Pest and Disease Management through Precision Farming

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Introduction

Insects, diseases and weeds are the major pests that the farmer encounters during crop cultivation. Plant diseases detection is essential and critical operation and can affect crop yield. Pesticides play an important role in pest control but their role is under criticism due to perceived excessive use and potentially harmful to the environment and persons. Although, there are various means of pest management *viz*., cultural, mechanical, biological control etc., farmers continue to rely upon chemical control for its greater efficacy, easy handling and quick results. But, the over application of pesticides lead to the problem of chemical residues in soil as well as in the produce. Hence, it is essential to apply appropriate amount of pesticides. Considerable variability exists in the population dynamics of pests over every piece of land. However, in conventional agriculture, without considering this variability pesticides are being applied at a uniform rate throughout the field. Precision pest management (PPM) and disease management emphasizes on this aspect and deals with judicious pest and disease management at micro-level wherein only required quantities of pesticides are applied giving due consideration to the existing variability of pests and diseases.

Integrated Pest and Disease Management (IPM and IDM)

Agricultural pesticides are potential pollution threats to surface and groundwater quality. Integrated pest management (IPM) and integrated disease management can help protect water quality by minimizing the amounts of pesticides and fungicides that producers use and by helping producers to apply pesticides in ways that decrease the risk of chemicals washing off fields into lakes and rivers or leaching into groundwater. This High Intensity IPM and IDM practice provides an opportunity for the producer to develop multiple management strategies that will integrate all aspects of pest and disease management within the agricultural production system – this is called Integrated Pest Management, or IPM and integrated disease management or IDM.

The IPM and IDM philosophy of pest and disease management involves three fundamental steps:

- Use cultural methods, biological controls, and other alternatives to conventional chemical pesticides when practical.
- Use field scouting, pest and disease forecasting, and economic thresholds to ensure that pesticides are only used against real and not perceived pest problems.
- Match pesticides with field site features so that the risk of contaminating water is minimized. Substitute lower risk pesticides when feasible, and alternate the use of pesticides from different chemical classes.

Precision pest management (PPM)

PPM deals with judicious pest management at micro-level wherein only required quantities of pesticides are applied giving due consideration to the existing variability of pests. It is also defined as the art and science of utilizing advanced technologies for enhancing crop yield while minimizing potential environmental threat to the planet.

Precision disease management

Precision Agriculture (PA) techniques were used to improve soil-borne disease management. Inoculum levels were often found to differ between PA management zones. Satellite imagery or ground-based data (yield, electrical conductivity and elevation) were best for defining disease risk zones. Differences in inoculum level between zones were frequently associated with differences in root damage and plant growth, but were only sometimes associated with yield differences. Methods were devised to define disease risk zones using soil sampling.

Components of precision pest and disease management:

Geographical information system (GIS), Global positioning system (GPS), remote sensing (RS) and Farmer are the major components of precision farming.

- **Geographical information system (GIS):** As the precision pest and disease management is information based and concerned with spatial and temporal variability of pest and disease population, GIS is the part and parcel of it. GIS is the key to extracting value from information on pest population dynamics. GIS is the brain of precision farming system and it is the spatial analysis capabilities of GIS that enable precision farming. But due to complex nature of available GIS software packages, non-specialists may find it difficult to practice in pest management. Therefore, some simple, easy to use formats need to be developed for suitability of this technology in production agriculture including pest and disease management. The pest and disease population dynamics could be better understood through computer simulation modeling and linking of GIS with these models is crucial for precision management.
- **Global positioning system (GPS) :** All the aspects of precision agriculture require positioning information and it can efficiently be provided by the GPS. It was initially developed by the US military. GPS provides accurate positional informational which is useful in locating the existing spatial variability. The inherent accuracy of GPS is about 5m, which is based on a 95 % probability that the position given will be within 5m of the true value position. Development of precise GIS/GPS auto-navigation systems increased the efficiency of the field operations in precision agriculture. Although the GPS signal is ubiquitous, there are problems in making available GPS for pest and disease management and the agricultural practices at the required precision. Simplification of the system with wider use is urgently needed to solve the problem.
- **Remote sensing (RS) :** Remote sensing is already being used for soil mapping, terrain analysis, crop stress, yield mapping and estimation of soil organic matter, but on a scale larger than what is required for precision agriculture. Remote sensing at high resolution can be of great use in precision pest and disease management because of its capacity to monitor the spatial variability.
- **Farmer:** Precision pest and disease management is information and

knowledge based practice. Therefore, farmers have to be trained adequately so that they can monitor the dynamics of pest and disease and take right decision at the right movement.

Insect-Pest and Disease Management

Insect pests and diseases are significant issues in crop protection. For this reason, improved sensors for precision farming are constantly being improved. Such modern technology includes pest detection sensors which detect disease and insect pest occurrence on crops. Basically, the sensors provide real-time data from the field.

Sensors for Accurate Insect Pest Detection

Farmers can use various sensors for insect pest detection on crops. These range from simple to the most complex work principle. Some of the most common sensor types are:

- **Low-power Image Sensors :** The low-power image sensor is an wireless autonomous monitoring system that is based on a low-cost image sensor. Placed in a single trap, the wireless sensor periodically captures images of the trap contents and sends them remotely to a control station. Sent images are then used for determination of the number of pests found at each trap. Based on insect population number, a farmer can plan when to start with crop protection and in which field areas. Farmers use this sensor to monitor large areas with very low energy consumption. Low image sensors provide many benefits in farm production. Some of them are:

  1. Significant reduction of pest monitoring costs.
  2. No human intervention in the field required.
  3. Applicable for small and big areas.
  4. Low maintenance cost.
  5. Real-time insect pest monitoring

- **Acoustic Sensors :** An acoustic sensor is an insect pest detection sensor which works by monitoring the noise level of the insect pests. How does it work? Wireless sensor nodes connected to a base station are placed in the field. When the noise level of the pest crosses the threshold, a sensor transmits that information to the control room computer, which then accurately indicates the infestation area. These sensors help detect an infestation at a very early stage, thus greatly reducing crop damage. These are a great tool for the monitoring of large field areas with very low energy consumption. The occurrence of insect pests can be also monitored with sensors for Leaf Area Index (LAI) measuring. Insect pest feeding destroys leaves. This causes plants to lose chlorophyll. This leads to a reduction in the total leaf area, and as a result, the reduction of the plant's capacity to photosynthesize. By measuring the leaf area index, the sensor can identify an insect attack at an early stage and warn farmers to take the appropriate actions. This sensor uses radiation measurements and other parameters to accurately calculate leaf area index in real-time, in the field. This type of sensor is also used for crop disease detection.

Sensors for Early Crop Disease Detection

Crop diseases, if not treated timely and properly, can significantly reduce the yield, thus endangering global food security. For this reason, disease protection is the most important task for every farmer. Since early detection can successfully control disease, farmers use modern farm measures to protect their crop. These measures include direct and indirect disease identification methods.

Direct detection methods are mainly laboratory-based techniques of disease detection. The most common are polymerase chain reaction (PCR), immuno-fluorescence (IF), fluorescence in-situ hybridization (FISH), enzyme-linked immunosorbent assay (ELISA), flow cytometry (FCM), and gas chromatography-mass spectrometry (GC-MS). Although providing accurate data, these methods can't be used for on-field disease detection.

Unlike direct, indirect methods are used directly in the field. Based on plant stress and levels of plant volatility, indirect method sensors can identify biotic and abiotic stresses, as well as pathogenic diseases in crops. These are optical sensors which, based on thermography, fluorescence imaging, and hyperspectral techniques, are able to predict plant diseases.

- **Thermography Disease Detection Method :** Thermography sensors measure the differences in surface temperature of the plant leaves and canopy. The sensor captures infrared radiation emitted from the plant surface. If there is a pathogen infection, the plant surface temperature will increase due to the transpiration reduction. Based on the change in temperature, the sensor can analyze disease presence. Thermography sensors can detect the changes due to the disease before it even appears. Precision disease control is limited due to its high sensitivity to the change of environmental conditions during measurements. Another problem is that the thermography method can't be used to identify the type of infection.
- **Fluorescence Disease Detection Method :** Sensors using the fluorescence method measure the chlorophyll fluorescence on the leaves and measure the incident light and the change in fluorescence parameters. It measures changes in chlorophyll and photosynthetic activity, thus detecting the pathogen presence. Although fluorescence measurement provides sensitive detection of abnormalities in photosynthesis, the practical application of this technique in a field setting is limited.
- **Hyperspectral Disease Detection Method :** Sensors implementing the hyperspectral method use a wide range of spectrum, between 350 and 2500 nm, to measure plant health. They measure the changes in reflectance that are the results of the biophysical and biochemical characteristic changes experienced upon infection. Hyperspectral cameras collect the data in three dimension, with X- and Y- axis for spatial and Z- for spectral, thus providing more detailed and accurate information about plant health. In order to monitor a large field area, sensors are usually fitted to an unmanned aerial vehicle (UAV). Hyperspectral sensors are used for early crop disease detection, thus allowing a farmer quick and timely crop protection.
- **Gas Chromatography Disease Detection Method :** This is a non-optical sensor used for crop disease detection and is used to determine volatile chemical compounds released by the infected plants. Pathogens on plants release specific volatile organic compounds (VOCs) that are characteristic of each pathogen type. The same thing happens when the plant is stressed due to mechanical damage. In this regard, sensors using gas chromatography can accurately identify the type and nature of infection. The only lack of this method is required sampling of pre-collected volatile organic compounds for a longer time before data analysis, which severely limits its on-field application.

Precision survey in agriculture for pest management

Various types of precision systems have been applied in agriculture. The use of remote sensing in agriculture in India started with the detection of wilt disease in coconut at Kerala Coast. But later main emphasis was shifted to crop acreage estimation, crop condition assessment and yield forecasting using different crop simulation models. Optical and video imaging in near-infrared and microwave regions were used to quantify even the nocturnal flight behavior of *H. armigera.* Recently, forecasting methods of potato late blight, apple scab, mango powdery mildew and rice blast are available. The application of remote sensing in pest monitoring, detection, early warning and management aspects in the field of agriculture are summarized as follows:

- **Survey of ecological conditions and forecasting locusts :** Over the years, strategies of Desert Locust control have evolved from curative efforts to an emphasis on prevention, *i.e.* finding and treating infestations before they form large hopper bands and swarms. This requires regular monitoring of locust breeding areas and the ability to quickly mount small scale control operations in many of the 60 countries affected by the Desert Locust. It has only been during this century that our understanding of the Desert Locust and its relationship with the environment has increased to a point that allows for better management of this pest through improved strategies of monitoring and control. Remote sensing imagery can assist in the detection of green vegetation and thereby help to guide ground survey teams. These locust data helped to prioritize the different areas according to their interest for the locust ecology.
- **Assessment of crop infested with insect pests:** Initial recognition of pest infestation by means of remote sensing will spreads, for precision farming practice. Normalized Difference Vegetation Index (NDVI), Standard difference indices (SDI) and Ratio Vegetation Index (RVI) are used for analyses using ENVI 4.8 and SPSS software. Using these indices as indicator can clarify the threshold for zoning the outbreaks.
- **Early detection of wild hosts and reducing the populations build up :** Remote sensing has been used to detect the wild host plant areas early in season and also to detect pest infestations within cotton fields and crop maturity levels related to these pest infestations during the cropping season.
- **Early detection of insect pests :** Early detection of the pest infestation could reduce overall applications of pesticides using variable rate application technology, thus saving the producer's money. During non-cropping periods, tarnish plant bugs feed and reproduce on broad leaf wild host plants. Remote sensing and spectro-radiometry showed distinct differences between broad leaf hosts and non-host grasses. High spectral resolution remote sensing imagery with more bands and narrower bandwidth is required for remote sensing diagnosis of crop disease stress.
- **Locating hot spots of pest infestation in crops :** Preliminary remote sensing revealed spider mite infestations reddish hot spot patterns in cotton fields and discerned them from healthy and drought stressed cotton in 1999. This information may be useful in the targeting of precision pesticide applications. Because spider mites and

aphids occur in heterogeneous areas of the fields, it is possible that these "hot spots" can be differentiated from other sources of variation, using the wavelengths in the NIR.

- **Monitoring conditions favourable for pest outbreak :** Various factors such as intensive cultivation, mono-cropping, changing weather conditions and indiscriminate use of pesticides have resulted in frequent outbreaks of crop pests and diseases causing huge crop losses. Minimizing these losses is one way of enhancing grain production and remote sensing tool has been found very useful in monitoring large areas frequently. The Earth observing systems are useful in monitoring weather and ecological conditions favorable for crop pests and diseases. Weather conditions such as temperature, humidity (moisture), sunshine hours (light) and wind play major influence on the densities of pest population and their natural enemies. Among the weather parameters that can be remotely sensed, type of cloud, extent of cloud cover, cold cloud duration (a surrogate for rainfall) are the most easily retrievable.
- **Remote sensing of individual species of insects :** 1. Locusts: Remote sensing (satellite information) appears a promising tool in locust monitoring. Satellite data are increasingly used for monitoring and forecasting two locust species, the desert and the Australian plague locust. 2. Moth flight: Entomological radar observation programs have, up until now, been strongly focused on large insects (moths, migratory grasshoppers) ?ying under stable boundary layer conditions at night. 3. Aphids and spider mites: Wavelengths in the NIR were fair to moderately accurate predictors of aphid-and mite infestation. Concentration of airborne aphids up to 1200 m. above the sea level have been detected by using very powerful 10 cm RADARS. 4. Plant hoppers and leaf hoppers: India used hyper-spectral remote sensing to detect the brown planthopper (BPH), *Nilaparvata lugens* (Stal), stress on rice plants under glasshouse as well as field conditions and revealed that variation in plant reflectance due to BPH damage was smaller at shorter wavelengths (350-730 nm) and larger at longer wavelengths, *viz*., NIR (740-925 nm) followed by mid infrared (MIR) (926-1800 nm), which indicated the possibility of detection of BPH stress on rice and thereby issuing prompt forewarning to stakeholders.
- **Survey of insect pests of crops and fruit trees :** Sooty mould has been used to indicate the presence of corn leaf aphid, *Rhopalosiphum maydis* and sweet potato white fly, *Bemicia tabaci* Glover. In a study, photographs were taken from 2000 meters and different levels and areas if infestation were successfully measured with the aid of photographic enhancements and computerized area estimation methods. The white fly induced sooty mould could be detected on cotton from 300 meters and photographs from 2000 meters yielded good resolution of mould growth patterns. A number of insect pests like soft scale, *Coccus hesperidium*, infesting citrus groves; citrus mealy bugs, *Phenococcus citri*, citrus black fly, *Aleurocanthes woglumi* produce honey dew that serves as host medium for sooty mould fungus. This mould blackens foliage and thus provides a clue for quick detection of insects by aerial photography. Wavelengths in the NIR were fair to moderately accurate

predictors of aphid and mite infested cotton.

- **Mapping of geographical distribution of pests along with GIS :** GIS is another tool, which can be used effectively for mapping geographical distribution of pests, delineating the hotspot zones. GIS methods can be divided into two sub groups- Remote Sensing and Digital Cartography. Fundamentally, GIS techniques create data abstractions to describe the real world life systematically classifying features into a series of thematic layers. Each layer can be evaluated independently or features between two or more layers can be analyzed together. Remote sensing has also been used in conjunction with GIS for monitoring changes in crop conditions.
- **Rainfall and outbreak of pests :** Flying moths of the east-African armyworm, *Spodoptera exempta*, are concentrated by convergent winds associated with rain storms and the subsequent mass laying of the aggregated moths leads to massive outbreaks of destructive caterpillars. Remote sensing of rain storms in the appropriate areas thus presents the prospect of rapidly locating potential outbreaks.
- **Survey of habitats of insect vectors of plant disease :** Remote sensing imagery (from high-resolution aerial photography to coarse-resolution satellite imagery) when combined with GIS spatial analyses techniques can play an important role in existing vector surveillance and control programs at local and regional scales. By applying the remote sensing and GIS techniques for mapping vector habitats, vectors' presence, abundance and density, assessing the risk of vector-borne diseases, disease transmission, spatial diffusion, we can find the root cause of the disease infection, and source of infection. With the availability of multispectral, multi-temporal and real time satellite data products, GPS assisted geo-referenced epidemiological data are being integrated under the umbrella of the GIS software for mapping distribution of vector borne diseases.

The Future of Pest Detection Sensors

Along with the aforementioned, there are many more sensors that can be used for crop disease and insect pest detection using electrical, chemical, electrochemical, optical, magnetic, or vibrational signals. However, farm technology is modernizing rapidly. New sensors are constantly being developed in order to support early pest identification based on bio-recognition elements such as DNA/RNA, antibody, and enzymes. In aiming to produce enough food to feed the growing population and to secure a sustainable future for society, farmers need all the help they can get in order to get the best from their farmland. This can be achieved by using sensors in crop production. Knowing what is going on in the field at any given time makes farming easier, secures harvests, and boosts yields, all of which work to protect the environment.

Conclusion

The use of geospatial data and technology plays a significant role in improving the production of yield and overcoming food security issues. As the population grows, the production of crop needs to be increased as well to ensure all the people in whichever country or region get enough nutrients. This paper has reviewed the role of geospatial technologies to tackle the issue of pest and disease affecting plant health that has a big impact on crop yield production in producing food for the world population. Geospatial technology has been used, from the early tasks of surveying the status of crop health to managing the collected data. From the review, there are many studies which have applied remote sensing technology in monitoring plant health for large groups that become commodities for a country, such as oil palms, paddy and wheat, whereas less study has been applied on the crops planted on a small scale, such as in the orchard. This might be due to the high cost to use the technology, which might not feasible to apply for a small area. Moreover, it is not easy to detect plant health for crops that are planted randomly on the ground, especially on a mixed land use, from the satellite images. Therefore, GPS technology has been applied to complement the ground crew during field survey to automatically record the location of affected plants for further action. Distribution of pest and disease incidence on the affected crops has been mapped to visualise the events from a large-scale view. The power of spatial analysis has been used in predicting the possibilities of incidence likely to be occurred in a few years time. Global trade liberalisation and climate changes have presented major challenges for the local crops to produce good products and to secure food for the world population generally. Nevertheless, the advancement of geospatial technology has made the activities of combating various pests and diseases affecting plant health much easier than before.

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