 14mm is called the thermal IR region. Since thermal IR radiation is absorbed by glass lenses of conventional cameras and cannot be detected by photographic film.

Special optical mechanical scanners are used to detect and record images in the thermal IR region. IR radiation at wavelengths larger than 14mm is not utilized in remote sensing as the radiation is absorbed by the earth's atmosphere.

Atmospheric transmission Thermal sensing of solids and liquids occurs in two atmospheric windows, where absorption is a minimum, as shown in this spectral plot taken from Sabin's (Remote Sensing: Principles and Interpretation, 1987).

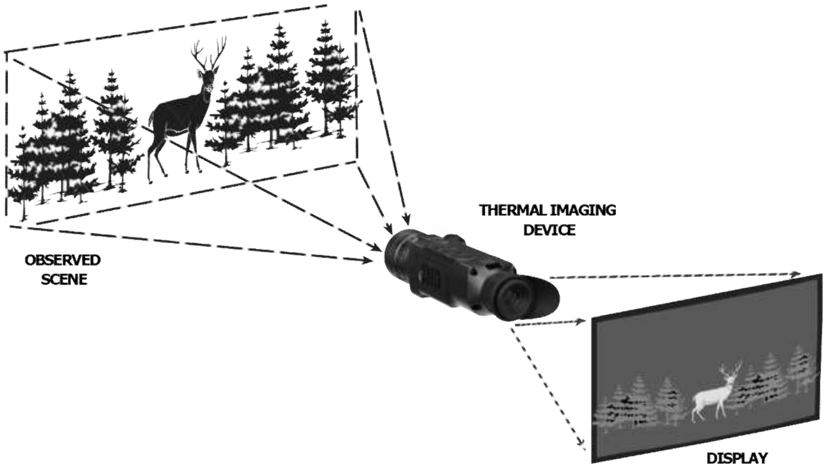


Source: http://sar.kangwon.ac.kr/etc/rs_note/rsnote/cp7/cp7-2.htm

Not all wavelengths of thermal IR radiation are transmitted uniformly through the atmosphere CO2, Ozone and water vapor absorb energy at certain wavelengths IR and radiation at wavelengths from 3-5 mm and from 8-14 mm is readily transmitted through the atmosphere windows. A narrow absorption band occurs from 9-10 mm occurs due to the ozone layer present at the top of the earth's atmosphere.

To avoid the affected of this absorption band, satellite thermal IR systems operate in 10.5 - 12.5mm. Systems on aircraft flying below the ozone layer are not affected and record the full 8-14mm band.

The windows normally used from aircraft platforms are in the 3-5 mm and 8-14 µm wavelength regions. Space borne sensors commonly use windows between 3 and 4 µm and between 10.5- 12.5 µm. None of the windows transmits 100 percent because water vapor and carbon dioxide absorb some of the energy across the spectrum and ozone absorbs energy in the 10.5-12.5 µm interval. In addition, solar reflectance contaminates the 3-5-µm windows to some degree during daylight hours, hence is used for Earth studies using night-time measurements.



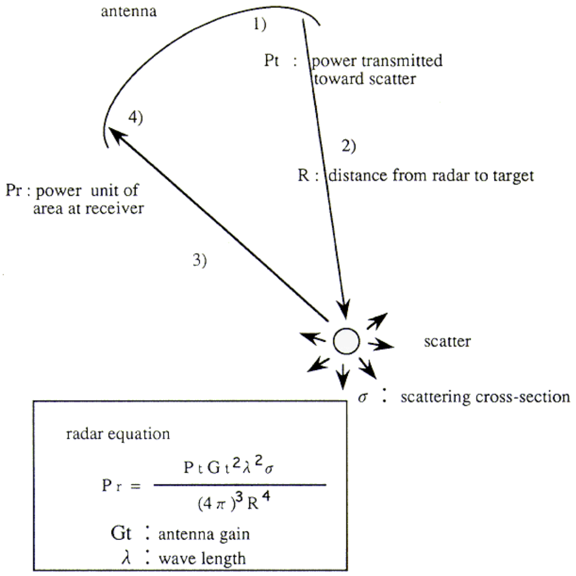
Source: http://sar.kangwon.ac.kr/etc/rs_note/rsnote/cp7/cp7-2.htm

4.7 PRINCIPLES OF MICROWAVE REMOTE SENSING

Microwave remote sensing, using microwave radiation using wavelengths from about one centimetre to a few tens of centimetres enables observation in all weather conditions without any restriction by cloud or rain. This is an advantage that is not possible with the visible and/or infrared remote sensing. In addition, microwave remote sensing provides unique information on for example, sea wind and wave direction, which are derived from frequency characteristics, Doppler effect, polarization, back scattering etc. that cannot be observed by visible and infrared sensors. However, the need for sophisticated data analysis is the disadvantage in using microwave remote sensing.

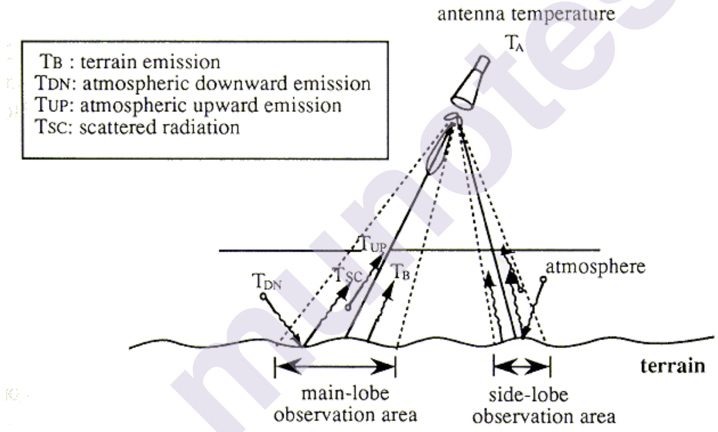
There are two types of microwave remote sensing; active and passive. The active type receives the backscattering which is reflected from the transmitted microwave which is incident on the ground surface.

Synthetic aperture radar (SAR), microwave scatter-o-meters, radar altimeters etc. are active microwave sensors. The passive type receives the microwave radiation emitted from objects on the ground. The microwave radiometer is one of the passive microwave sensors. The process used by the active type, from the transmission by an antenna, to the reception by the antenna is theoretically explained by the radar equation as described in Figure 3.1.1.



Source: http://sar.kangwon.ac.kr/etc/rs_note/rsnote/cp7/cp7-2.htm

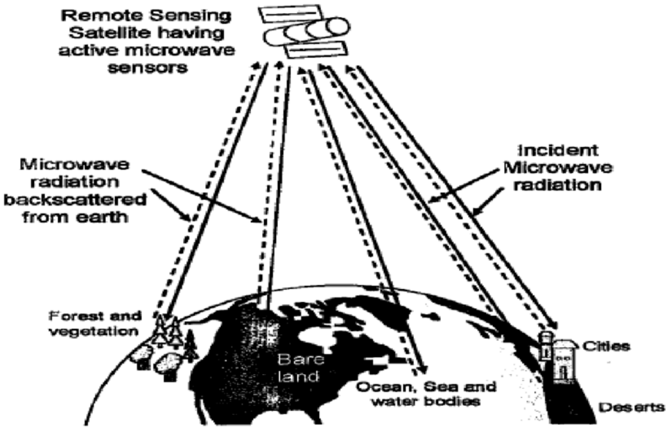
The process of the passive type is explained using the theory of radiative transfer based on the law of Rayleigh Jeans as explained in Figure 3.1.2.



Source:https://www.nrcan.gc.ca/

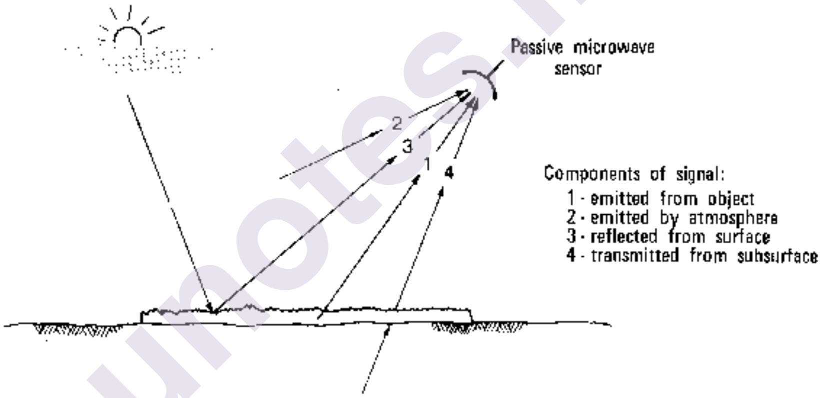
In both active and passive types, the sensor may be designed considering the optimum frequency needed for the objects to be observed.

In active microwave remote sensing, the characteristics of scattering can be derived from the radar cross section calculated from received power Pr and antenna parameters (At,Pt, Gt) and the relationship between them, and the physical characteristics of an object. For example, rainfall can be measured from the relationship between the size of water drops and the intensity of rainfall.



Source:https://www.nrcan.gc.ca/

In passive microwave remote sensing, the characteristics of an object can be detected from the relationship between the received power and the physical characteristics of the object such as attenuation and/or radiation characteristics.



Source:https://www.nrcan.gc.ca/

4.8 SUMMARY

Let us now summarise what has been discussed in this unit:

- Image interpretation is the process of extraction of information both qualitative and quantitative from aerial photographs and satellite images in the form of a map. This technique is used to collect information for a variety of purposes.
- Image interpretation is carried out either manually or with the help of computer software and is known as visual and digital interpretation, respectively.
- Visual interpretation is a process of identifying features seen on photographs/images and communication of information obtained from them to others for evaluating their significance.

- The information extraction from aerial data (i.e., photo interpretation) is based on the characteristics of photograph features, such as size, shape, tone, texture, shadow, pattern, and association. The basic elements of visual image interpretation are like those used in aerial photo interpretation.

- The criteria for identification of an object with interpretation elements are called an interpretation key.

4.9 CHECK YOUR PROGRESS/EXERCISE

1. Identify the tone of the given image?

2. Find the texture of the features available in the image.

3. Identify the shapes depicted in the given image.

4. Describe the association of the image and the given sizes of the features.

5. Explain the pattern of the features viewed in the image.

6. Define the site captured in the image.

4.10 ANSWERS TO SELF-LEARNING QUESTIONS

Mention your answers in the given format:

		Elements of image interpretation							
		Tone	Texture	Association	Shape	Size	Shadow	Site	Pattern
Features	Class 1								
	Class 2								
	—								

	Class n								

4.11 TECHNICAL WORDS AND THEIR MEANING

- **band:** The information stored in one raster, often recording a specific bandwidth of the electromagnetic spectrum. An image may be composed of one or more bands.
- **classification scheme:** A set of class categories to which image pixels or objects will be assigned. Appropriate classification schemes depend on the type of sensors utilized, their resolution, feature types of interest and the biome or landcover / land use imaged.
- **classification:** The computational process of assigning pixels or objects into a set of categories, or classes, having common spectral, shape, elevation or other definable characteristics.
- **collection characteristics:** Attributes describing how imagery was collected, including spectral, radiometric, spatial, and temporal resolutions, viewing angle, and extent.
- **colour (image element):** characteristic of an object of interest derived from combinations of the red, green, and blue spectral bands of imagery, used to help identify the object
- **electromagnetic energy:** Energy (like that emitted from the sun) that moves through space at the speed of light at different wavelengths. Types of electromagnetic radiation include gamma, x, ultraviolet, visible, infrared, microwave, and radio.
- **image elements:** all the characteristics of an image, including its tone/colour, shape, size, pattern, shadow, texture, location, context, height, and date
- **image filter:** On a raster, an analysis boundary or processing window within which cell values affect calculations and outside which they do not. Filters are used mainly in cell-based analysis where the value of a centre cell is changed to the mean, the sum, or some other function of all cell values inside the filter. A filter moves systematically across a raster until each cell has been processed. Filters can be of various shapes and sizes, but three-cell by three-cell squares are common.
- **insolation:** the amount of solar radiation received by an area over a given period of time
- **location (image element):** the x, y, and z coordinates of an object of interest, used to help identify the object.
- **pattern (image element):** the spatial arrangement or configuration of objects, used to identify an object of interest.
- **scale:** The ratio or relationship between a distance or area on a map and the corresponding distance or area on the ground, commonly expressed as a fraction or ratio. A map scale of 1/100,000 or 1:100,000 means that one unit of measure on the map equals 100,000 of the same unit on the earth.
- **shadow (image element):** the consequence when the sensor's ability to capture reflectance or radiance of a feature on the ground is hindered by another feature; used to help identify objects of interest
- **shape (image element):** the form of the outline of an object of interest, used to help identify the object
- **size (image element):** the extent of an object of interest, used to help identify the object

- **slope:** The incline, or steepness, of a surface, measured in degrees from horizontal (0–90), or percent slope (the rise divided by the run, multiplied by 100). The slope of a TIN face is the steepest downhill slope of a plane defined by the face; the slope for a cell in a raster is the steepest slope of a plane defined by the cell and its eight surrounding neighbours.
- **temporal resolution:** The frequency at which images are captured over the same location on the earth's surface.
- **texture (image element):** the feel or appearance of the surface of an object of interest, used to help identify the object
- **tone (image element):** characteristic of an object of interest derived from the intensity of spectral response in each band of an image, used to help identify the object
- **topography:** The study and mapping of land surfaces, including relief (relative positions and elevations) and the position of natural and constructed features.

4.12 TASKS

1) Discuss in brief the elements of visual image interpretation.
2) What do you understand by image interpretation keys?
3) What is the importance of scale in image interpretation?

4.13 REFERENCE FOR FURTHER READING/STUDY

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