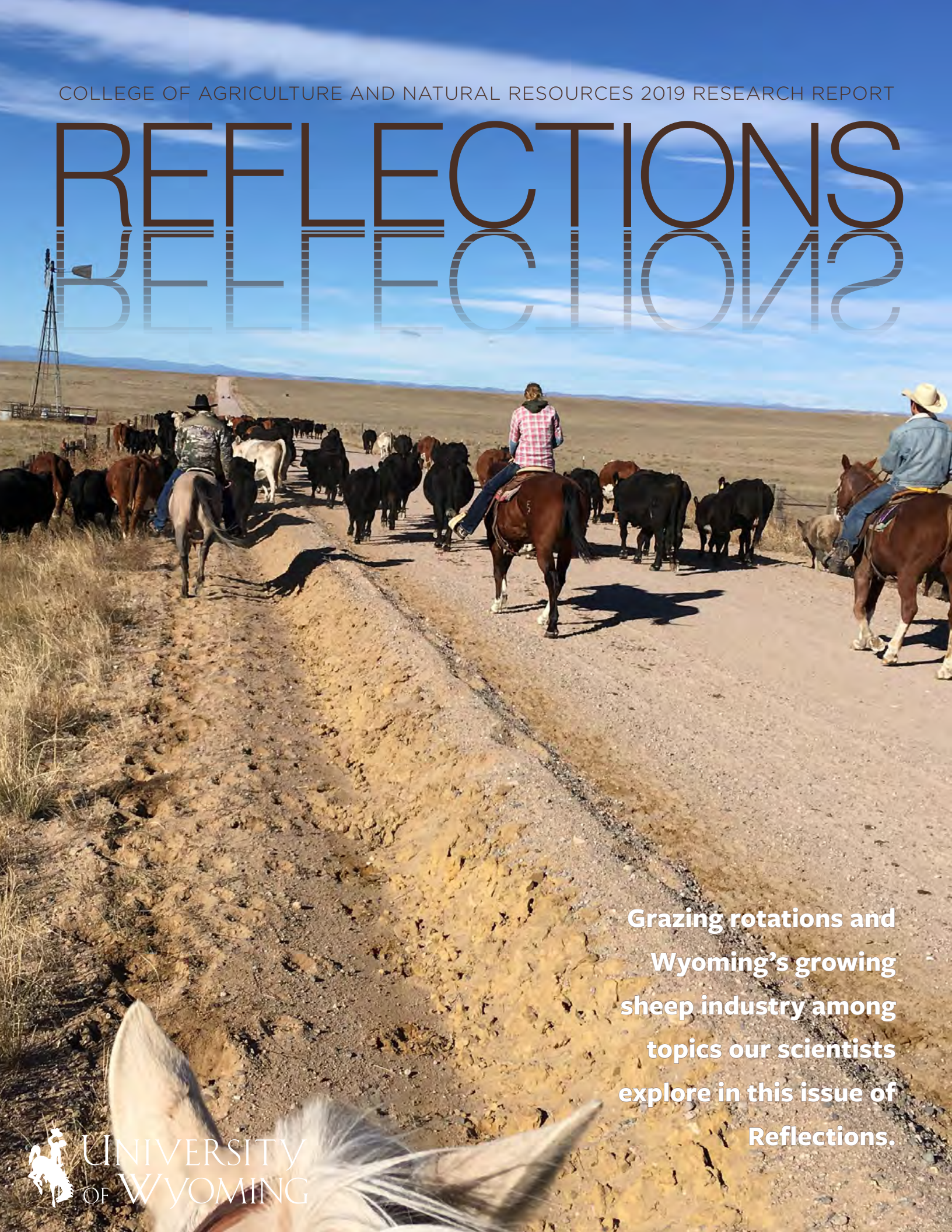
COLLEGE OF AGRICULTURE AND NATURAL RESOURCES 2019 RESEARCH REPORT

REFLECTIONS



Grazing rotations and Wyoming's growing sheep industry among topics our scientists explore in this issue of Reflections.

University of Wyoming

REFLECTIONS

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Welcome to the 2019 edition of Reflections, the research magazine of the University of Wyoming's College of Agriculture and Natural Resources.

John Ritten

We have had to say goodbye to some colleagues over the last year. Dean Frank Galey retired from UW to move on to the provost position at Utah State University, and Glen Whipple retired as associate dean and director of UW Extension. More recently, Bret Hess, long-standing associate dean and director of the Wyoming Agricultural Experiment Station, resigned from UW to better engage in leadership roles at a regional (and national) scale.

I thank all of these individuals for their leadership. They helped set the stage to ensure the college's future prosperity.

This year brings new faces to the college's leadership team. I want to welcome our new dean, Barbara Rasco. She comes to us from the Palouse, Washington, area, where most recently she served as director of the School of Food Science, a joint program between Washington Sate University and the University of Idaho. Barbara brings a lot of energy and excitement, and we are all happy to have her leadership in the college.

Kelly Crane has been named associate dean and director of UW Extension, and I have agreed to fill the associate dean and Agricultural Experiment Station director position in an interim role. Warrie Means will continue to serve in his current capacity as interim associate dean of Academic and Student Programs.

The future holds a lot of promise for our college. With new leadership, we may see some refocusing of efforts and resources. I believe these changes will lead to more engaging and fruitful efforts – in education, extension, and research. In this issue of *Reflections* I hope you see the college continues to focus on research that will have a meaningful impact on the lives of the people in our state and beyond. I look forward to helping expand these state-relevant efforts over the next year.

I welcome any comments, suggestions, or questions regarding work presented in this issue or about the research enterprise of our college, at aes@uwyo.edu or (307) 766-3667.

Thank you,

John Ritten

Interim Associate Dean and Director of the Wyoming Agricultural Experiment Station

YouTube https://www.youtube.com/user/UWyoAgExpStation

Search Wyoming Agricultural Experiment Station

Cover photo: Tamarah Jorns, USDA-ARS

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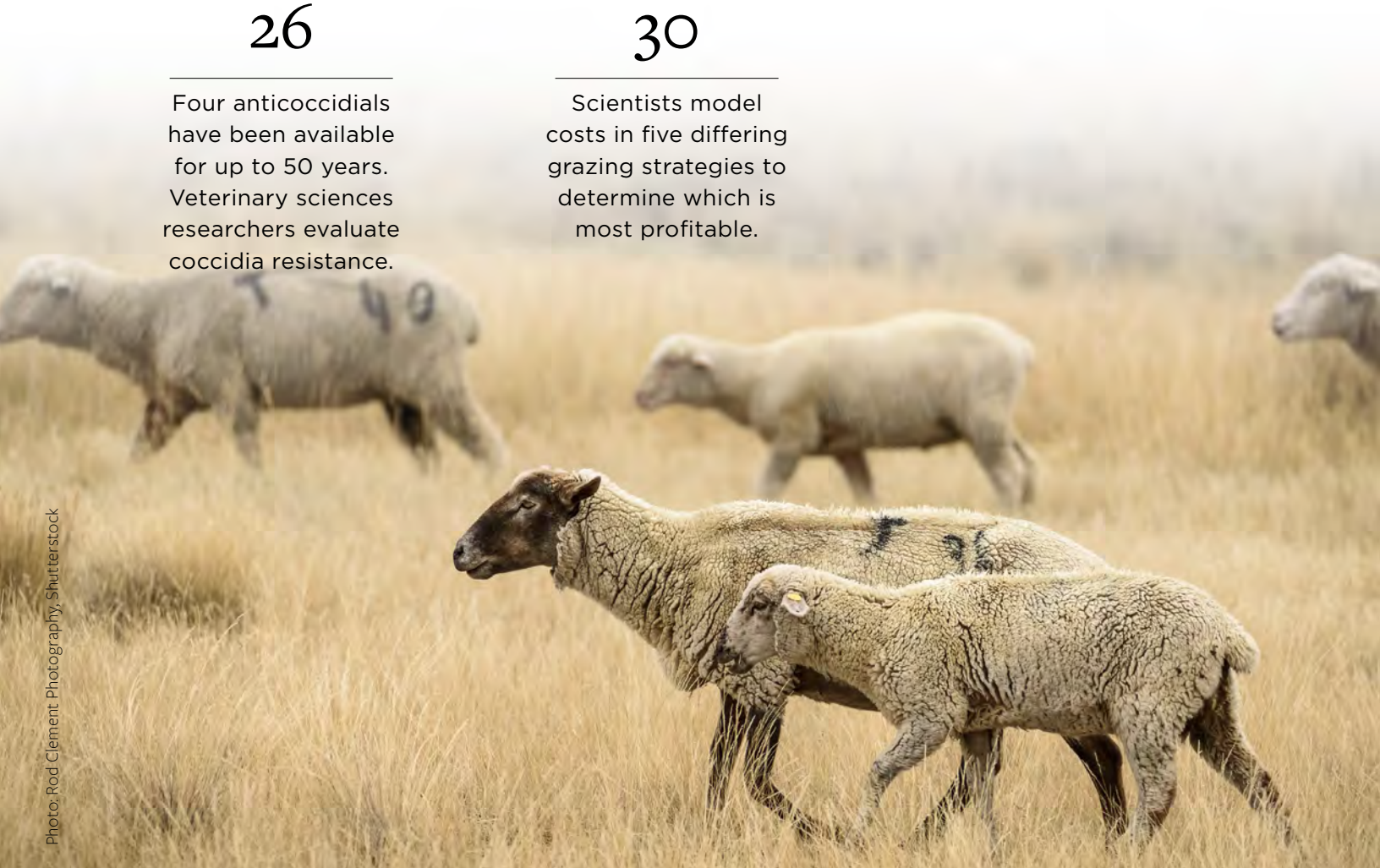

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EFFORTS TAILOR SHEEP NUTRITION TO WYOMING'S UNIQUE PRODUCTION LANDSCAPE

Efforts are under way to sample sheep ranches throughout Wyoming to identify trace mineral deficiencies and help producers assess where their forage resources might be falling short for a particular trace mineral.

Whit Stewart
Assistant Professor
Extension Sheep Specialist,

Chad Page
Ph.D. student
Department of Animal Science

People tend to underestimate Wyoming.

As the least populated state, expectations seem to be Wyoming's contribution to the country is as limited as the households on our census.

Anyone who knows Wyoming knows this isn't true. Especially important to those interested in sustainable livestock production, we are one of the key players in the U.S. sheep industry.

Like the Wyoming assumption, trace nutrients importance, specifically zinc, for sheep tends to be underestimated. Larger scale operations and larger scale ambitions for the sheep industry as a whole require more and more acutely refined precision management, even down to trace nutrients.

Low input - High output

Zinc is an essential micro-nutrient to sheep production. Wyoming produces high-quality sheep off the back of a rugged landscape. The physiologically challenging timepoints of breeding, pregnancy, and lactation on the sheep production calendar (fall-winter) occur when rangeland forages are at their lowest nutritional quality.

While Wyoming's output of meat and wool has been impressive, there is room for improvement. Sheep are being selected for greater productivity, but the recommendations specific to certain nutrients haven't kept pace. Reviving and refreshing previously discovered insights can help enrich and enlighten today's practices.

Zinc and modern production

Scientists in the 1930s discovered zinc was essential for sheep production. The element is the second most abundant trace mineral in the body with important functions in:

- gene expression,
- immune function,
- reproduction,
- appetite regulation, and
- wool production.

Unlike other minerals, zinc is stored in the body in only small amounts and needs to be supplied continuously.

The zinc content of grazing diets is adequate in early summer in most cases, but in later months, zinc levels decline to inadequate concentrations. This results in suboptimal performance, especially during the most physiologically demanding times of breeding and pregnancy.

A national forage survey conducted by USDA National Animal Health Monitoring System in 1993 found 63 percent of native grasses failed to meet dietary zinc requirements for sheep. Supplying additional zinc is a best practice to alleviate these seasonal shortfalls and demanding production periods; however, ensuring zinc consumption on extensive landscapes can be sporadic and as a result, some

producers opt not to provide the mineral during certain times of the year.

Complicating the present-day picture is that previously recommended zinc supplementation levels may be inadequate for the optimal performance of modern-day sheep. "Modern-day sheep" might be a bit vague for those of us who don't eat, breathe, and speak ruminant, so here are a few statistics:

- Over the past 50 years, fine-wool Wyoming sheep have achieved selection milestones including 50 percent greater growth rates, 30 percent greater mature body size, and as a result 25 percent increases in clean wool production.
- USDA data suggests that twin-bearing capacity has increased in the U.S. sheep flock since 1930.

Estimated zinc requirements need to increase from 34 milligrams/kilogram to and estimated 57 mg/kg, or 67 percent for the average ewe (Figure 1). Our goals for production have changed, sheep have changed, and recommending nutritional changes is important, too.

Major player in sheep industry

Wyoming is the "Wine Country" of lamb and wool production. We are fourth in total sheep numbers and third in breeding sheep numbers. Wyoming continues its tradition of making a lot with a little and comes in first in total wool production and value. Wyoming's industry makeup is uniquely larger in scale with over 17 percent of Wyoming's flocks comprising more than 300 head of ewes, compared to just 1.7 percent across the U.S. as a whole.

Photo: Whit Stewart

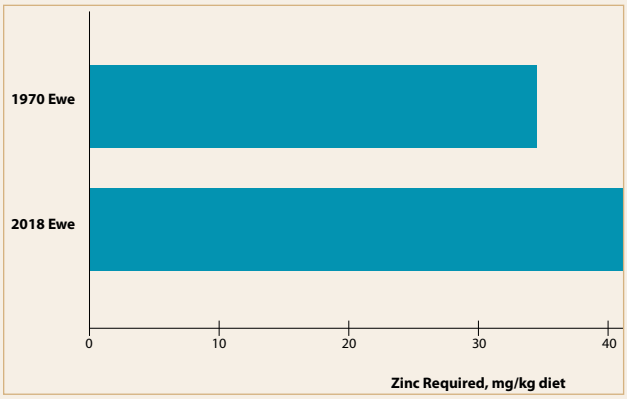

Figure 1. Changes in zinc requirements due to production improvements and body size for the average ewe in 1970 and 2018.

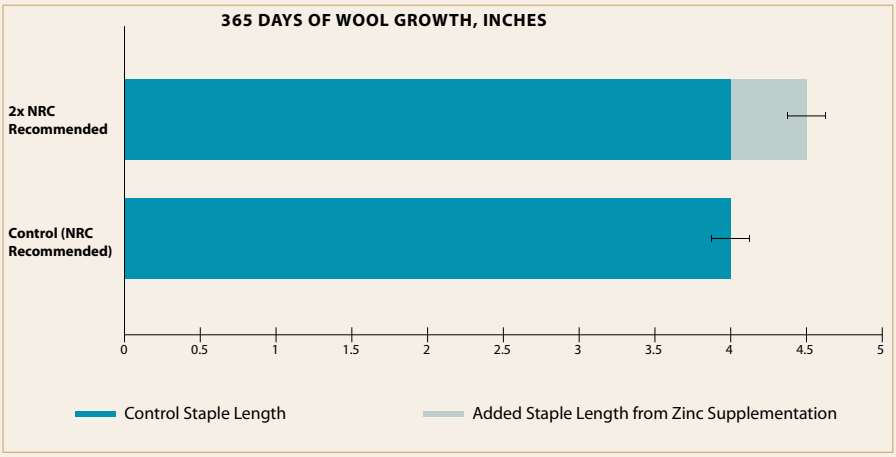

Figure 2. Wool growth (staple length) adjusted to 365 days in Targhee rams fed current recommended zinc levels or two times the NRC recommended Zn levels.

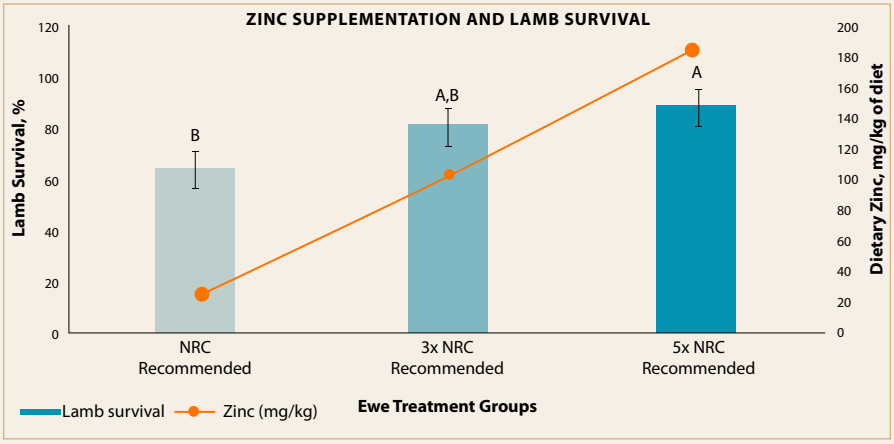

Figure 3. Effects of feeding the recommended, three times, and five times zinc levels to pregnant ewes on lamb survival from birth to weaning.

The right amount of zinc can pay dividends

Current research evaluates whether feed supplements contain adequate levels for the best health and well-being of sheep, in addition to comparing different chemical forms of zinc in sheep diets.

Recently completed research in 2017-2018 found rams grew 14 percent longer wool when fed double the recommended levels of zinc, resulting in more pounds of wool (Figure 2). Considering the record high wool prices in 2018, this increase in production can increase margins.

Agriculture in America thrives or dies on the margins. These same rams fed increasing levels of zinc also had greater feed conversion efficiency; they grew more with less feed when compared to rams eating the current recommended levels, benefitting the sustainability of the producers and the environments in which they produce.

Zinc benefits extend beyond the ram. In a separate study conducted at the University of Wyoming, pregnant sheep were fed increasing levels of zinc. This resulted in a 40 percent increase in lamb survival from birth to weaning (Figure 3). Relatedly, collaborative work between Montana State University, UW, and the USDA Sheep Experiment Station in Dubois, Idaho, concluded ewes with lower zinc levels were associated with sub-clinical (difficult to visually detect) mastitis producing 33 fewer pounds of lamb (and $52 less) than those with healthy udders.

Current research is examining whether greater zinc levels fed throughout pregnancy can reduce the incidence of bacterial infections of the udder, preventing lost production potential. Research from our group has found 20 percent of ewes in a flock suffer from sub-clinical bacterial infections of the udder. This intervention could save the average 400-head producer over $4,000 a year.

There is still work to do in understanding the optimum levels of zinc in

sheep diets. For example, understanding breed differences that may require additional zinc levels is an important delineation.

We are trying to more closely tailor zinc requirements to the type of sheep Wyoming raises. So far, we've discovered breed differences exist in how much zinc is transferred to the newborn lamb. Fine-wool lambs have greater zinc concentrations at birth than meat breeds. The chemical form of zinc (zinc sulfate vs. zinc amino acid complex) has shown to have differential effects on the rumen bacteria and subsequent performance of the animal. Determining what chemical forms should be utilized, and at what ratio of zinc sulfate to zinc amino acid complex in a mineral, is a focus of future efforts.

Finally, and most important to tailoring a custom mineral for sheep ranches scattered throughout Wyoming, is understanding the trace mineral composition of the plants sheep consume at different times of the year. What are the differences in grass, forb, and shrub species, and how much zinc is actually available at different stages of plant maturity?

Efforts are under way to sample sheep ranches throughout Wyoming to identify trace mineral deficiencies and help producers assess where their forage resources might be falling short for a particular trace mineral. Conducting applied research that helps the Wyoming sheep producer while advancing knowledge in the field is a guiding principle behind these efforts.

Private industry-public institution partnerships

The next step in supporting the modern-day sheep is communicating research results to feed companies marketing products throughout Wyoming and surrounding regions. Leveraging the extension arm of the land-grant university pipeline, we'll continue to communicate translational research to industry partners and invite them to revisit their sheep mineral products.

Providing timely information to private industry also involves synthesizing late-breaking research into translational information that enhances decision making. Feed companies have repeated time and again their reliance on land-grant universities to generate the data that drives their decision-making.

In an era with fewer sheep research and extension programs we, as ever, are happy to oblige.

To contact: Stewart *can be reached at (307) 766-5374 or whit.stewart@uwyo.edu.*

Photo: Whit Stewart

'Smart' feeders (those that feed automatically) at the Laramie Research and Extension Center administer zinc-fortified supplements during ewe pregnancy.

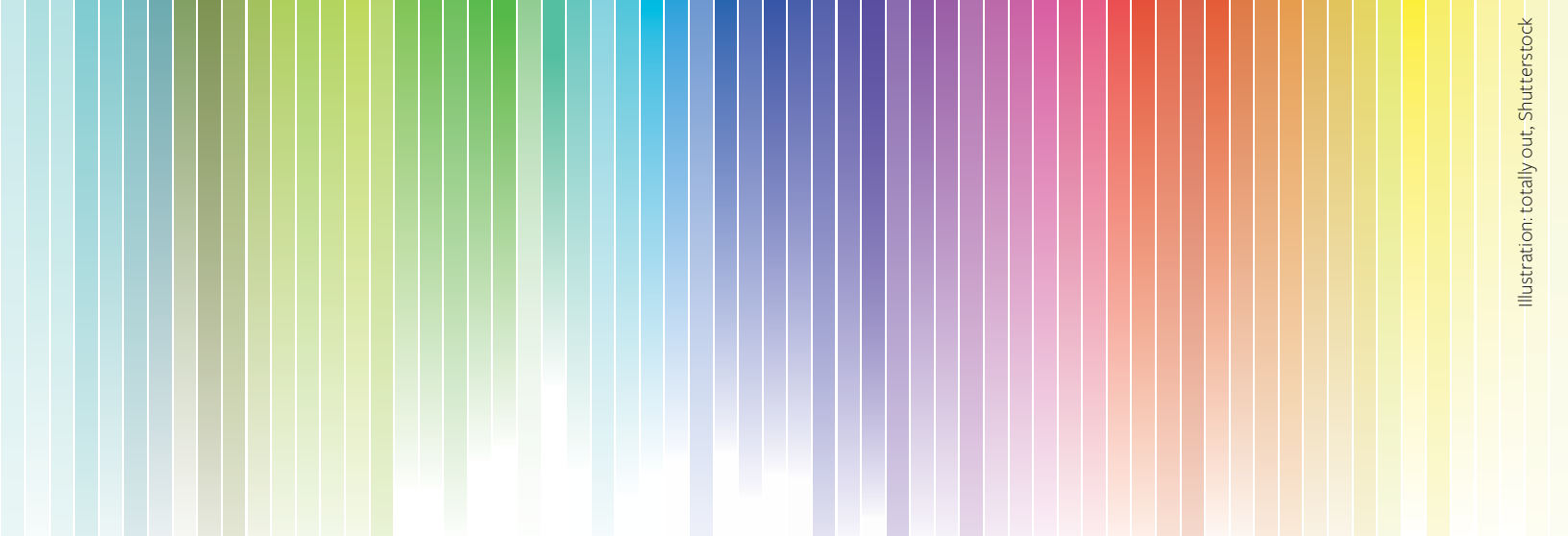

Illustration: totally out, Shutterstock

PHOTOACTIVATED CELLS COULD ACT AS FUTURE REMEDIES

Engineered cell therapies an emerging branch of medicine

‘We are at the dawn of a bioengineering revolution.’

Mark Gomelsky
Professor
Department of Molecular Biology

Biology is being rapidly transformed from an analytical to a synthetic, engineering discipline. For millennia, we have observed, described, and studied animals, plants, and microbes. We have tinkered with them for sure, and in many instances with remarkable success.

For example, by breeding and selecting for the desired traits in agricultural crops and animals, we have secured the food supply for several billion people; however, tinkering is slow and relatively inefficient. The progress in molecular, cellular, and developmental biology over the past few decades has enabled much more precise, fast, and efficient manipulation of genetic programs.

We now have the ingredients for reprogramming cells and organisms with increasing predictability of the outcomes. We are at the dawn of a bioengineering revolution. While no one can envision its full scope, engineered cell-based therapies give us a glimpse of what is coming.

The year 2017 was remarkable because the year marked the first approval of an engineered cell therapy. This involves isolating a patient’s T cells (a type of white blood cell part of the immune system) and reprogramming them in the laboratory so they can recognize and destroy specific tumor cells. The engineered T cells hunt and kill tumor cells upon injection in the bloodstream. Thousands of people with leukemia and lymphoma have been saved or their lives extended by the T cells that have been transformed into better tumor assassins.

Killing is not the only trick we can teach human cells. In regenerative medicine, cells are programmed to become better healers of damaged organs. Yet another emerging therapy relies on engineering cells to produce genetically encoded drugs. Such cells may be implanted under the skin or elsewhere in the body and work as miniature pharmaceutical factories patients carry with them.

Imagine a person with diabetes whose implanted cells produce insulin, or a severely obese individual whose implanted cells produce appetite-suppressing hormones and help in decreasing food portions, or a patient with a neurological disorder

whose implanted cells produce a therapeutic neuropeptide.

How can we control engineered cells inside the human body?

We need to control activities of the implanted cells to advance engineered cell therapies, but how do you send commands to cells? Students in my laboratory have been developing light-based cell communication devices. Such devices work similar to TV remote controllers: a beam of near-infrared light reaches a TV set where embedded photodiodes turn an electric circuit on or off.

We like light as a means of controlling cell activity because light has no side effects; light is easy to turn on and off and can be focused on a specific body location.

Near-infrared light is perfect; it penetrates human tissues much deeper than visible light (Figure 1). If we program cells to interpret near-infrared light signals, we can control their activity inside the body using external lasers or LEDs. Since human cells don't have near-infrared light sensors, we need to engineer and incorporate them into the existing cellular circuitry. Alternatively, we could engineer both light-sensing devices and a new circuitry through which to control cell activity.

We have made significant progress in both pursuits, but the road to success has been long and arduous.

Humans don't have photoreceptors for the near-infrared spectrum, but some bacteria do. They use photoreceptor proteins known as bacteriophytochromes to detect light in the 700-770 nanometer region, at the border of red and near-infrared (Figure 2). While studying how the photosynthetic bacterium Rhodobacter responds to light, postdoctoral fellow Marina Tarutina, and Ph.D. student

Figure 1. Images of red light penetrating fist (left) and breast tissue (right). To test what color light penetrates best through human tissues, turn on your cell phone flashlight and cover the LED with your thumb. You'll see that of all colors comprising white light, only red light goes through. Light in the longer wavelengths, in the far-red and near-infrared spectrum (670-900 nanometers), penetrates even better. This spectral region is known as the near-infrared optical window.

What has made a bioengineering revolution possible?

Bioengineering has become possible as a result of several lines of progress. One of them is genomics, the field of science involved in determining genetic codes of different organisms. Not only has genomics brought us deeper understanding of genome structure, it has also exposed the breadth of genetic diversity in nature, that is the inventory of genetic parts available for engineering. Significant progress has been achieved in engineering of molecular tools with which we can precisely manipulate the genetic code – change existent genes, remove them, or add new genes. DNA synthesis technology has enabled fast and cheap gene synthesis based on the written code. The progress in biochemistry has illuminated functions of numerous proteins, the main molecular machines of a cell. Cell biology has explained how these proteins work together. The progress in developmental biology has taught how cells form organs, so we can reproduce natural genetic programs and design new ones. We understand reasonably well the genetic parts that code the components of the cellular machinery and have access to a myriad of genetic parts. We know the rules regulating how they interact and how cell fate is determined, plus we have the tools to modify genetic parts and to synthesize new ones. These are the prerequisites for successful bioengineering. We are at the dawn of the bioengineering revolution that will transform the bioworld around us and most likely us humans too.

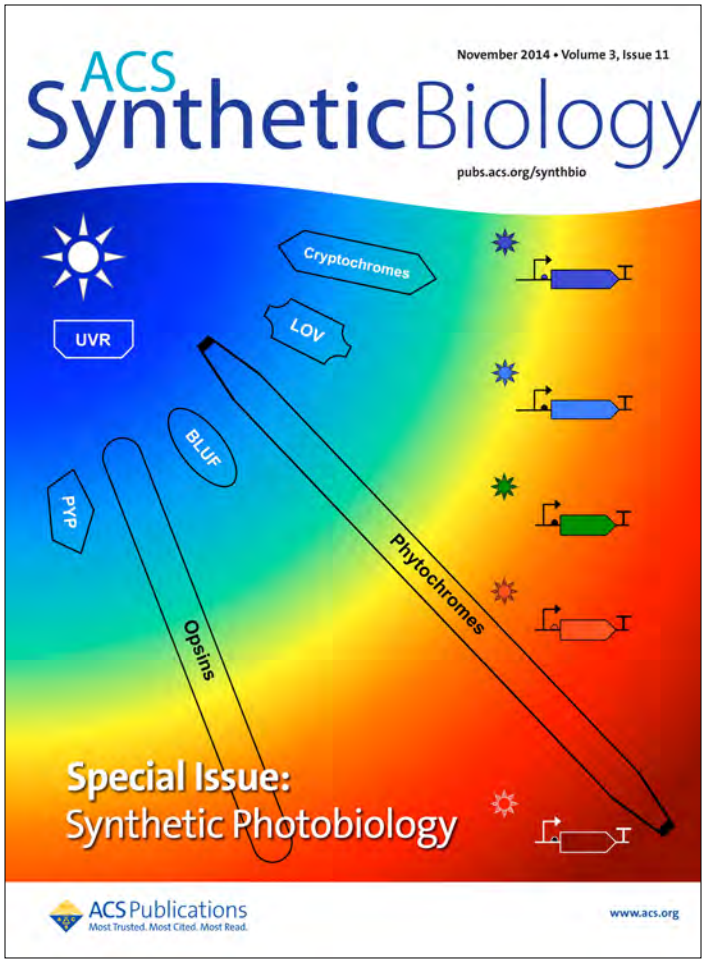

Figure 2. Cover of the special issue of the scientific magazine ACS Synthetic Biology depicting major classes of photoreceptor proteins found in nature. Bacteriophytochromes sense light in the longer wavelengths (700-770 nanometers), compared to other photoreceptors. This makes them ideal for engineering light-sensing genetic devices for implanted photoactivated cells.

Dmitry Ryjenkov, both from Russia, have identified and characterized its bacteriophytochrome proteins. This was almost 15 years ago. Back then we projected that one day bacteriophytochromes would be engineered to control mammalian cells (see inset below).

How to program cells to see near-infrared light?

The diligence and perseverance of another Ph.D. student, Min-Hyung Ryu from South Korea, brought that vision to fruition. Min-Hyung has undertaken a daring protein engineering project to construct a bacteriophytochrome with an artificial, adenylate cyclase, activity.

The bacteriophytochrome engineering method we have invented is now protected by patents owned by UW. Because an adenylate cyclase naturally controls various activities in animal cells, an engineered protein could be plugged into the existing cell circuitry, which we can now control using light. Our collaborators from the University of Pennsylvania Medical School put an engineered protein into the neurons of a worm, *C. elegans*, to control swimming behavior of this tiny animal using light. Other collaborators tried to control the behavior of mice, the next animal model in developing biomedical applications. Unfortunately, the engineered protein did not work in mice.

Disappointed yet defiant, we went back to the drawing board to methodically analyze what went wrong. Many things could potentially go wrong because bioengineering is not yet as straightforward as, for example, electrical engineering.

From a bacteriologist studying light sensing to a bioengineer developing photoactivated cell therapies.

Science moves in unpredictable ways, simply because discoveries cannot be planned. When I started my laboratory at UW, we were interested in understanding how a photosynthetic bacterium Rhodobacter sphaeroides adapts to changes in oxygen and light. Our search for sensors for these environmental factors has led us to the discovery (with other scientists) of a new type of blue light sensor (which we named BLUF). We found that, in addition to a blue light sensor, Rhodobacter has a gene for a sensor of red or near-infrared light whose function was unknown. That seemingly obscure photoreceptor, bacteriophytochrome, inspired our thinking about regulating human cells with light. Since the Rhodobacter bacteriophytochrome could not regulate mammalian cells in its native form, we had to modify it. Once our protein engineering project had succeeded (after years of failure), we wanted to test the engineered protein in human cells, although we had not worked with such cells before. One thing led to another, ultimately transforming my basic science lab interested in environmental sensing in bacteria into a bioengineering/ synthetic biology lab that uses bacterial genetic parts for solving biomedical problems. I am sure our expertise in light sensing and bacteriology makes us better engineers of photoactivated cells.

- First, genetic parts are not nearly as standard as transistors or electric switches.
- Second, our understanding of cellular circuitry is not nearly as complete as that of electrical circuitry.
- Last but not least, cellular circuitry is much more complex than any electric one.

Still, we determined the cause of our initial failure.

The genetic parts we used to engineer the original protein were taken from bacteria that cannot grow at human or mouse body temperature. Not surprisingly, the engineered protein worked well in worms at ambient temperature but failed to work in warm-blooded mice.

Another talented Ph.D. student, Anastasia Fomicheva from Russia, remade the photoactivated adenylate cyclase using genetic parts from 'tougher' bacteria. She showed that the next-generation protein can be produced by human cells grown in culture and works well at 100° F.

The students of Professor Qian-Quan Sun, our collaborator from the Department of Zoology and Physiology and director of the Sensory Biology Center, have now used this next-generation protein to control neuronal activity in mice using light. Brain neurons producing our protein can be turned on by using a hand-held, near-infrared laser. Importantly, laser light penetrates through the mouse skull and brain tissue causing no damage.

Before leaving for a postdoctoral fellowship at MIT, Min-Hyung designed yet another bacteriophytochome-based system with its own genetic circuitry. He perfected this system in *E. coli* cells, but this system can be used to control diverse cell types.

Chinese and Swiss bioengineers led by Professor Ye adapted our system for controlling production of insulin in human cells in response to light. Diabetic mice with implanted engineered cells were exposed to near-infrared light daily. During irradiation, the photoactivated cells produced insulin. The researchers calculated duration of irradiation daily based on blood glucose measurements. These diabetic mice have had blood glucose levels within the normal range for several weeks. That study was a remarkable demonstration of the power of photoactivated cell therapies.

Do you want to help develop photoactivated cell therapies?

Eos LABS (www.eosbiosystems.com) is a recently formed startup company whose goal is to develop and promote engineered photoactivated cell therapies. LABS stands for light-activated biosystems, and Eos is the name of the Greek goddess of the dawn. If you are excited about photoactivated cells and would like to contribute your molecular expertise, entrepreneurial skills, or financial resources to moving photoactivated cells toward therapeutics, we would like to hear from you.

Since then, two masters students in my laboratory, Marina Lazic from Serbia and Taylor Doherty from Laramie, have improved on Min-Hyung's system. Ph.D. student Tasneem Muna from Bangladesh, in collaboration with the laboratory of Professor Jared Bushman from the School of Pharmacy, is adapting that system to control proliferation of T regulatory cells. Our goal is to develop photoactivated T regulatory cells that will maintain light-controlled immunosuppression.

We expect it to help prevent rejection of transplanted organs in survivors of severe injuries and burns, common among war veterans.

A path to photoactivated cell therapies

Will future patients irradiate their implanted cells while watching their favorite Netflix shows or during sleep?

Will LED wristbands that irradiate pouches of implanted cells become a new fashionable trend?

I can't say.

Predicting fashion trends and social behavior is an exercise in futility. I do hope our bioengineering efforts will help progression of photoactivated cells toward therapeutic applications and that it happens in our lifetime.

To contact: Gomelsky *can be reached at (307) 766-3522 or gomelsky@uwyo.edu.*

WILL MARY JO OR JOHN DOE NEGOTIATE A HIGHER PRICE FOR THEIR LAMBS?

Research studies difference gender plays in agricultural markets

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Assistant Professor

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Professor

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Assistant Extension Educator

Amy Nagler
Assistant Research Scientist, Department of Agricultural and Applied Economics

Mary Jo sits down at her kitchen table with a potential buyer to negotiate the sale of her lambs.

She dislikes haggling over prices like many agricultural producers in Wyoming. She wonders if she will get a good deal compared to her neighbor John Doe.

Mary Jo is not alone: women operate more farms and ranches in Wyoming than ever. Nearly 7,000 women in Wyoming are producers, accounting for 35 percent of the state's agricultural producers who generate $81.2 million annually. Projections suggest these numbers will continue to increase.

Understanding how women in agriculture will fare financially is important for Wyoming agriculture and the communities dependent on farms and ranches. Recent USDA statistics indicate women operators have lower sales and lower returns on equity than males. Helping women like Mary Jo be successful means a better life for her and her family and a better economy for the state.

A changing market

Part of Mary Jo's success depends on the prices she receives for her lambs and how many lambs she sells, both dependent on how her lambs are marketed. Yet the way in which agricultural products are marketed is changing. Historically, selling livestock at an auction or marketing grain through a local elevator were the primary outlets.

Photo: goodluz, Shutterstock

Now more and more goods are traded through privately negotiated contracts. Over half of livestock and 35 percent of other commodities are now sold via contracting.

Agricultural producers in this marketing environment can find themselves negotiating contracts as both a buyer (purchasing inputs) and as a seller. These changes in the market may affect women's and men's finances differently if how they bargain is different.

Our past research finds sellers in general may be worse off as markets move to more privately negotiated contracts, but little is known about potential differences between women and men in these changing markets.

Using economic experiments in the laboratory

Most producers don't share detailed accounts of how they bargain over price and quantity with buyers. This means we must use different research methods to understand this issue. Economists rely on experiments conducted in a laboratory. Experiments allow us to create a market environment that mimics the real world and offers a glimpse into human behavior.

We simulated agricultural markets in the laboratory where buyers and sellers traded a generic agricultural product. Sellers earned a profit by negotiating a price with a buyer that was higher than their operating costs. Buyers earned a profit by negotiating a price with a seller that was lower than the amount for which they could resell the product. Laboratory participants were given a limited amount of time to trade their desired quantity of the given product. Once complete, these participants were paid in cash based on their decisions. Data collected from these transactions offer us a detailed look into human behavior when negotiating over price and quantity.

Our laboratory market mimics auctions and private negotiations to understand how women and men negotiate and how profitable each are. In auctions, numerous buyers bid against one another to

purchase a product from a producer. In privately negotiated contracts, one buyer and one seller actively negotiate with each other to reach an agreed-upon price.

How gender influences profitability

Results show buyers' and sellers' profits vary greatly between auctions and privately negotiated contracts (Figure 1). In auction markets, sellers outperform buyers, as buyers compete against each other to purchase a product. Buyers outperform sellers in privately negotiated contracts as sellers are focused on successfully negotiating a contract to cover their operating costs. The move away from auction markets is expected to hurt agricultural producers when selling their products.

We find the gender of an operator indeed plays a role in market success and profitability. Women sellers outperform men in auction market environments, suggesting the inactive role of a seller during the negotiation process in auction markets benefits women. Men, on the other hand, outperform women as buyers in auction markets. The competitive nature of bidding in these markets may be detrimental to women buying agricultural products at auction.

Men were found to outperform women as both buyers and sellers in privately negotiated contracts, further suggesting that more active negotiation environments negatively affect women's profitability.

Our results indicate women are expected to be disproportionally hurt as agricultural markets move away from auction environments toward privately negotiated contracts. The profitability, and thus viability, of women producers is expected to suffer.

What drives the gender difference?

Since profitability is dependent on revenues and operating costs, numerous factors can be at play. In the lab, by making operating costs constant across participants, we can isolate the impact of two factors on

Photo: Gena Melendrez, Shutterstock

profitability: negotiated prices and quantity traded. With these two factors, we find gender differences in behavior during negotiation that may cause the profitability differences by gender.

We find different tendencies between men and women when they bargain. Women tend to bargain in a manner that results in lower prices as sellers (higher prices as buyers) to move the sale along, which increases their number of trades, but results in a lower profit per trade. Men tend to bargain in a manner that leads to higher prices as sellers (lower prices as buyers) decreasing the quantity traded but resulting in a higher profit per trade (Figure 2).

Without the lab, determining which of these strategies is most beneficial would be virtually impossible. Yet, with the detailed information gathered from experiments, we find the best strategy depends not only on the market environment (auctions versus contracts), but also on the role an individual plays in the market (buyer or seller).

The strategy of trading more at lower prices, practiced by women, is only beneficial as a seller in auction markets. As agricultural products rely more on privately negotiated contracts, the negotiation strategy of focusing on a better price per trade, practiced by men, will lead to higher profits, and increased success.

What can we do to help producers like Mary Jo?

As women continue to increase their prevalence in agriculture, helping them succeed is vital for a strong and stable economy. Given the evolution of agricultural markets, our research suggests Mary Jo may not get as high of a price for her lambs as her male neighbors, and her profitability will suffer.

Educational opportunities need to be available for Mary Jo and others that stress the importance of strategy during negotiation. We, and others in the Department of Agricultural and Applied Economics, are now investigating ways to help all producers improve their bargaining skills.

We hope to develop educational information to help producers like Mary Jo be more successful as agricultural markets move toward more privately negotiated contracts.

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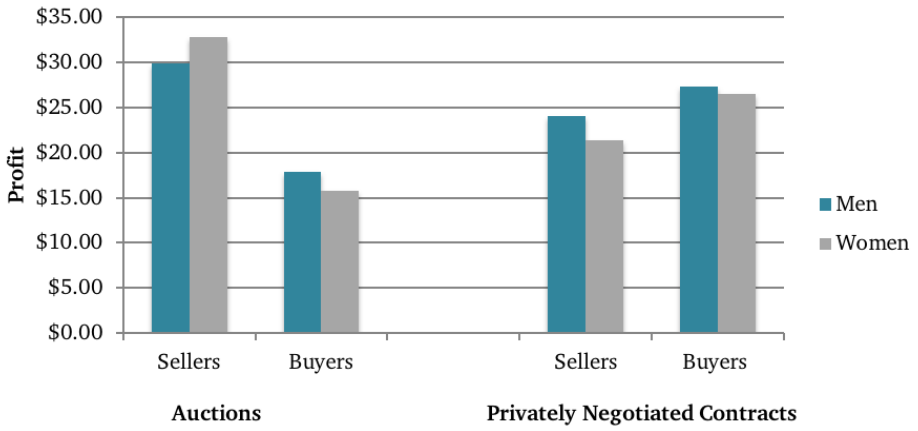

Figure 1. Profit by Gender

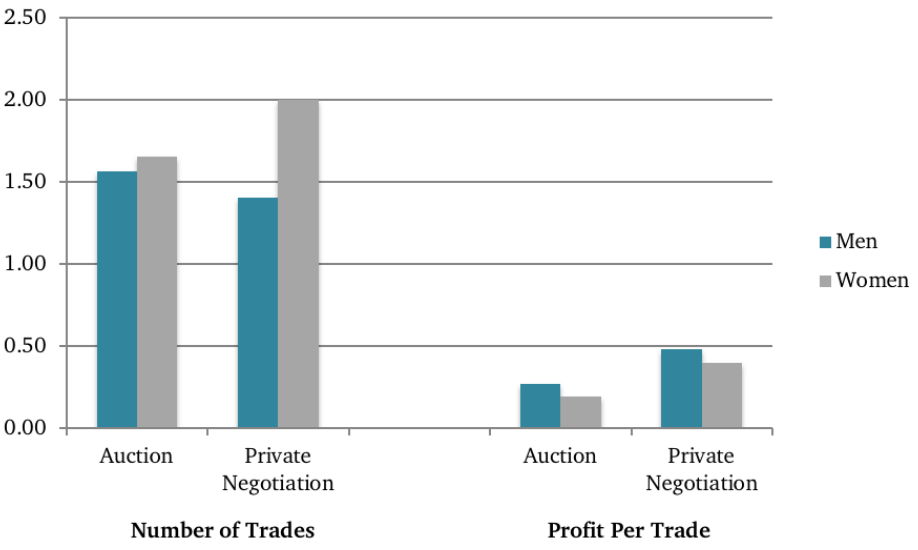

Figure 2. Gender Differences in Number of Trades and Profit per Trade

AEOLIAN DUST INPUTS

are an important source of phosphorus to ecosystems

Mengqiang Zhu
Assistant Professor
Department of Ecosystem Science and Management

Phosphorus (P) is essential to all life ranging from microorganisms, plants, and animals to human beings.

Phosphorus is a major structural component of bone, cell membranes, energy production and storage compounds adenosine triphosphate (ATP) and adenosine diphosphate (ADP), and nucleic acids deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) for the storage and transmission of genetic information.

Our research demonstrates how dust inputs can modify the Walker and Syers model of P transformations in semi-arid environments.

Not all forms of P are available to biota. For example, highly weathered tropical soils are P-fixing soils where P is strongly bound to iron (Fe) and aluminum (Al) oxides and not readily available. However, phosphate bound to calcium (Ca) is unstable and readily dissolves to provide available P in acidic soils. To evaluate the availability of P in soils and dust deposited by wind (aeolian), we need to know the chemical forms of phosphate.

Phosphorus exists as multiple forms of phosphate in soils and aeolian dust, including organic phosphate and phosphates associated with metal cations, such as Ca, Fe, and Al.

Phosphorous bioavailability during soil development is not only controlled by the total P content in soils, but also by P chemical composition because different P types have distinct bioavailability.

Accepted model displays inconsistencies

In 1976, Walker and Syers proposed a conceptual model to describe how P chemical composition changes or P transforms with time during soil development. Generally, the Walker and Syers model is applicable to P transformation in humid ecosystems; however, inconsistent results have been obtained for P transformation in arid and semi-arid ecosystems. The causes could be differences in the soil development of the two types of ecosystems.

The model also does not adequately consider the effects of wind-deposited (aeolian) dust to soils on P transformation. Dust deposition is ubiquitous in ecosystems, particularly for semi-arid and arid ecosystems that can receive massive dust contributions. In addition to terrestrial ecosystems, aquatic ecosystems, such as alpine lakes, are nutrient poor and receive significant aeolian dust.

Described below are our two studies on how aeolian dust inputs affect P transformations in a semi-arid ecosystem of northern Arizona and P availability of alpine lakes in the Rocky Mountains of Colorado.

Phosphorus from rock weathering

Soil P for plant uptake is ultimately derived from rock weathering that forms soils and releases otherwise-locked nutrients during ecosystem development. Nutrient levels in soils are not constant during ecosystem development. As an ecosystem develops, the soil N content increases due to development of animal and plant life, while the soil P content decreases because of leaching, surface run-off, soil erosion, and plant uptake. The ecosystem becomes increasingly limited by less and less P.

Phosphorus availability in soils affects not only crop yield but also functions and properties of natural ecosystems. Phosphorous limitation strongly affects primary productivity, decomposition, carbon and N cycling, and biodiversity in an ecosystem. High P limitation could cause a terrestrial ecosystem to decline or stop progression at the very late stage of development.

Overall, this work provides a foundation for understanding how dust influences P cycling during soil and ecosystem development, and indicates that dust inputs and composition and the soil weathering rate must be considered for developing integrated climate biogeochemical models with predictive power in terrestrial ecosystems.

To contact: Zhu *can be reached at (307) 766-5523 or at mzhu6@uwyo.edu.*

Case Study 1. Effects of aeolian dust inputs on P transformations in a semi-arid ecosystem[1]

We characterized P breakdown using P K-edge X-ray absorption near-edge structure (K-edge XANES spectroscopy - see explanation Box 1, page 16) in surface soils (0-15 centimeters) and contemporary aeolian dust collected at each site of a 3000-ky or 3 million volcanic soil chronosequence (spatially distinct sites of varying ages representing a time sequence) in a cool, semi-arid environment of northern Arizona. The soil chronosequence is a result of volcanic eruption at different times and is well-constrained in terms of other soil formation factors, including parent materials, vegetation, climate, and topography (Figure 1).

Surprisingly, we found the proportions of calcium-phosphorous (Ca-P) and iron plus aluminum (Fe+Al)-P fluctuated with increasing substrate age, not consistent with the Walker and Syers model. These soil fluctuations resulted from the accumulation and preservation of alkaline aeolian dust that contain mainly Ca-P during soil formation in the semi-arid climate,

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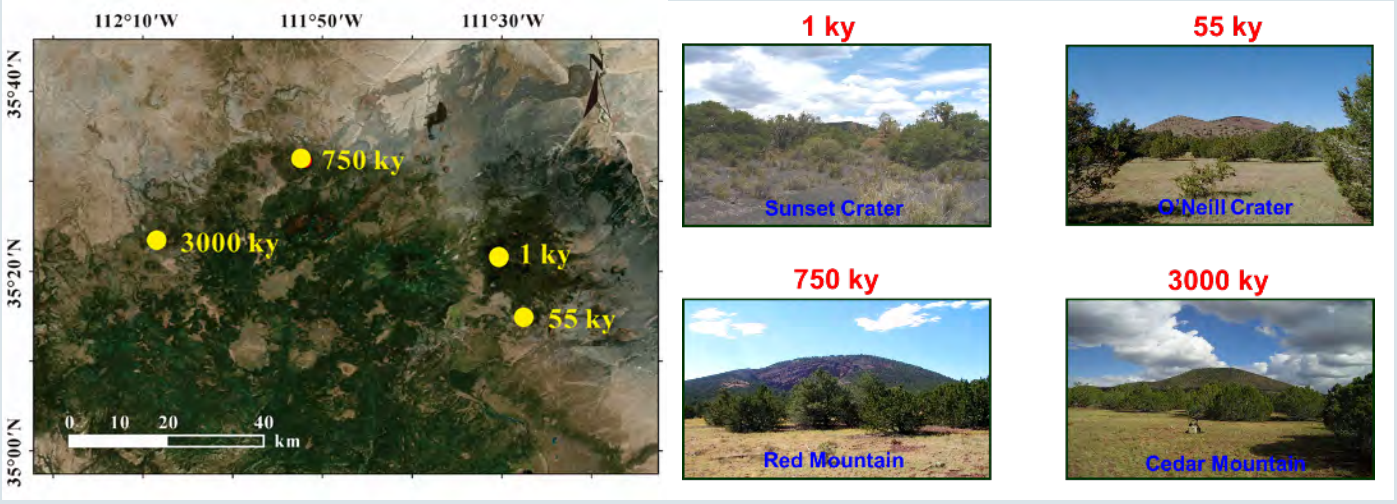


Figure 1. Substrate age gradient of Arizona in the San Francisco Volcanic Field (left). All four sites have similar climate, vegetation (pinyon pine, one seed juniper), topography (minimal slope: <1%), elevation (1,905 – 2,073 m), and parent material (basalt cinders). * ky = 1,000 years. Photos: Steve Hart, University of California - Merced.

continued from page 15

which significantly increased soil Ca-P while decreasing the total amounts and relative abundances of soil (Fe+Al)-P. We suggest the effects of aeolian dust input on soil P transformations are functions of the relative magnitude and chemical composition of the dust input and the soil weathering intensity (Figure 3).

For a given source of dust, when the net dust change is greater than the weathering rate, dust accumulates and alters the pattern of P transformations during soil formation; otherwise, the dust influence on soil P transformations is negligible.

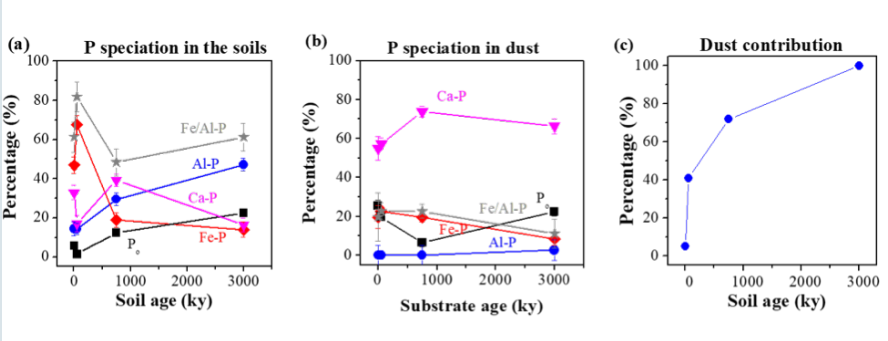


Figure 2. Forms of phosphorous in soils (a) and dust (b) and dust mass contribution to soils (c) as a function of substrate age.

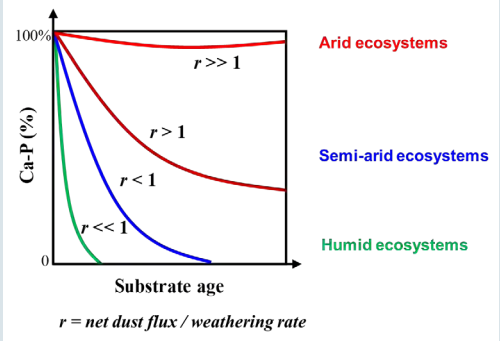
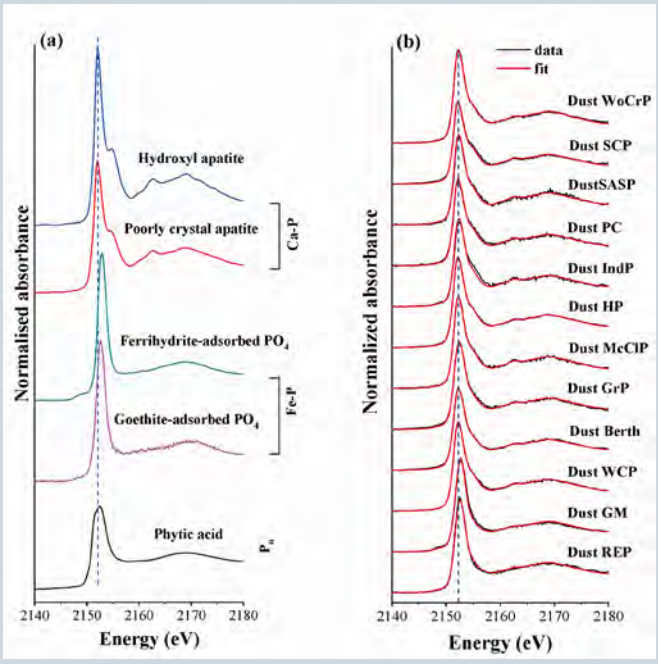


Figure 3. A conceptual model describing how the relative magnitude (r) of the net dust flux to the dust weathering rate affects the soil Ca-P proportions during long-term soil development in semi-arid or humid environments.

Box 1. Synchrotron X-ray techniques for analyzing P chemical forms

Synchrotron X-ray techniques have been widely used in physical and life sciences, including soil and environmental sciences. The techniques are available only at synchrotron X-ray facilities in national laboratories, such as the Advanced Photon Source in Argonne National Laboratory, Chicago, Illinois, and the Canadian Light Source, Saskatoon, Canada. In a synchrotron X-ray facility, the X-rays of superior quality are produced when a group of electrons travel in a vacuum ring at a speed close to that of light. The X-rays are emitted at the circle tangent direction of the ring and are used as the light source to build a beamline station where samples are measured. Each synchrotron X-ray facility houses many beamline stations for different types of synchrotron X-ray techniques. X-ray absorption spectroscopy, such as P K-edge XANES spectroscopy, is one of the kinds. Different P compounds have different P K-edge XANES spectra. By linear combination fitting of sample spectra with spectra of reference compounds, one can determine P chemical composition in a solid sample.



Case Study 2. Aeolian dust inputs to the Rocky Mountain areas and effects on alpine lakes[2]

Phosphorus can limit the primary productivity of oligotrophic (relatively low in plant nutrients and containing abundant oxygen in the deeper parts) alpine lakes due to the low P input from poorly weathered surrounding watersheds.

In such environments, mineral dust derived from dryland sediments is potentially an important P source, in particular when referring to alpine lakes at the margins of arid and semiarid regions, where dust mobilization and deposition are massive. The P supply from dust deposition can alter the nutrient composition, stimulate productivity, and shift bacterial abundance and phytoplankton-species composition in most alpine lake ecosystems.

The semiarid Colorado Plateau region is one of the main dust sources in the western U.S. Increased dust emission due to extensive grazing and prolonged aridity has increased P loading to nearby alpine lakes in the Rocky Mountain area. The pH of the alpine lakes ranges between pH 4.5 and 7.5 due to different degrees of lake acidification caused by elevated atmospheric nitrogen deposition.

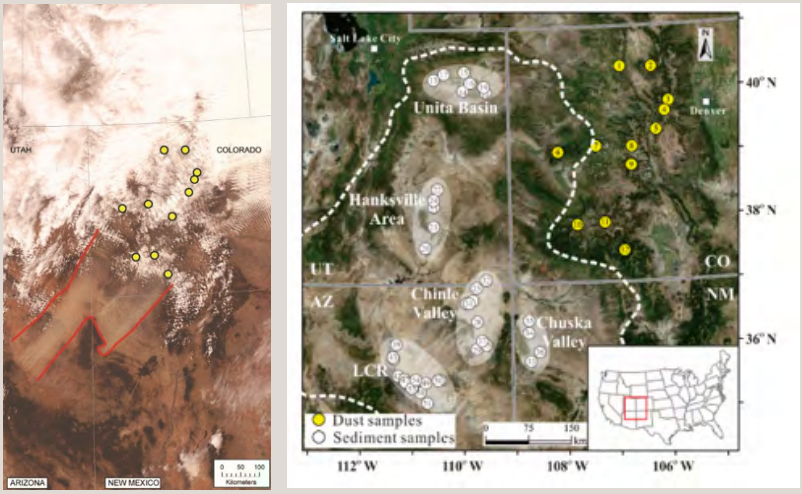
We identified the chemical forms of P in dust collected in the central Rocky Mountains of Colorado and sediment samples from major potential source areas using P K-edge XANES spectroscopy. To better comprehend the biogeochemical impact of dust-borne P deposition in alpine lake environments, we investigated P-release kinetics through dissolution experiments using synthetic alpine lake water of pH 5.0-7.5.

We found Ca-P is dominant in 10 of 12 dust samples (41-74 percent) deposited on snow in the central Rocky Mountains and all 42 source soil samples (68-80 percent), with a lower proportion in dust probably because acidic snowmelt dissolves some Ca-P in dust before collection.

Iron-bound P (Fe-P, ~54 percent) dominates the remaining two dust samples. Dust releases increasingly more P in synthetic lake water within 6-72 hours thanks to dissolution of Ca-P, but dust release of P declines afterward due to back adsorption of P onto Fe oxides present in the dust. The back adsorption is stronger for the dust with a lower degree of P saturation.

This work suggests that P speciation, poorly crystalline minerals in the dust, and lake acidification all affect the availability and fate of dust-borne P in lakes.

The dominant Ca-P in the aeolian dust deposited to the lakes will be eventually dissolved by the acidic lake water and transformed to either soluble P or P associated with Fe and Al oxides. However, the Ca-P species will likely remain in the sediments for lakes with circumneutral (pH approximately between 5.5-7.2) or alkaline pH (PH 7-14). The efficiency of dust deposition as P fertilizer depends strongly on lake water pH. The ongoing acidification of alpine lakes in Colorado will further promote dissolution of apatite and the related release of dissolved phosphate and subsequent fixation by Fe and Al oxides as well, over decades or longer time periods. On the other hand, a recovery from acidification can have the opposite effect.



(Above, left) Moderate resolution imaging spectroradiometer (MODIS) satellite image showing a major dust event originating in the Four Corners region of the southern Colorado Plateau on April 16, 2013. Dust trajectory is toward the dust on snow sites (yellow circles) to the northeast. Other potential dust source areas in eastern Utah are obscured by clouds. Credit: https://gec.cr.usgs.gov/dustdetection

(Right) A satellite image showing the locations where the dust (yellow circles) and source sediment (white circles) samples were collected. The dust sampling sites are in the central Rocky Mountains of Colorado. The dust source sites are centered in five areas on the Colorado Plateau (white dashed line). Map data from ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Notes

[1] Gu, C., Hart, S.C., Turner, B.L., Hu, Y., Meng, Y. and Zhu, M. (2019) Aeolian dust deposition and the perturbation of phosphorus transformations during long-term ecosystem development in a cool, semi-arid environment. Geochim. Cosmochim. Acta 246, 498-514.

[2] Zhang, Z., Goldstein, H.L., Reynolds, R.L., Hu, Y., Wang, X. and Zhu, M. (2018) Phosphorus speciation and solubility in aeolian dust deposited in the interior American West. Environ. Sci. Technol. 52, 2658-2667.

STUDY GROUP TESTS KIMCHI

TO DETERMINE IF FERMENTED FOODS BOOST HEALTHY GUT

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Assistant Professor

Taylor Kraft
Master's student,
Department of Family and Consumer Sciences

Fermentation is an ancient method of making food safer and last longer. Carbohydrates are converted to alcohol or organic acids through the actions of bacteria (or yeast) in an oxygen-free environment.

The presence of bacteria makes these foods a probiotic, or a product that contains live bacteria, which may confer health benefits.

Therapeutic use of probiotics to promote healthy gut function has increased due to health concerns arising from an imbalance in the type and number of bacteria in the gut (aka gut microbiota).

Why kimchi?

Fermented foods are common in diets across the globe; however, they are rarely included in nutritional guidelines/recommendations. Common fermented foods include yogurt, sauerkraut, kombucha, kefir, and kimchi. Kimchi is commonly consumed in Korean diets but less so in the typical U.S. consumer diet. Kimchi is made by fermenting a mixture of cabbage, salt, red peppers, radishes, and a variety of other spices. The main ingredients of kimchi, predominately the cabbage and other vegetables such as daikon radishes and garlic, also provide "prebiotics" or food for the healthy bacteria in the gut.

Photo: Jiang Hongyan, Shutterstock

What did we want to know about fermented foods?

- Does regular intake of fermented foods (specifically, kimchi) have an effect on stomach/gastrointestinal problems?
- What do people think of the taste, smell, and other sensory characteristics of kimchi?

Why do we care if fermented foods influence gut function?

All of us have likely experienced gastrointestinal (GI) symptoms (nausea, vomiting, diarrhea, constipation). They can range from mildly annoying ("my stomach is noisy") to debilitating ("I can't leave the house" or "I always need to know where the nearest restroom is located").

Irregular GI symptoms affect about 14 percent of the U.S population, although only a little over 3 percent are clinically diagnosed with irritable bowel syndrome (IBS). The effects of irregular GI symptoms are associated with a severe decrease in quality of life for an individual and a substantial financial burden on society due to missed work and doctor visits. Because IBS is experienced differently by each person and is difficult to diagnose, physicians rely heavily on patient symptoms alone.

The limited information available for consumer acceptability of fermented foods, including kimchi, is another reason to explore fermented foods. While there has been a recent rise in popularity of functional fermented foods, little is reported on preference for kimchi in the U.S., including sensory characteristic evaluations.

How did we evaluate the impact of fermented foods?

We recruited 20 people for a dietary intervention study during fall 2017. Those healthy people were between the ages of 18-40 years and were experiencing irregular GI symptoms following consumption of foods typical to their respective diet.

The first thing we asked them to do: Sample the kimchi

We asked participants to rate the sensory characteristics of the kimchi (appearance, flavor, texture, aroma, mouthfeel, and overall acceptability) on a 7-point scale (7= extremely like, 4= neither like nor dislike, 1= extremely dislike).

We also asked them to rate the overall palatability and feasibility of including kimchi in their typical diet, again using a 7-point scale (7=strongly agree, 1=strongly disagree) for five statements:

- "I enjoy consuming fermented foods as part of my regular diet",
- "I am aware of different types of fermented foods and how to prepare them",
- "I am interested in learning more about the different types of fermented foods",
- "I am willing to eat kimchi in the future", and
- "I plan on consuming kimchi regularly".

The second thing we asked them to do: Eat the kimchi for two weeks

We asked participants to consume one-half cup of kimchi twice a day for 14 days. We asked them to complete a few forms at the beginning and the end of the test period:

- Three-day food records (one during week 1, one during week 2)
- Gastrointestinal Symptom Rating Scale (GSRS) (Figure 1)
- Stool diaries using the Bristol Stool Scale (BSS)

What happened when people included kimchi in their diet?

Sensory analysis (Figure 2): Overall, participants favored the sensory qualities associated with kimchi.

Food intake: No significant differences between week one and week two were detected for any of the selected nutrients. This helped us see if any changes in GI function were due to the kimchi or other dietary changes. The kimchi in this study

Basic Napa Cabbage Kimchi

1 (2-pound) napa cabbage
1/2 cup kosher salt
About 12 cups cold water, plus more as needed
8 ounces daikon radish, peeled and cut into 2-inch matchsticks
4 medium scallions, ends trimmed, cut into 1-inch pieces (use all parts)
1/3 cup Korean red pepper powder
1/4 cup fish sauce
1/4 cup peeled and minced fresh ginger (from about a 2-ounce piece)
1 tablespoon minced garlic cloves (from 6 to 8 medium cloves)
2 teaspoons Korean salted shrimp, minced
1 1/2 teaspoons granulated sugar

Cut the cabbage in half lengthwise, then crosswise into 2-inch pieces, discarding the root end. Place in a large bowl, sprinkle with the salt, and toss with your hands until the cabbage is coated. Add enough cold water to just cover (about 12 cups), making sure the cabbage is submerged (it's OK if a few leaves break the surface).

Cover with plastic wrap or a baking sheet and let sit at room temperature at least 12 hours and up to 24 hours.

Place a colander in the sink, drain the cabbage, and rinse with cold water. Gently squeeze out the excess liquid and transfer to a medium bowl; set aside.

Place the remaining ingredients in a large bowl and stir to combine. Add the cabbage and toss with your hands until evenly combined and the cabbage is thoroughly coated with the mixture. Pack the mixture tightly into a clean 2-quart or 2-liter glass jar with a tightfitting lid and seal the jar. Let sit in a cool, dark place for 24 hours (the mixture may bubble). Open the jar to let the gases escape, then reseal and refrigerate at least 48 hours before eating (kimchi is best after fermenting about 1 week). Refrigerate for up to 1 month.

Makes approximately 1-1/2 quarts.

Recipe courtesy of Chowhound, http://bit.ly/chowhoundkimchi.

contributed an additional 4 g of dietary fiber and 1,400 mg sodium per day.

GI symptoms (from the GSRS): Consuming one-half cup (75 grams) of kimchi twice a day for 14 days contributed to a significant decrease in severity of:

- Abdominal pain,
- Heartburn,
- Acid regurgitation,
- Abdominal rumbling and distention, and
- Eructation (belching) and gas production

Stool form (from stool diaries using the BSS): The kimchi consumption had no significant effect on typical stool form; however, we did measure a slight increase in frequency of slow and normal bowel movements between the first and second week.

Implications for health and nutrition professionals

Use of a functional probiotic food source is becoming increasingly popular. Interpreting the ability for kimchi to act as a probiotic with the potential of improving GI health provides health professionals an additional option to recommend to patients or clients. Kimchi allows for inclusion of a nutrient-dense vegetable source that has potential to impact GI health. Importantly, kimchi, as a fermented food, may provide a feasible and appetizing method of including probiotics in people's diets.

Implications for consumers

Kimchi is a nutrient-dense, palatable (according to our participants!) option for consuming probiotics. Probiotics have proven health benefits, so here is some encouragement to include some delicious fermented foods as part of your regular diet!

Future directions

Our hope is to expand this research to have a larger group of participants try fermented foods, perhaps through coordination with medical professionals in Wyoming who work with patients with IBS. We are also closely examining the microbial content of homemade kimchi versus commercially prepared kimchi.

To contact: Keith *can be reached at (307) 766-5248, jkeith5@uwyo.edu.*

Taylor Kraft presents his poster at the Sports, Cardiovascular, and Wellness Nutrition (SCAN) conference last year. He received his master's in food science and nutrition in May 2018.

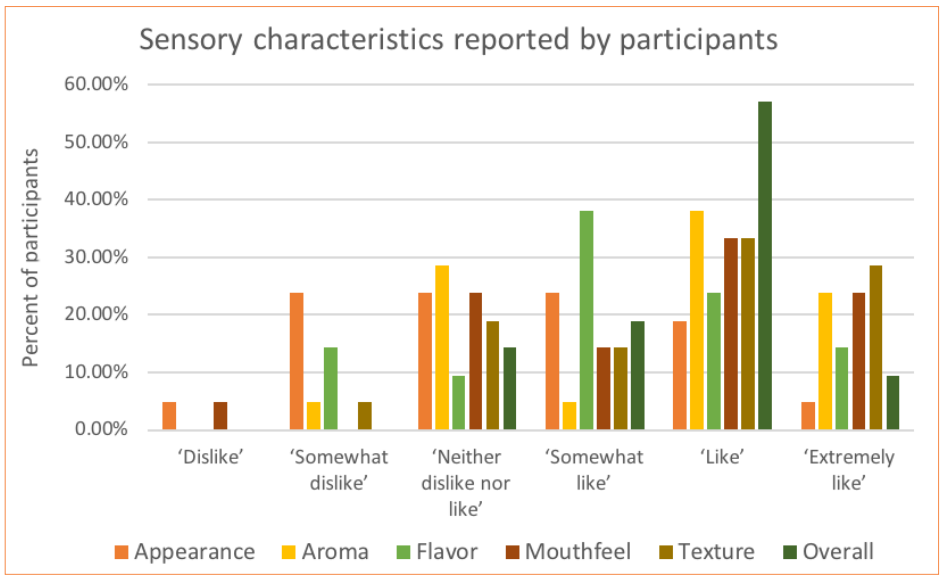


Figure 2. Evaluation of sensory characteristics

Research collaboration studies whether

CONSERVATION-BASED AGRICULTURE BOOSTS SOIL HEALTH, SUFFICIENT INCOME

to small-holder farmers in Sub-Sahara

Urszula Norton
Associate Professor
Department of Plant Sciences

Jay Norton
Professor
Department of Ecosystem Science and Management

The idea was conceived while sitting at a table drinking coffee and chatting about a recently released request for proposals funded by USAID (United States Agency for International Development) to conduct international studies in Feed the Future* countries.

We and two Ph.D. students from Kenya saw a unique opportunity to bridge the expertise from the University of Wyoming and research and extension capacities in Kenya and Uganda.

A few months later, Jay Norton led a group of scientists from the departments of ecosystem science and management, plant sciences, and agricultural and applied economics in the College of Agriculture and Natural Resources, and from the College of Business, with collaborating universities and non-governmental organizations from Kenya and Uganda. The group received $1.85 million for what the reviewers described as "The most out-of-the-box idea."

The now-completed, five-year study assessed the effects of adopting conservation agriculture (CA)-based strategies by small-holder farmers in the border region of Kenya and Uganda in many unique ways with the legacy reaching far and beyond the duration of the project.

Sub-Saharan agriculture

Small-holder farmers are predominant in sub-Saharan Africa, the region south of the Sahara Desert. They farm less than 1 acre and grow maize (*Zea mays* L.) intercropped with common bean (*Phaseolus vulgaris* L.) on heavy, weathered, and nutrient-poor soils by using deep (to a 10-inch depth or more) inversion-type tillage.

Animal-drawn plows and hand hoes invert the soil. Frequent deep tillage causes significant declines in soil fertility and crop yields. Weed competition is also a serious problem, and using tillage for weed control has not been very effective.

In addition, Mt. Elgon Highlands have a bimodal pattern of precipitation characterized by long and short rainy seasons. Crops are grown during one

Farmer collaborator Shadrack Tuwei, right, shows his field under reduced tillage to former University of Wyoming plant sciences Ph.D. student Dennis Oshilenje, left. Oshilenje was one of the collaborators on the research project and an instructor in the local NGO Manor House in Kitale, Kenya.

long growing season in the cooler, higher-elevation parts and during two growing seasons (long and short) in the warmer, lower-elevation areas. Year-round cropping and inversion-type plowing have resulted in soil degradation, increasing yield gaps and the overall major threat to sustainability of local farming and food security.

Adopting conservation agriculture strategies has become a necessity rather than a choice given projected increases in human population in the sub-Sahara.

CA strategies focus on reducing soil tillage, retaining post-harvest crop residue, and the inclusion of dinitrogen (N_2)-fixing cover crops in crop cycles.

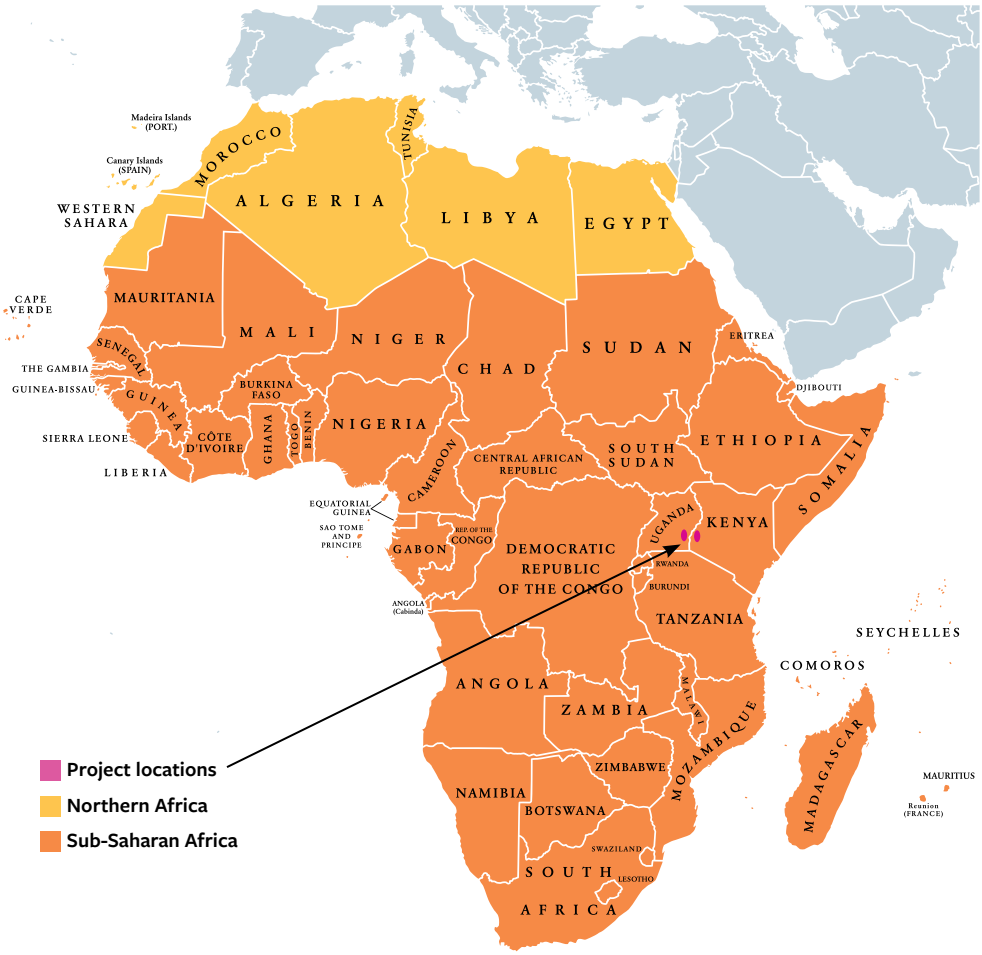
Although successful in many parts of the world, small-holder farmers in this region have had mixed successes. Limited adoption was largely caused by slow realization of the benefits associated with soil health during the first few years of the transition and limited understanding of the intermediate and longer-term advantages, especially weed control practices.

Transition from conventional to conservation agriculture

This project assessed environmental and socio-economic outcomes of CA practices using research tools that rely on farmer-researcher co-design and co-innovation. We wanted to evaluate the effects of transition from conventional maize/bean intercropping to CA tillage and cropping systems on weed populations, maize growth, and management costs.

We hypothesized reducing tillage and rotating maize/bean intercropping with cover crops would result in soil health improvements and declines in weedy species populations with no negative effects on maize performance.

The project was deployed at four locations around Mt. Elgon: two on the east side of Uganda and two across the border in western Kenya. Out of each two, one site was at the highlands (one



long growing season) and one at the lower elevation, where farmers are able to grow two crops per year.

Cropping systems consisted of a series of scenarios that included cover crops in typical maize-bean intercropping. Specifically, mucuna (*Mucuna pruriens* (L.) DC.) was relayed in maize and planted in maize interrows following bean harvest or planted in a strip-intercrop arrangement in which maize, beans, and mucuna were grown in monocultural strips narrow enough for advantageous interactions such as light interception and complementary root growth. Each system was planted using three tillage approaches: conventional moldboard plow, minimum tillage, and no tillage.

Understanding weed response during transition

This study suggested introducing minimum till and no-till resulted in immediate declines in weedy grass and forb populations. Not only did the overall grass and forb cover decline, but the most notorious weeds showed significant reduction. Reductions in weed density, however, were more pronounced at the higher elevation site, where crops are grown during one long growing season and managed with fewer tillage operations.

Greater declines in weed density in response to reduced tillage rather than new cropping systems confirmed to us that the effectiveness of using cover crops to control weeds may become evident later in the transition.

Reduced- and no-till approaches became viable options in socio-economic settings in which farmers have access and capital to purchase herbicides.

Alternate tillage approaches are also viable in areas where reducing tillage did not negatively impact crop production due to, for example, high accumulations of clay in the sub-surface soil horizons. Costs of manual labor, however, should be considered in relative terms, as some of the work was usually performed by family members, reducing the overall cash flow outside of the household. A combination of reduced tillage and herbicide use may bring the most desirable effects.

Soil health improves

Conservation agriculture practices improved soil health within the first five years. Our observations revealed greater soil organic matter loss and lower yields in regions where crops were grown during two seasons per year compared with one long growing season.

Growing crops during two growing seasons required more frequent tillage and resulted in shorter periods of soil rest. High soil organic matter mineralization with low plant residue returns and low overall yields suggested that continuing typical crop production in this region may ultimately become more challenging and unsustainable.

Small-holder farmers at lower elevations were in economic need to grow crops during two growing seasons; the alternative adoption of fallowing the land during short rains might limit success. Other alternatives may include government-supported incentives. Since the incidence of crop failure during short rains at low elevation was likely to become more frequent, focusing efforts toward one-season crop production during long rains may also be of value to farmers.

Conclusions and considerations

In general, the lack of immediate increases in farm income while transitioning to CA has been often associated with reduced success of CA adoption. Evidence suggested during the initial period of transition that declines in crop yields could discourage small-holder farmers from continuing and was driven by an inability to support family and generate income.

Since small-holder farmers generally value short-term returns more than long-term benefits, practices that reduce investments in labor and, ultimately, require fewer chemicals to combat reduced populations of weeds became beneficial. Better understanding of herbicide use, availability at local distribution outlets, and smaller packaging aided adoption of alternative tillage by smallholder farmers.

CA needs to cater to local climate, soil resources, and structure of the needs of the farmers. In addition, introducing new N_2-fixing cover crops required additional expenditures and reduced the amount of land otherwise allocated to grow food.

Finally, reducing or eliminating tillage also necessitated additional cost investments and replaced manual, family-contributed labor with chemical weed control.

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*Feed the Future is a U.S. government global hunger and food security initiative (www.feedthefuture.gov).

Plant sciences Associate Professor Urszula Norton, right, with the Shadrack Tuwei family.

LEGACY OF PROJECT LIVES ON

Many Ph.D. graduates in soils and plant sciences who attended the University of Wyoming are now back in Kenya and Uganda holding leadership posts as politicians, department heads, university scientists, and non-governmental organization leaders. **Judith Odhiambo** is now a lecturer and head of the Department of Crop and Soil Sciences, Kisii University in Kisii, Kenya. **Jeremiah Okeyo** and **Onesmus N'getich** are faculty members of the University of Embu. Former Ph.D. student and post-doctoral associate **Eusebius Mukhwana** is deputy commissioner of Higher Education in Kenya. **Rael Otuya** and **Dennis Ashilenje**, who originally worked in one of the collaborating NGOs, are now working on their Ph.D. degrees at UW and Ohio State University.

We think this project was a great "out-of-the-box" success. The legacy has grown in so many trajectories. Not only did the research set root in farmers' continuous efforts to adopt conservation agriculture practices, it also resulted in creating tremendous human capacity and built long-lasting legacies of human understanding across the globe.

— Urszula Norton
— Jay Norton

SCIENTISTS INVESTIGATE ANTICOCCIDIAL DRUG EFFICACY

Study could bring major advancements in controlling these harmful parasites

Livestock such as cattle suffer from many infectious diseases farmers and veterinarians fight every day.

Parasites are one very important group of disease agents. Effective antiparasitic drugs help agriculture by keeping animals healthy and production economically successful; however, most of the active ingredients have been used for decades, leaving parasites plenty of time to develop mechanisms to survive treatment.

Resistances are shown in parasitic worms and insects but also unicellular parasites, such as protozoa, adapt easily to heavily used drugs. They deal with antiparasitics by changing their metabolism to evade the toxic drug effects.

Coccidia cluster

One group of protozoa called coccidia represents a cluster of parasites that harm livestock including cattle, sheep, goats, poultry, and rabbits. Coccidia mostly reside in the gut of one specific animal species and damage the gut mucosa. Especially in young animals, these parasites provoke diarrhea, fluid and weight loss, and reduced animal growth, and can cause death. Once fully developed in surviving animals, the parasite is excreted with feces and is ready to infect the next host by feed contamination.

In cattle, we see coccidia on nearly all farm operations. There are no recent investigations on the prevalence of cattle coccidia in the U.S.; however, studies from Europe show that up to 95 percent of calf-rearing farms struggle with coccidia. Calves, heifers, and young steers are most prone to the related disease called cattle coccidiosis. Many farmers suffer immense financial losses due to coccidiosis.

Long-term effects like lower final adult body weight and prolonged increased feed costs occur in affected animals and herds. The cattle industry relies heavily on chemical drugs (anticoccidials) to alleviate the animal health and financial implications of coccidiosis. Unfortunately, all four anticoccidials available on the U.S. market have been sold and used for up to 50 years, and they are used every day on most cattle-rearing farms. That implies parasites are under constant treatment pressure not

Berit Bangoura
Assistant Professor
Department of Veterinary Sciences

only in the U.S., but worldwide, and may develop resistance.

Interestingly, no study is available that investigates the current level of drug efficacy against coccidia.

Studies in chickens show coccidia can develop resistance within a few years, and we know that in poultry there are many multi-drug resistant strains widespread in the field.

Anecdotally, we know farmers are dissatisfied with the efficacy of the anticoccidial treatment they apply to young cattle. There may be many reasons contributing to reduced treatment effects, such as underdosing of the drug or a too-short treatment period; however, diagnostic fecal samples submitted from operations using a strict regimen of anticoccidial drug treatment often contain pathogenic coccidia, some in alarming amounts.

How widespread is resistance?

In light of these field findings and the known economically threatening scenario in chickens, we developed the plan to investigate the resistance situation in cattle

Photo: Steve Miller

coccidia. These are the major questions driving our research:

- Are these bovine parasites already resistant against our few available anticoccidial drugs?
- How widespread is the resistance, and is there any drug that should be preferably used?

We asked cattle producers in Wyoming and Colorado to answer standardized questions regarding their management and husbandry conditions as well as the farm history of anticoccidial treatments.

We visited the farms of those willing to cooperate and collected fecal samples from different age groups of young cattle. The feces were analyzed for coccidia, and positive samples were stored and the parasites purified from the fecal matter. They were passaged through calves to obtain enough material to conduct the drug resistance testing.

The recovered parasites from various field strains are the starting point for the following investigations. Though not yet complete, the first important step is the development of a suitable cell culture readout assay that can serve as the basis for the drug resistance assessment in cattle coccidia. No such test system is known to be available at other laboratories. By establishing this assay, we look forward to gathering significant data on the drug resistance situation using modern parasitological tools.

Collected cattle coccidia

The study design includes the infection of bovine cell cultures with the collected cattle coccidia strains. In the cell culture setup, the parasites will invade the bovine cells and start to multiply within them, just as they would in the gut of young cattle. We can develop an assay to test drug efficacy without the need of extensive animal experiments. The cell cultures are grouped in parasite-infected, untreated cultures that allow the parasites to multiply without limitations, and infected and drug-treated cultures.

From the control cultures, we can measure the parasite number formed in a given time if optimal conditions exist. In the other cell cultures, parasites are challenged with the different drugs and expected to grow and multiply much less if the drugs are effective. In the end, the genetic material from each cell culture will be isolated and tested. We can calculate the number of parasites per treatment group and know if the treatment was able to reduce the parasite growth significantly.

Drug resistance is indicated if we discover the treatment did not lead to highly reduced parasite numbers

Photo: Christopher Boswell, Shutterstock

in our cultures. Such resistance will be examined for all available drugs. We will be able to tell if there are resistances, and how widespread they are; in other words, how many different field strains of coccidia from Wyoming and Colorado are affected.

Right treatment for specific strain

This pilot study will deliver important insights into the efficacy of anticoccidial drugs used every day in the U.S. cattle industry. Any resistances detected would strongly confirm prior findings of lacking drug efficacy in the field and would have a great impact on cattle farming. Farmers would have to ensure the anticoccidial treatment they apply is the right choice for the coccidia field strains on their operations.

Farm-specific advice on the most suitable anticoccidial drug would not only be necessary, but available once our assay is validated.

Our hope is the study brings major advancements to controlling these harmful parasites. Nonetheless, now is the time to address the ever-present challenge of coccidiosis in cattle rearing on an evidence-based treatment regimen instead of fostering resistance development by untargeted drug use.

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Photo: Maria Jeffs, Shutterstock

Photo: Tamarah Jorns, USDA-ARS

RESEARCH UNWRAPS COSTS OF FIVE GRAZING SITUATIONS, DETERMINES WHICH MOST PROFITABLE

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Preserving and passing the land on to future generations has been noted as one major reason ranchers stay in the livestock business despite its mental, physical, and financial hardships.

Although profit and economic incentives are not always the driving forces behind decision-making, ranchers would still choose the most profitable management strategy to ensure the legacy of the ranch.

Many ranchers use rotational grazing to rest pastures from grazing each season and change the timing of grazing in pastures across years; however, rotational grazing is reported to be more expensive regarding initial costs for infrastructure (fencing and water), and ecological advantages have been elusive in scientific literature compared to other grazing systems, specifically continuous grazing systems.

A review of past research shows many instances in which continuous grazing outperformed rotational grazing in both plant and animal production and economics, or where there were no significant differences between the two systems; however, there must be

some reason ranchers choose rotational grazing despite these findings.

Compare continuous, rotational grazing

A collaborative long-term study comparing continuous and rotational grazing systems using a ranch-scale approach was started in 2012 between the University of Wyoming, the USDA Agricultural Research Service, Colorado State University, Texas A&M, and a stakeholder group of resource management professionals.

Data is collected on the effects of each grazing system on vegetation, wildlife numbers, and habitat (specifically grassland bird species of concern), and livestock productivity. Our focus is on the economics of the two grazing systems taking into consideration the infrastructure and labor costs and the revenue generated based on livestock performance.

The cost differences between the two grazing systems include fencing and water (including wells, windmills, and stock tanks) infrastructure, and labor required for regular care of the cattle and for moving the cattle among pastures.

We assessed five scenarios to cover a larger variety of actual ranch configurations (Figure 1):

1. One large 3,200-acre pasture, continuously grazed,
2. One large 3,200-acre pasture cross-fenced into ten 320-acre individual pastures using barbed-wire fencing or
3. One large 3,200-acre pasture with temporary electric fencing and rotationally grazed,
4. Ten non-contiguous 320-acre pastures grazed continuously, and
5. Ten non-contiguous 320-acre pastures with larger water tanks rotationally grazed.

We assume improvements to infrastructure will be mortgaged, with costs spread over the life of the infrastructure to mimic real-world conditions. For example, ranchers do not install new fence or replace fence all at once, so we calculated the equivalent annual cost for all infrastructure spanning the payments across the life of the infrastructure while also accounting for interest, depreciation, and risk.

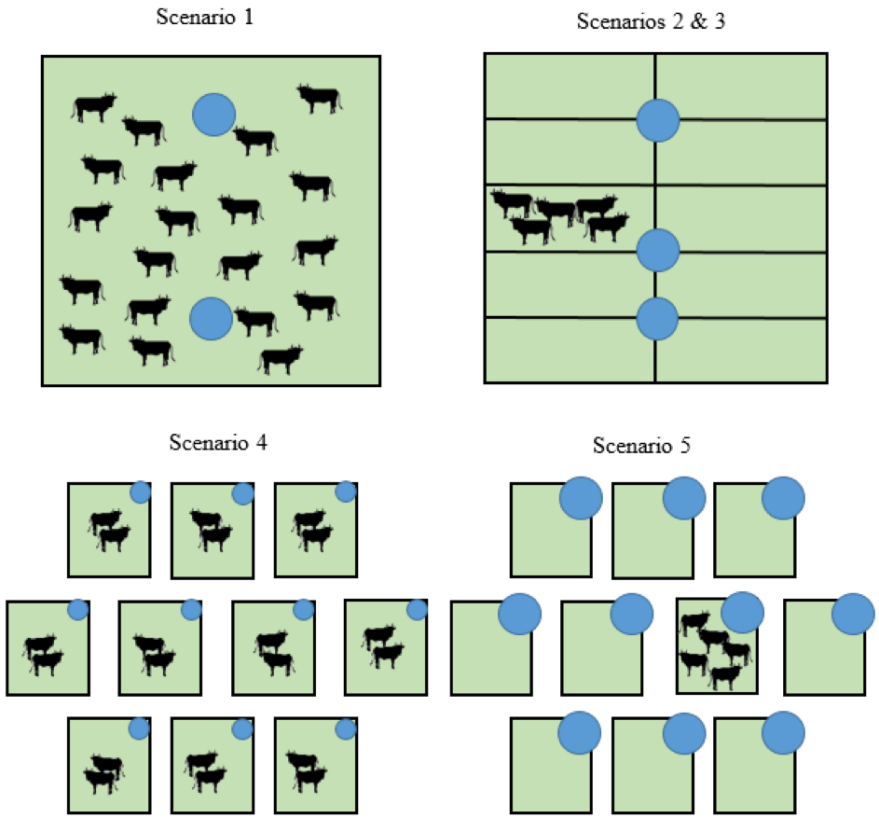

Figure 1. The five scenarios we use to model costs are: 1) one large pasture, grazed continuously, 2) one large pasture subdivided using permanent barbed-wire fencing, rotationally grazed, 3) one large pasture subdivided using temporary electric fencing, rotationally grazed, 4) ten non-contiguous pastures, grazed continuously, and 5) ten non-contiguous pastures, rotationally grazed.

Decreased labor offsets infrastructure increases

As expected, costs increased across the scenarios as the amount of infrastructure required increased (Figure 2). However, contrary to the rotational grazing increasing infrastructure costs, the consolidation of the entire herd in a 320-acre pasture

decreased weekly checking times (labor costs) for Scenarios 2, 3, and 5.

Due to size, the large 3,200-acre pasture increased checking times in Scenario 1, but the largest time requirement came with checking all 10 individual, dispersed pastures of Scenario 4.

Scenarios 4 and 5, being non-contiguous pasture systems, also had the added cost of moving the cattle out to and back from pastures at the beginning and end of the grazing season (Scenario 4), as well as through the pastures for the grazing rotation (Scenario 5). Added labor costs for rotational grazing were not realized compared to the added costs of checking cattle in dispersed or contiguous pastures with continuous grazing.

After determining annual cost differences between grazing systems, we then calculated revenues generated by the sale of livestock (yearling steers in this case). Prior controlled, scientific studies have consistently shown that even when stocked at the same rates, rotational grazing results in similar or lower seasonal weight gains for individual animals than continuous grazing systems.

Here, the stocking rate was the same between grazing systems, but stocking density was 10-fold greater with rotational grazing, and the yearling steers in the rotational grazing treatment consistently exhibited a 12-16 percent reduction in seasonal individual animal weight gains. However, a market phenomenon known as a price slide has the potential to make this difference much less impactful in terms of revenue generated per head. The price slide results in lighter weight steers selling for a slightly higher price per hundredweight (cwt) than their heavier counterparts.

We used market price data from Colorado over the last 20 years for each weight class of cattle at the start and end of the grazing season for each study year. The prices were run through a Monte Carlo simulation to determine the probability of the steers selling for each price over multiple years and ensuring correlations of cattle prices across weight classes.

When comparing the value of gain on a per-head basis across the average simulated prices for each year (value per animal at the end of the grazing season less the value of the animal at the start of the grazing season), we found there was statistically no difference in the values of the steers from each grazing system based on actual animal performance in most years.

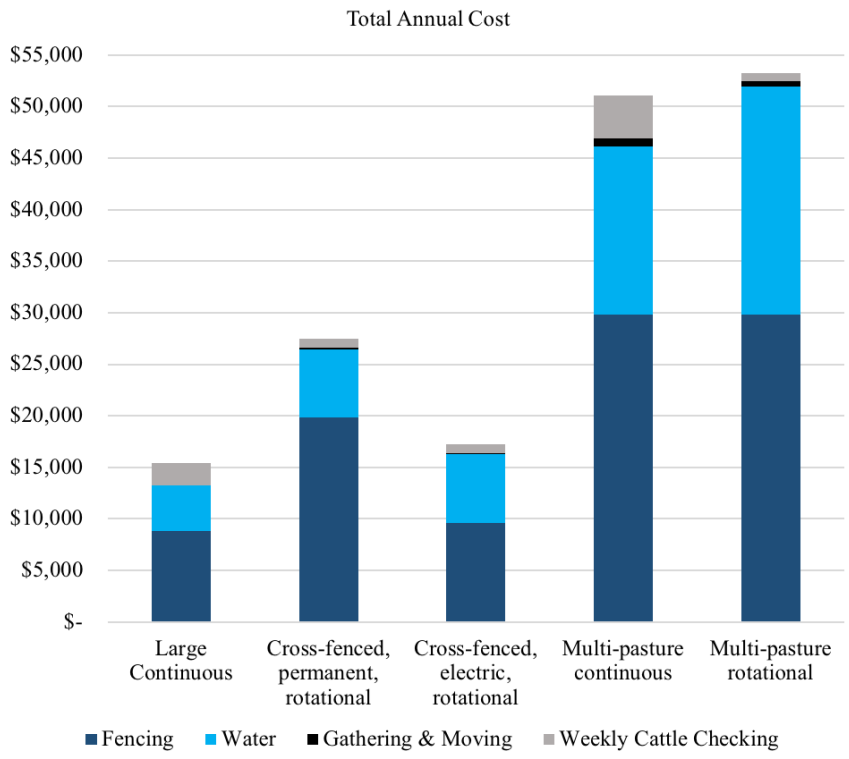

Figure 2. Total annual costs for fencing infrastructure, water infrastructure, and labor costs for each of the five scenarios.

Non-contiguous grazing highest costs

Given we only accounted for costs that changed between the two grazing systems, and not total costs, we can only suggest the differences in profits related to switching from a continuous to a rotational grazing system. Due to our revenues generally not differing between the two grazing systems, profit differences are a direct result of the cost differences between the different scenarios. These profit differences range $2,000 to $12,000 a year for our contiguous pastures depending mainly on the type of cross-fencing used, and about $2,000 a year

for our noncontiguous pasture systems; however, when looking at the contiguous compared to the non-contiguous pastures, the profit differences increase to as high as $38,000 a year.

Our results suggest ranchers who have contiguous parcels of land incur much lower infrastructure costs than those who have noncontiguous ranches and will likely have more profitable operations by using a continuous grazing system.

One caveat in this study is that the noncontiguous pastures are no more than 6 miles away from each other, but in a landscape as vast as Wyoming, noncontiguous ranches could have much greater distances between pastures.

One application of this data is for young ranchers just starting out and who may not have the funds to lease or purchase a contiguous ranch. An additional eight hours a week spent checking cattle would be necessary for our Scenario 4 costs to equal Scenario 5 costs, a difference that could easily result from greater travel distances.

All of the rotationally grazed scenarios, although requiring a higher infrastructure investment, had lower labor costs and used 20-60 percent less time on a weekly basis than the continuously grazed scenarios.

Future economic research should focus on additional returns, such as grass banking opportunities for drought mitigation, bird habitat creation, or other risk management and ecosystem services that rotational grazing might create to offset some of the added infrastructure costs.

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Photo: Tamarah Jorns, USDA-ARS

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