Soil Amendment Addition and Microbial Community Recovery Following High-Severity Fire

ROGERS RESEARCH SITE, NORTH LARAMIE MOUNTAINS, WYOMING

By Claire D. Wilkin, Stephen E. Williams, Linda T.A. van Diepen,
Michael A. Urynowicz, Larry C. Munn, and Robert W. Waggener

University of Wyoming
Agricultural Experiment Station

Rogers Research Site Bulletin 8
February 2019

ROGERS RESEARCH SITE BULLETIN 8: SOIL AMENDMENT ADDITION AND MICROBIAL COMMUNITY RECOVERY FOLLOWING HIGH-SEVERITY FIRE, ROGERS RESEARCH SITE, NORTH LARAMIE MOUNTAINS, WYOMING

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Layout and design by Tanya Engel

University of Wyoming College of Agriculture and Natural Resources

Wyoming Agricultural Experiment Station

This is Bulletin 8 in an ongoing series focusing on research, teaching, extension, and other activities at the University of Wyoming's Rogers Research Site (RRS) in the Laramie Mountains, north Albany County, Wyoming. The approximate 320-acre site was bequeathed to UW in 2002 by Colonel William Catesby Rogers.

Colonel Rogers spent much of his retirement time at the mountainous, remote property, which he called the Triple R Ranch. UW renamed the property "Rogers Research Site" in memory of Colonel Rogers, who passed away in 2003 at age 96.

The February 16, 2002, amended living trust of Colonel Rogers states that:

> said ranch be used for the public benefit as a center for studies, a retreat for conducting meetings, conducting conferences, or conducting research in connection with the improvement of wildlife and forestry, or to hold as a natural wooded area in its original state with specific instructions that no part of it be subdivided or sold for residential or private business purposes but held as an entire tract. Said restriction is to continue in perpetuity. If violated, said property shall revert to the ownership of the U.S. Forest Service.

Overseeing management of RRS is the Wyoming Agricultural Experiment Station (WAES), UW College of Agriculture and Natural Resources. RRS is placed administratively under one of the WAES research and extension centers, the James C. Hageman Sustainable Agriculture Research and Extension Center (SAREC) near Lingle, Wyoming.

SUGGESTED REFERENCE

Wilkin, C. D., Williams, S. E., van Diepen, L. T.A., Urynowicz, M. A., Munn, L. C., and Waggener, R. W., 2019, Soil amendment addition and microbial community recovery following high-severity fire, Rogers Research Site, north Laramie Mountains, Wyoming: University of Wyoming, Wyoming Agricultural Experiment Station, Rogers Research Site Bulletin 8, *iv* + 64 p.

ON THE COVER

Co-author Steve Williams on July 18, 2012, collects soil samples at RRS. This photo was taken just over two weeks after the Arapaho Fire burned across RRS and surrounding lands. Because of the fire's intensity, the majority of RRS and surrounding lands had nothing but ash and dead trees remaining. (Photo by Stanley Bellgard)

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Issued in furtherance of State Agricultural Experiment Station work of the 1887 Hatch Act, as amended through public law 107–293, November 13, 2002, in cooperation with the U.S. Department of Agriculture. Bret Hess, director, Wyoming Agricultural Experiment Station, University of Wyoming, Laramie, Wyoming 82071.

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ABOUT THE AUTHORS

CLAIRE D. WILKIN

Claire Wilkin is among the University of Wyoming graduate and undergraduate students who have conducted research at or relating to the Rogers Research Site (RRS) in the north Laramie Mountains of southeast Wyoming.

While earning her master's degree at UW, Wilkin focused her studies at RRS on pre- and post-fire soil comparisons, work that is detailed in RRS Bulletin 7; and nutrient additions and soil microbial community recovery following the 2012 Arapaho Fire, research that is detailed in this bulletin.

Her faculty advisers were co-authors Stephen Williams and Michael Urynowicz, and she was also mentored by former UW Professor Patricia Colberg, now department chair, professor, and National Academy of Education fellow at the University of Idaho's Department of Civil and Environmental Engineering.

Wilkin was awarded a master's degree in environmental engineering at UW in 2014. This effort led to the publication of her 81-page master's thesis, *Soil Amendments and Microbial Community Recovery Following High Intensity Forest Fire*, which provided the base work for this peer-reviewed bulletin.

Prior to coming to UW, Wilkin earned a bachelor's of engineering degree in bioresource engineering from McGill University, Montreal, Quebec, Canada, in 2010.

After graduating from UW with her M.S., Wilkin was hired by WSP|Parsons Brinckerhoff, a global engineering and professional services firm that has since become WSP. Initially based in San Francisco, California, Wilkin was later transferred to WSP's environmental division in San Jose, California, where she is now an assistant environmental engineer with the company.

Wilkin says that she enjoys solving problems where innovative solutions are applied to complex environmental challenges. Her duties include project management, technical oversight, and regulatory reporting on projects involving site characterization, remedial investigation, and implementation, and water treatment system permitting and operations.

"I am interested in opportunities to contribute to groundwater and surface water management for urban and watershed-scale problems," Wilkin says. "I would say that my most interesting work involves groundwater—well drilling, injections, monitoring, pumping, and treating, anything that lets me see the subsurface!"

Among the causes that Wilkin's cares about are economic empowerment, education, the environment, health, human rights, and science and technology.

Claire Wilkin, here relishing a winter outing among snow-covered conifers, enjoyed participating in triathlons while she was a graduate student at the University of Wyoming.

STEPHEN E. WILLIAMS

University of Wyoming Professor Emeritus Steve Williams has been at the forefront of early research and planning at the Rogers Research Site (RRS), both before and after the 2012 high-intensity Arapaho Fire.

Williams advised lead author Claire Wilkin while she carried out soil studies at RRS, and he also mentored UW graduate student Mollie Herget, lead author of RRS Bulletin 5, which details an ongoing post-fire ponderosa pine restoration study at the 320-ac (~130-ha) site in southeast Wyoming's Laramie Mountains. He also conducted a soil-borne pathogenic fungi study at RRS with plant pathologist Stanley Bellgard of New Zealand.

Williams co-authored six of the first eight peer-reviewed bulletins in the RRS series, and says that his time spent at the site was a very memorable part of his nearly four-decade career at the university.

"At UW I was able to renew long-standing interests in forest, range, and wildland soils. Now, looking back, I realize how much I learned from other faculty, and also from my

Steve Williams has spent much of his career enjoying the great outdoors, studying forest, range, and wildland soils while collaborating with scientists and mentoring students. "This picture shows me in the process of excavating a soil sample in one of New Zealand's kauri forests. Though it might seem like work, it is also the ultimate in recreation," Williams says.

Co-author Linda van Diepen on September 30, 2016, conducts ponderosa pine seedling surveys at one of the restoration study plots at RRS. (Photo by Elizabeth Traver)

students, including those I worked with at the RRS."

He adds: "Late in my career at UW, I started work at the RRS, a new site slated for forestry- and wildlife-related research in the Laramie Peak area of southeast Wyoming. The ecosystems at RRS have taught me much, but I am cowed in the face of what we do not know."

Williams earned a B.S. degree in biology from New Mexico State University in 1970, an M.S. in agronomy from NMSU in 1972, and a Ph.D. in soil science from North Carolina State University in 1977. While finishing his doctorate, Williams was hired by the UW Department of Plant Sciences as an assistant professor of soil science. He was promoted to associate professor in 1984 and professor in 1987.

"My focus has been applied to microbial amelioration of contaminants including hydrocarbons and toxic metals; large-scale disturbances such as fire, intense grazing, and climate change; and amelioration of lands drastically disturbed during energy development or extraction, including surface mines, oil and gas pad development, and disturbances related to wind farm development and road construction," he says.

While at UW, Williams taught a variety of courses in the Department of Ecosystem Science and Management, including environment and society, agroecology, soil microbiology, soil classification genesis and morphology, readings in microbial ecology, forest and range soils, and soil biology and biochemistry.

He advised or co-advised more than 30 graduate students, and was also on the graduate committees of nearly 140 M.S. and Ph.D. students in departments across campus.

In addition to his teaching, research, and advising, Williams served as head of the Department of Plant Sciences from 1993 to 1998, was dean of the UW Graduate School from 1998 to 2003, and directed the Wyoming Reclamation and Restoration Center within the College of Agriculture and Natural Resources from 2007 to 2009.

Since retiring in 2013, Professor Emeritus Williams and his wife, UW Professor Emeritus Karen Cachevki Williams, have operated an environmental and educational consulting business based in Laramie, Wyoming.

LINDA T.A. VAN DIEPEN

Linda van Diepen, along with several graduate and undergraduate students she has and is mentoring, began conducting vegetation- and soils-related studies at the Rogers Research Site (RRS) shortly after coming to the University of Wyoming in 2015.

"I was fortunate to inherit the post-fire restoration experiment set up at RRS by Dr. Steve Williams and others (detailed in RRS Bulletin 5)," van Diepen says. "RRS is a great site for conducting post-fire ecosystem recovery studies, and in addition to the ongoing vegetation and soils measurements, the site offers a great opportunity to do many other studies, including wildlife responses to fire, grazing potential, forest management, entomology, and others."

Van Diepen joined the faculty in the UW Department of Ecosystem Science and Management as an assistant professor. Her research focus is ecosystem ecology, with an emphasis on the role of the microbial community in biogeochemical processes such as nutrient and carbon cycling.

"I am interested in understanding the responses of an ecosystem to various disturbances and how soil processes and plant-microbe interactions mutually control these ecosystem responses," van Diepen says.

She earned B.S. (1999) and M.S. (2002) degrees in environmental science in The Netherlands, and a Ph.D. (2008) in forest science at Michigan Technological University, Houghton, Michigan.

From 2009 to 2010, van Diepen was a postdoctoral fellow at the University of Michigan, Ann Arbor, Michigan. She then worked as a postdoc and later as a research scientist at the University of New Hampshire, Durham, New Hampshire, where she studied fungal ecology.

She has co-authored more than 20 peer-reviewed publications and co-presented over 40 abstracts and posters at scientific meetings across the country.

MICHAEL A. URYNOWICZ

Michael Urynowicz is a professor of environmental engineering in the University of Wyoming's Department of Civil and Architectural Engineering. He has been involved in a wide range of research; however, of particular interest are field studies like the work performed at the Rogers Research Site. "These types of projects afford students and faculty alike with exceptional opportunities to better understand the complexities of natural systems through controlled experimentation," he says.

Since joining the faculty at UW in 2002, Urynowicz has advised more than 15 M.S. and Ph.D. students, and has served on the research committees of more than 20 graduate students. He teaches a variety of undergraduate and graduate classes, including environmental engineering microbiology, solid waste engineering, hazardous waste site remediation, and engineering economics.

He earned a B.S. in chemical engineering at Michigan State University in 1990, an M.S. in civil and environmental engineering at the University of Wisconsin in 1995, and master's and doctorate degrees in environmental science and engineering at the Colorado School of Mines in 1998 and 2000.

Urynowicz was hired as an assistant professor at UW in 2002. He was promoted to associate professor in 2008 and professor in 2014. He has been involved in many projects while at UW, including analysis of evaporation rates and drift patterns for mechanical evaporators, enhanced natural attenuation using fast and slow oxygen releasing compounds, and laboratory testing to support ASTM methods for determining permanganate soil oxidant demand.

Professor Urynowicz is faculty co-adviser of the UW Chapter of Engineers Without Borders, and he directs the Center for Biogenic Natural Gas Research within the UW School of Energy Resources. In that role, he has been involved in a number of projects relating to low carbon renewable natural gas production from coalbeds, the implications for carbon capture and storage, and enhanced microbiological generation of coalbed methane.

University of Wyoming Professor of Environmental Engineering Michael Urynowicz works with a student while on a trip to Honduras in 2010.

LARRY C. MUNN

Larry Munn is a professor emeritus of soil science in the University of Wyoming's Department of Ecosystem Science and Management. He started as an assistant professor at UW in 1981, and was promoted to associate professor in 1986 and professor in 1992. Munn began conducting soil studies at the Rogers Research Site (RRS) in 2009, and that work continued after the 2012 Arapaho Fire.

Since retiring in 2014, he completed his writing and soils mapping work for RRS Bulletin 6 (soils of the Rogers Research Site), and he since became involved in the work on this bulletin as well as RRS Bulletin 7 (pre- and post-fire soil comparisons).

Munn says that the site has good potential for additional research and teaching, and he encourages both graduate and undergraduate students to develop and carry out studies with their faculty mentors. "I believe there are many opportunities up there, for example, a soil genesis project and the post-fire restoration of organic matters in the forest soils over time."

While at UW, Munn focused his research across Wyoming on soil genesis, morphology, and classification; soil–native plant community relationships; mine land reclamation; and the effects of coal-bed methane development on soils and landscapes. Munn taught a number of soils-related undergraduate and graduate classes at UW, and also led special-topic courses focused on the research of soil–geology–plant relationships in native, agricultural, and drastically disturbed ecosystems. He received the John P. Ellbogen

Larry Munn obtains Global Positioning System coordinates in 2012 at one of the sites in and adjacent to RRS where soils were sampled. This particular work was carried out shortly before the Arapaho Fire burned across RRS and surrounding lands in the north Laramie Mountains of southeast Wyoming, providing important baseline data for future research at the site.

Meritorious Classroom Teaching Award in 1993 and was named the UW College of Agriculture's "Outstanding Teacher" in 1999.

After serving his country in the Vietnam War, Munn earned a B.S. in agronomy (emphasis on soils) in 1972 from The Ohio State University, an M.S. in natural resources (forest soils) from OSU in 1974, and a Ph.D. in crop and soil science (range soils) from Montana State University in 1977. After joining the faculty at UW, Munn served on the western regional coordinating committee of the National Cooperative Soil Survey (NCSS), including two years as committee chair; the soil taxonomy and soil interpretations committees of the NCSS; and the soils and geomorphology committee of the American Society of Agronomy.

Munn retired on a small-acreage near Laramie, where he and his wife, Mary Lynne, enjoy raising an assortment of animals including horses, dogs, and chickens. He is a member of the Board of Supervisors of the Laramie Rivers Conservation District, one of 34 conservation districts across Wyoming.

Since his childhood days growing up in Green River, Wyoming, Robert Waggener has enjoyed exploring the state's great outdoors, from the Green River Basin, Red Desert, and Wind River and Absaroka ranges of western Wyoming, to the Bighorn Mountains in the north-central part of the state, to the Snowy Range and Laramie Mountains of southeast Wyoming. Among his adventures were winter ascents of Cloud Peak, elevation 13,171 ft (4,014 m), the namesake mountain of Cloud Peak Wilderness in the Bighorns.

ROBERT W. WAGGENER

Rogers Research Site (RRS) bulletin project manager and co-author Robert Waggener has been involved in the development of the first eight RRS publications, work that he oversaw for the Wyoming Agricultural Experiment Station (WAES) and one of its four Research and Extension centers, the James C. Hageman Sustainable Agriculture R&E Center (SAREC) near Lingle, Wyoming.

WAES and SAREC manage the 320-ac (~130-ha) site in the north Laramie Mountains, land that was bequeathed to the University of Wyoming by Colonel William C. Rogers.

Waggener, a freelance editor, writer, and photographer, calls his work on the peer-reviewed RRS bulletin series one of the most rewarding challenges of his career. It has combined his interests in agriculture, natural resources, and the great outdoors with his experience in editing, writing, background research, photography, project management, and completing tasks at hand.

In addition to working with nine co-authors to complete the first eight bulletins, Waggener collaborated with more than 100 people to bring the entire project together, and it was his intention to acknowledge each and every person in the Acknowledgments section of the publications.

Among Waggener's goals for the RRS bulletin series are to detail studies that have taken place at the site, and provide important background information for future site planning and research.

And, just as important, he hopes the bulletins inspire students, both undergraduate and graduate, to work with faculty mentors and others on projects that will benefit the many resources that this rugged, remote range has to offer, including a variety of habitats that support a myriad of plant and wildlife species.

STANDING ON THE COLONEL'S SHOULDERS

Colonel William C. Rogers lived proudly, and he died proudly after taking a bold step

By Robert Waggener

> *"One should die proudly when it is no longer possible to live proudly."*

This quote by the German philosopher, composer, and poet Friedrich Nietzsche most likely followed the physically ailing Colonel William C. Rogers from his remote Triple R Ranch in Wyoming's north Laramie Mountains to a caregiving facility in California. That's where this deeply proud, fiercely independent man began to see his adventurous life unravel. His doctor had recommended a move to a lower-elevation locale because of ailments including severe arthritis and a bleeding ulcer, and he chose an assisted-living center in Redwood City because he didn't want to ask friends for help. "All of that was hard to watch because here was a man with so much pride, a man who worked so hard on his land," says Colleen Hogan, who, with her mother and stepfather, became close friends with Rogers during summer visits to his property.

Now, instead of entertaining friends amongst towering ponderosa pines, driving his Ford Bronco to the Platte County Library for a day of reading, or venturing to Mexico to study the Tarahumara Indians, Rogers was confined to a small bedroom with bare walls and little elbow room. Here, he continued to peruse the *Wall Street Journal* and actively invest in stocks, but contented days spent caring for the mountainous tract he purchased for retirement were now behind him—and so was his driving spirit.

University of Wyoming Professor Rebecca Hilliker had heard story after story about Rogers, and was expecting to meet a vibrant, energetic man when she traveled to Redwood City to discuss a possible financial donation to the UW Department of Theatre and Dance. Instead, she found a demoralized man who was no longer living life proudly. "He was miserable there. He just hated it," Hilliker remembers of her first trip in the late 1990s to meet Rogers. "The assisted-living facility didn't suit him; that just wasn't his style. Colonel Rogers said he was tired of being in that place so we took him out to lunch."

Within hours, Hilliker began to see the person that she had heard so many stories about, the person that friends either called "Bill" or "The Colonel." Spending time outside, away from the confines of the caregiving facility, cheered Rogers, made him feel much better, remembers Hilliker, who quickly learned about his passion for literature, music, theater, and dance. He was in his early 90s at the time and had saved a vast fortune—reportedly more than $50 million—from his inheritance, military career, work on railroads, active stock trading, and frugal lifestyle, including wearing hand-me-down clothes. And he wanted to put his estate to good use both before and after his death.

During her visit, Hilliker says that Rogers excitedly talked about film festivals he had attended, including the famous Telluride Film Festival in Colorado's mountains. "At the time, we didn't have any equipment to make films or teach acting-for-the-camera at UW," says Hilliker, then chair of the university's Department of Theatre and Dance. When she relayed that information to Rogers, he replied: "If I give you some money will you add that to your program and your curriculum?"

Hilliker responded enthusiastically, and as their lively conversation continued she learned of The Colonel's retirement property in the Laramie Mountains, where he would spend summers reading books by Nietzsche and other poets, novelists, playwrights, and philosophers, including Fyodor Dostoyevsky, D. H. Lawrence, Oscar Wilde, and Johann Wolfgang von Goethe; typing letters to friends and acquaintances around the world; and working extensively on his own research and writings.

Hilliker, like many of The Colonel's friends, would learn that he adored his time spent in the Wyoming mountains, where he raised fruits and vegetables in a small garden, collected cow patties to make compost, pruned pine trees, cut firewood, and enjoyed cold beer, salted peanuts, and good conversation with friends from near and far. Rogers wasn't a man to show emotion, but Hilliker knew that he was crying inside. "He was really sad to leave that property because he loved being up there. He really was an outdoors kind of person. He loved the wildflowers. He loved the mountains. He loved the trees. He didn't want to leave his land behind, but he really had no choice because he just physically couldn't do it anymore. His arthritis had gotten too bad."

Friends back home in Wyoming also learned that Bill was ailing from arthritis and depressed by his confinement to the assisted-living facility. Among them were Casper school teacher Levida Hileman and daughter Colleen Hogan, who helped with chores around his property during summer visits years earlier. "While cleaning out some drawers this morning, I came across two letters written to me by The Colonel in his declining years," Mrs. Hileman told the author of this story in spring 2017. "They are a little sad for me to read as he was such a proud man—always a proud man."

Colleen also corresponded with her friend Bill during his last years in California. "Sometimes The Colonel would share stories in his letters. He would also talk about the weather. Toward the end, he talked about how painful his arthritis was and that he didn't want to go to a nursing home," she says. Concerning the latter, the ordinarily pennywise Rogers finally took matters in

Figure 1. Following his retirement from the military and railroad work, Colonel William C. Rogers, his property's caretaker, and guests lived in cabins like this one, dubbed the "Original House" by friends interviewed for this story. In a June 4, 1966, letter that Rogers wrote to a prospective tenant, he stated that water from a spring that never freezes flows into the kitchen sink of one of the cabins. This particular cabin, in addition to a root cellar behind the structure, burned down one summer when The Colonel accidentally started a fire with hot ashes. The majority of other structures on the property, including the "Original House," were destroyed during the 2012 lightning-caused Arapaho Fire. (Photo from the William C. Rogers Papers, University of Wyoming American Heritage Center [AHC])

hand, splurging on a nice home in Carmel, California, and hiring caretaker friends to help him as his physical health continued to decline. Relying on others for help was a bold step for Rogers, but it helped to allow his mental health to quickly improve. "On my next visit to California, he was now living in the home with his caretakers, and he was happy," Hilliker says. "He was in a wheelchair by then, and he would paddle himself around in the chair by shuffling his feet. His caretakers would help him clean the house, and they would take him to the library every day. He enjoyed spending time there, and he enjoyed doing other things that gave him a more fulfilling life. You could see that. He was feeling like he had a genuine life again, something that wasn't controlled by all of these other forces in the assisted-living place. He was glad to get out of there."

Rogers continued reading the *Wall Street Journal*, day-trading literature, and other publications focused on the markets and investing, and he continued investing in his favorite stocks, knowing that one day the proceeds would benefit causes and institutions he believed in. By the late 1990s, his favorites included several Internet-based companies in which he invested heavily. These companies were part of the "dot-com bubble" that started around 1997 and peaked in 2000. "I heard that his main caretaker had lectured him over and over and over and over again, saying: 'Bill, you have to diversify. You really have to diversify.' Colonel Rogers would respond, 'Well, I am doing so well. Every day I make a lot more money.' Yes, he was making money hand over fist. And all of a sudden, much of it was gone," Hilliker says.

Cheyenne attorney Greg Dyekman did not know Rogers personally, but he became involved in matters relating to his estate on behalf of the University of Wyoming Foundation. He said that UW Foundation Chief Executive Officer Ben Blalock and then UW President Philip Dubois had traveled to California to meet with Rogers at the assisted-living facility. "Ben and Phil went out there because they were told Colonel Rogers had a very large estate and that much of it was coming to the university. They wanted to get to know The Colonel and understand his philanthropic purposes," says Dyekman, a UW Foundation emeritus board member. "But toward the end of his life Colonel Rogers suffered major financial losses because his self-traded portfolio wasn't adequately diversified."

Figure 2. For several years after purchasing his property in the Laramie Mountains, Colonel Rogers and others used this root cellar to store vegetables from a garden on the property. In a 1966 letter to a prospective tenant, Rogers stated that the garden is irrigated by spring water. He added in the two-page typed note, which is contained in his collection at the UW AHC: "The soil is rich and the garden yields luxuriantly. There is a large vegetable cellar in the mountain side back of the house, which maintains a constant 40–43 temperature the year 'round. This is a great asset." The letter is signed, "Yours very sincerely, William C. Rogers." After the root cellar was destroyed by a fire accidentally started by Rogers, guests helped move many of the rocks to build stone pathways and retaining walls. This photo was taken in July 2015, three years after the lightning-caused Arapaho Fire. (Photo by Michael Curran)

The dot-com bubble, the bulk of Rogers' stock portfolio, burst between March 2000 and October 2002, a period now infamously known as the "dot-com crash." One of Rogers' biggest losses was EMC Corporation (which years later became part of Dell). The price for one share of EMC stock climbed from about $2 in early 1996 to $100 by mid-2000. In just over two years, however, the stock plummeted to $4.50 a share—losing a whopping 95 percent of its value.

Mr. Dyekman, who now practices with Long Reimer Winegar Beppler LLP in Cheyenne, and Dr. Hilliker, now a UW professor emerita, felt compelled to share this information because Rogers felt strongly about the education of young people, and his experiences with the stock market—decades of great success followed by months of horrendous losses—could help both young and old alike. "He suffered extraordinary losses, and that's not a happy story," Dyekman says. "But it is a good lesson for business students, investors, and many others."

While he was still alive, The Colonel, who spent part of his retirement living in rustic cabins (Fig. 1), storing vegetables in a root cellar (Fig. 2), and buying clothes and housewares at second-hand stores, gifted $1.6 million to UW for the construction of a 4,000-square-foot addition to the Crane Studio within the UW Fine Arts Center, including a rehearsal hall, projection booth, and television control room. His donation also paid for a renovation of the studio, named for UW Professor Emerita Gladys Crane, including new light booths and seats, in addition to cameras and video editing systems for the newly added acting-for-the-camera class that Rogers excitedly talked about with Hilliker months earlier.

And deeply moved by the murder of UW student Matthew Shepard in 1998, Rogers donated $1 million to UW for the Shepard Symposium on Social Justice, a donation that was matched by $1 million from the State of Wyoming. An annual event since 1997, the symposium brings speakers and audience members from around the state, region, and nation to have an open dialog on issues relating to social justice, particularly within

Figure 3. William C. Rogers and a close friend, Virginia Scully, spent much time in Mexico researching the Tarahumara Indians. This photograph, likely taken by Rogers, is among the Tarahumara-related research materials, photographs, and manuscripts contained in his collection at the UW AHC. (Photo from the William C. Rogers Papers, AHC)

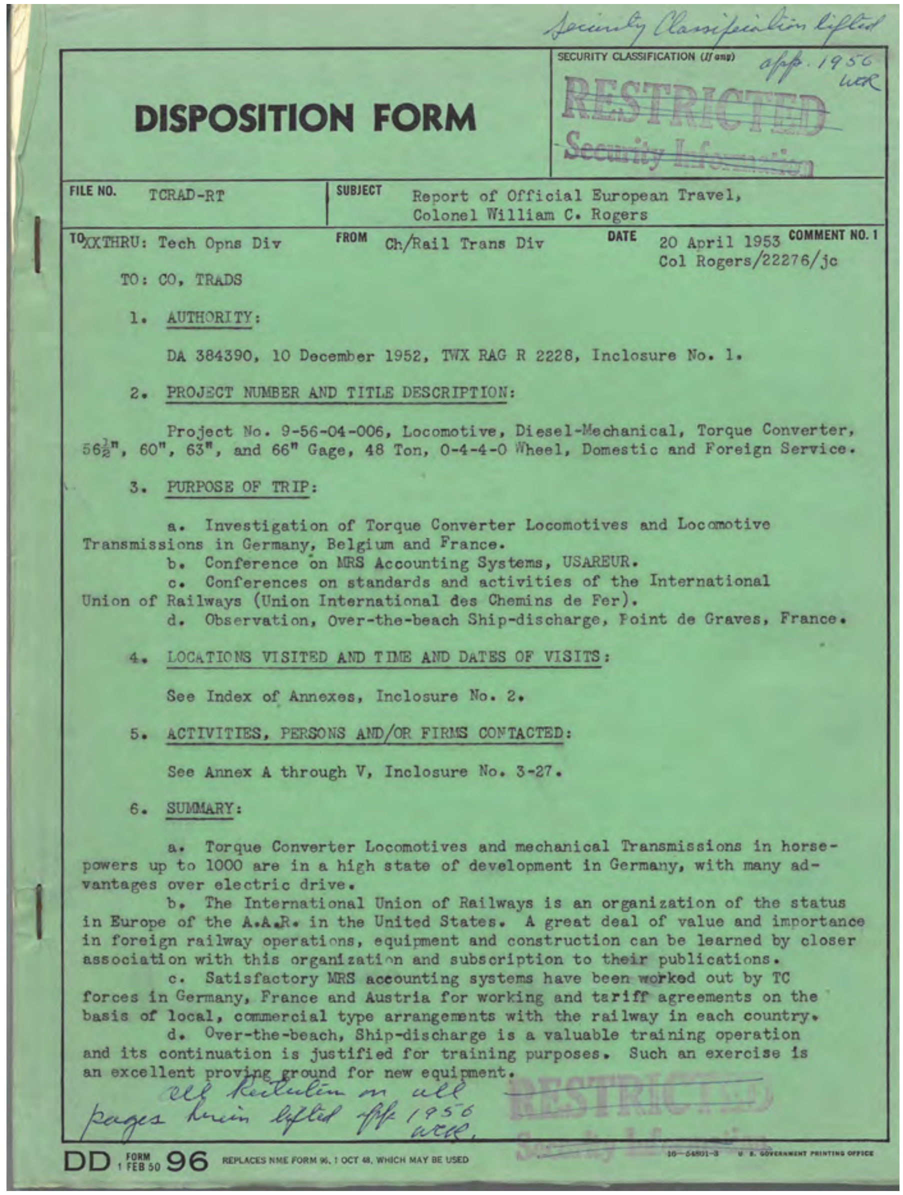
the context of public education, a cause that Rogers embraced.

He, too, cherished his friendships, and continued writing letters, turning to pen and paper instead of his old manual typewriter because of declining physical health. Levida Hileman knew that her friend's condition was continuing to decline when she started receiving letters that were nearly impossible to read instead of the typed letters that he wrote from his cabin in the Wyoming mountains. "He used an old upright manual typewriter, and he would hunt and peck. The Colonel had no formal training on a keyboard, so when he typed it was 'look for the letter and peck the key.' At the time, he typed everything, I think, for even his postcards were typed. He always signed his signature 'Colonel William C. Rogers, Ret.,' but in all his correspondence with me and Colleen he always signed 'Bill'."

Late in his life, when he began sending those hard-to-read handwritten letters to friends, Rogers learned that bugs the size of rice grains were ravaging the forests of eastern Wyoming, including pine trees on his beloved retirement property in the Laramie Mountains. "He frequently discussed the conditions on the mountain. He was concerned about the beetle kill and keeping the forest healthy," says Mrs. Hileman, who always responded with a letter of her own.

But when Levida's last letter went unanswered, she knew that something had happened to her friend, a man whom she had grown to deeply respect, a man who had become a grandfather figure to daughter Colleen.

Colonel William Catesby Rogers, who had served his country with distinction in World War II and who had relished retirement with a venturesome spirit, died on April 30, 2003, at age 96. His final resting place was the cold, deep waters of the Pacific Ocean, where employees of the Neptune Society of Northern California quietly disposed of his ashes. Those who knew Rogers say he lived proudly, and also died proudly, able to enjoy days in the library despite physical limitations,



Security Classification lifted

SECURITY CLASSIFICATION (If any) — RESTRICTED Security Information — app. 1956 wcR

DISPOSITION FORM

FILE NO. TCRAD-RT | SUBJECT Report of Official European Travel, Colonel William C. Rogers

TO XX THRU: Tech Opns Div | FROM Ch/Rail Trans Div | DATE 20 April 1953 | COMMENT NO. 1 | Col Rogers/22276/jc

TO: CO, TRADS

1. AUTHORITY:

DA 384390, 10 December 1952, TWX RAG R 2228, Inclosure No. 1.

2. PROJECT NUMBER AND TITLE DESCRIPTION:

Project No. 9-56-04-006, Locomotive, Diesel-Mechanical, Torque Converter, 56½", 60", 63", and 66" Gage, 48 Ton, 0-4-4-0 Wheel, Domestic and Foreign Service.

3. PURPOSE OF TRIP:

a. Investigation of Torque Converter Locomotives and Locomotive Transmissions in Germany, Belgium and France.
b. Conference on MRS Accounting Systems, USAREUR.
c. Conferences on standards and activities of the International Union of Railways (Union International des Chemins de Fer).
d. Observation, Over-the-beach Ship-discharge, Point de Graves, France.

4. LOCATIONS VISITED AND TIME AND DATES OF VISITS:

See Index of Annexes, Inclosure No. 2.

5. ACTIVITIES, PERSONS AND/OR FIRMS CONTACTED:

See Annex A through V, Inclosure No. 3-27.

6. SUMMARY:

a. Torque Converter Locomotives and mechanical Transmissions in horsepowers up to 1000 are in a high state of development in Germany, with many advantages over electric drive.
b. The International Union of Railways is an organization of the status in Europe of the A.A.R. in the United States. A great deal of value and importance in foreign railway operations, equipment and construction can be learned by closer association with this organization and subscription to their publications.
c. Satisfactory MRS accounting systems have been worked out by TC forces in Germany, France and Austria for working and tariff agreements on the basis of local, commercial type arrangements with the railway in each country.
d. Over-the-beach, Ship-discharge is a valuable training operation and its continuation is justified for training purposes. Such an exercise is an excellent proving ground for new equipment.

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Figure 4. After serving his country in World War II, William Rogers, an expert on trains and railway systems, was assigned as chief of the Rail Operations Branch, the Transportation Research and Development Station, at the U.S. Army's Transportation Center in Virginia. That work took him on a classified trip to Germany, Belgium, and France, in part, to investigate torque converter locomotives and locomotive transmissions. He detailed his trip in a lengthy document titled Disposition Form, which was declassified in 1956. (Document from the William C. Rogers Papers, AHC)

and knowing that his estate would help many people across the globe. Though he had lost much of his fortune during the dot-com crash of the early 2000s, his stock portfolio was still valued at approximately $8 million in April 2003, according to the William C. Rogers Papers housed at the UW American Heritage Center (AHC).

"Charles Graves, the long-time attorney for Colonel Rogers, sent a letter and a copy of the will to the recipients of Bill's estate. That's when my mother and I found out that The Colonel was worth a lot of money, which surprised us very much based on how he lived," says Colleen Hogan. The Colonel willed small gifts to Colleen and other young people he had befriended over the years, indicating that the money be used for their education. And

Figure 5. Colonel Rogers was evidently fascinated with windmills as his collection at the AHC contains two folders of photographs that he took of windmills, both large and small, in the region. Another folder contains a notebook, pamphlets, and other materials related to his windmill research. (Photo from the William C. Rogers Papers, AHC)

Figures 6–7. The Rogers' collection at the AHC contains a photo of his parents, Anne Burwell Jones Rogers and Ernest Garfield Rogers (right), who raised their family in Newport News, Virginia. They bear a striking resemblance to their son, Colonel William Catesby Rogers, below. Rogers was named after Catesby ap Roger Jones (1821–1877), the U.S. Navy officer who commanded the first Confederate ironclad warship, the CSS Virginia, formerly the U.S.S. steam frigate Merrimac. Rogers' family is directly related to Catesby Roger Jones (the "ap" in his name is a Welsh patronymic meaning "son of"). (Photo of Mr. and Mrs. Rogers from the William C. Rogers Papers, AHC; photo of Colonel Rogers by Colleen Hogan, from RRS Bulletin 1)

he willed large gifts to causes and institutions he believed in, including the University of Wyoming, Southern Poverty Law Center in Alabama, and Memorial Sloan Kettering Cancer Center in New York.

Among his gifts to UW, Rogers established the University of Wyoming Excellence Fund, which has a broad purpose to support proposals and projects that "show promise of stimulating creative and innovative activities." And, in 2002, he bequeathed his 320-acre Triple R Ranch to UW with the stipulation that the property be used, in part, for conducting research that would improve forestry and wildlife resources. He would be pleased knowing that UW graduate and undergraduate students, working in collaboration with their faculty mentors and others, have conducted a variety of studies on his land, both before and after the 2012 Arapaho Fire, which burned nearly 100,000 acres in the north Laramie Mountains, including RRS lands. Among the studies are soils and vegetation mapping, restoration of ponderosa pine following high-intensity fire, pre- and post-fire soil comparisons, and, as detailed in this bulletin, soil amendment additions and microbial community recovery following fire.

Rogers, an avid reader, donated his book collection to the Harrison Memorial Library in Carmel, California, where he was able to enjoy a more fulfilling life with the assistance of caretakers. And he donated $5,000 to the John A. Stahl Library in West Point, Nebraska, a small agricultural-based community where Rogers spent part of his winters during retirement helping a friend on her farm.

With the exception of his private papers, which were to be destroyed per instructions in his will, Rogers donated many of his written materials and photographs to the UW American Heritage Center. The collection, which is open to the public, fills 14 boxes. Of those, four contain in-depth materials about the life of Martha Jane Canary—better known as Calamity Jane—research that was conducted by Rogers and close friend Virginia Scully, who became an accomplished researcher, writer, and publicity director despite being stopped by her parents from attending college. In the files are interviews with people familiar with the American frontierswoman and army scout along with research notes, personal correspondence, and a manuscript by Rogers and Scully simply titled *Calamity Jane*. The authors open with: "This is the story of our last territorial frontier and of the woman who typified it, who was in the vanguard of the discoveries all the way, who rose to the full fruition of her life at the peak of the frontier movement and whose life ended with the ending of the frontier…"

In addition to his love for reading, Rogers was also a prolific researcher and writer of both fiction and non-fiction. In addition to *Calamity Jane*, other manuscripts and related materials focus on the Tarahumara Indians (Fig. 3); railroads, including one paper titled *The Great Gamble: Harriman's Reconstruction of the Union Pacific Railroad*; and issues faced by the gay community. Interestingly, the collection also includes a complete, handwritten translation by Rogers—from French to English—of a 422-page book about the history of food and gastronomy by French doctor Alfred Gottschalk, titled *Histoire de l'Alimentation et de la Gastronomie: Depuis la Préhistoire jusqu'à nos Jours*.

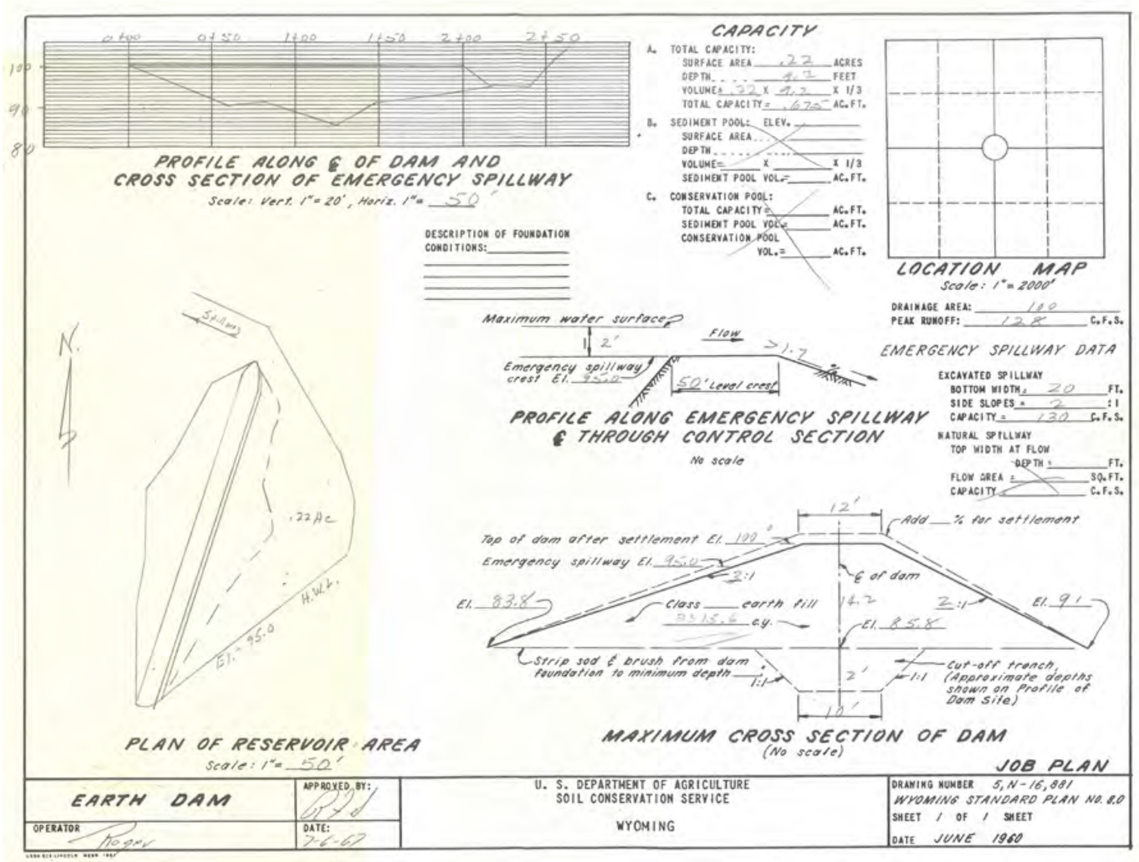
During his career with the U.S. Army, Rogers became an expert on trains and railway systems, eventually serving as commanding officer of a railway shop battalion in the Persian Gulf Command, one of his numerous assignments during World War II. Following the war, he was assigned as chief of the Rail Operations Branch, the Transportation Research and Development Station, at the Army's Transportation Center in Virginia. That work took him on a classified trip to Germany, Belgium, and France, in part, to investigate torque converter locomotives and locomotive transmissions. He detailed his trip in a lengthy document titled *Disposition Form* (Fig. 4). The document originally had a "Restricted" security classification, but that was lifted in 1956. This report along with Rogers' military discharge papers are also at the AHC.

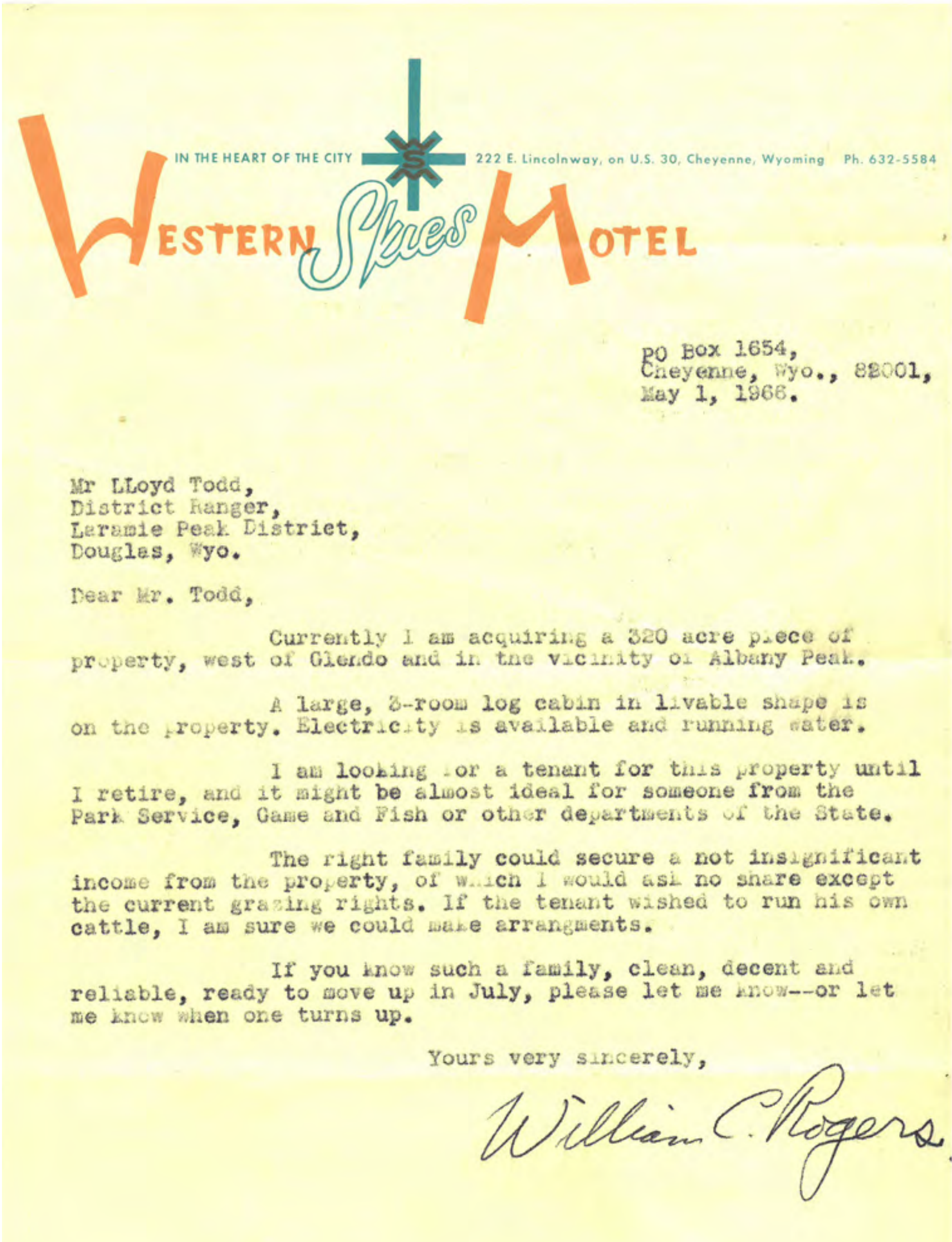
Figure 8. This photo, possibly taken by Colonel Rogers, shows horses on his property in the north Laramie Mountains. He allowed some cattle grazing during the summer, but this was limited because the parcel of land is only 320 acres. (Photo from the William C. Rogers Papers, AHC)

The collection also reveals his great interest in windmills, both large and small (Fig. 5), which he documented photographically and through research across the High Plains. Also contained in the boxes is a photo of his parents, Virginia residents Anne Burwell Jones Rogers and Ernest Garfield Rogers (Fig. 6), who bear a striking resemblance to their son, William Catesby Rogers (Fig. 7).

There is also a box in the collection focusing on Rogers' parcel in the Laramie Mountains. Included is a photo of one of the cabins on the property (Fig. 1), dubbed the "Original House" by friends interviewed by the author. Another cabin, along with the root cellar (Fig. 2), was destroyed one summer when The Colonel accidentally started a fire with hot ashes, according to friends and a local firefighter interviewed for these stories. The box also includes a photo of Rogers enjoying a conversation over the campfire with guests, a hand-drawn map of his Triple R Ranch (see RRR Bulletin 1), and a picture of him at the throttle of a high-horsepower, high-speed Union Pacific freight locomotive in Cheyenne, Wyoming (see 'Personal Message' in back of this bulletin). There is also a photo of horses on his mountainous property (Fig. 8), a detailed drawing (Fig. 9) of the earthen dam (Fig. 10) that he and helpers constructed, and a letter he wrote in 1968 to the Laramie

Figures 9–10. The Rogers' collection at the AHC contains a detailed drawing of the small earthen dam that was constructed on his property in the Laramie Mountains. The drawing was part of an application to the Wyoming State Engineer's Office to build the reservoir, which had a surface area of 0.22 acres and a maximum depth of approximately 9 feet at the time of construction. The depth is likely shallower today because much silt poured into the pond following the 2012 Arapaho Fire. When Rogers owned the property, he had fish stocked in the reservoir, which was surrounded by ponderosa pine prior to the fire. In the background, right, is Laramie Peak, elevation 10,272 feet. (Drawing from the William C. Rogers Papers, AHC; photo by Kelly Greenwald, from RRS Bulletin 5)





IN THE HEART OF THE CITY 222 E. Lincolnway, on U.S. 30, Cheyenne, Wyoming Ph. 632-5584

WESTERN Skies MOTEL

PO Box 1654,
Cheyenne, Wyo., 82001,
May 1, 1966.

Mr LLoyd Todd,
District Ranger,
Laramie Peak District,
Douglas, Wyo.

Dear Mr. Todd,

Currently I am acquiring a 320 acre piece of property, west of Glendo and in the vicinity of Albany Peak.

A large, 3-room log cabin in livable shape is on the property. Electricity is available and running water.

I am looking for a tenant for this property until I retire, and it might be almost ideal for someone from the Park Service, Game and Fish or other departments of the State.

The right family could secure a not insignificant income from the property, of which I would ask no share except the current grazing rights. If the tenant wished to run his own cattle, I am sure we could make arrangements.

If you know such a family, clean, decent and reliable, ready to move up in July, please let me know--or let me know when one turns up.

Yours very sincerely,

William C. Rogers

Figure 11. Colonel Rogers advertised for a caretaker to manage his property in the Laramie Mountains, in part, by sending personal letters to people. This note seeking a tenant was written on May 1, 1966, when Rogers was reportedly working for the Union Pacific Railroad, one of the jobs he had following his retirement from the U.S. Army. At the time, Rogers was in the process of purchasing the land when he sent this letter to Lloyd Todd, then district ranger of the Laramie Peak Ranger District of the Medicine Bow National Forest. (Letter from the William C. Rogers Papers, AHC)

Ranger District of the Medicine Bow National Forest. In the letter (Fig. 11), Rogers stated that he was seeking a tenant to watch over his land until retiring. It concludes: "If you know such a family, clean, decent and reliable, ready to move up in July, please let me know--or let me know when one turns up."

Shortly after acquiring Rogers' small ranch following his death, UW renamed the property "Rogers Research Site" in his memory. Overseeing management and research of RRS is the Wyoming Agricultural Experiment Station (WAES) within the UW College of Agriculture and Natural Resources. "WAES had the piece of land now known as the Rogers Research Site donated for the purpose of forestry and wildlife research under the auspices of the James C. Hageman Sustainable Agriculture Research and Extension Center," says UW Professor John Tanaka, retired associate director of WAES. Adds Toby Marlatt, vice president for marketing and communications at the UW Foundation, which was actively involved in the property transfer: "Colonel Rogers felt very strongly about his property, and he had a field research facility in mind. I appreciate the fact that faculty, staff, and students are using it for research and academic purposes, and that would make The Colonel very happy, too."

Rebecca Hilliker was among the people who traveled to the property in the Laramie Mountains to gather materials intended for the AHC archives and the Department of Theatre and Dance. When they arrived, they found piles and piles of paper in a little hut, evidence of The Colonel's tenacious research and manuscript writing during retirement. Some of that material is now in the Rogers collection at the AHC, and it is clear that he intended to publish some of the manuscripts, though apparently that never happened. When Hilliker scheduled a meeting with representatives of the AHC to discuss the manuscripts and related materials, they, like many others, knew nothing about the man and his most interesting life. "And when we had our initial conversation, our first meeting, they went, 'Oh, wow, there would be a lot of people interested in this, interested in digging into his history,'" Hilliker says.

She adds: "He's such a fascinating person. He led such a distinctly different kind of life. Just from knowing Colonel Rogers he was a huge figure in terms of his personality and his life experiences, whether it was the secret service in the Army, his travels in Mexico, or living out in the boonies in Wyoming for years, even when he was an old, old man. He lived lots of different lives and just shifted at will. If something attracted his focus, he wasn't afraid to go do it."

In the end, Colonel William C. Rogers, who lived life proudly and who died proudly, spent only $1,275 for his direct cremation into the Pacific Ocean so he could help many institutions and causes, in addition to individuals like the now retired school teacher, Levida Hileman, and her daughter, Colleen Hogan, a health facility surveyor for the Wyoming Department of Health. One fall day, a check arrived in Colleen's mailbox, and with it was a note from her late friend's will with instructions to use the money for her "advanced education." She honored The Colonel's wishes by paying off student loans and putting the rest in the bank for a rainy day.

"It was a very generous gift from The Colonel, a gift that helps to describe the kind of person he was," Colleen says. "When we visited Colonel Rogers on his property, he attracted a lot of eclectic kinds of people, liberal folks, people who read *Mother Earth News*. But he also got along very well with the local ranchers, conservative folks. He really got along with most everyone. He liked people and they liked him, and I think that tells you a lot about Colonel Rogers."

ACKNOWLEDGMENTS

I owe a great deal of gratitude to the many people who shared information for the stories about Colonel William C. Rogers that appeared in the first eight Rogers Research Site bulletins. Contributing information for this particular story were Levida Hileman and her daughter, Colleen Hogan, who became close friends with Colonel Rogers during summer visits to his property while Levida worked as a school teacher in Casper, Wyoming; University of Wyoming Professor Emerita Rebecca Hilliker, who became friends with The Colonel late in his life; Cheyenne attorney and UW Foundation emeritus board member Greg Dyekman, who became involved in matters relating to the estate of Colonel Rogers; UW Professor John Tanaka, retired associate director of the Wyoming Agricultural Experiment Station (WAES), which helps to oversee management of the Rogers Research Site (RRS); and Toby Marlatt, vice president for marketing and communications at the UW Foundation, which was actively involved in the transfer of Rogers' property to UW.

Also contributing information for the story were Mary Laura Kludy, archives and records management specialist at the Virginia Military Institute in Lexington, Virginia, where William Rogers graduated in 1927; Sarah Stark Serra of Virginia, a niece of Colonel Rogers; and north Laramie Mountains resident George Portwood. Thank you to the faculty and staff at the UW American Heritage Center (AHC) with help relating to the papers of William C. Rogers and Virginia Scully. It took a team effort to pull more than 30 boxes from the AHC archives and then refile those boxes once the author was complete with his research. A tip of the hat goes to Vicki Glantz, AHC reference archives specialist, for help with photo and document scanning.

Much appreciation is extended to Tanya Engel, graphic designer in UW Extension's Office of Communications and Technology, for her work designing the first eight bulletins. Most of the photographs and other visual material in this story came from the William C. Rogers Papers at the AHC. Also providing photos were Colleen Hogan; UW graduate student Michael Curran, who has assisted with several research projects at RRS; and Kelly Greenwald, administrative assistant at the James C. Hageman Sustainable Agriculture Research and Extension Center near Lingle, Wyoming, which oversees RRS management with WAES. And thanks to Leslie Waggener for guidance and copy-editing. A tip of the hat to Professor Bret Hess, director of the Wyoming Agricultural Experiment Station in the UW College of Agriculture and Natural Resources, along with Professor Tanaka for supporting research at RRS and the subsequent publication of the RRS bulletin series. Finally, I and many others, including UW students and faculty members, owe a great deal of gratitude to Colonel Rogers for donating his land in the Laramie Mountains to UW for research, extension, teaching, and other activities.

SOIL AMENDMENT ADDITION AND MICROBIAL COMMUNITY RECOVERY FOLLOWING HIGH-SEVERITY FIRE, ROGERS RESEARCH SITE, NORTH LARAMIE MOUNTAINS, WYOMING

By Claire D. Wilkin,[1–2] Stephen E. Williams,[3] Linda T.A. van Diepen,[4] Michael A. Urynowicz,[5] Larry C. Munn,[6] and Robert W. Waggener[7]

KEY WORDS
actinomycetes, ammonium, ammonium nitrate fertilizer, Arapaho Fire, arbuscular mycorrhizal fungi, bacteria, compost, compost tea, fire ecology, fungi, high-severity wildfire, Laramie Mountains, nitrate, phosphate, phospholipid fatty acid, ponderosa pine (*Pinus ponderosa*), post-fire soil amendment study, protozoa, Rogers Research Site, soil amendment, soil microbial community, soil nutrients, University of Wyoming, Wyoming Agricultural Experiment Station

ABSTRACT

A study was performed at the Rogers Research Site (RRS) in the north Laramie Mountains, southeast Wyoming, to investigate the effectiveness of soil amendments (compost tea, 'traditional' compost, and ammonium nitrate [NH_4NO_3] fertilizer) for re-establishing the soil microbial community and hastening the recovery of the site to a healthy successional environment following a high-severity forest fire that occurred in 2012. The long-term goal of this effort is restoration of the burned forest stand; however, this study was directed toward an evaluation of the belowground ecosystem and, specifically, the microbial communities in the soil on short time scales. The study was designed to determine the extent to which the microbial community responds to different nutrient treatments after the wildfire with respect to fungal and bacterial abundance, microbial composition, and inorganic nitrogen cycling. The treatments included a control (no additions), a water-only control (water added at the same levels as in the treatments),

1 For specific questions about this report (along with general questions about RRS research, information about access, driving directions to RRS, etc.) please contact the James C. Hageman Sustainable Agriculture Research and Extension Center (SAREC) at sarec@uwyo.edu; 307-837-2000; or 2753 State Highway 57, Lingle, WY 82223-8543.

2 Environmental consultant with WSP, San Jose, California. At the time of this research, Wilkin was a graduate student at the University of Wyoming. Wilkin, who was co-advised by co-authors Professors Steve Williams and Michael Urynowicz, earned a master's degree in environmental engineering in 2014.

3 Professor emeritus of soil biology and biochemistry, University of Wyoming Department of Ecosystem Science and Management, Laramie, Wyoming.

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7 Laramie, Wyoming-based freelance editor, writer, and photographer covering agriculture and natural resources in Wyoming and the West, and part-time editor for the Wyoming Agricultural Experiment Station.

Figure 1. Lightning started the Arapaho Fire on June 27, 2012, in the north Laramie Mountains during a severe drought. This photo was taken one day later, when the fire was already well established. (Photo by Josh McGee)

Figure 2. The 2012 high-intensity Arapaho Fire consumed most of the vegetation at RRS, including thick-barked ponderosa pine (*Pinus ponderosa*), which has evolved to survive frequent, low-intensity fires. This image, from Seymour et al., 2017, was taken on July 18, about two weeks after the fire burned through RRS. (Photo by Steve Williams)

two compost tea treatments, a traditional compost treatment, and a fertilizer treatment (NH_4NO_3). All treatments were replicated seven times across the area designated for this study. Dead tree density was constant over the experimental area, burn intensity was very similar across the zone, and the experimental units were randomized across the experimental zone. Results showed that in late November 2012, one week post-treatment, there was an increase in nitrate (NO_3^-) across all plots—and it was significantly higher in the plots fertilized with NH_4NO_3. This disappeared by the following spring. The compost, compost tea, and NH_4NO_3 fertilizer had increased ammonium (NH_4^+), and the compost also had higher nitrate (NO_3^-) at the end of the summer, 2013 (nine months post-treatment). The different treatments did not have consistent effects on the microbial community, and most of the effects were only visible the first week after additions. A longer-term study at RRS with a stronger emphasis on characterization of post-fire vegetation development and well-defined functional groups of microorganisms (e.g., N-fixing bacteria and mycorrhizal fungi) is recommended to understand the long-term implication of external amendment additions to this severely burned forest ecosystem.

INTRODUCTION

Fires impact forest soil ecology by altering subsurface physical, chemical, and biological processes. These impacts can include an increase in soil nutrient availability, clearing of protective layers of duff (dead plant material that has fallen to the ground), a rise in soil aggregate stability, and a flush of dormant seed germination (Certini 2005; Scharenbroch et al., 2012). High-intensity fires, as at the Rogers Research Site (RRS) during a severe drought in 2012 (Fig. 1), can volatilize released nutrients, including soil organic carbon (Bárcenas-Moreno and Bååth, 2009), imparting more long-lasting ecosystem effects (Fig. 2). In general, the more intensely a forest burns, the longer duration the impacts can be. Fires can also result in increased runoff and soil erosion during subsequent rainfall events and during snowmelt (Figs. 3–6). During higher-temperature fires (upward of 300°C [575°F]), much of the soil C can be oxidized to aromatic rings imparting greater recalcitrance. This, plus the incomplete combustion of wax-like components of the organic matter, can result in a hydrophobic layer just under the soil surface (DeBano, 1991; Madsen et al., 2011). This effect is increased for burns under dry soil conditions (Robichaud, 2000). Incomplete combustion of organic matter under pyrolytic conditions can also result in the charring of the organic C into black carbon (dark ash). This process can increase black carbon porosity and surface area while reducing its bulk density. Although the final material is often very resistant to degradation and wetting, it can act as a substrate for nutrient sorption and microbial colonization (Certini, 2005). Dissolved black carbon runoff into freshwater and marine systems constitutes a large percentage of the global dissolved organic C levels (Jaffe et al., 2013).

Soil heating during intense events causes significant interactive and long-term impacts to soil microbial populations through direct mortality and by reducing the soil water content and changing nutrient availability (Fig. 2; Hart et al., 2005). Hydrophobicity reduces water infiltration, and black ash can increase surface temperatures leading to increased evaporation resulting in lower soil water availability, which negatively affects bacterial, protozoan, and fungal populations (Fig. 7). Increased runoff carries with it surface ash and nutrients (Figs. 5–6). These effects are more dramatic with increased fire intensity and severity (Neary et al., 1999). After fire, soil ecological damages may lead to a prolonged recovery period. Stand replacement may be particularly unsuccessful or slowed without a diverse and functioning microbial community (Korb et al., 2004).

Soil microbiota play a vital role in forests as the primary drivers of nutrient cycling, organic matter decomposition, and soil aggregate stability. Plant-microbe interactions offer mutualistic benefits, improving nutrient and water uptake by plants and C-uptake by soil-dwelling organisms. These interactions seem to be susceptible to the effects of disturbance, including both physical and chemical changes. Using soils under slash piles as a study medium, Korb et al. (2004) found differences in recovery of arbuscular mycorrhizal fungi (AMF) colonizers, total nitrogen (N) and carbon (C) content of surface soils, and native seed bank across a fire intensity gradient from 3 m (10 ft) inside the slash burn scar to 3 m outside.

Beyond the scope of these observable soil microbe and plant interactions lies the remainder of the soil microbial community. Fire adds to the diverse and extreme spatial and biological heterogeneity of soil by inducing acute changes, as well as affecting the system long-term. Many studies have examined long-term microbial community recovery in burned forested environments (Hart et al., 2005;

Figure 3. Fires such as the 2012 Arapaho can result in increased runoff and soil erosion during rainfall events, especially during unusually wet periods. That was the case shortly after the fire burned across RRS and surrounding lands in the north Laramie Mountains, when more than 2 inches (5+ centimeters) of precipitation fell during a significant rainstorm in July. (Photo by S. Williams)

Figure 4. Following the Arapaho Fire and subsequent rainfall events, this material eroded onto the foot of a slope at RRS. This was part of the erosion of materials from uplands to lowlands. This photo was taken in August 2014, just over two years following the Arapaho Fire. (Photo by Larry Munn)

Figure 5. Precipitation events carried silt and ash from burned hillsides into this small reservoir at RRS. This photo was taken on September 11, 2012, about 10 weeks after the Arapaho Fire burned across RRS and surrounding lands. (Photo by Jim Freeburn)

Figure 6. Ash and silt are evident in this small reservoir at RRS on March 15, 2013, approximately seven months after the Arapaho Fire burned across the site. A significant rainstorm in July 2012, shortly after the fire, contributed much ash and sediment, and erosion during late winter–early spring 2013 snowmelt added to the problem. (Photo by S. Williams)

Figure 7. Black ash left behind from fires can increase surface temperatures, leading to increased evaporation and lower soil water availability. This photo was taken in September 2013 at RRS, 14 months after the Arapaho Fire burned across the site. (Photo by S. Williams)

Dangi et al., 2010; Holden et al., 2013; Kurth et al., 2013). General trends suggest significant community shifts toward bacterial dominance over the course of successive vegetation recovery, while the fungal communities shift in species distribution. Holden et al. (2013) found that in an Alaskan fire chronosequence the relative abundance of fungal taxa shifted in forest soils from Basidiomycota (common mushrooms, puffballs, stinkhorns, etc.) to Ascomycota (morels and other sac fungi). Further, they observed that those fungi with ectomycorrhizal strategies can be especially slow to recover in number—in some cases up to 24 years following fire (Holden et al., 2013). In an Arizona fire-recovery study, long-term differences in fungal species composition were observed between nearby severely burned and unburned sites (Kurth et al., 2013). The authors investigated fungal species richness, diversity, and community composition of wood-decomposing organisms, finding that composition differed significantly over short-term (four years) and long-term (32 years) recovery periods. These long-term community shifts can lead to altered ecosystem nutrient cycling, as in the case of C pools stored in standing dead and decaying woody biomass.

Another important group of organisms affected by heating are the protozoans. These are important predators in the soil microenvironment, acting to control bacterial and fungal populations and improving nutrient turnover. Of particular note is the relationship between protozoans and bacteria when aiding plant uptake of nitrogen (N). When N-fixing symbionts act in concert with soil protozoans, plants improve their uptake of N, even in non-N limiting systems (Koller et al., 2013). In burned forests, the protozoan communities can be particularly diminished, especially with increasing fire intensity (Henig-Sever et al., 2001).

In the case of high-intensity forest fires, it is clear that changes are occurring from the macro to micro scale, intersecting physical, chemical, and biological spheres. This issue of microbial diversity and subsequent metabolic impacts—coupled with altered microsite, nutrient availability, and hydrologic characteristics—is being increasingly studied as it could lead to attenuated plant succession over the long-term (Holden et al., 2013). The majority of these studies are examining effects of different burn intensities and burn-management strategies (Choromanska and DeLuca 2001; Korb et al., 2003) on the recovery of these organisms to achieve desirable ecosystem services (Korb et al., 2004; Kim et al., 2011).

Tree establishment is dependent on reasonable seed availability and viability, nutrient competition, water availability, mycorrhizal fungi densities, absence of pathogens, and absence of invasive plants (Korb et al., 2003). Many of these requirements involve the resilience and diversity of the soil microbes and microfauna.

OBJECTIVES

In the interest of re-establishing the soil microbial community and quickening recovery to a healthy successional environment at RRS, we applied soil amendments in the form of compost tea, 'traditional' compost, and ammonium nitrate (NH_4NO_3). These nutrient treatments were chosen based on literature supporting their use for vegetation growth and as microbial stimulators (Williams et al., 2018). William et al. (2018) developed several hypotheses about soil community response, among them: (1) nutrient treatments will result in marked soil microbial community growth and increased recovery of inorganic N cycling compared to untreated soils; and (2) soil microbial community recovery over nine months will vary with season, but will show general community response to treatment.

To test these hypotheses, we designed a randomized complete block design experiment. The objectives of this research were twofold: (1) compare nutrient treatment impacts on soil community recovery to that of the control in a post-fire environment; and (2) monitor belowground microbial community and inorganic N nutrient dynamics over a nine-month period after nutrient treatment.

STUDY AREA

The 320-ac (129.5-ha) Rogers Research Site (RRS) is located in the north Laramie Mountains of southeast Wyoming. It is named after Colonel William C. Rogers, who bequeathed his 'Triple R Ranch' to the University of Wyoming in 2002. Later renamed in his memory, RRS is approximately 25 mi (40 km) northwest of Wheatland, Wyoming, and ~5 mi (8 km) southeast of the prominent Laramie Peak (Figs. 8–10; Williams and Waggener, 2017a). Elevations at RRS range from ~6,700 to 7,300 ft (~2,000–2,200 m), and historically the site and surrounding public and private lands were predominately a ponderosa pine (*Pinus ponderosa*) forest (Figs. 8, 11). RRS is managed by the Wyoming Agricultural Experiment Station as part of the James C. Hageman Sustainable Agriculture Research and Extension Center (SAREC).

2012 ARAPAHO FIRE BURNS RRS AND NEIGHBORING LANDS

RRS was among the approximate 98,000 ac (~40,000 ha) across the Laramie Peak region of the Medicine Bow-Routt National Forests that burned during the 2012 Arapaho Fire (Figs. 12–13). The lightning-caused wildfire, which occurred during a severe drought, started on June 27, 2012, and was declared contained August 23 (InciWeb, 2012), but some areas continued to smolder well into the fall. On July 2, the fire reached the RRS (Williams and Waggener, 2017a). Prior to the fire, approximately 80% of RRS lands were covered with ponderosa pine in a variety of age classes (Figs. 8, 11), 4% was quaking aspen (*Populus tremuloides*), 10% was a mix of understory shrubs, forbs, and grasses, while the remaining acreage consisted of a small reservoir (Fig. 8), unimproved roads, and rocky outcrops (Seymour et al., 2017). The fire killed approximately 95% of the trees on-site, producing substantial surface ash in the process (Figs. 2, 13). The soil surface ash color remaining post-fire can provide

Figure 8. Ponderosa pine covered RRS and surrounding lands when Colonel William C. Rogers bequeathed his 320-acre (~130-hectare) property in the north Laramie Mountains to the University of Wyoming in 2002. In the background, right, is Laramie Peak, elevation 10,272 ft (3,131 m). This photo (from Herget et al., 2018) also shows the small reservoir that Rogers, with the help of others, constructed on his land. (Photo by Kelly Greenwald)

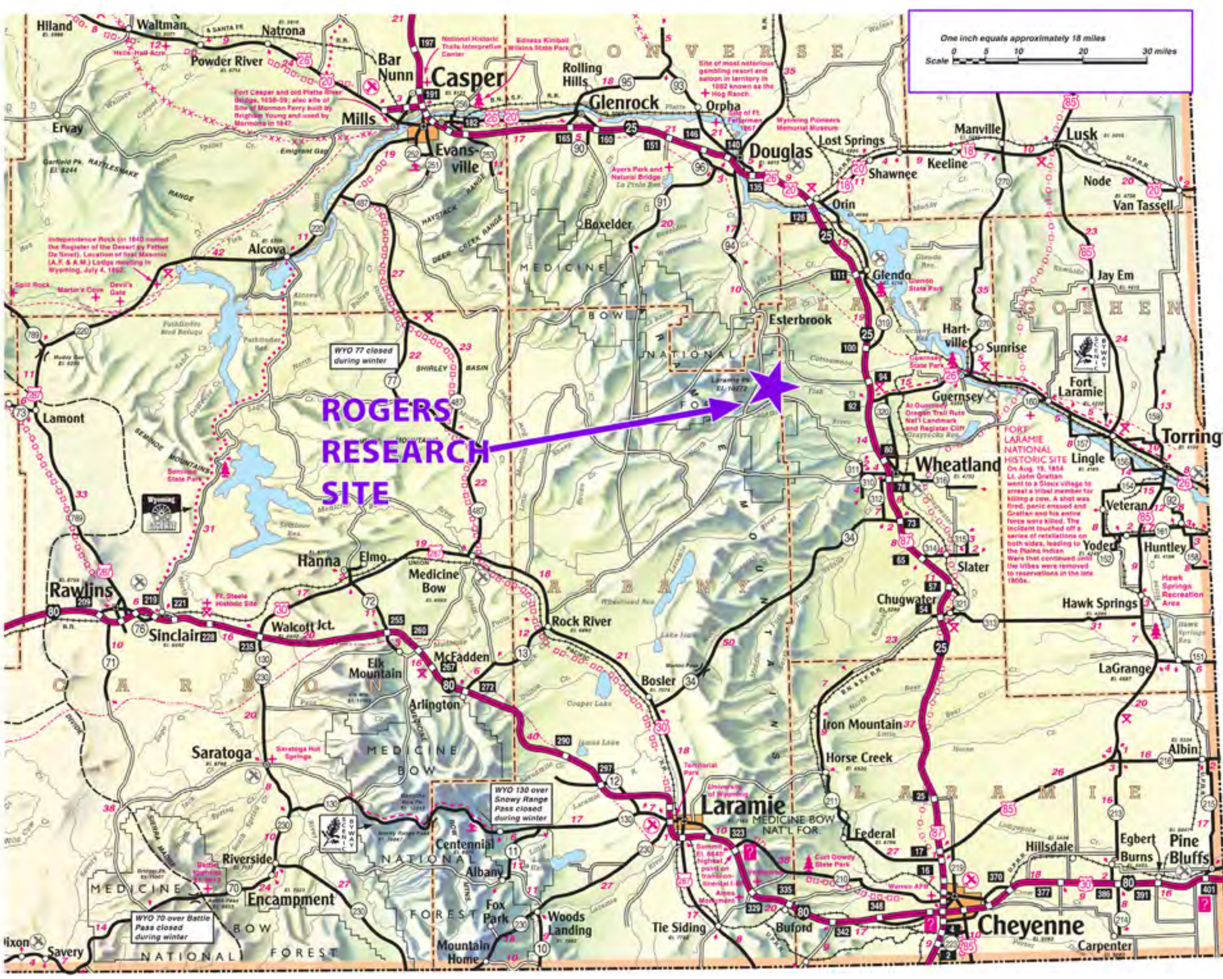


Figure 9. General map (revised from Williams and Waggener, 2017a) of southeast Wyoming showing the location of the Rogers Research Site (RRS), northeast Albany County. RRS is located approximately 25 mi (40 km) northwest of Wheatland, Wyoming, and ~5 mi (8 km) southeast of the prominent Laramie Peak. (Official State Highway Map of Wyoming; RRS overlay by Tanya Engel)

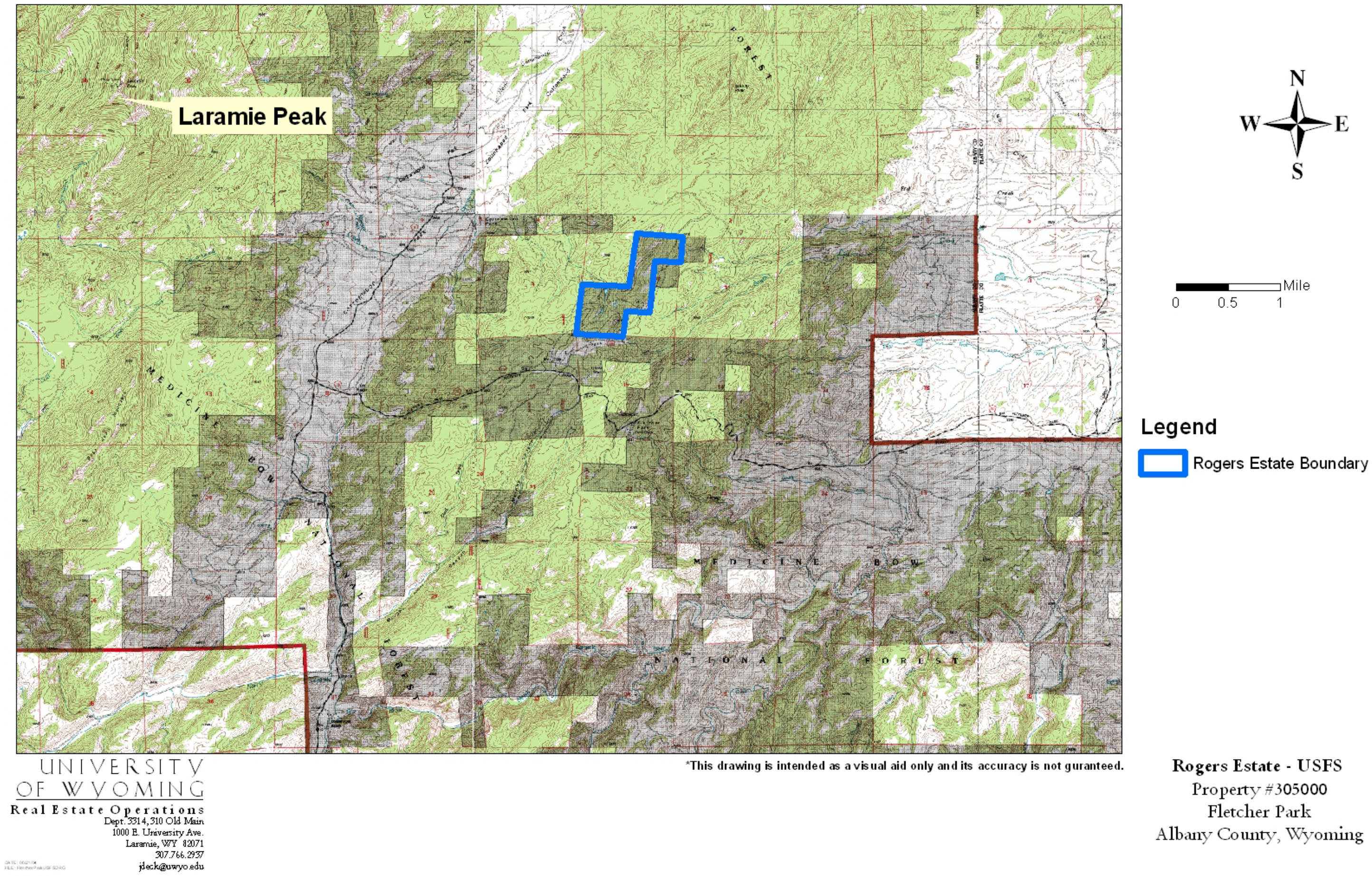


Figure 10. RRS (outlined in blue) is located approximately 5 mi (8 km) southeast of Laramie Peak (10,272 ft (3,131 m) in the northern reaches of the Laramie Mountains. Elevations at RRS range from ~6,700 to 7,300 ft (2,000–2,200 m). This map (from Williams and Waggener, 2017a) shows U.S. Forest Service lands to the east, north, and west (light green) of RRS, and state trust and private lands to the south (dark green). (Base map by USFS; RRS mapping by Josh Decker/UW Real Estate Operations)

Figure 11. Historically, the 320-acre RRS and surrounding public and private lands in the north Laramie Mountains were predominately a ponderosa pine (*Pinus ponderosa*) forest. The sparse and dense stands of pine at RRS were in various age classes because of prescribed thinning over many years. This photo, from Williams and Waggener, 2017b, was taken in June 2007. (Photo by S. Williams)

Figure 12. A firefighter works on a fire line during the 2012 Arapaho Fire, which burned approximately 98,000 ac (~40,000 ha) of forested lands in the Laramie Peak region of the Medicine Bow-Routt National Forests. (Photo by Jim Kibler, courtesy of InciWeb)

Figure 13. The high-intensity Arapaho Fire killed all vegetation in many areas of RRS and surrounding lands, even thick-barked ponderosa pine, which have evolved to survive frequent, low-intensity wildfires. This photo was taken shortly after the fire burned across RRS lands on July 2–3, 2012. (Photo by J. Freeburn)

some insight into the fire intensity: yellowish to brown represents low-intensity, black moderate-intensity, and white high-intensity (>500°C [900°F]) (Dūdaite et al., 2011). Ash color observations made on walking tours at RRS from mid-July through mid-August 2012—along with approximate tree stand death counts—showed that RRS experienced moderate- to high-intensity burning (Figs. 2, 13–14; Williams and Waggener, 2017a; Williams et al., 2018).

POST-FIRE SOIL AMENDMENT STUDY SITE

A single site within RRS was chosen to conduct this part of the research, a post-fire soil amendment study. The 27 × 37 m (89 × 121 ft) plot was located on a uniform low-angle, west-facing slope (Fig. 15). It had a fairly uniformly distributed white surface ash layer prior to treatment, indicating the site experienced high-intensity soil heating. Ponderosa pines were uniformly spaced across the site, with an average diameter of 20–30 cm (8–12 in) at breast height (i.e., 1.4 m [4.5 ft]). Post-fire soil pH was 7.2 in the top 10 cm (4 in), and 6.4 below 10 cm. Soils in the area are largely sandy, gravelly loams, including Alderon (RRS-01, an Alfisol); Cathedral taxajunct (RRS-02, an Entisol); Dalecreek (RRS-03, a Mollisol); and Kovich (RRS-04, a Mollisol) (Figs. 16–19; Munn et al., 2018). Typical features include three to five horizons, an A with partially or well decomposed plant materials (often with some ash in the surface), and a B with or without a small clay content, followed by paralithic horizons. Depth to bedrock varies between 15 cm and 120 cm (6–47 in) (Reckner, 1998; National Cooperative Soil Survey, 2014; Munn et al., 2018; Williams et al., 2018). Soil taxonomy for the 27 × 37 m plot was the Alderon complex (Figs. 18–22)—fine-loamy, mixed, super active, frigid Typic Haplustalfs with mixed-clay mineralogy and high cation exchange capacity (Munn et al., 2018; Williams et al., 2018).

TREATMENTS AND TREATMENT DESIGN

The post-fire soil amendment study included six treatments applied in a randomized complete block design using seven replicates for a total of 42 treatment plots (Fig. 23). The six treatments included two steeping times of compost tea, ammonium nitrate (NH_4NO_3), traditional compost, water-only control, and blank control.

COMPOST TEA TREATMENTS

Compost tea (a liquid produced by extracting plant growth compounds and beneficial microorganisms from compost steeped in water) has been used by farmers for centuries to reduce influence of pathogens, improve crop yields and quality, and increase soil nutrient availability (Scheuerell and Mahaffee, 2002). While these claims have historically been poorly rooted in scientific method, the past two decades have seen an increase in the number of studies investigating the impacts and potential of these products (Siddiqui et al., 2009; Shrestha et al., 2011; Evans et al., 2013). The majority of these studies apply compost tea (CT) to horticultural or agricultural systems, with alternately positive and unclear results (Hargreaves et al., 2008; Pant et al., 2009; Fritz et al., 2012; Pane et al., 2012). CT is produced in a variety of ways, typically involving matured compost mixed with water at a ratio of one part compost to 5 to 10 parts water (volume/volume [v/v]), and can be stirred or steeped from minutes to days. The liquid amendment is a dark brown broth that can be sprayed or dripped onto soil or foliar environments. It is thought that the majority of water-soluble nutrients available from the composted materials, along with many of the organisms that performed the decomposition, are extracted into this broth (Carballo et al., 2008; Siddiqui et al., 2009). One benefit of this product is that it can be adapted for application over very large areas, such as forest burn sites. For this study, the CT was aerated

Figure 14. Ash color observations made on walking tours at RRS from mid-July to late-August 2012—along with approximate tree stand death counts—showed that RRS experienced moderate- to high-intensity burning. (Photo by S. Williams)

Figure 15. Co-author Steve Williams on July 18, 2012, collects soil samples at RRS. This photo, from Williams and Waggener 2017a, was taken just over two weeks after the Arapaho Fire burned across RRS and surrounding lands. Because of the fire's intensity, the majority of RRS and surrounding lands had nothing but ash and dead trees remaining. (Photo by Stanley Bellgard)

Figure 16. The four soil series at RRS—Alderon, Cathedral, Dalecreek, and Kovich—support a variety of vegetation. Kovich soils are found in riparian areas (foreground), Dale Creek soils are at the bases of slopes, and Alderon soils are on the ponderosa pine-covered slopes (background). The Cathedral taxajunct is the shallow soil adjacent to rock outcrops (background). This photo was taken in August 2014, a full two years following the Arapaho Fire, and shows how quickly riparian vegetation responded. Hillsides will likely come back in ponderosa pine, but that could take decades or longer. (Photo by L. Munn)

Figure 17. Co-author Larry Munn led a project to map soils at RRS prior to the lightning-caused Arapaho Fire, and his work continued after the fire (for details, see Munn et al., 2018). This is an example of Kovich soil, which occupies riparian areas at the site. The soil, which is dark enough to qualify as a Mollisol, contains an accumulation of organic matter and fine particles (silt and clay). This photo was taken in August 2014, a full two years after the Arapaho Fire. (Photo by L. Munn)

Figure 18. Samples for this study came from a site at RRS like this one, which contains the Alderon series, by far the dominant soil type at RRS (Munn et al., 2018). The Alderon (RRS-01, an Alfisol) has historically supported ponderosa pine forests in the north Laramie Mountains. This soil complex is fine-loamy, mixed, super active, frigid Typic Haplustalfs with mixed-clay mineralogy and high cation exchange capacity. Soil samples were collected, fortuitously, just days and weeks before the lightning-caused wildfire, and then additional samples were collected shortly after the fire (see Figs. 15 and 17). This photo was taken in August 2014, just over two years after the Arapaho Fire burned across the site; it shows some grasses and forbs beginning to reestablish. (Photo by L. Munn)

Figure 19. Following the 2012 Arapaho Fire, a combination of coarse-textured soils with low water-holding capacity and moderate clay content lowered water available to support tree biomass in areas at RRS having Alderon soils, the predominate soil at the site (Munn et al., 2018). (Photo by L. Munn)

Figure 20. Following high-intensity wildfires, surface protection is greatly reduced, and there is additional loss of stability as the roots of the fire-killed trees begin to decay, usually in two to three years. This tree is among the hundreds that have fallen at the 320-ac (~130 ha) RRS, typically during wind events. Their root balls are a source of short-range variability in forest soils. The photo was taken in August 2014, just over two years after the Arapaho Fire burned through the area. (Photo by L. Munn)

Figure 21. Soil samples for this study came from a site at RRS like this one, which contains the Alderon series. This soil occurs where ponderosa pine forest has historically occupied the steep, convex upper side slopes, which typically range from 25 to 50% (Munn et al., 2018). This photo was taken on July 23, 2015, approximately three years after the Arapaho Fire. The scene is similar to Figure 22, but is looking upslope toward a ridgetop. (Photo by Michael Curran)

and steeped at a ratio of one part compost to five parts water (v/v). Two steeping times were chosen: 24 hours and 48 hours. The 24-hour (one-day) compost tea is designated CT1 in this study, while CT2 is the 48-hour (two-day) solution. The compost used was a 50/50 mixture of vermicompost (the process of composting using worms) and green waste/sheep manure compost. The vermicompost, which was produced by the Wyoming Worm Wranglers in Laramie, Wyoming, used the following inputs: cardboard, rabbit dung, horse manure, and kitchen green waste. These were digested and composted for 3 to 6 months and sieved through a 60 mesh (0.6 cm [~1/4 in]) screen. The green compost source was Gulley Greenhouses and Garden Center in Fort Collins, Colorado. Once steeped, the teas were applied at a rate of 1 liter/m^2 (2.8 gal/100 ft^2) across the treatment areas.

AMMONIUM NITRATE TREATMENT

Ammonium nitrate (NH_4NO_3) fertilizer was applied for the reason of understanding nutrient addition as an independent effect on the soil. Nitrogen (N) was applied alone as it is generally the most common deficiency displayed by plants (Troeh and Thompson, 1993). Further, N additions to boreal and ponderosa pine forests are well studied (Lamontagne and Schiff, 2000; Selmants et al., 2008).

Although extractable ammonium and nitrate N as well as % total N increased in the A horizon post-fire at RRS (Williams et al., 2018), this post-fire N is very soluble and rapidly lost via leaching or taken up by very early successional plants (DeBano, 1991). This experiment was established some months after the fire, and several large rain events had occurred. Likely N losses were probably similar to those described by Baird et al. (1999). N content of the O horizon at RRS pre- and post-fire was not determined. The presence of white ash on the experimental site selected within RRS strongly suggests that there was virtually no organic matter left in the material and no N, as the O-horizon was completely removed by the fire.

Killham (1994) provides estimates of the levels of N in several forest types globally. This author estimates that for temperate

Figure 22. This photo, similar to Figure 21 but taken from the ridgetop looking downslope, shows the Alderon soil series, which historically supported ponderosa pine in the north Laramie Mountains, including RRS lands. The Arapaho Fire killed the majority of ponderosa pine, but some trees survived. The pine forest contributes acid-forming litter to the surface and, prior to the 2012 Arapaho Fire, provided stability to the surface through canopy coverage and root mass. (Photo by M. Curran)

conifer forests, the total N in such forests is about 20,000 kg/ha (~17,800 lb/ac). Of this, roughly 0.75% becomes available and is taken up by plants annually. This 0.75% equates to 150 kg N/ha (~130 lb N/ac) annually. Total N at RRS was probably lower because of its inherent low fertility. After the fire there undoubtedly was much less total N than the total estimated by Killham (1994). We added 45 kg N/ha (~40 lb/ac) as the level of N as ammonium nitrate (NH_4NO_3) to these plots to stimulate belowground microbial response. The NH_4NO_3 was added as an aqueous solution at the same levels of application as the compost teas and the water-only control (1 liter/m^2 [2.8 gal/100 ft^2]).

TRADITIONAL COMPOST TREATMENT

Since compost tea is a product combining microbial, carbon, and nutrient amendments,

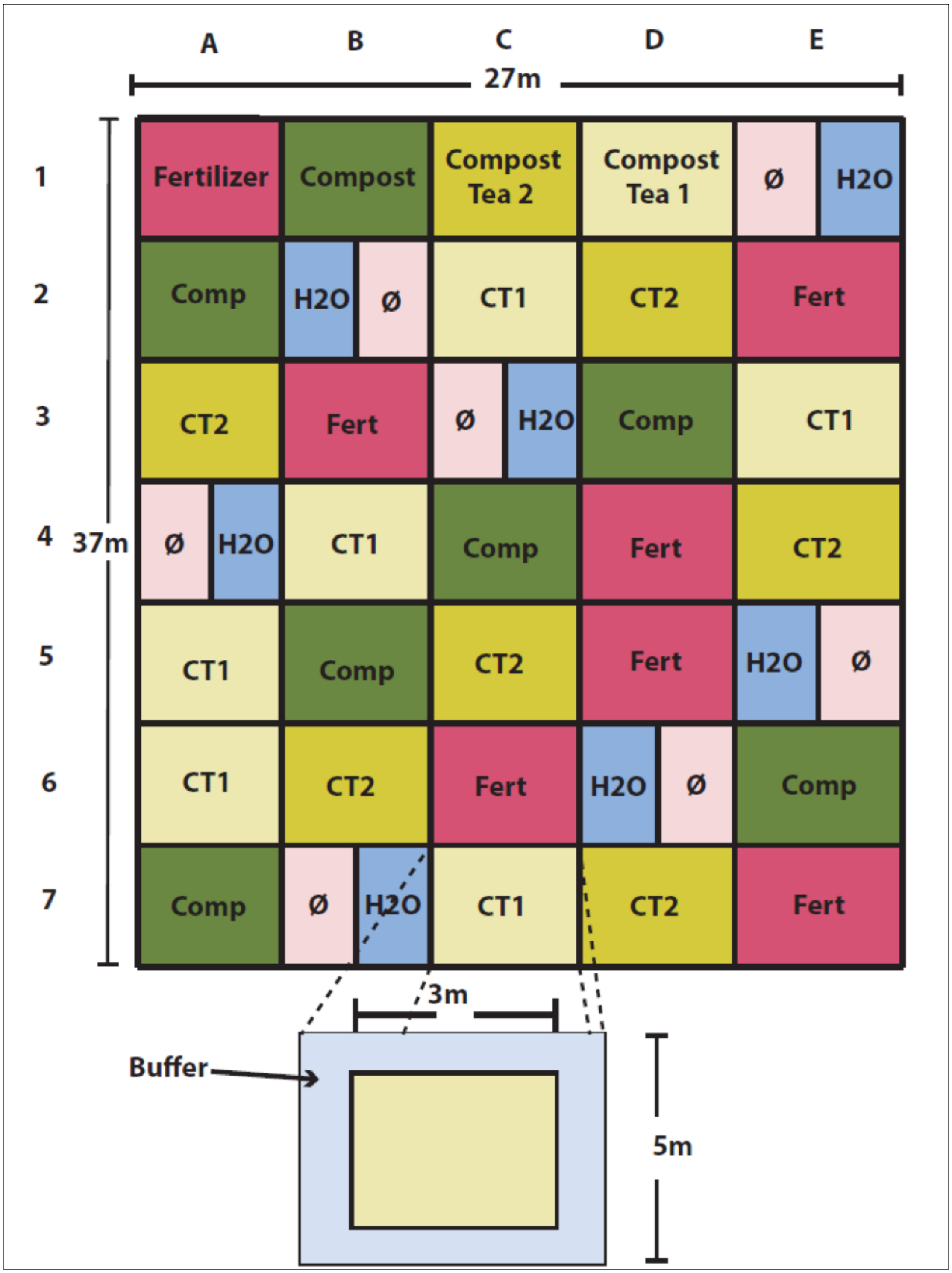


Figure 23. Design of randomized assignment of six treatments across seven blocks. The treatments included: fertilizer in the form of ammonium nitrate (NH_4NO_3), traditional compost (Comp), two steeping times of compost tea, blank control (Ø), and water-only control (H2O). The 24-hour (one-day) compost tea is designated CT1, while CT2 is the 48-hour (two-day) solution. The compost used was a 50/50 mixture of vermicompost and green waste/sheep manure compost.

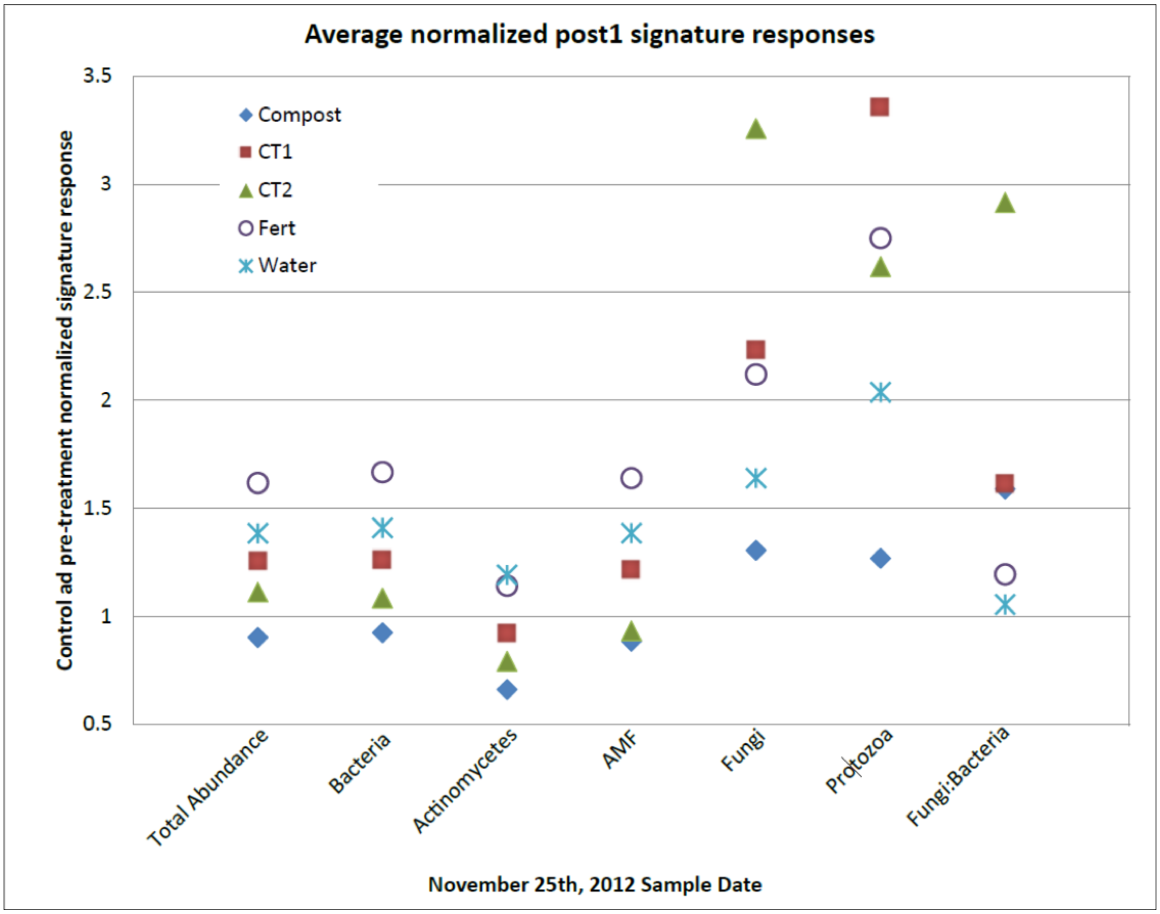


Figure 24. Post-treatment 1 phospholipid fatty acid (PLFA) signature responses normalized to pre-treatment and control. Each colored symbol represents a different treatment. Standard deviations and significance are not included in the figure due to high variability, which would crowd the data points. Table 2 (page 39) shows the mean and standard deviations for each value, and Table 3 (page 40) shows Fisher's protected LSD rankings and *p*-values for each post-treatment measurement of microbial response variables. Please refer to Figure 23 caption for more information.

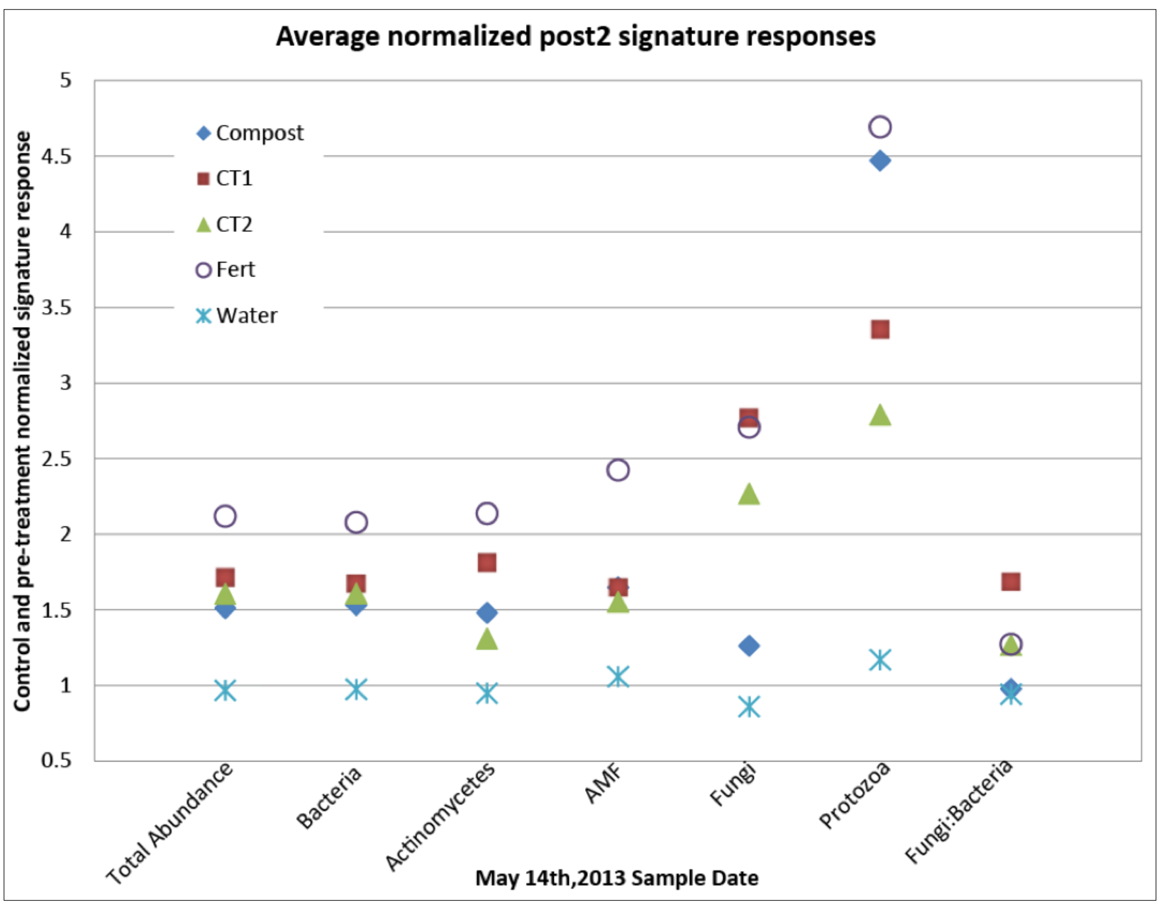
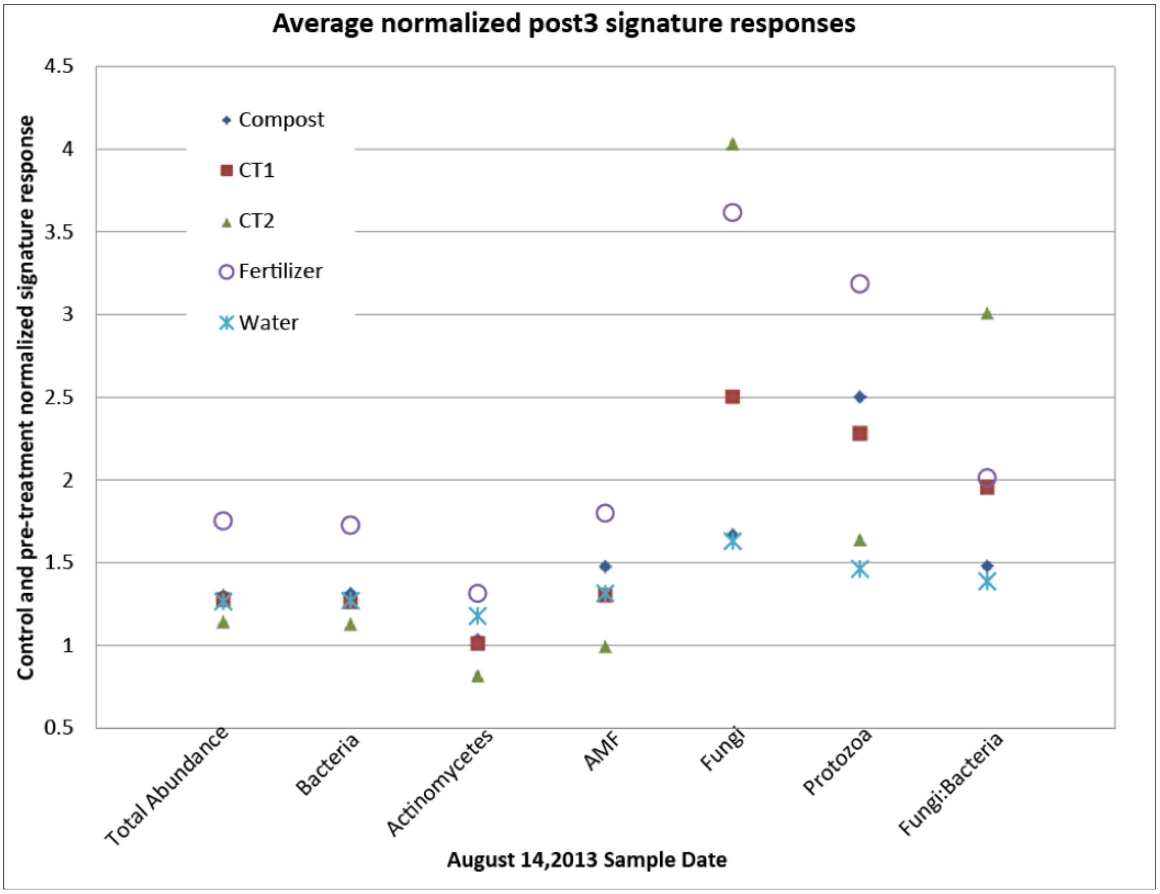


Figure 25. Post-treatment 2 PLFA signature responses normalized to pre-treatment and control. Each colored symbol represents a different treatment. Please refer to Figure 23 and 24 captions for more information.

Figure 26. Post-treatment 3 PLFA signature responses normalized to pre-treatment and control. Each colored symbol represents a different treatment. Please refer to Figure 23 and 24 captions for more information.



'traditional' compost was applied by itself as a separate treatment for the purpose of understanding the effect of the extraction process on soil microbial community development. The same compost used for tea production was applied to the compost-treatment plots. The rate of application was 1.0 kg/m^2 (0.24 lb/ft^2). This application rate was chosen as a balance between the rate used by Kim et al. (2011) and the rate for CT application. Assuming a C content of 30% (Suthar, 2008; Kim et al., 2011), and a C/N ratio of 1/30 (Suthar, 2008), this compost application was the equivalent of 100 kg N/ha (~90 lb N/ac).

WATER-ONLY AND BLANK CONTROLS

A blank control and a water-only control were used to measure background soil properties. Where water only was applied, it was applied at the same rate at 1 liter/m^2 (2.8 gal/100 ft^2). The blank control did not receive any additions.

SOIL COLLECTION AND ANALYSES

Soil samples were collected at four different dates: one day prior to the November 14, 2012, nutrient treatments, and approximately one week (November 25, 2012), six months (May 14, 2013), and nine months (August 14, 2013) post-treatment. These sample dates are referred to as pre-treatment, and post 1, 2, and 3, respectively. Soil samples were collected from the surface to a depth of 5 cm (~2 in) at three random locations within each of the nutrient treatment plots. The three samples were composited per treatment plot, resulting in a total of 42 samples (six treatments with seven replicates each). To minimize post-sampling microbial activity, soil samples (three-subsample composite) were immediately placed on dry ice, and upon return to the lab frozen to -20°C (-5°F). Samples remained at this temperature until just before analysis.

Phospholipid fatty acid (PLFA) extraction yields the mass of fatty acids per gram of soil, giving an indication of microbial group concentrations in each sample. PLFA extraction was done based on the methods of Bligh and Dyer (1959), with modifications by Frostegård et al. (1991), Buyer et al. (2002), and Buyer and Sasser (2012). Briefly, five grams (0.18 oz) of freeze-dried soil were extracted using a mixture of methanol, chloroform, and phosphate buffer (2:1:0.8). The extracts were separated using a silica column and underwent methylation to form fatty acid methyl esters (FAME). These esters were purified by filtering through an amine (NH_2) and nitrous sulfate (N_2SO_4) column to produce the final extract for gas chromatograph (GC) analysis. The GC used flame ionization detection (FID) to provide concentration and identification of fatty acid esters present in the sample. GC output included up to 120 signatures, of which 18 were chosen to represent the most commonly and clearly identifiable microorganisms in the soil. These included: (1) actinomycetes using the 16:0,17:0, and 18:0 10-methyl esters; (2) arbuscular mycorrhizal fungi (AMF) using 16:1ω5c and 20:1ω9c; (3) fungi using 18:2ω6c; (4) protozoa using 20:2ω6c, 20:3ω3c, and 20:4ω6c; and (5) bacteria using i14:0, i15:0, a15:0, i16:0, 16:1ω7c, a17:0, cy17:0, 18:1ω9c, and 18:1ω7c. Total microbial abundance is the sum of all fatty acid concentrations, and fungi:bacteria ratios were calculated dividing the concentration of total bacteria fatty acids by the fungal fatty acids (Table 1 in Williams et al., 2018, delineates the signatures applied to each group of organisms in this study).

Electrical conductivity (EC) and pH measurements were taken from each soil sample for baseline soil chemistry data. EC and pH were measured using a 1:2 soil to distilled water ratio and a combination EC and pH probe. Ammonium and nitrate concentrations were also measured to provide insight into biological cycling of inorganic N over time. Ammonium (NH_4^+) and nitrate (NO_3^-) concentrations were determined after extraction using 2 moles KCl (potassium chloride). Four grams (0.14 oz) of w/w (weight per weight) soil were extracted in 20 ml (0.7 oz) of KCl. Filtrate underwent a colorimetric assay using a BioTek™ PowerWave HT microplate reader based on Doane and Horwáth (2003) following a one-hour (NH_4^+) or 18-hour (NO_3^-) incubation.

STATISTICAL ANALYSES

PLFA and inorganic N (NH_4^+ and NO_3^-) were compared using a split-plot in time analysis of variance (ANOVA) in SAS. Data were grouped by sample date to check for differences between treatments in a single sample date, as well as by treatment to check for differences across sample dates. These follow-up tests were performed using an ANOVA. All analyses had equality of variance and displayed normality of residuals. Data points for the post-treatment experiment were adjusted to their pre-treatment values by dividing each post-treatment plot sample by its pre-treatment equivalent. For example, a value of 1 (Figs. 24–26) would indicate that the signature value on a data post-treatment was equal to the value pre-treatment. An example of how the data was adjusted, take the total abundance (TA) signatures for plot 3CT1—meaning the compost tea 1 plot located in the third block (see Fig. 23). To determine the post-treatment 1 data for this plot, the following formula was applied:

$$\frac{\left(\frac{\text{TA for 3CT1 post-treatment 1}}{\text{TA for 3CT1 pre-treatment}}\right)}{\left(\frac{\text{TA for 3control post-treatment 1}}{\text{TA for 3control pre-treatment}}\right)}$$

Figure 27A. Nitrate nitrogen (NO_3^-N) average responses for pre- and post-treatment analyses. NH_4^-N mg/kg = ammonium nitrogen in milligram/kilogram dry soil. Example: 50 mg/kg of NH_4^-N = 100 lb of NH_4^-N per acre in a layer 8 inches thick, the latter of which is commonly called an 'acre furrow slice' (AFS). The assumption for the AFS is that the soil has an average bulk density of 1.33 g/cm³ (~50% pore space by volume). The result is 100 lb NH_4^-N in an AFS that weighs 2 million pounds.

Different letters indicate significant differences between treatments on a single sample date ($p<0.05$). An asterisk (*) indicates significantly higher response for a single treatment compared with other sample dates. The four sample sets include: one day prior to the November 14, 2012, treatment (pre-treatment), and approximately one week (post 1), six months (post 2), and nine months (post 3) post-treatments.

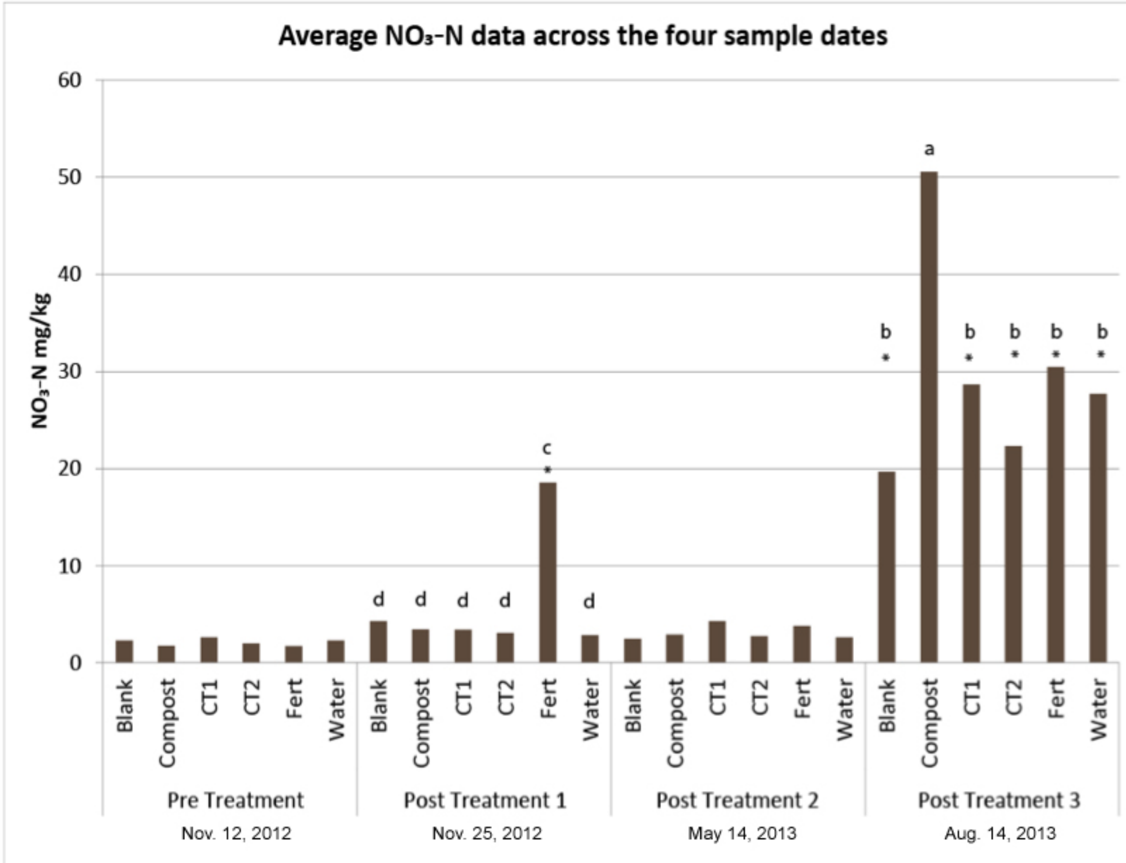
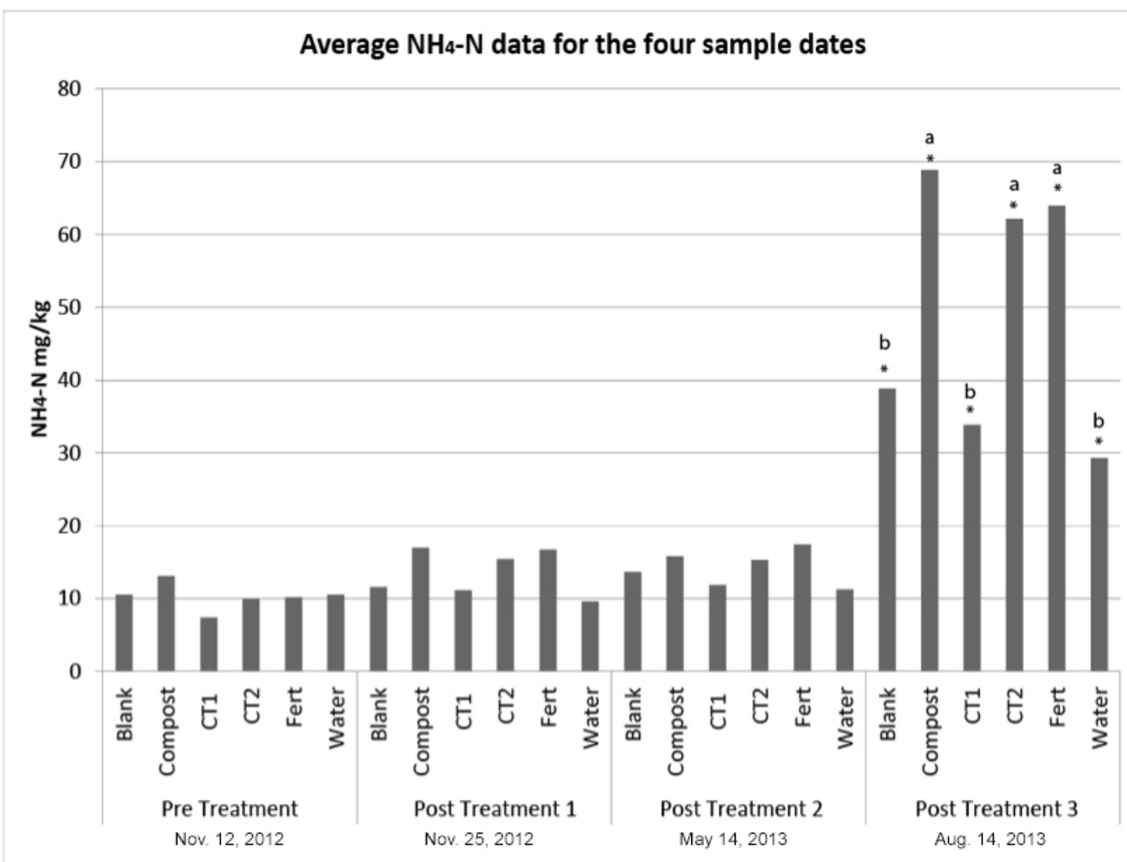


Figure 27B. Ammonium nitrogen (NH_4^-N) average responses for pre- and post-treatment analyses. Please refer to Figure 27A caption for more information.



RESULTS

Compost, vermicompost, the 50:50 mixture of composts, along with compost tea 1 and 2 were analyzed for elemental Mg, Ca, K, Na, and phosphate (PO_4^{3-}) (Table 1). Main differences were found for the Mg, Ca, and PO_4^{3-} concentrations, with lower concentrations in compost tea 1 and 2 compared to the other treatments.

Pre- and post-treatment pH and EC measurements were compared for pre-sampling (November 14, 2012—one day prior to the treatments), post 1 (November 25, 2012), and post 2 (May 14, 2013). No significant differences were observed over the course of the study, with the sole exception of a significant increase in EC in the fertilization treatment plots in the post 1 measurement, reflecting dissolved salts in the form of ammonium nitrate (NH_4NO_3).

Nitrate treatment averages showed little to no trend initially, with a notable significant increase in NO_3^- in the fertilizer treatment on post-treatment 1, but this observed spike was absent for the subsequent post-2 sampling (Fig 27*A*). No significant changes were observed in the NH_4^-N data over the same sampling period (Fig 27*B*). Both ammonium (NH_4^+) and nitrate (NO_3^-) were significantly increased on the post-3 sample date (9 months post-treatment in August 2013) compared to the other sampling times, and within the post-3 sampling significant differences were observed between treatments (Fig 27). Notably, compost had a significantly higher concentration of NO_3^- compared to all the other treatments, while compost, CT2 (aerated 48 hr), and fertilizer treatments had significantly higher levels of NH_4^+ compared to the other treatments (Fig 27).

Table 1. Elemental concentrations (parts per million) of applied treatments.

	Element (ppm)				
Sample	**Mg**	**Ca**	**K**	**Na**	**PO_4^{3-}**
Compost	242	437	935	242	149
Vermi	286	623	831	145	129
50/50	176	304	820	224	139
CT1	83	73	872	274	55
CT2	106	94	1031	330	80

Compost = traditional compost; Vermi = vermicompost; 50/50 = 50% vermicompost and 50% green waste/sheep manure compost; CT1 = compost tea one aerated 24 hours; CT2 = compost tea two aerated 48 hours; ppm = parts per million; Mg = magnesium; Ca = calcium; K = potassium; Na = sodium; PO_4^{3-} = phosphate.

The PLFA data revealed high variability in individual block and seasonal response. This variability reflects response to factors such as temperature, precipitation, heterogeneous topography within blocks, distribution of trees and other vegetation, time, and baseline soil community before treatment. Many of these confounding factors were not addressed rigorously in this study; however, an untreated control and a water-treated control plot were used within each block as a way to understand how the baseline microbial response to these external factors varied without addition of amendments seasonally. Prior to statistical analysis of post-treatment community response, the pre-treatment PLFAs of all six sets of treatment replicates were compared to understand just how heterogeneous the research site was (Fig. 28). Results of this ANOVA revealed that total microbial abundance (TA [the sum of all fatty acid concentrations]), bacteria (B), AMF, fungi (F), and protozoans (P) were marginally significantly different in at least one treatment set of plots ($\alpha<0.1$), while AMF and fungi were significant to $\alpha<0.05$ (Fig. 28). Fisher's protected least significant difference (LSD) post-hoc test revealed that the plots chosen for blank and water-only controls showed the highest concentrations of these significant groups (Fig. 28). To prevent these inherent plot differences from interfering with interpretations of post-treatment data, all plot-response variables were divided by their pre-treatment value and then normalized to the control. The control was chosen as the baseline because it represents variability in the soil environment without the addition of any external amendment. This allowed

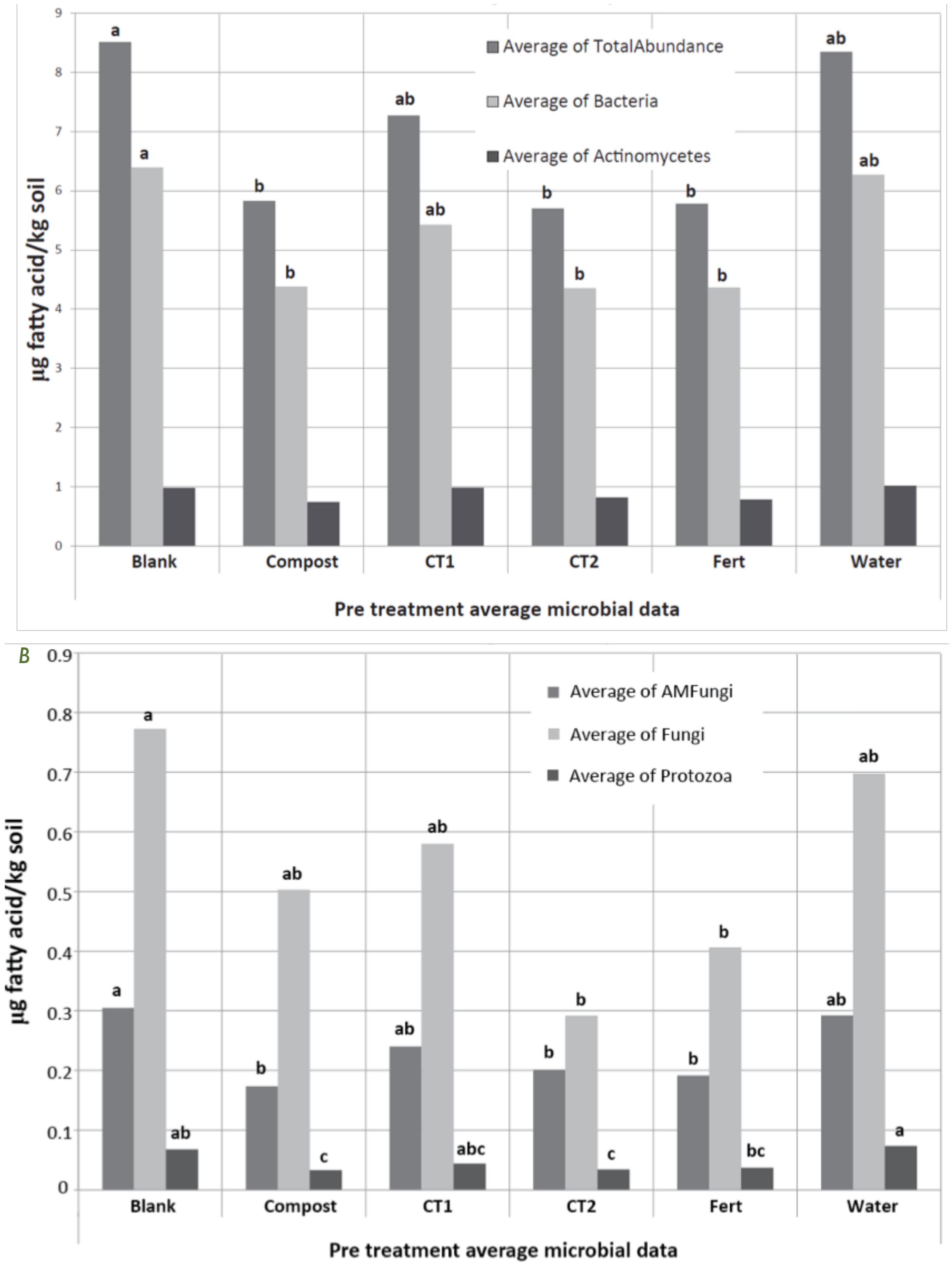


Figure 28. Distribution of baseline phospholipid fatty acid (PLFA) signature responses across randomized complete block design site prior to application of treatments, including: ***A***, Total abundance (sum of all fatty acid concentrations), bacteria, and actinomycetes; and ***B***, Arbuscular mycorrhizal fungi (AMF), fungi, and protozoa.

μg = microgram; kg = kilogram; different letters indicate significant differences between treatments (α<0.1); AMF and fungi were significant at α<0.05; Blank = control (no additions); Compost = traditional compost; CT1 = compost tea one aerated 24 hours; CT2 = compost tea two aerated 48 hours; Fert = fertilizer treatment (NH_4NO_3); Water = water-only control (water added at the same levels as in the treatments).

for the remaining treatments to be directly compared with the control, e.g., a value *above one* indicates that the abundance of a microbial group (based on PLFA signatures) responded positively to the treatment with respect to the control, while a value *below one* indicates that the treatment decreased the abundance compared to the control plot (Table 2).

Using the normalized data, no significant interactions between sample date and treatment were found across all response variables, indicating all treatments changed in a similar direction over time. All microbial groups, as represented by PLFA signatures, were highly variable among plots, which was apparent from the significant block effect in the split-plot in time mode ($p<0.05$). Leaving this blocking term in the model—for both the split-plot in time and ANOVA—allowed the true differences between sample dates and treatments to be better observed.

Overall, responses of the microbial groups across the three post-treatment sample dates showed that all treatments had either similar or higher activity than the control plots (Figs. 24–26; Table 2), though only few responses were significant (Table 3). No treatment differences were found at any of the post-treatment sample dates for total microbial biomass, total bacteria, and protozoa (Table 3). Actinomycetes abundance was significantly higher in the water treatment compared to all the other treatments (except fertilizer treatment) on the post-1 sample date (Fig. 24, Table 3), but this response disappeared in the following sample dates. AMF abundance was significantly higher in the fertilizer treatment in the post-1 measurement, but again, this response was no longer present in the following sample dates. Total fungal abundance showed marginal differences on the post-2 sample date, with the CT1 and fertilizer having a significantly greater abundance compared to the water treatment (Fig. 25, Table 3). Fungi-to-bacteria ratio was only significantly higher in the CT2 treatment compared to the fertilizer and water treatments on the first post-treatment sample date (Fig. 24, Table 3).

Table 2. Means and standard deviations of control-adjusted phospholipid fatty acid (PLFA) data.

Treatment	Sample Date	Total Abundance	Bacteria	Actinomycetes	AMF	Fungi	Protozoa	FB Ratio
Compost	Nov. 25, 2012	0.90 ± 0.30	0.92 ± 0.33	0.66 ± 0.27	0.88 ± 0.37	1.30 ± 0.75	1.27 ± 1.06	1.59 ± 0.98
Compost	May 14, 2013	1.51 ± 0.87	1.53 ± 0.85	1.48 ± 1.26	1.65 ± 0.91	1.26 ± 0.59	4.47 ± 4.44	0.98 ± 0.66
Compost	Aug. 14, 2013	1.30 ± 0.89	1.31 ± 0.89	1.04 ± 0.68	1.48 ± 1.11	1.67 ± 1.15	2.50 ± 2.30	1.48 ± 1.21
CT1	Nov. 25, 2012	1.26 ± 0.54	1.26 ± 0.45	0.92 ± 0.40	1.21 ± 0.55	2.23 ± 2.29	3.35 ± 3.88	1.61 ± 1.41
CT1	May 14, 2013	1.71 ± 1.20	1.67 ± 1.15	1.81 ± 1.91	1.65 ± 1.28	2.77 ± 2.57	3.35 ± 3.33	1.69 ± 1.21
CT1	Aug. 14, 2013	1.27 ± 0.47	1.26 ± 0.46	1.01 ± 0.35	1.30 ± 0.53	2.50 ± 2.41	2.28 ± 1.75	1.95 ± 1.58
CT2	Nov. 25, 2012	1.11 ± 0.38	1.08 ± 0.37	0.79 ± 0.34	0.93 ± 0.36	3.26 ± 3.18	2.62 ± 2.97	2.91 ± 2.44
CT2	May 14, 2013	1.60 ± 1.36	1.61 ± 1.32	1.31 ± 1.20	1.55 ± 1.42	2.27 ± 2.30	2.79 ± 4.65	1.27 ± 0.46
CT2	Aug. 14, 2013	1.15 ± 0.59	1.13 ± 0.58	0.82 ± 0.23	1.00 ± 0.46	4.04 ± 6.57	1.64 ± 1.25	3.01 ± 3.37
Fertilizer	Nov. 25, 2012	1.62 ± 1.00	1.67 ± 1.07	1.14 ± 0.75	1.64 ± 1.10	2.12 ± 1.69	2.75 ± 2.82	1.19 ± 0.57

Table 3. Means and protected least significant difference rankings for control and pre-treatment normalized PLFA data, α = 0.1.

Total Abundance	Sample Date Nov 25, 2012			Sample Date May 14, 2013			Sample Date August 14,2013		
	Treatment	Means	LSD 0.534	Treatment	Means	LSD 0.901	Treatment	Means	LSD 0.631
	Fertilizer	1.617	n.s.	Fertilizer	2.119	n.s.	Fertilizer	1.751	n.s.
	Water	1.383	n.s.	Water	0.967	n.s.	Water	1.263	n.s.
	CT1	1.256	n.s.	CT1	1.713	n.s.	CT1	1.275	n.s.
	CT2	1.111	n.s.	CT2	1.604	n.s.	CT2	1.147	n.s.
	Compost	0.900	n.s.	Compost	1.511	n.s.	Compost	1.301	n.s.
Bacteria	Sample Date Nov 25, 2012			Sample Date May 14, 2013			Sample Date August 14,2013		
	Treatment	Means	LSD 0.564	Treatment	Means	LSD 0.883	Treatment	Means	LSD 0.631
	Fertilizer	1.666	n.s.	Fertilizer	2.078	n.s.	Fertilizer	1.725	n.s.
	Water	1.409	n.s.	Water	0.974	n.s.	Water	1.270	n.s.
	CT1	1.261	n.s.	CT1	1.672	n.s.	CT1	1.263	n.s.
	CT2	1.083	n.s.	CT2	1.608	n.s.	CT2	1.132	n.s.
	Compost	0.923	n.s.	Compost	1.531	n.s.	Compost	1.314	n.s.
Actino	Sample Date Nov 25, 2012			Sample Date May 14, 2013			Sample Date August 14,2013		
	Treatment	Means	LSD 0.380	Treatment	Means	LSD 1.210	Treatment	Means	LSD 0.551
	Water	1.191	A	Water	0.948	n.s.	Water	1.176	n.s.
	Fertilizer	1.141	AB	Fertilizer	2.137	n.s.	Fertilizer	1.313	n.s.
	CT1	0.921	B	CT1	1.811	n.s.	CT1	1.012	n.s.
	CT2	0.792	B	CT2	1.309	n.s.	CT2	0.824	n.s.
	Compost	0.660	B	Compost	1.480	n.s.	Compost	1.035	n.s.
AMF	Sample Date Nov 25, 2012			Sample Date May 14, 2013			Sample Date August 14,2013		
	Treatment	Means	LSD 0.560	Treatment	Means	LSD 1.140	Treatment	Means	LSD 0.782
	Fertilizer	1.639	A	Fertilizer	2.424	n.s.	Fertilizer	1.798	n.s.
	Water	1.384	AB	Water	1.058	n.s.	Water	1.314	n.s.
	CT1	1.213	AB	CT1	1.647	n.s.	CT1	1.303	n.s.
	CT2	0.932	B	CT2	1.553	n.s.	CT2	0.997	n.s.
	Compost	0.884	B	Compost	1.648	n.s.	Compost	1.475	n.s.
Fungi	Sample Date Nov 25, 2012			Sample Date May 14, 2013			Sample Date August 14,2013		
	Treatment	Means	LSD 1.980	Treatment	Means	LSD 1.54	Treatment	Means	LSD 3.746
	CT1	2.232	n.s.	CT1	2.768	A	CT1	2.502	n.s.
	Fertilizer	2.119	n.s.	Fertilizer	2.708	A	Fertilizer	3.616	n.s.
	CT2	3.258	n.s.	CT2	2.268	AB	CT2	4.036	n.s.
	Compost	1.305	n.s.	Compost	1.261	AB	Compost	1.666	n.s.
	Water	1.639	n.s.	Water	0.860	B	Water	1.630	n.s.
Protozoa	Sample Date Nov 25, 2012			Sample Date May 14, 2013			Sample Date August 14,2013		
	Treatment	Means	LSD 2.59	Treatment	Means	LSD 3.18	Treatment	Means	LSD 1.835
	CT1	3.354	n.s.	CT1	3.354	n.s.	CT1	2.282	n.s.
	CT2	2.618	n.s.	CT2	2.790	n.s.	CT2	1.645	n.s.
	Compost	1.268	n.s.	Compost	4.470	n.s.	Compost	2.501	n.s.
	Fert	2.750	n.s.	Fert	4.693	n.s.	Fert	3.185	n.s.
	Water	2.037	n.s.	Water	1.169	n.s.	Water	1.461	n.s.
Fungi: Bacteria	Sample Date Nov 25, 2012			Sample Date May 14, 2013			Sample Date August 14,2013		
	Treatment	Means	LSD 1.415	Treatment	Means	LSD 0.707	Treatment	Means	LSD 2.086
	CT2	2.915	A	CT2	1.267	n.s.	CT2	3.012	n.s.
	CT1	1.613	AB	CT1	1.686	n.s.	CT1	1.955	n.s.
	Compost	1.589	AB	Compost	0.977	n.s.	Compost	1.477	n.s.
	Fert	1.193	B	Fert	1.272	n.s.	Fert	2.011	n.s.
	Water	1.055	B	Water	0.941	n.s.	Water	1.386	n.s.

Fertilizer = NH_4NO_3; Water = water-only control (water added at the same levels as in the treatments); CT1 = compost tea one aerated 24 hours; CT2 = compost tea two aerated 48 hours; Compost = traditional compost; Actino = actinomycetes; AMF = arbuscular mycorrhizal fungi; LSD = least significant difference.

Figure 29. RRS was significantly affected by the 2012 Arapaho Fire, and likely this ecosystem will take many decades to recover to pre-fire levels of ponderosa pine production. This photo was taken in July 2015, three years following the fire, and it shows grasses and forbs reestablishing. Soil samples for this study came from a site at RRS like this one, which contains the Alderon series. (Photo by M. Curran)

Figure 30. A long-term study at RRS with an emphasis on post-fire vegetation development and well-defined functional groups of soil microorganisms is recommended to understand the full implication of external amendment additions to this fire-impacted forest ecosystem. Soil samples for this study were taken from sites below ridgelines similar to this one, where the area's dominant soil, the Alderon series (RRS-01, an Alfisol), has historically supported ponderosa pine. This photo was taken in July 2015, three years after the Arapaho Fire. The foreground shows the Cathedral taxajunct (RRS-02, an Entisol), a shallow soil that occurs intermixed among bedrock outcrops and the deeper Alderon soils, usually on the upper portion of ridges. In the background is the prominent Laramie Peak and thousands of acres of dead ponderosa pine. (Photo by M. Curran)

Figure 31. An ongoing study at RRS is examining whether various post-fire timber cutting treatments and the planting of native grass seed are helping to reestablish ponderosa pine. The team, led by co-author Linda van Diepen and graduate student Stephanie Winters, is also studying whether the various treatments affect soil biogeochemistry and the microbial community, and whether there is a correlation with forest restoration success (Winters and van Diepen, 2018). Important baseline data for these ongoing studies are contained in Seymour et al., 2017; Herget et al., 2018; Munn et al., 2018; Williams et al., 2018; and this bulletin. (Photo by S. Williams)

DISCUSSION

With the knowledge that RRS soils were moderately to severely affected by the Arapaho Fire (Williams et al., 2018), our randomized complete block design study was set up to examine soil inorganic N and microbial properties following application of four surface amendments and two controls. Our results demonstrated that there can be extreme biological heterogeneity in a burned ponderosa pine forest soil. Even with efforts to ensure site-wide consistency in slope, tree density and age, burn severity, randomization of treatment, and subsampling, the site showed a great deal of variability. This was evident with respect to the phospholipid fatty acid (PLFA) data, as shown by the significant block term split-plot in time analysis, but not with the inorganic N data.

INORGANIC NITROGEN

The ammonium and nitrate measurements, carried out over the four sample dates, demonstrated a strong seasonal trend. The pre-treatment measurement did not show any statistical differences across the 42 treatment plots for either ammonium (NH_4^+) or nitrate (NO_3^-). Following treatment, the plots with fertilizer showed a significant spike in NO_3^-, not unexpected after the addition of ammonium nitrate (NH_4NO_3) as fertilizer. This spike disappeared by the post-2 measurement; there was not a similar spike in the NH_4^+ data. Due to the highly soluble and, therefore, mobile nature of nitrate, we expect that this added N was leached from the

Figure 32. Though the high-intensity Arapaho Fire killed the majority of ponderosa pine across approximately 98,000 ac (~40,000 ha), some areas were spared, like this one at RRS. How will the soils, microorganisms, and vegetation in these areas compare over time to the vast majority of the burn area, which experienced intense soil heating? This picture, taken in August 2014, shows an area of Alderon soil (which has historically supported ponderosa pine in the north Laramie Mountains) and adjacent Cathedral taxajunct and bedrock outcrops. (Photo by L. Munn)

Figure 33. This photo, taken in August 2014, shows an area at RRS having all four soil types. The dominant Alderon soil (RRS-01/Alfisol) occurs where ponderosa pine forest historically occupied the steep, convex upper side slopes. The Cathedral taxajunct (RRS-02/Entisol) is shallow to bedrock and occurs intermixed among the bedrock outcrops and the deeper Alderon soils, usually on the upper portions of ridges. The Dalecreek soil (RRS-03/Mollisol) occurs on the concave slopes leading down to stream channels; this soil has a high water table within the profile, which drops during the growing season. The Kovich soil (RRS-04/Mollisol) is dominated by a high water table, organic matter buildup, and accumulation of fine particles (silt and clay) due to its position low in the landscape near springs and along streams (Munn et al., 2018). How will soils and the microbial communities they support change over time in the various ecosystems at RRS and surrounding lands, some of which experienced intense soil heating while others did not? (Photo by L. Munn)

Figure 34. Quaking aspen show good regeneration following the Arapaho Fire. This photo was taken at RRS on August 14, 2014, just over two years after the fire burned through the site. Aspen often inhabit Dalecreek soil (RRS-03/ Mollisol) at RRS, which occurs below the lower tree line of the coniferous forest on the concave slopes leading down to stream channels (Munn et al., 2018). Prior to the fire, a project was planned at RRS to research the aspen communities, including comparing planned aspen treatments to stands that were not treated. That project was indefinitely postponed because of the fire, but future treatments and subsequent changes in these ecosystems could be part of a larger study focused on post-fire vegetation developments and changes in soils and microorganisms. (Photo by L. Munn)

system during spring snowmelt, immobilized by microbial activity, or taken up by early season vegetation. The lack of a signal in the NH_4^+ data was likely due to high activity of nitrification, which would have had sufficient time during the 10 days post-treatment to convert the applied ammonium to nitrate by the post-1 sample date. It has been hypothesized that nitrifying bacteria are especially active following severe forest fires (Andersson et al., 2003).

What was most interesting was the nearly fourfold increase in both NH_4^+ and NO_3^- at the post-3 sample date. This increase in both inorganic N values coincided with seasonal environmental changes, as summer 2013 was relatively wet and mild, especially in the week prior to the August 14 post-3 sampling (see Appendix A for weather information). Higher moisture content in the soil may also reflect loss of the conifer canopy and subsequent reduced water uptake after the fire. Ginzburg and Steinberger (2012) monitored soil inorganic N seasonal changes over four years following a *Pinus brutia* (Turkish pine) forest fire in northern Israel and found significant spikes in total soluble N every fall (September through December) in the burned area compared to neighboring unburned soils. What is interesting about the Ginzburg and Steinberger (2012) study is that their fall conditions were wet and mild, similar to summer and fall 2013 at RRS and surrounding lands, the year following the Arapaho Fire (Appendix A).

Within the post-3 ammonium and nitrate sample dates, statistical differences between treatments were observed (Fig. 27). The compost treatment showed significantly higher concentrations of NO_3^- over all other treatments, and higher NH_4^+ than the water-only control, blank control, and CT1 treatments. One explanation for the increase in inorganic N is that manure compost and vermicompost, alike, are long-term sources of inorganic nutrients. This is due to the decomposition of input materials and slow release of organic-bound nutrients, as well as stimulants of microbial N-fixation and assimilation (Kim et al., 2011). Vermicompost, in particular, tends to maintain higher amounts of labile N (Ngo et al., 2011),

Figure 35. University of Wyoming graduate and undergraduate students, along with their faculty mentors and others, have been actively involved in several research projects and teaching activities at RRS, where there is still much to learn about the belowground ecosystem. Here, a student determines soil texture using the hand method during a field trip to RRS in 2012, shortly after the Arapaho Fire burned through the site. The student was among those in a forest and range soils course taught by co-author Steve Williams. On this particular outing, they sampled soils and examined post-fire vegetation. (Photo by S. Williams)

Figure 36. In an attempt to better understand the belowground ecosystem at RRS, co-author Steve Williams and Stanley Bellgard, a plant pathologist with Landcare Inc., New Zealand, spent a portion of their 2012 field season conducting a pathogen survey at the site. "Our focus was on soil-borne pathogenic fungi," Williams states. "We did find a few mildly pathogenic fungi, but there is still much to learn." This photo was taken two weeks after the Arapaho Fire burned across RRS. (Photo by S. Williams)

potentially due to the lower temperatures maintained during the composting process. Researchers tend to agree that vermicompost is a more stable organic amendment. During composting there is a reduction in the carbon content, but N contents are maintained. This then creates a more stable, humified product (Suthar, 2008). Ngo et al. (2011) also suggested that vermicompost presents a more microbially available substrate than compost from the same parent material. This may be further evidenced by the large concentration of NH_4^+ in the compost tea-2 treatment. The addition of extracted N-rich products as well as the stimulation of ammonification through fire-release of NO_3^- has culminated in a large spike in ammonium, but both blank and water treatments also showed increased N levels in August 2013.

PHOSPHOLIPID FATTY ACID

The split-plot in time analysis of control-adjusted changes in phospholipid fatty acid (PLFA) data revealed that no significant trends emerged between the four treatments and two controls over the course of the nine-month study. The research of others (Lipson and Schmidt, 2004; Kim et al., 2011) suggests that sample date has a large effect on the relative activity of certain groups of microorganisms. Kim et al. (2011) found that bacterial groups varied more strongly across seasons than across organic-treated or non-treated soils in their post-fire soil amendment study. We found similar results with changes in microbial abundances across sampling dates, but within each sample date, there were only a few statistical differences in microbial responses between treatments, and no consistent treatment effects across the different sampling dates (Table 3). The one-week post-treatment sampling (November 25, 2012) showed actinomycetes responses, which indicated that fertilization had an effect on soil microbial activity, even after a significant flush in macro nutrients following the fire. These significant differences across treatments, however, disappeared by the May and August 2013 sample dates. These seasonal trends in the diversity and abundance of bacterial groups were also observed by Lipson and Schmidt (2004) in Rocky Mountain soils, across a March–June seasonal sampling gradient.

Fungal community response differences to treatments were observed during the May 2013 sample date (post 2), with CT1, CT2, and fertilizer having the highest response, followed by compost and water treatments (Fig. 25). These increases were no longer statistically significant as of the August 2013 measurement, nine months after the November 2012 treatment and 13 months after the fire (Table 3). Kim et al. (2011) showed that the addition of compost to soils following forest fires caused the greatest impact on soil fungi, rather than soil bacteria. They concluded that the changes imparted by compost resulted in soil fungal communities to be more similar to non-burned soils than untreated, burned soils. Our study showed that the extraction process for compost tea not only stimulated AMF activity (post 1) and fungal growth (post 2), but the fungi:bacteria ratio was increased to levels well above the blank control and water treatments (post 1) (Figs. 24–25). A longer-term experiment on these plots is recommended to determine if any of these effects create long-lasting impacts on soil microbial communities, N cycling, and vegetation response. Future work could include characterization of the functional diversity of bacterial and fungal communities to increase understanding of whether compost and compost teas contribute to significant long-term changes in bacteria diversity, and what effect they have on nutrient cycling and future plant root associations (such as AMF associations).

CONCLUSIONS AND FUTURE STUDIES

The RRS was significantly affected by the 2012 Arapaho Fire, and likely this ecosystem will take many decades to recover to pre-fire levels of ponderosa pine production (Fig. 29). The release of organic-bound nutrients and the charring of woody materials may have long-term effects on soil bacteria populations. The addition of organic amendments, in the form of compost and its aerated *teas*, may have stimulated ammonification and fungal activity and narrowed fungi:bacteria ratios over the short-term. The observed changes in PLFA signatures in the experimental surface soils were typically variable and non-significant as the seasons changed and different environmental conditions allowed microbial communities to wax and wane. A longer-term study at RRS with an emphasis on characterization of post-fire vegetation development (Figs. 30–34) and well-defined functional groups of microorganisms (e.g., N-fixing bacteria and mycorrhizal fungi) is recommended to understand the full implication of external amendment additions to this fire-impacted forest ecosystem.

There is yet much to understand about the belowground ecosystem (Figs. 35–36). Part of the problem is access, and some is cultural. Access is normally restricted to excavations, which can be difficult, plus such excavations change the soil environment from one of restricted oxygen, light, and energy (Williams et al., 2004). Investigations of soil biology require numerous indirect methods (many chemical, many microscopic). Investigation of soil organisms is at a frontier as molecular techniques and indirect non-disturbing methods are being developed. The results reported here are for a highly variable environment in a remote forested site in Wyoming. Compared to intensively managed agricultural lands, wildlands including forest and range environments are much less understood. Still, these are highly valued environments not only for wood, water, wildlife, recreation, etc., but also aesthetic appeal and cultural values. It behooves us to understand them better. If there is a take-home message from the work here it is that the belowground ecosystem is complex, and we do not understand it well, which encourages further study.

ACKNOWLEDGMENTS

The University of Wyoming's Department of Civil and Architectural Engineering provided early funding for lead author Claire Wilkin's work on this project, as well as academic support during the completion of her master's degree. Her M.S. led to the publication of Wilkin, 2014, which provided much of the baseline information for this bulletin. The UW Department of Ecosystem Science and Management and the Wyoming Agricultural Experiment Station (WAES) provided additional funding for research at RRS following the 2012 Arapaho Fire. WAES and one of its Research and Extension (R&E) centers, the James C. Hageman Sustainable Agriculture R&E Center (SAREC), provided funding to complete Bulletin 8 and other bulletins in the RRS series. We extend much appreciation to Bret Hess, WAES director, and John Tanaka, retired SAREC director and WAES associate director, for providing the necessary resources to bring this and other RRS research projects to fruition. During this study, Frank Galey, former dean of the UW College of Agriculture and Natural Resources, provided incentive and support to develop RRS into a site for extension, research, and teaching.

Professor Patricia Colberg was a guiding light in Wilkin's search for a project that matched her interests and also fit with the goals of her two faculty co-chairs, along with their respective departments: Professor Michael Urynowicz, Civil and Architectural Engineering, and Professor Stephen Williams, now retired, Ecosystem Science and Management. At the time of Wilkin's graduate work at UW (2012–2014), one of her mentors, Dr. Colberg, was the first woman to achieve the rank of professor in the UW College of Engineering and Applied Science. Dr. Colberg is now department chair, professor, and National Academy of Education fellow at the University of Idaho's Department of Civil and Environmental Engineering.

During her graduate work, Wilkin says that Professors Williams and Urynowicz, who would later collaborate with Linda van Diepen, Larry Munn, and Robert Waggener to complete this bulletin, provided three years of academic support. In her thesis, Wilkin writes: "Dr. Urynowicz was kind enough to see my potential and seek me out to begin a project at the university, and then hardly bat an eye when I needed to venture off on my own into relatively unknown territory. Dr. Williams responded to my vague research ideas with unparalleled enthusiasm, and without his continued patience, encouragement, and wise oversight, this project would never have been realized. Having both advisers there for guidance and discussion was an invaluable contribution to this research."

Professor David Legg, statistician in the UW Department of Ecosystem Science and Management who has since retired, provided vital insight and opportunity for discussion on the statistical design and analysis of the various components of this project. Laboratory work was supported by a McIntire-Stennis formula grant, as well as Peter Stahl and his phospholipid fatty acid research space. Pete is a professor of soil ecology in the UW Department of Ecosystem Science and Management and directs the Wyoming Restoration and Reclamation Center. Appreciation is extended to Kelli Belden, research associate and director (now retired) of the former UW Soil Testing Laboratory for analyzing soil cations, and to Caley Gasch, Leann Naughton, and Rachana Giri Paudel for their help in sample analysis. Assisting with various field operations were Christine Sednek, Dave Rider, Michael Curran, and Jesse Hahm. Also present for some of the field work was Espresso, Christine Sednek's canine companion. "Espresso joined us for moral support," says Christine, who earned a master's degree in environmental engineering from UW in 2012 and is now an environmental engineer with Burns & McDonnell in Centennial, Colorado. Brian Mealor, associate professor in the UW Department of Plant Sciences and director of the Sheridan R&E Center, helped to lay out the study conceptually. Stanley Bellgard, a plant pathologist with Landcare Inc., New Zealand, helped with soil sampling in 2012. Mick Mickelson, who lives near RRS, proved to be the finest of neighbors in times of need at this remote site.

More than 100 people have helped in our efforts to publish the RRS bulletin series, including many who assisted with various aspects of Bulletin 8. We are grateful for the weather data provided by George Portwood, a long-time Laramie Peak-area resident and ranch manager who has recorded weather information for the National Weather Service since 1974. We thank those who reviewed the paper: Joey Knelman, Ph.D., Institute of Arctic and Alpine Research, whose specialties include microbial ecology, soil microbiology, and biogeochemistry; and Stephanie Winters, M.S. student in soil science, UW Department of Ecosystem Science and Management.

Much gratitude is extended to UW Extension's Office of Communications and Technology for a variety of outstanding assistance. Graphic designer Tanya Engel has spent many, many hours on each and every bulletin, helping in a variety of ways, including bulletin layout and design, figure and table development, and consultation with authors, an editor, and a research assistant. Tanya worked to develop a bulletin template that would appease to a wide audience, from students learning about soils and ponderosa pine to researchers carrying out post-fire studies, and that template has consistently followed each bulletin to the finish line. Ann Tanaka, website designer/developer, has overseen the posting of each bulletin on the SAREC website at http://bit.ly/RogersResearchSite. And those familiar with the UW Extension website can also find the bulletins at http://www.wyoextension.org/publications/. Type "Rogers Research Site" in the Search Publications bar. Steve Miller, senior editor in the office, worked with us on news release distribution. And we also tip our hat to Tana Stith, retired manager of the office, for allowing her incredibly busy staff to devote time to the bulletin series. The office deserves major kudos and an equally major award for exceptional work.

Josh Decker, manager of UW Real Estate Operations, and his staff provided valuable assistance throughout work on the RRS bulletin series. Base maps for three figures appearing in this bulletin were provided by the State of Wyoming, U.S. Forest Service, and National Agriculture Imagery Program. Leslie Waggener has provided support and guidance throughout development of the entire bulletin series.

We offer a 'click of the shutter' to those who took photos appearing in Bulletin 8: in addition to co-authors Larry Munn and Steve Williams, they include Stanley Bellgard; Josh McGee, incident commander of the Arapaho Fire; Jim Kibler, courtesy of InciWeb, an interagency incident website primarily used for wildfires, prescribed fires, and other fire-related incidents; Michael Curran, UW graduate student who helped with soil sampling and many other tasks associated with this project and other studies at RRS; Kelly Greenwald, SAREC administrative associate; and Jim Freeburn, former SAREC director who is now the regional training coordinator for Western Sustainable Agriculture Research and Education.

Thank you to the faculty and staff at the UW American Heritage Center (AHC) with help relating to the papers of William C. Rogers and Virginia Scully. It took a team effort to pull more than 30 boxes from the AHC archives and then refile those boxes once co-author Robert Waggener was complete with his research. A tip of the hat goes to Vicki Glantz, AHC reference archives specialist, for help with photo and document scanning. Finally, we owe a great deal of gratitude to Colonel William C. Rogers for donating his land in the Laramie Mountains

to the University of Wyoming for research, extension, teaching, and other activities. For it was his gift that is allowing students, faculty, staff, and others to research pre-and post-fire soils, examine post-fire ponderosa pine restoration practices, and carry out other studies in Wyoming's great outdoors. May this expand our knowledge about Wyoming's natural resources, and, ultimately, lead to the improvement of forestry and wildlife resources at the Rogers Research Site, Laramie Mountains, and beyond for generations to come.

We acknowledge the many University of Wyoming undergraduate and graduate students, faculty and staff members, and others who have conducted research or assisted with those efforts at the Rogers Research Site in the north Laramie Mountains of southeast Wyoming. Colonel William C. Rogers, who bequeathed his land to the University of Wyoming, would be proud knowing that students and their faculty mentors are not only enjoying the great outdoors, but are working on projects to benefit forestry and wildlife resources for generations to come. This photo was taken in August 2014, two years after the high-intensity Arapaho Fire burned through the area. (Photo by Larry Munn)

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APPENDIX A. 2012–2014 WEATHER DATA

This appendix includes: (1) monthly weather data leading up to the Arapaho Fire (July 2012) and during our study (July 2012–August 2013); and (2) daily weather data one week prior to pre-treatment soil sample collection, and one week prior to each of the three post-treatment soil sample collections. Key dates for this study follow:

- July 2–3, 2012 — Arapaho Fire burns across Rogers Research Site
- November 12, 2012 — Pre-treatment soil samples collected
- November 25, 2012 — Post-treatment #1 soil samples collected
- May 14, 2013 — Post-treatment #2 soil samples collected
- August 14, 2013 — Post-treatment #3 soil samples collected

NOTE: The weather data was provided by George Portwood (Fig. 1), a longtime Laramie Peak-area resident and ranch manager who has recorded weather information for the National Weather Service since 1974. The weather station on Mr. Portwood's property is located approximately 5 mi (8 km) southwest of RRS at an elevation of ~6,400 ft (1,950 m). Elevations at RRS range from ~6,700 to 7,300 ft (2,000–2,200 m). Mr. Portwood says that the weather at his property is similar to the weather at RRS, though it would vary slightly because of the differences in elevation and proximity (G. Portwood, personal communication, 2017).

Figure 1. Longtime Laramie Peak-area resident George Portwood has voluntarily collected weather data for the National Weather Service since 1974. He recorded the information at the Double Four Ranch from 1974 through 2005, and since retiring in 2006 he has continued to collect data on his own property. The Double Four weather station was located approximately 5 mi (~8 km) south-southwest of RRS. The station on Mr. Portwood's land is about five miles (~8 km) southwest of RRS. Both sites are at slightly lower elevations. (Photo by Bonnie Parker)

MONTHLY WEATHER DATA

PRECIPITATION (inches)							
Monthly	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**1974–2013 Avg**
January	0.44	0.07	0.63	0.22	0.62	1.18	0.42
February	1.01	0.70	1.12	1.04	1.75	2.10	0.58
March	0.00	0.08	2.21	0.68	1.45	1.17	1.03
April	0.69	3.08	1.79	3.94	3.16	2.14	2.00
May	1.35	1.53	2.14	4.69	3.01	4.03	2.63
June	0.22	0.55	2.01	1.56	1.03	0.42	1.97
July	2.15	2.20	3.80	1.73	0.67	1.29	1.64
August	0.12	1.45	1.68	0.17	0.96	1.06	1.31
September	0.38	4.30	2.09	0.20	0.77	1.74	1.23
October	1.41	1.84	0.14	1.17	0.23	0.72	1.05
November	0.18	0.35	0.55	0.57	0.54	0.69	0.75
December	0.33	0.67	1.19	0.58	1.59	0.93	0.59
TOTAL	**8.28**	**16.82**	**19.35**	**16.55**	**15.78**	**17.47**	**15.20**
Cumulative	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**1974–2013 Avg**
January	0.44	0.07	0.63	0.22	0.62	1.18	0.42
February	1.45	0.77	1.75	1.26	2.37	3.28	1.00
March	1.45	0.85	3.96	1.94	3.82	4.45	2.03
April	2.14	3.93	5.75	5.88	6.98	6.59	4.03
May	3.49	5.46	7.89	10.57	9.99	10.62	6.66
June	3.71	6.01	9.90	12.13	11.02	11.04	8.63
July	5.86	8.21	13.70	13.86	11.69	12.33	10.27
August	5.98	9.66	15.38	14.03	12.65	13.39	11.58
September	6.36	13.96	17.47	14.23	13.42	15.13	12.81
October	7.77	15.80	17.61	15.40	13.65	15.85	13.86
November	7.95	16.15	18.16	15.97	14.19	16.54	14.61
December	8.28	16.82	19.35	16.55	15.78	17.47	15.20
TOTAL	**8.28**	**16.82**	**19.35**	**16.55**	**15.78**	**17.47**	**15.20**
SNOWFALL (inches)							
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**1974–2014 Avg**
TOTAL (in)	**47.50**	**129.00**	**102.00**	**96.00**	**109.50**	**119.50**	**83.23**
1st snow	Oct 5	Oct 4	Sep 11	Nov 6	Nov 17	Oct 8	NA
Amount (in)	0.50	5.00	0.50	0.50	1.50	0.50	NA

PRECIPITATION (inches)							
TEMPERATURE (°F)							
Average High	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**1974–2015 Avg**
January	40.81	35.80	37.10	39.00	35.90	30.80	50.40
February	40.97	37.90	39.30	43.82	44.21	42.40	54.00
March	64.00	52.00	48.80	56.45	52.23	54.30	64.20
April	69.57	53.80	58.70	59.57	59.07	56.30	74.60
May	75.23	69.70	68.10	59.35	63.65	64.30	82.30
June	93.80	87.30	78.20	78.40	85.20	79.80	91.10
July	96.87	91.80	86.60	86.76	91.00	91.90	95.10
August	93.97	91.80	84.90	87.77	87.32	79.10	92.80
September	85.10	79.90	75.90	83.93	78.07	69.70	88.20
October	61.32	56.20	65.30	67.27	67.26	56.20	77.20
November	53.67	48.90	44.00	44.27	54.10	49.50	63.90
December	37.16	32.30	38.50	35.42	30.87	37.30	51.90
AVERAGE	**67.71**	**61.45**	**60.45**	**61.83**	**62.41**	**59.30**	**73.81**
Average Low	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**1974–2015 Avg**
January	18.68	14.40	14.60	17.81	15.58	12.70	-12.30
February	13.10	14.80	9.60	19.32	20.55	20.50	-12.80
March	27.10	21.00	22.10	24.23	23.94	27.20	-1.20
April	29.70	22.30	29.00	27.73	29.33	28.20	9.80
May	34.74	36.10	37.10	35.74	34.16	35.30	21.80
June	46.60	46.90	41.50	48.33	46.57	44.10	31.30
July	58.13	53.10	49.80	48.84	52.65	51.70	37.70
August	52.71	54.10	48.20	49.55	47.35	48.40	34.90
September	44.17	46.20	41.10	43.30	42.43	42.30	24.10
October	46.90	28.50	33.90	36.84	37.16	30.80	12.20
November	27.50	30.00	18.50	21.87	25.73	27.90	-3.20
December	16.26	11.40	18.60	15.32	10.23	10.90	-13.70
AVERAGE	**34.63**	**31.60**	**30.30**	**32.41**	**32.14**	**31.70**	**10.72**
Average Mean	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**1974–2015 Avg**
January	29.75	25.10	25.90	28.41	25.74	21.70	19.05
February	27.04	26.30	24.50	31.57	32.38	31.50	20.60
March	45.55	36.50	35.50	40.34	38.09	40.70	31.50
April	49.64	38.10	43.90	43.65	44.20	42.30	42.20
May	54.99	52.90	52.60	47.55	47.91	49.80	52.05
June	70.20	67.10	59.80	63.37	65.89	62.00	61.30
July	77.50	72.50	68.20	67.80	71.83	71.80	66.40
August	73.34	73.00	66.60	68.66	67.34	63.70	63.85
September	64.64	63.10	58.50	63.62	60.25	56.00	56.15
October	54.11	42.30	49.60	52.05	52.51	43.50	44.95
November	40.59	39.50	31.30	33.07	39.92	38.70	33.55
December	26.71	21.80	28.60	25.37	20.55	24.10	19.10
AVERAGE	**51.17**	**46.51**	**45.40**	**47.12**	**47.28**	**45.48**	**42.27**

PRECIPITATION (inches)

Average Mean Each Decade Since 1974		
1974–1983	41.34	
1984–1993	42.36	
1994–2003	44.09	
2004–2013	45.67	
2014–2017	46.33	
Highest and Lowest Mean Since 1974		
Lowest	39.58	1976
Highest	51.17	2012

Number of Days above 100.0°F (37.8°C) Since 1974		
1974–2006	none	
2007	12	
2008	4	
2009	2	
2010	3	
2011	1	
2012	28*	
2013	8	
2014	2	
2015	2	
2016	3	
2017	4	

DAILY WEATHER DATA

WEEK PRIOR TO PRE-TREATMENT SOIL COLLECTION (11-12-12)

Date	Precip (inches)	Temp (°F high)	Temp (°F low)	Temp (°F mean)
11-05-12	0.00	57.00	31.00	44.00
11-06-12	0.00	66.00	34.00	50.00
11-07-12	0.00	70.00	36.00	53.00
11-08-12	0.00	61.00	31.00	46.00
11-09-12	0.00	69.00	24.00	46.50
11-10-12	0.09	42.00	15.00	28.50
11-11-12	0.00	27.00	02.00	14.50
11-12-12	0.00	31.00	12.00	21.50

Average Mean Each Decade Since 1974				
Total/Average	**0.09**	**52.90**	**23.10**	**38.00**
WEEK PRIOR TO POST-TREATMENT #1 SOIL COLLECTION (11-25-12)				
Date	**Precip (inches)**	**Temp (°F high)**	**Temp (°F low)**	**Temp (°F mean)**
11-18-12	0.00	55.00	31.00	43.00
11-19-12	0.00	53.00	34.00	43.50
11-20-12	0.00	57.00	32.00	44.50
11-21-12	0.00	61.00	40.00	50.50
11-22-12	0.00	48.00	26.00	37.00
11-23-12	0.00	48.00	12.00	30.00
11-24-12	0.00	54.00	37.00	45.50
11-25-12	0.00	54.00	25.00	39.50
Total/Average	**0.00**	**53.80**	**29.60**	**41.70**
WEEK PRIOR TO POST-TREATMENT #2 SOIL COLLECTION (05-14-13)				
Date	**Precip (inches)**	**Temp (°F high)**	**Temp (°F low)**	**Temp (°F mean)**
05-07-13	0.06	76.00	33.00	54.50
05-08-13	0.00	69.00	36.00	52.50
05-09-13	0.03	71.00	34.00	52.50
05-10-13	0.16	66.00	33.00	49.50
05-11-13	0.05	65.00	37.00	51.00
05-12-13	0.00	85.00	43.00	64.00
05-13-13	0.00	93.00	50.00	71.50
05-14-13	0.00	91.00	52.00	71.50
Total/Average	**0.30**	**77.00**	**39.80**	**58.40**
WEEK PRIOR TO POST-TREATMENT #3 SOIL COLLECTION (08-14-13)				
Date	**Precip (inches)**	**Temp (°F high)**	**Temp (°F low)**	**Temp (°F mean)**
08-07-13	0.32	82.00	49.00	65.50
08-08-13	0.00	84.00	50.00	67.00
08-09-13	T	84.00	50.00	67.00
08-10-13	T	89.00	48.00	68.50
08-11-13	0.00	88.00	53.00	70.50
08-12-13	0.00	85.00	47.00	66.00
08-13-13	0.03	89.00	42.00	65.50
08-14-13	T	91.00	48.00	69.50
Total/Average	**0.36**	**86.50**	**48.40**	**67.40**

A PERSONAL MESSAGE AND THANK YOU

We owe a great deal of gratitude to the then anonymous donor of the Triple R Ranch

By Robert W. Waggener

In the early 2000s, shortly before his death, an anonymous person was quietly willing millions of dollars to young people to further their education; to causes he believed in, like social justice, civil rights, and poverty; to missions he cared about, including the Tarahumara Mission in Mexico; to institutions that helped people, such as the Memorial Sloan Kettering Cancer Center in New York; and to schools of higher education, notably the University of Wyoming. The anonymous donor created the UW Excellence Fund to stimulate creative and innovative activities at UW, provided $1.6 million for Department of Theatre and Dance facilities and curriculum, and gifted $1 million to the Shepard Symposium on Social Justice. UW would also learn that it was to receive a 320-acre parcel of forested land in the Laramie Mountains of eastern Wyoming. The anonymous donor directed the institution to use the property, in part, for research relating to forestry and wildlife resources.

After the person died in 2003—and the land had passed to UW—graduate and undergraduate students, faculty and staff members, academic professionals, and collaborators began studying soils and vegetation on the land that had become known as the Rogers Research Site, named in memory of that anonymous donor, Colonel William C. Rogers. One team used specialized techniques and equipment to map vegetation from the air, verifying their findings with field visits known as ground-truthing; another classified soils; a third team researched the ponderosa pine ecosystem; while a fourthset out to document the resources of RRS, including plant distribution, water sources, topographic features, and belowground biota. While they conducted their studies, team members knew very little to nothing about Colonel Rogers, something that became very evident to me when I was hired by the Wyoming Agricultural Experiment Station (WAES) in mid-2016 to work with co-authors to publicize their research findings and to also compile other bulletins focused on planning meetings and public input that would help guide management, research, teaching, and other activities at the site. As work on these publications commenced, people would ask: "Who is Colonel Rogers?"

This is an official U.S. Army photo (circa 1951) of William C. Rogers when he was a lieutenant colonel in the Army. By 1955 he had been promoted to colonel. After retiring from the military and civilian jobs, including railroad work, he spent much time on his beloved property in Wyoming's north Laramie Mountains, as well as in Mexico and on a farm in Nebraska. (Photo from RRS Bulletin 1, courtesy of Mary Laura Kludy, Preston Library, Virginia Military Institute)

"I have no idea," I would respond, stating that I was specifically hired by WAES to oversee the publication of peer-reviewed bulletins detailing studies at the site and early planning efforts.

But as work continued on the bulletins, the 'who-is-Colonel-Rogers' question followed me at practically every turn. I finally decided that I could no longer ignore the question, that I would launch my own research to tell the story about the man behind the land, Colonel William C. Rogers. Since then, I have spent approximately 200 volunteer hours trying to answer that question since this part of the first eight Rogers Research Site bulletins was out of the scope of my job duties. But in the end, I am glad I made that volunteer effort because I feel like I've gotten to know a most unique man, a man who led an adventurous life and who positively impacted the lives of so many, including myself and those involved in studies on the land he donated to UW.

Colonel William C. Rogers (Ret.) at the throttle of a high-horsepower, high- speed Union Pacific locomotive in 1965—for a full-tonnage test run from Cheyenne, Wyoming. (Photo from RRS Bulletin 1, courtesy of the William C. Rogers Papers, University of Wyoming American Heritage Center)

After graduating from the Virginia Military Institute in 1927, William Catesby Rogers was called to active duty. His career in the military would take him to the Western Front of the European Theatre during World War II, and it would take him around the world as he became an expert in trains and railway systems. Some of these trips were classified at the time, including one to Belgium, France, and Germany to investigate torque converter locomotives and locomotive transmissions. After serving his country with distinction in the U.S. Army, Colonel Rogers entered civilian life, working with railroads like the Union Pacific (UP), where he tested high- horsepower, high-speed freight locomotives on full-tonnage runs. And he also began very actively trading stocks, making $10,000 a day when things were going well, according to friends I interviewed for the stories about him that appeared in the first eight bulletins, including this one. While working for the UP Railroad in Cheyenne, Wyoming, Colonel Rogers fell in love with the state's rugged beauty, and he started looking for a place that he could call home after retiring. That place became a remote piece of land in the north Laramie Mountains, where he wanted to live in isolation while at the same time expanding his worldly views and meeting new people. I would learn that Colonel Rogers had a very conservative side to him, but at the same time he was a liberal. But those things really didn't matter to him. What mattered was his relationship with friends and strangers alike—he quickly befriended ranchers and mountain folks in the area, and also began to host hippies from across the country, as well as writers, artists, school teachers, weavers, and even an herbal medicine researcher after running ads in publications like *Mother Earth News*. One of these guests became a close friend who would join The Colonel, as he became known, on trips across the country to study Calamity Jane and on ventures to Mexico to research the Tarahumara Indians.

Rogers pursued anything that fascinated him, and in the process he became a prolific researcher, traveler, reader, and writer, and this became evident while looking at his papers that he donated to the University of Wyoming's American Heritage Center (AHC), a collection that is open to the public. I would learn from his friends and acquaintances that he was independent, unusual if not downright eccentric, intelligent, very caring, respectful, and eclectic, to name a few. I can only imagine that one of his many mottos might be: "If you have a goal or an interest, pursue it—and pursue it fiercely."

Rogers, who by retirement was worth many millions—in part because of the profits he made off of stocks during the famous "dot-com bubble" of the late 1990s—lived a most frugal life and sacrificed his own comforts so that he could give to many others in the end. But his eternal optimism became a double-edged sword as his self-traded, narrowly invested stock portfolio took a horrendous hit during the infamous “dot-com crash” of the early 2000s, sinking his net worth estimated at more than $50 million to approximately $10 million just before his death. I debated whether to include such information in these stories. But Colonel Rogers believed strongly in the education of young people, and the tremendous financial losses he suffered in a matter of months after decades of successful stock trading can teach all of us an important lesson when it comes to finances and saving for the future. Prudent stock investing, in part, depends on developing a sound plan based on things like diversification; adding non-correlating assets as well as dividend-paying and value stocks to a portfolio invested heavily in growth stocks, like those of the dot-com bubble; and well-thought-out stop loss and/or trailing stop orders. These and other strategies can help to protect investors from losses like Rogers suffered during the dot-com crash. Fortunately for many, he still had about $8 million worth of stocks at the time of his death, and that money continues to help individuals, institutions, and causes across the U.S., Mexico, and beyond, including UW. Colonel Rogers would be happy knowing that, and he would also be elated knowing that students and their faculty mentors, in collaboration with others, are carrying out studies on the land he loved, and that their research is being compiled into peer-reviewed publications to help advance the knowledge of others.

With that, I am grateful to WAES Director Bret Hess and retired Associate Director John Tanaka for having the confidence in me to help guide the first eight RRS bulletins to fruition. I thank the co-authors for their contributions, former and current UW students Mathew Seymour, Mollie Herget, Claire Wilkin, and Stephanie Winters; retired and current UW faculty members Steve Williams, Larry Munn, Linda van Diepen, and Michael Urynowicz; and academic professional Kenneth Driese. Tanya Engel, a graphic designer in UW Extension’s Office of Communications and Technology, spent many hours putting together visually appealing publications—which reminds me of a quote by my late photojournalism and typography instructor at UW, Robert Combs Warner: “Presentation is half the battle.”

William C. Rogers enjoys a quiet afternoon visiting with guests Levida and Brock Hileman, at right, along with Levida’s daughter, Colleen Hogan, the picture taker, at Rogers’ Triple R Ranch in the north Laramie Mountains. The Colonel, as he was known by friends, purchased the property for a place to enjoy retirement—hosting both friends and strangers alike; researching, reading, and writing; and performing physical labor, whether splitting firewood, making compost for his garden, or pruning trees. He later donated the 320 acres to the University of Wyoming for studies relating to wildlife and forestry resources. (Photo from RRS Bulletin 1, courtesy of Colleen Hogan)

One of the most enjoyable aspects of this entire project was getting to know Colonel William Catesby Rogers, and I thank many for sharing stories about this most interesting man, information about his Triple R Ranch, and other details, among them Levida and Brock Hileman, Colleen Hogan, Duane and Tiny Walker, Rebecca Hilliker, George Portwood, Bryan Anderson, Jim Clyde, Sarah Stark Serra, and Greg Dyekman. Also providing information were Mary Laura Kludy, archives and records management specialist at the Virginia Military Institute (VMI), and faculty and staff at UW's American Heritage Center (AHC).

Among the many people who contributed photos for the bulletins were Colleen Hogan, Bonnie Parker, Michael Curran, Kelly Greenwald, Jim Freeburn, Mollie Herget, Linda van Diepen, Steve Williams, Larry Munn, Steve Paisley, Sarah Stark Sarah, Dorothy Tuthill, Ryan Amundson, Nichole Bjornlie, Tim Byer, Grant Frost, Martin Hicks, Stephanie Winters, and Vivek Sharma, as well as those associated with the AHC, VMI, and InciWeb, the latter of which provided photos from the 2012 Arapaho Fire, which burned nearly 100,000 acres in the north Laramie Mountains, including RRS lands. Fortuitously, much research had previously taken place at RRS, which provided valuable baseline data as research turned to the wildfire and its affects, both short- and long-term, on vegetation, soils, and other natural resources at the site and surrounding lands Maps, too, became an important part of the bulletins, and many thanks go to Josh Decker and his staff at UW Real Estate Operations and to Shawn Lanning in the Wyoming Geographic Information Science Center.

In all, more than 100 people helped in our efforts to publish the first eight publications in the RRS series, and they are acknowledged in each bulletin. This project, I am proud to say, became one of the most challenging and rewarding endeavors of my 36-year professional career of writing, editing, photography, and project management. A big thank you goes to my wife, Leslie, who offered guidance throughout the 2½-year endeavor She, like me, became fascinated with the story of William Catesby Rogers, and it's our hope that his quiet legacy gains steam, just like the new high-powered locomotives that he engineered on test runs decades ago. As one of his favorite authors, Friedrich Wilhelm Nietzsche, wrote, "The secret of reaping the greatest fruitfulness and the greatest enjoyment from life is to live dangerously."

Soil samples for the study detailed in this bulletin came from locations at the Rogers Research Site (RRS) like this one, which contains the Alderon series (RRS-01, an Alfisol). The Alderon soil occurs where ponderosa pine forest historically occupied the steep, convex upper side slopes at RRS and surrounding lands, which typically range from 25 to 50%. Though the thick-barked ponderosa pine (*Pinus ponderosa*) has evolved to survive frequent, low-intensity fires, the 2012 Arapaho Fire burned with such intensity that it killed the majority of pine and other vegetation. This photo was taken on September 24, 2015. (Photo by Steve Williams)