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APPLICATIONS OF REMOTE SENSING IN HORTICULTURE : A REVIEW

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ABSTRACT

The sophisticated technique related to remote sensing (RS) helps collect and update data for the creation of scientific management plans. Numerous sensor types, including cameras, magnetic sensors, laser meters, and microwave radiometers, record electromagnetic readings to provide precise, extensive information about the Earth's surface and atmosphere. Aircraft or satellites can collect remotely sensed data that includes crop electromagnetic emittance and reflectance information. This data can be used to determine soil conditions, growth stages of plants, infestation by weeds, and other topics. Research programs for site-specific plants management can experience substantial improvements with this knowledge, which is also reasonably priced. In order to take use of the available methods for effective crop management, a quick review of the possible application of RS approaches in horticulture is given.

***Keywords*:** Horticulture, mapping, near infrared, remote sensing, aircraft

Introduction

Fruits, vegetables, flowers, spices, plantation crops, and medicinal plants are examples of horticultural crops that are important to the nation's economy, employment, health, and food and nutritional security. The growth of horticulture has been one of the main areas of focus in the agriculture industry in recent years. Timely and accurate information about the nature, extent, and geographical distribution of horticulture land resources, as well as their potential and limitations, is crucial for the sustainable maximum use of these resources. Crop growth and production are influenced by various factors, including soil properties (e.g., pH, nutrient levels, drainage efficiency, texture, permeability, and water-holding capacity), climate variables (e.g., temperature, rainfall, solar radiation, chilling hours, growing degree days), land-use characteristics (e.g., soil properties, topography), plant population density, fertilization, irrigation practices, and pest infestations.

To effectively manage and optimize agricultural outputs, a comprehensive geographic database must encompass all these physical and environmental elements (Schumann & Zaman, 2003; Panda *et al.*, 2011).

Remote Sensing (RS) systems provide precise databases on the spectral behavior of crops and their growing environments, including soil and atmospheric conditions. This is due to their consistent, synoptic, multispectral, and multitemporal coverage of regions. RS systems are widely utilized in various agricultural applications, such as crop inventory, crop condition assessment, crop production forecasting, fruit quality evaluation, leaf area index estimation, crown cover analysis, monitoring of horticultural crop growth and health, as well as drought and flood damage assessment. They are also valuable for managing range and irrigated lands (Min *et al.*, 2008a; Mondal & Basu, 2009).

In order to successfully implement site-specific crop management (SSCM), determine fruit yield, quantify and schedule precise and appropriate fertiliser, irrigation needs, and pesticide application for pest and disease management, orchard delineation and spatial analysis using geospatial technology can yield additional information for management and decision making. Additionally, it has the potential to optimise resources and increase net returns (Ray *et al.,* 2006; Panda and Hoogenboom, 2009). Viticulture decision support products pertaining to irrigation planning, vine balance, and field uniformity monitoring were developed using high-resolution multispectral satellite imagery (Johnson *et al.,* 2003).

In precision agriculture, crop yield is arguably the most crucial piece of data for crop management. The majority of harvesters lack yield monitors, despite their rising use and commercial availability. Additionally, issues such as fertilizer deficits, water stress, and pest infestations must be addressed during the growing season, whereas yield monitor data is primarily useful for post-season management. Both within-season and after-season management may be possible with RS imagery acquired during the growth season. Furthermore, in situations when yield monitor data are unavailable, yield maps produced using RS imagery might be utilised as a substitute (Li *et al.,* 2010).

Remote sensing is the scientific technique used to gather information about objects or areas from a distance, often via aircraft or satellites (NOAA). This practice involves measuring the radiation reflected and emitted by a location to identify and monitor its physical characteristics. Remote sensing systems consist of four key components: the energy source, transmission line, target, and satellite sensor, all of which are essential for capturing and recording data about a region from afar (Singh *et al.*, 2014). Sensors mounted on aircraft or satellites detect transmitted signals, and by analyzing the electromagnetic radiation, they categorize various landforms or objects on Earth.

There are two types of remote sensing: active and passive. Active remote sensing occurs when the sensor itself emits a signal and detects its reflection, while passive remote sensing relies on the sensor detecting reflected sunlight (Schowengerdt, 2007; Schott, 2007). Remote sensing enables the estimation of area coverage, mapping, and classification of land use and land cover elements, such as vegetation, soil, water, forests, and human-made structures (Singh *et al.*, 2014).

Using satellite imagery, remote sensing allows for the extraction of vegetation data based on image attributes like color, texture, tone, pattern, and association. The near-infrared band (>700 nm) in satellite images is invisible to the human eye but is highly sensitive to leaf water content and cell structure, leading to greater reflection from healthy vegetation. Chlorophyll absorbs red and blue light and reflects green, which gives leaves their characteristic color. These spectral features represent the unique properties of matter (Singh *et al.*, 2014).

As a result, significant information about vegetation, including stress, damage, and pest or disease infestations, can be rapidly and cost-effectively obtained, and most importantly, without causing harm, by measuring the reflectance in the visible and infrared bands (VIR) (Zhang *et al.*, 2008; Naidu *et al.*, 2009).

Fundaments of remote sensing

Process of remote sensing

The remote sensing process involves the interaction between incoming radiation and the objects or targets being studied. This is demonstrated through the use of imaging systems, which incorporate the following seven components:

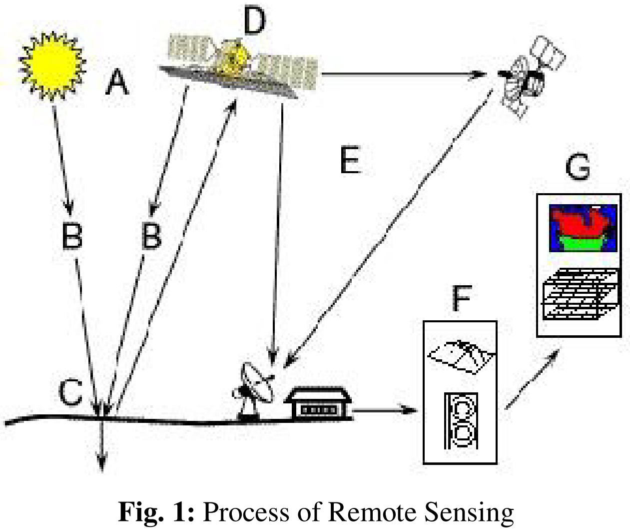

Fig. 1: Process of Remote Sensing

1. **Source of Energy or Light (A):** The first requirement for remote sensing is an energy source that illuminates or provides electromagnetic energy to the target of interest.
2. **Radiation and Atmosphere Interaction (B):** As the energy travels from its source to the target, it interacts with the atmosphere. This interaction occurs again as the energy moves from the target to the sensor.
3. **Interaction with the Target (C):** Depending on the characteristics of the target and the radiation, the energy interacts with the target after passing through the atmosphere.
4. **Recording of Energy by the Sensor (D):** A sensor, which is remote and not in direct contact with the target, collects and records the electromagnetic radiation after it has been reflected or emitted by the target.
5. **Transmission, Reception and Processing (E):** A sensor, which is remote and not in direct contact with the target, collects and records the electromagnetic radiation after it has been reflected or emitted by the target.
6. **Interpretation and Analysis (F):** To obtain information about the illuminated target, the processed image is analyzed either visually or through digital/electronic methods.
7. **Application (G):** The final step in the remote sensing process involves applying the knowledge gained from the imagery to gain a deeper understanding of the target, uncover new insights, or address a specific problem.

Remote Sensing Platforms

To collect and record energy reflected or emitted from the target, the sensor must be positioned on a stable platform, away from the target. Remote sensor platforms can be situated on the ground, on a satellite or spacecraft outside Earth's atmosphere, or on an aircraft or balloon.

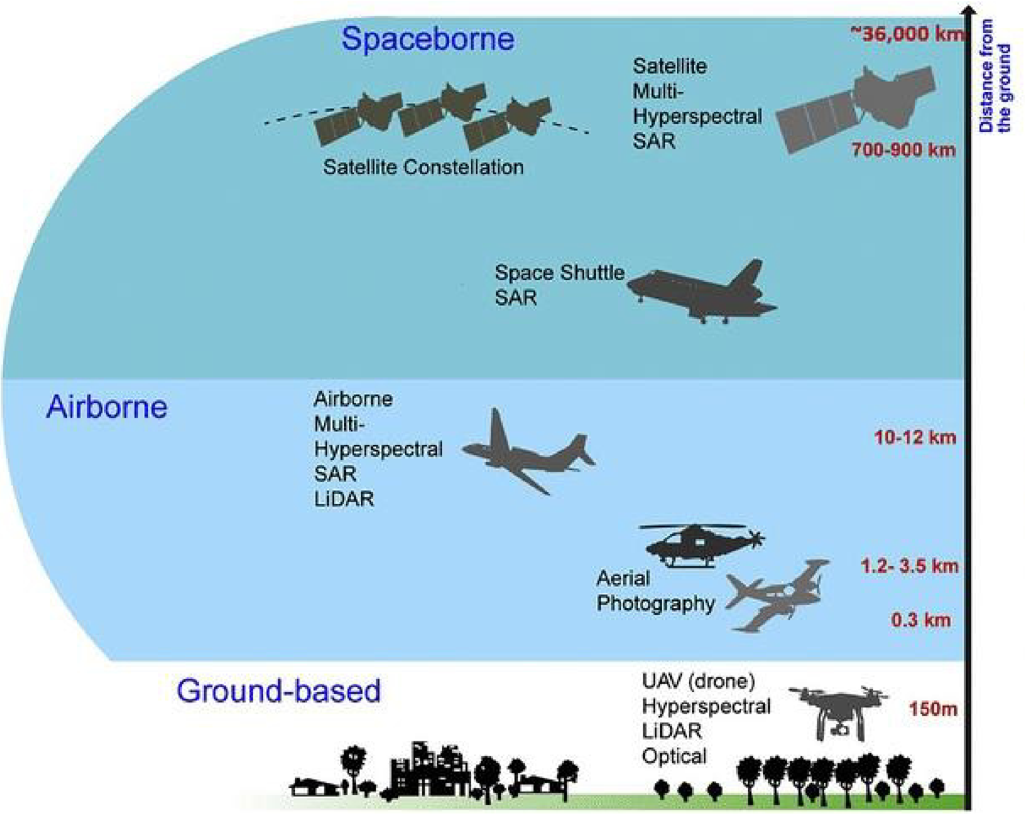

Fig. 2: Remote Sensing Platforms

In contrast to airborne or space-based sensors, ground-based sensors are used to capture detailed information about the surface. It is sometimes feasible to better grasp the information in the imagery by using this to better characterise the target that the other sensors are imaging. It is possible to position the sensors on a crane, big building, ladder, etc. Though helicopters are infrequently utilised, fixed wing aircraft make up the majority of aerial platforms. Aircraft are used to collect data from nearly any part of the Earth's surface at any time, capturing highly detailed images. In space, remote sensing is typically carried out from satellites, though it can also be conducted from the space shuttle.

Types of Remote Sensing

1. Remote sensing can be classified into two types based on the energy source: passive remote sensing and active remote sensing.

a. Passive sensors can only detect energy when natural sources of energy are present. For reflected energy, this can only occur when the Sun is illuminating the Earth.

b. Active sensors generate their own energy source for illumination. The sensor emits radiation toward the target, and the radiation reflected from the target is then detected and measured by the sensor.

2. Based on the range of the electromagnetic spectrum, remote sensing can be classified into three types.

a. **Visible Remote Sensing:** It can measure wavelengths ranging from 300 to 3000 nm, encompassing the visible, near, middle, and short-wave infrared regions.

b. Thermal Remote Sensing: The wavelength range it measures is 3000–14000 nm. It captures the energy that the planet emits.

c. **Microwave Remote Sensing:** It can measure wavelengths between 1 mm and 1 m. This kind of remote sensing may function in any weather or environmental state because it uses active sensors.

GIS

Computer-based systems known as geographic information systems handle almost any kind of feature-related data that may be accessed by geographic location. Both locational and attribute data regarding the features can be handled by these systems.

Constituents of GIS

GIS consists of the following six components

1. **Hardware:** Also included are powerful computers, printers, output devices such as monitors, input devices, and ample disk space to store the large GIS datasets.
2. **Software:** It refers to both free and commercial software packages that enable GIS users to perform functions such as manipulating, storing, querying, and analyzing spatial and non-spatial data.
3. **Data**: It refers to all spatial and non-spatial data stored digitally on the computer. A GIS can display this data as maps, graphs, or other visuals, helping users to interpret and navigate through large volumes of information.
4. **Methods:** It includes the formulas, statistics, analyses, and algorithms used to transform data into meaningful information, facilitating its easy interpretation.
5. **People:** It pertains to the users of GIS, encompassing both the general public and experienced GIS professionals.
6. **Network:** It refers to both the computer network and the social network.

- **Energy Source or Illumination (A)** – The first requirement for remote sensing is an energy source that illuminates or provides electromagnetic energy to the target of interest.
- **Radiation and the Atmosphere (B)** – The energy interacts with the atmosphere as it travels from its source to the target. This interaction may occur again as the energy moves from the target to the sensor.
- **Interaction with the Target (C) -** Depending on the characteristics of the target and the radiation, the energy interacts with the target after passing through the atmosphere.
- **Recording of Energy by the Sensor (D) -** A remote sensor, not in direct contact with the target, is required to collect and record the electromagnetic radiation after it has been scattered or emitted by the target.
- **Transmission, Reception, and Processing (E) -** The energy recorded by the sensor is typically transmitted electronically to a receiving and processing unit, where it is converted into either a digital or printed image.
- **Interpretation and Analysis (F) -** To gather information about the illuminated target, the processed image is analysed either visually or through digital/electronic methods.
- **Application (G) -** The final step in the remote sensing process involves using the extracted information from the imagery to gain a deeper understanding of the target, uncover new insights, or address a specific problem.

Application of Remote Sensing

Applications of remote sensing in horticulture

- Precision farming
- Surveillance of farms
- Crop yield potential assessment
- Sampling procedure (soil and crop)
- Improving assessment of irrigation water use at regional scale

- Field-based plant phonemics
- Plant abiotic stresses (water, heat, nutritional, pollution stress)
- Plant biotic stress (diseases, weeds)
- Crop water status
- Canopy volume/crop biomass detection, crop cover fraction
- Light penetration of the canopy
- Application of canopy measurements
- Soil nutrients and other soil characteristics
- Visible (VIS)/NIR spectroscopy
- Mapping soil types
- Wind and water erosion, flooding
- Monitoring the extent and type of vegetation
- Assessing water resources

Table 1 : Classification of fruit crops via remote sensing

S. No	Crop	Distinguishable	High absorption	Highest reflection rate	Reference
1.	Lingon blueberry	–	–	Very low reflectance compared to grasses and forest trees	Rao (2007)
2.	Blueberry	680–700 nm (red) and 800–900 nm (NIR)	680–700 nm (red) and 800–900 nm (NIR)	-	NASA, Virginia
3.	Red blush citrus	600–650 nm (green)	950-1000 nm(NIR)	1000-1150 nm(NIR)	Bowker *et al.* (1986)
4.	Orange trees	650-700 nm	650-700 nm	800-1100 nm(NIR)	Bowker *et al.* (1986)
5.	Prickly Pear	700 nm	700 nm	750-900 nm(NIR)	Bowker *et al.* (1986)
6.	Piches	650 nm	650 nm	750-1200 nm(NIR)	Other digital image characteristics such as the textural feature should be used to distinguish peach trees from orange trees
7.	Olive Tree Orchards	Clustering assessment techniques	-	-	Bowker *et al.* (1986) Torres *et al.* (2008)
8.	Citrus, stone fruits, and grapes	Decision tree-based Classification	-	-	

Soil and drainage maps

Soil maps: Separate soil samples are taken using the grid sampling technique from grids of uniform size that are spread out across the field. The potential for variation in soil types within each grid is an issue with this sampling technique. It is far more difficult to identify soil properties within the grid for crop input management reasons because of this unpredictability. Smaller grid sizes are required to minimise this issue, which necessitates taking a lot more soil samples for a greater number of grids.

Drainage maps: It has been demonstrated that colour infrared (CIR) aerial photos are a useful tool for identifying unknown subsurface tile lines. After being digitalised for pre-processing, the image data is geo-referenced with ground control points. Based on the kind and moisture content of the soil, the CIR images display varying shades of grey. Soil moisture content in dry soils, which exhibit higher reflectance, can be differentiated from wet soils that have lower reflectance by removing spectral reflectance variations caused by soil type. The final graphic displays the locations of the tile lines as well as their functionality.

Monitor crop health: Farmers can keep an eye on the status and health of crops thanks to remote sensing data and photos. Reflected light in the infrared/ultraviolet range can be detected by multispectral remote sensing. The plant leaf's chlorophyll absorbs the majority of the sun's red and blue light waves while reflecting green light. Compared to healthy plants, stressed plants reflect different light wave lengths. Healthy plants reflect more infrared radiation from their spongy mesophyll tissue than stressed plants. Farmers will have more time to assess the issue and implement a solution if they can identify plant stress regions before they become apparent.

Estimation of crop canopy: Crop canopy assessment is crucial in horticulture because it determines the appropriate amount of fertilizer, pesticides, and other chemicals to be applied. Furthermore, canopy volume indicates crop health and expected yield (Smart 1999); (Schumann *et al.,* 2008). The majority of horticultural crops were eventually left unaccounted for, even instances when the canopy cover of large crops was calculated using remote sensing techniques for years (Thomas *et al.,* 2008). NDVI values obtained through remote sensing are linked to the canopy cover of major horticultural crops in commercial fields, which have different planting patterns and stages of maturity (Thomas *et al*., 2008).

Water stress: There has been very little success using remote sensors to assess soil moisture directly. Direct measurements of soil moisture have been made using Synthetic Aperture Radar (SAR) sensors, which are sensitive to soil moisture. To eliminate surface-induced noise from SAR data, such as vegetation, topography, and soil surface roughness, significant processing is needed. A decline in crop evapotranspiration rate is a sign of water stress or other agricultural issues like insect infestation or plant disease. Field changes have been measured by using a crop water stress index (CWSI) model with remote sensing photos.

Weed management: The use of aerial remote sensing for tracking and identifying scattered weed populations has not yet shown itself to be very beneficial. Among the challenges are the fact that weeds are frequently scattered throughout spectrally similar crops and thus detection and identification will require very large-scale, high-resolution photos. Remote sensors are mounted directly on the sprayer apparatus in order to detect and identify weeds using machine vision technology systems. The crop is in close proximity, allowing for extremely high spatial resolutions. With the real-time capabilities required to operate sprayer equipment, machine vision systems can be deployed in the field.

Insect detection: Insects have not been reliably identified and located directly using satellite or aerial remote sensing. Traditionally, annual crops have not employed indirect insect detection via identifying plant stress. By the time remote sensing detects plant stress, the economic harm level for treatment is typically exceeded. In order to identify insects in time for cost-effective and efficient chemical treatments, entomologists prefer to do direct field scouting.

Nutrient stress: High resolution colour infrared aerial photos can be used to identify areas of plant nitrogen stress in the field. The reflectance of visible red, visible green, and near-infrared wavelengths shows a strong correlation with the amount of nitrogen applied in the field. A reliable indicator of real crop production is the red canopy reflectance.

Yield forecasting: Plant tissues reflect a significant amount of energy in the near-infrared (NIR) wavebands while absorbing most of the red light. The vegetation index (VI) is defined as the ratio of these two bands. Normalised Difference VI (NDVI) is calculated by dividing the difference between the red and NIR values by their sum. NDVI data derived from multispectral pictures has been connected with production yields, biomass, crop height, and leaf area index (LAI) for crops such grain sorghum. During the growing season, this data must be paired with input from weather models to produce yield projections that are at least somewhat correct.

Soil Mapping: Another kind of map created with data from remote sensing is a soil map. When the amount of soil covered by plants is less than 30–50%, these maps can be created using satellite or airborne imagery. Maps of soil show uniform soil zones with comparable characteristics and growing conditions. These maps are helpful for locating soil moisture sensors, creating irrigation plans, and selecting soil sampling sites for in-depth soil investigations. One useful technique for mapping and forecasting soil degradation is remote sensing. The eroded portions of the soil are immediately identifiable on the photos because the soil layers that rise to the surface during erosion differ from non-eroded soils in colour, tone, and structure.

Land cover mapping: One of the most prevalent and important applications of remote sensing data is in land use and land cover analysis. Land use refers to human activities on the land, such as industrial areas, residential zones, and agricultural fields, while land cover describes the physical characteristics of the Earth's surface, including forests, grasslands, and paved areas. The initial step involves developing a land cover classification system, typically organized into various levels and categories.

One of the few nations in the world that employs land-based observations and space technology to produce frequent updates on agricultural production statistics for the purpose of supplying inputs to ensure sustainable crop output is India. The 1970 coconut withering experiment was the first recorded use of the remote sensing technique in India (Ray, 2016). Since then, Indian academics have contributed significantly to the development of in-house software and the expansion of digital image processing. According to Navalgund and Ray (2000), Panigrahy and Ray (2006), Navalgund *et al.* (2007), some of these applications include horticultural development, crop acreage and production estimation, precision farming, cropping system analysis, agricultural water management, drought assessment and monitoring, watershed development, soil resources mapping, potential fishing zone forecast, climate impact on agriculture, and more. Following successful trials and thorough testing to solve real-world issues encountered in the field, some of these apps are moved to user departments, eventually resulting in the institutionalisation of remote sensing applications nationwide (Parihar and Manjunath, 2013). The inventive things that researchers may accomplish with satellite photos or remote sensing techniques are truly astounding.

Few of them are listed below

Crop insurance: The climate has become extremely unpredictable and damaging due to the evident effects of global warming and climate change; in these situations, farmers who experience crop loss as a result of abrupt weather changes may find crop insurance to be a blessing. However, there are cases of insurance fraud as well. Insurance firms can verify seeded crops to detect fraud by utilising the red and infrared bands of satellite photos in conjunction with the Normalised Difference Vegetation Index (NDVI) (source: http://gisgeography.com).

Soil moisture: Soil moisture plays a crucial role in the water cycle, weather prediction, and the monitoring of droughts and floods. Remote sensing techniques, employing both active and passive sensors from space, are valuable for evaluating soil moisture conditions. Passive sensors capture naturally emitted electromagnetic waves, providing high accuracy but lower spatial resolution. In contrast, active sensors emit their own signals and measure the reflected backscatter, yielding high spatial resolution but lower accuracy. To harness the benefits of both methods, NASA launched the Soil Moisture Active Passive (SMAP) project (Source: http://gisgeography.com).

Crop stands: Remote sensing is highly effective for identifying crop stands, allowing for accurate estimation of the area covered by crops and their overall production.

Crop conditions: Using the NDVI, remote sensing can be a useful technique for determining crop condition. In horticulture, healthy vegetation is identified by near-infrared radiation. Good vegetation absorbs red and blue light and reflects green light. Changes in canopy water stress, chlorophyll content, and green biomass abundance all affect the NDVI. The technique is simple to use and works well for predicting soil characteristics, particularly in situations where there is exposed soil within the foliage and the vegetation is not extremely dense. Equation 1 is the standard formula used to calculate the NDVI:

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{NIR} + \mathrm{RED}} \qquad (1)$$

Spectral reflectance in the red (visible) and near-infrared bands is represented by RED and NIR, respectively. Since green biomass absorbs radiation from photosynthetically active vegetation, this vegetation index shows a strong correlation with various vegetation parameters (Hao., 2011; Jensen, 2000; Tucker, 1986). Deb *et al.* (2014) also suggest that hyperspectral reflectance data obtained from canopy reflectance can serve as a highly accurate source for estimating crop production.

Crop classification: Multispectral photography is an effective tool for distinguishing horticultural crops from other green-leaved bushes, shrubs, and trees that have nearly identical spectral signatures to healthy vegetation, by focusing on their color patterns (Dakshinamurti *et al.*, 1971). Unsupervised clustering for image segmentation can help identify fruit and nut trees from forest vegetation, especially in areas with unusual land cover, as these trees share similar spectral features (Panda and Hoogenboom, 2009).

Crop area estimation: Horticultural crops often face considerable fluctuations in both production and demand, resulting in a volatile market and pricing. As a result, accurate data on crop yield and acreage is essential for export and market planning. Remote sensing plays a vital role in assessing the supply situation. For instance, it can predict the acreage and productivity of crops like potatoes, which are grown in large, contiguous fields, with over 90% accuracy (Nageswara Rao *et al.*, 2004). However, due to the overlap of spectral signatures, estimating the area covered by mango orchards with trees older than five years is challenging (Usha *et al.*, 2013), a problem not encountered with younger mango trees.

Crop canopy measurement: The crop canopy of horticultural crops plays a vital role, as its size determines the amount of fertiliser, pesticides, and other chemicals to be applied. Additionally, the canopy volume offers insights into the expected yield and the overall health of the crop (Smart *et al.*, 2000; Schumann, 2008). While remote sensing methods have long been used to assess the canopy cover of key crops, many horticultural crops have historically been overlooked (Thomas *et al*., 2008). However, studies have shown that the canopy cover of significant horticultural crops in commercial fields, with varying planting patterns and stages of maturity, correlates with remotely detected NDVI (Thomas *et al*., 2008).

Yield estimation: Although remote sensing has proven to be an effective method for estimating the yield of various annual crops, its use for fruit trees and vegetables has been relatively scarce (Maja and Ehsani, 2010; Usha *et al*., 2013). A few studies have explored this application, such as research on the correlation between modified normalized difference vegetation index (NDVI) and leaf area index in processing tomatoes (Koller and Upadhyaya, 2005b), and predicting tomato yield using crop growth models and aerial imagery. Yang *et al.* (2008) utilized reflectance spectra and aerial photography to assess the physical traits and yield of cabbage. Citrus orchards were mapped by Whitney *et al.* (2002) and Zaman *et al.* (2006) using an automated yield monitoring system equipped with sensors and ultrasonic technology.

Detecting pest and disease occurrence: The two primary causes of output and, thus, financial losses in the horticulture sector are pests and illnesses. Remote sensing has proven to be a valuable tool in pest and nematode management as well as early disease detection by identifying changes in plant pigments, leaf damage caused by insects, and vulnerable areas of plants (Usha *et al*., 2013). Johnson *et al.* (1996) developed an aerial multispectral digital imaging system that related crop canopy reflectance and density to varying levels of phylloxera stress. Cook *et al.* (1999) utilized multi-temporal NIR videography to monitor the seasonal progression of the soilborne fungal complex and southern root knot nematode (Meloidogyne incognita Chitwood) in kenaf (*Hibiscus cannabinus* L.). Borengasser *et al.* (2001) demonstrated that the spectral reflectance of citrus leaves in the 600–700 nm wavelength range changed when citrus canker lesions appeared. Additionally, Hahn (1999) developed a prediction model for tomato late blight and mango anthracnose using the NIR band.

Monitoring abiotic stress: Remote sensing is an effective method for monitoring how plants respond to various abiotic stressors, such as drought, flooding, salinity, and temperature fluctuations. For instance, an increase in reflectance for wavelengths that are weakly absorbed will be seen if any abiotic stress results in the suppression of chlorophyll formation (Usha *et al.,* 2013). In 1993, Carter demonstrated that plants experiencing stress-induced chlorosis will have increased reflectance in the 690–700 nm range. With the recent establishment of the Mahalanobis National Crop Forecast Centre (MNCFC), an organisation within the Department of Agriculture & Cooperation, Ministry of Agriculture, remote sensing has become institutionalised in India. Through this institute, ISRO implements two of its programmes of crop forecasting and draught assessment besides other programmes related to assessment of agricultural activities (Ray *et al.,* 2014).

The National Remote Sensing Centre (NRSC) of the Indian Space Research Organisation (ISRO) employs Indian satellite sensors such as AWiFS and LISS-III/IV for post-harvest analysis, site suitability assessments, disease mapping, yield modeling, and monitoring year-to-year variations in fruit, vegetable, and plantation crop inventories. ISRO, the nation's space agency, has launched multiple sensors and satellites that contribute to the development of various agricultural applications at the national level by utilizing remote sensing data. Additionally, the Department of Agriculture and Farmers' Welfare has recently initiated a project called Coordinated Horticulture Assessment and Management using Geoinformatics (CHAMAN) to support the assessment and management of horticultural crops like onions, potatoes, and mangoes using geospatial technologies.

The program aims to develop action plans for horticultural development, including site suitability, infrastructure improvement, crop intensification, orchard rejuvenation, and aqua-horticulture. Its primary objectives are to estimate the area and production of seven key horticultural crops (potato, onion, tomato, chili, mango, banana, and citrus) across 180 districts in 12 major states. This will be achieved using satellite remote sensing data and Geographic Information System (GIS) tools. Geospatial applications for horticultural development and management planning (orchard rejuvenation, crop intensification, post-harvest infrastructure, site suitability, GIS database building, and aqua-horticulture) are additional elements. Additionally, the CHAMAN program aims to carry out several research projects on precision farming, disease assessment, and horticulture crop condition studies (Source: Mahalanobis National Crop Forecast Centre, New Delhi).

Here are several other significant projects launched by ISRO to monitor and evaluate horticultural production:

- The Coordinated Programme for Horticulture Assessment and Management through Geoinformatics (CHAMAN)
- Inventory of onion crops

- Inventory of plantation crops such as tea, coffee, and rubber
- Estimation of the total area and production of onion and potato crops
- ISRO has made significant progress in improving horticultural practices in the North Eastern states, including Sikkim, by mapping and characterizing existing "jhum" lands, identifying suitable areas for specific horticultural crops, and setting phased implementation priorities.

Some of the areas where ISRO has targeted to start their upcoming ventures are:

- Development of remote sensing techniques to spatially map sparsely distributed horticultural crops in hilly terrains
- Creation of a geodatabase for horticultural crops
- Selection of suitable wetland crops for feasibility analysis in aqua-horticulture
- Early detection and forecasting of various biotic and abiotic stresses
- Development of a crop insurance system using geomatics technology

Conclusion

While there are several benefits to using remote sensors to identify and research important crops, the majority of horticultural crops have not been included in those studies. Despite the significance of horticulture in the areas discussed in this study, including food security, health, social, and labour concerns, it is remarkable how little its operational management makes use of GIS tools. As demonstrated below, scientific output in the field of RS applications in horticulture is still quite restricted and, in its infancy, in keeping with the two previously mentioned features. However, the future of GRS in horticulture looks bright thanks to higher-resolution sensors and platforms, free-access collection imagery (such as Sentinel-ESA and Landsat-NASA), aircraft-mounted sensors, UAVs, computational processing power, fusion data the historical yield information., and the mayor's access to digital big data. The method of food demands and territory management, when combined with the context of human security, offers a fresh viewpoint for horticultural analysis and research. To engage the academic community and users with the potential of geospatial technology in horticulture, this contribution includes a brief review of experiences with the application of remote sensing in peri-urban production, along with elements pertaining to the significance of this field and some intriguing future perspectives.

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