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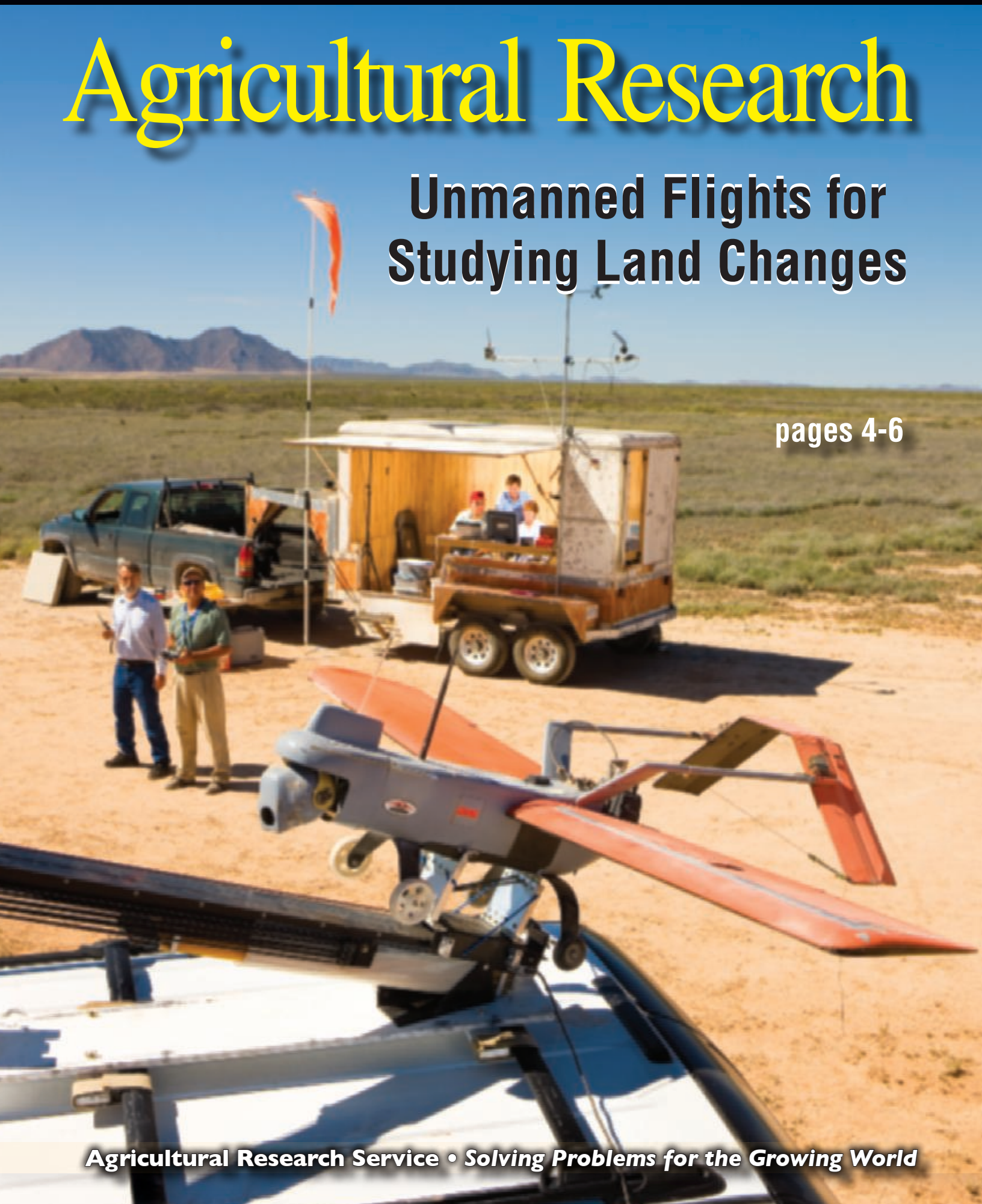
Agricultural Research

Unmanned Flights for Studying Land Changes

pages 4-6



FORUM

Managing Land with Aerial Digital Cameras

Imagine taking a ride in a small plane or helicopter that's flying as low as possible while trying to keep your binoculars on one geographic feature. Try to stay focused on that feature while you experience the roll, pitch, and yaw of the aircraft as it is buffeted by winds and while atmospheric haze blocks your view.

That's what can sometimes make aerial photography and imaging more challenging than collecting data from ground instruments or from satellites flying above the atmosphere. But very-high-resolution aerial photography with digital cameras aboard low-flying ultralight aircraft and unmanned aerial vehicles (UAVs) has evolved into another important tool for remote sensing of natural resources.

This has come about in part because of the shift towards research focused on entire landscapes and watersheds instead of on isolated portions. It is also made possible by rapidly advancing technologies, starting with increasingly smaller digital cameras and specialized spectral sensors. The cameras offer lightweight, instant-image alternatives to the bulky large-format film cameras traditionally used for aerial photography.

The revolution in camera technology even affects ground monitoring, as described in the article on landscape panoramas on page 7 of this issue.

Digital aerial photography has become an integral part of rangeland monitoring. The imagery has many other uses, such as monitoring alterations of forests and other vegetation caused by human activities like farming, gas and oil exploration, and urbanization. The need for monitoring land-use changes is nationwide.

Digital aerial imagery is an adjunct to satellite imagery, ground-level imagery, and ground sampling. There is a time and place for each, and often one is used in combination with others. Ground sampling has to be done coincident with aerial or satellite imaging. Being able to tie ground-based samples to image information enables greater use of imagery and reduces the frequency of ground sampling—a major goal of remote-sensing research. Aerial imagery is also less expensive than intensive ground sampling, thus enabling more frequent landscape surveys. Doing surveys on a consistent basis allows scientists to identify trends in landscape changes and relate these changes to consequences of management actions.

Aerial photography, especially from 300 to 700 feet above the surface, provides more detail than satellite imagery taken from 3,000 to 6,000 miles in space. It is this greater level of detail that makes low-level aerial imagery ideally suited

for land-management decisions. The imagery is proving useful for monitoring crop fields, rangelands, forests, streambanks, wetlands, and wilderness areas. But experience has shown that we need a range of resolutions and detail, depending on the use of the imagery. These uses include taking field and regional looks at winter cover crops to measure crop intake of nitrogen to keep it out of waterways; identifying plant species on western rangelands; and directing pesticide spray from "crop duster" airplanes. Even within aerial imagery, there are different tools for different purposes. Cameras and sensors mounted on model airplanes, UAVs, and ultralight aircraft bridge the gap between ground sampling and imaging from higher altitudes via airplanes or satellites.

Right now, we have to fly low and slow when very high resolutions are needed, but quickening the shutter speed of a telephoto lens is one way to increase the resolution from higher altitudes without further reductions in speed. The story on page 4 discusses this technology.

A researcher with the Agricultural Research Service in Beltsville, Maryland, invented a way to convert a common digital camera so that it can take infrared aerial images for land-use monitoring and plant-nutrient condition assessments. ARS patented the invention jointly with David Linden, who is currently at Science Applications International Corporation, headquartered in McLean, Virgina. The exchange of ideas between scientists from different parts of the country, as shown in this article, illustrates the advantages of having ARS locations nationwide, and working with other agencies, industries, and universities.

There is a saying in management that you can't manage what you can't measure. Aerial imagery and the continuously evolving technologies of remote sensing offer affordable ways to measure. Imagery also helps adaptive management by providing feedback on a regular basis, so that management changes can be made quickly in response to the feedback.

Information from airborne and spaceborne imagers can also help us understand ecological interrelationships to better manage natural resources. Soil, water, forests, crops, and wildlife are intertwined such that a management change in one area can affect others. Information from imagery coupled with ground-based research of landscapes enables producers and land managers to maintain productive yields while safeguarding other valued products and services of our landscapes and watersheds.

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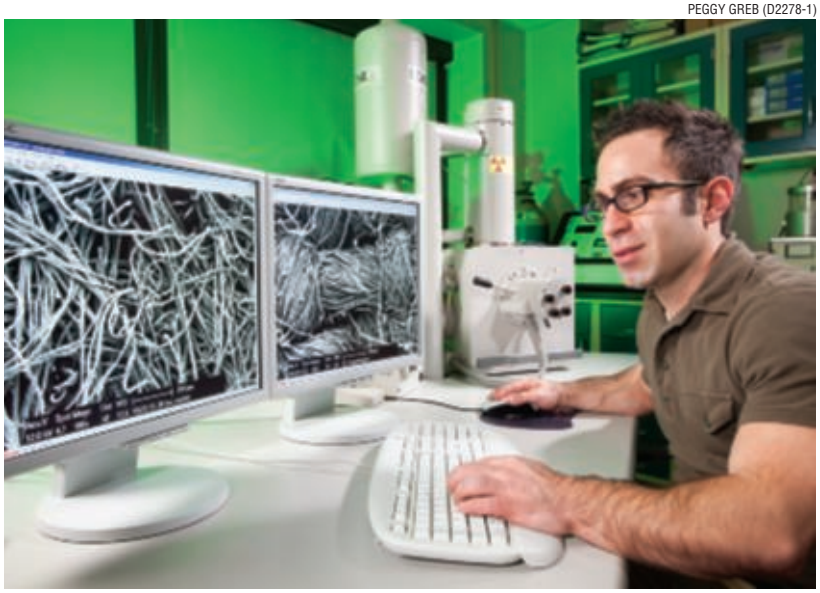
PEGGY GREB (D2278-1)



Ryan Slopek, postdoctoral research associate, compares the structure of nonwoven (left) and woven (right) cotton fabrics using a scanning electron microscope. Nonwoven fabrics are made by entangling the fibers, which gives the fabric strength. Story begins on page 14.

Cover: At the Jornada Experimental Range in Las Cruces, New Mexico, a team of scientists prepares to launch an unmanned aerial vehicle from a catapult. The mission: to survey vegetation on the ground in studies of vegetation changes over time. In the foreground are engineering technician Craig Winters (left) and pilot Dave Thatcher. Other researchers are in the ground control station. Story begins on page 4. Photo by Stephen Ausmus. (D2250-1)

TERRY BOOTH (D2251-2)

Photographing Land Changes From Low in the Sky

During a 2008 aerial survey of streamside vegetation in Nevada, Joe Nance of Cloud Street Aerial Services, Fort Collins, Colorado, flies a light sport plane at about 300 feet while using a remote-sensing package developed by ARS.

TERRY BOOTH (D2253-1)

Image taken from about 300 feet above the ground. The blooming plant, growing on a slope in Wyoming, is arrow-leaf balsamroot *(Balsamorizha sagittata)*. A photo taken later that year showed that this area had become covered with cheatgrass *(Bromus tectorum),* an invasive weed that increases the chance of wildfire.

Three years after the Deep Fire Burn, a devastating wildfire that burned 38,000 of the Medicine Lodge Project Area's 54,683 acres, northwest of Dubois, Idaho, pilot Joe Nance is flying just over 300 feet above the area, going north from the Upper Snake River Plain to the Continental Divide on the Montana-Idaho border. He is flying a Moyes-Bailey Dragonfly, a two-seat light sport airplane with a 34-foot wingspan. He sees a landscape covered in native mountain big sagebrush interspersed with native fescue grass—and the invasive leafy spurge.

As he flies at 40 to 60 miles per hour, every 1,000 feet the plane's special navigation system automatically triggers two digital cameras mounted on the side of the airplane and powered and triggered by GPS-interfaced equipment in the second seat. An 11-megapixel camera has a 100-millimeter (mm) lens, and a 16-megapixel camera has a special 840-mm lens. Both have the fast shutter speeds needed for clear, high-resolution photos from a low-flying airplane. The pilot will fly 25 different flight lines across the survey area, triggering more than 1,400 pairs of photographs for later computer analysis.

One camera takes images at a 1- by 1-mm resolution, the other at a 10- by 10-mm resolution. Usually the plane is outfitted with three cameras, with the third camera providing a 20-mm resolution.

Leafy Spurge Displacing Mountain Big Sagebrush

Using this survey method, called Very Large Scale Aerial (VLSA) imagery, Agricultural Research Service rangeland specialist Terry Booth and colleagues discovered that leafy spurge was displacing sagebrush seedlings. "We believe this is the first evidence of this," Booth says.

Overall, the research shows that the VLSA survey method, developed by Booth, is a good way to sample vast areas of the western United States. "We recommend that it be used with ground-based methods for early detection of invasive species that might threaten native plant populations," Booth says.

Pesticides and biological-control insects were used to control leafy spurge before and after the burn. But leafy spurge still managed to expand in drainage areas and up canyon slopes.

"The type of aerial survey we did can be repeated to keep checking on whether the pesticides or insects are working," Booth says.

Booth is in the ARS Rangeland Resources Research Unit, in Cheyenne, Wyoming.

He received funding and technical assistance from the U.S. Department of the Interior's Bureau of Land Management (BLM).

For this type of high-resolution aerial photography, Booth found that a 10-mm resolution worked better than 1 mm for detecting leafy spurge because it gives the best balance between resolution and field of view. "But," Booth says, "the 1-mm resolution was often needed to confirm

spurge identity. There are times when we need the 20-mm resolution, so it depends on whether we need a wider field of view, or need more details. It's best to have multiple resolutions available."

The larger field of view of the 20-mm resolution images help Booth locate areas on large U.S. Department of Agriculture (USDA) color infrared images taken at a 3- by 3-foot resolution.

Advances in cameras, image sensors, storage media, and image processing have moved monitoring natural resources by aerial photography to these new realms.

Flying From East to West

ARS scientists throughout the nation are using aerial photography to monitor a variety of lands with digital cameras and sensors, from the flat lands of the Chesapeake Bay's Maryland Eastern Shore to the national parks, forests, mountains, and deserts of the West. The cameras and sensors are flown aboard all sorts of aircraft—from regular small passenger planes to light airplanes like the Dragonfly to unmanned aerial vehicles (UAVs).

Besides Idaho, Booth has also done aerial surveys in Colorado, Nevada, New Mexico, North Dakota, South Dakota, Oklahoma, and Wyoming, looking at a variety of vegetation, including invasive and native trees, juniper woodlands, grasslands, and shrublands—on sites as diverse as gas pipeline rights-of-way and riverbanks.

Booth did the Idaho survey in mid-July, when leafy spurge was flowering, because colleague Ray Hunt found that was the easiest stage to identify spurge. Hunt developed a technique to detect leafy spurge by its showy yellow-green flowers, which bloom in June and July. Hunt is a physical scientist at the ARS Hydrology and Remote Sensing Laboratory in Beltsville, Maryland.

NASA Aircraft

Hunt has used the National Aeronautics and Space Administration's (NASA) Airborne Visible Infrared Imaging Spectrometer sensor flown aboard NASA aircraft over public lands in the West. NASA's advanced sensor can detect leafy spurge only when there are color differences compared to the surrounding vegetation. VLSA imagery may be able to detect invasive weeds based on leaf shape, even when color differences are not apparent.

In fact, Hunt and Dean Hively, a scientist with the U.S. Geological Survey who is stationed at Beltsville, have added color infrared capability to commercial digital cameras using a method patented jointly by ARS and David Linden, currently with Science Applications International Corporation, headquartered in McLean, Virginia. They did this by choosing a 12-megapixel camera sold without an internal filter that blocks near-infrared (NIR) light. All they had to do then was add a custom-made lens filter to block red light and transmit the NIR. The result is a camera that photographs with light in the NIR, green, and blue bands—which are needed to measure the "greenness" of vegetation and extent of crop canopy cover. "There is no need for further processing, so the images are available immediately upon landing," Hunt says. "The cameras are also lighter and more compact than the traditional large-format cameras used for aerial infrared photography," Hively adds.

They have found the photographs useful for detecting the extent of coverage from winter wheat and other winter cover crops in the Chesapeake Bay Watershed.

Flying Without a Pilot

Hunt and Hively use their cameras aboard both airplanes and small UAVs. UAVs can fly as low as a few hundred feet. With only a regular camera lens, the scientists get a resolution of 1 square inch. "This is enough to measure areas covered by crops, but we'd like to put a fast telephoto lens, like the one Booth uses, onto our camera system to identify plant species and to measure the amount of chlorophyll in a single leaf of a crop," Hunt says. "Chlorophyll in leaves may indicate the amount of nutrients in the soil, so VLSA imagery may be a way to help farmers save money by applying fertilizers more efficiently, which also helps protect the Chesapeake Bay."

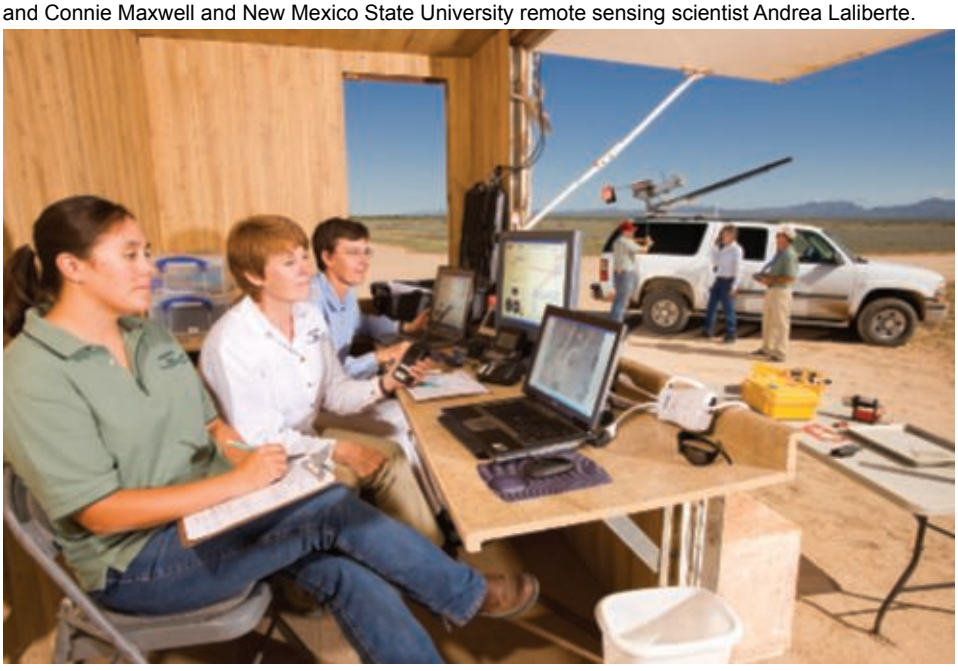
The infrared digital cameras add to the advantages of aerial photography because living vegetation strongly reflects NIR light, eliminating confusion from soil reflectance and shadows that can hide vegetation.

So, Booth, in turn, recently made space for one of Hunt's cameras on the Dragonfly.

"Regular infrared photography has too slow a shutter speed for use in low-altitude, high-resolution aerial photography," Booth says. "But that technology is advancing too, and Hunt and Hively are helping that along."

At the USDA-ARS Jornada Experimental Range in Las Cruces, New Mexico, Al Rango, Jeffrey Herrick, and Craig Winters, ARS scientists based at the range, and

In Las Cruces, New Mexico, researchers prepare to launch an unmanned aerial vehicle from a catapult (atop the vehicle). Left to right in the ground control station: ARS technicians Amy Slaughter and Connie Maxwell and New Mexico State University remote sensing scientist Andrea Laliberte.



STEPHEN AUSMUS (D2249-10)

Andrea Laliberte, a New Mexico State University researcher, are studying the use of a UAV that cruises 700 feet above the Earth, collecting digital photographs of rangeland areas so large they are difficult to cover in ground-based surveys. The aircraft weighs 20 pounds, has a 6-foot wingspan, and is launched from a catapult.

Satellite imagery is improving, but satellites can't provide the resolution needed by BLM for assessments of millions of acres of federally owned lands. UAVs allow operators to survey line-of-sight areas repeatedly or immediately after a major rainstorm or forest fire. When photographs must be obtained in conditions that would put a pilot at risk, UAVs have the advantage over manned airplanes, and they can acquire imagery at very high resolution.

The goal of using aerial imagery is to measure rangeland vegetation cover as well as collect enough information about landscape patterns to determine which areas merit closer ground level surveys, Laliberte says. Booth adds that aerial photography reduces the number of ground surveys needed. "But before you can analyze aerial photography of, say, plant communities, you need a lot of experience identifying the plant communities on the ground."

In a study partially funded by BLM, the researchers flew the UAV over the ARS Reynolds Creek Experimental Watershed in southwestern Idaho. They took just over 400 aerial photographs of 700 acres over 2 days. The researchers assembled the images into three mosaics, determined the percentage of vegetation cover using image-processing techniques, and compared the data to information collected with conventional ground-based measurement techniques.

Digital Mosaics

In a second study, the researchers looked at the classification accuracy of different types of vegetation, such as mesquite and yucca plants, identified by a computer program designed to analyze mosaics assembled from hundreds of digital images taken during flights over two tracts in Idaho and two in New Mexico.

In both studies, they found the aerial data sufficiently accurate to be comparable to information gathered in ground-based surveys for shrubs, grasses, and other plants that can be distinguished by their top canopy layer. This UAV aerial data is not the same as 1- by 1-mm resolution data, but it can be the right resolution for other important information needs, Booth notes.

Current federal safety requirements and associated costs limit the use of UAVs. Even with a Certificate of Authorization from the Federal Aviation Administration, UAVs are not allowed to be flown out of sight of ground operators. But this and other restrictions may change in the future. The research on UAVs is designed to ensure that the strengths and weaknesses of the technology are sufficiently understood regardless of the status of the regulations.

Ultimately, UAVs and other aircraft are tools for remote sensing, along with satellites, digital cameras, infrared cameras, and infrared imaging sensors, Booth says. "You can use any one of these or any combination of these, depending on your needs. The exciting part is that all of these technologies are advancing at a quick pace."—By **Don Comis** and **Dennis O'Brien,** ARS.

This research is part of Pasture, Forage, and Rangeland Systems (#215) and Climate Change, Soils, and Emissions (#212), two ARS national programs described at www.nps.ars.usda.gov.

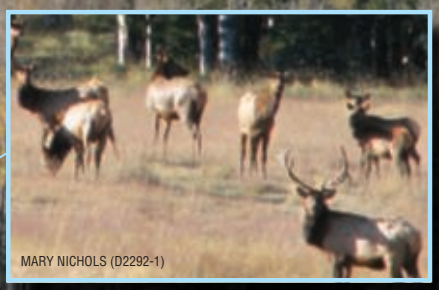
To reach scientists mentioned in this article, contact Don Comis, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1625, donald.comis@ars.usda.gov.

PEGGY GREB (D2287-1)

In a field of winter wheat in Beltsville, Maryland, ARS physical scientist Raymond Hunt (right) uses a camera that detects near-infrared, green, and blue light. Near-infrared and green light are needed to measure the "greenness" of vegetation and relate it to the crop's nitrogen status. Dean Hively (left), a physical scientist with the U.S. Geological Survey at Beltsville, is measuring greenness with an "on-the-go" sensor available commercially.

MARY NICHOLS (D2291-1)

Rangelands Are Ready for Their Close-Up

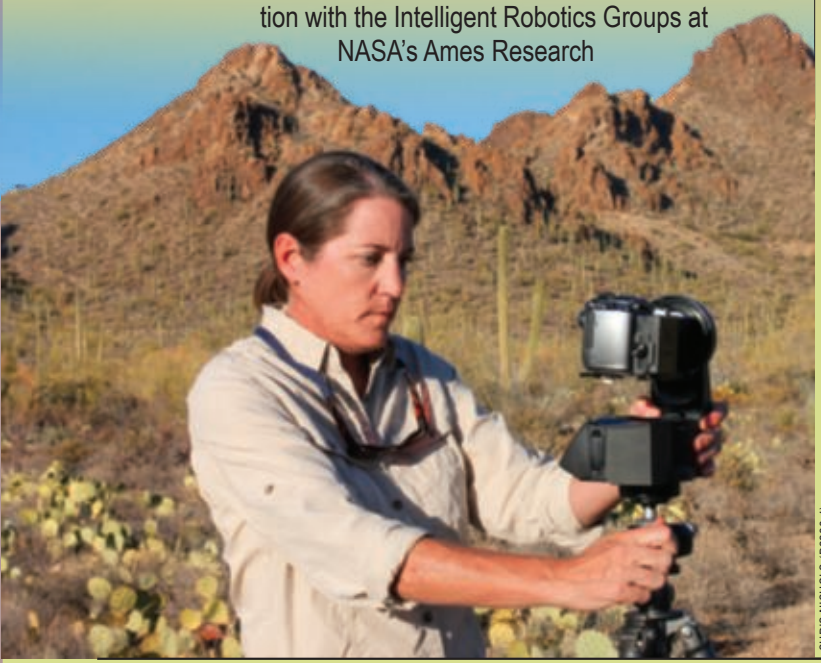


MARY NICHOLS (D2292-1)

Unlike some other Agricultural Research Service researchers, hydraulic engineer Mary Nichols prefers to keep her feet—and imaging equipment—on the ground. In 2008, she began participating in Carnegie Mellon's Fine Outreach for Science Fellows Program, which allowed her to explore how rangeland ecologists could use high-resolution digital panoramas to track landscape changes. (Because of the Fine Outreach Fellowship, Nichols is sometimes referred to as a "Fine Fellow.")

"This technology is perfect for rangelands, because all rangeland scientists take photos," says Nichols, who works at the ARS Southwest Watershed Research Center in Tucson, Arizona. "It's a great opportunity for taking photographic monitoring up several notches."

The process for creating these panoramas was developed by Carnegie Mellon University and Charmed Labs, LLC, in collaboration with the Intelligent Robotics Groups at NASA's Ames Research Center in Moffett Field, California, and support from Google. A digital camera is placed on a robotic camera mount and takes a series of pictures as the mount rotates. A custom computer program stitches the pictures together to create a panoramic image. In the end, hundreds—and sometimes thousands—of individual detailed photographs become part of a single high-resolution landscape panorama that users can zoom in on to study individual plants, animals, or geomorphic features in the surrounding landscape.



In October and November of 2008, Nichols created three rangeland panoramas in Arizona to see whether scientists could use the images to monitor riparian areas, wildlife, or invasive plants. The resulting panoramas were so detailed that she could count the elk in a distant herd—and even evaluate the condition of each animal.

Nichols could also identify stands of invasive buffelgrass, which turns golden yellow in the fall and presents a striking contrast to surrounding vegetation. With this information in hand, it was possible to document the extent of the buffelgrass invasion in the Santa Catalina Mountains, which provided a baseline assessment of the plant's establishment that could be used to track its subsequent spread.

Researchers can share their panoramas by posting them on www.gigapan.org.

"I'm also collaborating with University of Arizona researchers to develop a website specifically for high-resolution rangeland panoramas," Nichols says. "For instance, we could use this type of imaging to compare old photos from the 1930s and 1940s to current photographs and measure changes in plant communities and other geomorphic factors."—By **Ann Perry,** ARS.

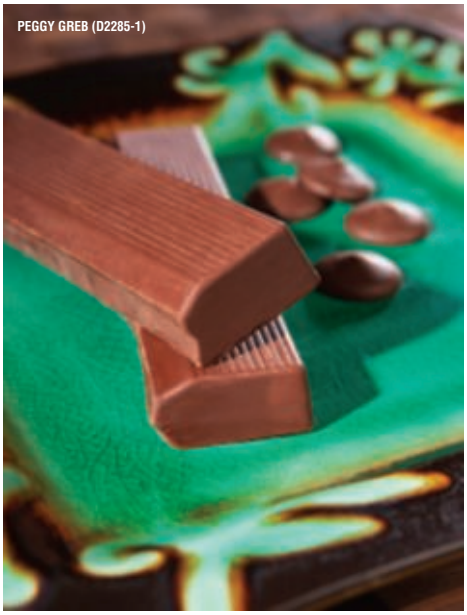
CHRIS NICHOLS (D2290-1)

Left: Using a high-resolution digital camera in the Tucson Mountains, ARS hydraulic engineer Mary Nichols obtains a series of photographs that can be put together to create a panorama. Above: A panorama by Nichols of part of Arizona's Apache-Sitgreaves National Forest. The resolution is high enough to focus on individual elements, like the elk shown in the inset.

Peruvian Cacao Collection Trip Yields Treasures


ARS (D2286-2)

A village on the bank of Rio Pastaza, in Peru. Two wild cacao populations were found and sampled near the upstream portion of this river.


PEGGY GREB (D2285-1)

Fortunato No. 4 chocolate, a fine-flavor product made from the Pure Nacional type of cacao identified in northern Peru.

Chocolates are always in demand—from Valentine's Day and beyond. In the chocolate world, the fastest growing segment of the industry is fine-flavor, high-end chocolates. Until now, the source of these specialized confections has been largely limited to small regions of Venezuela and Ecuador.

A stand of very old trees, in an unexpected location, has yielded a coveted type of cacao tree. Usually, cacao trees are found along rivers, but these gems were found at a higher altitude than normal, and in Peru instead of Ecuador or Venezuela.

Collection expeditions in 2008 and 2009 through the Amazon Basin of Peru uncovered the exceptional find, along with other distinctive new populations of cacao.

Agricultural Research Service researchers at the Sustainable Perennial Crops Laboratory (SPCL) and the Systematic Mycology and Microbiology Laboratory (SMML) in Beltsville, Maryland, and Peruvian collaborators came away with hundreds of new cacao tree samples from these trips. One of these, discovered by additional collaborators from Marañon Chocolate, was Pure Nacional—an old, very rare, and highly coveted variety that has garnered a great deal of interest from makers of fine-flavor chocolates.

SPCL research leader Lyndel Meinhardt, SPCL geneticist Dapeng Zhang, and SMML mycologist Gary Samuels (now retired) collaborated with the Instituto de Cultivos Tropicales (ICT), a research center in San Martin, Peru, to identify the new varieties of cacao. The researchers are studying 342 cacao specimens collected from 12 watersheds and categorizing the

DNA of the specimens. The group has identified new cacao types with unique flavors that are distinctly Peruvian, which may one day be marketed in the same way as wine—by geographical provenance.

Start from the Beginning

The cacao tree, *Theobroma cacao,* produces beans that provide the raw material to make chocolate. The tree is cultivated in some tropical countries with the right environmental conditions. The origin of cacao is the Amazon region of South America. Like many tropical tree crops, seeds of this plant lose their viability quickly after being harvested. For this reason, varieties or types of cacao must be maintained in living germplasm banks.

"The majority of the material in cacao germplasm banks was collected prior to the 1940s. There are more than 5,000 different varieties of cacao currently in collections around the world," says Meinhardt. "While this sounds like a large amount, most are breeding lines derived from a small number of types, so it actually represents a small fraction of the genetic diversity that still exists in the wild, especially in the center of origin of this species."

To address this limitation, expeditions were begun in 2008 to explore the upper Amazon River area in Peru. The purpose of these trips was to find and collect wild cacao trees and attempt to establish them in a living germplasm bank in Tarapoto, Peru, Meinhardt says. These trips were jointly funded by the U.S. Department of Agriculture and INCARGO, Peru's Ministry of Agriculture.

PEGGY GREB (D2282-1)

ARS (D2286-1)

Using a sterile technique, ARS scientist Gary Samuels extracts a sample of living plant tissue from a wild cacao tree on the bank of Rio Marañon in Peru. Fungi in the sample could prove useful as a biological control agent of important cacao pathogens.

"In 2008, 7 river systems were explored, and 190 cacao trees were sampled. Of the initial 190 trees collected, 128 were successfully reestablished in the germplasm bank. In 2009, 5 more river systems were explored in 2 expeditions and a total of 152 trees were collected and reestablished in the germplasm bank in Tarapoto," explains Meinhardt. "From the 12 river systems explored, we have identified 3 completely new populations of cacao that were not previously known to science." These expeditions collectively represent one of the largest efforts ever conducted to search for wild cacao.

New Flavors and Disease Resistance?

These new populations could be sources of diseases resistance or could have potential new flavor traits. The fine-flavor chocolate industry is keenly interested in obtaining new and unique flavor sources.

"Our results combined with the needs of the fine-flavor chocolate industry have led to new collaborations that will look at the primary gene pool of cacao. Together with industry we will attempt to gather information on the genetic diversity of wild cacao from all of the countries in South America within the center of diversity," says Meinhardt.

Niche chocolates from South America are not new. The varieties Arriba, from Ecuador, and Porcelana, from Venezuela, are two of the most famous. Arriba has a strong, complex taste that stays on your

At the Sustainable Perennial Crops Laboratory in Beltsville, Maryland, technician Stephen Pinney (right) and visiting scientist Kun Ji prepare cacao leaf samples for DNA fingerprinting.

PEGGY GREB (D2284-1)

ARS (D2286-3)

During the 2008 collection trip, ARS researchers Gary Samuels (left) and Lyndel Meinhardt (center) and plant pathologist Enrique Arevalo, of the Instituto de Cultivos Tropicales in Peru, examine cacao leaves infected with witches' broom.

tongue for a long time, while Porcelana features a unique light fruit flavor. ARS and ICT are helping Peru create its own niche in the chocolate industry by working with San Martin's Oro Verde cooperative and Marañón Chocolate. Peru's tropical conditions—60 percent of the country is covered in tropical forest—make it ideal for producing exceptional chocolates.

PEGGY GREB (D2283-1)

In Beltsville, Maryland, Gary Samuels examines microscopic structures of fungi collected in Peru.

Witches' Broom Watch

During the 2008 collection trip to Peru, Meinhardt also recorded the incidence of the devastating witches' broom disease (WBD) in wild cacao trees in the upper Amazon region. The scientists studied areas along the Aypena, Charupa, Nucuray, Pastaza, Ungumayo, Ungurahui, and Urituyacu Rivers and determined the overall severity of WBD infection based on the percentage of symptoms on flower cushions, flushes (new stem growth), and fruits.

A team of scientists, including ARS's Zhang, Meinhardt, and Samuels and ICT plant pathologist Enrique Arevalo, found that 14.7 percent of flower cushions and 13.7 percent of trunks were infected, and 9.1 percent of the trees along the Aypena River were infected. The other river areas had similar results.

The incidence of WBD observed during the survey suggests that there is a high level of WBD resistance in these wild Peruvian cacao populations. The scientists are now studying the samples to determine which are best suited for both unique flavor and WBD resistance. WBD can cause yield losses of 75 percent in susceptible varieties.

Friendly Fungi

In addition to collecting cacao germplasm, the team isolated other fungi from disease-free leaves and trunks of the wild cacao trees. This large collection of "endophytic" fungi—fungi that occur in disease-free tissues of all plants—may provide protection against diseases such as WBD either by stimulating the immune system of the plants or through direct parasitism or antibiotic effects against pathogens. Samuels found that several fungal species previously unknown to science were found in the cacao tissues. The potential for biological control using these endophytic fungi is being evaluated at Beltsville by SPCL scientists Bryan Bailey and Ron Collins.

The genome for WBD has been sequenced and it may hold clues for developing control measures to reduce its impact in the future. This was reported in the journal *Biomed Central Genomics* in 2008.

While scientists have the genomes of some cacao populations in hand and are working diligently to improve production and disease resistance, improvements can sometimes lead to unintended consequences, like a change in flavor, according to Meinhardt.

"There are a lot of great chocolate sources; the task is to find them and preserve them before they are lost," says Meinhardt. "Mother Nature has done a great job of creating these exceptional cacao trees."—By **Sharon Durham,** ARS.

This research is part of Plant Genetic Resources, Genomics, and Genetic Improvement (#301), Plant Diseases (#303), and Crop Protection and Quarantine (#304), three ARS national programs described at www.nps.ars.usda.gov.

Lyndel Meinhardt is with the USDA-ARS Sustainable Perennial Crops Laboratory, 10300 Baltimore Ave., Beltsville, MD 20705; (301) 504-1995, lyndel.meinhardt@ars.usda.gov.

A New Arrangement for Potato Production

When Idaho farmers started making the state famous for its potatoes, they seeded their crops in ridged rows and watered the plants by channeling surface irrigation to flow through the furrows between the rows. But even though most commercial potato producers in the Pacific Northwest now irrigate their crops with sprinklers, they still typically use ridged-row planting systems.

"The problem is that sprinkler irrigation can actually work against efficient water management because runoff from the sides of a ridged potato row allows water to pond in the furrow," says agricultural engineer Bradley King, who works at the ARS Northwest Irrigation and Soils Research Laboratory (NWISRL) in Kimberly, Idaho. "So some of the irrigation water is wasted because the excess water in the furrows percolates below the crop root zone and becomes unavailable to the plants. Under these conditions, nitrate leaching from the soil can increase."

King worked with NWISRL research leader Dave Bjorneberg and soil scientist David Tarkalson on a series of studies to see whether planting potatoes in flat beds instead of ridged rows could increase irrigation water-use efficiency and the overall efficiency of potato production. For a 2-year study, they set up experimental fields near their laboratory in Kimberly and compared three planting systems: conventional ridge-row systems, a five-row planting configuration on a raised bed where the plant rows were 26 inches apart, and a seven-row planting configuration on a raised bed where the plant rows were 18 inches apart. They also varied nitrogen application and irrigation rates for the experimental beds.

With the help of a grant from the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) and assistance of industry partner Western Ag Research LLC, the team also set up a 5-year study with commercial producers in eastern Idaho on 62 fields, a study area that totaled around 6,900 acres. They looked at how irrigation rates and variety selection affected yields for each producer, but in this study, they only compared ridged-row systems and five-row raised-bed systems.

Results? The researchers found that using the flat-bed system increased yields by an average of 6 percent, even though 5 percent less water was used for irrigation—which meant that using flat beds instead of ridged rows for potato production led to a 12 percent increase in irrigation water use efficiency. They attribute these gains to several factors, especially the probability that planting potatoes in flat beds improves water- and nitrogen-use efficiency because more water reaches the potato roots.

These findings, which were published in 2011 in the *American Journal of Potato Research,* could help commercial farmers in Idaho and other states increase yields and profits, save valuable water resources, and reduce nitrate leaching. Idaho farmers who use a high level of irrigation water management—methods identified by NRCS that help producers monitor soil moisture needs, such as electronic moisture sensors and data loggers—in combination with the potato bed planter are now eligible for state funding.

The work could also create new opportunities for farmers who are looking for ways to increase production efficiencies in the cultivation of specialty potatoes for niche markets.

King concludes, "What's great about the results is that this is another example of where a conservation measure can also result in increased income."—By **Ann Perry,** ARS.

This research is part of Climate Change, Soils, and Emissions (#212) and Water Availability and Watershed Management (#211), two ARS national programs described at www.nps.ars.usda.gov.

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Left: Conventional ridge-row potatoes with rows spaced 36 inches apart. **Right:** Seven-row planting configuration on a 12-foot-wide raised bed with rows spaced 18 inches apart.

BRADLEY KING (D2294-1)

BRADLEY KING (D2293-1)

Peering at Genes To Detec

The eyes are said to be the windows into the soul of humans, but in the case of cattle, they may hold clues to overall animal health. A closer look at pinkeye is offering insight into other costly bacterial diseases as well.

Researchers at the Agricultural Research Service's Roman L. Hruska U.S. Meat Animal Research Center (USMARC) in Clay Center, Nebraska, have found that genes are linked to the incidence of several diseases. Eduardo Casas, a geneticist in the Genetics and Breeding Research Unit at the time of the study, and former ARS scientist Gary Snowder discovered a quantitative trait locus (QTL), or location, on bovine chromosome 20 that is associated with pinkeye, foot rot, and bovine respiratory disease.

Looking Beyond the Pathogens

Scientists have known for some time what causes pinkeye, also known as "infectious bovine keratoconjunctivitis," and other diseases. The bacteria *Moraxella bovis* is the most common pathogen associated with pinkeye. Pathogens associated with bovine respiratory disease include viruses, such as bovine viral diarrhea virus, bacteria, like *Mannheimia hemolitica,* and mycoplasma. *Fusobacterium necrophorum* and *Porphyromonas* spp. are the main bacterial pathogens for foot rot, or infectious pododermatitis.

"Scientists have spent a lot of effort and money studying the pathogens that make animals sick," says Casas, who is now research leader for ARS's Ruminant Diseases and Immunology Research Unit in Ames, Iowa. "We've made a lot of progress, but the microbes are still around. Therefore, the main focus of this research was to look at diseases from the animal's point of view."

Casas' approach was to examine the genetic makeup of cattle for evidence of genes associated with conferring resistance or tolerance to diseases. His initial study focused only on pinkeye because it's easy to see and measure in cattle, he says.

Different breeds vary in their pinkeye tolerance. For example, Herefords are very susceptible, but Brahmans are highly resistant. With this in mind, a Brahman-Hereford crossbreed sire was mated to other breeds to yield more than 540 offspring.

"This particular bull was heterozygous for all genes that would confer tolerance to pinkeye," Casas says. "Half of the offspring inherited the resistant gene, and the other half inherited the susceptible gene."

When scientists looked at 36 offspring affected by pinkeye, they found that regions on chromosomes 1 and 20 harbored genes that influence the presence of bacteria, but no strong linkage to a QTL was identified. So the team took a different approach.

A Tale of Three

Following up on a theory that the immune system is influenced by various genes, Casas and Snowder conducted a second study. They combined the incidences of three highly prevalent bacterial diseases affecting feedlot cattle—pinkeye, foot rot, and bovine respiratory disease.

"When you put all three diseases together, you're looking at the overall health of the animal, or resistance to multiple diseases, rather than a disease-specific response," Snowder says. "In other words, the particular loci affecting an individual disease may not be easy to pick up, but it might be easier to pick up markers that are related to the general health of the animal."

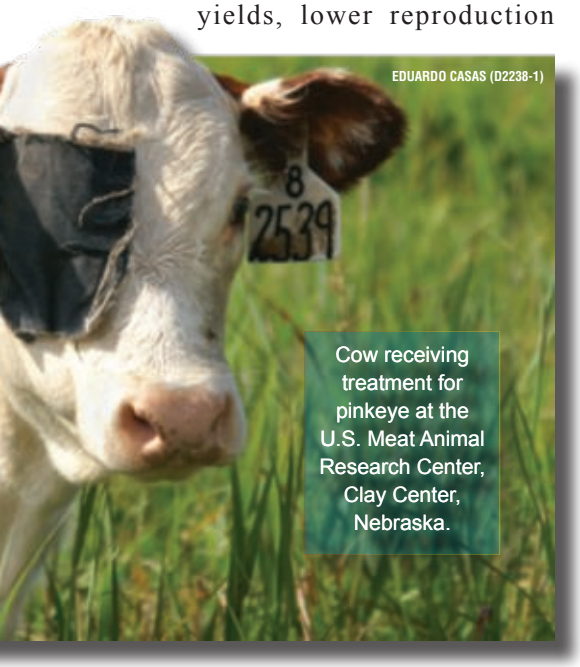
Selection for disease resistance is one of several possible interventions to prevent or reduce economic loss associated with animal disease and to improve animal welfare, according to Casas and Snowder.

A common condition affecting breeding-age beef heifers, pinkeye has a marked economic impact on the cattle industry—costing an estimated $150 million a year due to lower weight gains, decreased milk production, and treatment. Although not fatal, this highly contagious disease can affect up to 80 percent of a herd. Calves being weaned are even more susceptible and can lose as much as 10 percent of their body fat if they contract the disease.

Bovine respiratory disease—pneumonia—is the most common and costly feedlot disease in the United States. It accounts for 75 percent of feedlot morbidity and up to 70 percent of all deaths. Economic losses to cattle producers exceed $1 billion annually from animal deaths, reduced weight gain, lower feed efficiency, treatment costs, and poor-quality meat and hide products.

t Origin of Cattle Diseases

While foot rot is not as expensive as other diseases, it is estimated to cost dairy producers about $120 to $350 per animal. Foot rot causes lameness and leads to reduced milk yields, lower reproduction performance, increased involuntary cull rates, and discarded milk.



Cow receiving treatment for pinkeye at the U.S. Meat Animal Research Center, Clay Center, Nebraska.

Producers have been managing these diseases with various treatments and management practices. USMARC, which has more than 6,000 head of cattle, provided an ideal location to study different breeds affected by pathogenic diseases.

Breeds Apart

In addition to the Brahman-Hereford family studied in the pinkeye experiment, three other half-sibling families were produced to detect QTLs associated with combined incidences of the three diseases.

The second half-sibling family was developed from a Brahman-Angus sire and produced 176 offspring. A Piedmontese-Angus sire fathered 209 calves, and a Belgian Blue-MARC III (part Red Poll, Pinzgauer, Hereford, and Angus) sire produced 246 offspring.

Researchers used microsatellite markers—short, repetitive DNA sequences used as genetic markers to track inheritance—to screen the genome of each family. Informative markers were chosen within a family based on their location in each chromosome.

All animals were observed daily throughout their lifespan for pinkeye, pneumonia, and foot rot and treated when symptoms occurred. The 240 calves infected by one or more of the diseases were classified as affected by a microbial pathogenic disease and coded. Analysis of DNA blood samples taken from these animals revealed QTLs for disease activity.

Though scientists have discovered genetic locations that may influence resistance or susceptibility to bacterial diseases, there's more to do.

"We don't know what the gene or genes are yet, and that's what we are working on," Casas says. More study needs to be done to confirm the association between the genes and disease.

"What's interesting about the markers on chromosome 20 is that they are in very close proximity to other markers related to other diseases. That particular region may have a significant effect on the general health of animals," Casas says.

Additional studies are under way to detect genes associated with reduced susceptibility to bacterial diseases, including Johne's disease and bovine viral diarrhea.

"The costs for treating animals that have these diseases are enormous," Casas says. "Identifying genes responsible would provide an opportunity for effective crossbreeding to produce animals with increased disease tolerance, which would greatly reduce the economic impact to the cattle industry."—By **Sandra Avant,** ARS.

This research is part of Food Animal Production (#101), an ARS national program described at www.nps.ars.usda.gov.

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Geneticist Eduardo Casas (right) and technician Sandra Nejezchleb prepare bovine DNA samples for mass-spectrometry. Results are used to assess whether changes in DNA sequence are associated with pinkeye, also known as "infectious bovine keratoconjunctivitis."

STEPHEN AUSMUS (D2236-9)

PEGGY GREB (D2274-1)

Cotton technologist Paul Sawhney (left) and research leader Brian Condon examine needled-punched nonwoven products made with classical raw (greige) cotton and precleaned raw cotton, respectively.

Cotton's Potential for Padding Nonwovens

About 98 percent of cotton produced worldwide today is used in woven and knitted fabrics and a variety of threads, ropes, and cables. These materials are known as "traditional textiles." A wide variety of machinery, chemicals, and manufacturing processes are involved in producing these textiles. For example, carding machines, which are outfitted with fine wires of different shapes, separate and coax cotton fibers into alignment. The aligned fibers then are formed into a long braidlike material called "sliver," which becomes the basic material for spinning yarns. These yarns are used mostly to weave or knit fabrics and to ply into sewing threads.

Innovations in textile technologies continue to automate and integrate manufacturing processes to increase fabric productivity and quality. During the last century, a new generation of textile equipment began making fabrics—known as "nonwovens"—in a continuous sheet form and at a very high production rate compared to that of woven fabrics.

New Uses for Cotton Fibers

Nonwoven fabrics, made from natural or synthetic fibers, are made *without* spinning or weaving yarns. Instead, these flat, porous sheets of fabric are mostly made by entangling or bonding the fibers. "The process of entangling fibers gives nonwoven fabrics strength," says Brian Condon, research leader with the Agricultural Research Service's Cotton Chemistry and Utilization Research Unit, in New Orleans, Louisiana. The unit is part of the ARS Southern Regional Research Center (SRRC).

At first, nonwoven fabrics were made using synthetic polymer-type fibers, such as polyester, polypropylene, and polyethylene, and some regenerated fibers, such as rayon, which is plant based. But in recent years, some nonwovens manufacturers have begun adding cotton to nonwovens used in absorbent hygiene products and personal-care wipes.

In 1968, a U.S. trade association was formed called "The Disposables Association." Recognizing that nonwoven fabrics were being used in an increasingly wider variety of end products, the organization changed its name in 1972 to the International Nonwovens and Disposables Association (INDA). The U.S. nonwoven fabrics industry now includes machinery producers, roll-goods producers, and raw-materials suppliers and converters. In 1976, INDA changed its name yet again to the Association of the Nonwoven Fabrics Industry, although the INDA acronym remains.

Ian Butler, INDA's director of market research, predicts rapid growth in some segments of nonwovens in both household and institutional markets. During the past few decades, the nonwovens markets in the United States, Europe, and Japan expanded greatly, mainly because of considerable advances in equipment, processing technologies, and product developments, according to Butler.

"The industry is now growing in most regions around the world. Total worldwide

growth of this industry is about 7 to 8 percent per year," says Butler. "The wipes industry segment in particular is undergoing tremendous growth."

From Hygiene to Auto Products

The disposable nonwovens markets include several different product categories, including absorbent hygiene products (baby diapers, feminine sanitary napkins, tampons, pantiliners, adult incontinence products, and underpads) and wipes for baby, personal, household, and medical care.

"We are astounded at the phenomenal growth of the general wipes industry, with some markets growing in the double-digit range per year," says Butler. "In the late 1990s, retail sales of all wipes in the United States and Canada combined was about $700 million; but within 5 years—by 2005—those sales jumped to $2 billion."

The nursing-facility industry, for example, is using adult diapers and bathing wipes made of nonwovens. At SRRC, projects are in the works to produce disposable bedsheets that would be particularly attractive to hospitals and nursing facilities.

Cotton, a premium fiber, enjoys the greatest market share of all natural fibers sold worldwide today, according to Janet O'Regan, director of strategic initiatives with Cary, North Carolina-based Cotton Incorporated.

While the use of cotton in nonwovens consists of less than 2 percent of all fibers currently used in nonwovens worldwide, some U.S. commercial products, like cosmetic pads and facial wipes, contain 100 percent cotton, according to experts.

"Since cotton is a significant crop internationally, we want to aggressively promote value-added utilization of cotton—particularly in the rapidly growing nonwovens industry," says Condon. "Cotton fibers can be added to nonwoven fabrics to produce products that are economical, functionally efficient, eco-friendly, and sustainable."

Materials engineer Dharnidhar Parikh, also at the ARS cotton utilization unit in New Orleans, reported that nonwovens made from blends of plant-based fibers—cotton, kenaf, jute, and flax—and polypropylene could be used in automobiles to insulate passengers from engine and outside noise. One study showed that each of the above-mentioned cellulose-based nonwovens had sound-absorbing properties comparable to those of the materials actually used in auto interiors.

Parikh also reported that the nonwovens made from blends containing biodegradable natural fibers could be made lighter in weight than their all-synthetic counterparts. "These blends have the potential to lower operating costs, because making lighter weight cars leads to better gas mileage," said Parikh. The 2007 study was published in *Textile Research Journal.*

Mattresses and other bedding products are required to be made with flame-retardant materials. One reason is that nonwoven materials are fluffy, so they burn more readily. It has been shown that suitable mattress and bedding nonwoven materials can be made from raw, virgin lint, which is ginned cotton that has not been bleached. Virgin cotton is referred to by industry as "greige" (pronounced "gray") cotton.

"Virgin cotton is much less expensive than bleached cotton or some synthetics," says Condon. ARS studies are now under way to determine the flame-retardant properties of such materials and to improve those properties. "We are working on several specific approaches to improving flame-retardant performance, and so far, we've seen several good successes in the lab," he says.

Triumph Over Adversity

Use of cotton fibers in the nonwovens sector has been limited partly by the production costs of bleaching cotton. "We wanted to explore new research avenues to increase the use of cotton in nonwovens," says Condon.

Then, a crisis occurred that accelerated change.

In 2005, Hurricane Katrina shut down the SRRC. "We used that disaster as a turning point to change direction and emphasize use of cotton in nonwovens as our new area of cotton research," said Condon. "We purchased a new fleet of state-of-the-art nonwoven machinery and equipment for conducting basic and applied research to develop new technologies to incorporate cotton into existing and new products." In 2007, SRRC opened its Cotton Nonwovens Research Laboratory and Pilot Facility.

The machinery includes three lines of nonwovens research equipment totaling 16 machines. The needle-punch line is made by TechnoPlants; the hydroentanglement line is made by Fleissner; and the finishing line is made by Mathis.

Hydroentanglement, sometimes called "spunlacing," is a process in which closely

PEGGY GREB (D2275-1)

Technician Pablo Ali Salami (left), research leader Brian Condon (middle), and technician Lucien Duplessis apply a new treatment to a hydroentangled greige cotton nonwoven fabric on the Mathis laboratory equipment. This device is part of a fleet of state-of-the-art equipment for the Cotton Nonwovens Research Laboratory and Pilot Facility at the Southern Regional Research Center in New Orleans.

PEGGY GREB (D2276-1)

Cotton technologist Paul Sawhney (left) and textile technologist Michael Reynolds prepare an experimental trial for producing a hydroentangled cotton nonwoven fabric on a commercial-grade hydroentanglement system.

spaced, high-pressure water jets strike a web or batt of loosely held fibers supported on a screenlike moving belt made of polyester woven fabric. The jet-impacted fibers are then rearranged and entangled to form a strong sheet of woven-like fabric. This hydroentangling technique is a leading technology, especially within the cotton and staple-fiber nonwovens sector, and is sometimes combined with needle-punching.

Several test instruments were purchased to assess the products of the research efforts. Condon also had existing cotton carding equipment modified to produce a web of cotton fibers instead of sliver. The result of this lab-equipment revolution is the ARS-SRRC Cotton Nonwovens Research Center. The expanded research effort now involves efficient use of the new fleet of sophisticated equipment, more emphasis on processing nonwoven fabrics, and more outreach to a variety of potential markets.

Nonbleached Cotton's Debut

"Most of the cotton fiber used in the nonwovens sector up until now has been bleached cotton," says Butler. "But bleached cotton is relatively expensive and complex to process, so there is considerable effort to develop a wipe using nonbleached cotton."

ARS cotton technologist Paul Sawhney, the lead scientist of the cotton-based nonwovens research program at the center, and colleagues conducted preliminary studies to investigate the use of virgin cotton in nonwovens. The studies showed that ginned virgin cotton could be processed directly on existing cotton carding equipment. "Cotton's natural waxes actually provide a measure of lubrication that considerably helps in carding the fibers," says Condon. "Bleached cotton fibers create tough problems in the carding process."

"We then efficiently processed the virgin cotton on the center's modern nonwoven fabrics production equipment," says Sawhney. "We were pleased with the quality of the first experimental 100-percent virgin cotton nonwoven fabrics that we produced." Sawhney reported some of those findings in the proceedings of the 2009 International Cotton Conference, held in Bremen, Germany.

"We have produced several lightly preneedled condensed webs of virgin cotton on commercial-grade needle-punch equipment to investigate the

Technician Adrian Mejia (left) and textile chemist Chuck Allen (center) examine a cross-lapped web (batt) as they prepare to feed it into the needle-punch machine to produce a fabric containing mostly cotton. Technician Farrell Screen waits for the fabric on the exit side.

PEGGY GREB (D2279-1)

Needle-punch equipment is used to entangle fibers to produce a delicate, lightweight nonwoven material from greige cotton. This material may be used in industrial wipes.

PEGGY GREB (D2280-1)

hydroentanglement process of fabricating nonwovens," says Sawhney. "We have evaluated the processing of virgin cotton on a TechnoPlants needle-punch machine and on a Fleissner hydroentanglement system and the properties and characteristics of the nonwoven fabrics produced." The team found that greige cotton, which is naturally water repellent, can be made absorbent mainly by controlling the hydroentanglement water pressure.

Various forms of cotton include by-products, such as discounted cottons, ginning waste (motes and linters), and textile processing wastes (card strips, comber noils). Sawhney believes that these forms of cotton could be suitable for use in nonwovens such as wipes, upholstery, and quilt-blanket inserts.

The researchers published these findings in a 2010 study, "Advent of Greige Cotton Nonwovens Made Using a Hydro-Entanglement Process" in *Textile Research Journal.*

No Bleach, No Debris

About 25 years ago, Tom Gary, owner of Greenwood, Mississippi-based Wildwood Gin, Inc., began specializing in cleaning gin waste, or linter, and providing that fiber to paper mills and traditional textile mills. But in the last decade, Gary's team, which includes son Lawson Gary, began purchasing and drastically modifying textile equipment to create an entirely new plant and textile process.

"The new process removes trash from regular cotton fibers at unprecedented levels," says Lawson Gary. Trash includes leaves, sticks, burs, bark, and other debris in ginned cotton.

"In the past 2 years, we have been working with scientists at the SRRC Cotton Nonwovens Research Center to produce and evaluate fabrics made with our ready-to-use, clean, natural-cotton fibers," says Gary. "We provide high-quality reprocessed cotton fibers that are cleaned with no chemical bleaching, water, or process heat." According to Gary, these fibers have been very well received by hydroentanglement and needle-punch nonwovens manufacturers in the United States and western Europe.

"Working with the SRRC scientists has allowed us to test our fibers' performance in a number of 100-percent cotton nonwoven materials," says Gary. The result is that Wildwood Gin has begun marketing mechanically cleaned, natural cotton to manufacturers of personal care products within the nonwovens industry.

"Elimination of the scouring process in cotton-based nonwovens is a major milestone in the value-added utilization of greige cotton in nonwovens."
—Paul Sawhney

"An international brand is making plans to roll out a number of personal-care nonwoven products that include our fibers," says Gary. "The SRRC researchers have made first-of-a-kind samples and modeled production runs of 100-percent cotton nonwoven fabrics in their pilot facility. Those cotton-containing test fabrics helped us with proof-of-concept and enabled real-time use of these fibers in personal-care products."

"The ability to put precleaned, nonbleached greige cotton directly into nonwoven fabrics could be considered an industry breakthrough," says O'Regan.

In a new study, SRRC scientists have compared two forms of cotton: One was ginned and conventionally cleaned, and the other was cleaned with Wildwood Gin's new mechanical-cleaning process.

The study showed that nonwoven textile plants, with certain nominal modifications, could use the mechanically cleaned, natural cotton without adding new equipment. This comparison study was published in 2011 in *Textile Research Journal.*

According to Sawhney, mechanically precleaned, nonbleached greige cotton is a good candidate for use in newer and improved nonwoven materials and end-use products, such as disposable, reusable, recyclable, washable, and perhaps even flushable wipes. Other products could be institutional uniforms, toweling, sheeting, furnishings, tablecloths and mats, napkins, undergarments, pajamas, and even sustainable "green" denims.

"Elimination of the scouring process in cotton-based nonwovens is a major milestone in the value-added utilization of greige cotton in nonwovens," says Sawhney.

"The SRRC researchers are helping industry understand how to process virgin cotton and use it directly in nonwoven fabrics without bleaching," said O'Regan.

New Nonwoven Products

SRRC's textile technologist Michael Reynolds says that in 2010, several nonwovens roll-goods manufacturers and retailers expressed interest in the development of cotton-containing nonwoven products, especially wipes.

"We have a trust agreement with one group to develop cotton-based nonwoven products for the home sewing, crafting, and quilting markets," said Reynolds. "Another group gave us specifications to develop a very-heavy-weight, needle-punched, 100-percent cotton nonwoven material." SRRC provided a piece of the required material, and the cooperator is evaluating the sample for potential commercial application.

"We anticipate that cotton can be useful in many other end-use applications of existing nonwoven products," says Reynolds.—By **Rosalie Marion Bliss,** ARS.

This research is part of Quality and Utilization of Agricultural Products, an ARS national program (#306) described at www.nps.ars.usda.gov.

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Technician Pablo Ali Salami (left) and textile chemist Chuck Allen discuss new uses for the colorful cotton-based nonwoven fabrics they dyed and finished in the wet-finishing laboratory.

PEGGY GREB (D2277-1)

Tools To Help Make Decisions for Better Nitrogen Use

PEGGY GREB (D2254-1)

Colorado State University soil scientist Neil C. Hansen (left) and ARS soil scientist Jorge Delgado assess soil water content of a rotation that includes deep-rooted alfalfa with limited irrigation.

Jorge Delgado is an expert in a very complicated field: the use of nitrogen-based fertilizers. How much fertilizer should be applied to the soil, when in a growing season to apply it, and what alternatives might work best are complex issues. "The right approach will vary from one location to the next and from one crop to the next, and it will also depend on a grower's management practices," says Delgado, an Agricultural Research Service soil scientist with the Soil Plant Nutrient Research Unit (SPNRU) in Fort Collins, Colorado.

The issue is critical because nitrogen-based fertilizers are a major reason why agriculture is a significant source of both greenhouse gas emissions and the pollution in waterways and estuaries that causes hypoxia. If growers apply too little fertilizer, it reduces crop yields. If they apply too much, the excess can be released into the atmosphere as nitrous oxide or may leach into the water as nitrate. Add in the nitrogen produced by animal waste, and it is easy to see why reducing nitrogen losses to the environment is a major goal in agriculture today.

"Nitrogen is intimately linked to water quality issues throughout the United States, particularly when you think of estuaries like the Gulf of Mexico and Chesapeake Bay. So any technique or tool that will help reduce the amounts of nitrogen going into our waterways will be of benefit," says Mark Walbridge, ARS national program leader for water availability and watershed management.

Nitrogen-based fertilizers are a necessity for high crop yields and global food security, but growers need to minimize the environmental aspects of using them. Delgado is helping growers, conservationists, and others determine how much nitrogen to apply to a field by fine tuning and promoting two ARS-developed tools, the Nitrogen Index and the Nitrogen Loss and Environmental Assessment Package (NLEAP). Both will analyze how much nitrogen is being used and lost from a field—a first step in finding better alternatives.

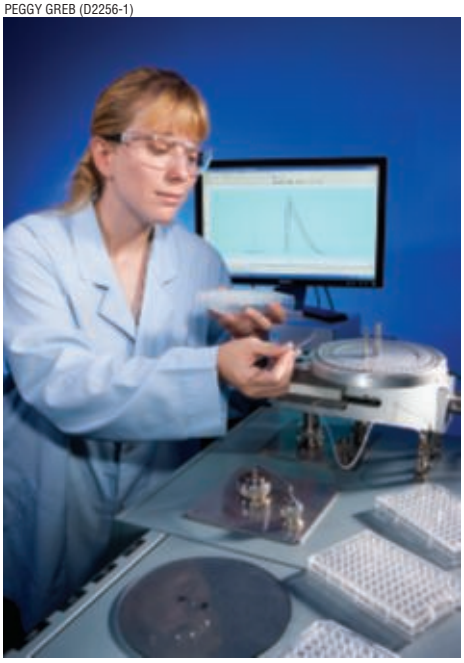
For the Nitrogen Index, nutrient managers use information that can be obtained in one visit to a farm, such as the crop being raised, the projected yield, whether irrigation is provided, and whether cover crops are used. This allows a quick assessment of the risk of environmental impact under current and alternative management practices.

NLEAP is a computer model that uses Geographic Information Systems data from a site, and it takes more time and skill to use. Details such as soil particle size, soil nitrogen content, rainfall amounts, and weather patterns are required. These tools have been distributed to hundreds of users, including farmers, agribusinesses, scientists, extension agents, state and federal agencies, and international users.

PEGGY GREB (D2257-1)

ARS soil scientist Jorge Delgado (far left) and colleagues from Bolivia and Ecuador discuss the potential to use the Nitrogen Index and other nitrogen tools in those countries. Pictured with him are Ana Karina Saavedra Rivera (Bolivia), Luis Orlando Escudero López (Ecuador), and Carlos Marcial Monar Benavides (Ecuador).

PEGGY GREB (D2256-1)



Technician Donna Neer conducts analysis of nitrogen and carbon in cover crops and potato plant samples.

In addition to NLEAP and the Nitrogen Index, Delgado has helped develop a tool designed for fledgling "environmental trading" credit programs that reward growers for reducing nitrogen losses. Known as the "Nitrogen Trading Tool" (NTT), it can determine how much a given management practice may reduce nitrogen losses and thus how much trading credit could be earned by switching to that practice. The concept of trading nitrogen credits to clean up waterways is in its early stages, but efforts have begun in Pennsylvania and Ohio, with municipalities and state environmental agencies in several states and watersheds studying the concept.

Getting the Word Out

Delgado spends much of his time tailoring the tools to the needs of growers throughout the United States and in overseas projects funded by the USDA Foreign Agricultural Service and the U.S Agency for International Development. He has also published a book on nitrogen management techniques with Ron Follett, SPNRU research leader, and has posted a link to an Internet site (ars.usda.gov/npa/spnr/nitrogentools) that allows users to download the Nitrogen Index and NLEAP and instructions on how to use these tools.

In recent years, Delgado has advised scientists, helping them calibrate NLEAP and the Nitrogen Index to assess the efficiency of nitrogen use in several states as well as in Argentina, Bolivia, Ecuador, Mexico, and Spain. He has also conducted nitrogen management research in cooperation with scientists from China, Switzerland, and other countries. He has worked with scientists at the USDA Natural Resources Conservation Service (NRCS) to develop a Nitrogen Index prototype that was found to be effective by scientists, growers, professors, extension agents, and conservationists in the United States and internationally. Delgado has also worked with scientists at the University of Puerto Rico at Mayagüez and NRCS to adapt the Nitrogen Index to the unique soil and climatic conditions of the Caribbean basin.

"His research has a long history of resulting in positive contributions and new technologies that can help us assess and manage nitrogen strategies in very different soils and geographic areas. His advice on the development of new concepts such as NTT has also been incredibly useful," says Shaun McKinney, an NRCS scientist in Oregon.

Delgado published details of his efforts to reduce nitrogen losses from corn and dairy farms in Mexico in the peer-reviewed journal *Terra Latinoamerica*. He has also published a peer-reviewed report in *Advances in Agronomy* that showed how NTT could be used to calculate the potential for nitrogen trading for different management practices in a Virginia no-till operation, an Ohio farm where manure is applied to grow corn and soybeans, and irrigated barley and potato fields in Colorado.

Effective at Selling Alternative Practices

The tools have also helped convince growers of the need to improve their soil-management practices by using conservation tillage, crop rotation, and cover crops such as wheat, rye, and other grasses. Such practices not only help keep nitrogen in the soil and prevent nitrates from leaching into waterways, but they also help prevent soils from eroding and keep carbon and nutrients sequestered in the soil.

The environmental benefits can be significant. In Colorado's San Luis Valley, where Delgado has worked for years, the tools have been useful in assessing the potential of reducing nitrogen fertilizer inputs by using cover crops in potato and vegetable fields. The switch has saved thousands of tons of topsoil each year that would otherwise be lost to erosion. Keith Holland, a valley grower, credits Delgado with steering him toward the use of cover crops on the 700-acre farm that he shares with his brother. With Delgado's guidance several years ago, Holland began using sorghum-sudangrass, a popular hybrid cover crop, and he has since been using less fertilizer, increased the yields from his barley and potato fields, and seen improvements in soil quality. The quality of his Russet potatoes, grown for fresh-market sale, has also improved. "They're bigger potatoes, and they're more uniform in size and shape," Holland says.—By **Dennis O'Brien,** ARS.

This research is part of Climate Change, Soils, and Emissions, an ARS national program (#212) described at www.nps.ars.usda.gov.

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RED ANGUS ASSOCIATION OF AMERICA (D2258-1)

New Test Detects Bone Disease in Red Angus

Red angus family.

When a rare and deadly birth defect called "marble bone disease" struck Black Angus cattle in the 1960s, producers had little alternative but to cull all animals related to affected calves in an effort to get rid of the mutation. When the same disorder resurfaced in Red Angus 3 years ago, scientists had a better and less costly option: Develop a DNA test to identify carriers responsible for the disease.

The return of marble bone disease, also known as "osteopetrosis," became a high priority for Larry Keenan, director of breed improvement at the Red Angus Association of America (RAAA) in Denton, Texas. To stop it from spreading, Keenan teamed up with Tim Smith, a chemist in the Genetics and Breeding Research Unit at the Agricultural Research Service's Roman L. Hruska U.S. Meat Animal Research Center (USMARC) at Clay Center, Nebraska, and Jonathan Beever, a molecular geneticist at the University of Illinois in Champaign.

A bone disorder that affects humans, cattle, and other animals, osteopetrosis is characterized by overly dense yet brittle bones that shatter easily. Calves that suffer from the mutation have deformed skulls, receding lower jaws, and protruding tongues. They usually are stillborn or die within 24 hours of birth.

Though osteopetrosis is not common in cattle, it has been reported in Hereford, Simmental, Holstein, and Angus breeds in the past, Smith says.

"Calves have to inherit the mutation from both parents," he says. With the recent incident in the Northern Plains, there was significant concern because the breed's most popular bull was related to some of the animals that had produced osteopetrosis-affected calves.

"A lot of calves were indirectly linked to that bull, so breeders wanted to make sure that they weren't continuously putting the DNA for the disease into their herd," adds geneticist Tara McDaneld at USMARC.

Smith, McDaneld, Beever, and geneticist Tad Sonstegard at the Henry A. Wallace Beltsville [Maryland] Agricultural Research Center collaborated with veterinary researchers at the University of Nebraska and University of Wyoming to identify the gene mutation responsible for the disorder and to develop a diagnostic test that identifies osteopetrosis carriers.

Tissue samples of seven affected calves were first examined for bovine viral diarrhea virus, a known infectious cause of osteopetrosis, but the results were negative. However, pedigree analysis of the seven calves revealed both maternal and paternal common ancestry, suggesting an association between their genes and the disease.

Scientists compared DNA from affected Red Angus calves and their carrier parents to DNA from unaffected animals. They then searched the entire genomes of all

calves for chromosomal segments common to the affected animals, but different from the normal animals.

A Tool for the Task

The Illumina Bovine SNP50 BeadChip, developed earlier by ARS researchers, along with industry and university partners, was used to identify suspect genes. The BeadChip, a glass slide containing thousands of DNA markers, identifies relationships between markers simultaneously.

"We had just the right tool to genotype DNA samples from animals with this mutation," Sonstegard says. "Once samples were assembled and extracted, running the chip didn't take very long."

A single chip generates more than 50,000 genotypes for each animal. DNA samples were applied to the BeadChip, chemically labeled, and scanned to produce genotypes.

"We were looking for those regions from the affected calves where the chromosome was similar on both the mother's copy and the father's copy," Sonstegard says. "We were able to detect through an analysis program when it was homozygous—having two copies of the same gene—only in a specific region of chromosome 4."

Identifying a Mutation

A segment on cattle chromosome 4 contains *SLC4A2,* a gene necessary for proper osteoclast maintenance and function, McDaneld says. Osteoclasts are types of cells responsible for breaking down old bone during bone development and remodeling.

In the osteopetrosis-affected calves, researchers found that some of the *SLC4A2* genetic material had been deleted. The discovery of the deletion in this gene was a first for cattle, McDaneld says.

While the cattle study was being conducted, scientists elsewhere were studying bone development in mice. They intentionally created a similar mutation in *SLC4A2* to determine the function of the gene, and it was observed to cause the same marble bone disease phenotype, McDaneld says. The fact that the exact same gene in mice was responsible for the osteopetrosis mutation confirmed the findings in Red Angus.

What once took years to accomplish was done within a matter of months with fewer samples.

Scientists were able to develop a PCR (polymerase chain reaction) test and have it available to breeders in less than a year. They also determined that the popular bull was not a carrier, to the relief of the industry.

"The mutation had crept into the pedigree of the offspring of the bull by his mating with a carrier heifer," Smith says.

Scientists looked at the genetic makeup of more than 450 normal Red Angus to see how common the mutation might be in the breed. No healthy animals were found to be homozygous for the mutation, consistent with the prediction that all animals with two copies of the mutation should be affected. More than 570 Black Angus bulls were also tested and found to be negative for the osteopetrosis-causing mutation.

Breeders now have a test they can use to manage the defect, identify cattle that may be carriers, and make decisions on whether the animal's other traits make it valuable enough to continue using for breeding, Smith says. This way, the bone disease can be eliminated from the herd without sacrificing other genetic progress made during development of the breed.

"What's really important is that with the rapid response time with which we can now put a test like this into the hands of producers, they don't have to be as afraid of genetic defects anymore," Smith says. "We can create tests relatively fast now and prevent these kinds of diseases from spreading throughout the herd."

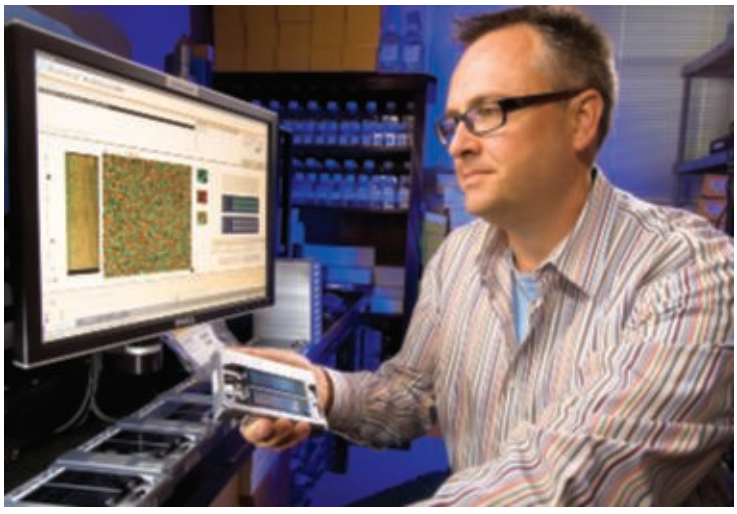
The newly developed PCR test—provided through RAAA—has been widely used and is required for registration of most Red Angus.

"If it had not been for the research team, we would not have this tool to provide to our customers in their ongoing quest to develop those reliable genetics," Keenan says. "The Red Angus Association is grateful for that."—By **Sandra Avant,** ARS.

This research is part of Food Animal Production (#101), an ARS national program described at www.nps.ars.usda.gov.

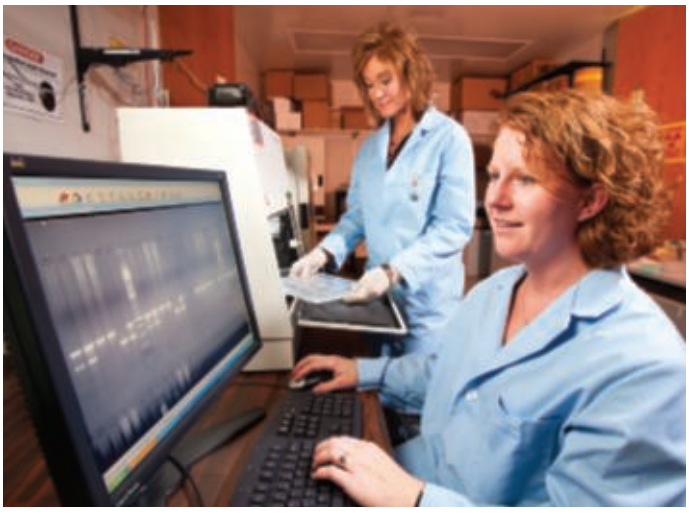
To reach scientists mentioned in this article, contact Sandra Avant, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1627, sandra.avant@ars.usda.gov.

Geneticist Tad Sonstegard analyzes BovineSNP50 BeadChips for genotypic data that decodes each animal's genome at more than 50,000 locations. This type of data is used in cattle research ranging from genome selection to mapping of congenital defects.



PEGGY GREB (D1527-1)

Geneticist Tara McDaneld (right) and technician Renee Godtel use a gel imager to evaluate genotypes of Red Angus cattle for osteopetrosis phenotypes.



STEPHEN AUSMUS (D2237-10)

New Potatoes Withstand Destructive Wireworms

Wireworm feeding damage is easy to spot, says Rich Novy, an Agricultural Research Service plant geneticist seeking to shore up America's $3.3 billion potato crop. The damage resembles a nail hole that has been punched into the spud, pitting its surface and making it less appealing for use in fresh-pack or processing markets.

Although organophosphate- and carbamate-based insecticides are available for use against wireworms on potato, the continued registration of some of these insecticides is uncertain, say Novy, who is in ARS's Small Grains and Potato Germplasm Research Unit in Aberdeen, Idaho. Plus, the chemicals don't always eliminate the slender, brownish-orange pests, which as larvae can survive beneath the soil for as long as 5 years before emerging as adult click beetles.

Over the last several years, Novy, ARS plant pathologist Jonathan Whitworth, and former University of Idaho associate professor Juan Alvarez have looked for a solution to the problem in the form of genetic resistance. In particular, they've focused attention on two wild relatives of cultivated potato obtained from Chile and Bolivia: *Solanum berthaultii* and *S. etuberosum*. Taking their cue from previous studies showing that the wild potatoes are resistant to Colorado potato beetles and green peach aphids, two disparate pests, the researchers decided to pit the plants against hungry wireworms as well.

JUAN MANUEL ALVAREZ (DUPONT CROP PROTECTION) (D2289-1)

A wireworm feeding on potato tubers and causing obvious damage.

To do this, the team crossed germplasm derived from the wild potatoes with a cultivated variety and then selected 15 top-performing plants from 3 generations of progeny. The researchers' next step was to plant the progeny lines, called "breeding clones," in wireworm-infested field plots in southern Idaho and compare the feeding damage they sustained to that of flanking rows of Russet Burbank potatoes treated with or without an insecticide commonly used for controlling wireworm.

As the researchers had hoped, the resistant clones fared as well as—and sometimes better than—the insecticide-treated Russet Burbank potatoes.

At this time, the mechanism of resistance to wireworm has not been determined, but it may be related to glycoalkaloids. These naturally occurring chemical compounds in potato tubers are known to deter some insect pests. Total concentrations of glycoalkaloids in many of the resistant clones are at levels suitable for human consumption, which may open the door to their use in the development of wireworm-resistant commercial varieties.

The team has submitted a paper on the research to the *Journal of Economic Entomology*.—By **Jan Suszkiw,** ARS.

This research is part of Plant Genetic Resources, Genomics, and Genetic Improvement (#301) and Plant Diseases (#303), two ARS national programs described at www.nps.ars.usda.gov.

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SCOTT BAUER (K9152-1)

The potato is the vegetable of choice in the United States. ARS scientists are now working to develop potato varieties with resistance to wireworms.

The Agricultural Research Service has about 100 labs all over the country.

Locations Featured in This Magazine Issue

Northwest Irrigation and Soils Research Laboratory, Kimberly, Idaho
1 research unit ■ 40 employees

Tucson, Arizona
2 research units ■ 57 employees

Aberdeen, Idaho
1 research unit ■ 66 employees

Las Cruces, New Mexico
2 research units ■ 53 employees

Fort Collins, Colorado
5 research units ■ 157 employees

Rangeland Resources Research Unit, Cheyenne, Wyoming
1 research unit ■ 33 employees

Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, Nebraska
6 research units ■ 132 employees

Southern Regional Research Center, New Orleans, Louisiana
7 research units ■ 221 employees

Henry A. Wallace Beltsville Agricultural Research Center, Beltsville, Maryland
30 research units ■ 953 employees

Map courtesy of Tom Patterson, U.S. National Park Service

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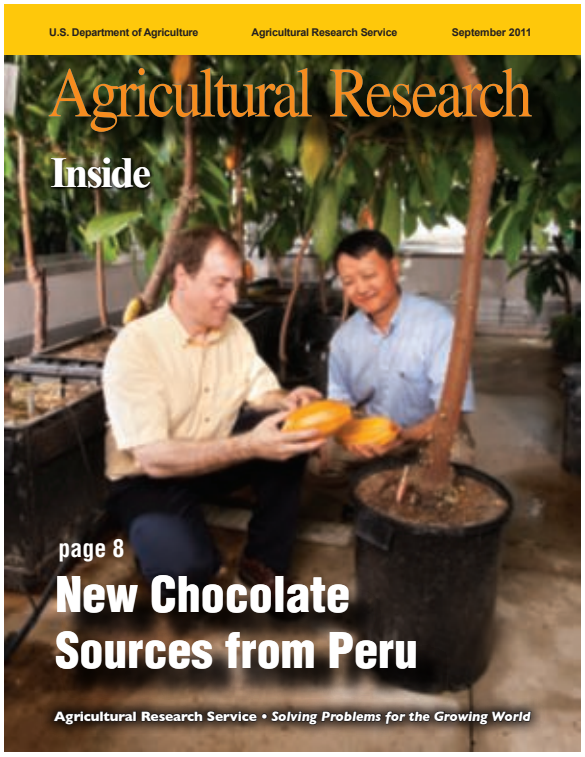

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