5 Applications of Remote Sensing in Pest Monitoring and Crop Management

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Abstract

Precision agricultural skill has constructed and will still construct the road we are moving into this novel theory of precision agriculture. By increasing the inspection and appliance of inputs on the land, farmers are changing from a usual, standardized treatment of every agricultural land to a perfect treatment for as little as possible districts. Remote sensing processes offer a basis for which vegetal stress and growth reaction can be estimated. Remote sensing research based on terrestrial and spatial domains has demonstrated that numerous kinds of plant illness, through pre-visual infection signs for pathogens, hostile species and also plant health indicators, can be identified through aerial hyperspectral imaging. Inspecting foliage using remote sensing data necessitates understanding of the organization and role of foliage and its reflectance characteristics. Sensors have been ameliorated to calculate the reflectance of incident bright at numerous wavebands and have been associated to plant evolution and plant cover. Remote sensing technology has the major advantage to obtaining data about a given entity or region without having physical exchange and frequently employs surface-based instruments or spatial pictures. Remote sensing would be considered as an economic and relevant instrument for land-scale pest controlling and study.

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5.1 Introduction

Since the start of agriculture, the huge concept changes are induced through recently developed methods and instruments to cultivate arable land with. To cite a few, plough and the agricultural truck have transformed the approach how humans cultivate the land (Zhang and Kovacs 2012). Nowadays, farmers are continuously developing and revolutionizing their modes of cultivation according to novel investigations and expertise. With the fast enhancement due to the rising examination of applied knowledge and the team-based research, the growth of novel devices in cultivation is happening quickly (Singh et al. 2016a, b). Precision agricultural skill has and will still construct the road farmers and engineers are moving into this novel theory of precision agriculture. By increasing the inspection and appliance of inputs on the land, farmers are changing from a usual, standardized treatment of every agricultural land to a perfect treatment for as little as possible districts (Singh et al. 2017).

Precision agriculture had its beginning in the middle of 1980s with sensors for soil organic matter and is currently developing exponentially. It has quickly evolved to include satellite, aerial and tractor-mounted or handheld sensors. It was not before the 1990s that precision agriculture became commercially available.

Precision agriculture had a number of objectives through its development to where it is now. It commenced with cultivating by means of soil and has improved to site-specific crop organization on the basis of supervision areas and grid sampling. Afterwards, there has been rising importance on synchronized active monitoring with soil-based captors. The correctness of the imagery has turned into better which permits assessment of soil and harvest characteristics at a very well-spatial presentation at the charge of improved data storage and handling requests. Precision agriculture has been inclined to provide improved farm productivity by increasing the harvest production (Gebbers and De Bruin 2010) and throughout increased organization of farm inputs guiding to less ecological contamination (Lake et al. 2008).

The big quantity of data that is being accumulated gives more precise and accurate appliance of the inputs on a terrain. This leads nevertheless again to increased crop yield and ecological value (Schellberg et al. 2008). There has in addition been a change from spatial data investigations and supervision alone to a spatial-temporal data investigations and supervision (Chen et al. 2015). The precision agriculture engages numerous steps of information organization, processing and examining of the information that is accumulated, scientific progresses in processor calculating, production monitoring, land location as well as captor design and remote sensing (Winstead et al. 2010). Precision agriculture implies numerous diverse recent skills and extends over a lot of supervision inputs for the cultivators. Captors and cameras can be climbed to any platform that can take them such as trucks, tools and satellites, which are generally employed.

With the quick expansion of technology, cameras and captors are becoming slighter and lighter, among best imagery quality. Along with these developments, the use and expansion of unmanned aerial motor vehicles offer the potentials of merging these to an aerial structure (Koleshko et al. 2012).

Infection disorders, pest invasion, nutrient lacks and climate changes continually menace to significantly reduce annual productions and consequently financial incomes. Ecological stress can impose damages in modern agronomic production structures (Khosla 2010). Identification of an operational and concrete device to detect and estimate regions of vegetal stress is required. In fact, confirmed growers can recognize various syndromes and pathogen insects; they could not have the possibility to methodically examine total plantations. Knowing the spatial dissemination of ecological stress in areas and the subsequent development, penalties can permit for modifications in organization exercises (Fenghua and Shujuan 2008). What is required is a lucrative approach for farmers to detect harvest difficulties in their soils without physically scouting the complete area. Remote sensing affords an occasion to assess plant communities via bright reflectance (Adam et al. 2010; Campbell and Wynne 2011). The assessment of recent processes and methods employed to understand plant evolution over a diversity of restrictions will imply the application of remote sensing practices for managing region harvests. In this review, we define the remote sensing characteristics and advantages in modern agriculture.

5.2 Remote Sensing: Novel Approach of Agriculture

5.2.1 Generalities

Remote sensing can be described as the discipline and ability of achieving information about an object, region or event via sensors that are not in touch among the segment below examination (Rees and Pellika 2010). Remote sensing actions include a huge number of activities, comprising the operation of satellite coordination, figure data achievement, the succeeding data step, analysis, distribution of the registered data and picture results (Sabins 2007).

On other hand, remote sensing affords an occasion to assess plant communities via bright reflectance (Ozdogan et al. 2010). The assessment of recent processes and methods employed to understand plant evolution over a diversity of restrictions will imply the application of remote sensing practices for managing region harvests. Besides, remote sensing processes offer a basis for which vegetal stress and growth reaction can be estimated. The question with technological yield examination via digital and numerical descriptions only is that recognizing crop difficulties can be stimulating, as technological methods are not very forceful (Ulaby et al. 2014). Multispectral description permits useful data to be matched about diverse bright bands, permitting for much easier recognition of crop obstacles (Schowengerdt 2006).

It is well known that solar spectrum has a waveband ranged from 400 to 3000 nm (Sabins 2007; Thenkabail and Lyon 2016). Within this range, the 4×10^2 to

25×10^2 nm segment is often calculated via a compilation of optical captors varying from multispectral (eg. Landsat) to hyperspectral (ex: AVIRIS) (Frohn and Lopez 2017; Gupta 2017). The Landsat platform offers the extensive constant space-based report of existing planet's area. Landsat satellites furnish major details to serve region managers to make conclusions concerning natural reserves and environmental conditions. Moreover, the airborne visible/infrared imaging spectrometer (called also AVIRIS) sensor compiles data that can be used for characterization of the globe's regions and pressure from geometrically logical spectroradiometric analysis. This information may be employed to works in the domains of environmental disciplines and agronomy. The connection concerning plant development and spectral answer in the observable and infrared wavebands has been well constructed via the quotient of infrared and also red reflectance or else further indices related on this quotient (Landgrebe 2005; Kuenzer et al. 2011). Sensors have been ameliorated to calculate the reflectance of incident bright at numerous wavebands and have been associated to plant evolution and plant cover.

Foliage reflectance characteristics are employed to determine vegetation indices. AAAThese deducted data are built since reflectance values in at least two wavebands through the optical range to study particular specificities of plant coverage, such as chlorophyll and water compositions (Bioucas-Dias et al. 2013; Lillesand et al. 2014). For diverse characteristics and also soil conditions, some indices in a class deliver results with greater validity compared with others.

In addition, the employ of particular indices has permitted operators to detect modifications in reflectance to transformations in canopy specificities (Schowengerdt 2012). Moreover, there are several index, all developed from quotients based on the reflectance of incident bright at particular wavebands. The normalized difference vegetative index (NDVI) has acquired widespread approval on the basis of its interface simplicity, only needing two wavebands, and the vegetal particularities has been combined also. NDVI has been employed to estimate nitrogen level of plant, chlorophyll amount, green foliage volume and grain harvest (Twomey 2013). Spectral data has been employed to calculate micronutrient lack, recognition of insect invasion and disease contamination of vegetal (Sabins 2007; Thilakarathna and Raizada 2018) (Fig. 5.1).

5.2.2 Vegetation Indices

Vegetation indices are known as empirical designs used within agriculture to extract biophysical characteristics such as leaf area index and biomass from remotely sensed images. The leaf area index can be defined as the ratio of green leaf area per area of ground, and biomass is estimated from optical sensors which in turn can be related to yield. The indices are based on the deduction that red light is actively griped by photosynthetic colours (eg. chlorophyll) found within living plantations, whereas near-infrared light either elapses through or else is redirected. As such, on a satellite capture image, zones covered with green plants will be very brilliant in the near-infrared, due to the fact that improved reflectance and also very obscure in

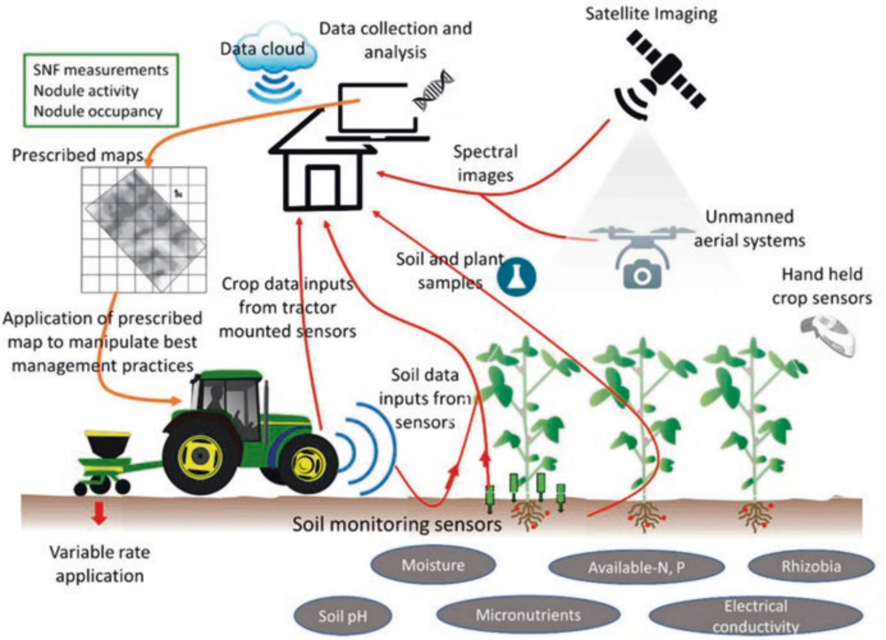

Fig. 5.1 A conceptual model showing how precision agricultural tools can be integrated together at the field level, using on-the-go variable management. (Adapted from Thilakarathna and Raizada 2018)

the red portion of the spectrum due to enhanced absorption. Vegetation indices employ a quotient of the reflected NIR and reflected RED wavelengths in numerous ways to achieve a value which is typical to the quantity of foliage present (Schowengerdt 2012; Lillesand et al. 2014). The most common index is NDVI, which computes the variance in reflectance subdivided by the addition of the reflectance in both wavelengths (Fig. 5.2).

The NDVI can vary from −1 to 1. A surface with a small contrast among the NIR and R channels will obtain a NDVI value nearby to zero, whereas surfaces of great dissimilarity, principally green foliage, will have NDVI rates much closer to one (Thenkabail and Lyon 2016). By investigating the association found among NDVI and the feature of interest, an easy empirical design can be generated.

5.3 Remote Sensing for Plant Disease Detection

Optical remote sensing makes employ of visible, near-infrared and shortwave infrared area of the range to form pictures of the globe's surface by perceiving the solar radiation returned from surface trait. Numerous matters return and absorb in a different ways at diverse wavebands. The reflectance range of a matter is a design of the part of radiation returned as a relation of the incident waveband and considers as

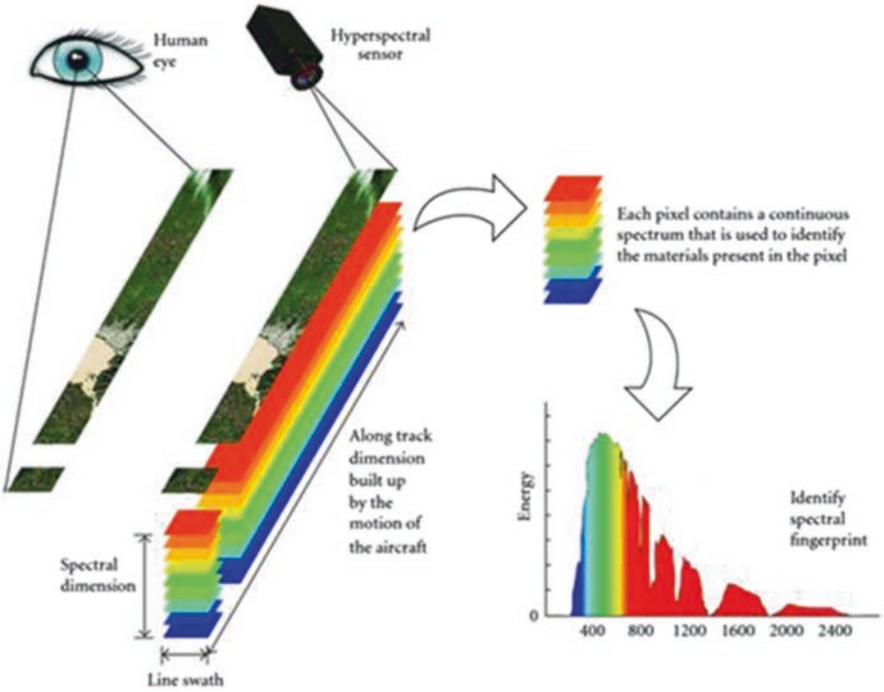

Fig. 5.2 Hyperspectral remote sensing of the earth. (Aiazzi et al. 2012)

a distinctive mark for the matter. Theoretically, a matter can be recognized since its spectral reflectance mark if the sensing structure has satisfactory spectral resolution to differentiate its range from those of other matters. This offers the foundation for multiple spectral remote sensing functions. As a consequence, the objectives can be distinguished via the spectral reflectance marks in the remotely sensed pictures. Crop stress as pest/disease stress or water stress are indicators usually detected as failure of green pigments and transformation in pigment constitution (called also chlorosis) or hurt of tissue as injuries (known as narcosis), or by lack of moisture of tissue or increase in tissue temperature.

Figure 5.3 represents remote sensing sensors which record indicators of forest health in this case, in two consecutive steps: Step 1 records spectral traits (ST) and spectral trait variations (STV); Step 2 distinguishes species, populations, communities and biomes of forest ecosystems depending on the spatial, spectral, radiometric, angular and temporal resolution of the remote sensing techniques, the distribution of ST/STV in space and their temporal changes, the choice of the modelling method (classification: biophysical/chemical parameter estimation), the geographic data representation [pixel-based or geographic object-based] and the appropriateness of the remote sensing algorithm and its assumptions for the given spectral traits.

Suitable detection as well as estimation of crop stress indicators is especially essential. Conventionally, insect and disease evaluation of plants is being done via

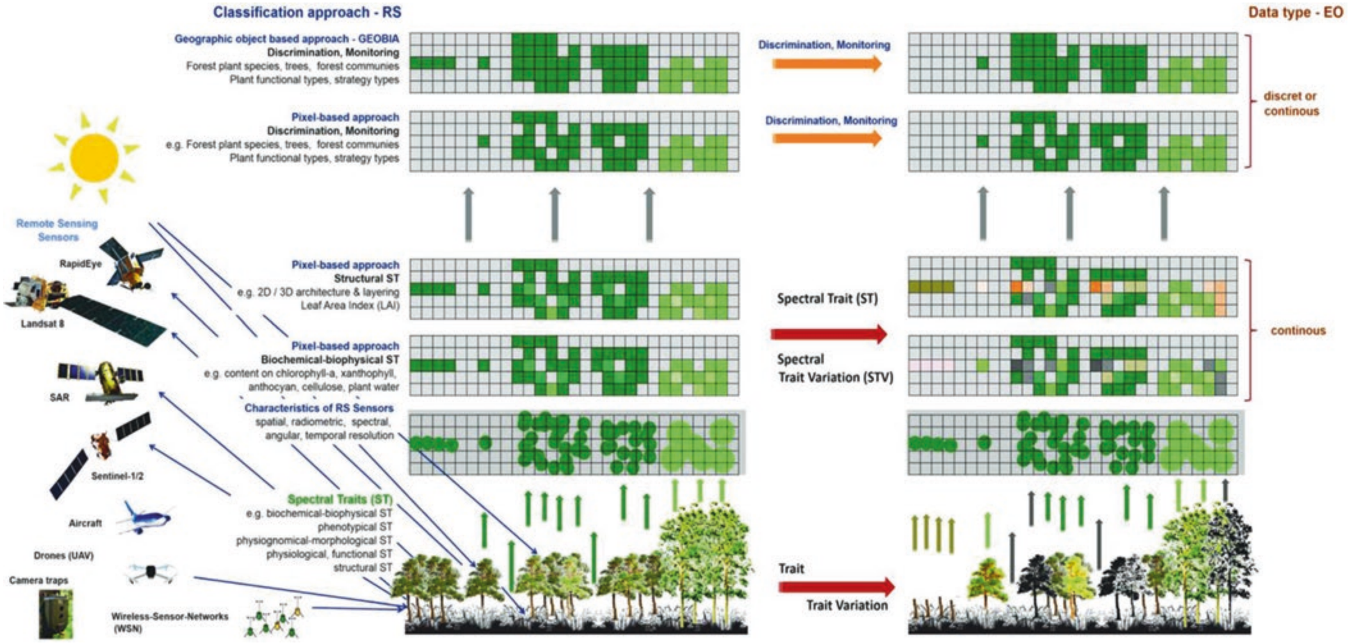

Fig. 5.3 Remote sensing—a physically-based system, which records indicators of vegetation health (ex: forest). (Adapted from Lausch et al. 2016)

an ocular approach, for example, relying up on eyes and mental capacity in order to calculate their occurrence. Nevertheless, the difficulty among the conventional approach is that they are frequently time demanding along with effort intensive. Modern progresses in the domain of remote sensing and radiometry skills attempt sufficient capacity for using these tools towards expanding a switch means that can improve or complete the habitual approaches.

Detection of vegetation stress through remote sensing is principally reliant with the statement that stress features that meddle with photosynthesis mechanism or else the physical organization of the plant influence the assimilation of light power and consequently modify the reflectance range of the plant. Leaf reflectance is influenced by numerous features as well as leaf internal compositions, surface characteristics, the amount and circulation of biochemical constituents, for instance, chlorophyll a and also water amount. Red and green wavelengths are appropriate to detect sign associated to transformation in coloured pigment; near-infrared wavelength is appropriate for tissue loss recognition. Shortwave infrared is responsive to humidity content/drying recognition, and thermal band is appropriate for modification in cover temperature that can be directly linked to photosynthesis activity. As a result, in relation on the signs of disease visible on the vegetation, the spectral mark in particular spectral wavelengths will modify from that of vigorous vegetation. Employ of remote sensing methods for revealing of yield pests and diseases is found on the statement that stress provoked by them meddles by means of photosynthesis and also physical constitution of the studied vegetation and influences the assimilation of light power and consequently changes the reflectance range of the studied vegetation (Anderson et al. 2007; Erener 2011).

Figure 5.4 shows the different processes of vegetation health determination; step (a) represents the impacts of diverse processes and factors such as fragmentation or infestations in forest ecosystems. After the impact of these diverse effects, vegetation reactions in vegetation ecosystems go after; step (b) consists in leading to changes in characteristics and attribute variations. Step (c) reveals that the spectral response can be estimated through close-range as well as airborne and spaceborne remote sensing (RS) data. The diagram (d) represents a case of the hyperspectral band answer, on the basis of fire impact. This procedure of transformation from forest traits to forest trait variances is an elementary theory that runs from close-range remote sensing processes, extending to spaceborne and airborne remote sensing records.

Quick and precise quantization of primary symptoms is significant from a pest supervision approach in addition to attempts at remotely identifying plant stress because disease or insect action employs rules of biophysical remote sensing (Lawley et al. 2016). Vegetation stress typically results in an amplification in observable reflectance caused by a decline in chlorophyll with a resulting decline in assimilation of observable light and a decline within NIR reflectance since transformations in the internal leaf composition (Zargar et al. 2011).

In addition, remote sensing has the immense capacity to be employed as an efficient and economical method to recognize diseased vegetation in a crop, principally contaminated plants comprise several spectral reactions when compared to vigorous

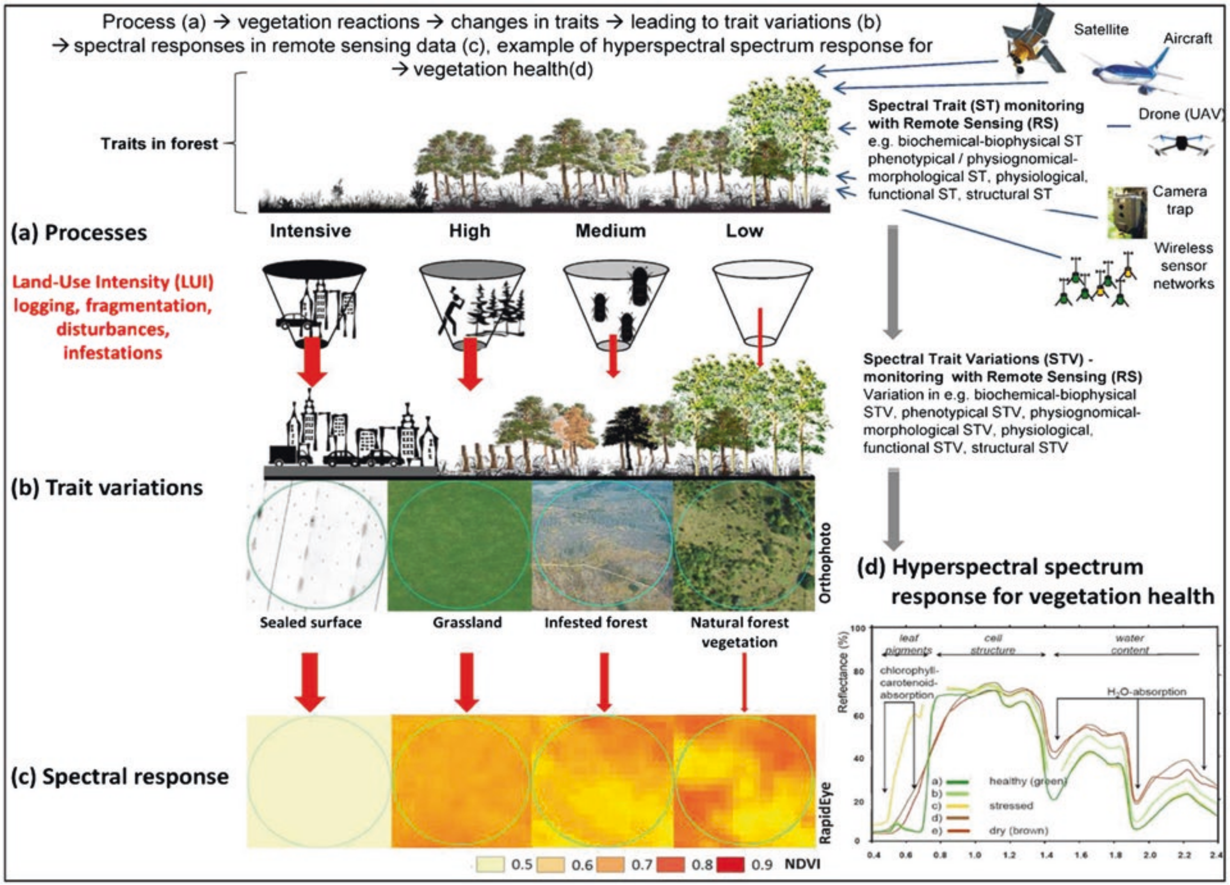

Fig. 5.4 Schematic diagram showing a chain of effects on vegetation health (eg. forest). (Adapted from Lausch et al. 2018)

plants (Agam et al. 2007; Dandois and Ellis 2010). Physiological responses of vegetation caused by infection result in a transformation of spectral reflectance imputable to the reducing chlorophyll quantity and modifying internal organization. Since the chlorophyll quantity is inclined to diminish under disease stress, the occurring solar energy assimilation of the green vegetation usually results in a decline in the visible area. Subsequently, the spectral reflectance normally is superior in the observable green spectrum relying on the disease severity. The potent spectral reflectance of green vegetation in the near-infrared range is essentially imputable to its internal foliar composition.

Vegetation under malady stress furthermore shows different degrees of internal structural modifications, which conduct to a decline of spectral reflectance in the near-infrared range. These spectral characteristics of vegetation are the foundation for remote sensing of malady-stressed vegetations (Wang et al. 2010). Pests and malady can provoke physiological tensions and physical modifications in vegetation, such as yellowing (decrease in vegetative pigment) or else chlorosis, necrosis expressed by damage on cells, etc. (Peijun et al. 2010). Accidentally, these variations can modify the reflectance properties of vegetation in the observable fraction of the electromagnetic range (from 400 to 700 nm); the reflectance of green vigorous vegetation is moderately small in perceptible fraction because of high assimilation via pigments (chlorophyll) in vegetative leaves. Whether there is a diminution in pigments caused by pests otherwise diseases, the reflectance in this spectral area will enhance. In stressed plants, leaf chlorophyll quantity reduces, thus changing the amount of light absorbing pigments, leading to a diminution in the total assimilation of luminosity. These modifications influence the spectral reflectance marks of plants throughout a diminution in green reflection and an enhancement in blue and red reflections, resulting in modifications in the usual spectral reflectance samples of vegetations (Barton 2012).

Recently, considerable advancement is made in remote sensing methods for monitoring diseases at subsequent four echelons: single leaf scale (ground-based), canopy scale (ground-based), field crop scale (aerial) and finally countries/regional scale (satellite-based). Remote sensing data at one leaf, canopy and field crop scale stages offer local and incomplete investigational information, whereas satellite-based remote sensing can offer an adequate and low-cost data base. It furthermore provides the benefit of constantly collected data and accessibility of instantaneous or archived data sets. A number of examples of satellite and other remote sensing methods employed for detecting crop diseases are presented in Table 5.1.

Table 5.1 Satellite and remote sensing methods employed for detecting crop diseases

Hosts	Diseases	Sensors	References
Wheat	Yellow rust	SPOT5 image	Zhang et al. (2009)
Rice	Sheath blight	ADAR system 5500	Zhihao et al. (2003)
Soybean	Cyst nematode	Landsat 7	Nutter et al. (2002)
Oak	Wilt	Hyperspectral satellite imagery	Blake et al. (2005)
Olive	*Xylella fastidiosa*	Hyperspectral/thermal aerial imagery	Zarco-Tejada et al. (2018)

5.4 Advantages and Benefits of Remote Sensing

Remote sensing techniques have been employed in diverse domains such as agroforestry, hydric resources management, land mapping and harvest estimation. The advantages of using remote sensing skill include the following:

- Spatial treatment over a large geographic region and accessibility through all periods.
- Comparatively low cost. In fact, remote sensing is an economically efficient method when replicated filed task is not required, and similarly a huge number of operators can exchange and employ the identical data.
- Tools are able to describe specified spatial distributions of regions under cultivation.
- Technology can incorporate any type of geospatial data into a database to do complete study and explanation; and then new and old data can be obtained without any directorial limits.
- Remote sensing platforms offer simpler techniques to revise and collect, therefore being user friendly in exhibiting the conclusions.

The main benefits of remote sensing are numerous. Firstly, remote sensing permits the achievement of graphical pictures over big geographical range on an appropriate foundation. It facilitates the capture data in various ranges. Moreover, it recovers the similar zones constantly and can be employed to identify transformations. Secondly, data can be saved in diverse wavelengths of the electromagnetic spectrum, which offer precise knowledge about the ground circumstances.

5.5 Conclusion

Precision agriculture is a relatively novel scientific domain that could possibly increase farmer incomes by decreasing pesticide usage, enhancing harvests, and decreasing work and operating expenses. On the basis of this deduction, the general targets were to construct an airborne/spaceborne imaging programme merging economic sensors with economic machines and consequently estimate the efficacy of this model at identifying infection and abiotic stress of plantation harvests. This will serve to the improvement of sophisticated devices that permit farmers to recognize crop complications through observation of their harvests. Remote sensing would be considered as an economic and relevant instrument for land-scale pest controlling and study.

It is clear that, based on remote sensing, it is possible to monitor vegetation health; nevertheless, due to sensor imprecision and image processing uncertainty, it is possible to produce some erroneous results. Therefore, it will be helpful to couple such approaches with artificial intelligence techniques allowing learning from past observations the right relationship linking the anomaly to the image.

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