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8. Remote Sensing with Different Types of Sensors and Platforms

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Abstract:

Remote sensing, a pivotal technology in contemporary Earth observation, involves the acquisition of information without direct physical contact through the emission and measurement of radiations. This paper provides an in-depth exploration of remote sensing, tracing its origins, and delineating the evolution of its technologies.

The discussion encompasses the classification of sensors into photographic and non-photographic types, as well as active and passive functionalities. Infrared radiations are further categorized into visual IR, near IR, and mid IR. The role of scanners, particularly multi-spectral scanners, is elucidated, with a focus on whiskbroom and push broom scanners, exemplified by LANDSAT MSS and SPOT HRV. The paper navigates through various platforms employed in remote sensing, encompassing ground-based (including handheld devices and towers), airborne (such as balloon platforms, airships, and aerostats), and space borne platforms (satellites and rockets). Altitude ranges and orbits, including geo-synchronous and sun-synchronous orbits, are detailed, emphasizing the significance of each platform in different applications. The conclusion underscores the refinement of remote sensing technologies, acknowledging challenges and underscoring the promising future of this field. As technology advances, remote sensing is poised to play an increasingly vital role in diverse sectors, providing precise data and interpretations. This paper offers a comprehensive exploration of remote sensing, from its historical foundations to its current applications, setting the stage for future developments and advancements.

8.1 Introduction:

Remote sensing is the process of acquiring information or data about an area or any object without any physical contact but with radiations that are emitted or reflected back at a certain distance (Reddy et al. 2023). In detailed version, it is the acquisition of information about an object on earth's surface or on any other planets by emitting some radiations on it and measuring the time and distance taken to get back the reflectance of those radiations.

In a simple way, it is the extension of observation and recordings of the human eyes. The term "Remote Sensing" was coined by Evelyn Pruitt, a geographer who has been worked under the United States Office of Naval Research. But as active remote sensing technology, it was used by Westinghouse under the sponsorship from United States Air Force for the first time in a side-looking airborne radar system in the year of 1954. Later, the world was surprised when the Soviet Union launched the world's first artificial satellite- "Sputnik" on 4th October,1957. Typically, satellites are used for a wider area observance by international security forces, agricultural land researchers, meteorological departments, National Disaster Response Force (NDRF) of India, and many other organizations.

8.2 Sensors:

Sensors are the devices that records the wavelengths of energy. In other words, it records the amount of Electro-Magnetic Radiation (EMR) emitted or reflected back by the object (Maram et al. 2023). Basically, sensors are mounted on a platform for an ease movement. Based upon the form of data output, sensors are classified into two major types – (i) Photographic sensors (analogue) and (ii) non-photographic sensors (digital) (National Council of Educational Research and Training, Book-Practical Work in Geography, Chapter-7: Introduction to Remote Sensing)

8.2.1 Types of Sensors:

Active sensors and Passive sensors are the main two types. Active sensors emit artificial energy on targets and measure the number of reflected signals, while passive sensors detect the radiations emitted by the target objects naturally (Aggarwal 2004). Scanning electron microscopes, radar, x-ray, GPS are examples of active sensors. Photographic, thermal, electric field sensing, chemical-based sensing, are some of the passive sensors. Infrared and seismic light comes under both active and passive sensors. Infrared radiations are again classified as:

- Visual IR
- Near IR
- Mid IR (Zhu et al. 2018).

8.3 Scanners:

In general, scanners consist of a mirror attached with a detector and they combined called as a reception system. Non-photographic sensors are the scanners used in remote sensing technology and are called Multi Spectral Scanners (MSS).

8.3.1 Multi-Spectral Scanners:

These are line scanning devices to observe earth's orbital tracks. A radiometer inside these scanners acquires images simultaneously in a way that images of various wavebands can be obtained at the very same time.

They measure the reflected solar radiation in different spectral bands such as red, green, blue and near infrared bands. MSS are sub classified into two types namely, Whiskbroom scanners and Push broom scanners.

A. Whiskbroom Scanners:

Whiskbroom scanners are also known as mirror or across-track scanners. The reception system of these scanners consists of a mirror and a single detector. They observe across the track of earth's orbit as they scan only in forth and back motion.

As a rotating mirror is used to reflect light onto the single detector, it is also referred as Spotlight scanners. Instantaneous Field of View (IFOV) can be achieved through this scanner as it can be placed at a particular dimension to scan a particular area on the earth's surface. It means, the total extent of the oscillating sensor is equal to the total field of view of the scanner.

Example: LANDSAT MSS

B. Push Broom Scanners:

Push broom scanners are referred as along-track scanners. It has a number of detectors arranged in a linear array as all small areas on the surface can be observed with the detectors. The scanning direction and the line of flight is parallel to each other.

A major advantage of this push broom scanner is that simultaneous viewing of all scan lines from all arrays is possible so that every single information of every small area is covered and stored.

Example: SPOT HRV

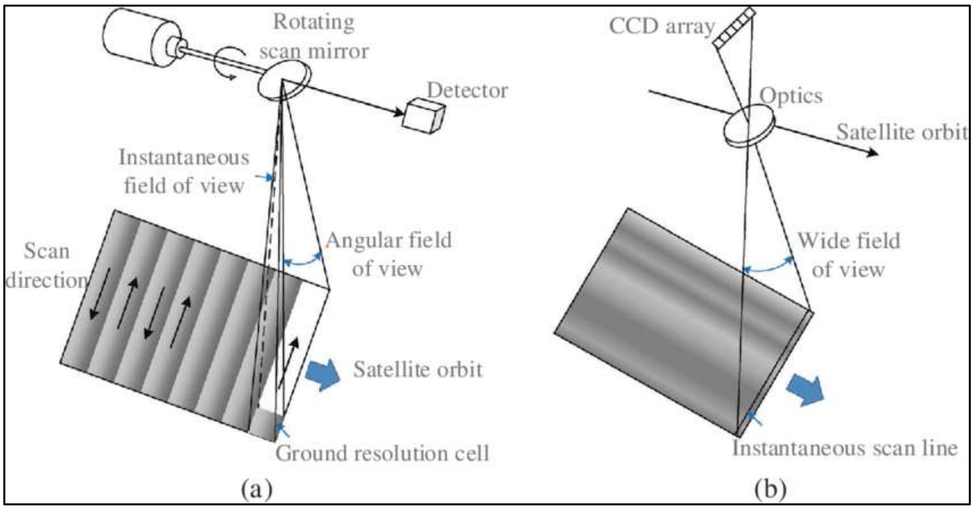


Figure 8.1: Multi-Spectral Scanners source: (Kang et al. 2017)

8.4 Platforms:

A platform used in remote sensing is a stage in which photographical instruments such as camera or sensors are placed or built in a way of investigating or acquiring data about a target. In simple words, a platform is a technically built base upon which other technologies are mounted or developed. Both manned and unmanned platforms are used in remote sensing.

8.4.1 Types of Platforms:

A. Ground Based Platforms:

Ground based platforms include hand held devices such as tripods in case of small sensor application usages. Towers, cranes are other such platforms which are more stable to mount camera/sensors to cover a large target area. They are operated by mobile hydraulic systems for the extension of height when needed for easy calibration and quality control. These types of platforms are used in long-term monitoring of terrestrial features as they can monitor even inside high canopy forests.

Cherry Picker hydraulic platform which can extend up to 15 meters are used in carrying spectral reflectance meters and other such photographic systems. Portable Masts are another type of ground-based platforms which are used in supporting cameras and sensors for testing and are portable to the place wherever needed. But the major disadvantage of this masts is that they are difficult to stabilize during storms.

B. Airborne Platforms:

These are flying platforms in atmosphere to cover a swath area of investigation and surveillance. They can be operated by either batteries or solar power for a longer existence. Under airborne class of platforms, there comes a series of sub-classifications based on their altitude range of flying and operating systems.

- **Balloon Platforms:**

When compared to towers and cranes, these reduces the shadowing effects as they have a higher elevation angle. Availability of balloon platforms can vary with its shape, size and performance levels.

These can run with a low acceleration which exhibits less vibrations and requires no power. As they require less altitude range covers than any other aircrafts, they are placed at 22-40 km distance in the stratosphere from the earth surface. While considering altitude ranges, they have some other classifications:

a. HAP (High Altitude Platforms)
b. MAP (Medium Altitude Platforms)
c. LAP (Low Altitude Platforms)

LAPs cover up to 0.3-4 km altitude ranges so as they mostly consist of one or more tethered balloons along with Wi-Fi technology to share data with intelligence teams, emergency hospitals, and other disaster rescue communities at the time of any flood, earthquake, tsunami, landslide. As they are easy to build in a short period of time (1-day max.) and a convenient way of faster communication with a high survival capability, they are used widely.

- **Airships:**

Airships are untethered platforms which can move from one place to another place because of their propulsion systems. Relocation and flying around in a same location also possible with these types of platforms.

- **Aerostats:**

Aerostats are more stabilized balloon type among all, as it has three tethers connected. These tethers reduce the need for propulsion system and are called as “Waveguides”. For more strength, 63mm corrugated waveguides are most widely used which can extremely save energy. It can easily fly through the air as it has fins built in its side and back portions for stability purpose. Most attractive and technical thing is its aerodynamic body shape as it can withstand even in windy conditions. These types of balloons come under High Altitude Platforms (HAPs). As a preventive measure during rainy days, a lightning striker rod also built in it.

C. Space Borne Platforms:

Satellites and rockets are those space borne platforms well known for all so far. Most expensive and technical minds involved in making these platforms. Covering a largest area from far distance, i.e., space, is made with the help of these platforms. Sensors are mounted on the rockets, space shuttles or satellites which can go around the earth’s orbit for frequent radiometric calibrations and repetitive coverages. A partially automated computers are fixed in satellites for instant findings and calibration data storage and communicating. The altitude ranges of space borne platforms differ with each other as follows:

- Space shuttle: 250-300 km
- Space stations: 300-400 km
- Low level satellites: 700-1500 km
- High level satellites: about 3600 km

8.5 Orbits:

Orbits are the tracks in which the satellites travel. The direction of movement or path of a planet around the sun or moon around its planet is called “Orbit”. Every planet in the solar system has its own orbit path. It looks stationary from the earth surface because of its inclination angle (i=0). There are two such orbits, (i) Geo-synchronous orbit and (ii) Sun-synchronous orbit.

- **Geo-Synchronous Orbit:**

Altitude level of this orbit ranges about 30,000 km at which weather-based satellite stands are made to move along with the earth's rotation rate (1,037 mph). These satellites capture the images in rectangular scenes for a detailed view and interpretation.

Example: NOAA (National Oceanic and Atmospheric Administration), GOES (Geostationary Operational Environmental Satellite) which has been sent to two directions called GOES-16 in East and GOES-17 in West direction.

- **Sun-Synchronous Orbit:**

This covers an altitude range up to 700 km and satellites sent for land monitoring purposes are made to travel in this orbit. The orbit pathway appears to be the same as sun's when seemed from its perspective. The images captured by these satellites are broken into rectangular scenes for interpretation as it captures a swath area in series.

Example: IMS-1, Cartosat-1, Cartosat-2, 2A, 2B, 2C, 2D respectively, HySIS, IRS-1A, etc.

8.6 Applications of Remote Sensing in Agriculture:

Remote sensing offers the advantage of repeatedly providing information without the need to physically sample crops, thus preserving them for further use in precision agriculture (Dutta et al., 2015). It's a cost-effective method for gathering data over large geographic areas. In India, satellite remote sensing primarily focuses on estimating agricultural acreage and crop production.

The technology has the potential to revolutionize global agricultural resource detection by leveraging the biophysical characteristics of soils and crops (Estel et al., 2018).

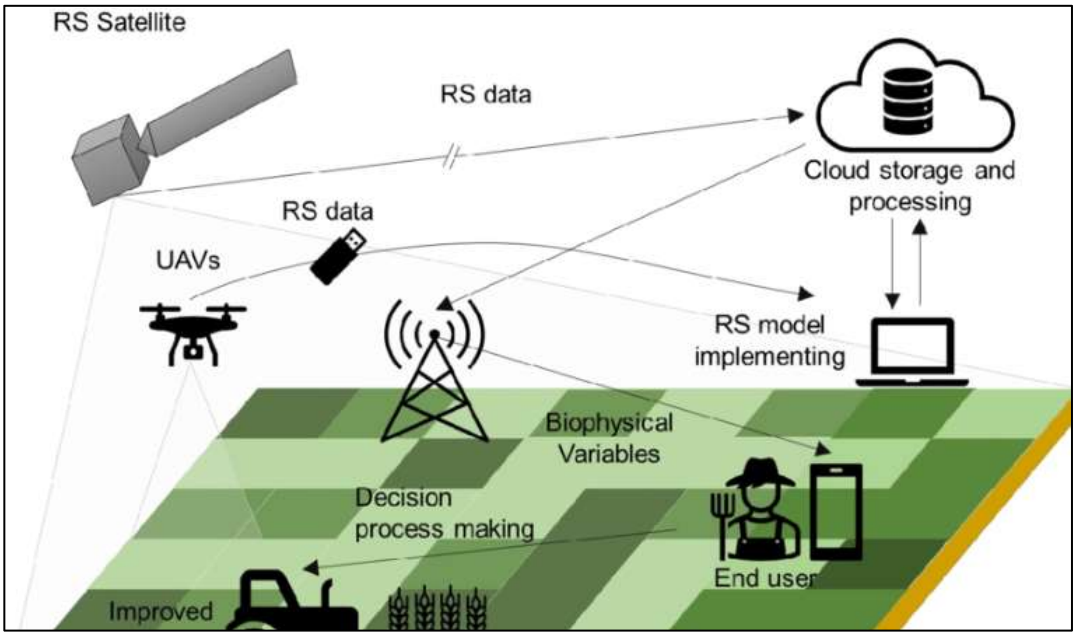
Remote sensing data from satellites serves various purposes, including estimating yields (Doraiswamy et al., 2005; Bernerdes et al., 2012), detecting stress (Gu et al., 2007), identifying disturbances, and tracking crop phenology (Sakamoto et al., 2005). When combined with GIS, remote sensing becomes even more powerful, allowing for the creation of informative spatial-temporal layers.

These layers find applications in diverse fields such as flood mapping, hydrological modelling, urbanization monitoring, land use adjustments, crop growth monitoring, and stress detection (Kingra et al., 2016).

The primary utilization of land, water, and biological resources worldwide is agriculture. For about 70% of the population, it is their primary source of income. Right now, increasing productivity to feed the world's expanding population and minimizing environmental damage from input-intensive agriculture are day agriculture's two main concerns. Sustainable agriculture may now be achieved in the following ways:

- Expand the area used for agriculture by locating cultivable wastelands and marginal areas; Boost cropping intensity by using improvised crops
- Utilizing techniques like as farming on fallows during and after the harvest season
- Boost production by offering inputs for soil fertility retention and enhancement, site-specific agricultural management, and expanding the area under high-yielding varieties (HYVs).
- Maintaining biodiversity;
- Building infrastructure that may be used for irrigation.

Field experiments preceded district-level estimations in the agricultural applications' development, which eventually led to an operating national program. One of the main agricultural initiatives in the nation, the Crop Acreage and Production Estimation (CAPE) program, has been extremely effective in utilizing remote sensing data (Navalgund and Kasturirangan 1983).



Picture source: https://www.linkedin.com/pulse/remote-sensing-agriculture-harshni-s-r/

Figure 8.2: Applications of Remote Sensing in Agriculture

8.6.1 Observation of Vegetation Canopy:

Remote sensing plays a critical role in agricultural classification, crop acreage estimation, and yield assessment. Various research techniques have utilized aerial imagery and digital image processing, reduced human efforts while enhanced precision in estimation (Kingra et al., 2016).

Hyperspectral data offers significant potential for improving characterization, classification, and modelling in crop and vegetation mapping compared to multispectral broadband approaches. The term "remote sensing" is widely recognized in this context (Thenkabail et al., 2011). The Normalized Difference Vegetation Index (NDVI) is commonly used for assessing vegetation condition and has become a widely adopted metric (Calvao and Palmeirim, 2004, Wallace et al., 2004). Efforts have been made to develop additional indices that minimize the influence of soil and atmospheric conditions on spectral observations. For instance, the Soil Adjusted Vegetation Index (SAVI) is an example of a vegetation index designed to mitigate the impact of soil on remotely sensed vegetation data (Bernardes et al.,2012).

8.6.2 Evaluation of Crop Condition:

Remote sensing provides timely spectral information that facilitates the analysis of crop health. Changes in the biophysical indicators and physiological processes of plants under stress can alter their spectral characteristics, enabling the remote detection of stressors (Prasad et al., 2006).

Regular crop monitoring throughout the growing season is necessary to identify and address potential production losses caused by various stressors. Factors such as soil moisture, planting dates, air temperature, and soil conditions influence crop development and progression.

For instance, high temperatures during pollination can adversely affect corn crop yields, emphasizing the importance of understanding temperature conditions during critical growth stages for accurate forecasting (Nellis et al., 2009). Drought poses significant challenges to agriculture and ecosystems, rendering land unusable and impacting human habitation, livestock, biomass potential, and plant diversity (Sankaran et al., 2010).

In recent years, satellite-based drought monitoring has become increasingly popular, with indices like the Vegetation Condition Index (VCI) and Normalized Difference Vegetation Value Index (NDVI) being widely recognized and utilized globally.

These indices help highlight agricultural drought in various ecoregions with diverse environmental conditions, aiding in early detection and mitigation efforts (Nicholson and Farrar, 1994; Kogan, 1995; Wang et al., 2001; Anyamba et al., 2001; Ji and Peters, 2003).

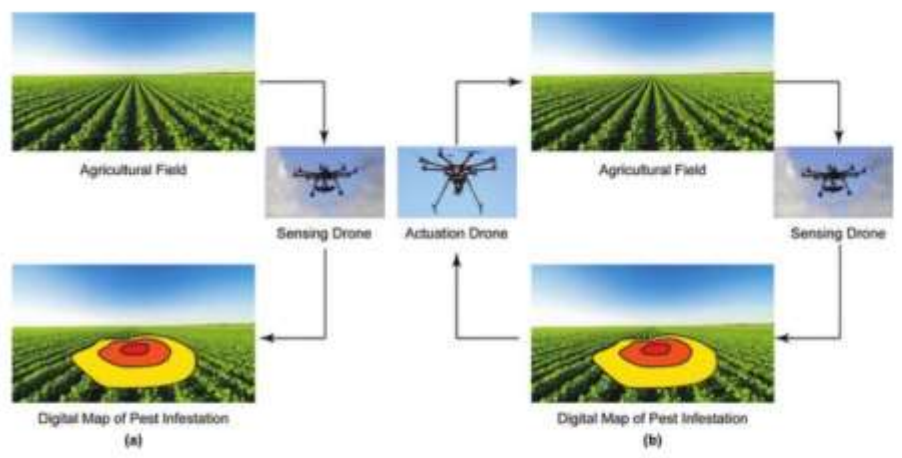
8.6.3 Irrigation Management:

Utilizing variable rate irrigation technology, such as the centre pivot system, in conjunction with remote sensing data can effectively identify variations within fields and optimize water application.

This approach aids in mitigating water stress resulting from both excessive wet and dry conditions, thereby promoting uniform high yields across the field while minimizing water and nutrient losses (Evans et. al, 2013; McDowell et. al, 2017).

Numerous indices and methodologies for precision water management have been devised and validated using remote sensing across optical, thermal, and microwave bands (Amani et al. 2016). For instance, Das et al. (2018) utilized a high-resolution land data assimilation system to create soil moisture and temperature maps, offering real-time data at a spatial resolution of 1 km across various soil depths and vegetation root zones. The advancement of hyperspectral bands, particularly in the thermal region, has significantly enhanced remote sensing's role in understanding crop-soil characteristics. Integration of this information with GPS technology holds promise for precision farming, facilitating more accurate and efficient agricultural practices.

A. Pest Management:



Picture source: Figure 8.3: (a) State-of-the-art open-loop remote sensing paradigm and (b) closed-loop IPM paradigm envisioned in this article. Sensing drones could be used for detection of pest hotspots, while actuation drones could be used for precision distribution of solutions. Adapted from Teske et al. (2019).

The interaction between electromagnetic radiation and plants is influenced by the wavelength of the radiation. The reflectance of plant leaves can vary significantly depending on their health and vigor, which can be measured and analysed (Luo et al., 2010). Healthy and vigorously growing leaves exhibit significant absorption by photoactive pigments, allowing for the identification of diseased leaves. Remote sensing methods have been employed to assess and monitor insect defoliation. By comparing the spectral responses to chlorosis (leaf and foliage yellowing) over time, it is possible to correlate, classify, and interpret these differences (Franklin, 2001). Remote sensing techniques are also used for detecting and mapping defoliation, characterizing pattern disruptions, and providing information for pest management strategies (Lee et al., 2010).

8.6.4 Limitations of Remote Sensing:

Most image processing tools rely on measuring surface physical properties like surface reflectance and temperature. However, a significant challenge in implementing image processing is converting digital images into these surface properties (Huang et al., 2018). Uncorrected and uncelebrated images make it difficult to obtain accurate output data, resulting in improper imaging. Analyzing remote sensing images requires specialized training, making it costly in the long run due to the need for additional training for technology users (Luo et al., 2010). Remote sensing technology can be expensive for analyzing small areas, especially for one-time analysis. Skilled human resources are essential for image data analysis and calibration. Generating large-scale maps from satellite data can be challenging. Dynamic image processing often necessitates repetitive aerial photographs, which can incur high costs. The selection, mounting, and timing of sensors are determined by humans, which may introduce errors if not carefully managed. Regular calibration of remote sensing equipment is essential to ensure accurate data collection; failure to do so can result in uncelebrated remote sensing data.

8.6.5 Remote Sensing in Precision Agriculture (PA):

Nearly every aspect of precision agriculture, from soil preparation to harvesting, can benefit from remote sensing. The landscape of precision agriculture has evolved with the proliferation of high spatial resolution, multi-temporal satellite data, affordable UAVs, and commercially accessible ground-based proximity sensors (Desai et al., 2023). Researchers have explored the potential applications of remote sensing in precision agriculture using various cutting-edge techniques, including empirical, regression, and various machine learning approaches (Ayushi et al., 2023). Additionally, numerous vegetation indices have been developed and tested for their utility in precision agriculture operations such as variable fertilizer management, irrigation scheduling, disease control, weed mapping, and yield forecasting. However, several challenges must be addressed before remote sensing technologies can be widely adopted in both commercial and non-commercial agriculture. Despite the availability of satellite data, processing them for practical applications often requires significant technical expertise and skill, including image pre- and post-processing (Smitha et al., 2023). Many precision agriculture tasks, such as weed and disease management, demand data with fine spatial resolution (at the centimeter scale) and high spectral and temporal precision (e.g., daily). However, most publicly available satellite data do not meet these criteria. Moreover, satellite imagery may not be suitable for use on cloudy days or under conditions of irregular or fluctuating solar irradiance.

8.7 Conclusion:

In this paper, we discussed about the technologies involved in remote sensing along with their challenges which are notable and are need to be addressed for future developments. Remote sensing is being an essential tool with comprehensive knowledge and accurate interpretations used in vast platforms. As technology keeps improving, remote sensing will also keep developing in future. Nowadays, advanced versions of sensors are developed for accurate calibrations with intrinsic parameters but with partial automations. This discussion led us to conclude that, the remote sensing has a refined prospective on our future.

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