Artificial Intelligence (AI) tools to detect crop diseases are on the way

Swarms of locusts devastating crops in East Africa, corn rootworms wreaking havoc in the Midwestern US. Blights destroying rubber trees in Brazil and ravaging potatoes in South India. Unpredictable and erratic weather patterns brought on by climate change will only exacerbate these problems — and, scientists say, make crop diseases more likely to strike and inflict major damage.

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A single warm winter can enable a pest to invade new territories. Maize- and millet-chomping armyworms and fruit-and vegetable-feasting Tephritid fruit flies have spread to new locations as a result of warming weather. Desert locusts, which destroy entire crops when they swarm, are expected to strike new regions as they change their migratory routes. It is a serious problem in a world in which an estimated 700 million to 800-plus million people faced hunger in 2021 and with the global population set to further grow.

Karen Garrett, plant pathologist at University of Florida, Gainesville
Credit: James Provost CC-BY-ND

Plant pathologist Karen Garrett of the University of Florida, Gainesville, believes that artificial intelligence (AI) could be immensely valuable in fighting these blights. If agriculture is equipped with cost-effective AI tools that can identify crop diseases and pest infestations early in their development, growers and others can catch problems before they take off and cause real damage, she says — a topic she and colleagues

explored in the 2022 *Annual Review of Phytopathology*. This conversation has been edited for length and clarity.

You specialize in studying plant diseases, so let's dive into this topic from that angle. How do changes in environment and climate affect plants and the emergence of plant diseases?

Most pathogens have a range of temperatures that favor them. From a pathogen's standpoint, some years can be better than others. Sometimes, a hard winter or a long drought will kill off a pathogen. But it will not in a mild year — so the pathogen will thrive, and there may be more disease in the following seasons.

Consider potato late blight. It's a famous example of a plant disease that had a big impact on European society during the mid-1840s. Late blight was one of the drivers of the Irish potato famine, which generated a big exodus of people from Ireland.

First, the pathogen was introduced. Then there were some years that had weather conditions that strongly favored the pathogen: cool and wet weather. As a result, the pathogen thrived, wreaking havoc on the crop. It's estimated that a million people died and a million fled the country during that time.

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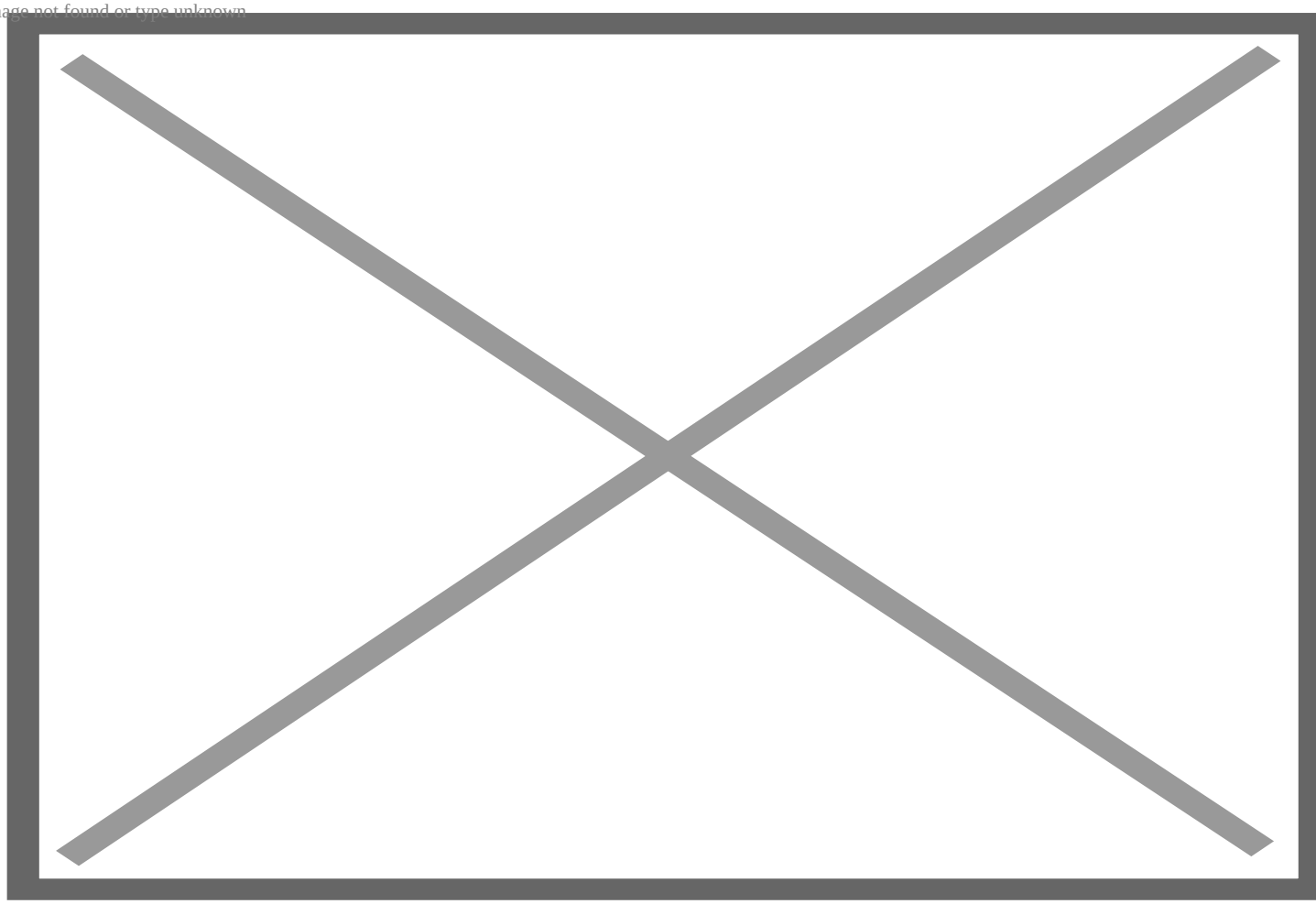


Corn infested by grubs of the fall armyworm, Spodoptera frugiperda (the Latin word “frugiperda” means “lost fruit”). The moth, which is native to the Americas, is a serious pest in southern Florida and Texas, where it can overwinter, and in tropical regions in Latin America. It is now spreading to other parts of the globe.
Credit KochieVMV via iStock.com

Today, where temperatures are getting milder, such as at higher elevations and toward the Earth’s poles, pathogens favored by mild conditions can move into new regions and become more destructive.

When new crop diseases arise, how can anyone be sure that they are linked with climate change?

Any given crop epidemic is kind of like a storm. It’s hard to say whether an individual storm is due to

climate change or not, but you can start to draw conclusions.

One thing that plant pathologists talk about all the time is the “disease triangle.” Getting a disease requires three things: a pathogen that is able to infect, a conducive environment, and a host plant that can get infected. If the environment changes, for example through climate change, so that weather favoring a pathogen is more common, it will make it easier for the pathogen to thrive and attack more plants. People’s decisions about how to manage plant disease are another dimension. Often, several of these components change at the same time, so it’s challenging to say how much of an epidemic’s damage is strictly due to climate change.

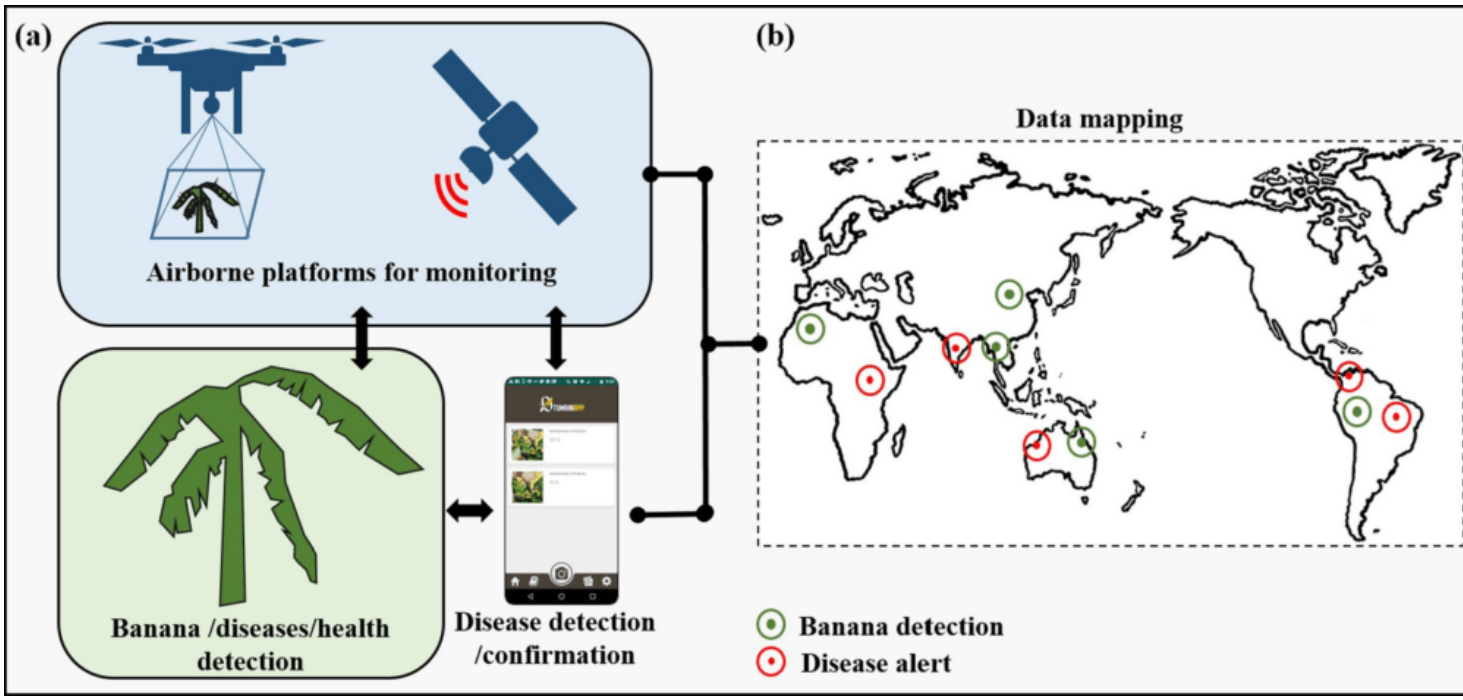
Let’s add artificial intelligence to this discussion. How can AI help to mitigate the threats of pathogens to crops?

Artificial intelligence is intelligence produced by a machine, such as a computer system equipped with learning algorithms that can keep improving its ability to make predictions as it gets more information. These tools are so advanced that they can process huge amounts of information within seconds. For crop resiliency, AI can help by making better tools for crop surveillance, designing better robots to deliver pesticides or harvest, and better software to help in breeding for traits like disease resistance and drought tolerance. It has a strong social angle, as it can help farmers and policymakers to make smart decisions.

Let’s break down each of these. How has AI been used in surveillance techniques and what are the existing technologies? Can you explain?

If you think about the rise of an epidemic in an area, at the early stages, the disease is only in a few locations. And then later, it will start to grow rapidly. There is potential for surveillance to employ remote sensing techniques like drones and satellite imagery that can identify the location of crops in farmlands that are infected with pathogens. AI tools can already use image analysis to spot changes in the coloration of leaves, flowers or fruits, and even their shapes or sizes.

Identifying diseases and taking action early can make it a lot easier to manage an epidemic. In the past, satellite data used to be very coarse: You couldn’t get a high enough resolution to diagnose a problem. But the resolution keeps getting better. As a result, their potential has been growing for use in surveillance.



This schematic shows the basic elements of an AI-powered disease-monitoring system that would allow users to detect disease from analysis of aerial surveillance data, as well as access alerts.
Credit: M.G. Selvaraj et. al. via ISPRS and Journal of Photogrammetry and Remote Sensing 2020

How exactly does AI use image analysis in these tools?

Well, there's a lot of work at the beginning. First, people have to collect and curate thousands of images of healthy and diseased plants in a range of conditions. So collecting and curating these images takes time and investment. Then algorithms are developed to learn from these images of healthy and diseased plants, to identify signatures of disease.

A lot of diseases have distinctive symptoms that can be detected visually. So if you have a drone, for example, that can go and take images in large fields, then those images can be compared and analyzed using AI to efficiently diagnose visible crop disease.

For example, our coauthor Michael Selvaraj in Colombia has been working on this technology for identifying diseases in bananas. In Florida, some growers have invested in drones for surveillance. Currently, some growers scan images from drones themselves, to get a quick view of their orchards. This will probably gradually be replaced by automated image analysis of the videos of orchards as image analysis develops further and can efficiently find diseased plants.

But there are also safety regulations issues, because unplanned use of drones could create safety hazards for the public as well. It's still a young industry. But as there are many advantages, I think it'll only expand, as policies strike a balance between protecting the public and providing benefits in agriculture.

In this study, machine learning analysis of aerial images permitted the identification of banana pla with banana bunchy top disease (BBTD, left) and Xanthomonas wilt of banana (BXW, right) with h accuracy. The ability to swiftly detect outbreaks of these serious diseases of banana and plaintain small-scale, mixed fields in which they are often grown would help to safeguard the food and econ security of tens of millions of people in Africa. Credit: M.G. Selvaraj et. al. via ISPRS and Journal o Photogrammetry and Remote Sensing 2020

And how can AI be used with robotic tools to aid in crop resiliency?

Agricultural robotics is a growing field right now. An interesting AI example already in place is segregating healthy fruit from those infected with pathogens or otherwise damaged.

Fruit can often be distinguished as diseased or not, based on color and shape. These AI tools can process those images a lot faster and more consistently so that the discolored and low-quality fruit — which are often infected with pathogens — are automatically separated.

Also, there's the idea of using drones that can collect and analyze images and then take immediate actions based on the analyses — for example, to decide to spray a pesticide. I think these tools will probably be ready for wider use in the near future, and will again need good policies.

Tell me more about how AI tools can help in plant breeding and in making more resilient strains.

You can think of plant breeding partly as a numbers game, because you have to breed plants and process lots of individual offspring when you are breeding for a trait. Crop breeders search among these offspring to find good traits for further development.

Plant breeders can use AI tools to predict which plants will grow quickly in a particular climate, which genes will help them thrive there, and which crosses between plant parents will likely yield better traits. The traits can relate to speed of growth, cooking properties, yield and resistance to pathogens. Crop breeders inoculate the offspring with a pathogen and see which ones are resistant, and what genes are associated with resistance.

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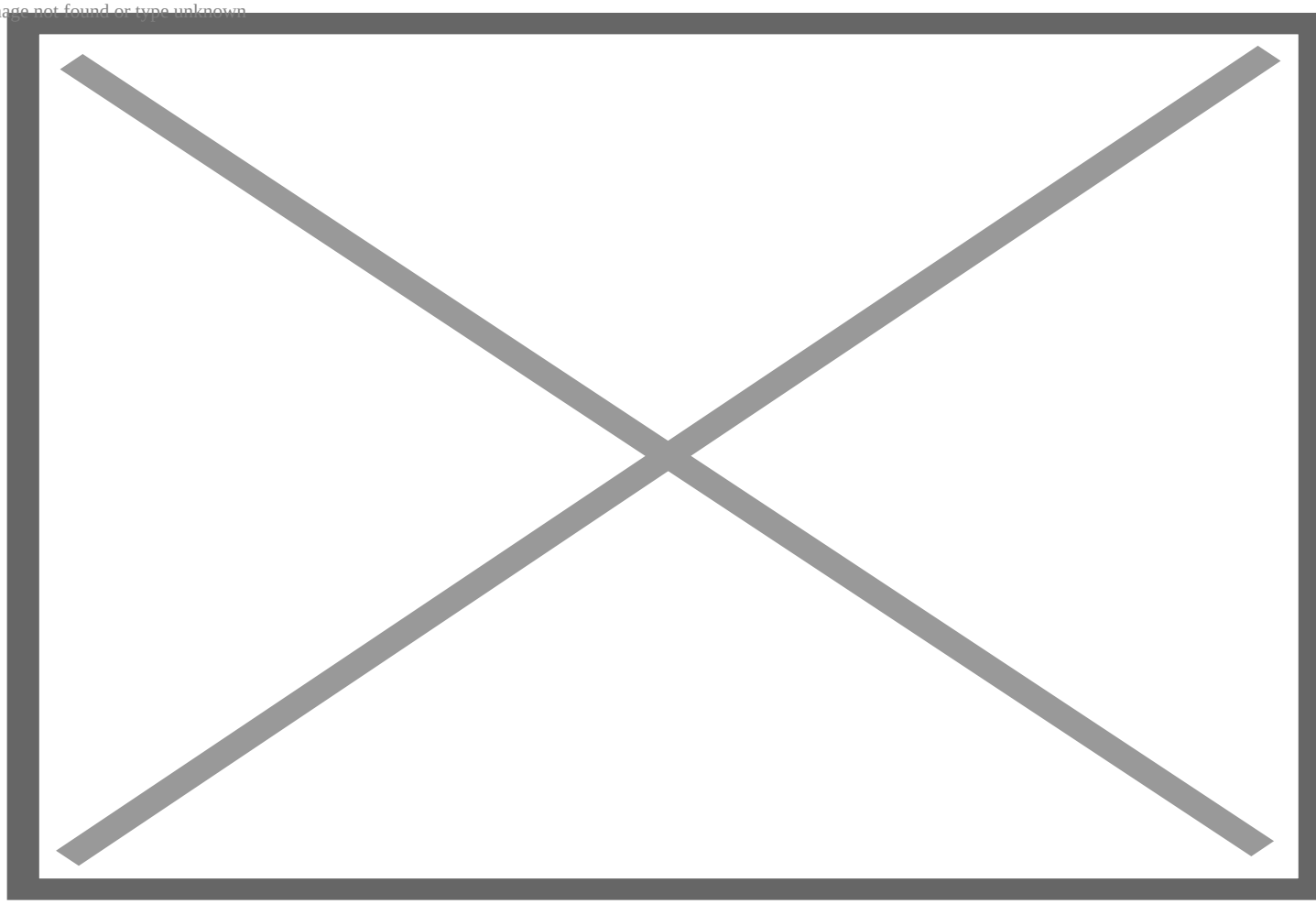


Credit: MIKI Yoshihito CC-BY-2.0

AI can speed up the analysis of great numbers of genetic sequences related to these properties and find the right combination of DNA sequences you need for a desirable trait. And image analysis is increasingly

being used for characterizing the offspring in breeding programs for major economic crops such as wheat, maize and soybean.

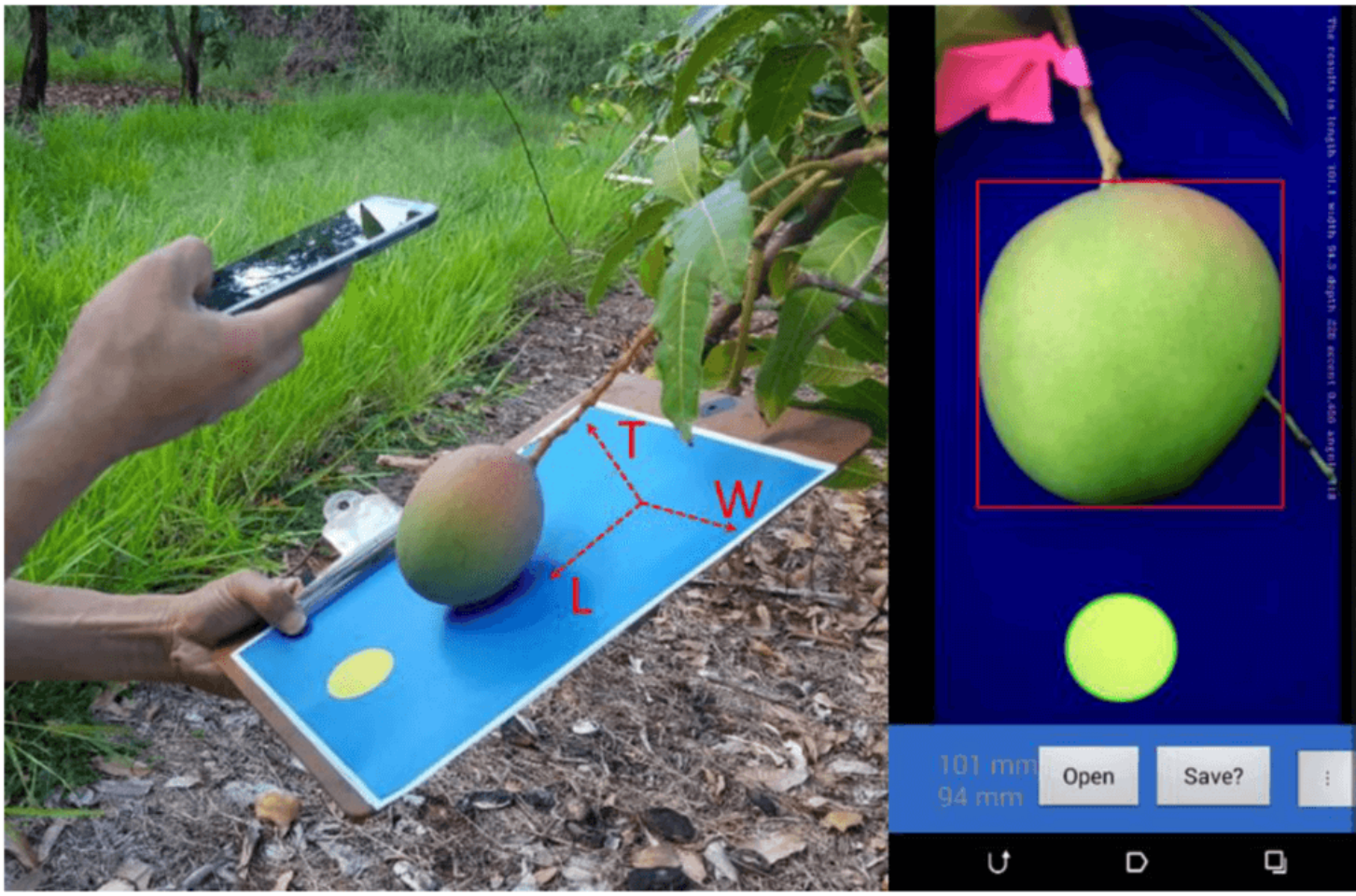
How have farmers gone about incorporating AI tools across the world?

People have been working on tools for image analysis of diseases so that farmers can take a photo of their plant and then get an assessment using a phone. For example, PlantVillage Nuru is a phone application that uses image analysis to diagnose potential diseases in crops. It uses machine learning and thousands of images of crop diseases collected by experts from around the world. The images are analyzed by AI and support growers in making informed decisions about crop management.

Image analysis for disease diagnosis is generally not 100 percent accurate, but it can provide a level of confidence to help growers diagnose their crop diseases and understand the uncertainty.

What are some of the challenges involved in developing these kinds of AI tools?

For one thing, you need a lot of data for the AI system to learn from. To make an image analysis tool for diagnostics, you need to include a representative set of crop varieties, which can have a wide range of shapes and colorations. One big challenge is just getting enough of these images that are labeled correctly to be used for the image analysis tool to learn.



Smartphone based image analysis. Credit: Wang et. al. CC-BY-4.0

Another big issue is cost. There can be a lot of tools that do what you want them to do, but is the benefit that they bring big enough that it's worth the cost investment? I think there are a lot of AI tools that are already useful, but they might not be profitable for farmers yet. Many current applications are in cases where very high-value materials are processed, such as in postharvest fruit handling and in crop breeding.

Another sort of challenge is training and capacity building so that the use of such tools isn't dependent on one expert but is more broadly used. A challenge for AI, and new technologies in general, is to make sure that the costs and benefits are fairly distributed in society.

What's your ideal vision for securing a climate-resilient food security system for the future?

To be resilient to climate change, our food systems need to be designed to respond rapidly to new challenges. We can predict some future challenges, but some changes are likely to be a surprise. Education and capacity building are key to resilience, along with effective cooperation locally and globally. An international proposal for a global surveillance system for plant disease is an inspiring vision.

For food security in general, we need to support science education and capacity building, to make the best use of our current technologies and to support the development of better technologies. We need to work for food systems that minimize negative effects of agriculture on wildlands and maximize benefits for human health.

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