UNIT 10

REMOTELY SENSED DATA

Structure

10.1 INTRODUCTION

You have read about basic sources of data including primary and secondary sources, census and sample surveys in previous Units 8 and 9. In this unit, you will study about sources of data which is obtained from latest state-of-the-art remote sensing (RS) methods and techniques. This unit basically provides the background of remote sensing and its array of important data products particularly aerial photographs and satellite imageries. Understanding of remotely sensed data is very necessary for topographical mapping and interpretation of landscape features for its diverse users including a cartographer, geographer, geoscientist or earth scientist, etc.

In Sec. 10.2, we have introduced the basics of data acquisition from the source of remote sensing. From Sec. 10.3, you will understand about the aerial photography and its products. With the passage of time, the continuous advancements in the field of satellite technology coupled with powerful computational systems and software enabled mapping techniques like geographic information system (GIS) have achieved tremendously greater heights and milestones. Such advancements have definitely landed us an edge over the aerial photography that enabled us to take precise daily and repetitive observation of the minute details with a sub-metre level resolution for the entire globe. It has been made possible through the satellite mounted sophisticated camera systems ranging from a few hundred kilometres to thousands of kilometres in altitude. To understand the satellite data products, which are obtained with the help of different cameras, you need to study Sec. 10.4.

Expected Learning Outcomes

After studying this unit, you should be able to:

- define remote sensing and understand the basics of data acquisition;
- explain about aerial photography;
- describe the satellite technology used in the collection of data of earth's surface features; and
- differentiate various remotely sensed data products used in earth's observation.

10.2 BASICS OF DATA ACQUISITION

You will be wondered to know that our planet earth is a self-contained spaceship. It is apparently maintained by the external energy source which is solely received from the Sun in the Universe. You are well aware that it has its own natural resources for example water, soil, forest and minerals, etc., that supports human existence along with innumerable floral and faunal species. Some of such vital precious bounties of nature are limited in supply and cannot be replenished easily and quickly. The increased burden on these natural resources due to uncontrolled population growth and over exploitation of resources coupled with unscientific practices has put our planet earth's systems in danger. Adverse effects of human activities are not only limited to earth's surface but also affects the surrounding climate and environment resulting into immeasurable local to regional and global impacts. We must use our precious natural resources optimally for meeting the present day needs without much affecting our earth systems by practicing good management strategies so that future generations of humankind can also be sustained. This is the time when everyone should realise, self-actualize and understand the changing scenario through which earth's countless phenomenon and its environment is passing through with a micro to macro level possible details laden with greater sensitivity. Accurate, timely, repetitive and reliable information on various aspects of landuse, agriculture, forest and wastelands, waterbodies, water flowing channels, runoff, coastal depressions, snow accumulation zones and ice melting, ocean salinity, etc., can be acquired by using a variety of remotely sensed data. Such cost effective technologies enable us to take better decisions in order to achieve the global economic and social development by taking proper care of the precious natural resources. For such vital goals, we require to observe our planet earth continuously far away from the earth.

If you go to the building roof top, you may be able to see the roads, surrounding building structures, and many other tangible objects and things. If you try to observe while travelling in aeroplane, you can better watch the large area, but may not be able to see the details of certain information related to various features on the earth's surface as our viewing capacity is limited. It is made possible by taking the synoptic view with the help of satellites in which camera lens or sensors are mounted and fixed. We will be able to scan and capture images of our entire planet within a short span of time through satellite equipped remote sensing technologies.

10.2.1 CONCEPT OF REMOTE SENSING

Let us first know what is remote sensing. Remote sensing is a science because it follows some procedures in terms of measurement, data processing, interpretation and analysis. Remote sensing is a tool because it can be utilized for creating inventories of resources and for solving different spatial problems. Thus, the remote sensing may be defined as a science of obtaining information about an objects or phenomenon from a distance without coming into physical contact, typically from aircraft or satellites. It uses reflected and emitted energy for measuring the physical properties of distant objects and their surroundings.

Now, we will discuss in detail about the concept of remote sensing. The intervening space between the object and the observer should be devoid of any sort of material. The available information about the sensed things must be put into a carrier of medium. Here, it is the ***electromagnetic energy*** that acts as a carrier of discrete array of information. The remotely sensed data basically consists of wavelength intensity information. It is done through the collection of the electromagnetic radiation by leaving the things at definite wavelength and by measurement of its intensity. Basically, the prime source of energy for the same is the Sun.

As defined by the United Nations, "the remote sensing acts as a means of sensing the earth's surface from space by making use of the properties of electromagnetic wave which gets emitted, reflected or diffracted by the sensed objects, for the purpose of improving natural resource management, land use and the protection of the environment". The basic process involved in the remote sensing is the interaction or emission of **electromagnetic radiation (EMR)** with the matter or objects. EMR is comprised of both electric and magnetic fields extending from very short wavelength gamma rays to long radio waves. This entire range of EMR is commonly referred to as electromagnetic spectrum. You may refer Fig. 10.1, for understanding the large spectrum of wavelengths. You must remember that in remote sensing we use some portions of the electromagnetic spectrum, not the entire spectrum.

When incident energy gets in touch with surface of the object, it may reflect, absorb, re-radiate or transmit through the material depending upon the nature of the object and the wavelength of the incident radiation. Different objects or materials have varying reflectance values covering in multiple wavelength portions. The remote sensing imageries record various objects containing radiance values. These radiance values are known as Digital Numbers (DN).

The reflectance values of various features are presented in Fig. 10.2. It helps us in studying a remote sensing imagery in which the DN values of multiple classes are scattered in a spectrum.

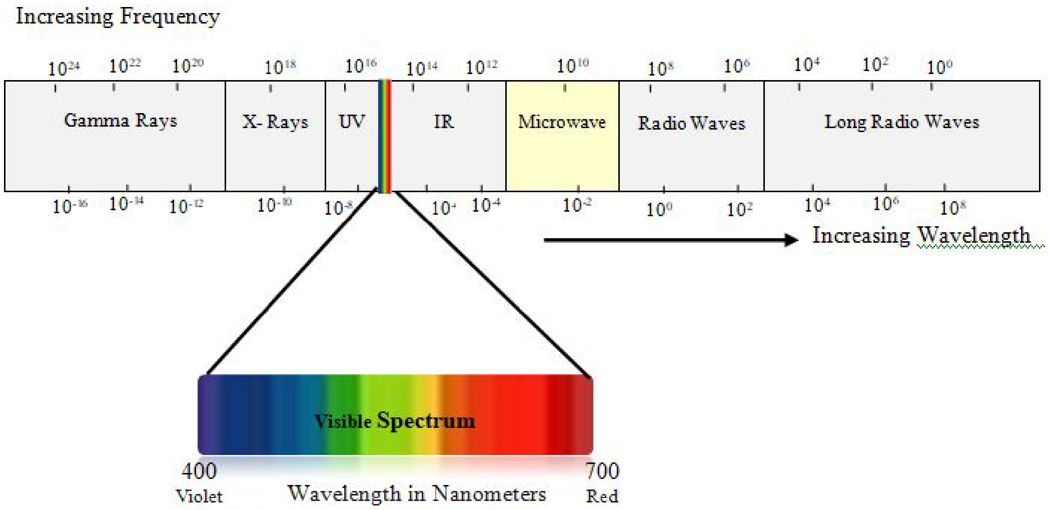

Fig. 10.1: Electromagnetic spectrum showing various wavelength regions.

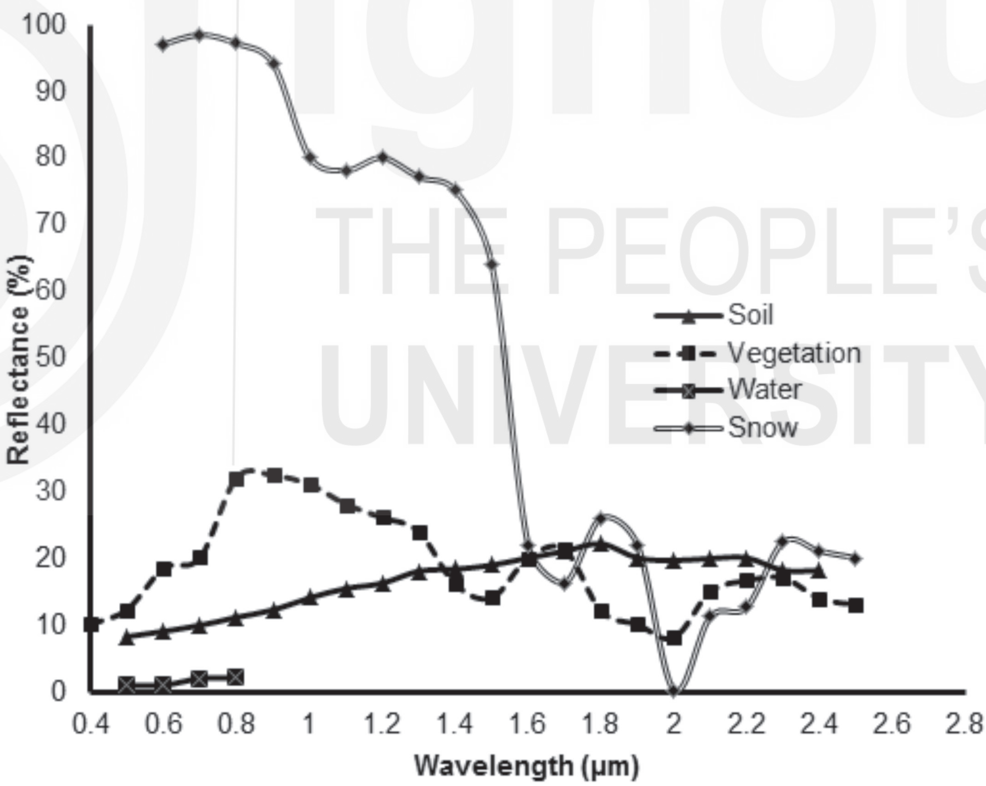

Fig. 10.2: Spectral reflectance values of land cover features.

10.2.3 Sensors and Platforms

You might have understood that remote sensing is a source of basic data, a science, and a tool. Let us now study the basic components of a remote sensing system which enables to make the entire process of remote sensing functional.

Sensors

Sensors are a kind of high end optical camera instruments mounted atop the satellites. These are being used in measuring the reflected or emitted amount of electromagnetic radiation from various objects of surface features. You may think of a sensor installed in the remote control of various electronic devices (e.g. air conditioner, television, etc.) that enables the operation of such appliances with the help of a tiny remote control. In remote sensing, we generally recognize two types of sensors namely passive sensors and active sensors. Passive sensors record the natural radiation which gets emitted or reflected back from the earth's surface. It includes both analogue (aerial photographs and videographs), and digital systems (scanners and radiometers). Active sensors are carried electromagnetic radiation of specified wavelength or band of wavelengths to illuminate the earth's surface. Example of active sensors are Radio Detection and Ranging (RADAR), Side Looking Airborne Radar (SLAR) and Synthetic Aperture Radar (SAR), etc.

Platforms

Platforms are designed to carry sensors while sensors are also designed keeping in view of aircrafts or suitable observation platforms that must be supported and accommodated. Presently, the two most universally and popularly used platforms are satellites and aircrafts. However, balloons, kites and rockets were also used for accommodating sensors during the initial days of aerial photography meant for earth's observation. These platforms may be stationary or mobile and are usually placed at pre-defined altitudes. You must remember that platforms can vary from stepladders to satellites. Acquisition of remote sensing data is said to be very expensive process in consonance with its resolution. In other words, you can understand that finer the resolution of a remotely sensed data, the cost will be more or high price.

Aircrafts are used for surveying in particular areas at short span of time by placing sensors from less than a kilometer to few tens of kilometers depending on the ability of aircraft and region of interest. On the other hand, satellite platforms are placed at a few hundred kilometers to thousands of kilometers capable of monitoring the very large area of the earth's surface with synoptic view. Satellites are primarily placed in two kinds of orbits viz. geostationary or geosynchronous orbit and sun-synchronous or polar orbit. Satellite is placed at an equatorial plane (about 36,000 kilometres), where the period of satellite is equal to that of earth's revolution is referred to as **'geostationary orbit'**. It is capable of taking constant view of a specific part of earth so that it can be used for getting meteorological information. When satellite moves around the poles by covering all points at given latitude as per the mean solar local time is called **'polar orbit'**. It can be repeated in its path from a few hundred to one thousand kilometres for covering the same area at intervals of a fixed number of days.

10.2.4 Resolution of Remote Sensing Data

When the sensing is taken at higher altitudes for observing the earth; we generally get the synoptic view of a larger area, but with a low resolution data.

The quality of remotely sensed datasets or products can be measured by considering parameters namely spatial, spectral, radiometric, and temporal resolution. How well a sensor can record spatial details of small object from its different sizes explains the **spatial resolution** of an image. Higher the spatial resolution, it means that the sensor is able to detect even smaller objects on one spectrum, whereas higher the **radiometric resolution**, smaller will be the radiance differences that can be detected between two objects. The data is recorded in specified wavelength portion of the EM spectrum which is called **spectral resolution**. **Temporal resolution** of satellite data is explained as the sensor's capability to view the same object under similar conditions at regular intervals of time.

Till now, you have understood about the remote sensing and its data that can be obtained through satellites and aircrafts from varying altitudes. The process of electromagnetic radiation while interacting with various ground features over the planet earth is measured by remote sensors mounted on various platforms. The film is used for detection and recording of signals from objects in 'traditional photography'. However, in satellite remote sensing, the collection of data in the form of pictures representing the image or digital data is called 'digital photography'.

Let us now study about the aerial photography and satellite data in detail. Remote sensing data became available since 1930s when photographic images were obtained from the aircrafts for mapping the earth's landscape.

SAQ 1

a) Define remote sensing.

b) What are the main characteristics of geostationary satellites?

10.3 AERIAL PHOTOGRAPHS

Since time immemorial, it is one of the most universal, multipurpose as well as inexpensive category of remote sensing. It is recorded in the literature that in the beginning, a French photographer named Gaspard-Felix Tournachon who was also popularly known as "Nadar" used a tethered balloon for taking first known aerial photograph over Val de Bievre, near Paris, France in 1858. Another person named J.W. Black also captured the earliest known aerial photograph of Boston city from a balloon in 1860.

In the later stage, the kites were used for obtaining aerial photographs. The credit goes to an English meteorologist Archibald, E.D., for kite photography who had clicked the first aerial photograph in 1882. The advantage of airplane instead of balloons and kites seized the opportunity by picking up considerable momentum for commercial utilization of aerial photos obtained from camera platforms since 1908. The main advantages of aerial photography in cartography is that one can study and interpret various features easily, because it provides a bird's eye view of much larger areas, and importantly photographs records permanently the existing scenario of the earth's landscape.

Aerial photographs are clicked with the help of a high-end precision aerial cameras. These may include continuous strip camera, panoramic camera, terrestrial camera and reconnaissance frame camera, etc. You will study and learn about these in the succeeding sections.

10.3.1 Basics of Aerial Photography

Aerial photography is the primary form of remote sensing that records the earth's landscape. Aerial photos can be obtained with the help of airplane on which cameras are installed. There are mainly three components viz. camera, filter, and film used in the areal photographic system. Cameras are fixed generally on stable mounts. However, sometimes adjustable mounts can also be used. The shutter speed of the camera is normally fixed matching with the speed of aeroplane. They carry photosensitive film placed at the focal plane and imaging of ground features that falls in the instantaneous field of view (IFOV) of the camera lens. Aerial mapping cameras are designed to produce small format (30 mm), medium format (70 mm) and large format (240 mm) images.

Large film format cameras are used for imaging sizeable areas with immense information. On the other hand, small format cameras are lighter and low cost used in the professional photography. These 35 mm/70 mm cameras are often taken into the low altitudes and are operated manually for obtaining vertical photos of small regions. Photographic films are generally coated with different types of emulsions according to the need of photographs. These emulsions coated films can record wavelength or spectral regions ranging between 0.3 micro-meter (μm) and 1.2 μm. There are mainly four emulsions namely Panchromatic (PAN), Black and White Infrared (B and W IR), True-colour and Colour Infrared emulsions. These are developed for imaging earth's landscape in this spectral range.

PAN records data in the range of 0.3 to 0.7 μm. These PAN bands are particularly used in creating photomaps and orthophotos. Infrared photographs are mainly used in identifying edges of rivers, lakes, waterbodies and other hydrographic features because water absorbs infrared energy more than visible light. IR images tend to show water in dark grey or black tone. The range of B and W IR films ranges between 0.3 and 0.9 μm.

True-colour film is similar to PAN. However, true-colour films record blue (B), green (G), and red (R) portion of visible energy to produce a realistic multi-colour image. A true-colour photograph can be used in crop monitoring, soil and water studies. Another advanced film is a colour-infrared film. It is sensitive to record green, red, and near-infrared (NIR) energy instead of B, G, and R as recorded in a true-colour film. Colour-IR photographs are typically used in mapping of vegetation damage and flooding areas, and landuse planning, etc.

10.3.2 Scale of Aerial Photo

Now, it is important for you to understand the simple geometry of aerial photography. An aerial photo is a perspective projection of the land surface. It explains how the emission of various ground features or objects passes through the optical centre of the lenses that are imaged on the film. In this simple case, the scale of photographs can be determined with the help of focal length of camera and the height of aeroplane above the ground (datum), not above the mean sea level.

Scale of aerial photo may be computed as;

$RF = C_f / H$

where RF is the representative fraction; C_f is the camera focal length; and H is the flying height. All units are in feet.

You will better understand after going through the below given example.

Example: If a photo is taken by a camera with 6 inch focal length and flying height of 12,000 ft, what will be the scale of the photograph?

Solution:

Here, C_f = 6 inch = 0.5 feet

H = 12,000 feet

Scale of photograph, $RF = C_f / H = 0.5 / 12,000 = 1 / 24,000$ or 1:24,000

A traditional aerial camera with six-inch focal length produces a photo of 23 x 23 cm which corresponds to approximately 23 square kilometer area on the actual ground. There is a 30% sidelap and 60% overlap between flight lines during the process of aerial photography. Most of the ground features certainly gets covered in two photographs because of such overlaps. Particularly, it will help for stereoscopic viewing of photographs that involves looking at the same area imaged on two adjacent photos resulting into 3-dimensional view of the landscape. The colour-IR images and other photos have been used by cartographers for compilation of topographical maps, landuse mapping, and delineation of natural resources at local and national levels.

Nowadays, large-scale photographs and electronic images are being obtained by various sensing devices mounted on low altitude, slow moving and fixed-winged aircrafts and helicopters, and even drones. However, the main drawback of aerial photography is that it causes relief displacement at edges of the aerial photos that hinders the complete synoptic coverage of an area.

SAQ 2

a) What are the colour regions recorded by true-colour films?

b) An aerial photo is taken by a camera with a 12 inch focal length lens. The flying height of the plane is 10,000 ft. Find out the scale of aerial photograph.

10.4 SATELLITE DATA

The advantages of space platforms including minimum relief distortion, high repetitive coverage, covering of large areas with greater details, etc. have enabled the earth's imaging from space very accurate. Different methods are used in collecting the remote sensing data since its invention. For easy understanding, these advancements for acquiring data are explained below under the title of satellite technology. You must remember that some of the methods and techniques explained here have also been used in aerial photography for acquiring data from the space.

10.4.1 Television Cameras Data

Since 1960's, the recorded data of satellites from the space began to be controlled from the ground stations. Weather satellites and earth's resources satellite images and data have been transmitted to ground processing facility centres for decoding and its utilization for environment and earth's resources monitoring and mapping purposes.

Television Camera was the first electronic system used for clicking the earth's pictures from the space. In 1960, **Television Infrared Observation Satellite (TIROS) -1** carried Vidicon television camera for viewing the earth for weather studies. These cameras were later used in several meteorological satellites. The initial TIROS cameras used 12.7 mm slow scan vidicon, at 400 TV lines per frame. Subsequently, the improved version of imaging tubes of these cameras got developed. Prominent examples are **Return Beam Vidicon (RBV)**, Image Dissector Tube (IDT), Secondary Electron Conduction Tube (SECT), etc.

The space borne high resolution TV camera i.e. RBV was used in the **LANDSAT** series of satellites for surveying the earth's resources. In 1972, the Earth Resources Technology Satellites (ERTS) program was launched and later it was renamed as LANDSAT in 1975 by **National Oceanic and Atmospheric Administration, (NOAA)** of United States of America.

LANDSAT television camera system consists of 3 RBV tubes with its associated lens filters being used in taking images in 3 spectral bands with 80 m spatial resolution. Each camera is read out sequentially, requiring approximately 3.5 seconds for each of the 3 spectral images.

BHASKARA-I and II, the Indian experimental remote sensing satellites, were installed in a two-band television camera system. One spectral band is operated in 0.54-0.66 micro-meter (μm) wavelength region and the other one in 0.75-0.85 μm region. Each picture frame covers an area of nearly 400 x 400 sq. km. with a spatial resolution of about 1 km. Although, these are efficient cameras but limitations of these tubes are also recorded which includes poor dynamic range, radiometric accuracy and geometric distortion etc.

10.4.2 Opto-Mechanical Scanners Data

To overcome the disadvantages of TV imaging systems, the Opto-Mechanical Scanners were developed. The information from the ground is recorded pixel by pixel by the detector. In these systems, the radiation received by the detector from an area on the ground is determined by the detector size and focal length of the optics. This is referred to as pixel or picture element. Due to motion of the scan mirror, the detector is also be able to observe and scan the adjacent pixels on the ground. In this way, the collected energy is channelled into a spectral dispersing system (known as spectrometer) to generate multiple imageries in more than one spectral band. These are called **Multispectral Scanners (MSS).**

It is important to know that the MSS are inbuilt scanners with a scan mirror, dispersal system and a collecting optics along with a set of detectors. Scanning is mainly carried out in the object plane mode. In this, a plane mirror is kept at 45° to the optical axis and is rotated around the optical axis. The main aim of dispersal system is to spread the incoming radiation into different spectral bands. The collecting optics collects the reflected or emitted radiation in broad wavelength region extending from visible to thermal IR regions. To achieve good quality images over a wide field of view, a three mirror optical system began to be used in the remote sensing. A detector is a device that produces an output signal. Generally, it converts optical energy into an electrical signal which can be measured easily. You can simply understand that each detector has a specific spectral or wavelength region for which only it can be used.

MSS used in LANDSAT series was the first operational satellite-borne opto-mechanical scanner. Landsat 1/2/3 satellites are also known as Earth Resources Technology Satellites (ERTS) maintained by the National Aeronautical Space Administration (NASA), USA. The details of LANDSAT data can be studied from the Table 10.1. LANDSAT-1/2 MSS had 4 spectral bands with 79 m spatial resolution that covers an area of 185 x 185 sq kms. Other LANDSAT MSSs had inbuilt system with an extra Band 5 to focus on the Thermal wavelength region with 240 m resolution. For more information, you may visit www.usgs.gov.core-science-systems/nli/landsat.

The advanced version of second generation opto-mechanical multispectral scanner carried onboard LANDSAT-4 satellite is known as **Thematic Mapper (TM)** sensor. It records the ground information by covering visible to thermal spectral regions. The Visible (Blue, Green and Red), NIR and SWIR bands produce 30 m spatial resolution imageries and 120 m spatial resolution for Thermal regions. LANDSAT-5 and 7 are having improved versions of TM sensor known as **Enhanced Thematic Mapper (ETM)**. It has an additional band i.e. Panchromatic (PAN) which provides 15 m spatial resolution black and white imageries (see Table 10.1).

The recent Landsat 8 **Operational Land Imager (OLI)** and **Thermal Infrared Sensor (TIRS)** produces images together with a total of 11 bands ranging from ultra blue (B1) to thermal (B11). OLI data consists of nine spectral bands in which band 1 (ultra blue) and band 9 are dedicated for coastal aerosol studies and cirrus cloud detection, respectively. Band 8 (Panchromatic-PAN) provides 15 m spatial resolution. Bands 10 and 11 (Thermal) provides 100 m spatial resolution imageries and are useful for studying surface temperature conditions. Remaining all bands from B1 to B7 in which B5 covers NIR region and B6 and B7 spreads in SWIR wavelength portions produces 30 m resolution imageries. You may refer to Fig. 10.3, for understanding the LANDSAT imagery. There are several other opto-mechanical scanners installed in various spacecrafts and aircrafts for example METEOSAT, INSAT, and so on.

Table 10.1: Details of landsat data.

Satellites	Sensors	No. of Bands	Spectral Resolution (µm)	Orbit
Landsat-1 (1972-78)	RBV & MSS	B1 to B3 & B4 to B7	0.475-0.575 (B1) 0.580-0.680 (B2)	18 days/ 900 kms
Landsat-2 (1975-82)	RBV & MSS	B1 to B3 & B4 to B7	0.69-0.83 (B3) & 0.5-0.6 (B4) 0.6-0.7 (B5) 0.7-0.8 (B6) 0.8-1.1 (B7)	
Landsat-3 (1978-83)	RBV & MSS	A-D (Single Band) & B4 to B8	0.505-0.750 & Same as above MSS (bands B4-B7) with 10.4-12.6 (B8)	
Landsat-4 (1982)	MSS & TM	B1 to B4 & B1 to B7	0.5-0.6 (B1) 0.6-0.7 (B2) 0.7-0.8 (B3) 0.8-1.1 (B4) & 0.45-0.52 (B1) 0.52-0.60 (B2) 0.63-0.69 (B3) 0.76-0.90 (B4) 1.55-1.75 (B5) 10.4-12.5 (B6) 2.08-2.35 (B7)	16 days/ 705 kms
Landsat-5 (1984)	MSS & TM	B1 to B3 & B4 to B7		
Landsat-6 (1993)	Launch failure			
Landsat-7 (1999)	TM & ETM+	B4 to B7 & B8 (PAN)	Same as above for TM bands & 0.50-0.90	
Landsat-8 (2013)	OLI & TIRS	B1 to B7, B8 (PAN) & B10 & B11	0.43-0.45 (B1) (Visible) 0.45-0.51 (B2) (Visible) 0.53-0.59 (B3) (Visible) 0.64-0.67 (B4) (Red) 0.85-0.88 (B5) (NIR) 1.57-1.65 (B6) (SWIR) 2.11-2.29 (B7) (SWIR) 0.50-0.68 (B8) (PAN) 1.36-1.38 (B9) (Cirrus) 10.6-11.19 (B10) (TIRS) 11.50-12.51 (B11) (TIRS)	

(Source: https://landsat.gsfc.nasa.gov/landsat-data-continuity-mission/).

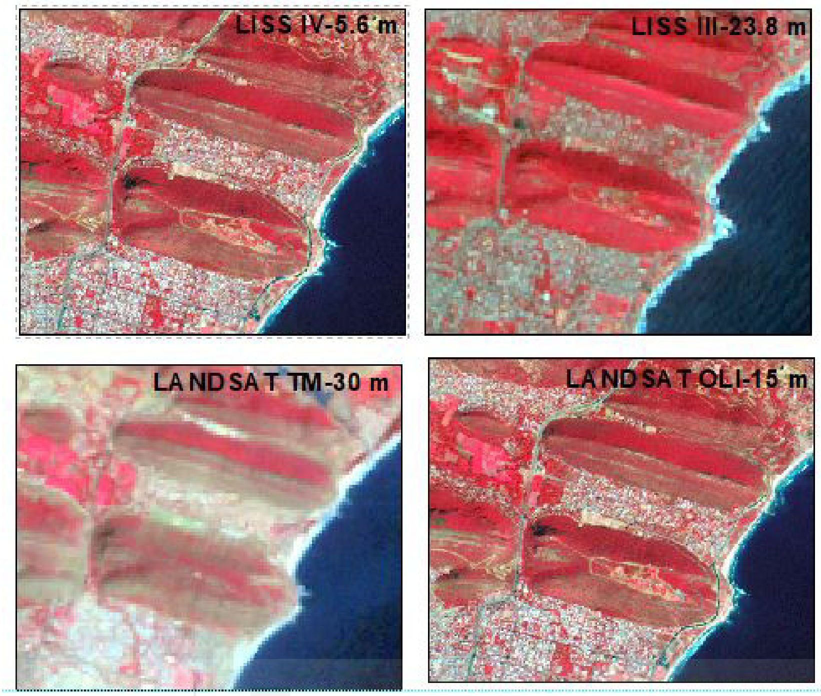

Fig. 10.3: Satellite data products of differents Sensors.

10.4.3 Pushbroom Cameras Data

Pushbroom Cameras in which internal electronic scanning is used instead of mechanical scanning. These are known to be better scanners than opto-mechanical scanners because they provide high spectral or spatial resolution imageries. **Charge Coupled Devices (CCD)**, also called **Solid State Sensors (SSS)**, consists of linear or 2-dimensional array of detectors which are used for acquiring remote sensing data from the space. Instead of scan mirrors, which are used in opto-mechanical systems, the detector array is used to produce one scan line of information. This type of scanning is sometimes referred to as 'Pushbroom Scanning'.

The pushbroom scanning operation was first performed in **SPOT-1** satellite by the French Space Agency, known as Centre National d'Etudes Spatiales (CNES). The full form of SPOT is **Systeme Probatoire d' Observation de la Terre**. SPOT series of satellites were actually commissioned in 1986 with the launch of SPOT-1 satellite into a near-polar orbit (832 kms high altitude).

There are two **High Resolution Visible (HRV)** cameras constructed with a multilinear array of detectors, operating in along the track direction. These are installed for imaging on ground each with 60 kms wide area by providing 3 band multispectral imagers with 20 m resolution and Panchromatic band of 10 m spatial resolution.

The second generation SPOT satellites viz. SPOT-4/5 has an additional band that also covers the Middle Infrared (MIR) region for multispectral imaging. This is named as **High Resolution Visible Infrared (HRVIR)** band. It also carries a new 5 band imaging system known as '**Vegetation Instrument'** which provides 1 km spatial resolution. Vegetation instrument is also having the same spectral bands as like that of HRVIR, with an additional band 1 (Blue band) incorporated for oceanographic applications. Each HRV or HRVIR offers an oblique viewing capability which enables the acquisition of stereoscopic

Table: 10.2. Details of SPOT satellite programmes.

Satellites	Sensors	No. of Bands	Spectral Resolution (μm)	Orbit
SPOT-1 (1986-1990)	HRV	B2 to B4 & PAN	0.50-0.59 (B2) 0.61-0.68 (B3) 0.79-0.89 (B4) & 0.51-0.73 (PAN-Visible)	26 days/ 832 kms
SPOT-2 (1990)				
SPOT-3 (1993)				
SPOT-4 (1998)	HRVIR & Vegetation	B2 to B5 & B1 to B5 (except B2)	0.50-0.59 (B2) 0.61-0.68 (B3) 0.79-0.89 (B4) 1.58 - 1.75 (B5-SWIR) 0.61 - 0.68 (Red-Mono) & 0.43-0.47 (B1) 0.61-0.68 (B3) 0.79-0.89 (B4) 1.58 - 1.75 (B5-SWIR)	
SPOT-5 (2002)	HRG & HRS & Vegetation 2	B1 to B4 and PAN & PAN & B0 to B4	0.50-0.59 (B1) 0.61-0.68 (B2) 0.78-0.89 (B3) 1.58 - 1.75 (B4) 0.48-0.71 (PAN) & 0.49-0.69 (PAN) & 0.45-0.52 (B0) 0.61-0.68 (B2) 0.78-0.89 (B3) 1.58 - 1.75 (B4)	

(Source: https://earth.esa.int/web/eoportal/satellite-missions/s/spot-6-7 & https://www.satimagingcorp.com/satellite-sensors/spot-7/).

imageries. SPOT-5 carries a single '**High Resolution Stereoscopic' (HRS)** instrument, two '**High Resolution Geometric' (HRG)** instruments, and a '**Vegetation instrument'** similar to that mounted on SPOT-4 satellite. The characteristics of SPOT-1 to 5 series of satellites are given in Table 10.2. HRS provides fore-and-aft stereoscopic data which helps to generate Digital Elevation Models (DEM) having 10 m resolution with coverage of 120 kms ground swath. HRG instrument provides imageries with 2.5 or 5 m spatial resolution for PAN, 20 m for mid-IR (B4) and 10 m for remaining bands. The swath width of HRG sensor is 60-80 kms. Vegetation 2 instruments provide 1000 m resolution data by covering 2250 kms swath width.

The images of SPOT satellites are useful in multiple areas of applications like geological, water stress and deficits, agriculture, and snow inventories etc. With high spatial and spectral resolutions, an excellent geometric fidelity, and the possibility of stereoscopic viewing, the SPOT images serve as a good cartographic source material.

Another mode of scanning system in space borne is '**Linear Imaging Self-**

Table: 10.3. Details of IRS satellite sensors.

Satellites	Sensors	No. of Bands	Spectral Resolution (μm and m)	Orbit
IRS-1A (1988-1996)	LISS-I & LISS-II	B1 to B4 & B1 to B4	0.45-0.52 (B1) 0.52-0.59 (B2) 0.62-0.68 (B3) 0.77-0.86 (B4)	22 days/ 904 kms
IRS-1B (1991-2003)	Same as IRS-1A			
IRS-1C (1995-2007)	LISS-III & PAN & WiFS	B2 to B5 & PAN & B3 to B4	0.52-0.59 (B2) 0.62-0.68 (B3) 0.77-0.86 (B4) 1.55-1.70 (B5) & 0.5-0.75 (PAN)	24 days/ 817 kms
IRS-1D (1997-2010)	Same as IRS-1C			
RESOURCESAT (2003-2004)	LISS-IV & LISS-III & WiFS		0.52-0.59 (B2) 0.62-0.68 (B3) 0.77-0.86 (B4) B3-default band for mono & 0.52-0.59 (B2) 0.62-0.68 (B3) 0.77-0.86 (B4) 1.55-1.70 (B5) & 0.52-0.59 (B2) 0.62-0.68 (B3) 0.77-0.86 (B4) 1.55-1.70 (B5)	24 days/ 817 kms

(Source: www.nrsc.gov.in)

Scanning' (LISS). Indian Remote Sensing Satellite (IRS)-1A was the first operational remote sensing satellite launched in 1988 with two payloads employing LISS sensors. **LISS-I** and **LISS-II** cameras were operated in the pushbroom scanning mode using linear CCD array of 2048 elements. The imaging lens assemblies have focal lengths of 162.2 mm and 324.4 mm for LISS-I and LISS-II, respectively. LISS-I and II sensors had four identical spectral bands providing data with 72.5 m and 36.25 m spatial resolutions, respectively. You may refer Table 10.3 for further information on IRS series of satellites.

The second generation satellites IRS-1C/1D had a **Panchromatic (PAN)** camera, 4 bands LISS-III multispectral (MX) and Wide Field Sensor (WiFS) cameras. Wavelength region of PAN is 0.5 to 0.75 μm and spatial resolution is 5.8 m. MX camera covers three bands (B2, B3 and B4) and an additional band (B5) spreading into Shortwave Infrared Region (SWIR). In addition to these, a Wide Field Sensor (WiFS) also carried for imaging in two spectral regions

(Band 3 and Band 4) with a spatial resolution of 188 m covering a swath of 770 kms. **LISS-III** camera is also designed similar to the LISS-I design, except B1 is replaced with B5 in Shortwave Infrared Region.

RESOURCESAT-1 (IRS-P6) satellite has onboard 3 electro optical cameras such as improved **LISS-III** and **Advanced Wide Field Sensor (AWiFS)**, and **LISS-IV** that was launched in 2003. RESOURCESAT-2 has also carried the same multispectral pushbroom scanners with linear array CCDs as detectors. Notably, a new multispectral camera LISS-IV produces a high spatial resolution (5.8 m) images in three spectral bands (B2, B3 and B4). It can be operated in mono or multispectral mode by covering 70 kms swath on the ground. The swath width and spatial resolutions of LISS-III and LISS-IV cameras are 141 kms and 740 kms, and 23.5 m and 56 m, respectively (Fig.10.3).

The basic optics is similar to that of PAN of IRS-1C/1D. All IRS payloads cameras namely LISS-I, II, III, and IV are operated in pushbroom scanning mode using linear CCDs. ResourceSat data find their application in several areas like agricultural crop identification and monitoring, crop acreage/yield estimation, precision farming, water resources, forest mapping, rural infrastructure development and disaster management, etc.

These satellites offer real-time and voluminous amount of data including both spatial and non-spatial data with diverse resolution. Such type of satellite data is being used by the various stakeholders including academia, administrators, architect and town planners along with professionals across the world. The purpose of the data ranges from weather prediction to wetland management to agriculture to water resources to climate change to urban planning and mineral prospecting, environment and disaster management, etc. This list is indicative only. **National Remote Sensing Centre (NRSC)** located at Hyderabad is the main nodal agency that takes care of the distribution of remote sensing satellite data products in India along with neighbouring countries as well. The satellite data is received at the earth station located at Shadnagar i.e. about 55 kms, away from Hyderabad. You must remember that most of the other sensors developed by various countries used in earth's resources satellites are similar to either SPOT-HRV or IRS LISS system configuration.

Particularly, in very high resolution imaging for example IKONOS, the technique known as **Time Delay and Integration (TDI)** is being used. It works on 2-dimensional array instead of single linear array as used in the conventional pushbroom scanners. TDI used in IKONOS satellite which is the first civilian remote sensing satellite system produces 1 m PAN data and also 4 bands (Blue-B, Green-G, Red-R, Near-Infrared-NIR) multispectral imagery effectively with 4 m spatial resolution. You will be amazed to know that our country, India has also demonstrated this technique for providing high resolution imageries. This type of high resolution imaging systems characteristically has smaller swath ranging between 12-15 kms.

Till now, you have studied and learned about two-dimensional images. The third-dimension (or popularly known as 3D) i.e. height can also be measured from the photographs or images. The height data is essentially useful in many applications such as soil erosion studies, hydro-geomorphological mapping and urban studies, etc. To generate 3D data, we require to take photographs from two locations. This can be achieved by vertical photographs with an overlap (stereo pairs). **Stereo pairs** are generated for an area by looking at from different imaging stations with different viewing angles. French SPOT-1, Japanese ALOS, and Indian Cartosat-1 are equipped to carry the dedicated fore-aft sensors for producing stereo photos. Cartosat is equipped with two cameras to produce high spatial resolution imageries with 2.5 m resolution and 30 kms swath. Panchromatic sensors have immensely helped us to generate digital elevation models from satellite based imaging systems. Several topographical maps have been compiled and revised on various scales by stereo viewing of oblique image pairs with the help of stereo plotting instruments and various photogrammetric softwares across the globe.

In nutshell, the collection of remotely sensed data or satellite imageries is not a big issue now. However, the operating nation's releases category-wise data based on the specific requirement for example public domain, commercial and restricted usage of images to facilitate the study of our earth's environment and resources. In case of public domain category, you will be able to get the data at free of cost from their respective websites. However, for recent data, you have to purchase from their respective organizations by following their procedures and guidelines which may change from time to time readily available in their websites. A few of them are given for acquiring remote sensing and other related data as under:

- https://bhuvan.nrsc.gov.in/bhuvan_links.php
- https://www.usgs.gov/centers/eros
- https://www.fsa.usda.gov/programs-and-services/aerial-photography/
- https://www.nrcan.gc.ca/maps-tools-publications/satellite-imagery-air-photos/air-photos/22030
- https://www.ssd.noaa.gov/
- http://www.surveyofindia.gov.in/

However, since 2020, the Govt. of India has started liberalising its space sector by allowing the private participation in satellite technologies that may enable the better availability and use of such data products in future for observing the planet earth's resources more precisely.

SAQ 3

a) Choose the correct answers- True or False.

   i) Return Beam vidicon is a television camera.

   ii) The earth's cover is recorded by pixel called opto-mechanical scanning system.

   iii) ETM^+ sensor has been introduced in Landsat 5 satellite.

   iv) Vegetation Instrument is a LANDSAT Sensor.

   v) SPOT is Japanese Satellite Programme.

b) What is LISS? Define its types.

10.5 SUMMARY

In this unit, you have studied so far:

- We are now better equipped to observe the minute details of earth's features from space by studying the remotely sensed data. The main advantage of such datasets or data products lies in providing a great synoptic view of the ground area.
- Remote sensing is the science of making observations and drawing inferences about the objects from measurements, made at a distance without touching the objects. It simply means the sensing of the surface of the earth from space.
- Electromagnetic radiation is the important part of any remote sensing system. The electromagnetic spectrum ranges from gamma rays to radio waves.
- Remote sensors and platforms are predominantly designed based on the requirement of data with pre-defined measurements.
- The quality of any remote sensing data product can be assessed by its spatial resolution, spectral resolution, radiometric resolution and temporal resolution.
- The first known aerial photo was obtained by balloon in 1858 and this is considered as a primary form of data collection from remote sensing.
- Small, medium, and large format photos are produced in aerial survey.
- There are four photographic films namely PAN, B&W-IR, True-colour, Colour Infrared used in imaging the earth's features in the wavelength portions between 0.3 μm and 1.2 μm. PAN photography particularly has many advantages in cartography.
- The RBV television camera is one of the space borne high resolution cameras used initially in the LANDSAT satellites in observing earth's landscape. MSS, TM, ETM, ETM+, OLI sensors are installed in various LANDSAT series.
- HRV, HRVIR, and VI are used in SPOT series of satellites.
- IRS satellites BHASKARA-I and II were also carried in two-band television camera system. LISS-I, II, III, IV, and AWIFS sensors are carried by IRS satellites.
- You have also learned about the availability of important sources of remotely sensed data which are readily available on web for educational and research purposes as well as commercial utilization.

10.6 TERMINAL QUESTIONS

1. Briefly describe about the sensors and platforms used in collecting the remotely sensed data products.

2. Describe about the aerial photography.

3. Write a short note on opto-mechanical scanners employed to collect remotely sensed data.

4. Explain the SPOT Programme.

10.7 ANSWERS

Self Assessment Questions

1. a) Remote sensing is the science of obtaining information about an object from a remote distance without thouching the object.

   b) The orbital altitude of geostationary satellite is about 36,000 kilometres. Orbital period of this satellite corresponds with that of earth's revolution. Such geostationary satellites are capable of clicking regular view of any specific portion of the earth's surface employed in weather forecasting. It is mainly used to procure meteorological data and information.

2. a) These colour regions are blue, green and red.

   b) The scale of aerial photograph is 1:10,000.

3. a) (i) True (ii) True (iii) False (iv) False (v) False

   b) LISS denotes Linear Imaging Self-Scanning. There are four types of LISS sensors namely LISS I, II, III and IV.

Terminal Questions

1. To answer this question, you should be covering the key features of sensors and platforms employed to collect the remotely sensed data by referring to Section 10.2.

2. Refer to the Section 10.3.

3. Refer Section 10.4.2 for precisely highlighting the key elements of opto-mechanical scanners which enables the collection of remotely sensed data.

4. Refer to the Sub-Section 10.4.3.

10.8 REFERENCES/SUGGESTED READINGS

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- Sarkar, A. (2008): *Practical Geography: A Systematic Approach*. Kolkata: Orient BlackSwan.

- Singh, R.L. and Singh, R.P.B. (2003). *Elements of Practical Geography*. New Delhi: Kalyani Publishers.

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GLOSSARY

Active Sensors: It means the camera sensors mounted atop a satellite with their own source of illumination or light is known as active sensors during the process of remote sensing. They have the advantage of capturing the data during any time of the day, season or year.

Aerial Photograph: It refers to a photo or an image clicked from the air-borne platforms by using a precision camera sensor.

Agricultural Census: Agricultural census was started in 1970-71 to collect the data on social group and size class wise covering multiple aspects of land like operational holding, tenancy, land use, irrigation and so on.

All India Educational Survey: All India Educational Survey is an activity to collect, organise and disseminate variety of information related to school education from infrastructure to attainments.

Band: It means the specific wavelength interval in the electromagnetic spectrum.

Census Schedule: Census Schedules are large sized proforma containing spaces to capture information related to housing or individuals.

Data Measurement Scales: All the data are classified and measured using certain scales are called data measurement scales. These are nominal, ordinal, interval and ratio.

Digital Image : It refers to an array of digital numbers (DN) organized in rows and columns in tabular from. It has the property of intensity values along with their spatial locations.

Digital Number (DN): It means the intensity value of a pixel in a digital image in remote sensing.

District Level Health Survey (DLHS): DLHS are health surveys based on samples in the country which collects data on household profile with amenities and facilities and maternal and child health and health care at district level since 1998-99.

Electromagnetic Radiation (EMR): It means the amount of energy which gets transmitted at a speed of light from the giant Sun.

Electromagnetic Spectrum: It refers to the entire gamut of EMR or energy ranging from meters to nanometers in wavelength traveling at a speed of light. It propagates through a vacuum such as outer space.

Field Mapping: Field mapping is a map making activity, manual, automatic or semi-automatic, in the field which includes drawings, field measurement and recordings.

Field Reports or **Field Diaries:** These are important sources of primary data, in which the observers record their observations and measurements in the field note books and later on translate into data and information.

Focus Group Discussion: Focus Group Discussion is a primary data collection tool, which involves the gathering of people of similar backgrounds in a group to get certain information about specific topic through group discussion.

Geostationary Satellites: These are located at a very high altitude approximately 36, 000 kilometers above the earth's surface.

Interval Scale: Interval scale includes the number, which has continuity and magnitude of difference. However, it indicates zero as reference point but there is no true zero in like temperature.

Interviews: Interviews are the primary data collection tools involving personal verbal interaction either on face to face mode or using electronic medias- telephone, video calls, etc. It is mostly two way communication.

Livestock Survey: Livestock census was started in 1919-20 to collect the information related to livestock and poultry with complete count. It has now completed the conduct of 19th survey up to the year 2012.

Microwave Remote Sensing: It is confined to the process of remote sensing in higher wavelengths ranging from 1 mm to 1 m. This category has the advantage of even penetrating and capturing the details during the cloudy season or overcast sky conditions.

National Family Health Survey (NFHS): NFHS health surveys based on samples in the country was started since 1992-93. It collects health related data primarily on maternal and child health and health care with background characteristics and many more crucial indicators.

National Sample Survey: These are a kind of surveys based on certain samples to collect the information on various aspects for the planning and development in the country.

Nominal Scale: Nominal scale is such that uses numbers to represent identities, where no number represents the size or weightage like 1 representing males and 2 representing females.

Observations: Observations are also the data collection tools, where the information is collected by way of investigator's own direct observation without asking from the respondent.

Optical remote sensing: It refers to the process of remote sensing in the visible, near infrared and middle infrared regions ranging between 0.3 mm to 3 mm.

Ordinal Scales: In ordinal scale, numbers represent rank order indicating the order of quality or quantity without giving the magnitude of quantity or degree of quality like 1, 2, 3 and 4 representing very good, good, moderate and poor.

Passive Sensors: It refers to the camera sensors which doesn't have its own source of light as like active sensors. Hence, such sensors are capable of recording the wavelength during the naturally available source of Sun's light.

Population Enumeration: Population enumeration or population census is a process where the detailed information of each and every member is collected through schedule. It is also known as census.

Primary Data: Primary data are those data which are directly collected by the researcher or user. These are first hand data collected for the first time for special purposes.

Primary Sources: Primary sources of socio-economic data are those through which the primary data are collected like primary surveys using data collection tools such as schedules and questionnaires, observations, interviews, focus group discussion, field reports or field diaries. The primary sources of physical or spatial data are field survey and mapping and remote sensing.

Questionnaires: A data collection tool in the form of format with a set of questions with structured questions for the collection of information/data primary data through various modes other than face to face interaction of the investigator and respondent.

Ratio Scale: Ratio scale includes numbers like interval scale, but it has true zero means absence of the object/phenomena of measurement, like weight or height.

Remote Sensing: It is an art and science of obtaining information about an object or earth's phenomenon captured by a sophisticated precision device that is not in contact with the object being sensed.

Resolution: In its broadest sense, resolution refers to the ability of a sensor to record and display finer details being captured from the ground objects during the process of sensing. There are four kinds of resolution namely spatial, spectral, radiometric and temporal taught in the science of remote sensing.

Sample Registration System (SRS): SRS is a term for vital or civil registration system only. It collects and provides reliable estimated data on fertility and mortality measures like birth rate, death rate and neonatal/infant/child mortality rates at disaggregated levels for rural and urban areas with total estimations across the states.

Secondary Data: The data which have already been collected and processed or tabulated and may be in published or unpublished form.

Secondary Sources: Secondary sources of socio-economic data are those from where the secondary data are collected like various published and unpublished documents and reports by the Government and non-government agencies including the United Nations and national and international organisations or data providers.

Schedules: A data collection tool in the form of format with a set of questions with structured questions for the collection of information/data primary data through face to face interaction of the investigator and respondent.

Socio-economic Survey: The survey through which socio-economic information are collected.

Sun-synchronous Satellites: These are designed to follow an inclined north-south orbit. Such satellites travel from north to south during sunny side in its descending course and travel from south to north during shadowy side in its ascending path.

Thermal Remote Sensing: It refers to the process of remote sensing in which the emitted radiation is captured ranging between 3 mm to 5 mm and 8 mm to 16 mm.

Vital or Civil Registration System: Vital or Civil Registration System is a system to record vital events like births and deaths by the Government.