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ORIGINAL ARTICLE

Evaluation of the Earth Surface: A Remote Sensing Perspective

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ABSTRACT

The present paper is an attempt to understand basic principal of remote sensing and their utilization in the exploitation or the evaluation of resources pertaining to the earth surface. The technique has acclaimed widely for its practical as well as theoretical applications in natural sciences. The earth surface has been commonly studied by various perceptions and curiosities hitherto. The subject of remote sensing has evolved in the early 1970 as an independent field of study. Thus, there is less known or explored about the potential of remote sensing in natural sciences as well as earth science as a whole. At graduate or postgraduate levels, it is studied as an addition subjects or supplementary paper along with other subjects in most of Indian university's curriculum. However, recent development shows that it is emerging as an independent subject in few numbers of universities. Therefore, it is pertinent to extend horizon of knowledge in this particular stream, and, hopefully, the present attempt is one of them.

Key words: *remote sensing, evaluation of resources, earth surface*

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INTRODUCTION

Recent advances in satellite technology have been leading to sustainable and meaningful evaluation of the surface of earth. The term remote sensing originated at the Willow Run Laboratories of the University of Michigan, USA, now it is known as the Environmental Research Institute (ESIM) of Michigan in the early 1970s. Working principles behind this technique bestow the naissance of remote sensing. As a geographic information system (GIS) tool, remote sensing provides a cost effective means of surveying, monitoring and mapping objects or near the surface of the earth. It has been rapidly been integrated among assortment of applications, and has proven to be valuable and effective in meeting the inventory of resources. Basic principle of remote sensing are primarily based on the properties of electromagnetic spectrum and the geometry of airborne or satellite platforms relative to their targets.

In general, it describes collection and obtaining reliable information about an object, area, phenomenon or the environment, through the process of recording, measuring and the interpreting imagery and digital representation of energy patterns derived from a distance with the help of sensors that are not having physical acquaintance with the targets. These sensors carried by platforms are coaxed to detect variations of emitted and reflected electromagnetic fluxes. For instances- Landsat Thematic Mapper (Landsat TM), Linear Imaging Self Scanning sensor -3 and advanced wide field sensor (LISS-3 and AWIFS) board on IRS P6 or SPOT (Satellite Pour l' Observation de la Terra), QUICKBIRD, IKONOS etc are the prominent sensors. A platform may be an aircraft, a balloon, rocket, satellite or even ground based sensor-supporting stand on which sensor can be mounted.

Despite the fact that reading to this article, even we will utilize the principle of remote sensing. In this case, ours eyes will play the role of sensors that respond to the light reflected from words, image and sentences. The stimulus response analogous to the light reflected from the dark and bright areas in the page are the signals or gesture of elements information which are congregate by our eyes. Those responses have to analyze by our mental computer to interpret the meanings, which contained in the words, pictures and sentences. The human eye-brain system may be mull over as one of the most advanced end-to-end remote sensing systems. However, it can assimilate only the information fetch to it by the visible light, which is very small part of the bandwidth of the electromagnetic spectrum. Moreover, acquiring data of the other parts of the electromagnetic spectrum, an advance sensor is utilized that should be specially equipped to collect the information of objects on the assorted approach in which the various earth surface features emit and reflect electromagnetic energy.

Remote sensing is extremely useful in climate and its related phenomenological investigations. Ability to provide data of inaccessible areas with global and repetitive coverage of same area enhances study on temporal scale. It also provides precise information and enables us to prepare thematic maps such as Land Use/Land Cover, Forest type, Agriculture, Soil, Geology, hydrology, urban land use planning, oceanography etc. Moreover, this technique also pertinent in medical, bio-medical and engineering research as MRI, CT-Scan, X-rays, Building structure mapping, water quality assessment, Archeological sites investigation, DEM generation, snow, cloud, water vapors and precipitation study, emergency management, decision support system and so on are the some examples.

COMPONENTS OF REMOTE SENSING

In so far, Remote sensing mechanism includes sensor, target, platform and source of energy either manmade as required for active sensor or sun for passive sensor. The overall process of remote sensing can be categorized into components as follows:-

1. Electromagnetic energy is emitted from a source (sun or transmitter carried by the sensor),
2. Transmission of that energy from the source to the surface of the earth but its interaction with the atmosphere,
3. Energy interaction with targets or surface of the earth , (reflection, absorption, transmission or self-emission),
4. Energy is detected and recorded by the sensor, converting it into photographic image or electrical output,
5. Data are displayed digitally for visual or numerical interpretation on a computer, Data analysis and interpretation.
6. Integration of interpreted images with other data towards deriving management strategies for various applications.

Moreover, the incident energy interaction on any given earth surface feature or with the objects leads to energy exchange process in the form of reflection, absorption and transmitted or emitted (see figure: 1). After processing and interpretation of data, visually or digitally/electronically, extraction of information about the target take place. It also reveals some new information, or assist in solving a particular problem.

ELECTROMAGNETIC SPECTRUM

All objects reflect or emit energy that moves with the speed of light in a harmonic wave pattern (figure 2) and broadly includes light, heat and radio waves. This energy is measured in the terms of wavelength and frequency. Thus, the information from an object to the sensor is passed out by the electromagnetic energy and could be dogged in the form of frequency, intensity and polarization of the electromagnetic wave. It is disseminated at the velocity of light from the target directly owing to free space as well as indirectly by reflection, scattering and re-radiation by aerosols to the sensor. According to the wave and quantum model (figure 2 and 3) the energy of quanta is inversely proportional to its wavelength means that longer the wavelength, lower the energy content (frequency). Thus, the interaction of electromagnetic wave with earth surface and atmosphere is strangely dependant on the frequency of the waves.

Figure 1: Process of Remote Sensing (courtesy: *NRSC,* Hyderabad)

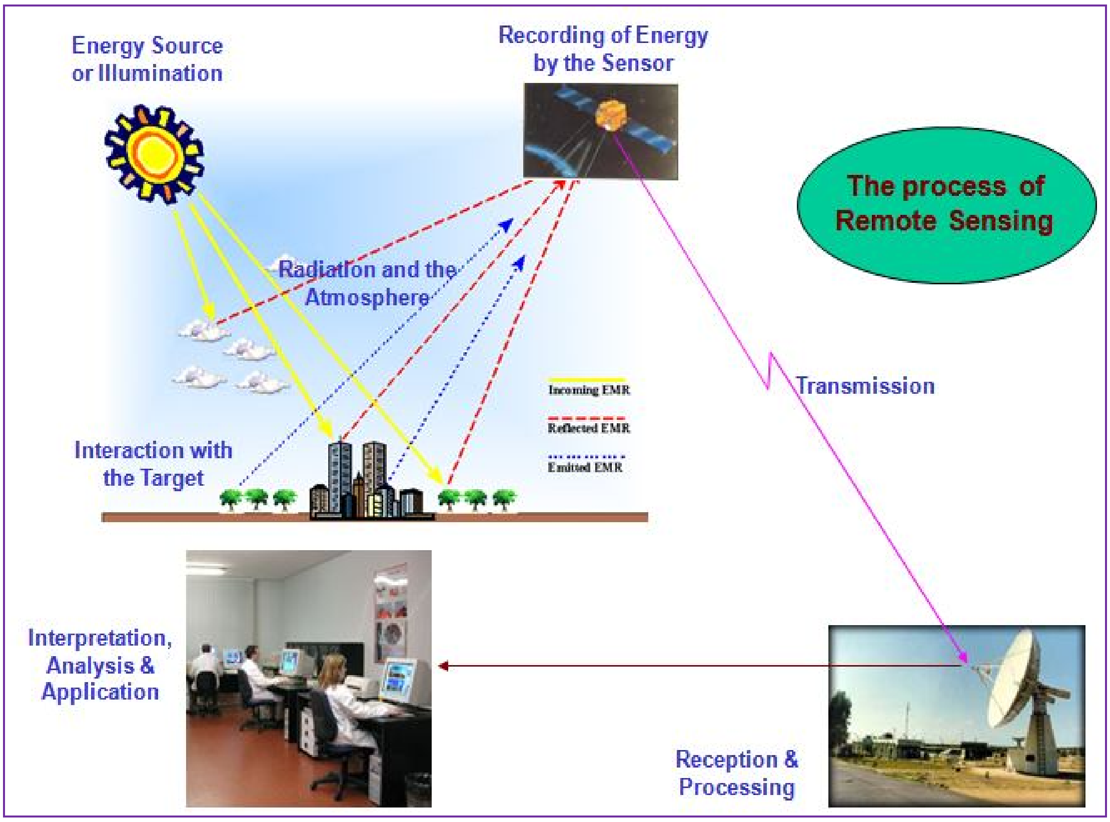
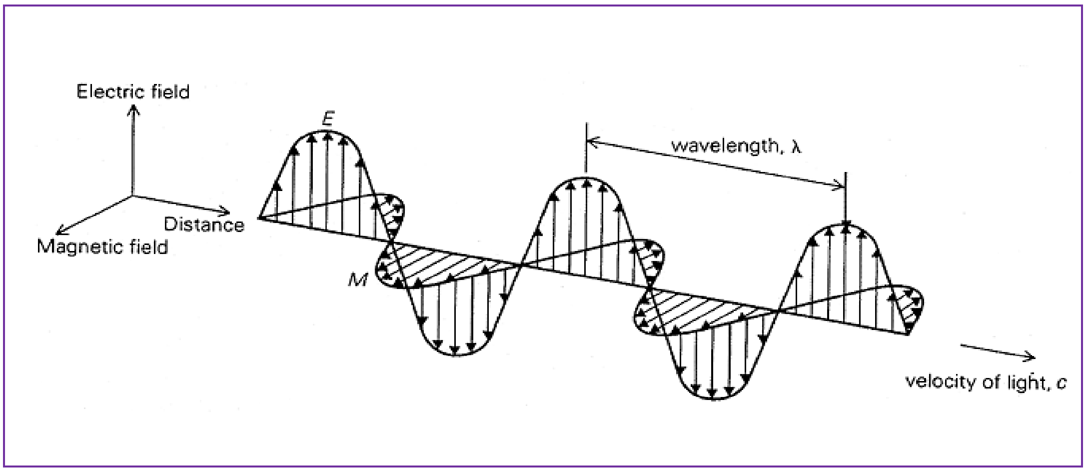
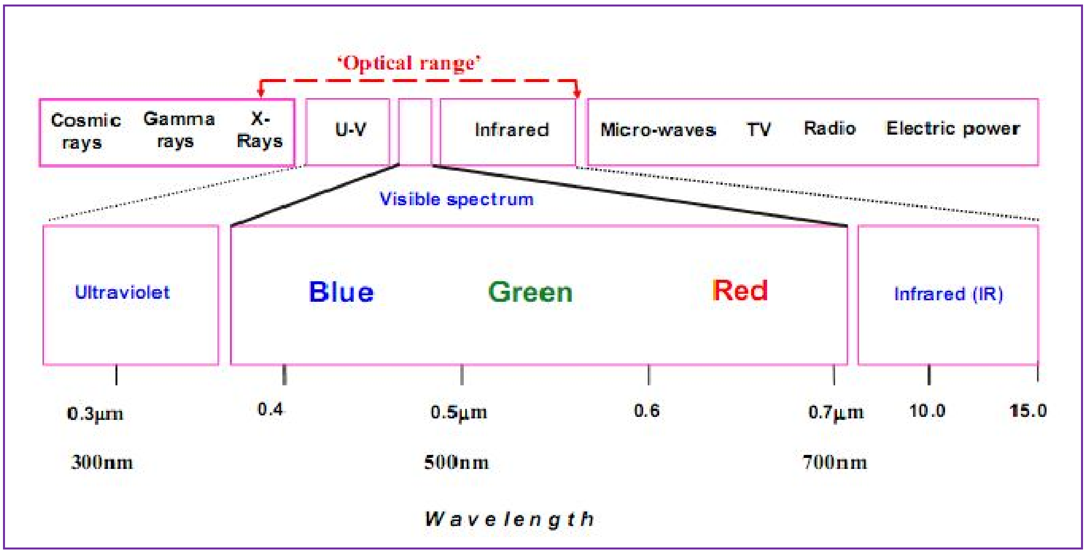


Figure 2: An Electromagnetic wave and its components (after *Lillesand Kiefer, 1987*)



As above discuss, any object at a temperature more than absolute zero radiates electromagnetic waves whose wavelength depend on the temperature. The total range of wavelengths, from a micrometer to meters, is commonly referred to as the *electromagnetic spectrum*. It is assorted into a large number of spectral regions or domain as illustrated in figure: 3. Different regions of the electromagnetic spectrum can provide discrete information about an object. Moving from the smallest wavelength domain towards lower frequency, section of spectrum follows as cosmic rays, gamma rays and X-rays which, however, cannot be studies with remote sensing methods.

Figure 3: Electromagnetic Spectrum (modified after *Jenson, 2008*)



The Ultra Violet Zone (0.300 to 0.446 μm) is the first zone in which sensors based on optical principles. UV wavelengths are used in geological and atmospheric science applications. Rocks and minerals emit or fluoresces visible light in the presence of UV radiation. Fluoresces quality strongly associated with natural hydrocarbon such as monitoring of oil field and oil seepage. Ozone (O3) layer is greater absorber of UV radiation, so that the upper atmosphere also becomes an important part for tracking the changes in Ozone layer. After the UV radiation, visible light is another part of spectrum which is also detected by bare human eyes. It is the only part of spectrum that can be perceived as colors. The range of visible light on electromagnetic spectrum is very short, and ranging from 0.4 to 0.700 μm. shortest visible wavelength is violet and the longest is red (color sequence as VIBGYOR). It is very useful in urban feature identification, soil and vegetation discrimination, ocean productivity, cloud cover observation, precipitation and snow cover related investigations. Further, the adjacent part of visible light on electromagnetic spectrum is known as infrared region and ranges from 0.700 to 100 μm. it is divided into two section namely reflective and thermal infrared due to some specific radiation properties. The reflective infrared region has ranged from 0.700 to 3.0 μm whereas the thermal region vary from 3.0 to 100 μm. the delineation of healthy versus unhealthy vegetation or fellow vegetation, and for the distinction among vegetation, rock and soil can be easily done by reflective IR because it shares radiation properties with visible light. Thermal IR considers emitted radiation that is radiated from the surface of the earth in the form of thermal energy. Thus, it is very useful in monitoring of temperature phenomenon of land, Water and ice also.

Moreover, the advance capability to penetrate the atmosphere under virtually all condition leads the immense advent of microwave remote sensing. Microwave radiation is the longest wavelength used for remote sensing and covers the spectral region of wavelengths from 1 mm to 1 meter (bands are listed in Table: 1). The radio wave covers region of wavelengths longer than 10 cm (frequency less than 3 GHz). The microwave also covers the neighboring region, down to a wavelength of 1 mm (frequency 300 GHz). The sensors operating in this region are RADAR, Microwave radiometer, Altimeter, Scatterometer and so on. It is used in the studies of meteorology, hydrology, oceans, geology, agriculture, forestry, ice and for topographic mapping. So far, the microwave emission is influence by moisture content, and then it becomes a useful information source for mapping soil moisture from space. Sea ice, currents and surface winds. Sophisticated SAR interferometric techniques enable monitoring of plate movements. Other applications include oil slicks, snow wetness analysis, profile measurement of atmospheric ozone layer and water vapor content.

Table 1: Wavelengths of various bands in Microwave region

Band	Frequency (GHz)	Wavelength (cm)
P	0.3 - 1.0	30 – 100
L	1.0 -2.0	15 – 30
S	2.0 - 4.0	7.5 - 15.0
C	4.0 - 8.0	3.8 - 7.5
X	8.0 - 12.5	2.4 - 3.8
Ku	12.5 - 18.0	1.7 - 2.4
K	18.0 - 26.5	1.1 - 1.7
Ka	26.5 - 40.0	0.75 - 1-1

Source: Microwave Remote Sensing – Active and Passive. Vol., I, II & III. (After *Ulaby, F.T., et. al. 2008*).

Table 2: Examples of Electromagnetic range for Use in various applications

Spectrum Region	Wavelength Range	Use
UV	0.300-0.446 µm	Florescent material such as hydrocarbons and roads, Ozone in stratosphere.
Visible-Blue	0.446-0.500 µm	Soil/Vegetation discrimination, Ocean productivity, cloud cover, precipitation, snow, and Ice cover
Visible-Green	0.500-0.578 µm	Corresponding to the green reflectance of healthy vegetation and sediment in water.
Visible-Red	0.579-0.7 µm	Distinguished in healthy vegetation, plant species and soil/geological boundary mapping.
Near Infrared (NIR)	0.7 - 0.80 µm	Delineates healthy versus unhealthy or fellow vegetation, biomass, crop identification, soil and rocks.
	0.80 - 1.10 µm	Delineates vegetation, penetrating haze and water/land boundary mapping.
Mid-Infrared	1.60 - 1.71 µm (SWIR)	Soil and leaf moisture, discrimination between cloud and snow, ice, used for minimizing the effect of thin cloud and smoke.
	2.01 - 2.40 µm	Geological mapping, plant and soil moisture, particularly hydrothermally altered rocks
Thermal IR	3.0 - 100 µm	Monitoring temperature variation in land, water, ice and forest fires (volcanic fire).
	6.7 - 7.02 µm	Upper troposphere water vapour
	10.4 - 12.5 µm	Vegetation classification, plant stress analysis, soil moisture, geothermal activity mapping, cloud top and sea surface temperatures.
Microwave	1 µm to 1 m	Soil moisture, sea ice, currents and surface winds, snow wetness, profile measurement of atmospheric Ozone and water vapour, detection of oil slicks.

TYPES OF SENSOR USED IN REMOTE SENSING

Broadly, remote sensing is concerned with detecting and recording the electromagnetic radiation from a target area in the field of view of sensor instrument. Since the 1960s, assortments of sensors have been used for the measurement of electromagnetic radiation that may originate from different components of the target. Radiation may be the solar

energy reflected or natural thermal/microwave energy emitted by the target or may be the reflection of energy transmitted to the target by the sensor itself in the form of reflectance, emission and scattering properties of the features on the surface of earth.
At the development in early stage, the sensors had only the capability of black - white data recording, and a little later to color images initiation. Color images provide better flexibility for the derivation of information in several fields. Sensors can also categories in mono versus multispectral channel on the basis of its data acquiring capability in number of electromagnetic spectrum region. Generally, sensors may categories on the basis of source of illumination means natural versus artificial in term of passive and active respectively.

PASSIVE SENSOR

A sensing system that utilizes a naturally- occurring source of illumination (as Sun light) or energy to acquiring information from the target is to be consider as passive sensor (figure: 4). For instances remote sensor are photographic cameras, multispectral scanner, television cameras, return beam vidicon (RBV), electro-optical scanner etc. Electro-optical sensors further divided into *whisk broom* and *push broom* on the basis of recording technique.

Fig. 4: The Passive Sensor

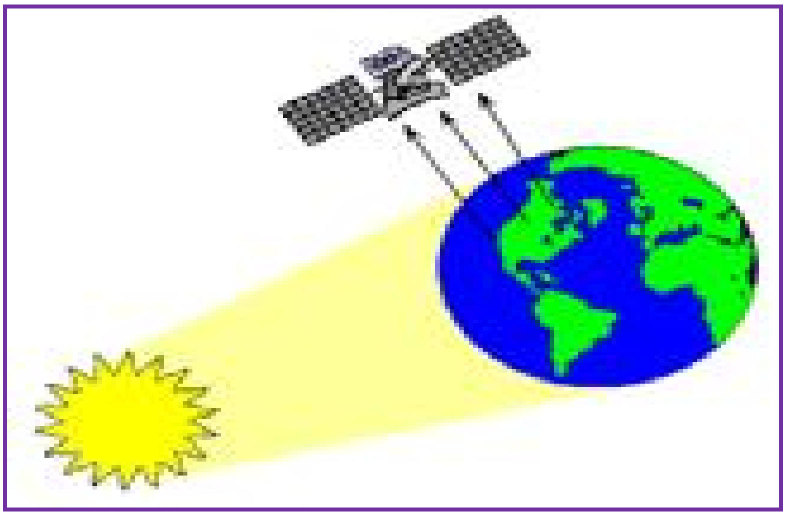
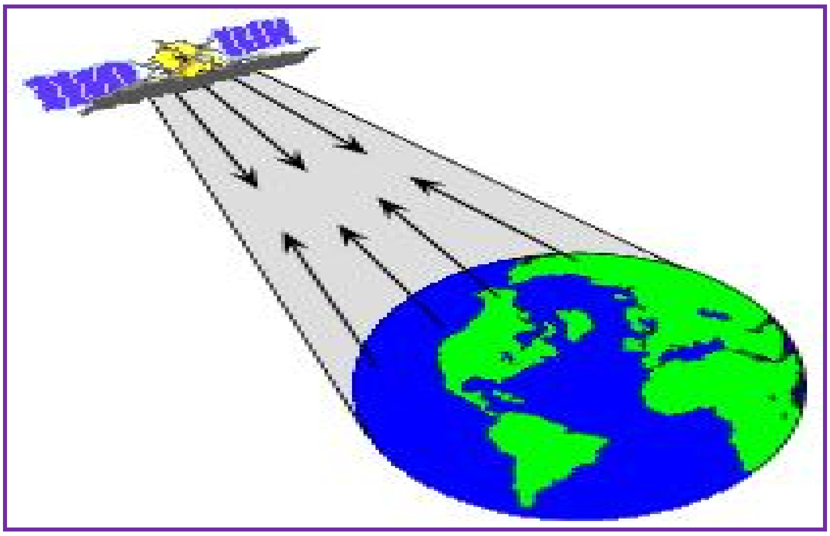


Fig. 5: The Active Sensor



ACTIVE SENSOR

Sensors that having man-made source of transmission for electromagnetic energy and also contain a specific wavelength or band to illuminate the target or surface of the earth are to be considering as active sensors (Figure: 5). Taking a photograph in a dark place with the help of flesh light is an example. Other example includes LIDAR (light detection and ranging), RADAR (radio detection and ranging) etc. The X-ray machine is also an active sensor, where the energy emitted from a source passes through the object and exposes the X- ray film.

CONCEPT OF SENSORS RESOLUTIONS AND ITS IMPORTANCE IN REMOTE SENSING

Evaluation of the surface of earth and its environment at regional as well as global scale and acquiring high-resolution images for urban and cadastral level planning leading the development of space based remote sensing. Higher resolutions are provided by the aircraft based platforms, while frequent and global coverage at somewhat coarser resolution is feasible through satellites. Presently some satellites provide images with finer resolution roughly comparable to aerial photograph. Further, resolution may be divided into four categories on the basis of characteristics of sensors capability that are follows:

- Spatial resolution
- Spectral Resolution
- Radiometric resolution
- Temporal Resolution

Spatial resolution refers to instantaneous field of view of sensors and also by "so and so meters of pixel size". In addition, it could be understood as measurement of the smallest object that can be resolved out by the sensor as an independent identity. It may be consider that smaller the size of pixel, the better (or finer) special resolution. It is controlled by geometry and power of the sensor system and is a function of sensor altitude, detector size, focal size and system configuration. For instances if the image having 30 meter pixel size then, it means, it will represent 30 meter square on ground. *Spectral Resolution* represents the number and size of wavelengths, intervals, or divisions of the spectrum that a system is able to detect. Fine spectral resolution consider as the power to resolve a large number of similar sized wavelength, as well as to detect radiation from a variety of regions of spectrum while in the case of coarse resolution it would be vice-versa. While *Radiometric Resolution* refers as the detector's capability to discriminate the alteration in the concentration of emitted or reflected electromagnetic radiation. And of course, it is also represent the number of possible brightness values in each band of data and is determined by the number of bits into which the recorded energy is divided. For instances, in 8-bit data, the brightness values can range from 0 to 255 for each pixel or in 7-bit data, the values range from 0 to 127.

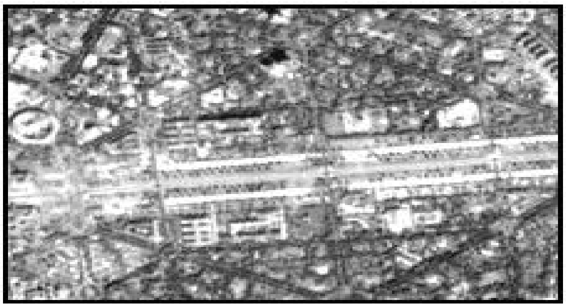
Moreover, *temporal Resolution* is the ability of sensor to recurrently observe or scene at the same location on a regular interval. It also refer the frequency of data collection, it is very useful in the change detection studies because different dates data allows to comparison of the surface features in respect of time. Most of satellite platform will pass over the same location or spot at regular interval that range from day to week, depending on their orbital properties and special resolution.

AERIAL PHOTOGRAPHY

A traditional form of interpretation, analysis and mapping of surface of the earth by remote sensing is the use of aerial photographs, which had been played remarkable role since the civil war when camera mounted on balloons and surveyed battlefield. First aerial photograph was captured by Frenchman 'Nadar' with the help of air balloon in 1858 which was very pale positive image covering only a farm, inn and three houses. Today, it provides a vast a variety and amount of surface detail. It is also very pertinent for fine spatial resolution and accuracy of the surface features. It can be divided in four types depending on optical axis of camera mounted on aircraft.

Picture: 1 President House

Image: 1 President House (IKONOS-1 m resolution)



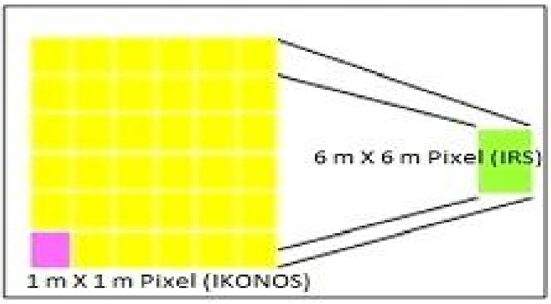


Image: 2 President House (IRS–5.8 m resolution). All Image Courtesy: *NRSC, Hyderabad*

Spatial Resolution

Table 3: Overview of some sensor and use with their properties

Sensor's Name	Swath (km)	Resolution				No. of Bands	Approx. Geog. Scale	Useful for (Level)
		Spatial (m)	Radio metric (Bits)	Temp-oral	Spectral (μm)			
AWIFS	740	56	10	24 days	0.52 to 1.70	4	1: 1000K	Global LULC
WIFS	810	188	7	3 -5 days	0.62 to 0.86	2	1: 1000K	Global LULC
LANDSAT-MSS	185	79	6	16 days	0.50 to 1.10	4	1: 250K	Regional LULC
LANDSAT-TM	185	30	6	16 days	0.45 to 2.35	7	1: 50K	District/ Sub-dist.
SPOT-XS+PAN	60	20 & 10	- - - -	26 days	0.50 to 0.83	3+1	1:30K	District/ Sub-dist.
LISS- III	141	24	7	24 days	0.52 to 1.70	4	1: 50K	District/ Sub-dist.
LISS-IV	24	5.8	10	5 days	0.53 to 0.86	4	1: 10K	Village/Cadastral
LISS-III PAN	70	5.8	6	5 days	0.50 to 0.75	1	1: 10K	Village/Cadastral
IKONOS-MS+PAN	11.3	4 & 1 PAN	11 & 8PAN	5 days	0.45 to 0.90	4+1	1: 8K	Village/Cadastral
QUICKBIRD-MS+PAN	16.5	2.44 & 0.6	11	5 days	0.45 to 0.90	4+1	1: 5K	Project/Planning
CARTOSAT-1	30	2.5	10	5 days	0.50 to 0.85	1	1: 10K	3D Urban LULC
CARTOSAT-2	0.96	0.8	10	5 days	0.50 to 0.85	1	1: 5K	3D Urban LULC
WORLDVIEW	16	0.45	11	5 days		1	1: 5K	Urban LULC
GEOEYE-MS+PAN	15.2	1.64 & 0.4 Pan	11	5 days	0.45 to 0.90	4+1	1: 5K	3D Urban LULC

Before going to pursue in any kind of investigation, it is useful to justify aim and objectives that will leads to selection of data. Fine resolution tends to lead to more accurate and useful information but it is not suitable for every project. The high-resolution satellite imagery may not be the suitable choice when study area covers a large special extent of surface. It is, therefore, important to determine the minimum resolution requirement needed to accomplish task from the outset. Thus, the consideration of resolution aspect should be decided by the project needs as for change detection study, temporal as well as radiometric resolution are required.

CONCLUSION

In concluding, the improvement in satellite images coupled with the ease of image processing has leading to plentiful and resourceful applications. Today, daunting of climate change pushing to understand the earth related phenomenon and exploration in a more varied way. Evaluation of the surface of earth and its environment at regional as well as global scale and acquiring high resolution images for urban and cadastral level planning providing a better opportunity of observation by space based remote sensing. Advancement in sensor resolution, particularly in spatial, spectral, radiometric and temporal, is offering a wide range of possible application. Governments and many agencies around the world are impending to meet the demand for reliable and continuous satellite coverage on both regional and global scales. Researchers are currently able to perform a 40 years temporal analysis using satellite data on critical areas around the world. Remote sensing has established itself as a powerful tool in the assessment and management of Indian Continent land.

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