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Detection of Diseases and Pest Damage from Remote Sensing

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SUMMARY

Remote sensing depends on measuring, recording, and processing the electromagnetic radiation reflected and emitted from the ground target, and it has long been used for the detection and management of crop plant diseases and insect pests. With advances in satellite, airborne and ground-based remote sensing, reflectance data are increasingly being used in agriculture. This article reviews various remote sensing methods designed to optimize the profitability of agricultural crop production and protect the environment. The report presents examples of the use of remote sensing data in crop yield forecasting, assessing nutritional requirements of plants and nutrient content in the soil, determining plant water demand, and weed control.

INTRODUCTION

Remote sensing is the technique of learning information about an object without physical contact and depends on the spectral behavior of living organisms. Electromagnetic radiation travels in a vacuum at the speed of light in the form of waves of different wavelengths, which is the information carrier in remote sensing. The broadest range of wavelengths that are most helpful for remote sensing includes visible light (VIS), near-infrared (NIR), short-wave infrared (SWIR), thermal infrared (TIR), and microwave bands. While active sensors create radiation that interacts with the target being studied and returns to the measuring instrument, passive remote sensing sensors record incoming radiation that is reflected or released from the objects. There are three types of remote sensing: Ground-based, satellite, and aircraft. The spatial and spectral resolution of a remote sensing platform must also be considered. The spatial resolution refers to the dimensions of the smallest object that can be recognized on the ground and determines the pixel size of satellite or airborne photographs covering the earth's surface. The size of the spectral bands that a sensor can capture reflected radiation depends on its spectral resolution. Today, remote sensing is used as an effective tool for the detection, forecasting, and management of insect pests and plant diseases on different fruit and crops. The main objectives of these applications were to collate data that help in decision-making for insect pest management and decreasing the environmental pollution of chemical pesticides.

Detection of diseases and pest damage

Ground-Based Remote Sensing:

By employing the data from remote sensing, it is possible to identify plants based on variations in their reflectance spectra brought on by the presence and degree of pests and diseases. Healthy and infected plants exhibit widely disparate spectral properties. A healthy leaf reflects light sparingly in the VIS range due to the heavy absorption of photosynthetic pigments. In contrast, the NIR bands have a very high spectral reflectance that is mainly affected by the interior structure and dry matter of the leaf. Detecting pest damage to crops has proven successful when using ground-based spectral reflectance. The damage caused to wheat by the sun pest (Eurygaster integriceps) was accurately determined by using a handheld radiometer and the Normalised difference vegetation index (NDVI) and structure-insensitive pigment index [Genc et al., 2008]. The research also revealed variations in reflectance between pest-damaged and healthy plants. The testing of three vegetation indices, Relative reflectance index (RVI), NDVI, and Green normalized difference vegetation index (GRVI), revealed that GRVI was the most vulnerable to cotton damage caused by thrips (Thrips tabaci Lind) [Ranjitha et al., 2014]. Field and laboratory spectroscopy was used to examine the spectral reflectance from healthy and infested mustard canopies in a study on aphid infestation. The findings demonstrated a substantial correlation between spectral indices NDVI, RVI, AI (Aphid index), and SIPI (Structure insensitive spectral index) and aphid infestation and these indices could be used for identifying aphid infestation in mustard [Kumar et al., 2010]. The greenhouse investigation can be used to identify wheat stress caused by the green bug. The wavelengths centered at 694 nm and 800 nm and spectral vegetation indices derived from those wavelengths were the most sensitive to wheat affected by green bugs [Yang et al., 2005]. In a greenhouse, a handheld radiometer, to portray the leaf reflectance spectra of wheat under Russian wheat aphid stress and normalized total pigment to chlorophyll a ratio index and leaf reflectance in the 625–635 nm and 680–695 nm ranges were reliable predictors of chlorophyll loss brought on by aphid feeding [Riedell et al., 1999]. The correlation between aphid abundance and four vegetative indices AI, NDVI, SIPI, and DSSI (Damage sensitive spectral index) is considered the wheat aphid. Wheat aphid abundance and AI for all fields were the only associations that were consistently observed and statistically significant [Mirik et al., 2007]. The ability of AI to detect aphid abundance better than NDVI, SIPI, and DSSI suggest that the development of novel spectral indices may increase the power of remote sensing to detect pests. However, it should be noted that field inspections should be used in conjunction with remote sensing techniques to detect pest abundance. The use of vegetation indices derived from a hyperspectral radiometer for detecting wheat leaf infections shows an example of the use of spectral measurements for diagnosing plant diseases. Using reflectance, Phytophthora infestans can be seen in tomatoes. The investigation demonstrated that the VIS range was significantly less beneficial than the near-infrared (NIR) region, notably 700–1300 nm was much more helpful than the VIS range for detecting disease symptoms caused by Phytophthora infestans. While the difference in spectral reflectance in the NIR area was greater than 10%, the difference in the VIS range between healthy and sick plants was just 1.19%. A hyperspectral approach to early detection of biotic stressors produced by Alternaria alternative, a disease of oilseed rape. The SWIR region between the water absorption bands (1470 and 1900 nm) of oilseed rape leaves showed the most significant spectral changes between the infected and uninfected areas [Baranowski et al., 2015].

Airborne Remote Sensing:

It is crucial to use a sensor with the proper spectral and spatial resolution when employing airborne images to identify infected plants in crops. The efficacy of distinguishing between wheat plants infected with brown rust (Puccinia recondita f. sp. tritici) using two hyperspectral cameras, one of which (AISA-DUAL, Specim LTD, Oulu, Finland) recorded the reflected radiation in the 498 channels in the range of 400 - 2500 nm with a spectral resolution of 2.5 - 5.8 nm and the second (ROSIS, German Space Agency, DLR) in the 115 channels in the range of 383 - 839 nm with a spectral resolution of 5 nm. It was easier to distinguish between healthy and infected plants in the AISA-DUAL photos than in the ROSIS images (84.32% vs. 80.33%), and this accuracy was linked to larger correlations at longer NIR wavelengths. Lower air absorption and scattering of the signal reflected from the field surface resulted in AISA photos with a larger signal intensity and higher spatial resolution (1.5 m and 2.0 m, respectively) than ROSIS images (2300 m and 2880 m, respectively) [Mewes, 2011]. The identified maize plots infested by corn rootworm (Diabrotica virgifera) using hyperspectral images acquired with spatial resolutions from 0.5 to 2.0 meters because sensors had the same Signal Noise Ratio (>500:1) and images were almost taken at the same time. Up to 99% of insect-infested plots could be classified correctly, which is calculated as the ratio of two bands in the VIS (648 nm) and NIR (747 nm) wavelengths, was used to determine the maximal separability between infested and uninfested maize. A crucial element in the plant detection process is the spatial resolution of the image data. UAVs, which offer greater-resolution photographs than piloted aircraft platforms, can produce better outcomes. The citrus greening disease is brought on by the motile bacteria Candidatus Liberibacter spp [Glaser et al., 2009]. The efficiency of citrus greening disease detection using a UAV-based sensor with an imaging system mounted on a piloted aircraft with spatial resolutions of 5.45 cm/pixel and 0.5 m/pixel, respectively. Classification accuracy of 67-85% acquired using UAV-based datasets was comparable to the findings attained using aircraft-based datasets, which ranged from 61-74%. However, a comparison of false negative results obtained using data obtained by UAV and aeroplane, i.e., 7-32 and 28-45, respectively, showed that the former method was superior to the latter [Garcia-Ruiz et al., 2013].

Satellite Remote Sensing:

Satellite images can also be used to monitor the presence of pests and plant diseases in crops. The orange rust (Puccinia kuehnii) disease in sugarcane may be located using Hyperion satellite hyperspectral images [Apan et al., 2004]. Gaeumannomyces graminis, the cause of the take-all illness, can be identified using Landsat multispectral images [Chen et al., 2007]. To find powdery mildew (Blumeria graminis) and leaf rust (Puccinia recondita) in winter wheat, high-resolution Quick Bird satellite multispectral imagery was used. The multi-spectral pictures are typically acceptable to detect infield heterogeneities in wheat vigor, especially for later fungal infection stages, but only somewhat suitable to discern early infection levels in wheat [Franke and Menz, 2007].

CONCLUSION

The use of remote sensing in precision agriculture has been developing rapidly in recent years. Monitoring weed infestations, pest damage, and plant infections are made more accessible by data collected from satellite, airborne, and ground levels, allowing for prompt counteraction. Increased yields and better-quality harvested seeds and fruits are vital for increasing crop profitability. Remote sensing data can be used to predict the fertilization needs of plants depending on the nutrient content of crops and soils.

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