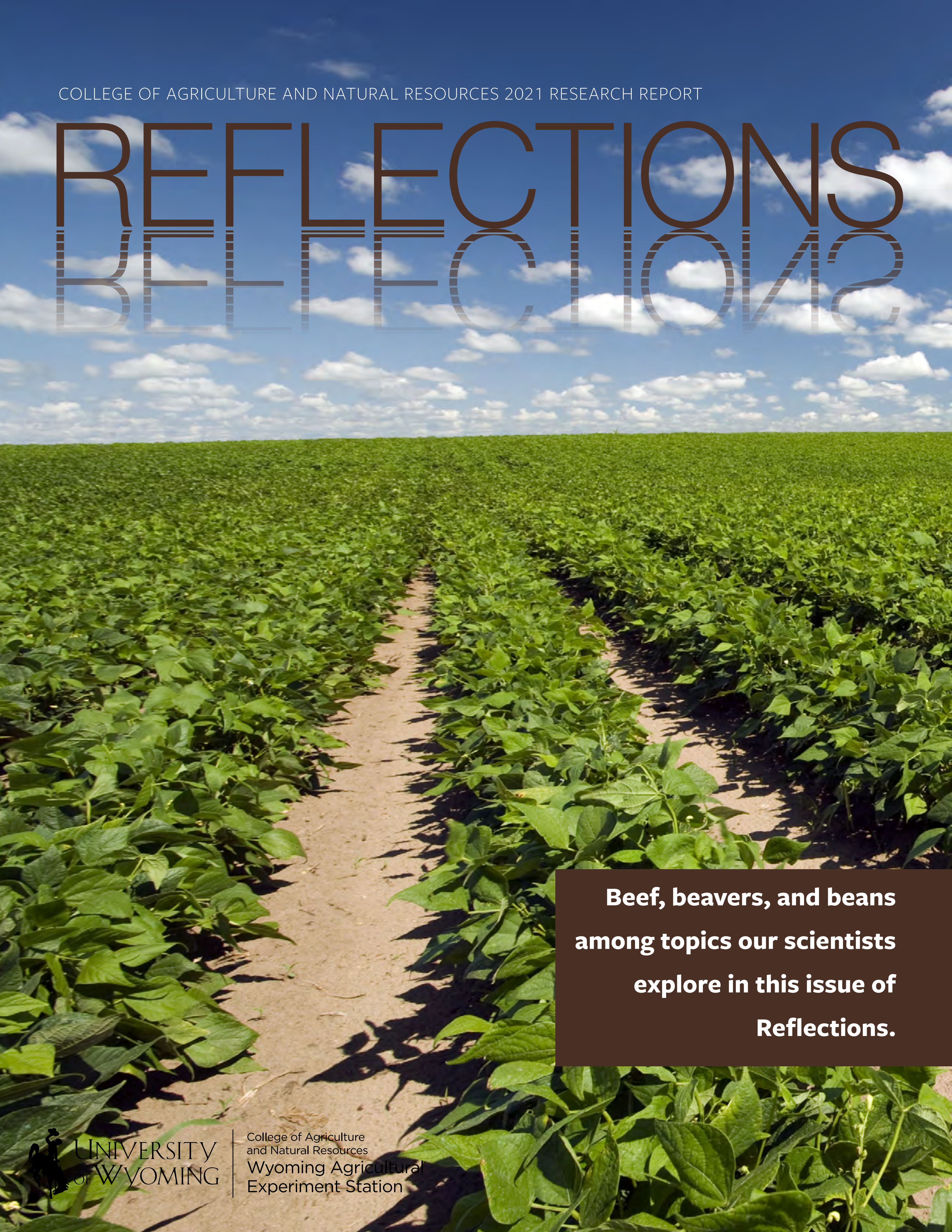

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES 2021 RESEARCH REPORT

REFLECTIONS

Beef, beavers, and beans among topics our scientists explore in this issue of Reflections.

University of Wyoming
College of Agriculture and Natural Resources
Wyoming Agricultural Experiment Station

REFLECTIONS

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OUR RESEARCH MEANT TO IMPROVE DAILY LIVES OF RESIDENTS, KEEP AGRICULTURAL PRODUCERS SUSTAINABLE

Tanya Engel, UW Extension

Draft horses Pistol and Pistol snack on hay with Eric Webster, who began as director of the Wyoming Agricultural Experiment Station in July.

The University of Wyoming College of Agriculture and Natural Resources has a long tradition of outstanding research, teaching, and extension. This year marks the 130th anniversary of the Wyoming Agricultural Experiment Station, and I am extremely excited to be the associate dean and director.

I have been involved with agricultural research my whole life. I had the privilege of growing up on a research station in Alabama. My dad was resident director of the Tennessee Valley Research and Extension Center. This center is part of the Alabama Agricultural Experiment Station and the Auburn University College of Agriculture.

I started working on the station when I was 13 years old but in reality, I worked on the station from the time I was old enough to walk. I spent my days shadowing my dad, going where he went and helping anyway I could. Most of the time you would find me riding on the wheel-well in the bed of his truck. I guess you could say this apple didn't fall far from the tree. As I write this, my father is near the end, and I wanted to pay tribute to him one last time. I would not be the person I am today without his guidance. Godspeed William B. "Dub" Webster.

After graduating high school, I attended Auburn University where I received a B.S. in agronomy and soils and an M.S. in weed science, in 1987 and 1990, respectively. I continued my education at Mississippi State University graduating in 1995 with a Ph.D. in weed science. After graduation, I worked for the University of Arkansas and then Louisiana State University as a research and extension weed scientist in several row crops over the last 26 years but mainly focusing on rice weed management.

Enough about me. I am excited about the research presented in this edition of *Reflections*. Inside, you will find articles focusing on many of our research areas within the College of Agriculture and Natural Resources. Most importantly, I believe this research will directly impact the citizens of Wyoming. This research will hopefully improve our daily lives and help the agricultural producers in Wyoming remain profitable and sustainable. I think you will find each of these articles informative and educational.

I am very excited to lead the Wyoming Agricultural Experiment Station. Stop by and see us if you visit campus. Visit one of our research and extension centers if you get an opportunity. I think you will find a group of individuals who care about the state and go to work every day to improve the lives of everyone in Wyoming.

Eric Webster
Associate Dean and Director of the Wyoming Agricultural Experiment Station

Search Wyoming Agricultural Experiment Station

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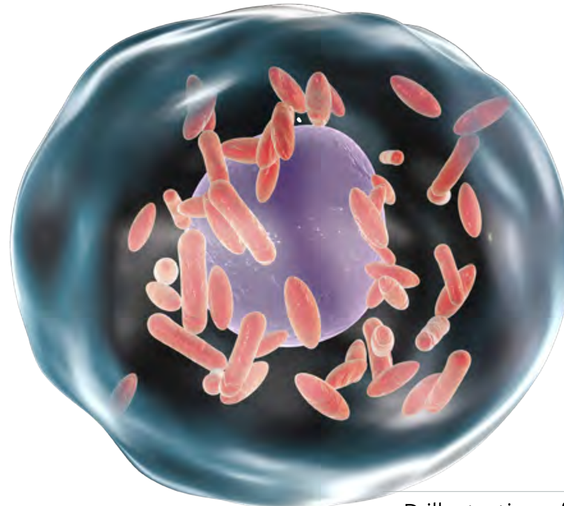
REFLECTIONS

Tanya Engel, UW Extension

Pistol and Pete help Elias Hutchinson feed the sheep at the Laramie Research and Experiment Station, March 2021. The Haflinger draft horses promote WAES and the UW College of Agriculture and Natural Resources across the state.

GENETIC STUDIES UNCOVERING Q FEVER MECHANISMS

[Q fever: A farm-raised zoonosis]



3-D illustration of bacteria *Coxiella burnetii* (small red) inside a human cell.

Zoonosis is a word many of us have become more familiar with as a result of the COVID-19 pandemic.

Zoonosis describes a human disease that can be contracted by contact with animals. Certainly, SARs-CoV-2 is of concern, as it can spread to people from bats, and now farmed mink. There are many less exotic zoonoses that hit close to home here in Wyoming, and they are carried by commonly domesticated animals.

Q fever is one such disease, a severe, flu-like illness humans can contract from infected cattle, sheep, or goats. There are often no symptoms in infected animals, but sometimes Q fever spreads through a herd and causes an abortion storm, which results in massive losses to producers and presents a major risk to their own health.

Humans are infected when they inhale dust contaminated with the bacterium that causes the disease, *Coxiella burnetii*. While most people infected with Q fever resolve the infection in a couple of weeks, about half of those who are ill require hospitalization, and 5 percent may go on to develop chronic illness that attacks the heart.

We see animals infected with *C. burnetii* every spring at the Wyoming State Veterinary Laboratory. During kidding season, bacterium once deposited in the soil can persist there for years, resistant to most environmental stresses and disinfectants. There is no licensed vaccine to prevent infection of animals or people. Culling infected animals is the main strategy to control widespread outbreaks.

My research aims to change that. We can develop better interventions to stem the spread of this zoonosis by focusing on the molecular mechanisms by which *Coxiella burnetii* establishes an infection.

Extreme lifestyle of *Coxiella burnetii* key to its success

Coxiella is an unusual bacterium. It prefers to infect the cells of the immune system designed to engulf and destroy invading pathogens. These white blood cells, called macrophages, are ordinarily on the frontline of defense against infectious diseases. When they encounter a bacterium or a virus, they immediately consume and direct it to a compartment inside the cell called the lysosome, where it is digested.

In contrast, *Coxiella* in a lysosome begins to change from its environmentally resistant form that exists outside of cells, called the Small Cell Variant (SCV), to its replicating

Elizabeth Case
Assistant Professor
Department of Veterinary Sciences,
Wyoming State Veterinary Laboratory

form, the Large Cell Variant (LCV), which is only found inside cells (Figure 1).

Coxiella can hide from the antibody response your body would normally raise against an infectious agent by invading the cells of the immune system. It is also a protected space free of faster-growing competitors that might deplete precious nutrients.

Living in a macrophage's stomach has its benefits, but it's not hazard free. Pathogens there must contend with very low pH, enzymes that degrade proteins, peptides that punch holes in bacterial membranes, oxygen radicals that damage DNA, and a scarcity of critical nutrients.

It's quite an extreme environment, and many other pathogens have developed elaborate strategies to avoid it.

Yet, *Coxiella* thrives there, lounging in the lysosome for a week or more, all the while modifying it into a habitable home called the *Coxiella*-containing vacuole (CCV), and replicating readily before shifting back into its extracellular, hyper-resistant form (SCV) for a new round of infection (Figure 1).

Searching for the genes that give *Coxiella* its edge

How can *Coxiella* survive in a place where other bacteria are killed?

My research goal is to identify the adaptations that allow *Coxiella* to flourish in this very dangerous environment. Using pools of randomly generated *Coxiella* strains that are each defective in only one gene, I developed a screen to find individual strains that cannot infect and replicate inside macrophages. If a given mutant strain was not capable of growing inside a macrophage, I attributed its poor survival to its single genetic defect.

As a control, I also measured the growth of those mutants in another commonly used cell type (Vero) that does not have all the antibacterial defenses present in a macrophage. By comparing the growth of the mutants in these two cell types, a few genes stood out as being nonessential for replication in the Vero cells, but required for growth

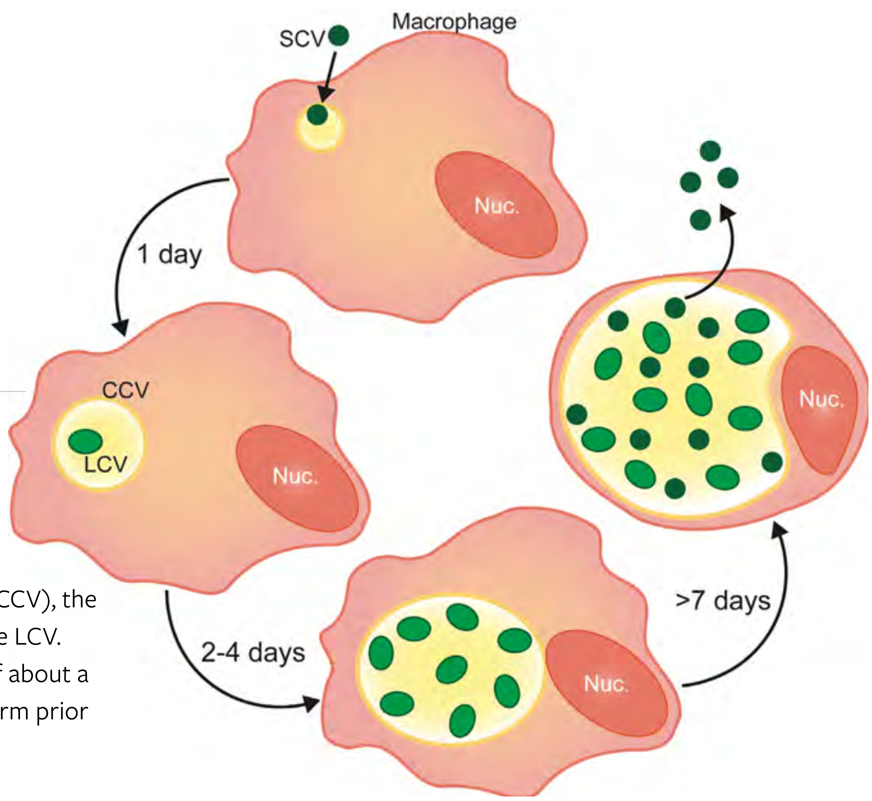


Figure 1. The replication cycle of *Coxiella burnetii*. *Coxiella* inhaled by a human host is taken up into the lysosomes of macrophages that reside in the lungs. The environmental form of Coxiella (SCV) is small, dense, and cannot replicate. When the lysosome develops into a spacious *Coxiella*-containing vacuole (CCV), the SCV changes into *Coxiella's* larger, replicating form, the LCV. The macrophage fills up with bacteria over a period of about a week, and they begin to change back into their SCV form prior to release for a new round of infection.

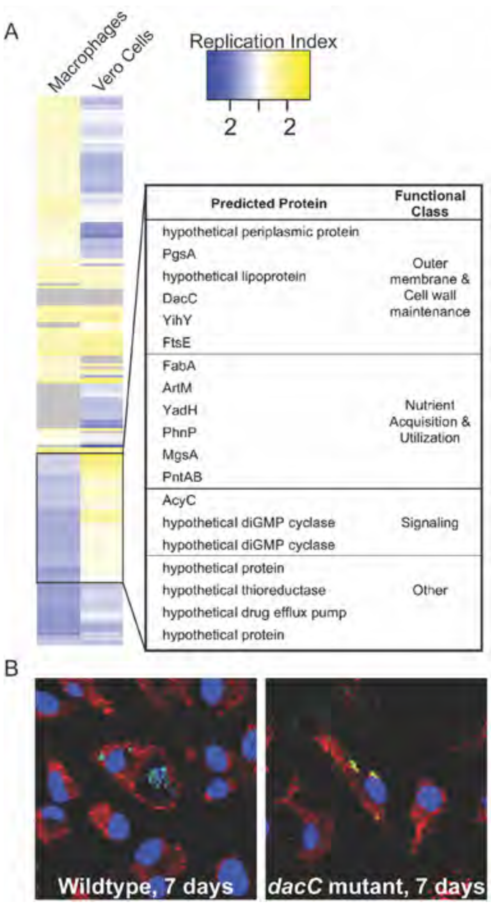


Figure 2. A screen of *Coxiella* mutants identified essential genes for replication in macrophages. (A) A comparison of the growth of different *Coxiella* mutant strains in macrophages and Vero cells was used to derive a "replication index." The individual mutants that replicated had an index greater than 1 (yellow), and those that did not had an index of less than 1 (blue), mutants with no change are labeled white, and those that were not detected at all are shown in grey. Mutants able to infect Vero cells were picked out but not macrophages. The table shows the most interesting mutants and the functional classes of their defective genes. (B) These images show what cells infected with wildtype *Coxiella* or the *dacC* mutant look like after seven days (bacteria are green, DNA is stained blue, and lysosomes and the CCV membrane are red).

in macrophages (Figure 2). The defective genes in these mutants are the focus of my work going forward.

I want to know why these particular genes make life in macrophages possible for *Coxiella*.

Identifying interesting genes is just the first step of the journey. What comes next is much harder—figuring out exactly what each gene contributes to the lifecycle of this bacterium.

One way to start is to compare the DNA sequence of each mutated gene to known genes of other bacteria to get a clue about its function. I found the genes required for growth in macrophages belong to several different functional classes: cell wall and membrane structure, nutrient acquisition, molecular signaling, and transport.

Still other genes were "hypothetical," which means we don't yet know what they might do. I am just beginning to unravel the mysteries of how these genes impart such hardiness upon *Coxiella*, but I have chosen one really interesting candidate upon which to focus.

Uncovering how peptidoglycan helps *Coxiella* resist macrophages and the environment

The dacC gene is a member of the cell wall and membrane maintenance class of genes that stood out in my screen. That gene is predicted to play a role in the modification of peptidoglycan, a critical component of *Coxiella*'s cell wall.

The protein made by that gene likely changes the structure of peptidoglycan when the bacterium transitions from its replicating form (LCV) to its environmental form (SCV). My initial studies with the mutant suggest it might not complete the transition from LCV to SCV.

How could that defect only affect replication in macrophages?

My hypothesis is the SCV is important not only for resisting the environmental stresses *Coxiella* experiences outside living cells, but also for resisting the initial antibacterial defenses it encounters when invading the lysosome of a macrophage.

This seems like an intuitive result, but there is a long history of research demonstrating that both forms of the bacterium are capable of infecting cells. My data suggests that might not be true when macrophages are the target host cell.

The experiments I have done to date have confirmed that *Coxiella* lacking *dacC* also have a very interesting defect when it comes to animal infection. The spleens of mice infected with that mutant do not display the same level of inflammation seen in mice infected with the strain of *Coxiella* found in nature (wild-type).

Despite this, the mutant bacteria still replicate quite well within the spleens of the mice (Figure 3, following page). This surprising finding suggests macrophages in the spleen that harbor the dacC mutant are not the same as the macrophages I culture in the lab.

One of my plans is to use the wild-type and *dacC* mutant bacteria as tools to distinguish the type(s) of cells in the mouse that play host to *Coxiella*. I suspect the strain lacking *dacC* invades a different set of cells in the mouse than its wild-type counterpart, resulting in less inflammation.

These experiments will give us a better understanding of the bacterium itself, as well as how the host's response to infection might cause inflammation and disease.

These findings also suggest that targeting the transition from LCV to SCV could be an effective way to design better therapies or preventative interventions for Q fever.

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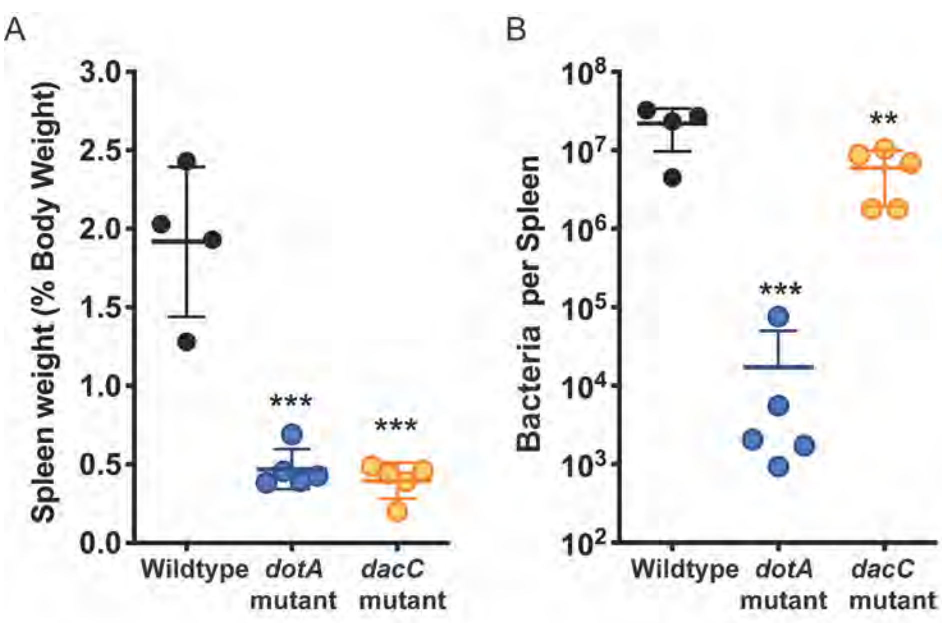


Figure 3. The *dacC* mutant cannot cause full disease in an animal. Individual mice (circles) were each infected with either wildtype (black), *dacC* mutant (yellow), or a mutant that cannot replicate in any kind of host (*dotA*, blue) to compare their ability to cause disease. After 14 days, the spleens of the mice were harvested and weighed to measure inflammation (A), and the bacteria in the spleens were counted (B). Wildtype *Coxiella* and the *dacC* mutant both replicated in the spleens of the mice, while the control strain did not. Interestingly, despite its ability to replicate, the *dacC* mutant did not display enlarged spleens. The error bars denote standard deviations, and asterisks show statistical significance.

RESEARCH PROBES COVID-19-CAUSED LABOR SHORTAGES AFFECTING U.S. FOOD SUPPLY SYSTEMS

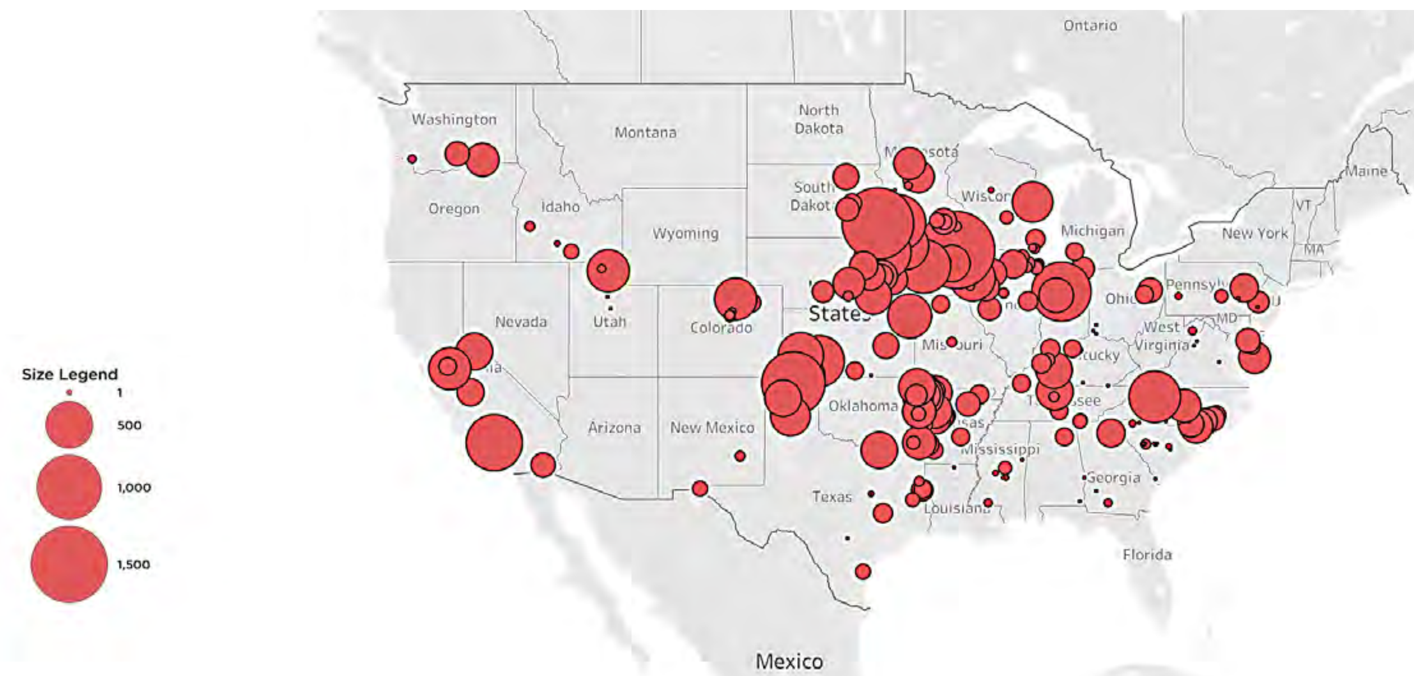
The COVID-19 pandemic spread rapidly around the world claiming an enormous number of lives, resulted in and presented unprecedented challenges to public health.

Many economies were brought to a near-standstill as countries implemented isolation and containment measures, contributing to the largest economic shock the global economy has suffered in many years.

The true extent of the devastating impact of the pandemic remains largely unknown because of the lack of data and an understanding of the mechanisms by which the effects are realized.

To address this, we examined the effects of COVID-19 on the U.S. agricultural and food supply chain by modeling the influence of labor shortages in agricultural, food processing, and retailing sectors, as well as the reduction in consumer purchasing power.

We developed a theoretical model that recognizes the vertical relationships between the different sectors of the



Leah Douglas, tableau.com

Figure 1. Meat packing plants affected by Covid-19. Source: Food and Environment Reporting Network, 2020, https://thefern.org/2020/04/mapping-covid-19-in-meat-and-food-processing-plants/.

Vardges Hovhannisyan
Assistant professor
Department of Agricultural and Applied Economics

agri-food supply chain and is applicable to both food and non-food industries of the economy.

Labor shortages and other factors resulted in meat display scenes like this throughout the country.

Less food, higher prices

Based on the predictions emerging from this model, we found the labor shortage in the food supply chain resulted in reduced food production and higher food prices in all sectors of the economy.

We further designed and estimated an empirical model of the U.S. meat supply chain that builds upon the production, processing, and retail sectors of the U.S. beef, pork, and chicken broiler industries.

An important feature of this empirical model is its allowance for consumer demand inter-relationships related to various meats. Our choice of the industry reflects the disproportionate effects of the pandemic on the U.S. meat production and distribution, especially at the processing stage (Figure 1, page 6).

Preliminary results from our empirical analysis reveal agricultural employment declined in all three meat industries, ranging from 6.4 percent for beef to 38.3 percent for the pork industry, the inevitable result of which was lower farm-level output. The reduced labor availability also led to higher wages in the farm sector, with wage changes extending from 20 percent in the beef industry to 41.5 percent in the pork industry.

We further found that feed consumption and feed prices have increased, which points to a certain degree of substitutability between labor and feed in meat production. Similarly, the equilibrium level of employment has declined in the processing sectors, which resulted in processed beef and pork output declining by 6.2 percent and 13.5 percent, respectively.

Fewer labor numbers, higher wages

The labor shortages in meat processing have also gone hand-in-hand with rising wages, with an increase in the range of 8.7 percent for pork to 11.7 percent for beef. Processed beef, pork, and broiler prices rose by 29.6 percent, 33.8 percent, and 22.5 percent, respectively.

Finally, changes in meat retailing mirror those in the upstream channels (all the activities needed to gather the materials required to create a product), with retail output declining from 3.9 percent for beef to 9.6 percent for broilers, and retail prices increasing from 12.7 percent for broilers to 24.6 percent for beef.

We also examined the effects of the decline in consumer income in recognition that COVID-19 led to precipitously declining consumer purchasing power. The implications of decreasing incomes in isolation translate into lower levels of employment, output, and prices in all sectors and industries, with retail and processed

Pandemic refashions food systems

According to anecdotal evidence, popular press reports, and a myriad of preliminary research studies, COVID-19 has been reshaping the entire food system, the full effects of which remain to be seen and may continue for many years.

Evolving consensus seems to be some of the remarkable changes in U.S. food systems include disruptions in the U.S. agricultural and food supply chain, declining incomes and purchasing power of the population, plummeting consumer spending on food-away-from-home, and the subsequent shifts in food consumption patterns and consumer food preferences induced by changing behaviors and lifestyles.

These changes can be divided into supply-side and demand-side effects based on the specific economic sectors bearing the impacts and the nature and severity of the effect of the pandemic.

On the supply side

The disruption in the agri-food industry reflects a supply-side effect, which was a result of the tightening government measures intended to halt the spread of the virus among thousands of employees. Specifically, numerous food processing and manufacturing plants were shuttered throughout the United States, leading to a soaring unemployment rate.

In particular, business operations were suspended for an unknown length of time at the Smithfield plant in South Dakota after hundreds of workers were infected with the virus; however, this was only the tip of the iceberg. The resulting disorder and interruption in the agricultural and food system inflicted huge economic costs not only on agricultural producers and food processors, but also on consumers and other economic agents.

The difficulty in acquiring foreign-supplied manufacturing inputs only made matters worse.

Food insecurity increasing

Plummeting consumer incomes resulting from the loss of more than 30 million jobs over a short period has been a noteworthy demand-side change. Such an alarming magnitude of job losses caused several billion dollars of forgone incomes, leading to precipitously declining consumer purchasing power.

The subsequent plummeting public confidence further fueled the economic downturn, contributing to declining consumer wealth and business revenues. This has become a significant threat to food industries and has created a new reality in which the vulnerability of millions to food insecurity has increased.

Food-at-home paradigm

Other important changes include a shift from food-away-from-home to food-at-home brought about by the simultaneous impact of mandatory stay-at-home orders and a lack of meals at restaurants, schools, etc., rising popularity of online purchases, as well as the social distancing at restaurants in the aftermath of the first wave of the pandemic

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meat prices recording the largest drop, respectively.

Predictably, retail beef demand sustained the biggest drop (17.6 percent), given the large magnitude of consumer responsiveness to income changes.

Meat prices continue to rise

Finally, we considered the combined effects of labor shortages and diminished income on the meat industry, given that these changes transpire simultaneously. Importantly, the findings emerging from our study are largely consistent with a recent survey of retail prices conducted by the USDA Economic Research Service.

As the number of cases continues to mount, our model predicts meat prices will remain on the rise in the foreseeable future because of the reduced productive capacity and dwindling consumer purchasing power; however, consumer food preference changes brought by shifting lifestyles and rerouting meat products intended for food services to food stores may further affect price dynamics making estimating meat prices less predictable.

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BEEF, LAMB, PORK, CHICKEN

Methods determining how much red meat is consumed have limitations. How does consumption compare to recommendations? And which are considered red meat in dietary studies?

Cody Gifford
Assistant Professor
Department of Animal Science

Livestock production continues to be an essential component in Wyoming and the Western U.S.

This industry is a vital part of the livelihood for numerous farm and ranch families in addition to being part of the food supply system that provides high quality sources of protein to the U.S. and the world.

While red meat, especially lean red meat, is a nutrient-dense component of many dietary patterns, red meat has not been without controversy among scientists and other health professionals. The role red meat plays in the human diet has been subjected to criticism about how much red meat individuals should be eating to maintain a healthy lifestyle and whether these foods are related to the risk of developing disease.

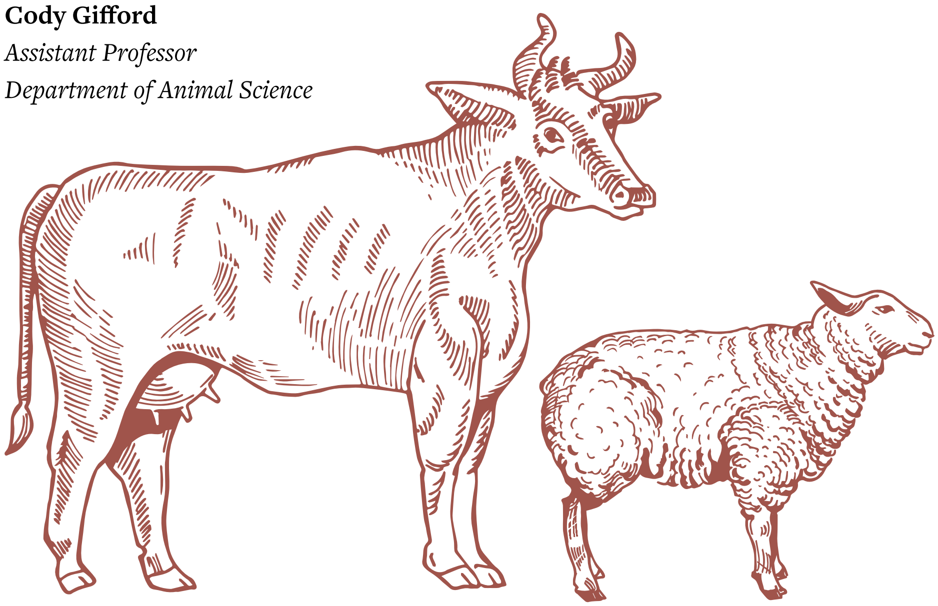
Understanding how much red meat is part of the human diet

Our research efforts target further understanding of how much red meat is consumed in the U.S. and how these protein foods can support healthy dietary patterns. Specifically, we aim to better understand:

- the impact of red meat consumption in various human diets,
- the quantity of red meat that is currently consumed and projected consumption, and,
- developing further classification systems to more accurately identify the types and amounts of meat products being assessed in nutrition research.

Red meat and dietary guidance

The impact of meat on human health continues to be a priority among nutrition researchers. Further work



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is needed to understand the role of meat in the diet.

For example, the American Cancer Society and American Diabetes Association generally recommends limiting or reducing red and processed meat in the diet; however, this leads to confusion about how much meat individuals are actually consuming and what dietary limits on meat consumption should be followed.

How do we determine how much we are eating?

The assessment methods available to nutrition researchers or dietitians can be challenging to accurately determine which foods, and how much, of those foods, are being consumed. Although other methods are currently being evaluated, there are three major assessment methods that continue to be used:

- dietary recalls,
- per capita food availability or disappearance data, and
- food frequency questionnaires.

How does meat consumption fit recommendations?

Previously, dietary recommendations have suggested individuals consume about 3 ounces of cooked lean meat per day or weekly target amounts. For example, the Healthy U.S.-Style Eating Pattern in the 2015 and 2020 dietary guidelines suggested consuming a combined amount of 10 to 31 ounces of meats, poultry, and eggs per week for a 1,000- to 2,400-daily calorie target. Similarly, the World Cancer Research Fund suggests consuming no more than 12 to 18 ounces of cooked red meat per week. Collectively, these recommendations are equivalent to about 3 ounces or less of red meat per day.

Assessing how much meat is being consumed and how that compares to some of these recommendations are goals of our research group. We examined the dietary recall information for the 2015-2016 National Health and Nutrition Examination Survey, since this was the most recent, fully available dietary data available during 2020.

Adults aged 20 years or older consumed an average of 1.62 ounces of meat per day. More specifically, 58 percent of adults indicated consuming less than 1 ounce of meat, 69.6 percent indicated consuming less than 2 ounces of meat, and 80.3 percent of adults consumed less than 3 ounces of meat.

Approximately 19.7 percent of adults reported consuming more than 3 ounces of meat and only 1.5 percent consumed greater than 10 ounces of meat.

Based on our review, it appears the majority of individuals in the U.S. are following these dietary recommendations, but further research is certainly needed to better understand consumption of red meat, especially among individuals that consume the most red meat.

The National Health and Nutrition Examination Survey (NHANES), which utilizes trained interviewers using protocols to probe subjects to recall all foods and beverages consumed in the previous 24 hours, is often a primary source for researchers to infer a nationally representative sample of dietary intake in the U.S.

The USDA Economic Research Service estimates the amount of food available from production throughout the food supply system available to consumers at retail. This method is based on the amount of food product available to the U.S. population and includes adjustments for food spoilage, plate waste, and other losses.

Food frequency questionnaires are another method used to assess dietary intake, often used in epidemiological studies are interested in estimating long-term patterns of intake from broad food categories; however, this requires people to remember what foods and how much of these foods were consumed over a long period of time.

The estimation of meat and poultry consumption can vary between each of the methods described, as shown in Figure 1. This complicates the understanding of how much meat is actually being consumed in the diet.

How is red meat defined?

There is often discrepancy about how red meat is defined in nutrition research. Figure 1 shows some of the classification discrepancies in these methods. Additionally, the 2015 and 2020 Scientific Advisory Committee Reports for the Dietary Guidelines for Americans have highlighted that dietary intake assessment by researchers inconsistently uses terminology to define and describe which meat products were assessed.

How has meat and poultry consumption changed?

Trends of meat and poultry per capita estimated consumption or availability between 1970 and 2017 are presented in Figure 2. The annual availability of combined veal and lamb has remained low but stable. Pork has slightly varied over time. The major changes are decreased beef availability or estimated consumption and increased availability of chicken during this timeframe. This is equivalent to about 3.2 ounces of red meat per day or 2.6 ounces of poultry per day.

Our next research steps

Fortunately, dietitians and other health professionals are able to provide nutrition advice to the public about how much and what foods are important to include in a healthy diet. Future goals of our research group are to work with nutrition researchers to assess trends of consumption over time, understand nutrients provided in the diet at recommended levels of consumption, and integrate current red meat consumption levels into further dietary pattern assessments.

Additionally, we aim to continue working to develop a better system for classifying red meat for researchers and individuals. Although the nutrient contribution of lean red meat has been well established, identification of lean red meat products and accurate assessment of the quantity being consumed will aid future research objectives of evaluating impact of red meat on human health in the U.S.

To contact: *Gifford* *can be reached at (307) 766-4214 or at cody.gifford@uwyo.edu.*

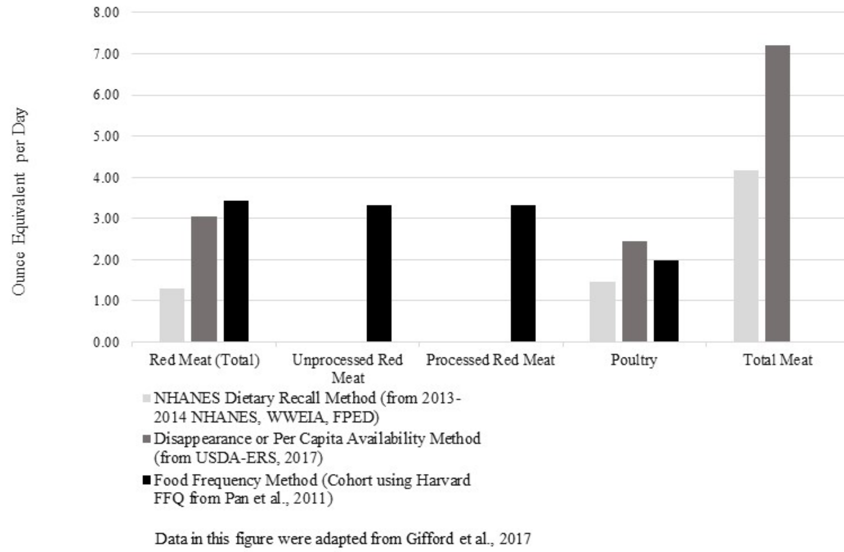

Figure 1. Comparison of estimated meat and poultry consumption by assessment method.

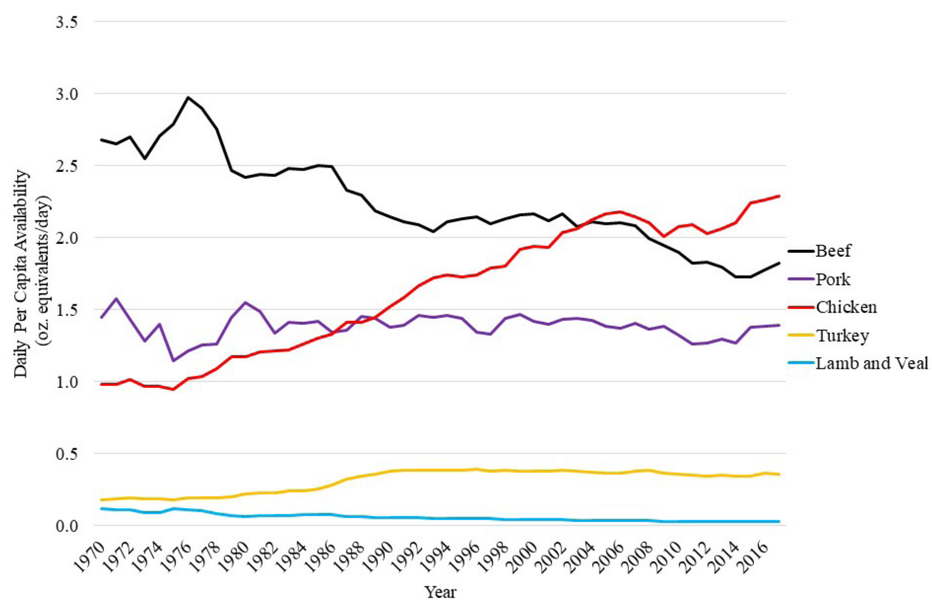

Figure 2. Trend of per capita daily ounce equivalent availability (estimated consumption) of red meat and poultry since 1970 in the U.S.

[1]Data adapted from the United States Department of Agriculture, Economic Research Service, Food Availability (Per Capita) Data System, Loss-Adjusted Food Availability, Meat, poultry, fish, eggs, and nuts (USDA-ERS, 2020)

WHERE THE WILD BEAVERS ARE

How training an algorithm to detect beaver ponds could aid beaver restoration efforts

Castor canadensis, the North American beaver.

Reviled by some, revered by others.

Farmers and ranchers have historically fallen into the first group, while the second group consists of environmentalists, academics, and a large portion of the public.

This formerly clear line has become somewhat blurred, with many private landowners now embracing the strong-teethed rodents on their properties.

Kyle Fitch, an ecosystem science and management graduate student in the Water Resources Program, and I have been exploring ways to identify beaver habitat in the Laramie Range in southeastern Wyoming. The Laramie Range is an ideal area for watershed research and specifically research on beaver ponds due to the large public Pole Mountain Area (PMA), where beavers have thrived for decades.

Views from above

We chose remote sensing, using aerial photographs, because it allows analyzing large regions in a fairly short amount of time without having to visit all those areas in person. We then turned to artificial intelligence, teaching an algorithm what a beaver pond looks like and then sifting through images to detect beaver ponds automatically.

Dan Pepper, shutterstock.com

Fabian Nippgen
Assistant professor
Department of Ecosystem Science and Management

We wanted to identify where beaver ponds are, how much pond area there was for a given year and watershed, and how variable they are over time. See more information about the vegetation index in "Going green – digitally".

Our results were somewhat unexpected: there was no relationship between overall pond area and metrics of precipitation, for example, maximum snow accumulation, spring precipitation, etc., and watershed size alone turned out to be an extremely poor predictor of beaver pond area—at least for small, first-order watersheds.

How do we use it?

We used aerial imagery from the National Agricultural Imagery Program (NAIP). The free NAIP imagery is collected about every three years via planes and has a high spatial resolution of 1 meter, meaning that every pixel covers 1 square meter on the ground. We had six coverages over an 18-year period (2001-2019, with 2006 being excluded for quality reasons).

All photographs, even the ones we take with our cell phones, consist of multiple layers, so-called bands. A cell phone picture contains three bands – red, green, and blue, referring to the visible part of the electromagnetic spectrum each band is sensitive to, that is, that the sensor in the camera can record.

NAIP imagery can additionally record in the near infrared spectrum, which is just outside of the visible spectrum, and is very useful for detecting water. Cameras essentially record how much light/energy is being reflected from an object in every band and then translate this to a number. While the numbers for each band are different, the algorithm is being taught that, for example, beaver ponds might have similar combinations of numbers across all bands.

After this learning step, the algorithm analyzes the imagery and decides for every pixel whether it is a beaver pond or not. The better an

Going green - digitally

We can calculate a greenness index from the National Agricultural Imagery Program data (called NDVI, Normalized Difference Vegetation Index) that ranges between -1 and 1.

Values are usually above 0, though, and the closer the value is to 1, the "greener" (or denser) the vegetation.

We derived NDVI for the entire Pole Mountain Area and compared the values of watersheds containing beaver ponds to the watersheds without beaver ponds to test whether the presence of beaver ponds leads to "greener" riparian vegetation.

It turns out it does. Not only that, beaver-pond watersheds maintain greener vegetation in the riparian area throughout the entire summer dry-down period. It is this greenness that can protect riparian areas from fires, provide habitat for wildlife, and produce higher quality forage for cattle.

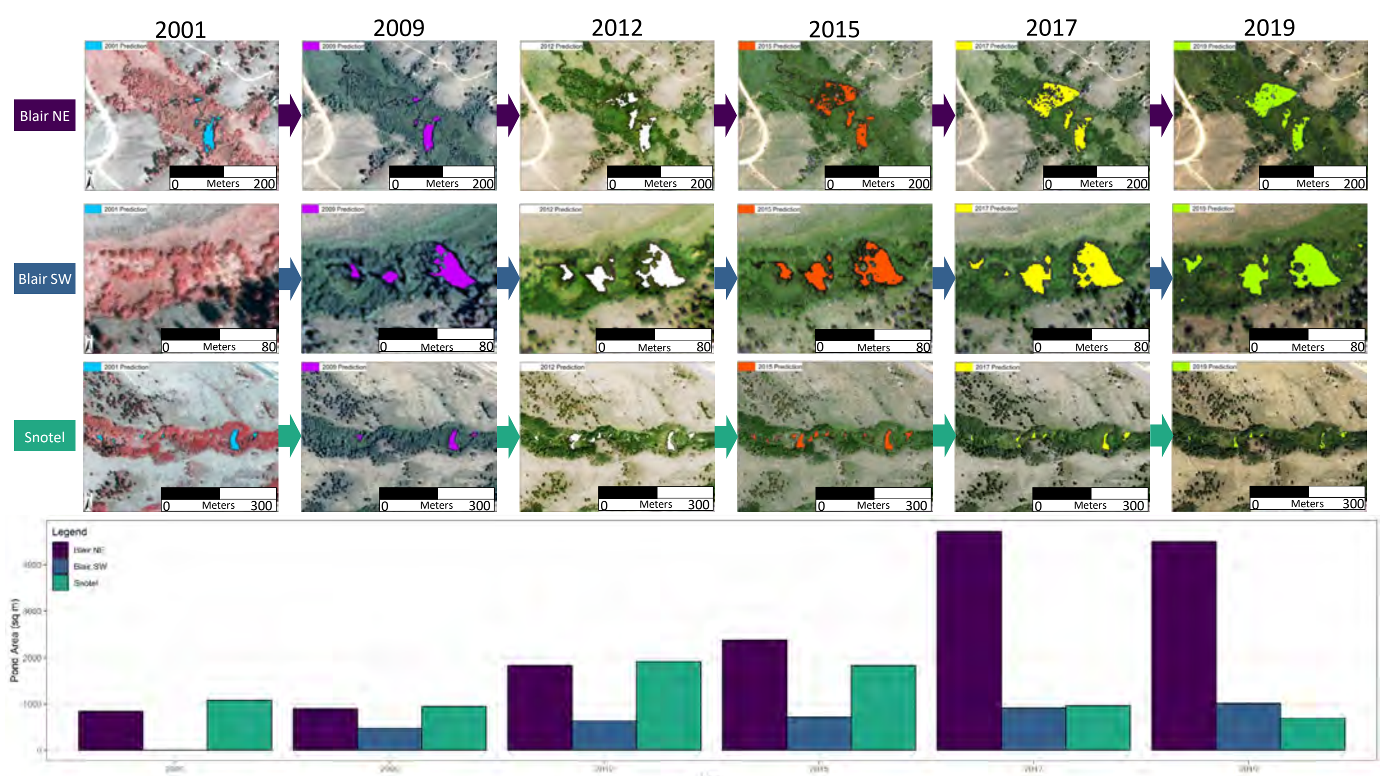

Figure 1. Our studies show beaver ponds lead to greener riparian vegetation. Above, photographs show the progression from beaver pond to greener riparian areas

Understanding where, why beavers build dams could aid restoration efforts

Beaver populations in the last several decades have been rebounding, but today's numbers are still only a fraction of what they were before decimation by trapping and hunting.

Private landowners may be hesitant to reintroduce or allow beavers on their property for fear of damage to woody plants, loss of usable land to beaver ponds, or potential road damage caused by clogged culverts; however, once allowed in stream corridors, the presence of beavers has cascading positive effects on stream and riparian ecosystems.

Beavers are known as ecosystem engineers for their habit to build dams, which lead to water impoundments. The benefits include—but are not limited to:

- Decreased sedimentation rates,
- Changes in riparian vegetation,
- Increased ecosystem metabolism,
- Increases in waterfowl numbers, and
- An altered hydrologic regime.

Most notably from a water quantity perspective is the potential to decrease peak flows and increase baseflows. Considering climate change and the especially devastating 2020 fire season across the Western U.S., a recent study even highlights that beaver impoundments can protect riparian areas from wildfires.

With all those positive effects, people are intent on bringing back beavers, either by releasing beavers directly or by coaxing them onto the land with so-called beaver dam analogs (the beaver equivalent of "If you build it, they will come").

These restoration efforts are often guided by knowledge of where beaver impoundments used to be historically (gnawed off tree stumps, signs of old dams). Beyond that, it gets a little more tricky. Some boundary conditions are obvious: there needs to be water, but not too much so that dams get blown out frequently during large storms or snowmelt, and there needs to be appropriate vegetation as building material.

ssteven3, shutterstock.com

However, the 2017 Beaver Restoration Guidebook states "that consensus is lacking as to what constitutes good beaver habitat and that there is no one tool appropriate for assessing a watershed in terms of beaver habitat suitability."

Improving our understanding of where (and maybe why) beavers decide to build dams could in return guide restoration efforts through better identification of "optimal" locations/watersheds.

algorithm is taught, the better the results will be.

Using this information across all years allowed us to determine how variable beaver pond areas are through time. We calculated the pond areas for each year of coverage for small first- and second-order watersheds, a size typically known as headwater streams. A little over 50 percent of the first-order watersheds did not have significant pond areas, less than than 12 square yards, which is well within the margin of the error of classification. Some watersheds approached 12,000 square yards.

Climate variability

Some watersheds experienced increases in pond area, while others lost beaver ponds (Figure 1, page 13) over the 18-year period with NAIP observations. This is to be expected, as old beaver ponds begin to grow over and simply become riparian area while new ones are being created. What was interesting, though, is that overall pond area was mostly independent of climatic variability.

The timing of the imagery collection is a complicating factor in this part of the analysis: the flights can take place any time during the summer. For example, the 2015 flight took place in mid-June, while the data in 2001 were collected the end of August. Still, precipitation appears to be only a minor factor that determines interannual variability on beaver pond areas, which to us was rather surprising. Overall, the total beaver pond area in the Laramie Range remained somewhat constant over the 18-year study period, with some ponds growing, some shrinking, new ponds being established, and old ponds growing over by vegetation.

Explaining pond area changes with climate is difficult. What determines the presence of ponds in a watershed in the first place? One intuitive answer to this is simply: watershed size. The larger a watershed, the more beaver pond area it may contain.

As it turns out, though, watershed size is an extremely poor predictor of beaver pond area. And this makes sense. We would not expect one single metric to be able to explain it all. Rather, it is likely a combination of physical factors that make up a watershed, such as size, slope, elevation, hillslopes, and more.

Return to algorithm

Luckily, all these metrics can be derived through landscape analysis with digital elevation models. Once again, we turned to machine learning and an algorithm that analyzed how individual landscape characteristics affect the presence or absence of ponds in a particular watershed.

For the Laramie Range, important landscape characteristics include the watershed elevation, possibly a proxy for overall precipitation amounts since higher elevation watersheds receive more annual precipitation, the sizes of the watershed and riparian areas and the average size of the hillslopes draining into the streams, which can tell us about the persistence of water delivery to the stream. Larger hillslopes deliver water more consistently than smaller hillslopes.

Using the physical watershed characteristics, we can then build a model that estimates pond areas for a given watershed.

How is this useful for beaver restoration?

With the information from the model, we can roughly estimate how much pond area could be expected for a given watershed and then select the most promising watersheds for beaver restoration/reintroduction projects!

Going forward from here, I want to expand the analysis so that we can directly suggest locations along a stream to target for restoration instead of "only" the most ideal watersheds. But that is work for another graduate student!

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Travis Calvin, Shutterstock

THE UPSIDE
Giving textile waste

Fast fashion creates a throwaway culture

The apparel and textile industry has various negative impacts on the environment. The manufacturing of apparel and textile products leads to air and water pollution, and the overconsumption of these products leads to land pollution in the form of waste.

Fast fashion refers to a business model that reproduces high fashion looks inexpensively and with quick turnover. This industry is characterized by low-quality clothing, poor working conditions, and cheap prices.

Fast fashion merchandise has been referred to as "disposable" and "throwaway" fashion. The quick turnover of styles and cheap cost entices consumers to purchase new styles and dispose of the previous garments while they are still functional, creating textile waste.

Only about 15 percent of all disposed textile products are recycled. The most recent statistics show approximately 21 billion pounds of textile products end up in U.S. landfills annually--about 70 pounds per person. Almost all of these textile products can be recycled in some form.

neenawat khenyothaa, shutterstock.com

Many consumers are aware they can recycle paper, plastic, glass, and aluminum.

Most don't realize they can also recycle their textile products—any good produced from cloth.

This includes clothing, but recycling can also include home furnishings such as bedding, upholstery and window dressings, among others.

Downcycling and upcycling refer to recycling during which the end result is of lower or higher quality, respectively, than the original product. Repurposing can include downcycling and upcycling but involves adapting the product for a different purpose.

This is the term I have chosen to use for my research.

Repurposing textile products: What have we done so far?

My research over the last seven years focused primarily on the design process of repurposing textile products for maximization of textile waste and to efficiently produce repurposed textile products.

Existing designers of repurposed apparel were surveyed to further understand their processes, successes, and challenges. A model was developed, and three levels of repurposing were discovered based on increasing amounts of labor, time, and skills required: Restyling, Subtractive, and Additive.

Restyling—This level involves making minor alterations to a garment, either for fit or embellishment, while not majorly altering the original style or silhouette of the garment. For example, this could include adding panels into the side seams of a shirt to increase the size or adding lace trim to a skirt for embellishment.

Subtractive—This level of repurposing requires more construction and pattern-making knowledge than the previous level. It involves cutting a pattern out of a larger piece of fabric,

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OF REPURPOSING.

a new life.

which could be a larger garment, such as a full-length skirt, or some other textile product, such as curtains.

Additive—The third level of repurposing identified by this study involves sewing together small fabric scraps, either pre-consumer cutting waste or post-consumer, smaller deconstructed textile products such as socks, to create a new textile. A pattern is then cut out of that new textile.

The next step in this research was to investigate how best to teach repurposing to design, merchandising, and textiles students.

I incorporated a repurposing project into my Advanced Apparel Construction course.

Students were shown examples of repurposed garments, and the three levels of repurposing were discussed. They were required to use a commercial pattern, develop a plan for how to best utilize their chosen materials, and write a paper over their process, successes, and challenges.

The papers were used to further analyze the repurposing design process and upon collection of this data, a fourth level of repurposing was uncovered, which I've titled intentional pattern making.

Intentional pattern making—This fourth level of repurposing is the most time-intensive and requires the most knowledge of sewing and patternmaking; however, it is also the most efficient use of deconstructed post-consumer textile products. This level involves deconstructing the textile product to flat fabric to assess the shape and size of the available pieces and developing a design to accommodate the fabric available.

Figure 4 a-d shows examples of all four repurposing levels.

Testing the final level of repurposing, intentional pattern making, is the most recent development in the research. Three designers, including myself, undertook designing a garment using this level. The designers agreed upon a common source of inspiration and type of garments and settled on a re-purposed two piece men's suit. Previous research showed there is a need to find a second life for men's and women's suiting as it does not sell well in second-hand stores.

Figure 4a. Restyling. Sleeves of the sweatshirt have been replaced with a different fabric and a pocket has been added. By Letecia Guevara

Figure 4b. Subtractive. Repurposing using a bed sheet for the top and tablecloths for both layers of the skirt. By Erin Irick

Figure 4c. Additive. Repurposing where scraps of pre-consumer textile waste have been used to create the textile for this kimono. By Oksana Topchiy

Figure 4d. Intentional pattern making. A deconstructed men's suit was used to create a women's shirt, jacket, and pants. By Erin Irick

Textile recycling levels

There are three levels of textile recycling:

1. Back to the fiber stage,
2. Back to the fabric stage, and
3. As it exists in its original product form.

Back to the fiber stage — Textile products can be chemically or mechanically recycled. Textiles being melted down and re-processed into new fibers is an example of chemical recycling. This process has been successful with natural fibers, such as cotton; synthetic fibers, such as polyester; and textiles with polyester/cotton blends. Chemical recycling uses 70 percent less energy in fiber production than producing virgin fibers.

Mechanically recycling fibers involves shredding textile products into a fiber fluff. This fluff can be used to create new yarns and fabrics for new textile products; however, those products have been found to be lesser in quality than virgin products. Mostly, this fluff is used as stuffing for various products, such as pet beds, geotextiles, or for housing insulation.

Back to the fabric stage — Textile recycling to the fabric stage involves repurposing or upcycling textile products. This means deconstructing the original product to a fabric stage then utilizing the fabric to create a new product. While this form requires less energy, it requires knowledge of design, sewing, and pattern making. It is also labor and time intensive, making a profit difficult for designers who utilize this method.

In its original product form — The third form of textile recycling involves garments being reused as they exist in their original product form. Usually, this consists of consumers disposing of their used apparel and textile products through donation to a second-hand store, passing on to friends and family, or selling through consignment, garage sales, or online marketplaces.

While all of these methods are legitimate recycling methods for used apparel or textile products, the second method, to the fabric stage, is the method focused on for this article.

The three designers did not confer with each other during the design process, and each created three very different garments utilizing three different pattern making methods:

- flat pattern—the paper pattern pieces were laid out within the available fabric,
- draping—the deconstructed fabric pieces were draped directly onto a body form; and
- computer-aided pattern making—the available fabric pieces were digitized and computer pattern making software was used to create new pattern pieces.

What's next?

The next step is to analyze the cost effectiveness for all four levels of repurposing considering labor, time, and materials. Lessons learned from the recent phase of this research along with the previously mentioned model will be used to develop a best practices approach to repurposing that could be implemented as a profitable and reproducible business model.

A repurposing business could help eliminate textile waste, provide jobs for the community and help stimulate the local economy, while also being used as a teaching tool for real-world experience for our students.

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THE FOREVER WAR BETWEEN MICROBIAL PATHOGENS AND PLANTS:

WORKING TO HELP OUR ALLIES COME OUT ON TOP

Figure 1. Plant leaves under microbial pathogen's attack. Brown spots in leaves are clusters of dead cells. Spots in leaf indicate the active defense from the plant.

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Assistant Professor
Department of Molecular Biology

A sad love song by the 1970s group ABBA lyrically says "knowing me, knowing you, there is nothing we can do ... we just have to face it ..." also could serve as the anthem for the silent war between plants and pathogenic microbes.

The immobile life of plants causes them to endure abrupt changes of seasons and environmental threats. Plants might look very calm with nothing happening; however, look carefully, and you will see evidence of an endless, brutal war in every plant cell, from roots to leaves.

Each cell is fighting invisible enemies for survival. This war often ends with pathogens getting eliminated from the battlefield; however, the damage to plants is not minor. In many cases, plants can win this battle only by sacrificing some portion of themselves to their enemies, Figure 1.

Inside plants where we can't easily see, entire cells actively and rapidly change their shapes and reorganize positions to optimize their defense against life-threatening microbial pathogens.

Our research group's effort seeks to understand the molecular mechanism of the plant-microbe interaction in the infected cells and provide new insights into improving outcomes of commercially important plants that come under biological attack.

Who's going to win this evolutionary war?

Some plants win the war; others lose—it's all part of the "circle of life." And through the evolutionary pressure these combatants are placed under, fitter organisms arise; however, as we humans have a vested interest in certain plants, for example, crops, coming out on top, we need to be a good ally for plants.

Crops have become more vulnerable to a pathogens' attack due to the loss of defense-related genes by breeding for better taste and yield. For example, the primary barrier to pests for apples, a waxy cuticle at the epidermis of the fruit, was diminished by breeding for softer and sweeter apples and this led to a higher susceptibility to disease.

Plants develop smart weapons

The war between plants and microbial pathogens, such as bacteria and fungi, likely started over 400 million years ago when plants moved out of

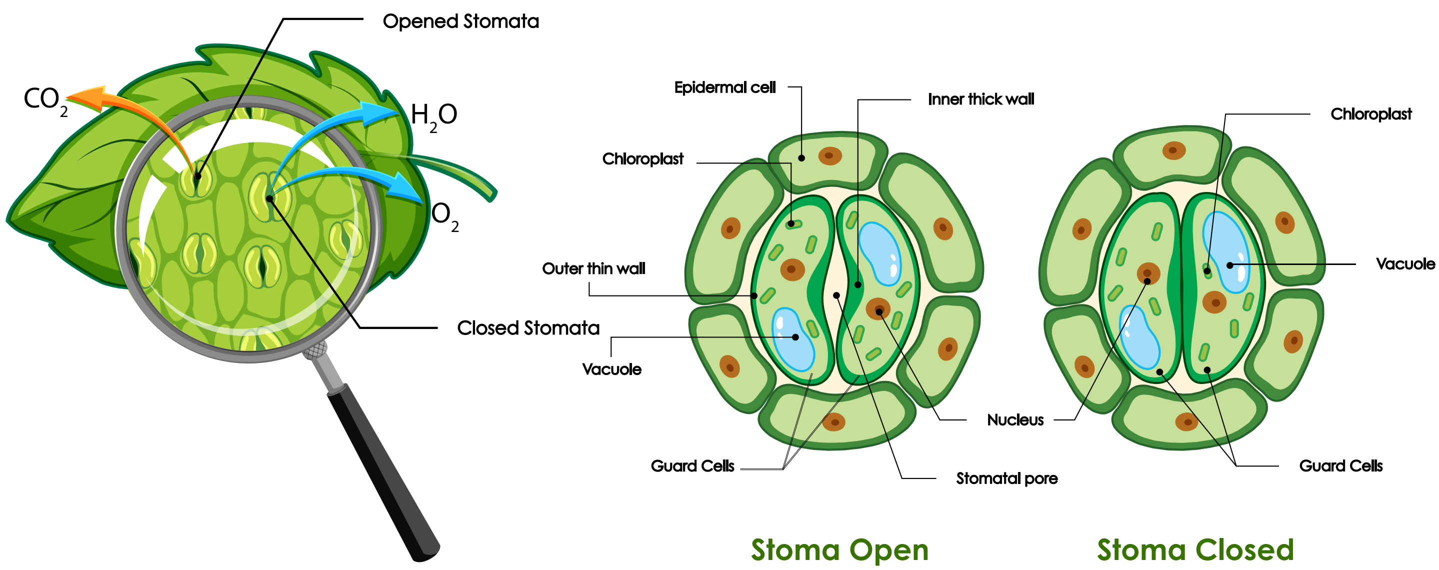

Figure 2. Leaf stomata illustration.

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water and began rooting on dry land. Plants quickly took the upper hand, developing a layer of cells on the plants surface, termed the epidermis, that produced a special waxy layer, providing a rigid barrier to prevent pathogens from penetrating.

Microbial pathogens countered by developing different strategies to break through this barrier. Bacteria optimized their motility to move about the surface of plants, finding openings that could allow entry. Plants need openings in the epidermis to breathe. This opening, called a stomata, is an aperture that is controlled by guard cells, and this is where plants exhale oxygen and water vapor and inhale carbon dioxide, Figure 2. Pathogenic bacteria ultimately developed strategies for getting into the space between cells, but then a strategy was needed to get into the cells that contain the nutrients bacteria were seeking for their own survival.

Microbial pathogens have developed additional ways to break into cells. Instead of getting in the plant cells themselves, bacteria produce small proteins, called effectors, and a delivery system to inject those proteins and manipulate the plant cells into giving the bacteria what they want—nutrients.

For example, *Pseudomonas syringae* developed a needle-like structure (called the Type III secretion system) to transport effector proteins inside the plant cells. Bacteria existing in the space between cells, the apoplast, can stick to a plant cell by poking the Type III needle in the cell. The effector proteins from the bacterial cells are transferred to the plant cell, and through mimicking plant proteins convince the cells to do things that benefit the bacteria, usually to the detriment of the plant.

This strategy works well and a different class of pathogen, fungi, also took a similar strategy, producing effector proteins that are trafficked into the plant cells to manipulate plant biological processes and compromise their defense systems. Modern biological techniques, similar to those used to sequence the human genome and investigate human pathogen, like COVID-19, identified hundreds of effector proteins from a wide variety of plant pathogens and their actions in plant cells are being characterized. I have concentrated my efforts here—figuring out how effectors from pathogens alter plant cells.

Shining a light on the weapons used by microbial pathogens of plants

The discovery of green fluorescent proteins (GFP) revolutionized visualizing proteins in living cells. The Nobel Prize-winning discovery from 2008 has taken biology by storm, with research groups joining the protein originally found in jellyfish that glows under UV light (emitting green light) to another protein of interest. They can often figure out a lot about its function. The GFP fusion protein technique has had many variations developed, and we have figured out how to use GFP fusion to plant pathogen effector proteins from *Pseudomonas syringae* (Pst), as they monitor their roles in the infection of plant cells in real time.

Because the Type III secretion needle of the pathogenic bacteria is too narrow to transfer the GFP protein, we developed a "split GFP" reconstitution system. We joined the effector protein with only a fragment of the GFP protein, and then created a plant that contains the remainder of the GFP protein in all of its cells—importantly, this plant portion of the GFP isn't functional without the bit of GFP attached to the bacterial effector protein. When the effector protein containing the small (but essential) portion of the GFP is injected into a plant cell, the intact GFP forms and can be seen in a microscope when the correct wavelength of laser light is shined on the cells.

With this critical tool in hand, we can now follow the injected effector protein, analyzing where in the cell it goes throughout the time course of the infection. While only in the early stages of our efforts, we have found that a microbial effector protein from *Pseudomonas syringae* critical for infection of plants, changes its localization in the plant cell as the war between bacteria and plant heats up. This effector protein, AvrB, is initially localized at the plant plasma membrane after release from the Type III secretion needles; however, as time goes by and the battle between pathogen and host rages, this effector protein travels inside the cell by highjacking a plant system for moving around plant proteins and cellular structures, the main "supply route" for normal cellular function and for mounting defense against pathogens.

This finding provides us a great opportunity to further investigate how the bacterial effector proteins change plant cell function and search for ways to help the plant combat those infiltrating enemy agents.

Knowing plants: Death can be a happy ending in plant life

Over time, plants developed a better defense mechanism to pathogen invasion, akin to a strategic retreat coupled with a scorched earth policy employed in battles fought by mankind through the ages. Shown in Figure 1, page 19, is a leaf that looks like it is dying from its microbial pathogen infections; however, the leaf is actually actively and successfully defending itself with an orchestrated defense mechanism in every cell. Killing infected cells quickly to restrict the pathogens' spreading to other cells (the strategic retreat) is the most effective defense strategy plants have evolved. By doing so, pathogens can't reach their food and are killed by toxic chemicals and enzymes produced by dying plant cells.

This effective immunity mechanism is known as the Hyper Responsive-Programmed Cell Death (HR-PCD) pathway. This robust and powerful innate immune system started from recognizing specific effector proteins secreted from the pathogens in plant cells by receptor proteins inside of the plant cells. The plant genome encodes numerous versions of these receptor proteins, developed through evolution during the never-ending war waged by pathogens.

When plants recognize an effector protein secreted by a pathogen, the infected plant cells start changing their metabolism to prepare for death. These preparation events occur rapidly and effectively; gene expression changes in the nucleus and physical changes throughout the cell occur in a very defined sequence.

In the HR-PCD process, organelles also contribute actively to prepare for this process. Organelles are membrane compartments in plant cells and have specific roles in the biology of the cell. We have found that chloroplasts, the organelle responsible for photosynthesis, dramatically change their structure in response to effector-triggered immunity, producing a tubular protrusion, termed a stromule, Figure 3.

Stromules are dynamic structures that extend and shrink in length significantly and provide a driving force to move the chloroplast bodies close to the nucleus during the plant immune responses.

We also found that stromules can serve as a pathway for transferring signaling molecules from the chloroplast to the nucleus during the plant cells' innate immunity response. Our research group is investigating the translocating signaling molecules as well as the regulatory mechanisms of the stromule and stromule-mediated communication between chloroplasts and the nucleus.

While a well-tended field of crops might appear serene—one might envision "amber waves of grain"—you now know that that is likely a ruse and, in fact, a raging battle between pathogen and plant is underway. With some luck and a lot of effort, we will have something to say about the outcome of that battle.

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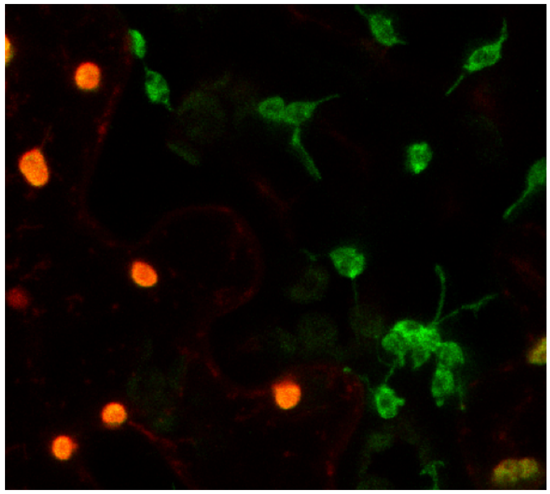
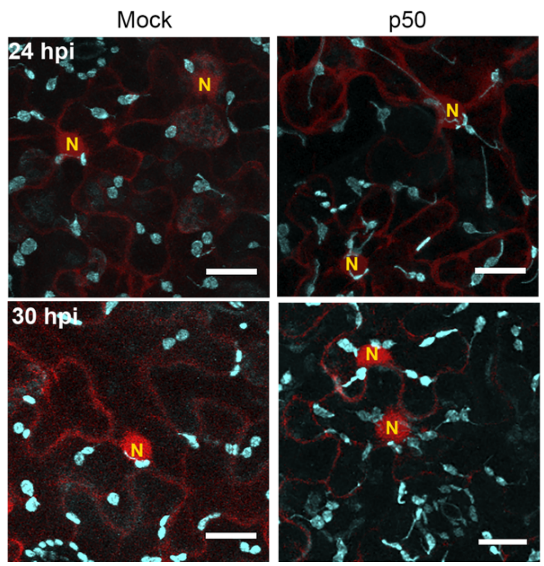
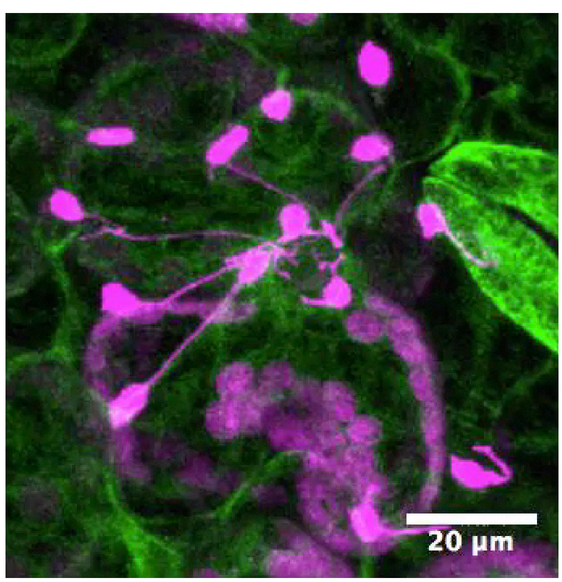
Figure 3. Dramatic chloroplast morphological changes in plant immunity.



Chloroplasts in normal healthy cells are usually round shaped (orange). While in the cells undergoing active HR-PCD triggered by the effector proteins from the microbial pathogens they produce a long tubular structure called stromule (green). The image was taken by a confocal laser scanning microscope.



Stromules contribute to move chloroplast bodies close to the nucleus during the immune responses, and this peri-nuclear clustering is a symptom of the immunity, the reason of this symptom is currently unknown. Cyan color indicates chloroplasts and red color shows cytoplasm and nuclei (N refers to the nucleus).



Imaging of the stromule attaching to the nucleus to lead chloroplast position close to the nucleus in plant immunity. Chloroplast and stromule are labeled in magenta color while the shadow of the nucleus were visualized by cytoplasmic GFP proteins in green. From a video taken under confocal laser scanning microscope every minute for 30 minutes.

Photo Image, shutterstock.com

DETERMINING OPTIMAL DRY BEAN FERTILIZER RECOMMENDATIONS A MOVING TARGET

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Researchers at the University of Wyoming's Powell Research and Extension Center are trying to identify optimal rates of nitrogen (N) fertilizer to apply to dry bean crops in the Intermountain West.

Pulse crops such as pea, lentil, and chickpea are popular among producers and consumers because they require little N fertilizer and provide a food product high in protein. Unfortunately, another pulse crop popular in Wyoming, dry beans, are often grown with 80 to 100 pounds of N fertilizer per acre.

I was quite ignorant of dry bean fertilizer management and unaware N was being applied to dry beans when I first arrived in Wyoming in 2014. Dry beans are a leguminous crop whose roots host a symbiotic relationship with N_2-fixing rhizobia bacteria. The crop obtains N from a combination of N in the soil and N derived from the atmosphere. In general, we don't apply N-fertilizer to legumes.

But dry bean remains an exception.

Fortunately, in my first years as an agronomist, I researched N-fertility and the interaction of rhizobia with lima beans, a crop species closely related to the dry beans grown in Wyoming, and we were able to hit the ground running.

Little economic incentive to reduce N

Nitrogen fertilizer can have negative environmental effects. Encouraging growers to reduce N-fertilizer will be a challenge because it is relatively cheap. There is rarely a yield penalty to dry beans if N is over-applied, so there is little economic incentive to reduce N rates. Fortunately, national funding agencies as well as our state's Wyoming Bean Commission has helped support our research.

Our primary focus has been on screening existing dry bean varieties for improved N efficiency. Former UW graduate student Ali Alhasan, who now teaches horticulture in Iraq, carried out many studies from 2015 to 2017 with dozens of pinto bean varieties, the mostly widely-grown dry bean market class in Wyoming.

Testing different varieties with 0 nitrogen, moderate rates

We have continued with studies from 2018 to 2020. The studies involve growing the different varieties under zero N fertilizer and also under a moderate N rate. We need to observe the performance of the varieties under both N-fertilizer conditions, not just zero-N, to get a full picture of how that variety performs across different conditions.

Dejan Dundjerski, shutterstock.com

New varieties, unexpected results pave way for reducing dry bean nitrogen applications

Agronomists for over 100 years in the U.S. have sought to determine the optimal levels of fertilizer to grow their crops profitably.

Unfortunately, deciding how much fertilizer is required and applying only that amount continues to be moving target.

Plant breeders are producing new and better varieties, fertilizer costs change monthly, and we are increasingly recognizing the environmental impacts of over-fertilization. Agronomists continually try to meet each year's current fertilizer management challenge even as new discoveries are made, and the process starts all over again with the new knowledge in hand.

There is an apparent need for higher fertilizer rates, but the relationship is not that simple as breeders develop higher yielding varieties. Environmental and economic effects of fertilizer application and usage play a role in a producer's decision. Fortunately, producers, environmentalists, and even the ag fertilizer industry are all on board to make sure only the necessary amount of fertilizer is applied.

Dozens of public and private agronomic programs across the globe routinely conduct their own fertility trials to identify optimal fertilizer rates. By necessity, a given study is focused on a narrow question and applying single-trial results to farms across a wide region is risky; however, results across many trials are routinely summarized together and ultimately recommendations are made available to producers.

Our commonly grown varieties have responded similarly to N, suggesting that none of them are more efficient than their counterparts. In 2019, we included some of our higher-yielding progeny and breeding lines along with popular commercial varieties in our research tests. The results again were similar with no line standing out.

The surprising result has been the inconsistent response of dry bean yield to N fertilizer, regardless of which variety was planted. We often see that applying N fertilizer does not affect dry bean yields.

Our observations are not unique; other labs across North America often fail to see improved yields from N-fertilizer. Sometimes we do see a positive response at modest N rates around 60 pounds of N per acre, and in those cases the farmer would likely recoup the return on investment.

Higher application rates of 80 to 100 pounds of N per acre, a rate often used by our region's producers, rarely outyield the 60-pound rate.

We knew from the beginning soil factors were going to play a key role in finding a solution to the dry bean--N fertility challenge. We expected pre-season soil-N concentration would be an important factor in whether or not dry bean yield responded to N fertilization, but results have shown the pre-season soil-N concentration plays a minor role and that other unknown factors must also be involved.

Testing for other factors

Efforts to determine what other factors might be at play – including other fertilizers such as phosphorus – have proved inconclusive. Along with agronomists from other states, we have tested different rhizobia strains to see if that would have an effect. We obtained vials of four different rhizobia strains from the USDA Collection in Maryland, and my UW microbiologist colleague, Gerry Andrews, cultured these strains in flasks for us so we could test the strains in greenhouse studies.

But like my counterparts in other states, the effects of the different rhizobia strains on dry bean yield have not provided clear results. It appears we need to get a better handle on what native rhizobia strains are found in our dry bean fields.

We have not given up, despite not finding a silver bullet. We have pretty good evidence producers can reduce their N application rates, save money, and reduce their impact on the environment while maintaining high yields.

We just need to do a better job of framing the metaphorical N-fertilizer bullseye for the producer. Once our dry bean growers are certain they can reduce N rates and optimize profit, we will have an impact.

Until then, we continue to seek answers that appear hidden in the soil.

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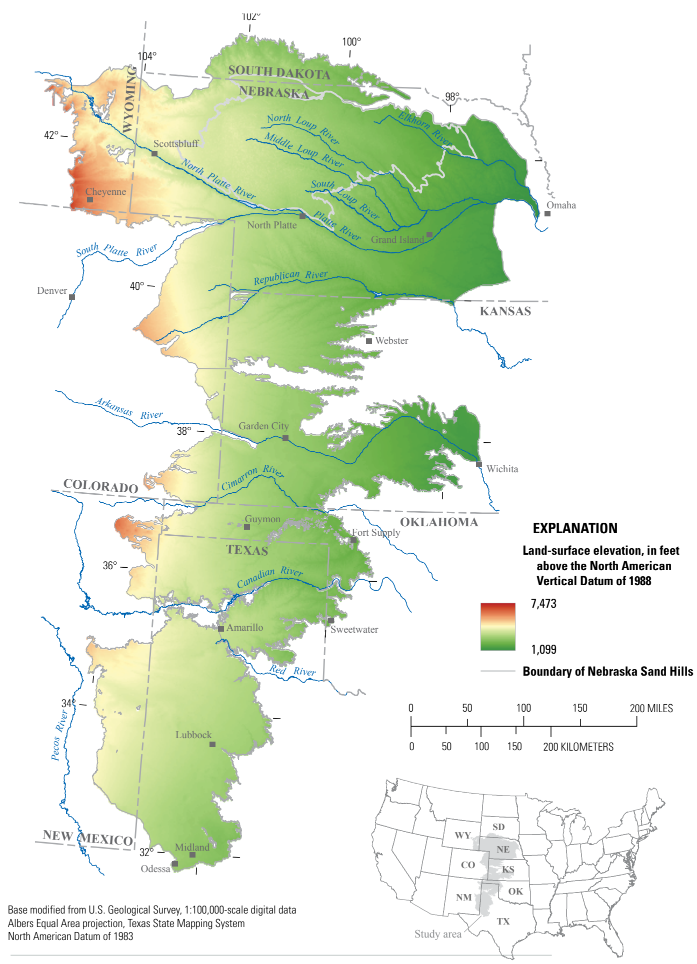
Selected *Reflections*
2021 top student story

IS MID-SEASON DECISION-MAKING IMPORTANT TO CALCULATING ECONOMIC IMPACTS OF GROUNDWATER MANAGEMENT IN SOUTHEASTERN WYOMING?

Agricultural communities in southeastern Wyoming rely heavily on groundwater from the High Plains Aquifer for crop production. As in other states across the High Plains, irrigation pumping rates in some areas exceed annual recharge (replenishment of water to the aquifer). These have caused significant drawdown in groundwater levels in some parts of the region, which can have detrimental impacts on agricultural communities.

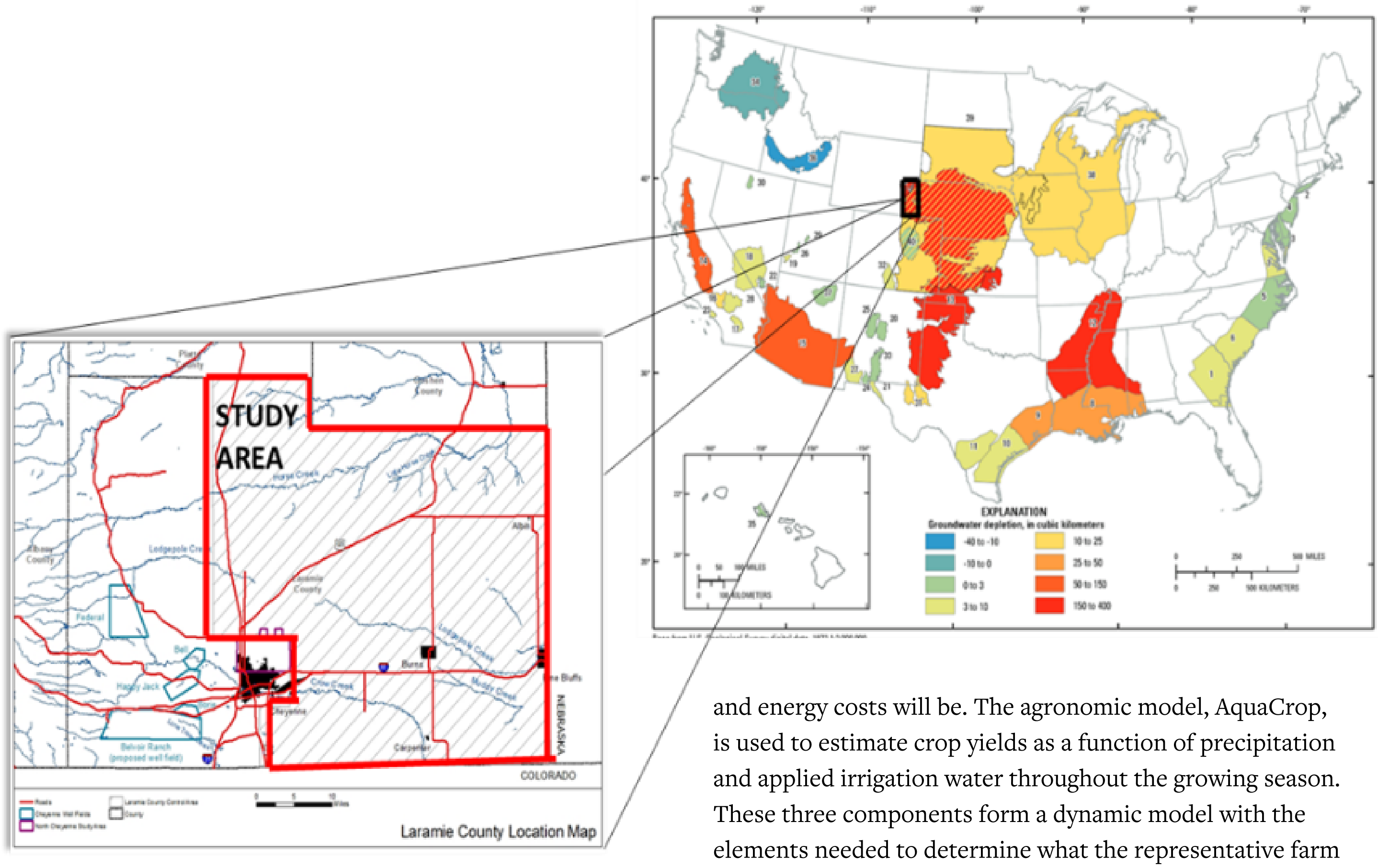
Considerable research has been undertaken on how agricultural producer profits change when water becomes limited, either due to varying water year conditions or the implementation of irrigation management policies designed to reduce groundwater use. Most of these economic studies assume a producer decides what crops to plant and how much to irrigate their crops at the beginning of the season and then makes no change to the irrigation regime at any point later in the growing season. In contrast to these annual models, intra-seasonal decision-making allows producers to make irrigation decisions throughout the growing season based on how much precipitation they have received.

This study compares the results of an annual and intra-seasonal models to see whether incorporating intra-seasonal decision-making (regarding irrigation in response to changes in precipitation) has an effect on a producer's expected profit and groundwater use.



High Plains Aquifer

U.S. Geological Survey, https://pubs.usgs.gov/ds/777/pdf/ds777.pdf



Study area and why

Our study area is southeastern Laramie County, which includes Albin, Carpenter, and Pine Bluffs. Laramie County consistently ranks in the top five agriculture-producing counties in Wyoming. Almost all irrigation for agricultural production in this area is from groundwater. Implementation of irrigation management policies, such as limiting the amount of water that can be applied to an acre, could potentially increase the longevity of agriculture in this area. The question is whether the negative economic impacts associated with reducing water use today is worth the additional water that becomes available for use tomorrow, as a result.

Modeling

Both the annual and intra-seasonal models are farm-level. We focus on one representative farm to help answer the research question. The 650-acre representative farm in this area grows alfalfa, corn, dry beans, and winter wheat. The annual and intra-seasonal models each have three components:

1. Economic
2. Agronomic
3. Hydrologic.

The economic component determines the expected profit for each model and scenario. The agronomic and hydrologic components help determine what the yield, groundwater use, and energy costs will be. The agronomic model, AquaCrop, is used to estimate crop yields as a function of precipitation and applied irrigation water throughout the growing season. These three components form a dynamic model with the elements needed to determine what the representative farm should grow based on expectations about the amount of water that will be available on the farm at various points during the growing season.

The difference between the annual and intra-seasonal versions is that the latter allows producers to make irrigation decisions at multiple points during the growing season. There are three irrigation decisions that can be made in the model:

1. Full irrigation,
2. Deficit irrigation (an amount less than full),
3. No irrigation.

The model makes these decisions based on how much precipitation occurs. Precipitation is also broken up into three categories:

1. Above normal (high)
2. Near normal
3. Below normal (low).

Precipitation data from Cheyenne is used to reflect precipitation patterns in southeastern Wyoming. Thirty years of precipitation are used to determine the probability of above normal (high), near normal, and below normal (low) occurring at each stage of the growing season. The probabilities are then factored into the calculation of expected profit.

The intra-seasonal version has three irrigation decision points (or three stages), where the model can make a decision on irrigation based on precipitation. For example, if the first stage of the growing season has above normal precipitation, the model may choose to reduce irrigation. If the second stage has below normal precipitation, the model will again adjust irrigation levels in response.

The annual and intra-seasonal models both have two scenarios: 1) baseline—no change in groundwater use and no management strategy implemented, and 2) allocation—limits the amount of water available on the farm to 12 acre-inches per acre. Twelve thousand acre-inches are available for the whole farm in the baseline scenario and 7,800 acre-inches are available in the allocation scenario. By comparing expected profit and water use in both scenarios and models, we can determine if making the model more realistic by incorporating intra-seasonal decision-making significantly affects the model results.

Is intra-seasonal modeling more realistic?

Our results indicate the intra-seasonal model is more realistic than the annual model and can be beneficial when modeling irrigation management strategies. Allowing the model to make irrigation decisions mid-season based on precipitation is representative of how producers make decisions.

Table 1 shows the difference in results for the baseline scenario between the annual and intra-seasonal models. The annual model has an expected profit of $242,090 versus an expected profit of $245,160 for the intra-seasonal model. This is a 1.26 percent increase in expected profits. Expected profit increases under the intra-seasonal model because producers in the model are able to respond mid-season to changes in precipitation. When conditions are dry, they irrigate more; when conditions are wet, they irrigate less. The total groundwater use is 8,384 acre-inches (annual) versus 7,981 acre-inches (intra-seasonal), which is a 4.81 percent decrease.

The difference in results for the allocation scenario are more significant. Expected profit for the annual model is $191,292 versus an expected profit of $221,165 for the intra-seasonal model. This is a 15.62 percent increase in expected profit, which is a much larger increase than was

Scenario	Expected Profit	Water Use Total (acre-inches)
Annual - Baseline	$242,090	8,384
Intra - Baseline	$245,160	7,981
Annual - Allocation	$191,292	6,135
Intra - Allocation	$221,165	6,430

Table 1. Results for baseline (when water is plentiful) and allocation (when water is restricted) scenarios.

observed for the baseline scenario. The total groundwater use is 6,135 acre-inches for the annual model versus 6,430 acres-inches for the intra-seasonal model. This is actually a 4.80 percent increase in groundwater use.

In sum, expected profit and water use in the annual and intra-seasonal models are quite similar to each other under the baseline scenario; however, the two models under the allocation scenario—when water is limited—yield quite different results.

Importance of study

Annual decision-making models that fail to reflect the reality that producers are making irrigation adjustments throughout the season may miss the mark in predicting how well producers will fare economically when water is limited. Intra-seasonal decision making can be important to incorporate in analyses of irrigation management policies.

This research can help facilitate important discussions on groundwater use, irrigation scheduling, and the economics of intra-seasonal decision making. Many producers in southeastern Wyoming do not currently find it economical to implement irrigation scheduling technologies, but they may in the future, if water restrictions are imposed or in response to changing climate conditions.

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