GIS and Remote Sensing in Plant Pathology

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According to the world summit on food security, the global population is expected to be doubled by 2050. Over the past century, numerous technical advancements, including the green revolution, have impacted how agriculture is practised. The third agricultural revolution, commonly referred to as the "Green Revolution," occurred between the 1960s and the 1980s and was characterised by high yield crop varieties, the use of synthetic fertilisers, pesticides, and a water system (Pingali, 2012). Since the 1960s, the global population has doubled and the consumption pattern has increased threefold, but agriculture has only been able to keep up with demand by increasing its cultivated area by 30% (Wik *et al.*, 2008). According to the world bank, the need for food and agricultural products will rise by another 30% by 2025 and by more than 70% by 2045.

Remote sensing is the art and science of acquiring data from a distance about real-world items or areas without coming into contact with the object being studied directly. It is a tool for more precise and accurate monitoring of the earth's resources using satellite technology in addition to terrestrial observations. The idea behind remote sensing is to analyse the features of the earth using electromagnetic spectrum (visible, infrared, and microwaves). These wavelength ranges are utilised to differentiate between vegetation, bare soil, water, and other similar characteristics because the normal responses of the targets to these wavelength regions vary. Along with field observations, it can also be used for crop growth monitoring, land use pattern and land cover changes, water resource mapping and water status in the field, disease and pest monitoring, yield estimation, forecasting the harvest date, precision farming, and weather forecasting (Gebeyehu, 2019). Crop yield forecasting greatly benefits from the use of inputs from remote sensing in conjunction with crop simulation models.

Application of RS and GIS in plant pathology:

GIS can be used to track the spread of diseases in crops by analysing data from remote sensing and other sources. GIS can integrate spatial data on pest and disease occurrences with crop distribution, weather patterns, and environmental factors. By analysing these data, GIS can generate maps that identify high-risk areas for specific diseases. This information helps farmers and agricultural experts in implementing targeted disease control measures, such as precision spraying or timely application of fungicides. India began using remote sensing for national development comparatively earlier than other developing nations. Prof. Pisharoth Rama Pisharoty conducted the first experiment utilising remote sensing on the coconut root-wilt disease in Kerala in the early 1970s (Dakshinamurti *et al.*, 1971). In India, Professor Pisharoty—who also served as the founding director of the Indian Institute of Tropical Meteorology, Pune—is known as the “Father of Remote Sensing”.

Sensors used for plant disease detection:

Nearly all applications for remote sensing in precision agriculture research are covered by four types of sensors: RGB (Red Green Blue), multispectral, hyperspectral, and thermal. The role of sensors is to take pictures with a high spatial and temporal resolution, which can be useful for tracking a variety of vegetation related traits. Some of these sensors are discussed below.

RGB: In order to identify disease symptoms, nutrient deficiencies, damaged plants, specific weeds, and plant species in crop fields, colour or RGB (red, green,

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blue) images are helpful. An object's appearance in RGB images is determined by the light that it reflects, its optical properties, and how people perceive it. For weed discrimination, crop mapping, variable physiological process across a leaf surface, and plant stand counting, RGB-based image analysis has been used in agriculture.

Multispectral: Spectral data from the red, green, and blue electromagnetic spectrums, as well as the red edge and near-infrared wave ranges, are typically detected by multispectral sensors. For multispectral image processing, band ratio and the normalised difference vegetation index (NDVI) are the two effective vegetation indices used. These techniques can be used to detect weed species, crop damage from herbicide application, and various disease symptoms.

Hyperspectral: Using 5–10 nm bandwidths, hyperspectral cameras analyse the spectral reflectance of plants in the visible, near–infrared, and mid–infrared (350–2500 nm) portions of the electromagnetic spectrum. A spectral signature is the distinctive spectral reflectance of a particular plant species at the canopy or single leaf scale. The first step in determining the potential of remote spectral data to categorise weeds and crops and to identify various disease symptoms is to measure the spectrum of reflectance.

Thermal: The principle behind thermal imaging is that objects emit infrared energy in proportion to their temperature. In general, objects that are warmer emit more radiation than objects that are colder. In essence, thermal cameras are heat sensors that can identify temperature differences between objects. The infrared thermal camera detects electromagnetic radiation in the infrared range (800–1400 nm) and conveys it as a false colour image. A thermal sensor's pixels each have a distinct temperature value. Plant temperatures can be tracked using thermal imaging across an entire field. Increased canopy or plant leaf temperatures can be brought on by plant disease symptoms, water stressed plants, and pest infestations.

How remote sensing works in plant disease detection?

Depending on the remote sensing methods used, there are three distinct spectral domains of vegetation reflectance. Sahoo *et al.*, (2015) discussed how the biophysical and biochemical characteristics of vegetation, such as the leaf area index, the amount of living and dead biomass, the pigment and moisture content, and the spatial arrangement of cells and structures, strongly influence their spectral properties. The emerging diseases can be easily detected by the changing colour and pattern of the field. By analysing differences in the spectral characteristics of images collected at different times, remote sensing can help to track and monitor changes in various environments, including urban areas, forests, and agricultural landscapes. The ability to detect changes through remote sensing provides valuable insights for decision-makers in various fields, such as resource management, disaster response, and environmental monitoring.

Conclusions

The current chapter gives a thorough overview of how remote sensing and GIS are used in many aspects of agriculture. Globally, GIS is becoming an increasingly significant component of agriculture production, assisting farmers in improving output, reducing expenses, and better managing their land. It is necessary to establish a state- or district-level information system based on the information that is now available on different crops gathered through remote sensing and GIS techniques in order to properly use the information on crops for improving the economy. A GIS map makes it easier to compare data from the past and the present, which aids in disease and pest predictions. As a result, by offering a variety of geospatial maps, GIS has given researchers and planners additional options for tracking and predicting agricultural disease pests. These and other innovative methods will undoubtedly increase the value of remote sensing and GIS in many different areas of agricultural sciences.

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