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Remote Sensing in Nematology

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Remote sensing in nematology refers to the use of various technologies and techniques to study nematodes (roundworms) in agricultural and environmental contexts without direct physical contact. This field has seen advancements that enable researchers to gather valuable data about nematode presence, distribution, and impact over large areas efficiently.

Remote sensing: Remote sensing (RS) is the art, science, and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting imagery and digital representations of energy patterns derived from non-contact sensor systems.

Remote sensing in agriculture: Crop health analysis, crop intensification, crop assessment, crop production forecasting, crop identification, crop yield modelling and estimation, crop nutrient deficiency detection, irrigation monitoring and management, soil mapping, crop acreage estimation, soil moisture estimation, assessment of crop damage and progress.

Proximal sensing: This is a technique of acquiring information about an object while the sensor's fore optic is in contact or within 2 meters from the object. The data can be recorded with a handheld spectroradiometer or may be installed in a tractor to record on the go.

Remote Sensing Process

Here mainly natural solar radiation is used (passive sensing). The only exception is microwave sensing, where radar is used to emit microwaves (active sensing). The sunrays have to travel to a long atmospheric path, hit the target of interest, again travel through the atmosphere, captured by ground-based sensors, and after transmission, processing, and interpretation can be used to generate useful data. But due to large atmospheric absorption, it produces huge spectral noise, although it can cover a large area.

Active Sensing: In this sensing process, measurements can be obtained anytime, regardless of the time of day or season, and can be used for examining wavelengths that are not sufficiently provided by the sun, such as microwaves, or to illuminate a target in a better way.

Passive Sensing: It can only be used to detect energy when the naturally occurring energy is available. For all the reflected energy, this can only occur when the sun is illuminating the earth.

Remote sensing for Below-Ground Pests: Damage caused by nematodes in root induces spectral variations in the foliage, which leads to the unique spatial configuration in the field, low motility and clustered occurrence in the soil make nematodes and soil-borne pests an ideal target for detection through RS, introduction of new infection loci into a field are rare, precision detection used in one season can be applicable for future crops, chemical and biological control technologies are available that allow site-specific treatment.

Remote sensing in Nematology: A Flashback

Norman and Fritz conducted IR imagery for detecting PPN in 1965 in citrus to detect *R. similis* in citrus before visible symptom development. Heald *et al*., 1972 took IR aerial images of Texas cotton fields and were able to detect *R. reniformis*. Berg (1980) was able to differentiate *H. schachtii* infested patches from healthy areas in sugar beet fields in Germany through IR thermometry. Gebhardt (1984) also showed differences in canopy temperature of potato plants infested with PCN, on winter wheat. Nicolas *et al*., 1991 detected significantly higher canopy tempurature in moderately infested areas over lower infestations by *H. avenae*, using multispectral video imagery. Cook *et al*., 1999 discriminated between damage by RKN and root rot due to *P. omnivorum* alone as well as in combination. Heath *et al*., 2000 predicted the number of *G. p.* and *G. r.* parasitizing potato using non-destructive hyperspectral measurements, using a combination of GIS and RS technologies. Nutter *et al*., 2002 mapped the spatial distribution of *H. glycines* in soybean fields. Sivertsen *et al*., 2012 developed automatic nematode detection techniques in cod fillets.

Remote sensing plays a crucial role in nematode detection, identification, and management by providing non-invasive and efficient methods to study nematode populations and their effects on crops. Here's how remote sensing is applied in each of these aspects:

Detection

Satellite Imagery and Aerial Photography:

Detection of Crop Stress: Remote sensing can detect early signs of crop stress caused by nematode infestations. This includes changes in vegetation health, such as reduced chlorophyll content or altered canopy structure, which can be visible in satellite imagery and drone-based aerial photographs.

Spatial Mapping: Remote sensing allows for the mapping of areas with potential nematode infestations across large agricultural landscapes. This spatial information helps in targeting specific areas for further ground-based sampling and testing.

1. Spectral Analysis:

Hyperspectral Imaging: This technique enables the identification of specific spectral signatures associated with nematode-induced stress in plants. By analyzing the reflectance spectrum of plants, researchers can detect biochemical changes indicative of nematode damage.

Laser Induced Fluorescence (LIF): LIF sensors can detect fluorescence emitted by plants under stress, providing additional indicators of nematode presence and impact.

Management:

1. Mapping and Monitoring:

GIS Integration: Remote sensing data integrated into Geographic Information Systems (GIS) allows for the creation of spatial maps showing nematode distribution patterns. These maps guide targeted management strategies, such as adjusting irrigation practices or applying nematicides only in infested areas.

Temporal Monitoring: Regular satellite or drone-based monitoring provides temporal data on nematode dynamics, helping to assess the effectiveness of management interventions over time.

2. Precision Agriculture: Remote sensing enables precision agriculture practices tailored to nematode management. By identifying specific areas with nematode pressure, farmers can optimize resource allocation and minimize input costs, such as reducing pesticide usage and improving crop rotation strategies.

3. Early Warning Systems: - By detecting nematode infestations early through remote sensing, agricultural stakeholders can implement timely interventions to prevent widespread crop damage. This proactive approach helps in maintaining crop productivity and reducing economic losses.

Challenges

Most plant diseases or pests are symptomless at the early stage, and some of them tend to occur at mid to bottom layers in the canopy (Early-stage detection issue), several crop stress may occur simultaneously, and some diseases and pests may behave similar (Accurate detection problem), RS should have a sufficiently high resolution at all the spatial, spectral, and temporal dimensions, and lousy weather hampers the continuous acquisition of optical images (Problem of continuous tracking at a satisfactory resolution), lack of sufficient survey data for modelling for monitoring of diseases and pests and inaccessibility of the pooled data to support data mining and model training (Data and information sharing issue), we generally score nematode infestation based on parameters (number of eggs, egg masses, number of galls, IJs/galls, etc.) that are not visible directly or can't be assessed through RS approaches. So, an anomaly may be there in results obtained from the field in a conventional manner and data obtained through precision methods (Main constraints regarding detection of nematode infestation).

Conclusions

- Large scale farming requires on-time detection of diseases and pests where RS provides non-invasive, rapid, reliable, precise, and accurate estimates of diseases helping in monitoring and forecasting epidemics,
- Precision technology-based site-specific pesticide application may result in a decrease in the amount of pesticides used.
- Innovative sensor techniques assist in large-scale plant breeding experiments to speed up screening assays in resistance breeding.
- NRI sensors, spectroradiometry, and hyperspectral imaging microscopy are used in investigating the effect of pathogenesis on the cellular level.