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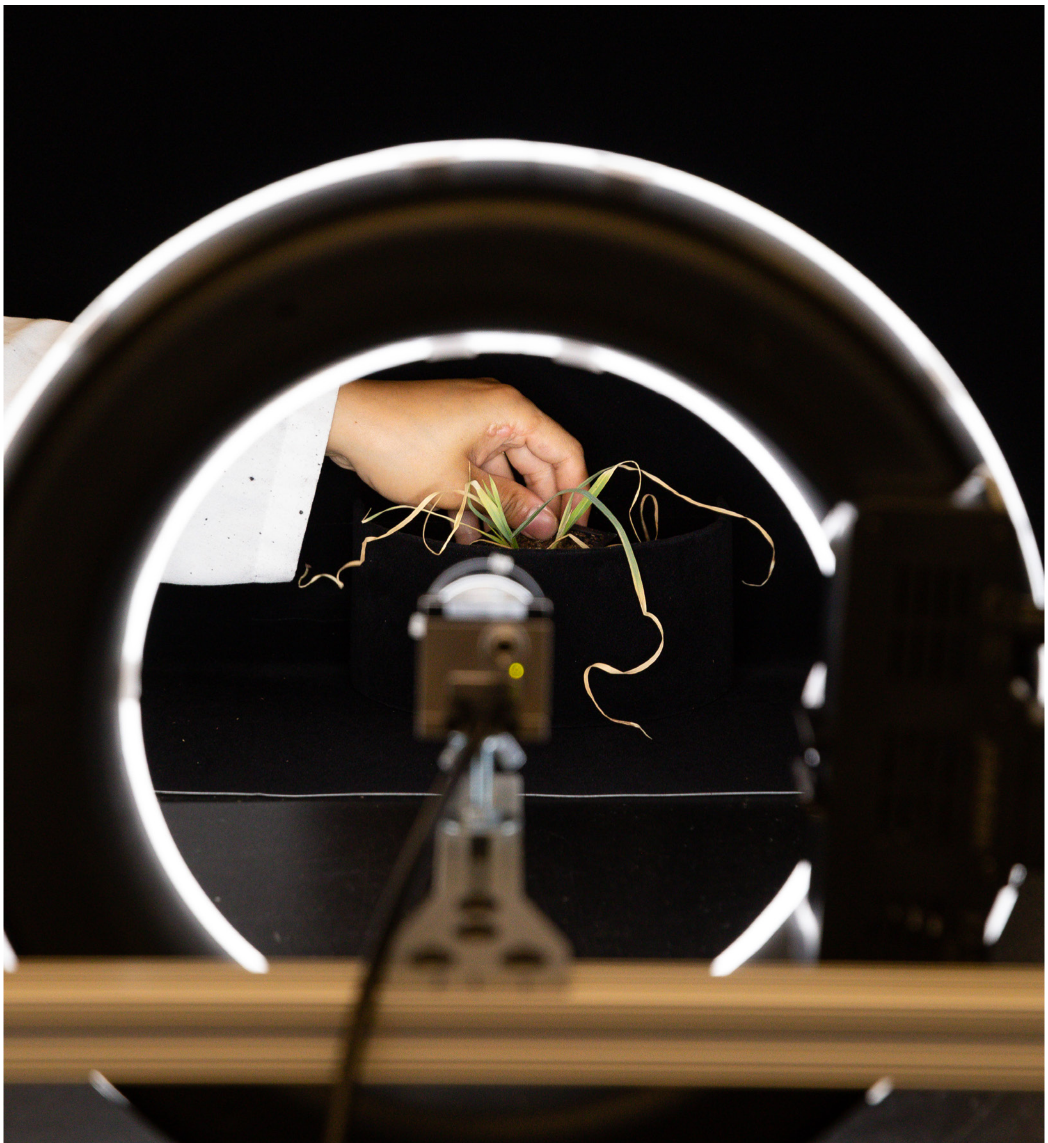
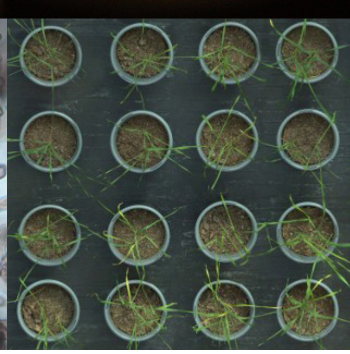
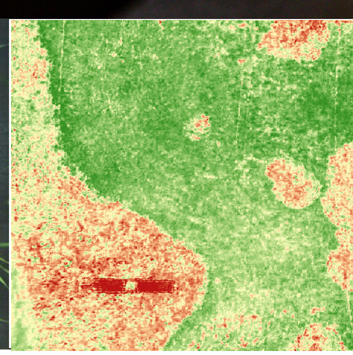
NOBLE**NEWS**&**VIEWS**







WELCOME TO THE TECH ISSUE

What Is Ahead and How We're Testing Its Potential to Benefit You

When discussing new ways of doing things in the agriculture industry, an often-stated axiom goes something like this: "That's not the way my granddaddy (or daddy) did it." Sometimes this statement contains a lot of wisdom. However, this wisdom is often taken out of context when we are considering new technology being developed and applied to agriculture.

Much of this new technology was not developed specifically for agriculture, but it has the potential to benefit agricultural producers by finding solutions to complex issues. Technology is increasing accuracy, precision and reliability of information. This saves time and money, increases productivity, simplifies tasks, and assists with decision-making for producers, consultants, researchers, managers and others who comprise the agriculture industry.

There will always be things that technology alone cannot do, and not every technology will be useful. However, technology will be increasingly called upon to improve agricultural productivity and much of it must add value to the producer if it is to be adopted.

This issue of *Noble News and Views* covers some of the technology that we are utilizing or evaluating for application with the focus on land stewardship in beef cattle production for producer profitability.

Technological advancements in this issue will cover measuring forage and livestock production, evaluating wildlife habitat, improving drought tolerance in plants, using GIS to help producers maximize their return on investment, gaining a better understanding of how different species of animals interact with each other on shared landscapes, and more.

SPATIAL AND APPLIED AG

How GIS and Drones Could Help Your Ranch

With visual representations of GIS data, producers can quickly make decisions on how to address key farming factors



by Kushendra Shah, GIS programmer and analyst | knshah@noble.org; Tresa Trammell, UAV program coordinator | tatrammell@noble.org; Dillon Payne, technology technical program manager | dbpayne@noble.org

There are types of technologies built to advance knowledge and practices in agricultural research and operations. Geographic Information System or Geospatial Information Technology (GIS) is one of the prominent technologies used in the agriculture realm. It is an integrated system comprising computer software, hardware, data, analytics and the users themselves, who help to address real-world problems with location-based information.

GIS HELPS MAXIMIZE RETURNS

In agriculture, a primary goal of producers is to maximize their return on investment (ROI). So exactly how does GIS impact agriculture to maximize returns? Well, using spatial extent

Story continues on next page

EXAMPLE OF SENSORS NOBLE IS EMPLOYING IN PRODUCERS FIELDS

Noble's DJI Matrice 600 (shown above) has six propellors to make the 600 capable of carrying a 13-pound payload. This payload allows for multiple sensors to be carried at the same time. Listed below are some of the sensors that the GIS team at Noble uses for research and data collection.

1. **DJI Zenmuse X5**
   RGB camera capable of shooting 4K quality video and imagery a few centimeter.
2. **Velodyne Lidar Puck**
   3D modeling sensor that can detect height and surface area.
3. **GPS Compass Pro**
   Provides satelite-based location data.
4. **RTK-GNSS**
   A satelite navigation system that provides geospatial positioning.

and location of agricultural fields, GIS tools and applications help to capture, analyze, and interpret pertinent data and information anywhere at any given time.

For instance, by gathering historical and current conditions of farmland, such as temperature, crop health and soil moisture, producers can come up with future yield capacity or risk of their farm.

With the visual representations of GIS data in the form of imagery, field survey maps and tabular data, producers can quickly make decisions such as how to address nutrient deficiencies and fertilizer treatments, crop health, weed control, etc.

WHERE TO FIND GIS DATA

GIS data can be available commercially and publicly. For instance, USDA's online web soil survey tool (bit.ly/usdasoilsurvey) hosts soil information, GIS maps and data that can be accessed and used at your fingertips. Similarly, interactive web applications such as USDA's CropScape (bit.ly/usdacropscape) provides GIS data that shows crop statistic information and acreage estimates based on different crops types.

While there are commercial and publicly available software and platforms that can perform our mapping needs, custom GIS web applications and online tools can perform similar tasks on-the-fly. One example is the Noble Research Institute's agricultural database mapping tool. This web tool allows a consultant to map a producer's property boundaries and footprints using ESRI cloud imagery and platform. In addition, to better leverage our consultation efforts, the tool also allows us to store cooperator information and provides decision-making abilities for producers. For example, it can calculate a producer's stocking rate and carrying capacity at the same time.

OBTAINING AGRICULTURE INFORMATION FROM THE SKY

GIS data, maps and imageries can be obtained from several platforms such as ground-based devices like GPS, airborne platforms like manned and unmanned aerial vehicles (drones), and space-borne platforms like commercial satellites.

These tools and technologies allow users to sense and collect data remotely — hence they are called remote sensing tools — at different heights from the ground. Ground-based sensors allow researchers to efficiently capture multispectral, laser and ultrasonic data, which ultimately provides forage quality and biomass yield information.

While most cutting-edge geospatial and remote sensing technologies were developed for other markets, the agriculture industry is now being transformed into a new frontier. With that perspective, we launched a UAV-based remote sensing program to empower scientists, consultants and stakeholders to tackle current agricultural challenges through advance research and technologies.

Looking at the technological pieces, we have several UAV fleets. These UAVs are paired with sensors and cameras including Global Navigation Satellite System (GNSS) as well as flight plan and processing software. This

Story continues on next page

UAV USES IN AG

WILDLIFE MANAGEMENT

UAVs have significantly helped researchers in wildlife management conduct surveys using thermal infrared remote sensing technology. In the past, thermal sensors were largely deployed in satellite systems and ground optical devices, but with the rapid advancement of robotics and automated systems, thermal sensors such as FLIR can be mounted onto UAVs. They are capable of identifying and tracking livestock and wildlife animals during the day and night based on heat signature patterns emitted from their bodies.

PASTURE AND RANGELAND HEALTH

UAVs have been proven useful to agricultural producers, allowing them to understand the health status of their pastures and rangeland. With visual and multispectral sensors, we can easily obtain crucial plant health information such as plant greenness, chlorophyll and nitrogen content. This metric is commonly known as Normalized Difference Vegetation Index (NDVI). Using this metric, healthy and diseased areas can be isolated, allowing producers to view area conditions that are otherwise invisible to the human eye.

CROP RESILIENCY

While the human eye doesn't have the ability to detect subtle temperature differences, thermal sensors are can better understand crop resiliency toward heat stress and soil moisture in response to our changing climatic conditions.

WHAT AG SENSORS CAN MEASURE

Sensors mounted on the UAVs are able to inexpensively capture very high resolution data at just a few centimeters. These high resolution images provide useful information, including:

VEGETATION GROWTH

SURFACE 3D ELEVATION AND VOLUMETRIC ANALYSIS

SOIL EROSION MAPPING

WILDLIFE SURVEYS

FENCE LINE INSPECTION

CROP DISEASE SURVEILLANCE

COMPARE DRONES, SENSORS AND PRICES ONLINE

www.sentera.com/agriculture-drones/

www.sensefly.com/

www.precisionhawk.com/drones

makes the fleet resemble a whole technological system, which is why it is called an unmanned aerial system or UAS.

During the data collection mission, UAV operations are conducted under Federal Aviation Administration (FAA) rules and regulations. Furthermore, survey flights are performed autonomously — the system can take off, scan the area and return home in autopilot fashion.

THE FUTURE OF SMART AGRICULTURE

Agricultural technologies are growing faster than ever before, which leads us to think about future technologic opportunities and challenges that can bring agricultural research and operation to the next level.

With the rise of Internet of Things (IOT), big data and innovative geospatial technologies, smart agriculture or smart farming practices have been implemented in many parts of the world. IOT-powered smart farming can eradicate inefficient farming practices and perform actions that require physical labor such as farm irrigation, crop scouting and weed control, and plant and soil health assessment. On the flip side, smart agriculture is challenging due to its integration on so many variables such as smart field devices, real-time data and analytics, wireless network, and so on. In addition to these, producers want very easy-to-use, cost-effective tools, and these are often difficult to find.

Smart agriculture requires several types of real-time data digestion from multiple sources. One source is the satellite data services. Sensors onboard the satellite platforms offer large fields of view, enabling researchers and farmers to see land surfaces at macro levels.

In addition, with multitudinous bandwidth and frequent earth visit, satellite data allows many possibilities to maximize efficiency in agriculture through yield modeling, monitoring of soil moisture and drought conditions, and detecting crop stress over large-scale farms.

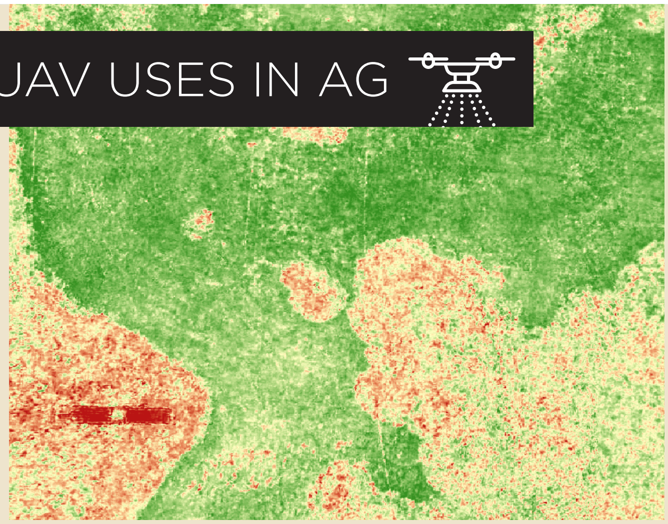
While there are openly available satellite data with low resolution from government entities like NASA, commercially available satellites from Digital Globe, Planet Lab and Astro Digital offer better resolution (below sub-meter) with higher quality.

In the coming years, researchers here will work on satellite data services to understand forage dynamics and biomass health across its farms. Wouldn't it be interesting to understand what additional information of our fields can be depicted from space?

Furthermore, satellite data in tandem with ground-based sensors and UAVs enable us to capture biomass and crop information at three altitudinal gradients. This combination of three-tier platforms allows citizen scientists, consultants and producers to intersect diverse sets of information and make data-driven decisions pertaining to agriculture and biomass productivity.

This will certainly help tackle our common agricultural interests and challenges leading to smart agriculture practices across the Great Plains.

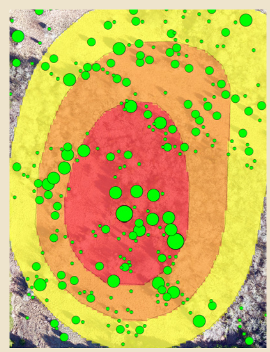
UAV USES IN AG



COTTON ROOT ROT

One example is mapping of the cotton root rot disease, also called Texas root rot — a fungus that originated from cotton plants and spreads out on the roots of other plants, killing them off gradually. This disease causes huge economic loss to producers annually. UAVs have obtained high quality images and prescription maps to identify and track disease movement, which allows consultants and producers to adequately plan and make treatment decisions during the disease progression.

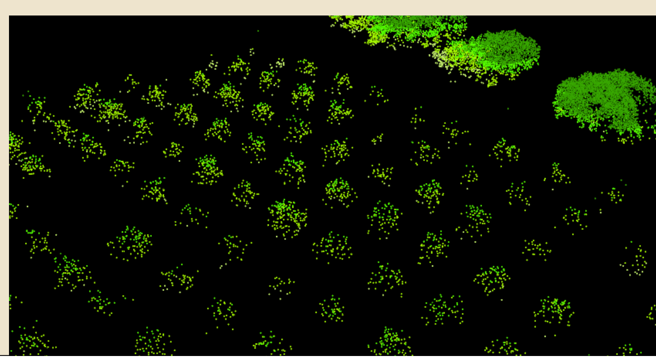
BRUSH MANAGEMENT



One recent examples is brush management work. As we all know, eastern redcedar is a nuisance to agricultural lands and pastures of the Great Plains. It not only competes with the growth of desirable biomass but also threatens the wildlife habitat and degradation of rangelands quality. We use UAVs to identify hotspots of cedar trees using high resolution visual and infrared imagery that can easily isolate cedar trees from the other tree species. This helps producers decide the best option to treat areas with invasive trees.

PECAN ORCHARD SURVEYS

Similarly, we observed that UAVs are a key tool for surveying pecan orchards. During the last couple of years, we've been monitoring pecan orchards using Lidar sensors mounted to the UAV fleet. It shoots pulse waves to the ground and measures height of any object based on the calculation of time the pulse wave return. Lidar scanning techniques are frequently and widely used to obtain digital elevation models (DEM) and surface models (DSM) with greater precision.



Before buying a drone for the ranch, consider what you want to do with it and check into the costs of the programs you will need to gather and store dat. Also be sure you are operating legally and remember the technology is constantly evolving. Find other considerations at www.noble.org/news/publications/ag-news-and-views/2018/february/evaluating-drone-based-sensors/

AERIAL SCANNING DRONE SENSOR OPTIONS

Each sensor has its own specific functions depending on what it can achieve from aerial scanning, so it is important to understand and evaluate the drone based on what you need in your business or operation. Since sensors capture actual data, the cost of UAVs are determined by the sensor types embedded in it. Some available sensors include:

HIGH RESOLUTION VISUAL BAND (RGB),

MULTISPECTRAL (INFRARED),

LIDAR (LIGHT DETECTION AND RANGING)

THERMAL

PLANT PHENOMICS

Plants in the Spotlight: Measuring Shoots From Images

Larry York, Ph.D., assistant professor, root phenomics | lmyork@noble.org; Anand Seethepalli, computer vision specialist | aseethepalli@noble.org

Plant growth is one of the most observable and important processes that ultimately determine forage biomass. Dry weight of forages is often collected periodically throughout a growing season by clipping in order to estimate shoot growth and forage potential. However, these periodic clippings miss the dynamics between clipping events and give no indication of plant structure or health. Therefore, technologies that can fill in these knowledge gaps will be invaluable for understanding the ability of forages to grow under a variety of conditions such as different soils, weather and fertility.

One such technology is image-based automated computer analysis, commonly known as computer vision. With the right images, we can capture predictors of plant mass and information about shoot architecture, such as the number of leaves, leaf lengths, leaf areas and leaf angles. Using the color information within the image, we can also give indicators of plant health based on its greenness, which is related to chlorophyll content that is responsible for photosynthesis — the act of converting atmospheric CO_2 to sugar.

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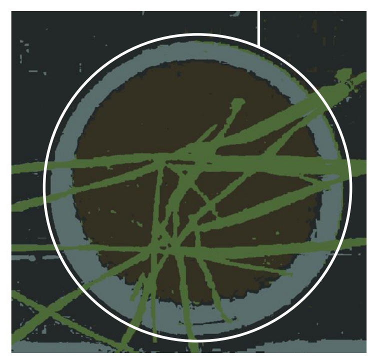


TECHNOLOGY IDENTIFIES PLANT HEALTH

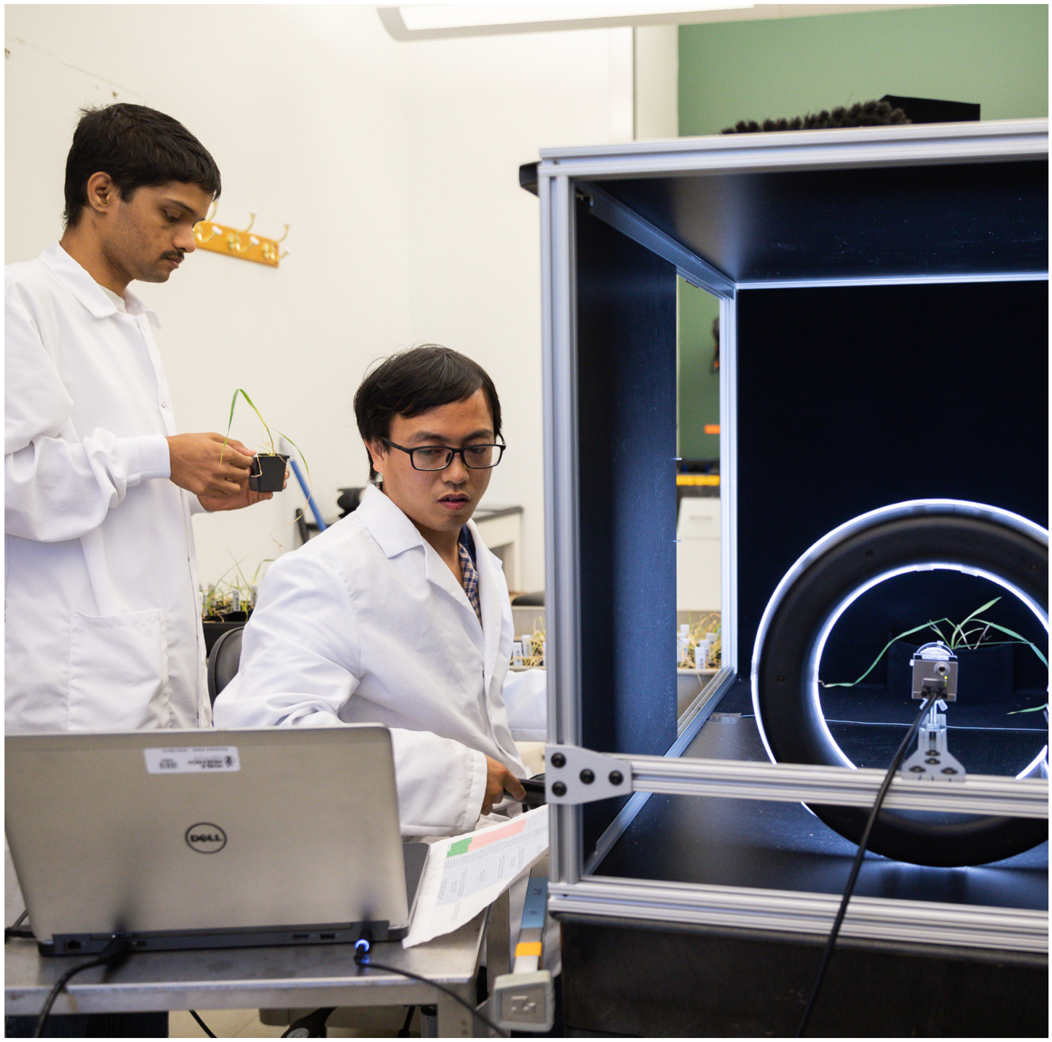
The Controlled Environment Imaging Gantry uses machine learning, cameras and software to identify key factors of plant health: leaf area, leaf number and plant greenness. First, the system identifies a single plant from a group of potted plants. Then it is individually cropped out (above left) before the plant portion is identified using machine learning (above right). The imaging gantry also produces a high resolution overhead view of the entire scene (below). This allows researchers to gain a better understanding of individual plants.

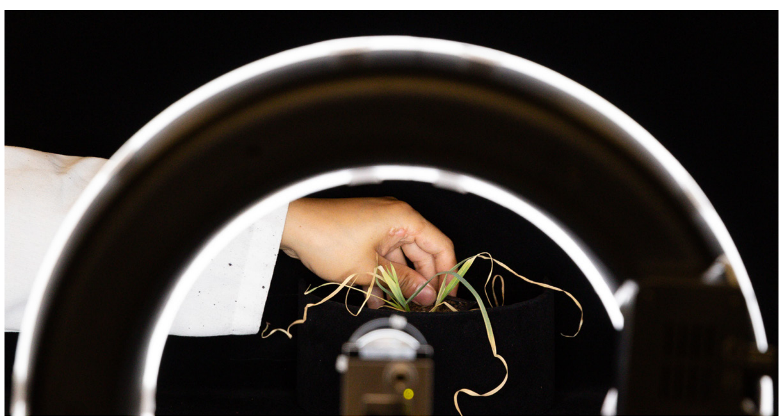
STUDYING HEAT STRESS IN WINTER WHEAT

Winter wheat for forage-only or dual-purpose is typically planted about one month earlier than wheat for grain only in order to increase biomass accumulation early in the season. However, this typically exposes the emerging wheat seedlings to greater heat stress and drought conditions. Therefore, increased heat tolerance and drought tolerance would be valuable traits for forage-focused wheat varieties.

Recently, we have designed and built two systems that measure plant shoots over time with a focus on early growth in controlled conditions. Controlled conditions are used to standardize the growth environment so experiments can be compared. We have several large greenhouse rooms and many small growth chambers. The greenhouse allows moderate control of temperature and lighting, while growth chambers allow precise control of both by acting as self-contained systems with their own lighting and heating and cooling systems.

We have designed an image-based systems called the "Controlled Environment Imaging Gantry" for use in the greenhouse and the "Controlled Environment Imaging Booth" to be used for plants grown in growth chambers for studying heat stress. This work has been conducted in collaboration with Xuefeng Ma, Ph.D., assistant professor in Noble's small grains breeding laboratory, and is partly supported by a grant from the Oklahoma Center for the Advancement of Science & Technology.





Anand Seethepalli (left), computer vision specialist, and Wangqi Huang (right), research associate, operate the Controlled Environment Imaging Booth created for monitoring the growth and health of plants subjected to normal temperatures or heat stress in growth chambers.

CONTROLLED ENVIRONMENT IMAGING BOOTH

The Controlled Environment Imaging Booth was created for monitoring the growth and health of plants grown in growth chambers. Wheat seedlings are grown in the chambers for a couple weeks at 77 degrees Fahrenheit (25 degrees Celsius). In one control chamber, this temperature is maintained, while the temperature is increased to 95 degrees Fahrenheit (35 degrees Celsius) in the other heat stress chamber. Images are captured using the imaging booth every week. The imaging booth consists of a covered aluminum structure with sliding doors. Telescope flocking paper was used as the background to create a uniformly matte black background. The same type of camera as used on the gantry is used in this system and positioned across from the black background inside a ring light to provide uniform illumination of the background. Plants grown in small cells grouped in trays are inserted individually directly in front of the background. We developed an imaging software called RhizoVision Imager to control the camera. Using Imager, a barcode on the tag is scanned, which triggers image acquisition and saves the image with the barcode ID as the file name. The optimized design of the imaging booth leads to high contrast images of green-yellow-tan plants on a stark, flat black background. Therefore, segmentation is relatively straightforward and can be accomplished using simple threshold-based techniques, rather than complex machine learning as described next for the Imaging Gantry. So far, the total leaf length has been extracted using RhizoVision Analyzer software previously developed for roots. The difference in leaf area between the control and heat stress treatments is readily determined. Recently, we have discovered that by calculating the "greenness" present in the plant image, we can approximate chlorophyll content — a good indicator of plant health.

CONTROLLED ENVIRONMENT IMAGING GANTRY

In order to study early wheat growth in response to drought, one of the greenhouse rooms contains a 10-foot-by-20-foot gantry system, or a moving bridge-like overhead structure, that is maintained by Noble's spatial and applied agricultural technology group. The Root Phenomics Laboratory outfitted the system with a color machine vision camera and computer that are attached to the carriage. This system allows the camera to "fly" over the whole area with precise imaging intervals that allow a series of overlapping

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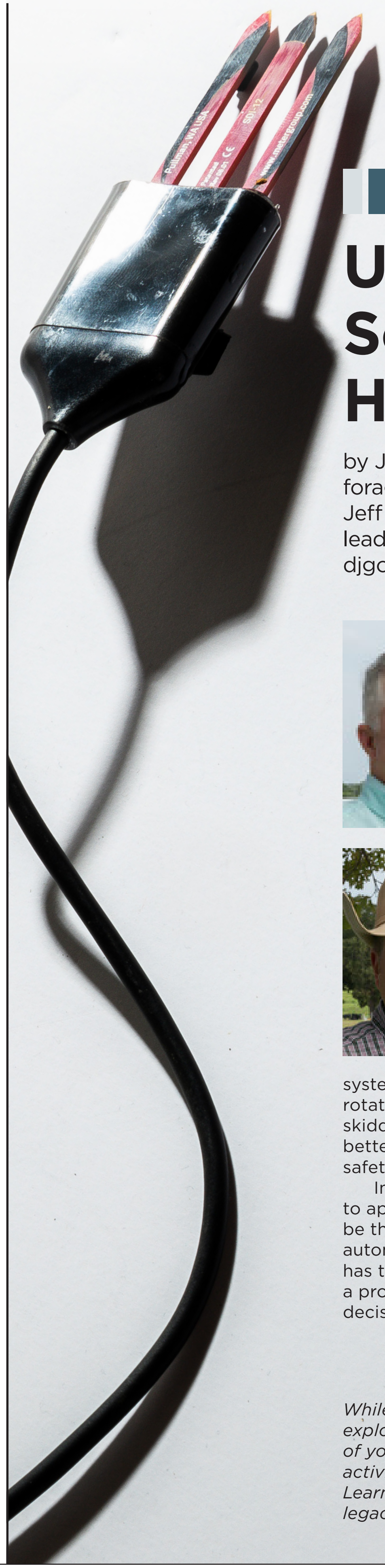
images to be taken. The basic idea is similar to how UAVs are used to make large image maps of farms and other landscapes. All the images overlap by about 60% of their area and are captured by the RhizoVision Imager software, which you can learn more about in the article "Measuring the Hidden Half." The software uses interval imaging of one second between each shot. An automated process called "stitching" identifies landmarks in each image that match to merge them together. In the case of the imaging gantry, approximately 450 images are combined to make one large, high-resolution image of all the potted plants below. We accomplish this using another software product called Agisoft PhotoScan, just like with the UAV work described in the article, "How GIS and Drones Could Help You on the Ranch Now and in the Future."

We acquire these images every day, so we can watch the plants grow. At the four-leaf stage, water is withheld from half of the plants, while the remaining plants remain watered. This allows us to watch as the plants respond to drought. Our idea is that we can see the final reduction in leaf area as well as which plants start to respond first with slowed growth or by turning from green to brown. However, to answer these questions, we first have to identify the individual pots and quantify the shoot traits of the plants. We have developed a general purpose tool that supports a user annotating, or marking, an image for regions of interest. We use this tool for selecting all the pots in the first day's image. Since the pots don't move, we can use this same template to select pots in all 50 days of images we acquire. This allows us to crop out individual pots from all the images. Once we have these, we still have to identify plants from the background. Healthy plants are green, while the background includes potting media, a gray plastic pot and black plastic trays. In order to identify the plants, we chose to employ machine learning, like what's used by Google Home or Amazon Alexa. Using our annotating software, we chose small areas containing only the plant, media, pot or tray. We used a probability model called a Bayesian classifier to train the computer to identify these. Now that the computer is trained, we can use this classifier on new images to identify the plants. Finally, we can calculate traits like leaf area and number and get an indication of plant health by evaluating greenness.

Image-based plant measurements are among the hottest topics in plant biology and crop science. We are utilizing the latest techniques in computer vision and machine learning along with state-of-the-art cameras in order to put plants in the spotlight. We aim to shed light on how plants grow and respond to stresses like drought and heat in order to develop the best forages possible for the Great Plains.



AGRONOMY

Understanding Soils With the Help of Sensors

by James Rogers, Ph.D., associate professor forage systems | jkrogers@noble.org;
Jeff Goodwin, conservation stewardship lead and pasture and range consultant | djgoodwin@noble.org;

Sensors are being used more in our everyday lives. Simply put, they are devices that measure or detect a change in our surrounding environment and provide feedback. The feedback provided then needs to be interpreted into useable information that can then be used for decision-making or to increase our understanding of how something, like a biological system, functions.

Sensor use has really taken off in the automotive industry and is helping drivers improve safety. Sensors can detect approaching vehicles and apply brakes or warn drivers of oncoming traffic when crossing a roadway. Anti-lock brake systems use sensors to detect changes in wheel rotation then correct braking pressure to avoid skidding. All of these automotive applications lead to better driving decision-making and improved driving safety.

In agriculture, we are still discovering new ways to apply sensor technology, and the sky appears to be the limit for future applications. Just as in the automotive industry, the data collected by sensors has to be interpreted into useable information that a producer can use to make a better management decision than they can currently.

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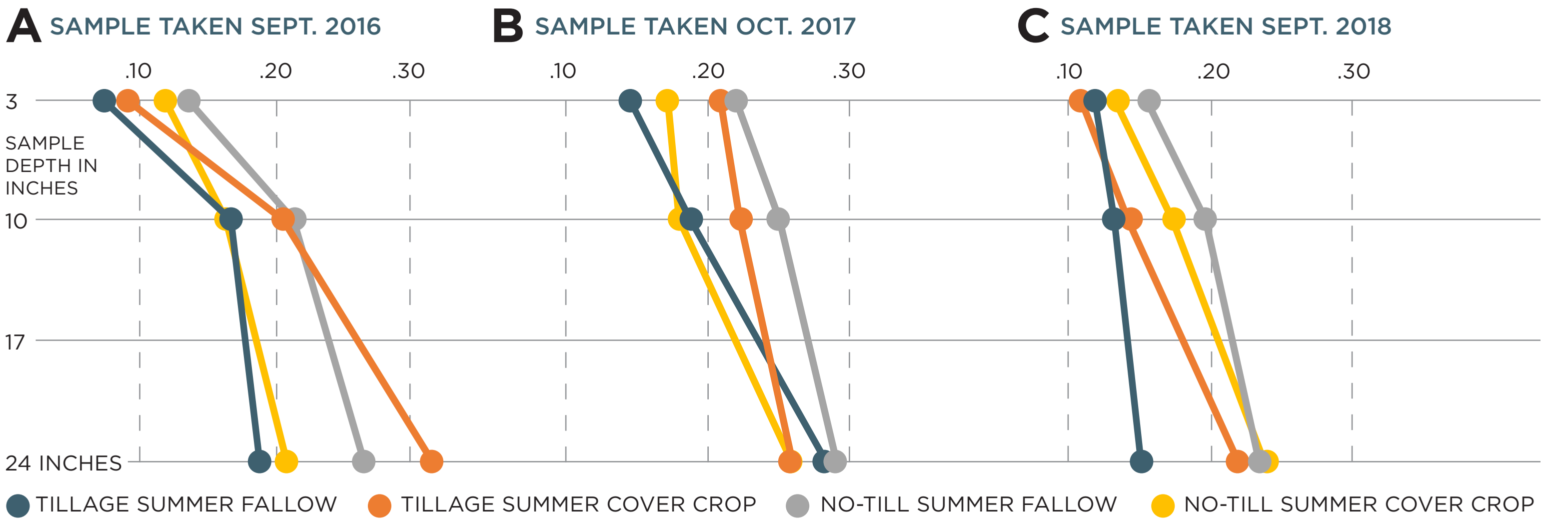
While sensor technology is enabling deeper exploration of soil, you can still get a good indication of your soil's health by evaluating its color, biological activity, structure, rooting resistance and smell. Learn more at www.noble.org/news/publications/legacy/2019/spring/how-can-you-see-soil-health

FIGURE 1: M³/M³ VOLUMETRIC SOIL WATER CONTENT

Figure 1. Volumetric soil content taken at the end of the summer period and prior to the establishment of winter pasture in 2016 (a), 2017 (b) and 2018 (c) located at the Noble Research Institute Pasture Demonstration Farm near Ardmore, Oklahoma.



SENSORS HELP CONSULTANTS MAKE BETTER RECOMMENDATIONS

Opportunities for sensor use in research appear to be just as boundless, but our objectives in the use of sensors is somewhat different. Research applications of sensors aid understanding of how a biological system works or gain a deeper understanding of treatment effects, and increase the resolution of data collection. All of this eventually leads to improved management recommendations for producers.

DETECTING SOIL MOISTURE AND TEMPERATURE

In applied research, we are using soil moisture sensors to increase our understanding of water use by summer cover crops in winter pasture forage systems as well as the effects of till or no-till within these systems. To do this, we are deploying soil moisture sensors at depths of 3 inches, 10 inches and 24 inches in each treatment replication.

In addition to detecting soil moisture, these sensors are also equipped with temperature sensors that provide us with soil temperature readings. Soil temperature is important for at least two reasons:

1. The warmer or hotter the soil gets, the more water is moving out of the soil due to evapotranspiration.
2. The effect of temperature on soil microbial activity as microbial growth will decrease when temperatures move past 85 degrees Fahrenheit.

Each sensor location has a data logger that collects readings once every hour then transmits that data to a central location via a radio signal. Readings are transferred to a computer with a software package that transcribes the raw data into useable information.

From the data gathered by the soil moisture sensors (Figure 1), we can see that tillage summer fallow soils tend to have the lowest soil moisture content compared to other soils while no-till summer fallow soils have the highest.

Something that is interesting to note is that the tillage cover crop treatment tend to have higher soil moisture than tillage summer fallow especially at lower depths. This is probably due to the cover crops shading and cooling soil temperatures, aiding the retention of soil moisture. The cover crops are using soil moisture for growth but not to the extent that tillage summer fallow soils are losing soil moisture due to evapotranspiration. Soil temperatures in the tillage summer fallow treatments have risen past 110 degrees Fahrenheit during the peak of summer, which suppresses soil microbial activity.

DETERMINING SOIL LOSS

Another sensor technology that we are employing with this study is the use of drones. We fly drones over the study area, which is 100 acres in size, to assess treatment effects on crop emergence and, most recently, to help us determine soil loss due to water erosion.

To determine soil loss, we fly the drone equipped with Lidar (light detection and ranging) cameras to measure the dimensions of eroded areas. Then, we calculate the volume of soil it would take to fill the eroded areas back up level with the surrounding field. In one of our tillage summer fallow treatment paddocks, we have an estimated soil loss of 8 tons. Take a moment to consider the ramifications of this on soil health. If this field is tilled and the eroded area is filled back up with tilled soil, we would lose another 8 tons of soil in the next big rain event.

MEASURING SOIL ORGANIC CARBON

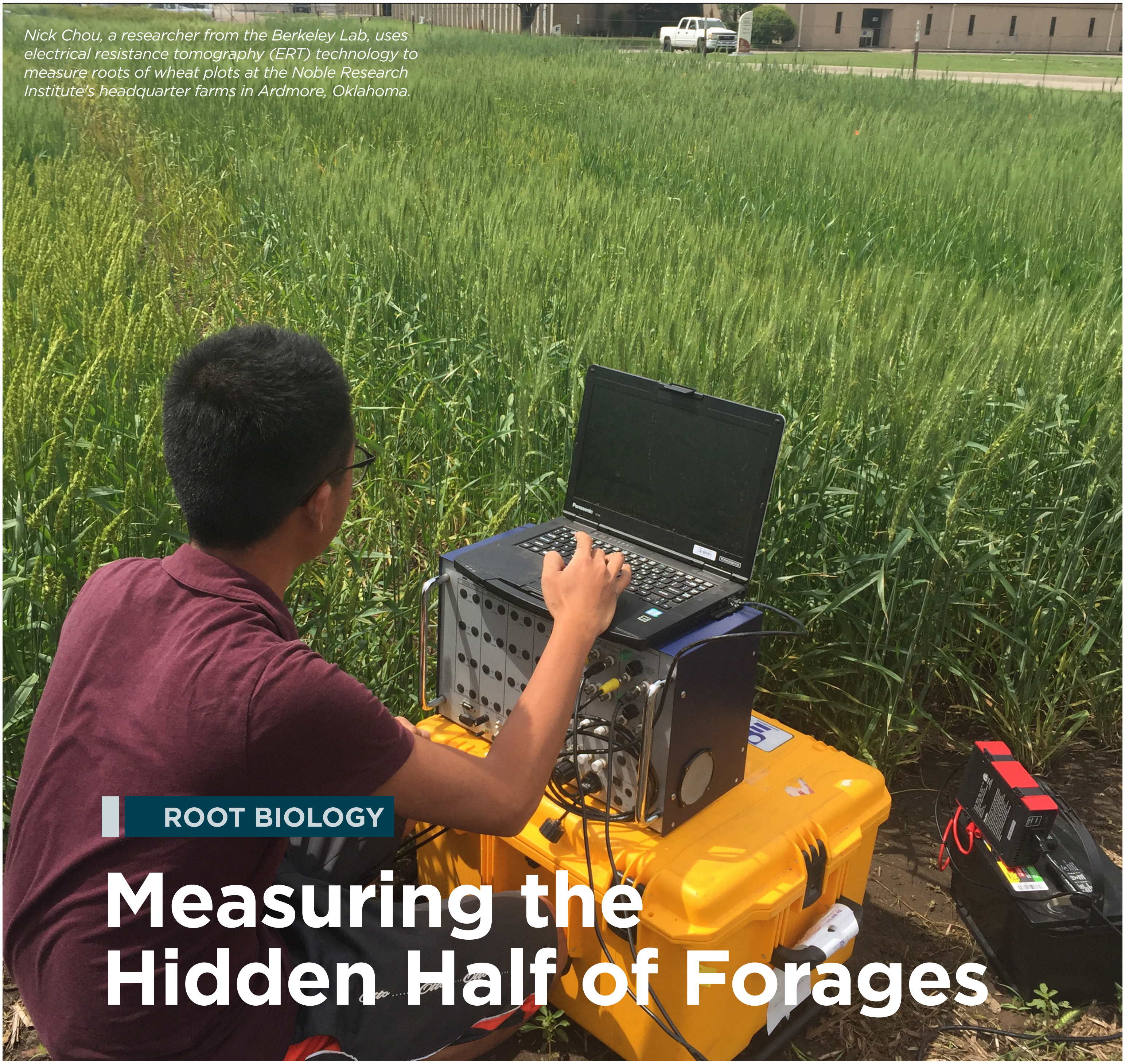
One last example of our current sensor technology research involves our desire to quantify soil organic carbon and its response to management. The potential for soil organic carbon sequestration in agricultural production systems has been well reported; however, the logistical mechanisms of dealing with spatial soil variability has posed problems for accurate quantification. Along with variability concerns, the cost of sampling fields for laboratory analysis with a level of moderate to high density can be prohibitive.

A method currently used to mitigate cost concerns is the use of spectroscopy, specifically, visible, near and mid-infrared spectroscopy. The prediction of various soil properties including soil moisture, soil organic carbon and total soil nitrogen content have been developed using near-infrared (NIR) spectroscopy techniques as a useful quantitative tool.

Spectroscopy using laboratory-based instrumentation has been used to predict soil carbon levels, but field conditions limit the accuracy of these estimates. The combination of geospatial data products along with visible/near-infrared (VNIR) spectroscopy measurements of soils to model soil carbon content may provide a solution.

VNIR spectroscopy has been reported as an effective method of detecting changes in soil carbon content based on their soil spectral reflectance. We are currently working with Yale University to test hand-held spectrometers, which is yielding positive early results. This approach provides considerable opportunity for providing decision-support information for agricultural producers at a reduced price point over conventional testing. It also offers a better way to understand viability across soil texture classes and soil depths as soil carbon concentration changes.

The use of sensor technologies is helping research understand the functioning of biological system and build a strong case for conversion to no-tillage practices.



Nick Chou, a researcher from the Berkeley Lab, uses electrical resistance tomography (ERT) technology to measure roots of wheat plots at the Noble Research Institute's headquarter farms in Ardmore, Oklahoma.

ROOT BIOLOGY

Measuring the Hidden Half of Forages


by Elison Blancaflor, Ph.D., professor, plant cell biology | eblancaflor@noble.org Larry York, Ph.D., assistant professor, root phenomics | lmyork@noble.org

Roots are crucial for acquiring water and nutrients from the soil, preventing erosion, and building soil carbon (see "Why Roots Matter to Soil, Plants and You" at www.noble.org/why-roots-matter). Furthermore, all these processes are also central to improving soil health (see "Look for These Soil Health Indicators in the Field" at www.noble.org/soil-health-indicators).

At the Noble Research Institute, we are addressing basic research questions about the genetics, development and physiology of roots while simultaneously applying this knowledge in forage breeding programs. We believe we can harness the power of roots to generate more nutrient-efficient, more resilient and more sustainable plant varieties that simultaneously increase producer profits while decreasing fertilizer inputs and pollution.

In root biology, the statement is cliché that roots are the hidden half. However, the description is appropriate. Because they are buried in soil, roots have been neglected in plant research due to a lack of technologies to efficiently study and

Story continues on next page

understand roots. Therefore, a fundamental aspect of root research at Noble is to envision, invent and deploy novel methods for studying roots in the field.

Recently developed image-based methods that rely on root excavation are currently being used in the field, while research continues to develop futuristic technologies that will allow noninvasive scanning of roots in the field.

Elison Blancaflor, Ph.D., right, and Xiuwei Liu, Ph.D., demonstrate the "shovelomics" method for excavating crop root crowns.

GETTING DIRTY

The most commonly applied methods for studying roots in the field require removal of roots and soil, which are subsequently washed and photographed for further analysis. One of these commonly used methods has been called "shovelomics" and is appropriate for screening entire breeding populations of several hundred varieties in replicated plots. A researcher enters a research plot and uses a normal shovel to excavate the root crown, or the top portion of the root system. This root crown is soaked in water and gently washed with a water hose nozzle before being placed in a plastic bag and kept cold until photographing. Generally, this root crown breaks off the roots in the vertical direction but not in the horizontal as it is being removed from the soil. Though a lot of roots are certainly lost during excavation and washing, a substantial body of research now exists to show that traits measured from the root crown are useful for understanding the differences among varieties and why they perform differently.

EXAMPLES OF EMERGING TECHNOLOGIES FOR NONDESTRUCTIVE MEASUREMENT OF PLANT ROOTS

ERT = Electrical Resistance Tomography

GPR = Ground Penetrating Radar

SIP = Spectral Induced Polarization

X-Ray CT = X-ray Computed Tomography

MRI = Magnetic Resonance Imaging

The most advanced platform for imaging, or photographing, these root crowns was recently developed at Noble by the root phenomics laboratory, led by Larry York, Ph.D. The RhizoVision Crown platform integrates custom hardware and software in order to efficiently acquire root crown images that can easily be automatically processed using computer image analysis. The hardware platform consists of a backlight in front of which the washed root crown is suspended. A monochrome (black and white) machine vision camera is placed directly across from the roots. These cameras are normally used in factories to automate assembly lines, and they provide many useful features such as being rugged and easily programmable. An imaging software called RhizoVision Imager has been developed to allow a barcode reader to be used to scan the barcode on the sample, which triggers image acquisition and saves the file with the sample identification. The imager also allows live view and changeable camera settings. The software is versatile and is currently being used for multiple imaging platforms developed at Noble.

The RhizoVision Crown platform makes acquiring thousands of root images relatively easy. Due to the use of the backlight, these images contain a nearly black root crown on a nearly white background. Therefore, image analysis is greatly simplified because the computer can so easily identify the roots. Another software, RhizoVision Analyzer, was developed to efficiently process these thousands of images and extract a suite of nearly 30 features including root length, number of roots, root diameters and root angles, all of which are known to be important for vital root functions.

In collaboration with the mycology laboratory under the direction of Carolyn Young, Ph.D., the RhizoVision Crown platform was used to quantify the root system architectural differences between alfalfa plants that had survived cotton root rot and those that had not been affected. The results were consistent with survivors having lost their taproot but having the ability to compensate with many finer diameter lateral roots. Machine learning approaches were able to use the image-based data to predict whether roots were survivors or not with 75% accuracy. In another large collaboration involving small grains breeder Xuefeng Ma, Ph.D., at Noble and Felix Fritschi, Ph.D., soybean physiologist at University of Missouri, among others, the platform was shown to be able to identify wheat and soybean root crowns with 99% accuracy using machine learning. We have also identified substantial genetic variation for these root traits in several species and have found that many relate to plant performance, as measured with shoot mass. This platform is expected to have substantial impact in the plant sciences and breeding communities by making measuring the hidden half more accessible.

THE FUTURE

The destructive nature of currently used technologies means that we can't follow the growth and development of roots in the field. We have to leave fields with holes from excavation and expend substantial manual labor in order to acquire data. To address these shortcomings, Noble Research Institute scientists are ramping up efforts to implement technology for nondestructive imaging of the complex world of roots underground. These nondestructive root-imaging initiatives involve techniques traditionally used in the biomedical or geophysical fields. For example, Noble researchers are collaborating with scientists at the Lawrence Berkeley National Laboratory (Berkeley Lab) and Subsurface Insights, LLC, a small business involved in software development for

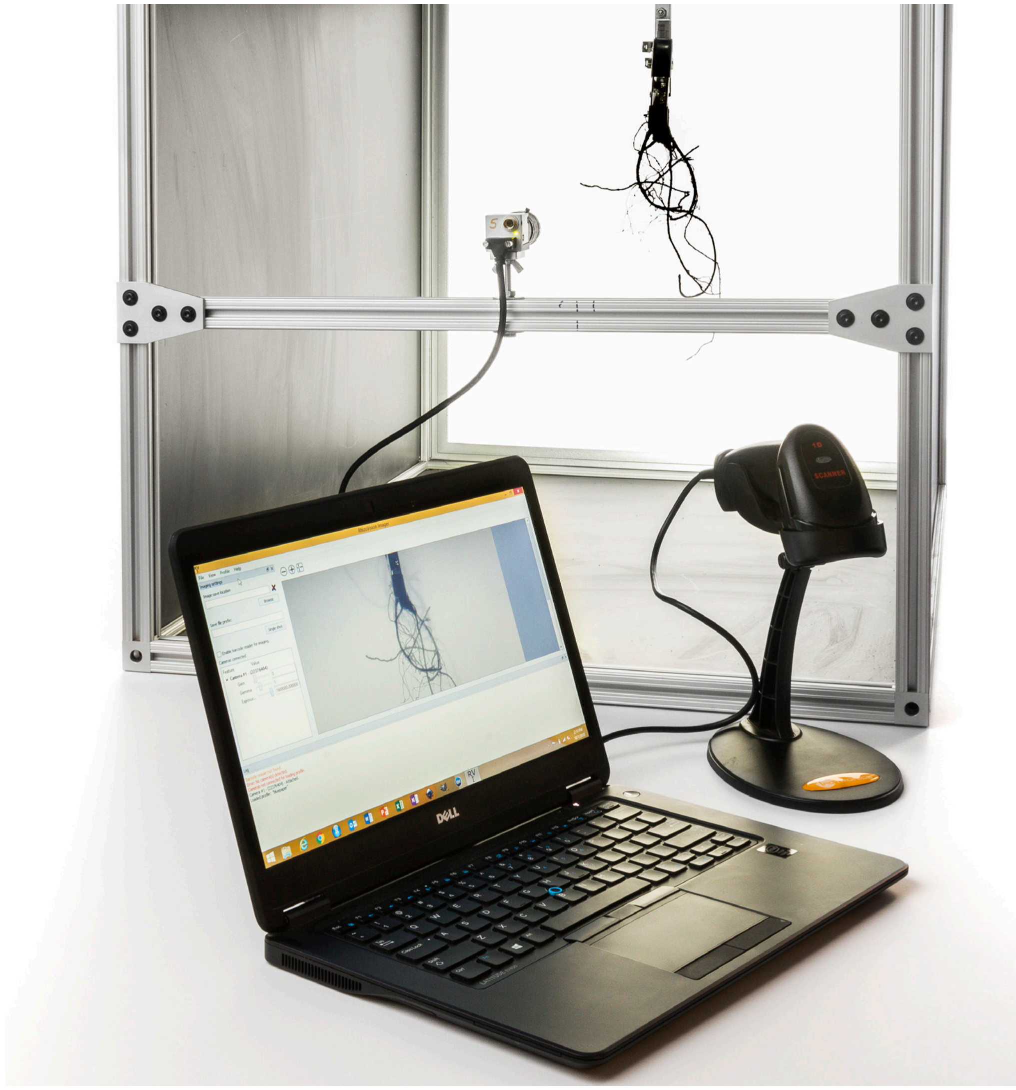
Story continues on next page

geophysical applications, on a project that uses electrical currents to image roots. The technology is analogous to a procedure called electroencephalography (EEG), which is used for imaging brains. In EEG, small metal discs with thin wires are attached to the scalp to detect brain electrical activity. Yuxin Wu, Ph.D., a geophysicist with the Climate and Ecosystem Sciences Division of the Berkeley Lab and Roelof Versteeg, Ph.D., founder of Subsurface Insights, LLC, coined the term Tomographic Electrical Rhizosphere Imaging (TERI) to refer to the EEG-like technology for measuring roots. The TERI technology involves injecting a small electrical current into the plant stem, which then travels throughout the root system. The TERI instrument is currently being refined so it can detect the electrical response of roots. The root electrical responses can then be translated into information about root mass, root surface area, rooting depth and root distribution in the soil. In addition to data on roots, TERI is expected to acquire data about soil texture and moisture content and to monitor how these soil variables change over time. The Advanced Research Projects Agency-Energy (ARPA-E) program of the Department of Energy funds Berkeley Lab, Subsurface Insights and Noble Research Institute scientists to develop TERI.

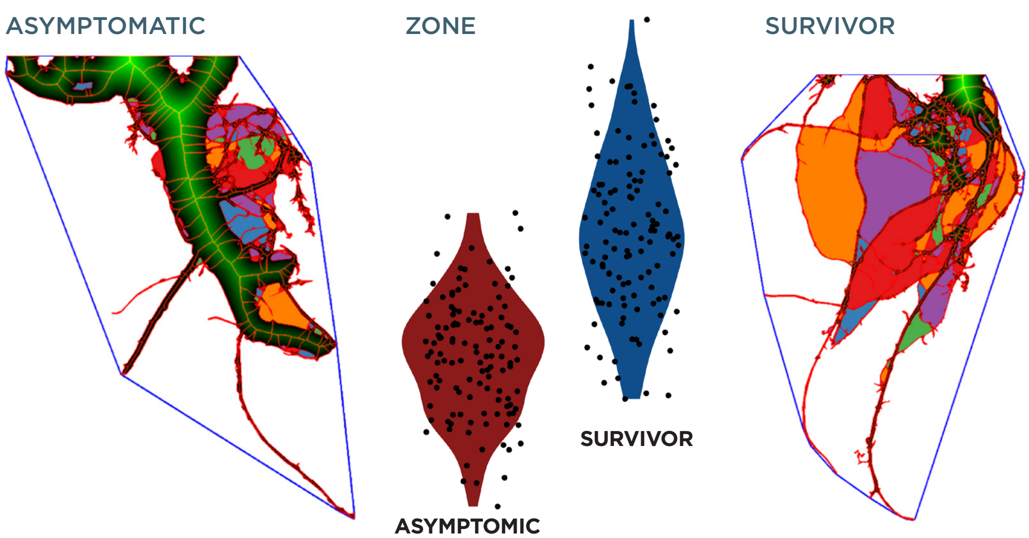
Ground penetrating radars (GPR) have also been tested at the Noble Research Institute to acquire information about roots in the soil without having to resort to digging up the plant. This geophysical technique uses electromagnetic radiation to locate objects beneath the ground. One major component of a GPR is an antenna that generates radar pulses, which are propagated through the ground. The radiation signals are reflected, absorbed or scattered by objects beneath the soil. A receiving antenna then detects variations to the radiation signals triggered by buried objects. Xiuwei Liu, Ph.D., a former Noble Research Institute postdoctoral fellow, who now leads his own group at the Chinese Academy of Sciences, collaborated with John Butnor from the U.S. Forest Service and Xuejun Dong, Ph.D., from Texas A&M AgriLife Research on applying GPR technology to detect roots of trees and wheat. Like the TERI technology described above, implementation of GPR on crops grown in agricultural fields will need additional years of refinement particularly with regard to correlating electrical and radiation signals with actual root distribution. A complicating factor in the implementation of these future technologies is the complexity of the soil. Nonetheless, these are the types of technologies that scientists at Noble and other research institutions worldwide are developing with the ultimate goal of breeding crops with improved root systems for more efficient capture of water and nutrients.

RHIZOVISION CROWN PLATFORM

The RhizoVision Crown platform represents a state-of-the-art instrument for high-throughput measures of crop root systems using hardware and software developed at Noble Research Institute.



Example data output from the RhizoVisoin Crown platform, including images with automated features overlaid on root images. A survivor alfalfa root crown (right) is compared to a nonaffected plant (left), and machine learning could identify these plants with substantial accuracy (middle).



GENOMICS

More Efficient Plants Ahead, Thanks to Genomic Technologies

by Maria Monteros, Ph.D., associate professor, legume genomics | mjmonteros@noble.org

Plants, unlike humans or animals, cannot move location to get away from danger. Instead, they have developed unique strategies to cope with environmental challenges such as drought or flooding, high and low temperatures, wounding, insect pests, and pathogens. These coping strategies are determined by the composition and sequence of letters (A, C, G and T) that make up each individual's DNA. Just like the words "stripe," "priest," "sprite," and "ripest," have the same letters but very different meanings, differences in the order of letters (A, C, G and T) that encode the genetic blueprint result in differences in how the plant looks, grows and produces seeds.

PLANTS WITH FEWER AND DEEPER ROOTS HAVE DIFFERENT LETTERS AT THE SAME POSITION OF CERTAIN GENES ASSOCIATED WITH ROOT GROWTH COMPARED TO PLANTS WITH MORE BRANCHED ROOTS.

MOLECULAR MARKERS "MARK" AREAS OF DNA THAT COULD HELP BUILD BETTER PLANTS

Advances in the technologies used for sequencing, or identifying the unique sequence of letters in the DNA of an individual, has reduced the cost and increased the speed of obtaining this

Story continues on next page

information. Sequencing the human genome cost millions of dollars a few years ago; now, it is possible to get a version of the genome sequence for about $1,000. The same technologies used to sequence the human genome are used in plants. These technologies identify specific letters in a plant's DNA that allow the plant to be either resistant or susceptible to a particular disease. These differences can be detected in thousands of plants using molecular markers, which are similar to sticky notes in that they are used to tag or mark a section of interest — in this case, a particular sequence in the genetic blueprint, that will result in a better plant.

Plants with fewer and deeper roots have different letters at the same position of certain genes associated with root growth compared to plants with more branched roots (Fig. 1). All plants with branched roots have T and A, while plants with a more predominant tap root have a C and a G instead at the same position.

DNA OF PLANTS WITH TAP ROOTS COMPARED TO PLANTS WITH BRANCHED ROOTS

Below is the genetic blueprint of a branched and tap root. T and A indicators are highlighted in the DNA sequence of a branched root.

TCATGCCAAGGTTGAAGTGAAAGACCATGAATGAATGTGTTGCAA

On a tap root the T and A indicators from above are replaced with C and G indicators with sequencing DNA.

TCATGCCAAGGTCGAAGTGAAAGACCATGAGTGGATGTGTTGCAA

Pictures provided by Deb Samac/USDA

IMPROVING DROUGHT TOLERANCE IN PLANTS

Initial sequencing technologies focused on evaluating differences in one or a few genes, such as a flower color (purple or yellow) or disease susceptible versus resistant. In this case, sequence differences in only one or a few genes are responsible for the differences in how the plant looks or responds to a pathogen attack. In contrast, more complex characteristics such as drought tolerance or biomass yield are the result of a coordinated network of genes working together, and each of these genes have a small effect. For example, we can help plants cope with drought stress by modifying the amount and composition of wax on the leaves to reduce water loss, increasing the amount of sugars accumulated in the plant to reduce water loss, or developing roots that can grow deeper to access water reserves in the subsoil.

TECHNOLOGIC ADVANCES MAKING PROCESS MORE EFFICIENT

Traditionally, the process of identifying the best plants for growing or developing a new variety include planting thousands of seeds in the field then waiting for them to germinate and grow — months, two or three years, or even seven to eight years in the case of pecan trees — before knowing how much biomass or nuts they produce.

Advances in the accessibility and speed of sequencing thousands of genes makes it possible to survey sequence differences in the entire genome compared to targeting a single gene. In this case, young leaves from plants that are about a week old can be used to screen thousands of plants to tag the plants with a specific section of DNA or molecular marker and predict the performance of the plant in the field in days versus months or years.

RESEARCH IN ONE SPECIES BENEFITS OTHERS

Many of the genes associated with plant growth and development, including seed retention versus seed shattering, are conserved between related species. For example, a seed shatter resistance gene first identified in soybeans is useful to detect differences between hairy vetch plants that retain seeds versus those that drop their seeds. This highlights how research investments in one species can be useful to develop a solution to the seed shattering issue in cover crop legumes.

COMBINING BENEFICIAL TRAITS

Another use of these molecular technologies is the ability to combine multiple beneficial traits such as drought tolerance, winter hardiness and disease resistance into a single plant. Further, it allows plant breeders to identify and integrate new resistance genes as new pathogens or insects develop in these biological systems much faster.

On a larger scale, the emergence of "genomic selection" takes into account small differences in performance associated with multiple genes that, when combined, can impact profitability for the year. The improved varieties developed can be identified based on their unique genetic blueprint and provide genetic solutions driven by natural differences between individual plants to address practical challenges that limit agricultural productivity.

PASTURES

Developing Technologies to Better Measure Forage

by April Mueller, cover crop research assistant | admueller@noble.org;
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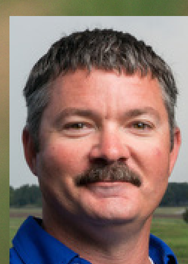
Dillon Payne, spatial and applied ag technology technical program manager | dbpayne@noble.org





In an effort to support the producers of the Great Plains, we have developed multisensor plant phenotyping platforms that indicate various parameters of forage. Measuring forages allows for more efficient and comprehensive analysis of real-time forage available to support beef cattle production.

Some of the sensors we use measure plant height to estimate yields, while others use multispectral wavelengths to infer characteristics of forage quality, such as crude protein content and digestibility. Using the data collected from different cultivars over several growing seasons, we are able to develop models that can predict both biomass and crude protein for various forages.

Our current ground-based phenotyping platforms are helpful tools for sampling forage, but these still require time and effort on our part. We aim to facilitate the development of increasingly comprehensive technologies to advance the automated process for forage estimation using remote sensing technology.

In looking to the future, we hope to be able to use satellite imagery to give producers land condition information in real-time. This leap forward will give producers incredible power in making educated economic decisions for their operation.

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DEVELOPING TECHNOLOGY YOU CAN USE TO MEASURE FORAGE

The evolution of our ground-based phenotyping sensor systems begins with the Spider. The Spider is a high-clearance, narrow-wheeled tractor with sensors mounted on the front. It was developed for research to help our plant breeders make decisions on cultivar advancement and development for commercialization. Our plant breeders sow many various varieties/breeding lines in small plot trials to form a performance comparison between the varieties. The Spider employs high-precision GPS, allowing for easier trial mapping and visualization tools when the data is processed.

Because of the success of the Spider platform, we sought to develop a platform that could be used in grazing research but could also be applicable and feasible for a producer. With this goal in mind, we developed the "forage box," which consists of laser, ultrasonic and an optical active sensor. About the size of a shoebox, this enclosed design is mounted on the front of a utility vehicle. Because it uses a GPS puck, the cost of this system is much more reasonable while still being able to effectively find forage averages across a pasture.

The forage box has been used to collect data on thousands of acres where cattle graze, and it has proven itself valuable in decision-making processes. Development is underway on a smaller, more user-friendly version of the forage box that we hope will be commercially available for producers in the future.

MEASURING FORAGE BIOMASS AND QUALITY

Measuring plant height is the first step to predicting forage biomass. Historically, plant height has been measured using a grazing stick and, in recent years, with a rising plate meter. While these methods are effective, they are both labor and time intensive. In an effort to calculate plant height more efficiently, we use two different sensor types. First, our systems contain an ultrasonic sensor that sends sound waves toward the plant canopy and measures the length of time it takes for the waves to return. This sensor is similar to a depth finder used on fishing boats. Second, we use laser rangefinder sensors, which trigger the laser to return to the sensor when an object breaks the laser's field of view. These two different measurements give us a depiction of what a plant stand looks like — whether it be short, tall, thick or sparse.

Another fundamental aspect of forage estimation includes measurement of forage quality. For this assessment, we employ multispectral sensors. This technology sends out three different wavelengths of light that are beyond the scope of human sight and measures the reflected wavelengths to estimate a plant's degree of greenness — or lack thereof. The sensor uses the data returned to measure plant health. In order to tie all the data together and down to an accurate location on a map, we tag the data with a location using GPS. Our high-precision GPS systems, useful in small-plot research trials, utilize a Novatel radio with OmniStar correction, which provides greater than 15 centimeters of accuracy. Projects that utilize the forage box, such as those on grazing and rangeland areas, require less accuracy, and a GPS puck will suffice. The puck makes the forage box a much more cost-effective platform than the Spider.

Another implement currently used to calculate forage biomass is a forage tower. The towers house a scanning laser, similar to those used in self-driving cars, that detects an object's distance from the sensor. They will be deployed on cattle pastures to record and transmit forage biomass data to a home computer. Because the units are radio-enabled, they require minimal human mediation for data collection events. Also, these towers allow data collection multiple times each day. This relayed information, when coupled with the Tru-Test Walk-Over Weigh systems, gives comprehensive information on forage quality in the context of animal performance.

FUTURE CHALLENGES AND OPPORTUNITIES

While we operate these systems year-round to measure various agricultural systems, we are pressing forward to employ more efficient systems that require less human intervention to operate. Every new technology requires "ground-truth" validation to ensure the measurement events are giving us data that correlates to the forage that is actually on the ground. With this challenge at the forefront, we are now working to deploy these sensor technologies on a UAV platform, providing both increased efficiency and greater producer availability to this technology.

The UAV-mounted Raptor ACS-225LR-IRT Aerial Crop Sensor contains similar sensors to the Spider platform for plant measurements, a high-precision GPS system, and a mode of transportation with greater flexibility to conditions on the ground. While the Spider system is a high-clearance option, there are still varieties that grow too tall for effective measurement with this equipment. The freedom of an UAV eliminates this limitation. Also, driving the Spider across forage after a rain creates the potential for getting stuck in the mud and tearing up the existing plant stand. While UAVs have their own limitations, they provide solutions to current technology with greater efficiency and opportunity in high-throughput phenotyping systems.

One challenge we face is the expansion beyond monoculture agricultural systems. Most producers have some amount of land that exists as native rangeland, polyculture or multicrop systems. It is important to note these sensor systems are sampling tools and are effectively building average measurements of an area. With these averages in plant height and health values, we can build statistical models that predict forage biomass and crude protein. In a mixed forage system, building models becomes increasingly complex as the included species increase. Deploying sensor systems on polyculture forage requires a comprehensive system of sensors and models built for forage combinations similar to the forage at-hand.

SENSORS

Animal Tech That Could Help You Make Decisions on the Ranch

by Stephen Webb, Ph.D., staff scientist / slwebb@noble.org

Technology has many definitions and means something different to all people depending on their needs.

Technology is:

- A manner of accomplishing a task using technical processes, methods and/or knowledge.
- Creation and use of technical means and their interrelation with life, society and environment.
- Knowledge and utilization of tools, techniques and systems in order to serve a bigger purpose, like solving problems or making life easier or better.

In the latter definition, there is mention of tools, which could be a form of technology. Consider Aldo Leopold's five tools of game management (published in 1933): axe, cow, plow, fire and gun. Those tools aren't what we would think of as technology, but they did help solve problems, accomplish tasks and meet the needs of the manager. We've come a long way since that time.

Skip forward 60-plus years, and terms like "precision agriculture" are now commonplace. Precision agriculture gained momentum with the development and use of global positioning system (GPS) technology. Now, there's a new kid on the block. It's called precision livestock farming; it isn't a thing of the future, it is already upon us. Precision livestock farming relies on animal technology, which is the technical means to collect, analyze and interpret a wide range of metrics on animals for the purpose of research, production, management or well-being.

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The term now being used for most animal technologies and sensors is "wearable technology." Wearable technology has become critically important for monitoring animal health. The correct sensors and technologies, when coupled with data analytics and communication, can provide real-time information and diagnoses of animals. Sensors and wearable technologies can be deployed, fitted or implanted on animals to measure body temperature or mass, observe behavior and movement, detect stress, analyze sound, monitor health, and many other things.

TRACKING INDIVIDUAL ANIMALS

The development of animal-based technologies began with individual cow identification, which started as visual ear tags then progressed to electronic identification (EID) tags, making EID tags one of the oldest wearable technologies. EID tags incorporate many different technologies, but most are passive tags, meaning they require another device (for example, a wand, data logger, tablet, etc.) to read the identification number and/or information from the tag.

The next type of tracking devices are much more accurate but much more costly and used primarily for research purposes. Global positioning system (GPS) collars are actually receivers that receive signals from satellites to aid in positioning, navigation and timing. If you have a smartphone, it likely is GPS-enabled so you don't get lost. GPS collars are a standard technology for the study of wildlife but also are deployed on livestock, mostly beef cattle. GPS collars can help collect information on activity, behavior, bedding/resting locations, habitat use, grazing site preference, migration, energy expenditure and more.

Despite the relatively high price tag of GPS collars, there are new systems being developed to control grazing of livestock. These new systems are known as virtual fences and require precise positioning from GPS collars to keep animals inside an invisible fence. Having an invisible fence and a collar to condition animals using sound and/or mild electric shocks to stay within a designated area negates the need for physical fences, which are costly and require maintenance. The application of virtual fences is still in its infancy with a few companies leading the way, and the future of this technology is unknown until more testing and validation is done.

PHYSICAL MEASUREMENTS OF ANIMALS

Taking physical measurements of animals has been a standard practice for assessing health, growth and success of management programs. The following technologies apply more to domestic animals than wildlife because they are easier to herd and work. However, when wildlife are captured, these methods provide an enormous amount of information about the animal itself and the environment in which it lives.

The two most frequently collected pieces of information are body weight and temperature, and, with just these two measurements, a wealth of information is waiting to be unlocked. Collecting body weight is standard for any production operation or for research, especially when linked to other data such as age, reproductive status or environmental variables. Typically, livestock are ran through chutes to collect body weight, but this is done at irregular or long intervals. To start understanding individual animals and their feed efficiency, new systems have been developed to take body weight more frequently. These systems

Story continues on next page

THERE ARE THREE MAJOR CLASSES OF EID TAGS:

1 Radio frequency identification (RFID) tags are likely the most common. RFID tags use low frequency radio waves, which only allows the tags to be read from a short distance.

2 Ultrahigh frequency (UHF) tags provide a longer read range, typically within line-of-sight, and they operate the same way as RFID tags.

3 Bluetooth is likely the next generation of ear tag. Bluetooth is a wireless technology that uses short wavelength UHF radio waves, so read distance can be up to 100 yards, but with recent developments, the read range may reach 1 mile or more. This technology could leverage existing Bluetooth capabilities within smartphones, something that many of us carry on a daily basis, to serve as the collection device.

WEARABLE TECHNOLOGY

Wearable technology is the use of sensors and technologies fitted on animals, and combined with data analysis and communication, to provide real-time information and diagnoses on animal health, status and well-being.

PRECISION AGRICULTURE

Precision agriculture is the use of new technologies coupled with GPS to increase yield, productivity and profitability while decreasing inputs (e.g., herbicide, fertilizer, water, etc.) through targeted application, resulting in greater economic returns and increased sustainability. Produce more with less.

PRECISION LIVESTOCK FARMING

Precision livestock farming relies on animal technology and the use of real-time automated processes to collect, analyze and interpret a wide range of metrics on individual animals for making management decisions, reducing economic losses, and increasing overall animal health and productivity.

include GrowSafe Systems Feed and GrowSafe Beef in pen weighing technology and the Tru-Test walk-over-weighing (WOW) platform and system, which collect body weight multiple times per day and attribute the data into a unique animal based on an EID tag.

Just like taking our own body temperature, taking the temperature of animals can provide an indicator of their well-being. Change in body temperature is one of the first symptoms of a body fighting an illness, an indicator of health. Collecting an animal's temperature can be done by traditional means such as using a rectal thermometer, but, with advances in technology, devices such as a rumen bolus or e-pill, muscular thermosensors, or tympanic (ear) or under-skin temperature sensors can provide automatic data collection. For example, a rumen bolus is swallowed by an animal, then sits in the reticulum and transmits data to a receiving unit using lower power radio frequencies. A rumen bolus may also be able to measure heart rate, respiration, rumination or rumen pH, but many of these applications are still being tested. Some applications of monitoring body temperature include assessing heat stress or energy expenditure and predicting when an animal is in heat.

If one wants to "look" inside an animal, then ultrasound or sonograms and stethoscopes offer noninvasive techniques, and both methods offer portability whether working in

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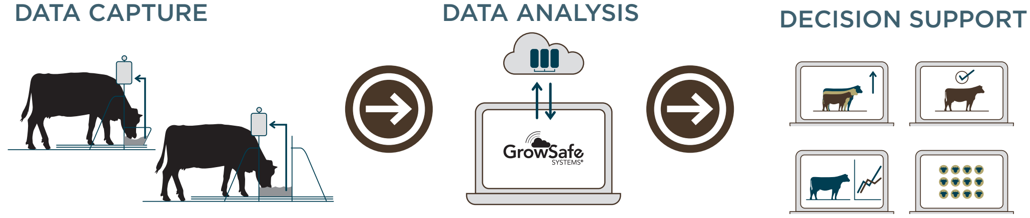
HOW THE GROWSAFE SYSTEM WORKS

STEP ONE
DATA CAPTURE

STEP TWO
DATA ANALYSIS

STEP THREE
DECISION SUPPORT



GrowSafe's measurement technology non-invasively captures millions of data points each day from feed intake and behavior to body weight and watering behavior.

The data collected is processed and interpreted in the GrowSafe Cloud, delivering advanced insights and predictions.

GrowSafe's predictive analytics and modeling software take business intelligence beyond the dashboard.

TRU-TEST WALK-OVER-WEIGHING PLATFORM

Tru-Test offers a walk-over-weighing platform and weigh scale that can be developed into a real-time data stream for collecting weight of cattle. The major components consist of the livestock scale and platform, electronic ear tag identification panels, and the associated data acquisition and recording instruments. Noble Research Institute researchers combined all components to a mobile platform (to enable greater portability), developed a solar-powered system and added wireless transmission capabilities. In the field, the system is deployed at a water source by using portable livestock fencing structures to ensure livestock walk across the scale and in close proximity to the ear identification panels. When an animal crosses the platform, the system records the animal's unique EID tag and weight by pasture, which is then sent wirelessly to a centralized master radio unit and data-logging software that retrieves, logs and writes the information to a Microsoft Excel spreadsheet.

the field or chute-side. Ultrasound has been used on animals to assess pregnancy, tumors, fat thickness or body condition. A stethoscope can be an invaluable tool in the right hands and when placed strategically on the animal. Stethoscopes are used to listen to the lungs as a way to monitor for respiratory diseases. For example, bovine respiratory disease (BRD) is a major cause of economic losses in cattle. When a stethoscope is combined with body temperature, a more complete health assessment of the animal is accomplished.

ANIMAL BEHAVIOR

Many of the technologies used to study animal behavior were developed out of necessity by wildlife researchers who have a difficult time obtaining animals for study. Many of these technologies were adopted from other disciplines as well. Accelerometers, which measure acceleration or velocity of travel, and magnetometers, which measure heading, are gaining in popularity. These are the exercise trackers of the animal world. The sensors provide very frequent data collection with minimal power allowing users to assess activity, movement, behavior, health, feeding, estrus, calving, etc. Outside of research, such as in a production setting, users are not interested in the data itself but the relationships between the data and a behavior of interest; this is determined through research, validation and sometimes machine learning.

Video cameras are not new but their application for animal monitoring or study is increasing. It is often difficult to sit in the field to collect data on animals because of many constraints and logistical issues. Collecting video of animal behavior, feeding, social interactions, etc., provides a permanent record of the event and allows the user to collect a broad range of data in the comfort of an office or home. Often, video cameras on animals are used to validate behavior from accelerometers and to study feeding habits such as forage selection, bite counts and cud chewing.

REMOTE COLLECTION OF ANIMAL DATA

There also lies many opportunities to collect data from animals using remote technology. A few of these technologies include the use of unmanned aerial vehicles (UAV) and systems (UAS), acoustic monitors, and imaging or photography. Although a stethoscope allows one to hear, it does not provide continuous or real-time monitoring; a few systems, such as a rumen microphone or rumination monitor, can do this very thing. Acoustic monitors, known as bioacoustics, and remote cameras are used to collect sounds or images from wildlife surveys. When coupled with artificial intelligence to automatically identify species, a wealth of information can be provided about wildlife presence as it relates to their environment.

The use of UAVs and UASs may be able to provide the tools to count or inventory animals remotely or to take photographs of animals to track development. For example, photographs of animals allow researchers to link photographic measurements of animals to known characteristics such as age, size or weight after research and development of prediction or adjustment factors are estimated. Thermal imaging may also hold promise for detecting heat stress or illness in animals. Thermal imaging cameras can be deployed on a UAV or hand-held thermal imaging cameras can be used, but they often require associated software.

THE FUTURE

The future is now. Technology is developing at an astonishing rate, especially for military and industry needs. The development and adoption of technology for agriculture or animals has lagged behind. However, it is predicted that technology developed specifically for agriculture will increase 2.5 times by 2025. It is very likely that mobile or smart devices will play a critical role. Other opportunities to expand technology to agriculture and animal operations include the miniaturization of devices and development of low-power or solar-powered devices. To have the greatest impact, the data collected from these devices will need to undergo well-designed research and validation that leverages artificial intelligence, machine learning and cloud computing to process the data into a usable format so users can make sound decisions.

NOBLE
NEWS&VIEWS

IN THIS ISSUE

SEPT. 10

Introduction to Integrity Beef

4-7:30 p.m.
Noble Research Institute Pavilion
No Registration Fee

Connect with Noble Research Institute consultants and Integrity Beef Alliance members to learn more about the Integrity Beef Alliance terminal calf program and replacement heifer development program. You will learn about membership benefits and advantages of being associated with a regionally and nationally recognized marketing program.

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UPCOMING EVENTS

Preregistration is required. Registration closes five business days before the event.
For more information or to register, visit www.noble.org/events or call 580-223-5810.
For other agricultural questions, please call our Ag Helpline at 580-224-6500.

Understanding Irrigation Systems and Technology for

AUGUST | 27

With the extreme environmental swings that we are experiencing, irrigation is critical for maximizing production and profitability in pecans. This course will allow you to gain a better understanding of different irrigation systems and the technologies that you can use to develop irrigation scheduling.

9 a.m.-noon
Kruse Auditorium
Entry 5
No Registration Fee

PART 1 SEPT. 5 | PART 2 SEPT. 12

Debunking Deer Myths

4-7 p.m.
Bass Pro Shops in Grapevine
2501 Bass Pro Drive
Grapevine, TX 76051
No Registration Fee

SEPTEMBER | 3

So You Want To Grow Pecans

6:30-8:30 p.m.
Kruse Auditorium, Entry 5
No Registration Fee

SEPTEMBER | 17

Demonstrating Pecan Orchard Floor Management

1-4 p.m.
McMillan Farm
14797 McMillan Road
Madill, OK 73446
No Registration Fee