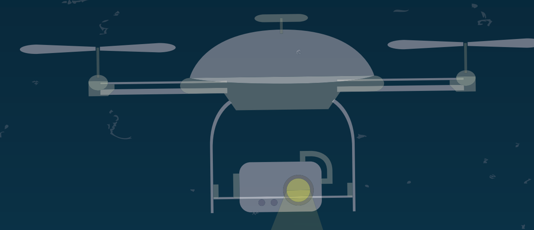


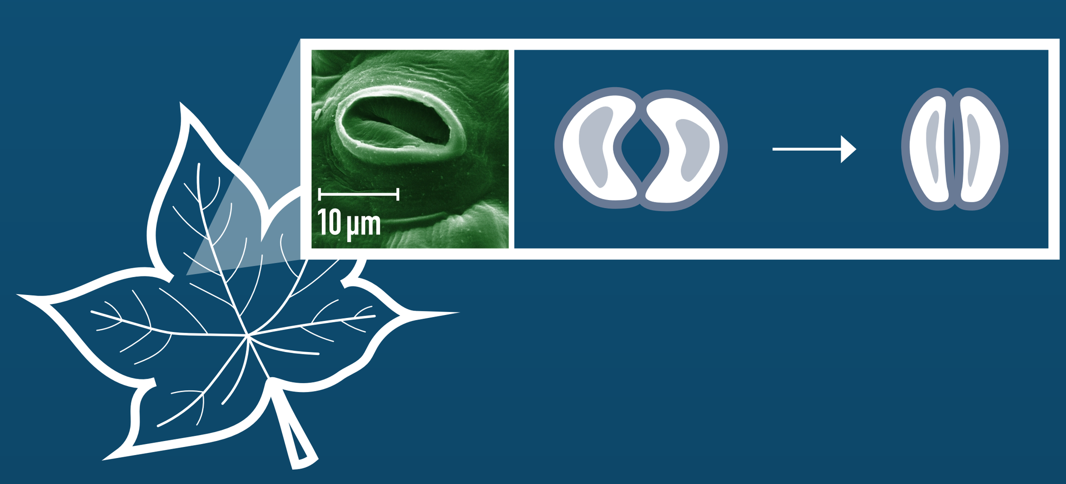
HARNESSING NEW TECHNOLOGIES TO IMPROVE CROP RESILIENCE

Farmers in the 21st century face a unique set of challenges. From unpredictable weather patterns to diminishing freshwater resources, it's becoming increasingly difficult to maintain crop health and productivity with traditional agricultural methods.

Dr. Michael Gore and his lab group at Cornell University are working to develop new ways to address these problems. Developing field and plant-scale remote sensing and machine-learning techniques along with quantitative genetics and genomics methods, they are helping advance crop science to increase crop quality and yield and improve resilience.

A MODERN ALTERNATIVE TO TRADITIONAL PHENOTYPING

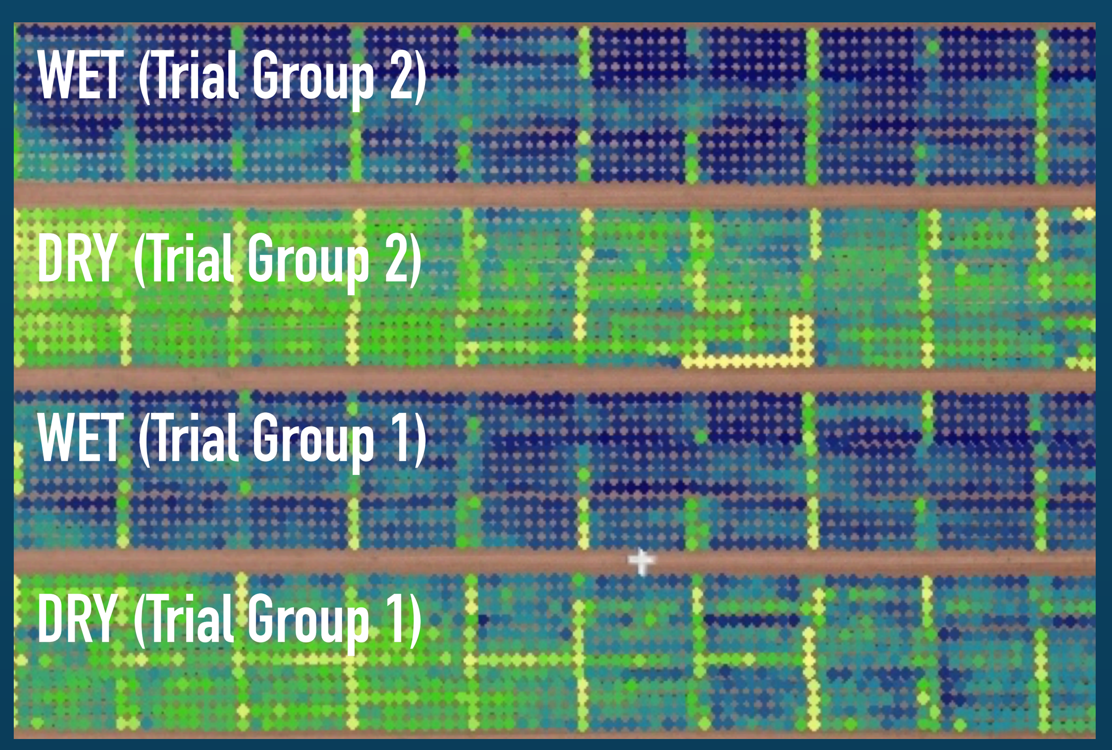
Traditionally, plant breeders have relied on manually measuring or phenotyping specific traits associated with higher yields and resistance to drought and diseases. However, these field trials are time-intensive and costly, often collecting a limited amount of data from small sample sizes. High-throughput phenotyping, or HTP, collects data associated with desired traits on a larger scale, enabling scientists and farmers to collect more information and improve selection and management, targeting plants with desirable (or undesirable) traits at a much lower cost over time.



CONSERVING WATER

Almost all terrestrial plants have pores to help with gas exchange and internal temperature regulation. These pores, called stomata, allow water vapor to pass through and cool the leaf through the process of transpiration. When drought conditions strike, abscisic acid— a hormone produced in the leaf—acts to trigger closure of the pores to conserve water. This results in less water available to cool the canopy.

Knowing plants under drought stress will generally display higher temperatures, investigating temperature variations across a field can pinpoint plants able to better self-regulate given the same water inputs.

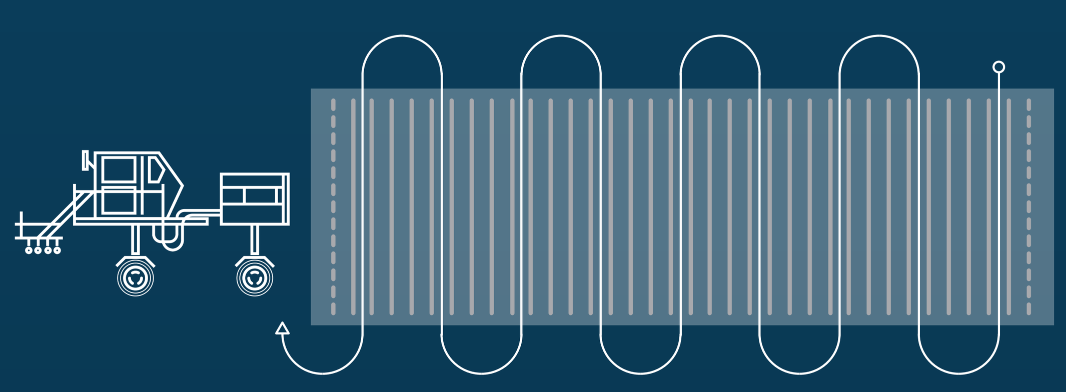


RIGHT: Figure depicting data collection through the plots. TOP: Geoprocessed canopy temperature data from 1pm on August 12, 2010, in Maricopa, AZ. Yellow indicates the highest temperatures while blue represents the coolest.

THE ROVING PLANT DOCTOR:

High-clearance tractors can be equipped with specialized sensors to diagnose drought stress at the field level. In a multiyear experiment, canopy temperatures of different cotton varieties were measured in plots under both well-watered (wet) and water-limited (dry) conditions using tractor-mounted InfraRed Thermometers (IRTs).

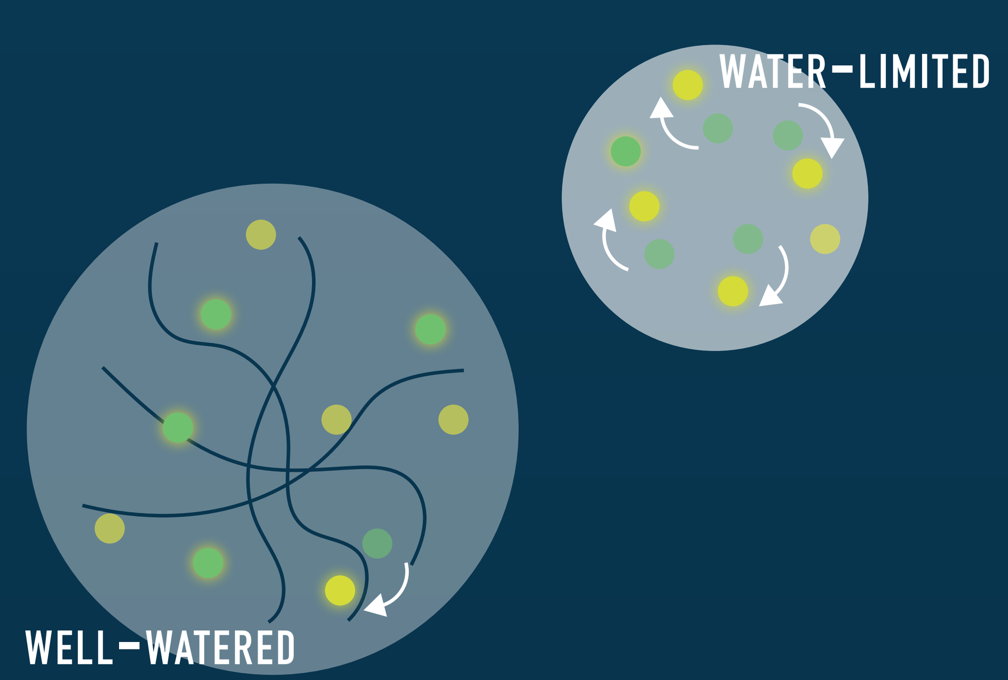
The results of this study demonstrated measurably different heat patterns, both between and within water treatments. In the trial pictured to the left, the wet plots were about 3-10° C cooler than the dry. Gathering temperature information during different points in the growing season can help breeders and farmers determine the stages in a plant's lifecycle most sensitive to drought stress, and select varieties most suited to growing weather conditions.



THE MORE YOU GLOW:

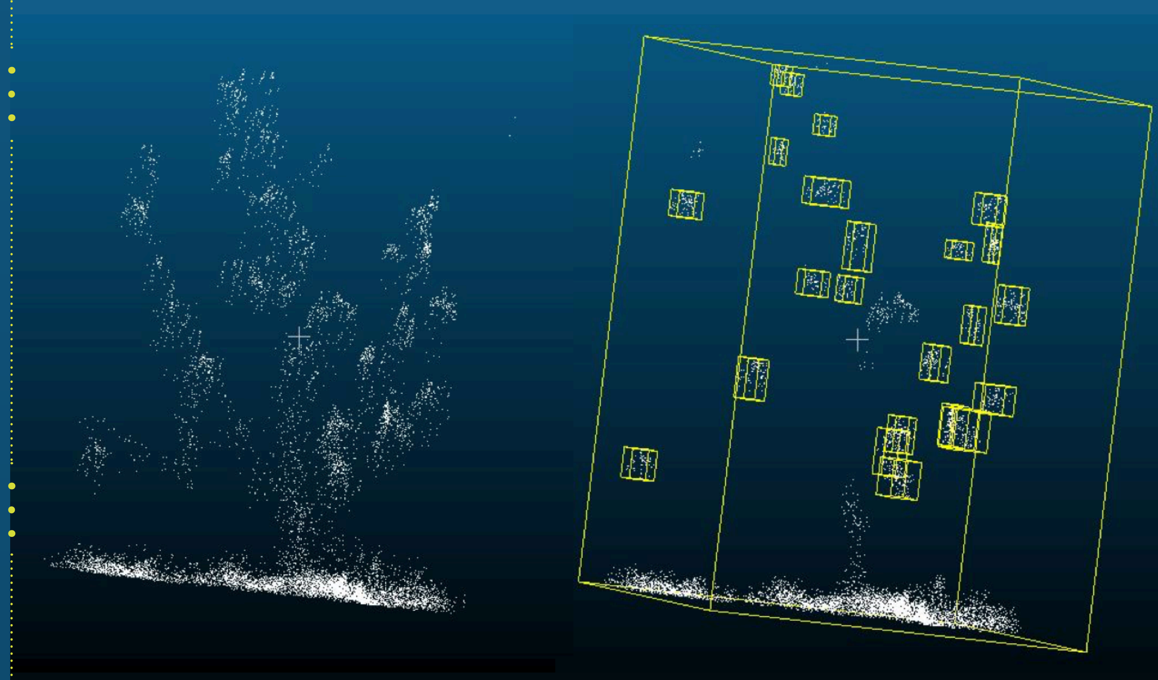
AquaDust is a fluorescent nanosensor that shrinks with decreasing water potential. When the leaf is fully hydrated, the fluorophores in the AquaDust particles, which are dispersed into the leaf apoplast, aren't coming into contact with one another. However, when the leaf is dehydrated, the fluorophores come closer together, causing localized "glows" in drought-stressed plants. Widespread nanoparticle use may one day help identify plants under drought stress at the field level. This "organism-as-sensor" strategy would use multispectral imagers carried on aerial and ground vehicles to quantify fluorescence and better couple irrigation practices to real-time plant water use.

RIGHT: Comparison of AquaDust particle fluorophore distribution and interactions after excitation in well-watered and water-limited leaves. Adapted from the work of Piyush Jain.



INCREASING YIELD

Meeting growing crop demands without sacrificing efficiency can benefit greatly from HTP. Implementing optical remote sensing techniques can lead to better estimates of crop yield before harvest as well as pinpoint higher-yielding varieties in breeding trials.



Oblique view of defoliated cotton plants surveyed with LIDAR in 2014. Individual cotton bolls can be discriminated. Point cloud visualization with CloudCompare (www.danielgm.net/cc)

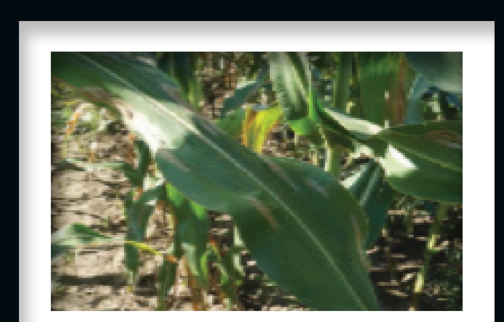
LiDAR (LIght Detecting And Ranging) instruments measure distances between targets using pulses of light, and can be used to recreate plant structures in three dimensions. The "point clouds" created in this process can then be analyzed with machine-learning techniques, creating estimates of leaf branch angle, cotton boll density, or other traits of interest and allowing for comparison between varieties. Coupling yield data with thermal measurements can help identify the highest "performing" plants under drought stress, helping agriculturalists maximize available resources.

DETECTING DISEASE

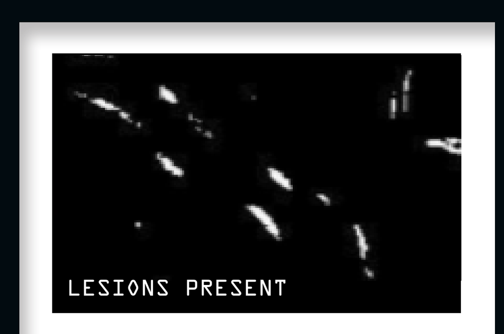
Plants are susceptible to many diseases that, left unchecked, can spread quickly and negatively impact harvest and future growth. However, visually assessing crop health by humans on the ground is time-consuming and often unreliable.

Deep learning algorithms can be used to train models that recognize image characteristics associated with specific disease symptoms. Northern Leaf Blight (NLB), a fungal disease affecting corn crops, causes grey-brown patches as plant tissue dies off. Shown on the right is an image of a diseased leaf, which was run through a convolutional neural network (CNN) to create a map of suspected NLB lesions. In this study, after the training process was refined, the final "test" set of images used to determine how well the model performed showed a 96.7% accuracy rate.

Pairing pre-trained CNN models for NLB incidence and severity with "drone coworkers" or handheld applications can potentially automate fast-tracking of disease detection, monitoring spread and alerting farmers when problems arise.



INPUT



DESIRED OUTPUT

THE POWER OF INFOGRAPHICS 2019 | SCIENCE: DR. MICHAEL GORE (https://blogs.cornell.edu/gorelab/) | ART: LEAH KUCERA (www.leahkucera.com)

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