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Remote Sensing: An Effective Tool for Environmental Monitoring

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Abstract-

Present age is the age of development of information's technology; everyone wants all the information's on his fingertips. To fulfill these requirements the remote sensing has emerged as a new but most important art and science of collecting information's about any object, area or phenomena without any direct contact with it. The present paper is an attempt to give a brief knowledge about remote sensing and its advantages over the conventional methods of sensing or data collection. Monitoring the environment is essential to understanding and mitigating the impact of human activities on ecosystems. The increasing complexity and interconnectivity of environmental factors necessitate advanced tools that can provide comprehensive and real-time data.

Keywords- Environmental Monitoring, Remote sensing, Energy interactions, reflectance curves, dynamic systems.

Introduction-

Remote sensing has emerged as a pivotal technology in environmental monitoring, offering a unique vantage point to observe, measure, and analyze the Earth's surface and atmosphere from a distance. As human activities continue to exert unprecedented pressures on the environment, the need for comprehensive and efficient monitoring tools becomes increasingly crucial. This introduction outlines the significance of remote sensing in environmental monitoring and introduces its role as an effective tool in understanding and managing the complex dynamics of our planet. [1] Nature has endowed us with a multitude of senses by which we can observe and identify any object before us.

In order to make some conclusive observations about any object we sometimes use more than one sense simultaneously. Whenever a new object comes before us each sense gives some identity information regarding the identity of that object when these information's reach our mind they are stored as the identity of that object, Whenever the same object comes again before us, we can immediately recollect the stored data about the object and make use of it as per our requirements.

The above methods we use in our daily life have certain limitations beyond which we can't make definite observations about any object for example.

a. We can touch only those objects that are in close contact of us.

b. We can hear and distinguish the sound coming from a source located within some specified area or range.

c. We can view up to a limited distance and further the ability of our eye to distinguish separately two object placed close to each other is also very limited.

The resolving power of human eye is 1' (minute) which means any two objects that subtend an angle greater than 1' on human eye can be resolved separately.

a. We can smell and identify the objects very close to us and this ability is also very limited.

b. By tasting also we can distinguish among a limited number of items and only those items that are edible.

c. In order to enhance our ability of observing an object using our natural senses we use some supportive instruments like telescope, microscope, photography camera etc. [2]

From the above discussion we may point out two main drawbacks of our natural and conventional methods of collecting information about any object or area.

1. Limitation of range:

The range up to which we can use our natural senses is limited to a very small region; further the rage of the supportive instruments like telescopes and cameras is also limited to some specified region. If we try to photograph a larger area then the resolution itself decreases and the resolution among different objects on earth surface becomes more difficult.

2. Limitation of data collection and retrieval:

The information collected in our mind in form of data about any object or area depends on our memory and further it is not possible to retrieve this data on demand as such without any distortion or change. The data collection through photography also has some limitations and drawbacks firstly it is difficult to store the photographs in well mannered way and to save this data is much more difficult, secondly the areas that are quite difficult to reach specially the mountain regions, are quit impossible to be photographed. The use of such photographed data for our research purposes and development planning is not as easy as we can't make any alteration according to our demands. A large group of users can't use this data at the same time. Any temporal change in this type of data can't be detected easily. [3]

Definition of Remote Sensing-

The limitations and drawbacks discussed here forced us to discover some better means of observation and collection of data and led to step by step progress and development of a technique that is widely used for geographical purposes called the 'Remote sensing'. First of all we define the term remote sensing, "Remote sensing is the science and art of obtaining the information about an object area or phenomenon under investigation through the analysis of data acquired by a device that is not in contact with the object area or phenomenon under investigation".[4]

In the context of Earth observation, remote sensing typically involves the employing sensors and instruments mounted on platforms. The intervening space between sensor and sensed object is partially or completely filled with air the only link possible between sensor and the object is made by electromagnetic waves. Aerial photographs and satellite imageries are the most common examples of remote sensing products.

Electromagnetic Waves and Electromagnetic Spectrum-

For visualisation of any object human eye depends on visible light, The light (visible) coming from the sun gets reflected by an object and enters our eye making an image on our retina. But apart from visible light there are some other forms of electromagnetic energy, like RW, UV etc. [5] Figure (1) shows the electromagnetic spectrum where the location of various forms of electromagnetic energy (waves) is located. [5] There is a very small visible section of the spectrum ranging from 0.4ìm to 0.7ìm; UV energy is located close to the visible spectrum's blue end. The several types of IR waves near IR are adjacent to the visible range's red end (from 0.7 to 1.3ìm), mid IR (from 1.3 to 3ìm) and thermal IR (beyond 3ìm to 14ìm). At much large wavelength (1m.m to 1m) is the microwave portion.

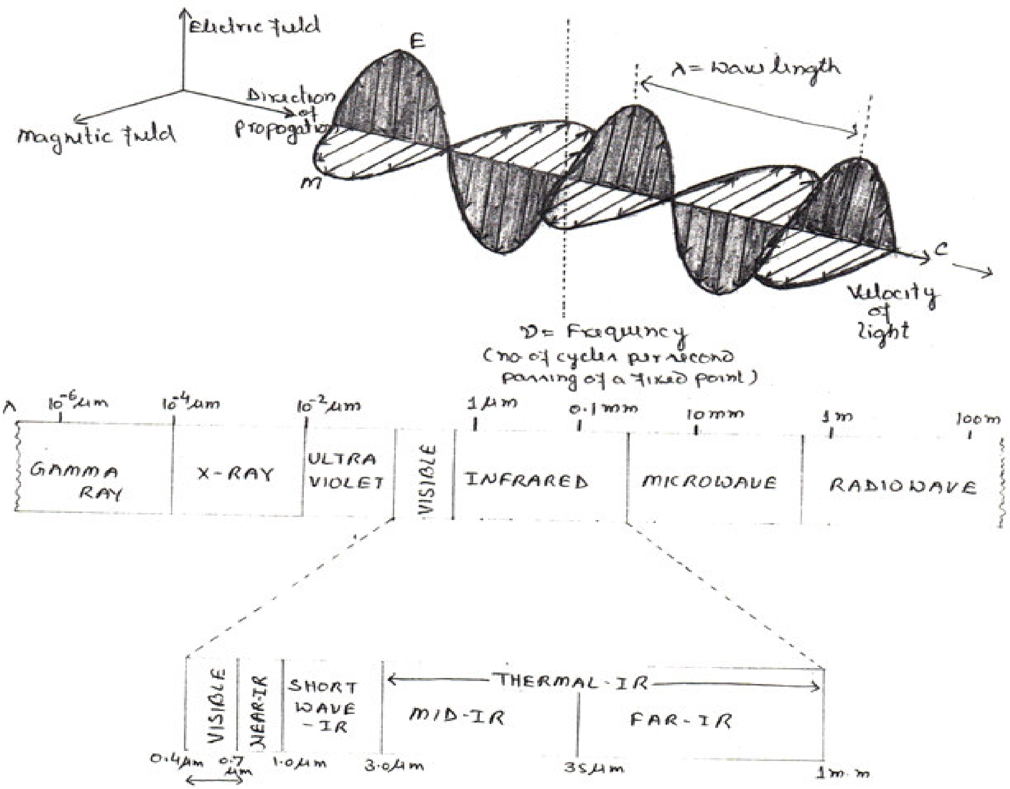

Figure (1) between 10^{-8} ìm & 10^{2}m (Electromagnetic spectrum)

Figure (1) shows the propagation of electromagnetic wave with its two components ie. a sinusoidal electric wave (E) and a sinusoidal magnetic wave (M) being mutually perpendicular and both being perpendicular to the direction of propagation. The relationship between wavelength (ë) and frequency (f) is given by the equation:

c = õë

Where c = 3×10^{8} meter/sec is essentially a constant called the velocity of wave.

Fundamental Principles of Remote sensing:

The underlying theories of remote sensing are

a. Energy interactions with earth surfaces
b. Special reflectance of vegetation, soil and water

Another source is interacting with earth's surface characteristics.

Energy interactions with Earth surfaces:

When electromagnetic energy coming from sun or another source is interacting with earth's surface characteristics, then three types of fundamental energy interaction are possible. As depicted in figure (2) it is possible for the different incident energy fractions to be transferred, absorbed, or reflected.

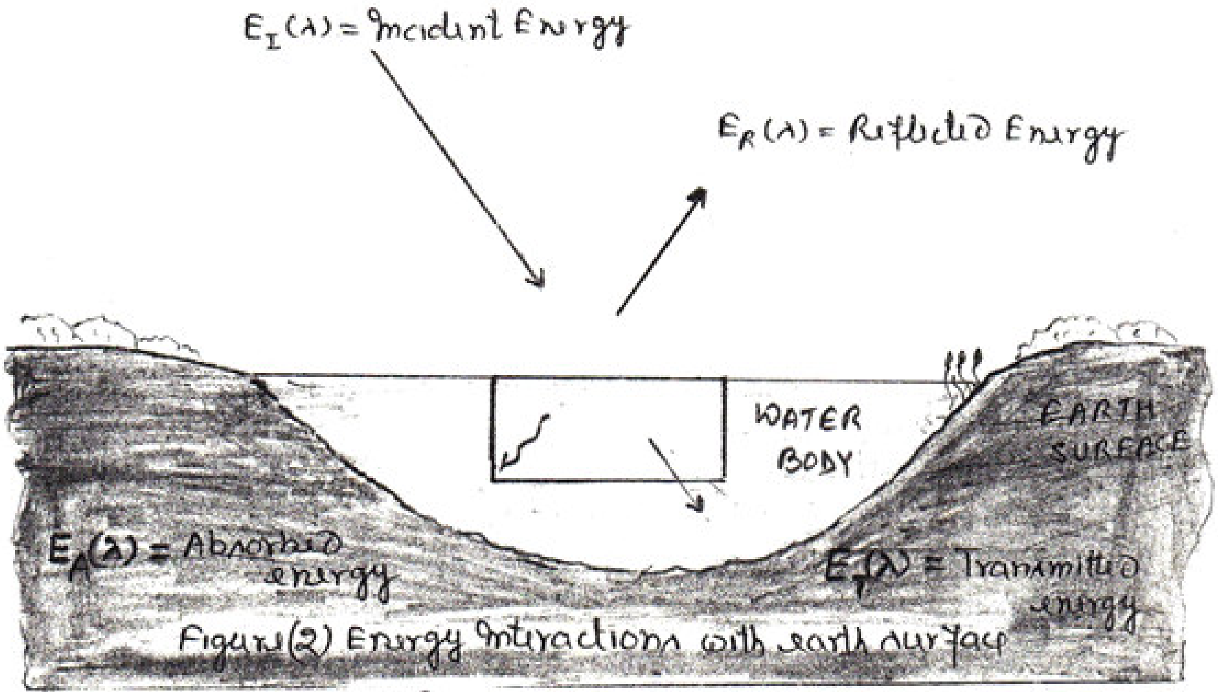

Fig. (2)

E_I (ë) = E_R (ë) + E_A (ë) + E_T (ë)

Where E_I (ë) = Incident energy with wave length ë

E_R (ë) = Reflected energy with wave length ë

E_A (ë) = Absorbed energy with wave length ë

E_T (ë) = Transmitted energy with wave length ë

The dependence of these energies on wave length, indicates that, even within a given in one spectral range, characteristics can be indistinguishable, but in another, they might be highly distinct and readily identifiable. In remote sensing, spectral reflectance is a crucial concept that involves measuring the amount of electromagnetic radiation (light) reflected by different wavelengths. Remote sensing instruments, such as satellites or airborne sensors, capture information about the surface of the Earth by observing the reflected light in various spectral bands. [6]

$$\text{spectral reflectance } (\rho\lambda) = \frac{E_R(\lambda)}{E_I(\lambda)}$$

$$\rho\lambda = \frac{\text{Energy of wavelength "}\lambda\text{" reflected from the object}}{\text{Energy of wavelength } \lambda \text{ incident upon the object}} \times 100$$

Spectral Reflectance of Vegetation, Soil and Water-

A spectral reflectance curve is a graphical representation of the amount of electromagnetic radiation, typically light, reflected by a material at different wavelengths across the electromagnetic spectrum. The curve shows how the material reflects light at different wavelengths. Different materials exhibit unique patterns of reflectance based on their molecular and structural properties. Vegetation substantially absorbs visible spectrum light in the red area due to chlorophyll, but it strongly reflects in the near-infrared (NIR) region. The red edge, which occurs around 700-750 nanometers.

Soils generally have varying reflectance within the observable spectrum. Factors such as soil composition and organic matter influence the reflectance. Soils often have higher reflectance in the SWIR region compared to vegetation. This can be useful in distinguishing between soil and vegetation cover.

Water absorbs light in the visible spectrum, particularly in the blue and red regions. As a result, water bodies often appear dark in these wavelengths. Water typically has low reflectance in the NIR and infrared regions, making it distinguishable from many land surfaces.

The figure (3) shows a typical spectral reflectance curve for three basic types of earth features i.e. clear lake water, vegetation and dry bare soil. As shown in figure the valleys Plant leaf pigments control the visible section of the spectrum, the chlorophyll in leaves powerfully absorbs light in the wavelength band of 0.45 and 0.67ìm. Plant reflectance in the range 0.7ìm to 1.3ìm is mostly caused by the interior structure of plant leaves. [7]

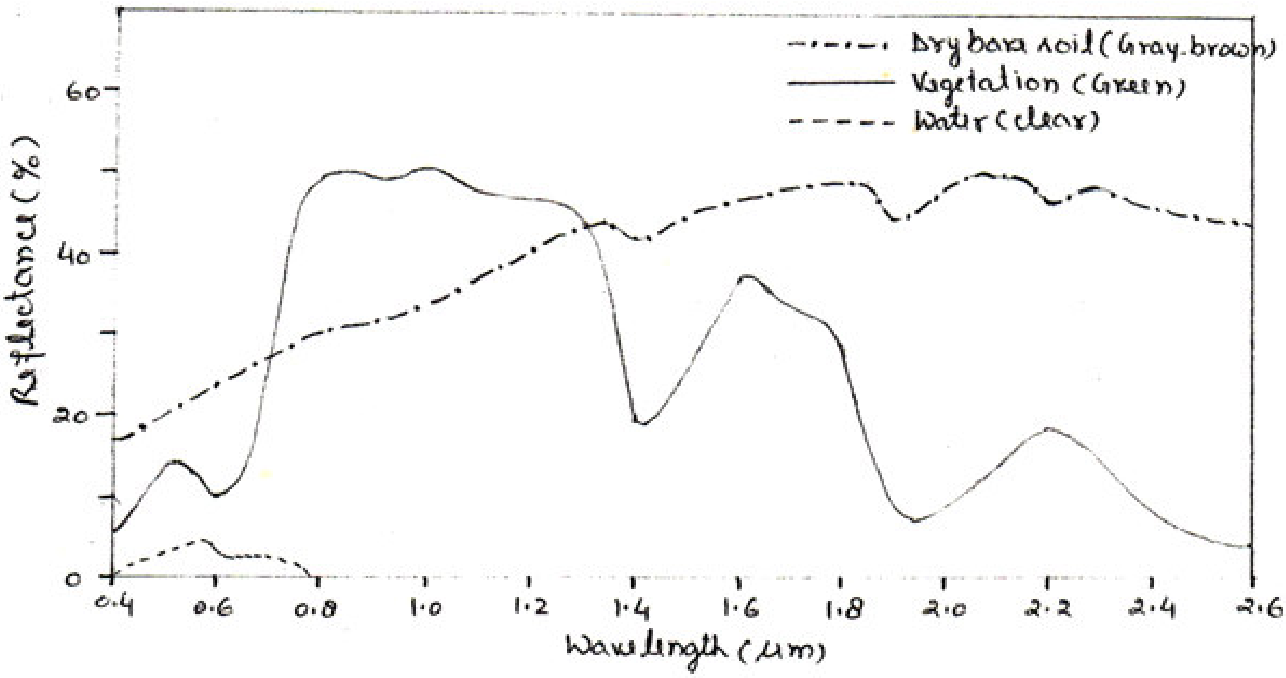

Figure (3) typical reflectance curves for water, vegetation& soil

Chlorophyll, the green pigment in plants, exhibits distinctive absorption bands in several spectral areas. These absorption features result in lower reflectance in these specific bands, making them essential for vegetation analysis. Changes in vegetation health, caused by factors such as diseases, nutrient deficiencies, or water stress, can be detected by analyzing alterations in the spectral reflectance patterns. Remote sensing technologies help monitor these changes over large areas. Understanding the water, soil, and vegetation's spectrum reflectance is essential for extracting meaningful information from remote sensing data. Advances in satellite and airborne sensors, coupled with sophisticated image processing techniques, continue to enhance our ability to monitor and manage Earth's ecosystems and resources. This knowledge is critical for applications ranging from agriculture and environmental monitoring to water resource management and disaster assessment.

Spectral reflectance refers to the proportion of incident light that is reflected by a surface at different wavelengths across the electromagnetic spectrum. Studying the water, soil, and vegetation's spectrum reflectance provides valuable insights into their composition, health, and dynamic changes over time. The importance of understanding the water, soil, and vegetation's spectrum reflectance in harnessing the full potential of remote sensing technologies. [8]

Data Acquisition and Interpretation-

We've talked about the origins of electromagnetic energy, its propagation through atmosphere and various types of Interactions of this energy with different earth features. The entire spectrum of electromagnetic waves includes a wide range of frequencies, with each frequency corresponding to a different type of electromagnetic radiation. Understanding the sources of electromagnetic energy is crucial for various scientific and technological applications, including telecommunications, medical imaging, astronomy, and energy production. [9] The ability to harness and manipulate electromagnetic waves has led to numerous advancements in technology and has facilitated the development of various tools and devices used in our daily lives.

Reference Data or field Data-

We have till now discussed the process of collection of information about any object or earth features through imaging and non Imaging instruments but all this information and data are of no use if they don't match with ground realities, technically called the reference data. These observations may be derived from various sources. The scope, composition, and state of agricultural crops, tree species that are land users, and the degree of water contamination could all be covered by the ground reality survey. It is common practice to record the geographic locations of field measurements and observations on a map base in order to make it easier to locate them in a related picture from remote sensing. [3]

The reference data or field data is generally following purposes-

a. To support the study and interpretation of data from remote sensing

b. In order to adjust a remote sensor

c. To verify the information extracted from remote sensing

There are four main aspects to be kept in mind when organizing the real truth of field data collection.

a. The timing of gathering ground truth data

b. Taking a Sample

c. Field data types

d. GPS study

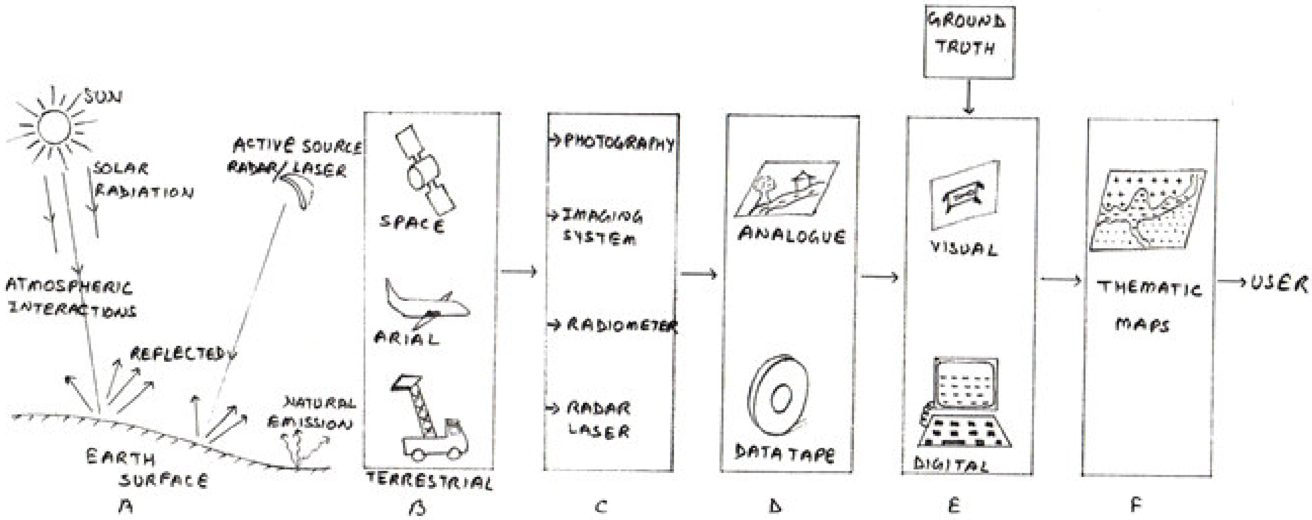

Figure (4) Scheme of a typical remote sensing programme

A - Sources of radiation and interaction
B - Platforms
C - Sensors
D - Data Products
E - Interpretation and analysis
F - Output

A Typical Remote Sensing Programme-

After discussing all the main point involved in remote running if we summerize them then a schematic programme of a typical remote sensing system may be as shown in figure (4). A typical remote sensing program involves a systematic process of collecting, analyzing, and interpreting data obtained from sensors and platforms located at a distance from the target area. Clearly articulate the goals and objectives of the remote sensing program. Identify the area of interest and the specific information needed. This could range from monitoring environmental changes to assessing land use or managing natural resources. [10]

Choose the appropriate remote sensing sensors and platforms based on the objectives and characteristics of the study area. Sensors can include satellite-based sensors, airborne sensors, or ground-based sensors. Determine the optimal time and conditions for data collection, taking into account factors like cloud cover, sun angle, and seasonal variations.

Collect remote sensing data using the selected sensors and platforms. This could involve satellite imagery, aerial photography, or other sensor data. Ensure that data collection adheres to the defined mission plan.

Apply image enhancement techniques this may involve contrast stretching, color balancing, and filtering to highlight specific features or patterns. Analyze the processed images to extract information relevant to the study objectives. This could involve visual interpretation, manual or automated classification, and the use of specialized algorithms for feature extraction. [11] A well-planned and executed remote sensing program provides valuable information for scientific research, environmental monitoring, land management, disaster response, and other applications. The iterative nature of remote sensing programs allows for ongoing refinement and adaptation to changing conditions and requirements.

Conclusion-

Remote sensing emerges as an exceptionally effective tool for environmental monitoring, offering unparalleled capabilities to observe, analyze, and comprehend the Earth's dynamic systems. The unique vantage points provided by satellite, airborne and ground-based sensors enable a comprehensive understanding of environmental changes on various spatial and temporal scales. The wealth of information derived from spectral reflectance patterns, thermal emissions, and other remote sensing data facilitates the monitoring of land, water, and atmospheric components with unprecedented precision. The effectiveness of remote sensing in environmental monitoring is evident in its diverse applications. From tracking deforestation, land-use changes, and urban expansion to assessing soil health, water quality, and biodiversity, remote sensing contributes to informed decision-making and sustainable resource management. The technology is instrumental in disaster response, providing timely information for mitigating the impacts of natural events such as floods, wildfires, and hurricanes. The integration of advanced technologies, including machine learning algorithms and data analytics, enhances the analytical capabilities of remote sensing. These tools facilitate the extraction of meaningful insights from vast datasets, automating the process of feature identification and change detection. Additionally, the ongoing development of hyper spectral and high-resolution sensors continues to push the boundaries of remote sensing, offering even finer details and more precise measurements.

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