INTELLIGENT MONITORING OF DISEASED PLANTS USING DRONES

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ABSTRACT

Plant diseases are one of the grand challenges that face the agriculture sector world-wide. In the United States, crop diseases cause losses of one-third of crop production annually. Despite the importance, crop disease diagnosis is challenging for limited-resources farmers if performed through optical observation of plant leaves' symptoms. Therefore, there is an urgent need for markedly improved detection, monitoring, and prediction of crop diseases to reduce crop agriculture losses. Advanced imaging technologies can detect such changes, and can, therefore, be used as noninvasive crop monitoring methods. Furthermore, novel methods of treatment precision application are required. Both sensing and actuation technologies can be mounted on equipment moving through fields (e.g., irrigation equipment), on (un)manned driving vehicles, and on small drones.

INTRODUCTION

Plant diseases, pest infestation, weed pressure, and nutrient deficiencies are some of the grand challenges for any agricultural producer, at any location and for whatever commodities or size of the operation is dealing daily. For instance, in the United States, plant disease causes losses of between 20 and 40 percent of the agricultural crop production annually. Therefore, farmers must promptly diagnose the different types of plant diseases to stop their spread within their agricultural fields. Traditionally, underserved farmers try to diagnose plant diseases through optical observation of plant leaves' symptoms, which incorporates a significantly high degree of complexity. Any misdiagnosis of crop decreases will lead to the use of the wrong fertilizers that could stress the plants and lead to nutrient deficiencies in the agricultural field. Machine Learning (ML) coupled with computer vision have already enabled game-changing precision agriculture capabilities by providing the ability to optimize farmreturns, preserve natural resources, reduce unnecessary use of fertilizers, and identify disease in crops and animals from remotely sensed imagery. Imagine a smart mobile-based system that farmers can use to identify the different types of plant diseases with high accuracy [3].

Importantly, use of drones in precision pest management could be cost-effective and reduce harm to the environment. Sensing drones could reduce the time required to scout for pests, while actuation drones could reduce the area where pesticide applications are necessary, and reduce the costs of dispensing natural enemies [4].

MATERIAL AND METHOD

Precision agriculture practices, which can help farmers make better informed decisions, have evolved significantly over recent years, with the global market now estimated to reach $43.4 billion by 2025. While drones, also known as unmanned aerial vehicles (UAVs), have not yet made it into the mainstream agriculture space, they are playing an increasingly important role in precision farming, helping agriculture professionals lead the way with sustainable farming practices, while also protecting and increasing profitability [1].

The use of global positioning system (GPS) technology, together with geographic information system (GIS) tools, form a large part of these precision agriculture practices allowing fine-scale monitoring and mapping of yield and crop parameter data within fields. These provide more intense and efficient cultivation methods, which can help farmers adjust fertilizer prescriptions or identify crop diseases before they become widespread. With more data at their fingertips, farmers can make decisions based on economic and environmental factors – for example, by optimizing fertilizer treatment and applying only the right amount at the right time, significant cost and environmental savings can be made.

There are various applications of drones in agriculture which are briefly discussed below:

Soil and field analysis: Drones can be used to mount sensors which are able to analyze the soil conditions, terrain conditions, moisture content, nutrients content and fertility levels of the soil which can be further used for planning the pattern of sowing of different crops, irrigation scheduling as well as for managing fertilizers application considering spatial variability of the crop growth and field conditions [5].

Planting crops and trees: Drones can be used for planting crops which can save labour cost and reduce human drudgery. As there would be no use of tractors for sowing crops in the field, drones can save fuels, reduce the emission of harmful gases formed during fuel exhaustion while operating tractors in the field, and can avoid the compaction of subsoil as well as formation of plough pan which generally forms due to repetitive movement of tractors on soil surface. Drones can be used to plant trees or crops in remote areas by throwing biodegradable seed pods or seed bombs (Figure 1). Thus, they can be used for the restoration of degraded lands by planting trees, and also for reforestation as well as afforestation activities [1].

Figure 1. Seed Bombing Drone [1]

Crop monitoring: Drones can be used for monitoring the conditions of crops throughout the crop season so that the need-based and timely action can be taken. The

quick and appropriate action can prevent yield loss. This technology will eliminate the need to visually inspecting the crops by the farmers. They can monitor the horticultural crops or other crops present in remote areas like mountainous regions. They can also monitor the tall crops and trees efficiently, which are otherwise challenging to scout physically by farmers. The data acquired by drones during crop monitoring could be used to compute vegetation indices, which can be integrated with weather forecast data and soil fertility data. This could be used to precisely estimate the time of harvesting and yield of the crops. This may help farmers and bureaucrats to plan for warehouse and processing facilities, as well as for marketing in advance [10].

Weed identification: Drones can be used to identify the weeds present in the field. These weeds could be timelyrooted out from the field so that they do not compete for resources with the main crop [1].

Crop spraying: Drones can be used to spray chemicals like fertilizers, pesticides, etc. based on the spatial variability of the crops and field. The amount of chemicals to be sprayed can be adjusted depending upon the crop conditions, or the degree of severity of the insect-pest attack. In this way, drones pave the pathway to precision agriculture. This ultimately increases the efficiency of the chemicals applied, thereby reducing their adverse impacts on the environment by decreasing the soil and water pollution. Thus, it can lead towards sustainable agriculture. Drones spray chemicals at a faster rate as compared to other methods. It can also result in the saving of the amount of chemicals applied, which can reduce input cost. There is also a problem of imbalance of tractor operated machinery while spraying chemicals over tall crops which may sometimes result in accidents. So, the spraying of chemicals over tall crops can be done easily by drones without any damage. The management of excess crop residues in the farm is the major problem faced by the Indian farmers after harvesting of the crops. Removing these crop residues from the fields is very costly and time-consuming. Therefore, farmers tend to burn these residues, resulting in environmental pollution and degradation of soil health. These residues can be efficiently and cost-effectively managed by the spraying of crop residue decomposing microbial formulations in the field. This operation can be effectively performed by the drones, which can maintain soil quality and prevent environmental pollution [8].

Irrigation scheduling of crops: Drones having sensors for optical, multispectral, and thermal imaging which can pinpoint the heat and water stress in the crops at a specific location. It can be used to apply irrigation to the crops based on their requirement. This will prevent the wastage of water and will ensure the efficient utilization of irrigation water.

Crop health assessment: *By using different kinds of sensors pertaining to visible, NIR and thermal infrared rays, different multispectral indices can be computed based on the reflection pattern at different wavelengths. These indices can be used to assess the conditions of crops like water stress, insect-pest attack, diseases, etc. The sensors present over the drones can see the incidence of diseases or deficiency even before the appearance of visible symptoms. Thus, they serve as a tool for early detection of the diseases. In this way, drones can be used for early warning system so that timely action can be taken by applying the remedial measures based on the degree of the stress.*

Geofencing or protecting the field from animal damage: The thermal cameras mounted over drones can detect animals or human beings during the night. So, it can be used to protect fields from the damage caused by animals, which are otherwise difficult to detect in the large fields during night time. So, it will work more efficiently than human guards.

Crop insurance: Drones can be used for precisely estimating and monitoring of the crop failure. So, it can be helpful for the farmers as well as for insurance companies in

providing insurance claims based on the degree of damage. This technology has great potential in accurate and effective implementation of crop insurance scheme, namely Pradhan Mantri Fasal Bima Yojana in India without any bias.

Livestock management: Drones can be used to manage the large herd of livestock. The sensors having high-resolution infrared cameras present over drone can detect the diseased animal swiftly by their heat signatures. The detected diseased animal can then be separated from their fellow animals, and the early treatment can be provided. So, the drone could be used for precision dairy farming [1].

Innovating the farming industry. Drones serve as a powerful tool to monitor the growth of crops. But this is not the only thing that these flying objects can help farmers with. In addition to supervision, they can also plant seeds, apply spray treatments, and even serve as a security tool to keep an eye on the area and make sure operations are going as planned. With so many applications and benefits, it is not an enigma why this technology is experiencing such rapid growth and why so many farms are turning their attention to drones [1].

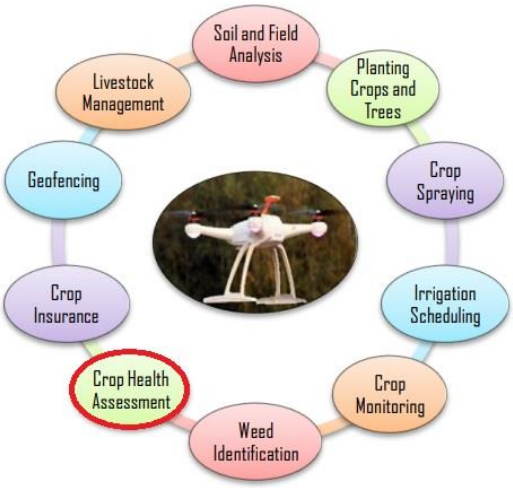

Figure 2. Applications of drones in agriculture [1]

RESULTS AND DISCUSSIONS

Drones help the agricultural industry by increasing crop production and monitoring crop growth.

Modern irrigation practices, livestock technology, fertilizer management, and various other tools have allowed farmers to improve different operations. But when it comes to crop production and growth monitoring, drones have established themselves as **the best solution for farmers**.

The drones are equipped with GPS systems and cameras that allow them to fly over every part of the field that needs to be inspected and take images. So once the crops have been planted and started to grow, farmers implement this technology and give a certain flight path based on the area they want to survey [6].

So what's new and innovative in flying camera drones? Well, the thing is, these cameras are not the normal ones. They are called **multispectral imaging cameras** that are so comprehensive that they are used for military purposes such as detecting landmines.

While landmine detection is useful for everyone, for farmers it is primarily used to improve crop, soil and fertilization management. The taken images are integrated with specific software that shows the image in different colors. For example, if the field shows green color, the crops in that area have good photosynthesis and their growth is healthy.

However, the areas showing the red and yellow color need attention, as the crops are not growing as they should. All of this information is vital as after looking at it, farmers can manually go and check what is causing the problem of unhealthy crops. Are the crops underwatered, insufficiently fed, are insects causing the issue or perhaps the plants are being overwatered? This allows farmers to be proactive rather than reactive when the problem is already visible and damaging. The ability to be proactive is due to drones that make the crop monitoring process fast and effective. Imagine farms of over a thousand acres. The human resource it would take to replace what drones effortlessly do would be immense. With flying technology, however, they not only save time but detect details that would be impossible to see with the naked eye, regardless of human resources [7].

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Using the aerial footage taken by drones, farmers can get some useful information about crops, as follows: may reveal patterns of irrigation or soil and fungal infestations that are not visible to the naked eye; the combination of multispectral images, infrared or visible, can create an image of crop that emphasizes healthy plants and those in need; by monitoring the crop at regular intervals, animations can be created, images that show changes over time, revealing problem areas or opportunities to better crop management [2].

CONCLUSIONS

Unmanned aerial vehicles are fast becoming key components of agricultural research and industry by being an important source of information of previously unavailable agro-meteorological data at field scale. They offer opportunities for mainstreaming climate-smart and precision agriculture into smallholder farming through improved crop health monitoring and agricultural water management as they are a source of high-resolution images acquired at user defined temporal resolution at low altitudes, sufficient to effectively monitor crops in near real-time.

Drones with remote sensing equipment (sensors) are deployed to monitor crop health, map out variability in crop performance, and detect outbreaks of pests. They could serve as decision support tools, as early detection and response to suboptimal abiotic conditions may prevent large pest outbreaks. When outbreaks do occur, different drones (actuators) could be deployed to deliver swift solutions to identified pest hotspots. Automating pesticide applications and/or release of biological control organisms, through communication between sensing and actuation drones, is the future. This approach requires multi-disciplinary research in which engineers, ecologists, and agronomists are converging, with enormous commercial potential.

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