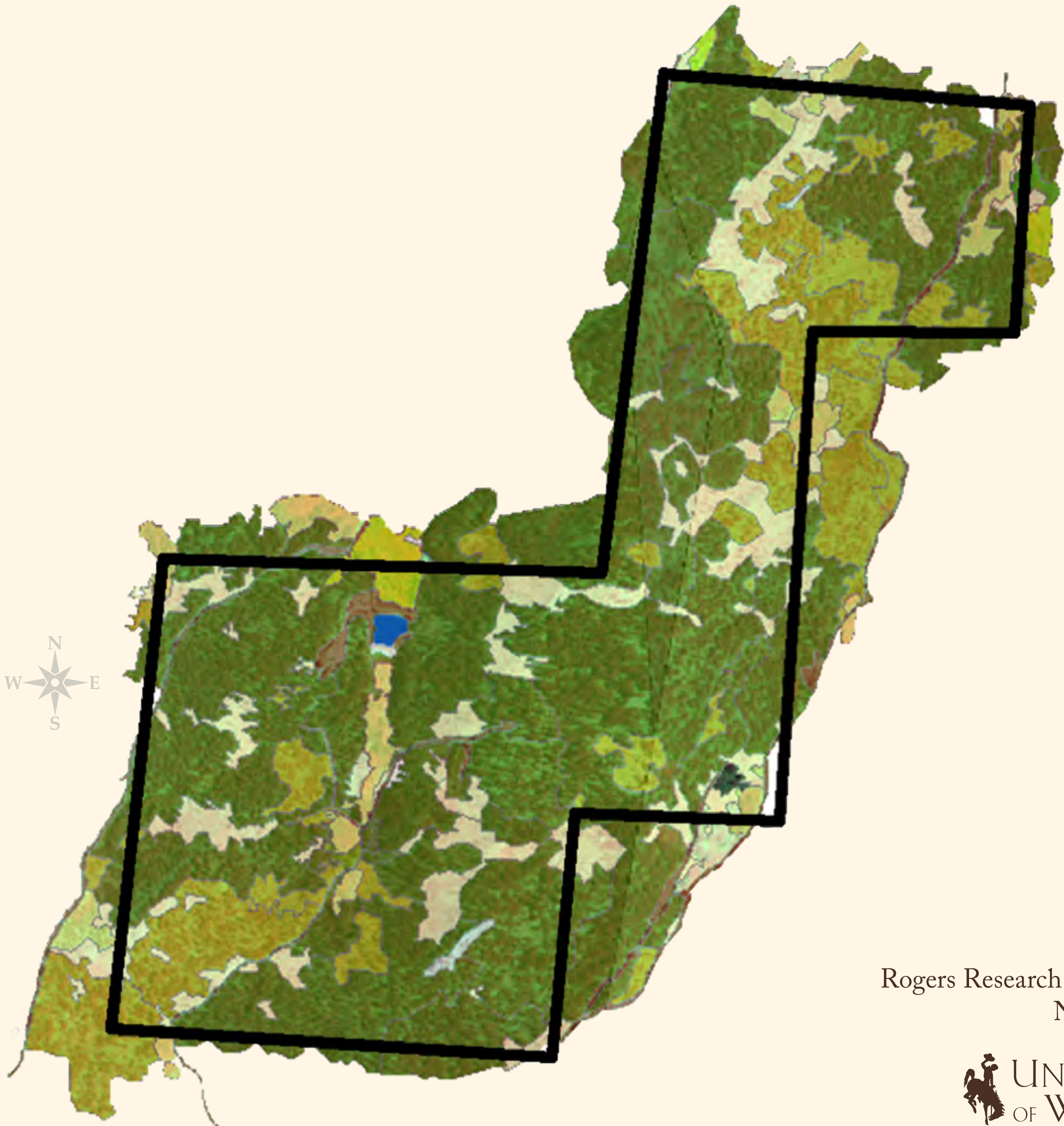
Vegetation Mapping of Rogers Research Site

NORTH LARAMIE MOUNTAINS, WYOMING, USING HIGH SPATIAL RESOLUTION PHOTOGRAPHY AND HEADS-UP DIGITIZING

By Mathew Seymour, Kenneth L. Driese, and Robert W. Waggener



Rogers Research Site Bulletin 4
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Agricultural Experiment Station

ROGERS RESEARCH SITE BULLETIN 4: Vegetation mapping of Rogers Research Site, north Laramie Mountains, Wyoming, using high spatial resolution photography and heads-up digitizing

By Mathew Seymour, Kenneth L. Driese, and Robert W. Waggener

Layout and design by Tanya Engel

University of Wyoming College of Agriculture and Natural Resources

Wyoming Agricultural Experiment Station

This is Bulletin 4 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. To learn more about Colonel Rogers, the property, and early planning efforts, see Rogers Research Site Bulletins 1, 2, and 3 at http://www.wyoextension.org/publications/ (type Rogers Research Site in the search bar).

SUGGESTED REFERENCE

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ON THE COVER

Land-cover map of the Rogers Research Site in 2006 showing ponderosa pine, aspen, willows, mixed grass/shrub habitat, and features such as old cabins, a pond, and unimproved roads. (Vegetation map by Mathew Seymour; cover design by Tanya Engel)

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CONTENTS

ABOUT THE AUTHORS

MATHEW SEYMOUR

Mathew Seymour—the lead researcher and author—is now a postdoctoral researcher in the Molecular Ecology and Fisheries Genetics Laboratory at Bangor University in Bangor, Gwynedd, United Kingdom. His current focus is on understanding the ecological relevance of environmental DNA (eDNA) for river biomonitoring.

Seymour became a "world traveler" at a young age as his military family regularly moved throughout Europe and the United States. He spent his last two years of high school in Wyoming, and that's what led him to the University of Wyoming, where he conducted research for this bulletin. In 2007 he earned bachelor's degrees in wildlife management and environment and natural resources.

While at UW, Seymour was awarded a scholarship to create a vegetation map of the Rogers Research Site (RRS) through the WyomingView program, which is headed by the Wyoming Geographic Information Science Center (WyGISC) on the UW campus (Appendices D–E). Helping to fund the internship and other aspects of the project were the Wyoming Agricultural Experiment Station, U.S. Geological Survey, and AmericaView Inc.

Seymour, who worked under the direction of Ken Driese, encourages other UW students to consider applying for internships through WyomingView. "Any opportunity for students to pursue external funding and learn new skills outside of their standard educational processes—but that are still in line with their career paths—is definitely in their best interest," he says. "The WyomingView program benefits by having experienced professionals who are willing to mentor students, which can have a huge beneficial impact on how students function later in their professional careers in regard to project management, effective communication, and increased confidence."

After completing his studies at UW, Seymour earned a master's degree at Hólar University College in Hólar, Iceland, in 2011, researching the landscape genetics and evolutionary biology of threespine sticklebacks in Belgjaskógur. He then obtained a Ph.D. at ETH in Zurich, Switzerland, in 2014, where he worked on understanding the influence of river network connectivity on metacommunity dynamics.

Throughout his college studies and professional career, Seymour maintained interest in using geospatial, biodiversity, and genetic data to assess spatial and temporal dynamics to better our understanding of how a changing world affects our environment.

KENNETH L. DRIESE

Ken Driese, who mentored Mat Seymour on his RRS vegetation mapping project, is a senior lecturer in UW's Department of Botany, where he teaches remote sensing and ecology. He established the remote sensing laboratory at WyGISC in 2001. His research focuses on using geospatial data for vegetation ecology.

Driese earned a B.A. (1981) in environmental science from the University of Virginia, Charlottesville, Virginia, and an M.S. (1992) and Ph.D. (2004) in botany from UW.

He loves travel and outdoor adventure with his family and is an accomplished landscape and portrait photographer, calling "culturally relevant travel photography" his favorite work (www.kendriesephoto.com).

ROBERT W. WAGGENER

Robert Waggener is a Laramie-based freelance editor, writer, and photographer focusing on agriculture and natural resources in Wyoming and the West.

He earned a bachelor's degree in journalism from UW (1983), where he also studied sociology and wildlife management. He worked at *The Sheridan Press* and *Buffalo Bulletin* newspapers in northern Wyoming prior to becoming an editor, writer, and photographer for the UW College of Agriculture and Natural Resources/UW Extension in 2004. He then served as editor-in-chief at the Wyoming State Geological Survey before launching his full-time freelance career in 2010.

He is part-time editor for the Wyoming Agricultural Experiment Station, copy editor for *Rocky Mountain Geology* journal, which is published by the UW Department of Geology and Geophysics, and contributing writer for Penton's *Western Farmer-Stockman* magazine. Among his other clients are DTN/*The Progressive Farmer* magazine and *Farm Journal Media*.

STANDING ON THE COLONEL'S SHOULDERS

An investment in knowledge—whether mapping vegetation, reading Hemingway, or researching the Preble's meadow jumping mouse—always pays the best interest

By Robert W. Waggener

> *"If a man empties his purse into his head, no man can take it away from him. An investment in knowledge always pays the best interest."*

That quote by Benjamin Franklin reminds me so much of a man whom I've never met, but whom I've grown to know so well over the past year. I'm referring to the late Colonel William Catesby Rogers, who practiced that philosophy in his own life and then reinvested it into the lives of others. One beneficiary of his investment was Colleen Hogan, who, as a young girl growing up in Casper, Wyoming, spent much time on Colonel Rogers' property in the north Laramie Mountains exploring boulder outcrops, hiking to the hilltop lookout, hanging out by the lake, refurbishing an old sheep wagon, picking weeds in the strawberry patch, and reading books while sitting underneath grand ponderosa pines.

"One time I told Bill I was reading Ernest Hemingway's *A Farewell to Arms*. Since he was a little hard of hearing, he always told me to slow down and enunciate my words. But he was always encouraging. When I told him about that book, he said, 'Oh, you're very well read.' That made me feel good; it made me feel important."

Colleen and her mother, Levida Hileman, along with many other visitors, continued traveling back to the property each summer, where they were welcomed by the man they grew to know as "The Colonel" or "Bill." And during these subsequent trips, when Colleen was in her late teens, she discovered why Colonel Rogers was so encouraging when he saw her sitting under a tree with Hemingway.

"I learned the value of education and reading from him because he was a very well-read man himself. He always made sure he had his reading time every day. He read the *Wall Street Journal* and *Smithsonian*, and he read lots of books—D. H. Lawrence, Oscar Wilde, Fyodor Dostoyevsky, and many others. He had boxes and boxes of books in a storage shed."

After Colonel Rogers passed away in 2003, at age 96, Colleen Hogan and others would learn that The Colonel had willed them money for their advanced education, or to help them develop job skills, or for professional use. In Colleen's case, she would earn bachelor's and master's degrees in nursing before working her way up to health facility surveyor for the Wyoming Department of Health. "The Colonel hoped that the money he left Colleen could be put to her education. I firmly believe that he would be very proud of what she's done in her life," Levida says of her daughter.

Colonel William Catesby Rogers enjoys his beloved Triple R Ranch in the Laramie Mountains of Wyoming in the mid-1980s. The Colonel, who would have been about 80 when this photo was taken, willed the land to the University of Wyoming, which renamed the property the Rogers Research Site in his honor. (Photo courtesy Colleen Hogan)

The Colonel, indeed, would be proud of Colleen's accomplishments, and he would be equally proud of the accomplishments of other young people who have invested in knowledge, like Mathew Seymour, who, as an undergraduate student at the University of Wyoming, mapped vegetation in the Laramie Mountains using high spatial resolution photography. He did this on the land that Colonel Rogers bequeathed to UW with the understanding it be used, in part, for conducting research to improve forestry and wildlife resources.

Mat would go on to earn two bachelor's (UW), a master's (Hólar University, Hólar, Iceland), and a doctorate degree (ETH, Zurich, Switzerland) before being hired as a postdoctoral researcher at Bangor University in Bangor, Gwynedd, United Kingdom, where he is developing environmental DNA methods for river biomonitoring. He was elated last year when I contacted him to see if he would be willing to put in the time and effort to publish his mapping research in a peer-reviewed bulletin through the Wyoming Agricultural Experiment Station (WAES), which had co-sponsored his project a decade earlier.

Looking back at his undergraduate years in Wyoming, Seymour told me, "I think the biggest impact on me during my time at UW was the time I spent interacting with faculty and staff members outside the standard school curriculum required for my degrees, participating in the UW Student Chapter of the Wildlife Society, and working in various laboratories. The ability for me to go about the UW campus and freely interact with so many people had a big influence on my eventual direction of study and personal development."

Among the people who had a positive influence on Mat was UW Department of Botany senior lecturer Ken Driese, who mentored him throughout the vegetation mapping project of the Rogers Research Site (RRS), as the property became known. Ken encourages students to take advantage of internship opportunities like the one that led Seymour to complete the work described in this bulletin when he was an UW undergraduate. "Internships give students invaluable research experience that often leads them in new directions, and the internships are valued by employers," Ken says.

The research presented in this paper provides baseline data for future studies relating to vegetation, wildlife, and other natural resources at RRS and surrounding lands in the Laramie Mountains. Further, the work by Mat and other UW students who have conducted studies at the property and who are preparing peer-reviewed WAES bulletins,

Seven-year-old Colleen Hogan of Casper, Wyoming, hangs out at the hilltop lookout on land owned by Colonel William C. Rogers. This photo was taken in 1977, the first year that Colleen and her mother, school teacher Levida Hileman, met The Colonel. Over the next two decades, they would spend many weeks each summer at the property in the remote Laramie Mountains. (Photo courtesy Colleen Hogan)

This is the sheep wagon that Colleen Hogan and her mother, Levida Hileman, would stay in during their visits to Colonel Rogers' Triple R Ranch. The Colonel willed the sheep wagon to Colleen and Levida because they spent much time refurbishing it during their frequent trips to the property. They have since moved the sheep wagon to a small piece of nearby land that they rent, and the old wagon remains their home-away-from-home. (Photo courtesy Colleen Hogan)

This is how much of the Triple R Ranch looked like from the 1980s through the early 2000s, when various age classes of ponderosa pine covered the landscape. In 2012, the Arapaho Fire burned nearly 100,000 acres in the Laramie Mountains, including the land that Colonel Rogers bequeathed to the University of Wyoming. UW faculty, staff, and students have and are continuing to conduct a variety of studies on the land. (Photo courtesy Colleen Hogan)

including Mollie Herget, Stephanie Winters, and Claire Wilkin, can inspire students and faculty/staff mentors to pick up the torch. As I've helped to produce these bulletins, I have often thought of the exciting research potential at RRS and surrounding lands, whether with wildlife such as bighorn sheep, northern saw-whet owls, Preble's meadow jumping mice, Rocky Mountain elk, or northern long-eared bats, or with plants like antelope bitterbrush, Pursh's wallflower, dwarf mountain ragwort, or dogbane. And the potential for collaboration is equally exciting, whether working with a neighboring rancher, a federal or state wildlife biologist, or a UW vegetation ecologist, rangeland scientist, GIS specialist, or soil microbial ecologist.

As this column sets the stage for Mat's vegetation mapping research, I think back to that quote by Benjamin Franklin and how it ties not only into the life of Colonel William Catesby Rogers, but also to what he gifted to others—a gift of encouragement to invest in one's knowledge, whether that knowledge is gained by mapping 364 acres of vegetation using high-tech photography, determining the reproductive condition of a juvenile Preble's meadow jumping mouse, or reading Hemingway under the shade of a stately ponderosa. To learn more about Colonel Rogers, see Rogers Research Site Bulletins 1–3 and upcoming bulletins in the RRS series.

VEGETATION MAPPING OF ROGERS RESEARCH SITE, NORTH LARAMIE MOUNTAINS, WYOMING, USING HIGH SPATIAL RESOLUTION PHOTOGRAPHY AND HEADS-UP DIGITIZING

By Mathew Seymour,[1,2] Kenneth L. Driese,[1,3] and Robert W. Waggener[4]

ABSTRACT

The Rogers Research Site (RRS)[5] is an approximate 320-acre (~129-hectare) area in southeast Wyoming that was bequeathed to the University of Wyoming in 2002 by Colonel William C. Rogers. The site in the Laramie Mountains includes important wildlife habitat and was donated to UW, in part, for forestry- and wildlife-related research. Previous habitat assessments of RRS were limited to unquantified personal observations. Therefore, in 2006, a vegetation map was created using high spatial resolution AEROCam photography and heads-up digitizing to provide an accurate inventory of existing vegetation within RRS and lands immediately surrounding the site. Our vegetation map shows that in 2006, RRS was predominantly ponderosa pine (*Pinus ponderosa*) forest (80%), with mixed grass and shrub lands (10%) and quaking aspen (*Populus tremuloides* [4%]). In 2012, however, a significant natural event occurred—the lightning-caused Arapaho Fire. The high-intensity wildfire, which started during a severe drought, burned approximately 98,100 acres in the Laramie Mountains, including RRS, dramatically altering the land cover of the entire area. The vegetation map presented here is, therefore, of great importance for ongoing and future work associated with RRS and the Laramie Mountains as a whole. Specifically, for researchers and managers planning to assess temporal changes in habitat structure and land cover (within RRS or across the Laramie Mountains), the legacy map described and presented in this bulletin will be invaluable.

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1 For specific questions about this research project, email Mathew Seymour at m.seymour@bangor.ac.uk, and Ken Driese at kdriese@uwyo.edu.

2 Mathew Seymour is a postdoctoral researcher in the Molecular Ecology and Fisheries Genetics Laboratory, Bangor University, Bangor, Gwynedd, United Kingdom.

3 Ken Driese is a senior lecturer in the Department of Botany, University of Wyoming, Laramie, Wyoming.

4 Robert Waggener is a Laramie, Wyoming-based freelance editor, writer, and photographer covering agriculture and natural resources in Wyoming and the West.

5 For driving directions to RRS, information about access, general questions about research projects, 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 157, Lingle, WY 82223-8543.

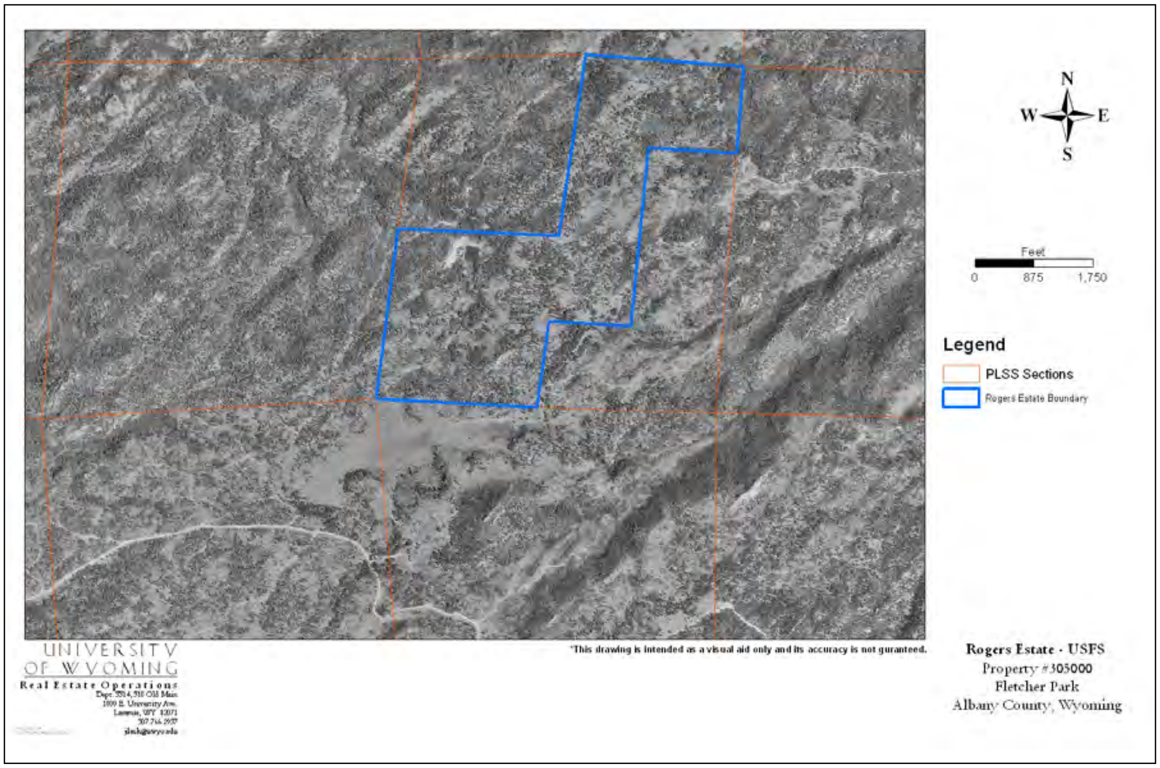

Figure 1. Digital orthophoto quarter-quadrangle (DOQQ) image of RRS (blue outline) and adjacent lands. It combines the image characteristics of the original aerial photograph (taken in 1994) with the georeferenced qualities of a map (created in 2005). (Image by USFS; mapping by Josh Decker, UW Real Estate Operations)

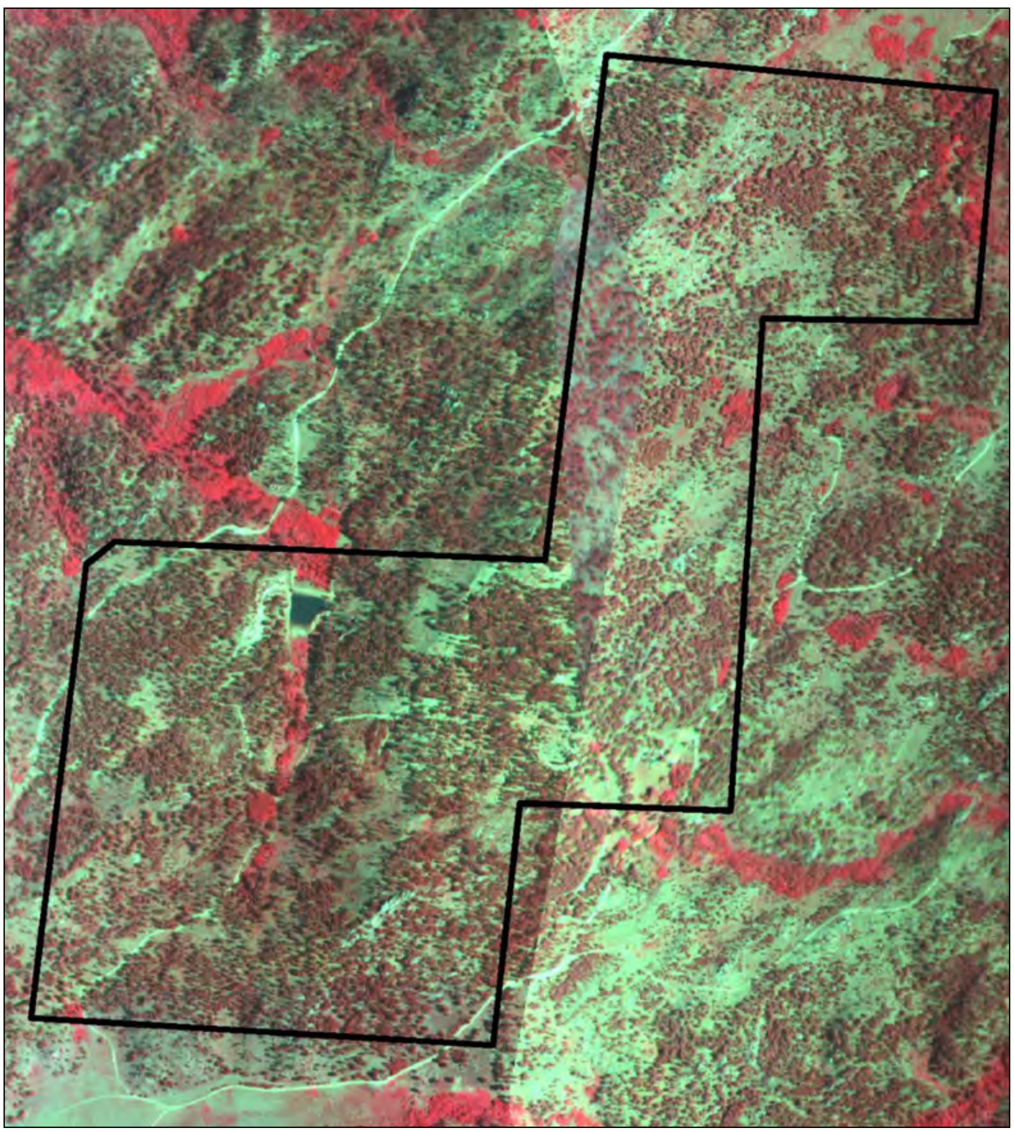

Figure 2. Infrared AEROCam photograph (taken in 2006) of the Rogers Research Site (~320 acres/black outline) and adjacent lands, northeast Albany County, Wyoming. (Image by Upper Midwest Aerospace Consortium [UMAC])

INTRODUCTION

In 2002, Colonel William C. Rogers[6] bequeathed approximately 320 acres (~129 hectares) of land in southeast Wyoming to the University of Wyoming (UW) (Figs. 1–2). The scenic property, which was covered by ponderosa pine (*Pinus ponderosa*) (Fig. 3; Appendix A) and other trees, shrubs, forbs, and grasses at the time, would officially become known as the Rogers Research Site (RRS) in memory of Colonel Rogers (Williams and Waggener, 2017a). Colonel Rogers was attracted to the Laramie Mountains for their great diversity of plants and wildlife, scenic beauty, ruggedness, and remoteness, and these features motivated him to acquire the parcel in northeast Albany County (J. Clyde,[7] B. Hileman,[8] L. Hileman,[9] R. Hilliker,[10] C. Hogan,[11] T. Marlatt,[12] S. Serra,[13] D. Walker,[14] and G. Dyekman,[15] personal communication, 2016; Williams and Waggener, 2017a). Following his distinguished military career, Rogers spent many summers on his property near Laramie Peak, where he welcomed friends and strangers alike. Those who knew him well called him "The Colonel" or "Bill," and they said he spent his time at RRS reading, writing, visiting with others around the campfire, and laboring to improve the land (Williams and Waggener, 2017a). This hard work continued well into his 80s, and people who did not know The Colonel well would be surprised to find him fighting a range fire in the area, toiling side-by-side with much younger, professional firefighters (B. Anderson,[16] personal communication, 2016; Williams and Waggener, 2017a). It was Colonel Rogers' love for the land and his desire to see continued improvement in forestry and wildlife resources that encouraged him to donate the property to UW. In his will, The Colonel stipulated that UW use the site, in part, for "the public benefit as a center for studies" and for "conducting research in

KEY WORDS
Geographic Information Systems (GIS), heads-up digitizing, high spatial resolution AEROCam photography, Laramie Mountains, ponderosa pine (*Pinus ponderosa*), remote sensing, Rogers Research Site, University of Wyoming, vegetation mapping, wildfire, wildlife, Wyoming Agricultural Experiment Station

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6 To learn more about Colonel William C. Rogers, please see Rogers Research Site Bulletins 1–3 at http://www.wyoextension.org/publications/ (type Rogers Research Site in the search bar); the introduction to this bulletin, "Standing on the Colonel's Shoulders;" and upcoming RRS bulletins.

7 Jim Clyde, a commercial logging contractor from Wheatland, Wyoming, did not personally meet Colonel Rogers, but he was hired to help manage The Colonel's Triple R Ranch, which became known as the Rogers Research Site when the land was acquired by UW. Clyde was later hired by UW to conduct additional prescribed thinning at the site.

8 Brock Hileman, a retired high school teacher and athletic director from Casper, Wyoming, became friends with Colonel Rogers during summer trips to the property. Hileman and his wife, Levida, retired in Truth or Consequences, New Mexico, but relocated to Cheyenne, Wyoming, in 2017.

9 Levida Hileman, a retired high school teacher from Casper, Wyoming, became close friends with Colonel Rogers during summer trips to the property for more than two decades. See footnotes 8 and 11 for more information.

10 University of Wyoming Professor Emerita Rebecca Hilliker became friends with Colonel Rogers late in his life. Hilliker, former chair of the UW Department of Theatre and Dance, now lives between Cheyenne and Laramie with her husband, Rich Nelson.

11 Colleen Hogan, who grew up in Casper, Wyoming, became close friends with Colonel Rogers during summer trips to his property with her mother, Levida Hileman, and later with both her mother and stepfather, Brock Hileman. Hogan, who now lives in Wheatland, is a health facility surveyor for the Wyoming Department of Health.

12 Toby Marlatt is the UW Foundation's vice president for marketing and communications.

13 Sarah Stark Serra, of Williamsburg, Virginia, is a niece of Colonel Rogers.

14 Duane Walker and his wife, Sharon "Tiny" Walker, who are lifelong residents of the Laramie Mountains' area, personally knew Colonel Rogers.

15 Cheyenne attorney Greg Dyekman, a UW Foundation emeritus board member, became involved on behalf of the UW Foundation in matters relating to settling The Colonel's estate.

16 Bryan Anderson is district forester for the Wyoming State Forestry Division (WSFD) in Casper. Anderson, who knew Colonel Rogers on a casual, work-related basis, was a member of the committee that developed short- and long-term goals for RRS (these are detailed in RRS Bulletin 3). At that time, Anderson was an assistant district forester with WSFD.

Figure 3. During this study (2006) ponderosa pine (*Pinus ponderosa*) forested much of RRS; however, the lightning-caused Arapaho Fire (2012) burned the majority of ponderosa and other vegetation at RRS and surrounding lands. This photograph was taken in 2007. (Photo by Steve Williams, UW Professor Emeritus)

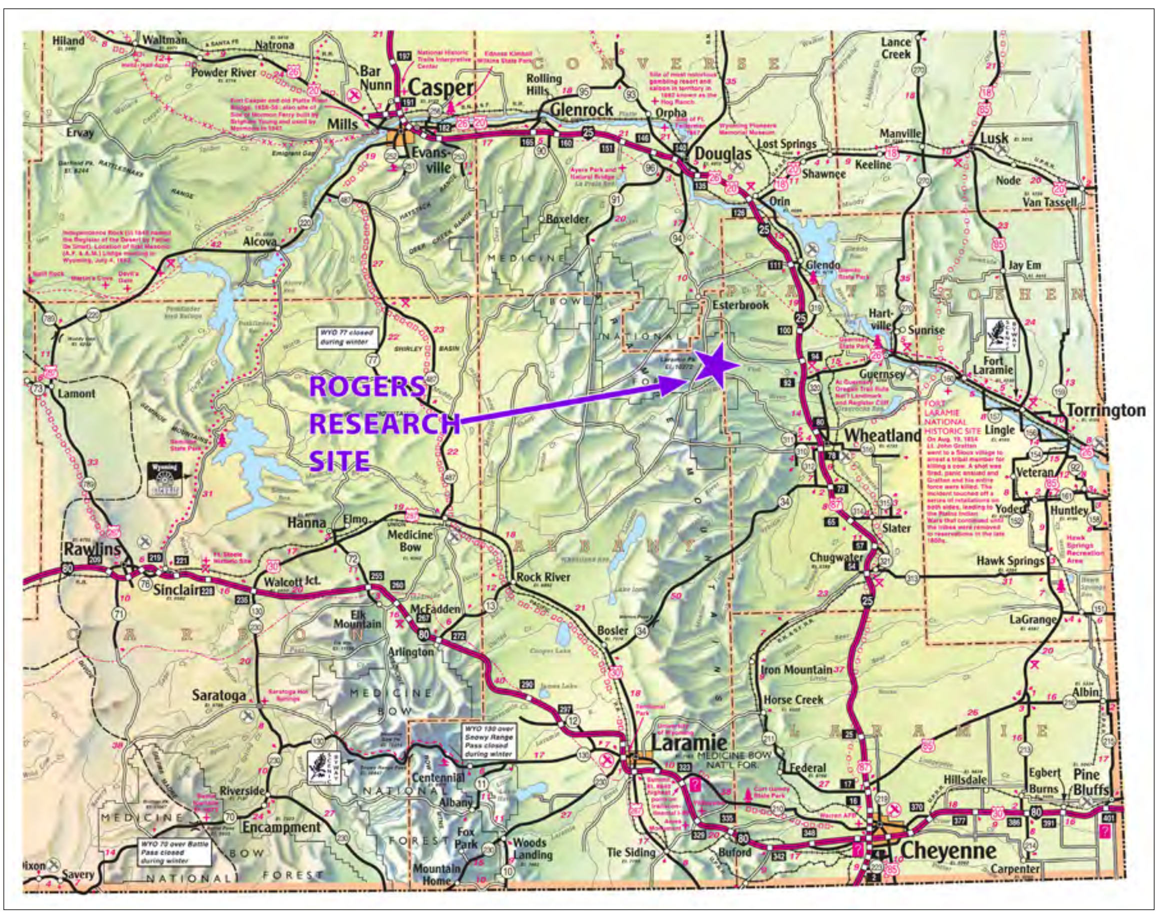


Figure 4. General map of southeast Wyoming showing the location of RRS, northeast Albany County. RRS is located about 25 mi (40 km) northwest of Wheatland, Wyoming. (Official State Highway Map of Wyoming; RRS overlay by Tanya Engel, UW College of Agriculture and Natural Resources/UW Extension)

connection with the improvement of wildlife and forestry resources (Rogers, 2002)."

Colonel Rogers died in 2003, at age 96. About two years later, his property became a component of the research and extension centers operated through the UW College of Agriculture and Natural Resources and its research branch, the Wyoming Agricultural Experiment Station (WAES). Overseeing management of RRS, in turn, is one of the research and extension centers under WAES, the James C. Hageman Sustainable Agriculture Research and Extension Center (SAREC) near Lingle, Wyoming.

In 2005, Jim Freeburn,[17] who was SAREC director at the time, and others expressed interest in UW working collaboratively with neighboring landowners—U.S. Forest Service (USFS), State of Wyoming, private individuals—and other stakeholders, including the Wyoming Game and Fish Department (WGFD), to improve forestry and wildlife resources on the site and surrounding lands (Kearns, 2005;[18] Waggener, 2017; Williams and Waggener, 2017a). Possible activities to achieve these and other goals included prescribed fire, selective timber harvest, weed control, and planned livestock grazing (Waggener, 2017; Williams and Waggener, 2017a, 2017b).

Previously documented land-cover assessments for the area, however, were limited to personal observations, which are not quantitative and could potentially bias future land-use projects, including those directed to forestry resources and wildlife habitat. Biased land-cover assessments are often influenced by personal conflicts and interest (Barrow and Conrad, 2006). Therefore, a careful and well-documented surface-cover assessment of RRS is crucial to mollify future political, ecological, or economic issues.

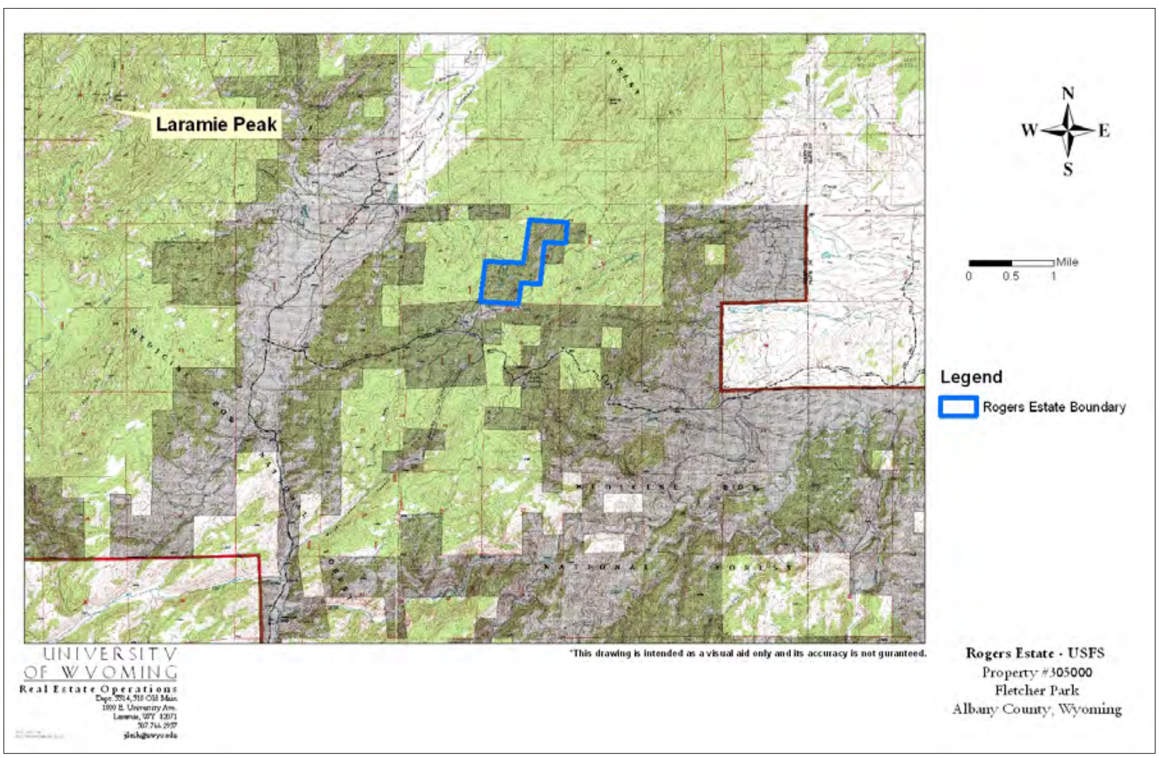


Figure 5. Rogers Research Site is located approximately 5 mi (8 km) southeast of Laramie Peak (10,272 ft [3,131 m]) in the northern reaches of the Laramie Mountains. Elevations at RRS range from about 6,700 to 7,300 ft (2,000–2,200 m). (Base map by USFS; RRS mapping by J. Decker)

[17] Jim Freeburn, of Torrington, Wyoming, is now the regional training coordinator for the U.S. Department of Agriculture, Western Sustainable Agriculture Research and Education's Professional Development Program.

[18] The UW news release by Jim Kearns—"Nearly 70 attend open house at new UW property near Wheatland"—is in RRS Bulletin 2.

STUDY AREA

GEOGRAPHY

The Rogers Research Site (RRS) is located in southeast Wyoming's Laramie Mountains, about 25 miles (40 kilometers) northwest of Wheatland, Wyoming (Fig. 4). Topography of the site—like the entire Laramie Mountains, which stretch from central Wyoming to northeastern Colorado—is highly variable, from level areas to steep slopes.

Elevations of the Laramie Mountains are highly variable as well, from approximately 4,200 to more than 10,000 feet (1,280–3,000 meters). At RRS, elevations range from about 6,700 to 7,300 ft (2,000–2,200 m). Just 5 mi (8 km) to the northwest of RRS is the highest point in the range, the prominent Laramie Peak, at 10,272 ft (3,131 m) (Figs. 5–6).

GEOLOGY AND SOILS

RRS is chiefly underlain by intrusive igneous rocks, including the widespread Laramie Peak Granite of Archean age (approximately 2.6 million years ago [~2.6 Ga]). Other igneous rocks in the area are intrusive mafic dikes, which are part of a Paleoproterozoic (~2.01 Ga) mafic dike swarm (Cox et al., 2000).

Soils of the range are mostly embryonic (recently formed soils exhibiting only early states of formation), low-nutrient status, shallow, and erodible. They are generally low in pH and salt content. Along watercourses, soils are generally much deeper with higher organic matter content and often have buried horizons. Erosion events can alter these soils periodically during high rainfall events, especially post-fire (Reckner, 1998; Williams and Waggener, 2017a).

Of the 12 orders of soil taxonomy, five orders are found in the Laramie Mountains: Alfisols, Aridisols, Entisols, Inceptisols, and Mollisols (Young and Singleton, 1977; Packer, 2000). Soils at RRS include Alfisols, Entisols, Inceptisols, and Mollisols (L. Munn,[19] personal communication, 2017). Alfisols occur

Figure 6. This is a view looking northwest from RRS toward the prominent Laramie Peak. The photo shows the severity of the 2012 Arapaho Fire, which killed the majority of ponderosa pine in the area. (Photo by S. Williams)

[19] Larry Munn is a professor emeritus of soil science in the UW Department of Ecosystem Science and Management. Munn performed soil mapping studies at RRS; his work is summarized in RRS Bulletin 1 and will be detailed in an upcoming RRS bulletin.

in semiarid to moist areas, forming primarily under forest or mixed vegetative cover. Entisols have little, if any, horizon development, such as dunes, steep slopes, and flood plains. Inceptisols are the beginning of horizon development; they occur in a wide variety of climates, from semiarid to humid. Mollisols have a dark-colored surface horizon relatively high in organic matter; they characteristically formed under grasslands (U.S. Department of Agriculture, Natural Resources Conservation Service, 2017).

At RRS, soils on forested slopes, e.g., ponderosa pine, are moderately developed Inceptisols and shallow Entisols. This is due to low inherent fertility, low water-holding capacity, and the erosive nature of the sloped topography, which developed from granitic substrate. Soils found under aspen and herbaceous vegetation along streams and other wet areas are Mollisols and Inceptisols, which are deeper, finely textured, and contain more organic matter than soils on the forested slopes (L. Munn, personal communication, 2017). On gentler pine-forested slopes and probably as inclusions in some of the aspen-vegetated soils are found some Alfisols. These are limited in extent, but are the deeper and more fertile forest soils at RRS (S. Williams, personal communication, 2017). (Detailed information about soils at RRS, including pre- and post-fire soil comparisons, will be presented in upcoming RRS bulletins.)

CLIMATE

The climate in the Laramie Mountains is semiarid with snowfall during at least half of the year. The growing season (temperatures above 32˚F/O˚C) is 100 days or less. Annual precipitation varies from around 12 inches (30 centimeters) in the foothills to as much as 40 in (100 cm) in the mountainous band that stretches northwest from Laramie Peak to Casper Mountain. The balance of the Laramie Mountains lies between these extremes, with probably 16–20 in (41–51 cm) being the most common (Reider et al., 1990; Williams and Waggener, 2017a).

The most complete weather records in the vicinity of RRS were kept by the Double Four Ranch (elevation 6,119 ft/1,865 m), about four mi (6.5 km) southwest of RRS. Weather was recorded at the ranch for 50

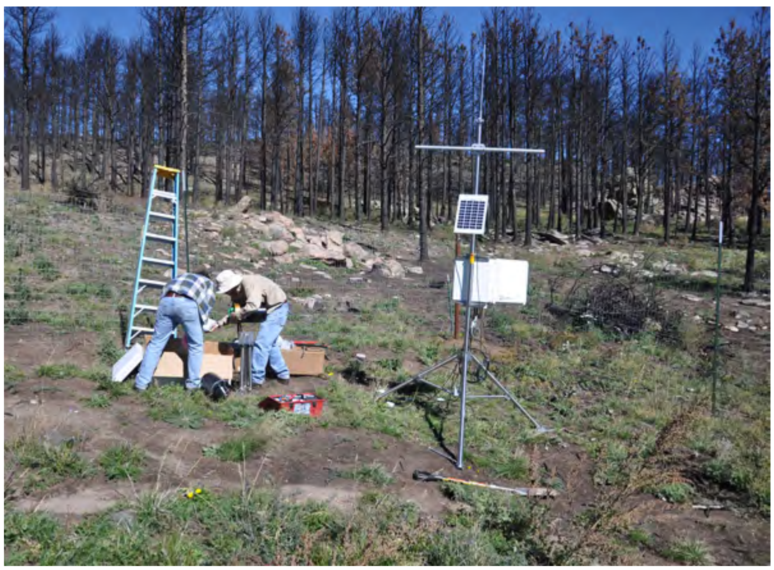


Figure 7. A weather station with remote access was installed at RRS in 2013, but mice that crawled up through a small opening in the box caused extensive damage to panel wiring and other electronic equipment. The weather station was repaired in 2017, and data is available on the Wyoming Agricultural Climate Network website at http://www.wrds.uwyo.edu/WACNet/Stations.html (V. Sharma and J. Tanaka, personal communication, 2017). (Photo by S. Williams)

Figure 8. Antelope bitterbrush (*Purshia tridentata*) is an important shrub for many wildlife species in the Laramie Mountains, including mule deer and bighorn sheep. (Photo by Dorothy Tuthill, UW Biodiversity Institute/Berry Biodiversity Conservation Center)

Figure 9. The northern saw-whet owl (*Aegolius acadicus*)—though an uncommon visitor to Wyoming—has been observed at RRS on several occasions. This one was photographed in a thick grove of quaking aspen (*Populus tremuloides*). Another northern saw-whet was photographed in a burned aspen grove following the 2012 Arapaho Fire (see RRS Bulletin 1). (Photo by S. Williams)

Figure 10. Rocky Mountain elk (*Cervus canadensis nelsoni* [syn. *C. elaphus nelsoni*]) are among the common big game inhabitants of public and private lands in the Laramie Mountains near Laramie Peak. (Photo by Tim Byer, USFS Medicine Bow-Routt National Forests)

Figure 11. Bighorn sheep (*Ovis canadensis*) are common in some areas of the Laramie Mountains, including the area around Laramie Peak. A portion of occupied sheep habitat on private and public lands, including RRS, was within the 2012 Arapaho Fire. The fire will have long-term benefits for bighorn sheep and other wildlife, but initially there was a flush of invasive species that land managers need to address (R. Amundson, personal communication, 2016). Among the noxious weeds are cheatgrass (*Bromus tectorum*) and Canada thistle (*Cirsium arvense*). (Photo by Ryan Amundson, WGFD)

years, from 1955 to 2005, after which the station was discontinued. Those records show an annual average precipitation of 15.4 in (39.2 cm) and a mean annual temperature of 47.5°F (8.4°C) (National Oceanic and Atmospheric Administration, 2014; Williams and Waggener, 2017a). (For more information about temperature and precipitation records at the Double Four Ranch, see tables 1 and 2 in Williams and Waggener, 2017a.) Additionally, recent weather data compiled by area resident George Portwood will be presented in the upcoming bulletin that details the post-fire ponderosa pine restoration study.

A weather station with remote access was installed at RRS in 2013 (Fig. 7), but during the winter of 2013–14 mice crawled up through a small opening in the bottom of the box that accommodated wiring (Waggener, 2017; Williams and Waggener, 2017a, 2017b). The mice built a substantial nest, and during their stay they caused extensive damage to panel wiring and other electronic equipment. The weather station was repaired in 2017 (this is discussed more in the Conclusions and Future Studies section).

PLANTS, ANIMALS, AND HABITATS

Wyoming is well-known for its wildlife, with more than 600 species of birds, mammals, amphibians, and reptiles (Orabona et al., 2016). Though we are not aware of a specific species list for the Laramie Mountains, the range is home to a rich array of resident and migratory wildlife—along with an equally rich array of resident and migratory insects and a variety of fish species. The Laramie Mountains, too, are home to a wide variety of plant species. Packer (2000) conducted an extensive floristic study of the range between 1997 and 1998 and identified 929 taxa (1,061 when including historical collections) inhabiting floodplains, grasslands, shrub lands, riparian areas, forests, boulder outcrops, and rocky summits.

The diversity of animal and plant species across the Laramie Mountains is largely due to variation in climate (mean annual precipitation is ~5–40 in [13–100 cm]), soil (five different orders), elevation (~4,200–10,200 ft. [~1,280–3,110 m]), vegetation, habitats, and water systems (Packer, 2000; Williams and Waggener, 2017a).

Wildlife habitat types include (1) cottonwood floodplains; (2) foothill grasslands (cool- and warm-season species); (3) foothill

Figure 12. Mountain lions (*Felis concolor*) inhabit the Laramie Mountains, including public and private lands around Laramie Peak. The mountain lion pictured here is in the center of the photo, just left of the tree. (Photo by Martin Hicks, WGFD)

Figure 13. During this study, a significant amount of acreage within RRS—along with surrounding lands in the Laramie Mountains near Laramie Peak—was covered with sparse or dense stands of ponderosa pine in various age classes. This photo was taken in 2007. (Photos by S. Williams)

Figure 14. The 2012 Arapaho Fire burned nearly 100,000 acres on the Laramie Peak unit of the Medicine National Forest from June 27 to late August. In early July, the wildfire swept through RRS, consuming most of the vegetation. (Photo by Jim Kibler, InciWeb)

shrub lands, e.g., antelope bitterbrush (*Purshia tridentata*) (Fig. 8; Appendix B), juniper stands (*Juniperus* species), mountain mahogany (*Cercocarpus montanus*), and sagebrush-steppe (*Artemisia tridentata* and other species); (4) mountain meadows, which include a variety of grass and shrub species, among them sagebrush; (5) stands of quaking aspen (*Populus tremuloides*) (Fig. 9; Appendix C) and willow (*Salix* spp.); (6) ponderosa pine forests; (7) mixed pine, spruce, and fir woodlands; and (8) boulder outcrops and rocky peaks (Packer, 2000; T. Byer[20] and M. Hicks,[21] personal communication, 2017; Williams and Waggener, 2017a). Found throughout the range, from the lowest to highest elevations, are numerous species of forbs. Water system habitats include a wide variety of riparian areas, wetlands, springs, creeks, rivers, ponds, lakes, and reservoirs.

Resident and Migratory Wildlife

The land within RRS and the neighboring Laramie Mountains are recognized by WGFD, USFS, and others as important habitat for many economically important wildlife species including Rocky Mountain elk (*Cervus canadensis nelsoni* [syn. *C. elaphus nelsoni*]) (Fig. 10), mule deer (*Odocoileus hemionus*), bighorn sheep (*Ovis canadensis*) (Fig. 11), and wild turkey (*Meleagris gallopavo*) (Kearns, 2005; Williams and Waggener, 2017a). Additionally, RRS and surrounding areas provide important habitat for other resident and migratory wildlife, including bobcat (*Lynx rufus*), mountain lion (*Felis concolor*) (Fig. 12), American black bear (*Ursus americanus*), blue grouse (aka dusky grouse, *Dendragapus obscurus*), ruffed grouse (*Bonasa umbellus*), northern saw-whet owl (*Aegolius acadicus*) (Fig. 9), turkey vulture (*Cathartes aura*), golden eagle (*Aquila chyrsaetos*), and mountain bluebird (*Sialia currucoides*) (Orabona et al., 2016; Williams and Waggener, 2017a).

Threatened Wildlife Species

The Preble's meadow jumping mouse (*Zapus hudsonius preblei*)—listed as "threatened" under the federal Endangered Species Act (U.S. Fish and Wildlife Service, 2017a)—is known to inhabit lands around RRS, including the Cottonwood Park and Albany Peak areas. The most recent detection was in 2014 by the WGFD nongame mammal biologist, Nichole Bjornlie (T. Byer, personal communication, 2017). In 2015, WGFD detected Preble's along Friend Creek, about seven miles west of RRS (N. Bjornlie, personal communication, 2017).

Another "threatened" species, the northern long-eared bat (*Myotis septentrionalis*) (U.S. Fish and Wildlife Service, 2017b), may also occur within the Laramie Mountains, but more information is needed to verify its residency. USFS currently has only one confirmed sighting, and it was on the western side of the USFS Douglas Ranger District (RRS is on the eastern side of the district) (T. Byer, personal communication, 2017).

Vegetation

During 2006 (the time this study was conducted), but prior to a significant wildfire in 2012 (discussed below), a wide variety of vegetation covered RRS and adjacent lands, including (1) several species of trees, predominately ponderosa pine (Fig. 3; Appendix A), but also quaking aspen (Fig. 9; Appendix C) and alder (*Alnus* spp.); (2) several species of shrubs, notably antelope bitterbrush (Fig. 8; Appendix B), an essential dietary component of mule deer and bighorn sheep, as well as sagebrush

[20] Tim Byer is district wildlife biologist for the U.S. Forest Service's Medicine Bow-Routt National Forests and Thunder Basin National Grassland. He works out of the Douglas Ranger District office in Douglas, Wyoming.

[21] Martin Hicks is a wildlife biologist with the Wyoming Game and Fish Department (WGFD). He is based in Wheatland.

Figure 15. The 2012 lightning-caused Arapaho Fire consumed most of the vegetation at RRS, including ponderosa pine. This image was taken on July 18, about two weeks after the fire swept through RRS. (Photo by S. Williams)

and willow; and (3) numerous grasses and forbs, discussed below (R. Amundson,[22] personal communication, 2016; Williams and Waggener, 2017a).

VEGETATION MAPPING PROJECT AT RRS

In 2006, a project was launched to produce an accurate land-cover map of RRS using high spatial resolution (3.3–6.6 ft [1–2 m]) multispectral (blue, green, red, and near-infrared bands) AEROCam photography (Appendices D–E) and a procedure called "heads-up digitizing," which is described below.

At the time of the study, a considerable amount of area within RRS was covered with sparse or dense stands of ponderosa pine in various age classes (mostly younger trees) (Figs. 3, 13; Appendix A). Additional vegetation included a small number of other tree species, including quaking aspen (Fig. 9; Appendix C), as well as antelope bitterbrush (Fig. 8; Appendix B), sagebrush, willow, and a variety of grasses and forbs. As this project was nearing completion and results were being compiled (discussed below), it was the lead author's recommendation that future assessments be conducted to track changes in land cover resulting from natural processes and human management.

2012 ARAPAHO WILDFIRE

In 2005, Dillon et al. (2005) concluded—with "high confidence"—that more stand-replacing fires would burn in the Laramie Mountains, especially the lower elevations where ponderosa pine is the dominant tree species. They based their conclusion, in part, on many years of effective fire suppression,

[22] Ryan Amundson is WGFD's statewide habitat biologist based in Wheatland. Amundson was a member of the 2010–2011 RRS Management Committee (see RRS Bulletin 3).

logging of older, more fire-resistant trees, and livestock grazing, the latter of which helps to remove forest litter. Collectively, these management decisions would lead to less frequent—but more intense—wildfires versus relatively frequent, low-intensity surface fires that historically killed many of the small trees, but few of the older, thick-barked ponderosa (Dillon et al., 2005).

Seven years after the Dillon et al. (2005) report, a momentous vegetation change occurred in the Laramie Mountains, when the lightning-caused Arapaho Fire swept through approximately 98,100 acres near Laramie Peak, including RRS lands (Fig. 14). The wildfire, the largest in the state that year and one of the largest in the country, started in late June 2012 when Wyoming and much of the U.S. were experiencing drought conditions from "abnormally dry" to "exceptional" (National Drought Mitigation Center et al., 2012; National Interagency Fire Center, 2012). Until being contained in late August, the high-intensity Arapaho Fire caused "extensive damage" to all 98,100 acres (National Interagency Fire Center, 2012), which was consistent with the predictions of Dillon et al., 2005 (Heidel and Welborn, 2015).

On RRS and neighboring federal, state, and private lands, the Arapaho Fire burned a significant percentage of the vegetation, including ponderosa pine (Fig. 15). Ponderosa pine has thick, fire-resistant corky bark, which is well suited to surviving low-intensity fires, making it one of the most fire-resistant conifers in the West (Fitzgerald, 2005). The Arapaho Fire, however, burned with such intensity that it *killed* the majority of ponderosa trees and left nothing but *black* or *white* ash on RRS and surrounding lands (C. Wilkin[23] and S. Williams,[24] personal communication, 2016 [their work will be presented in an upcoming RRS bulletin]; Williams and Waggener, 2017a, 2017b).

The soil surface ash color remaining post-fire can provide some insight into fire intensity: yellowish to brown represents low-intensity (<475°F [<250°C]); black, moderate-

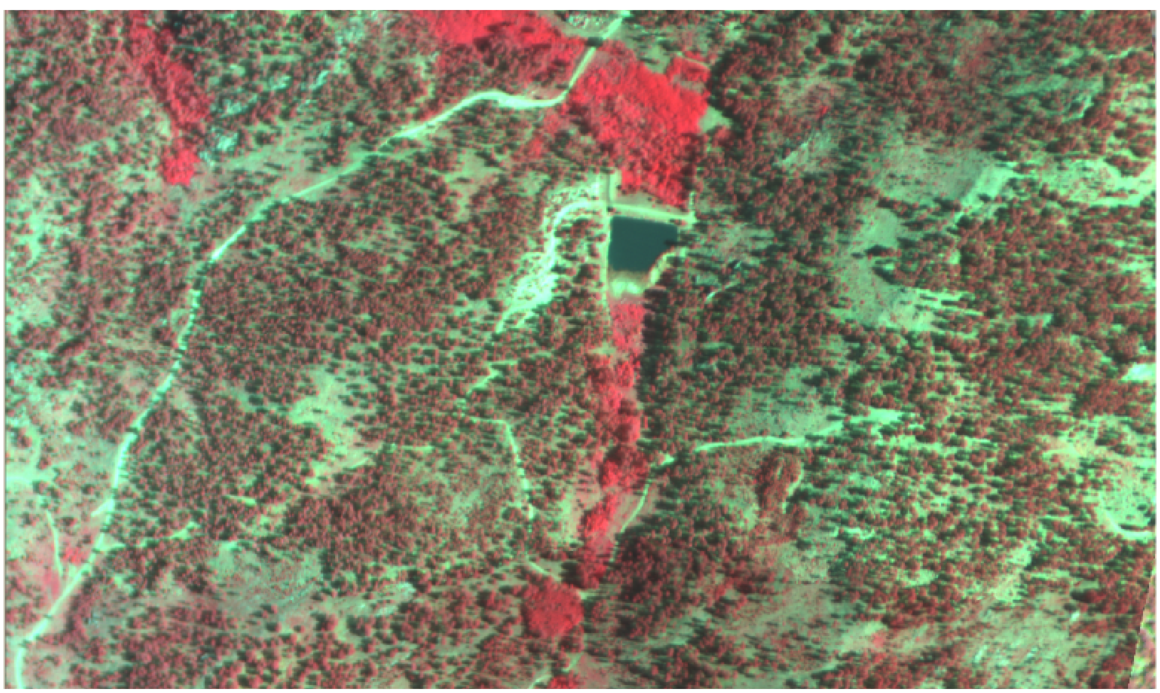


Figure 16. AEROCam photo taken in 2006 showing detailed road, water, and vegetation cover in the vicinity of the small reservoir (see Figs. 17–22) in the western reaches of RRS and adjacent USFS lands. (Image by UMAC)

[23] Claire Wilkin, who earned a master's degree in environmental engineering from UW in 2014, was at the center of much of the early research at RRS. She was co-advised by the lead author of RRS Bulletin 1, Professor Steve Williams, along with Professor Michael Urynowicz. Her soil research, which was conducted with Williams, Urynowicz, and others, will be presented in upcoming RRS bulletins. Wilkin is now an environmental consultant with WSP in San Jose, California.

[24] Steve Williams, the lead author of RRS Bulletin 1, is a UW professor emeritus of soil science. Williams retired in 2013, but has been actively involved in the RRS bulletin series. He will co-author upcoming bulletins with Wilkin and others.

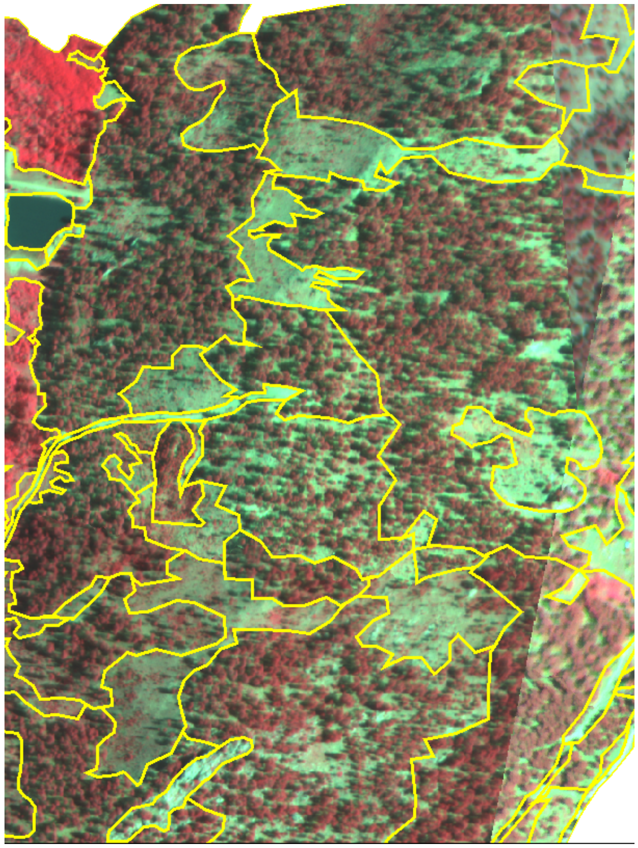


Figure 17. Example of land-cover polygons created using heads-up digitizing. (Image by UMAC; digitizing polygons by M. Seymour)

fire habitats are transitioning back to pre-fire states or are trending toward alternative ecological states. The project findings will also assist researchers, land managers, and others regarding land management for socioeconomic and other benefits.

METHODS

The general strategy adopted for the 2006 research was to use high spatial resolution color-infrared aerial imagery to create a map of land cover across RRS. The map was completed by manually interpreting the photography on-screen, using the procedure often referred to as "heads-up digitizing" (explained below). Digital vegetation classes were verified during field visits to the study area in fall 2006 (this is known as *ground-truthing*).

intensity (475–850˚F [250–450˚C]); and white, high-intensity (900˚F [500˚C]) (Dūdaite et al., 2011). C. Wilkin and S. Williams (personal communication, 2016; Williams and Waggener, 2017a, 2017b) concluded that the Arapaho Fire was a moderate- to high-intensity fire, with temperatures reaching nearly 900˚F (500˚C).

VEGETATION MAPPING PROJECT COMPLETED BEFORE ARAPAHO FIRE

With good luck and fortune, the mapping work that is contained in this bulletin (as well as soil sampling that will be presented in an upcoming bulletin) was completed prior to the fire. Thus, our project will help future researchers, land managers, and others examine various vegetational states as they existed pre-fire, and whether post-

Table 1. The land-cover classification scheme used to assign cover types to mapped polygons. (Classification by M. Seymour)

Vegetation	Non-Vegetation
Dense ponderosa pine	Water
Sparse ponderosa pine	Unimproved roads
Quaking aspen	Cabins/outbuildings
Willow	Rock outcroppings
Mixed grassland/shrub land	Unknown

AEROCAM IMAGERY

The former Airborne Environmental Research Observational Camera (AEROCam) was an aerial photography system owned by the University of North Dakota. It was available for use by members of the Upper Midwest Aerospace Consortium (UMAC), including Wyoming and other states, and was designed to take high spatial resolution photographs in the visible and near-infrared wavelengths. Such imagery is often used for vegetation analysis, an important tool in precision agriculture and natural resource management, and to aid in the rapid response to disasters (Upper Midwest Aerospace Consortium, 2007).

IMAGE ACQUISITION

In 2006, Rik Smith,[25] at the time an assistant professor in the UW Department of

[25] Rik Smith is now an associate professor at Columbia Basin College in Pasco, Washington.

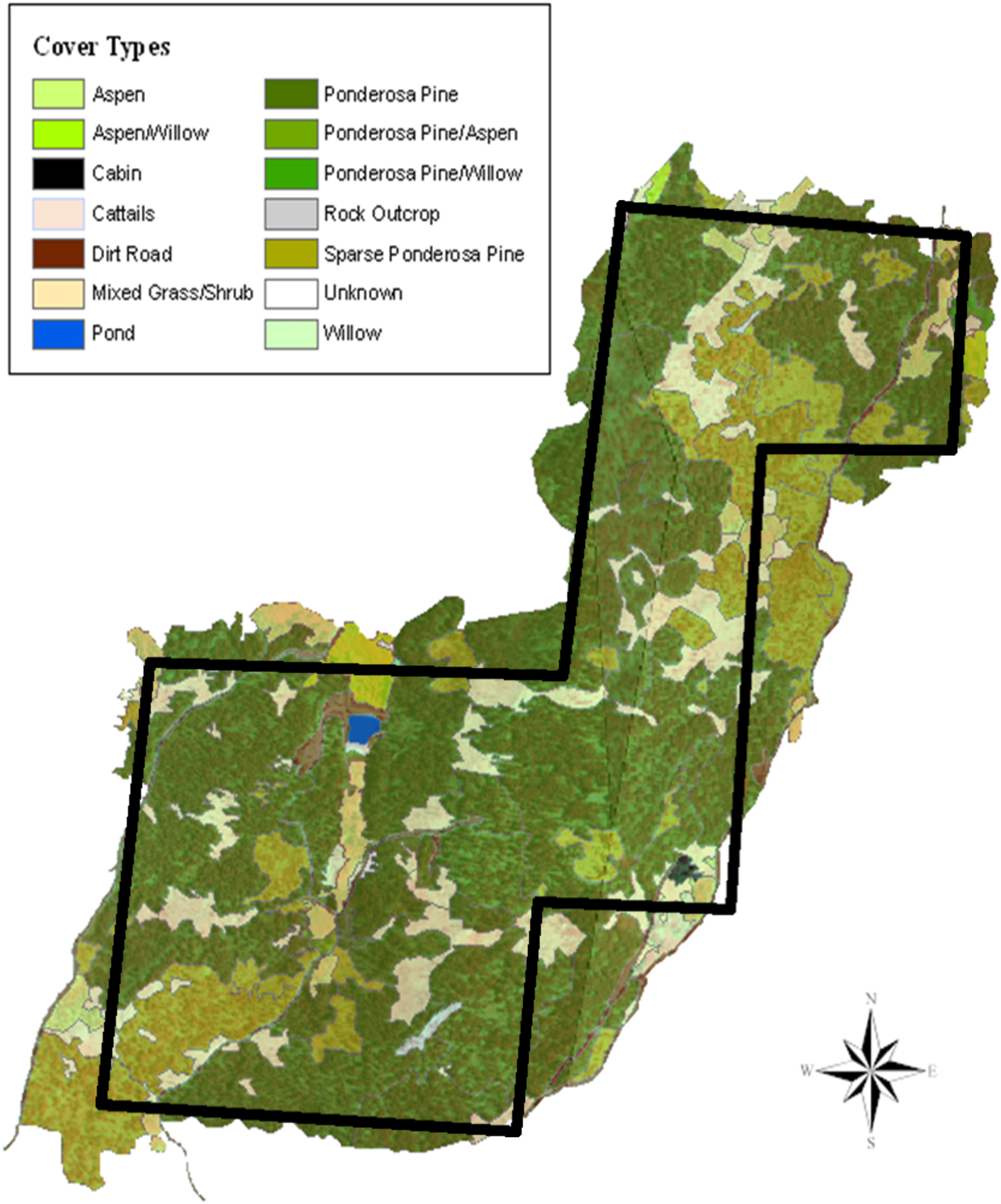


Figure 18. Land-cover map of RRS, 2006. At the time, RRS and surrounding lands were mostly forested with ponderosa pine. In 2012, a severe wildfire swept across the area, consuming most of the vegetation. (Map by M. Seymour)

Figure 19. Aerial image of RRS and surrounding lands taken in 2006, the same year our land-cover map was created. It shows that the area was covered by vegetation at the time. (Aerial image from National Agriculture Imagery Program [NAIP]; RRS mapping by Zarifa Dushdurova, courtesy J. Decker, UW Real Estate Operations)

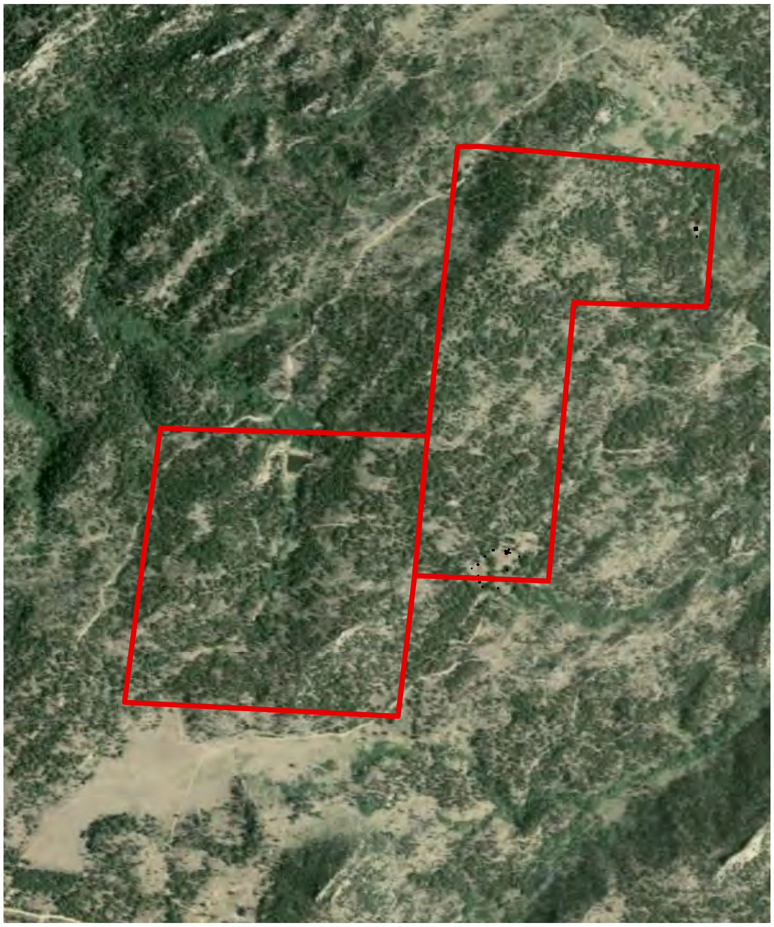
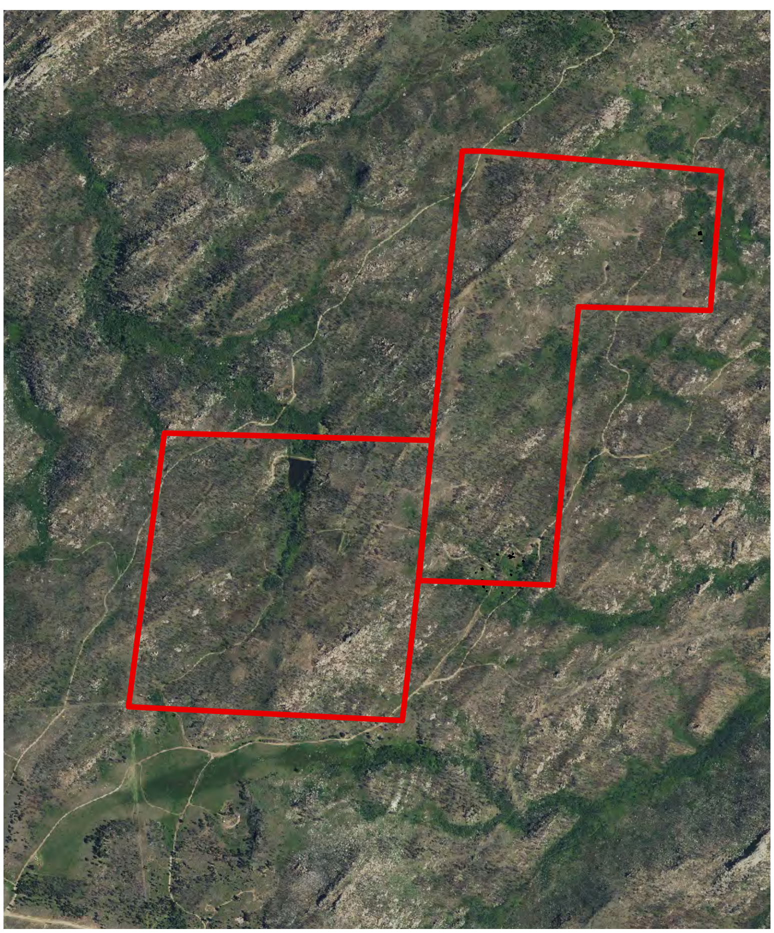


Figure 20. Aerial image of RRS and surrounding lands taken in 2015, three years after the Arapaho Fire burned nearly 100,000 acres in the Laramie Mountains, including the RRS property. (Aerial image from NAIP; RRS mapping by Z. Dushdurova, courtesy J. Decker).



Plant Sciences, and Dave Claypool, a master technician in the department, requested AEROCam images of RRS from UMAC on behalf of WAES (Appendix D). Photographs were acquired June 18 and August 23, 2006. These photos are of high spatial resolution (3.3–6.6 ft [1–2 m]) and show distinct landmarks and easily recognized land cover (Fig. 16). For this project, we used only the June 18, 2006, photographs, because the early summer land cover was more easily recognized compared to the August 23 photos, which were taken much later in the growing season. Images were created by using a collage of photos taken as the plane flew over the area several times. The photos were then georectified (linked to geographic coordinates) and mosaicked (stacked and combined) to create a single composite image of the study area.

FIELD RECONNAISSANCE

Ground-truthing conducted on October 30, 2006, provided three kinds of information: (1) major land-cover types (such as ponderosa pine and aspen woodlands) were identified (Tables 1–2); (2) major features (e.g., cabins, bare ground, etc.) from the AEROCam imagery were

Figure 21. This small reservoir is among the many features shown on the land-cover map. The "Rogers Reservoir," as it was called by some, was constructed in the late 1970s and was stocked with trout (Waggener, 2005). The photo was taken in 2009, three years before the Arapaho Fire, which burned much of the vegetation around the reservoir. This subsequently led to erosion, silt being deposited into the pond, and the death of many fish and other aquatic species (Williams and Waggener, 2017a). (Photo by Kelly Greenwald, James C. Hageman Sustainable Agriculture Research and Extension Center)

Figure 22. This photo, which shows the same pond as in Figure 21, was taken three years after the fire. It helps to reveal the high tree mortality. But it also shows the many grasses and forbs returning to the area. Also prevalent post-fire were invasive species. The prominent peak on the right is Laramie Peak. (Photo by S. Williams)

compared to attributes found within RRS; and (3) any major changes in the landscape since June 18, 2006, were noted. Field observations were limited to near roadsides because of time constraints. Additionally, ground-truth polygons were created with a field GPS unit (Trimble® GPS Pathfinder® system) for each of the different land-cover types to assist with the subsequent heads-up digitizing analysis.

DEVELOPMENT OF A CLASSIFICATION SCHEME

From examination of the AEROCam photographs, a vegetation classification scheme was created using classes that anticipated potential future use of the area (Table 1). These anticipated uses include resource management, scientific research, and human access, as well as the improvement of wildlife habitat and forestry resources, per the wishes of Colonel Rogers. The vegetation classes are clearly defined (see text below) to allow for cross-study comparisons and to include both natural and anthropogenic types. To provide a baseline for future research, a description for "dense ponderosa pine" and "sparse ponderosa pine" was developed (discussed below).

HEADS-UP DIGITIZING

A digital layer of land-cover types was created by heads-up (manual) digitizing, in which a computer mouse is used to create boundaries around features on the aerial photograph when it is displayed on a computer monitor. Using Esri® ArcMap software, land-cover polygons guided by the classification scheme (Fig. 17; Table 1) were created on the June 18, 2006 imagery. The polygons were labeled according to the classification scheme and then merged to create the final land-cover map.

POLYGON LABELS

Polygons were labeled with land-cover types from the classification scheme (Table 1) based on visual interpretation and field experience acquired during reconnaissance. In this way, each digitized polygon was assigned one land-cover attribute.

RESULTS

Our land-cover map (Fig. 18) shows that in 2006, RRS was predominantly ponderosa pine (*Pinus ponderosa*) forest (80%), with mixed grass and shrub lands (10%) and quaking aspen (*Populus tremuloides* [4%]). When our map and an aerial image of RRS and surrounding lands taken the same year (2006; Fig. 19) is compared to an aerial image taken in 2015 (Fig. 20), the dramatic effects of the 2012 Arapaho Fire on vegetation is easily seen.

LAND-COVER CLASSES

Based on the classification scheme and field observations of the area, we included 184 land-cover polygons on the map (Fig. 17). Land-cover classes and their approximate area are displayed in Table 2. The "unimproved roads" area is inaccurate because overhanging tree branches and trees and shrubs growing close to the roads obscure the roads on the AEROCam imagery.

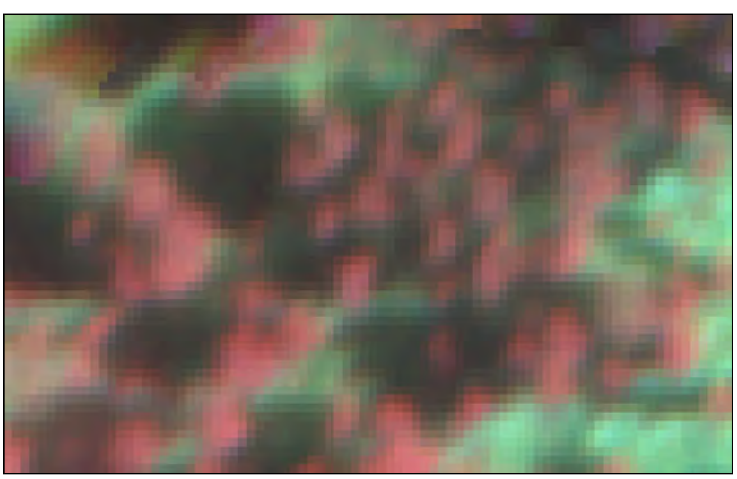


Figure 23. Close-up view of AEROCam imagery showing trees (red pixel groups) and tree shadows (black pixel groups), which, at this low resolution, occupy large areas in the imagery, and, therefore, would be difficult to classify correctly using automated methods. (Photo by UMAC)

PONDEROSA SPARSE VS. DENSE

Sparse ponderosa pine areas include approximately five to seven trees in a 50-ft (15-m) diameter circle plot (~670–940 stems/ac [~270–380 stems/ha]). Dense areas include up to 15 trees per 50-ft diameter plot (~2,040 stems/ac [~822 stems/ha]). The "ponderosa sparse" vs. "ponderosa dense" were based on previous classifications of "sparse" and "dense" tree cover, which differ in several ecological factors, including fire regime, biodiversity, and ecosystem function (Montes-Helu et al., 2009).

MIXED-CLASSIFICATION STANDS

Some areas of the map are described as mixed stands, combining two classification types. This description was used where the photograph shows approximately equal distribution between two classes in fine-grained mixtures that could not be separated into polygons of pure classes.

Number of Polygons	Area (Acres/Hectares)	
41	228.3 ac	92.4 ha
32	60.4	24.4
53	40.1	16.2
19	14.9	6.0
6	2.5	1.0
3	4.5	1.8
1	0.3	0.1
1	0.9	0.4
20	9.4	3.8
2	0.8	0.3
1	0.6	0.2
2	0.5	0.2
1	0.1	<0.1
2	0.5	0.2
184	363.8	147.1

Table 2. Classification types with estimated area and number of polygons drawn. (Classification by M. Seymour)

GRASSLAND/SHRUB LAND

Grassland and shrub land cover-types include a large variety of species. Predominant shrub species include antelope bitterbrush (Fig. 8; Appendix B) and sagebrush. Among the grasses are prairie Junegrass (*Koeleria macrantha*) and western wheatgrass (*Pascopyrum smithii*); however, these species' identifications were based on a superficial field observation, and other grasses, as well as a variety of forbs, are present. (Details on grass species were limited because of time constraints and time of year. More discussion of grasses will occur in upcoming RRS bulletins.)

UNKNOWN AREA

An area of the map was classified as unknown because the image was not clear enough to determine its physical characteristic. Instead of trying to interpret these areas, an unknown class was assigned until a personal observation or a second photographic interpretation is possible.

OVERLAP

Total area in the land-cover map is about 44 ac (18 ha) larger than the estimated RRS property area of 320 ac (~129 ha). The extra area is due to inclusion of property that is outside of RRS, including the area north/northwest of the pond (Figs. 21–22). This was included due to imprecise coordinates for RRS property boundaries to ensure complete coverage of the RRS property. This might overestimate the area of dense ponderosa pine cover, as well as areas of quaking aspen and willow cover-types.

DISCUSSION

Heads-up digitizing classifies land cover based on the analyst's personal understanding of the area and ability to interpret the imagery. This method was selected because the imagery was too detailed to use computer-determined unsupervised or other image classification algorithms. High spatial resolution imagery allows for detailed visual identification, as individual trees and shrubs can be seen in such imagery. But as Figure 23 shows, high resolution imagery also captures shadows, which are difficult to classify using automated methods, since the 'color' of a shadow pixel (or other non-cover features) does not match the 'color' of the cover-type class it represents. While the map resulting from this project (Fig. 18) included a measure of subjectivity inherent in any manually interpreted product,

Figure 24. Following the 2012 Arapaho Fire, weeds—among them Canada thistle (*Cirsium arvense*) and common dandelions (*Taraxacum officinale*), pictured, along with cheatgrass (*Bromus tectorum*)—infested many acres of the Laramie Mountains, including some areas within RRS. This image was taken in 2015. (Photo by S. Williams)

Figure 25. This photo was taken in May 2015, just shy of three years after the Arapaho Fire. It shows good regeneration of bluebunch wheatgrass (*Elymus spicatus*) and a variety of shrubs and forbs. (Photo by S. Williams)

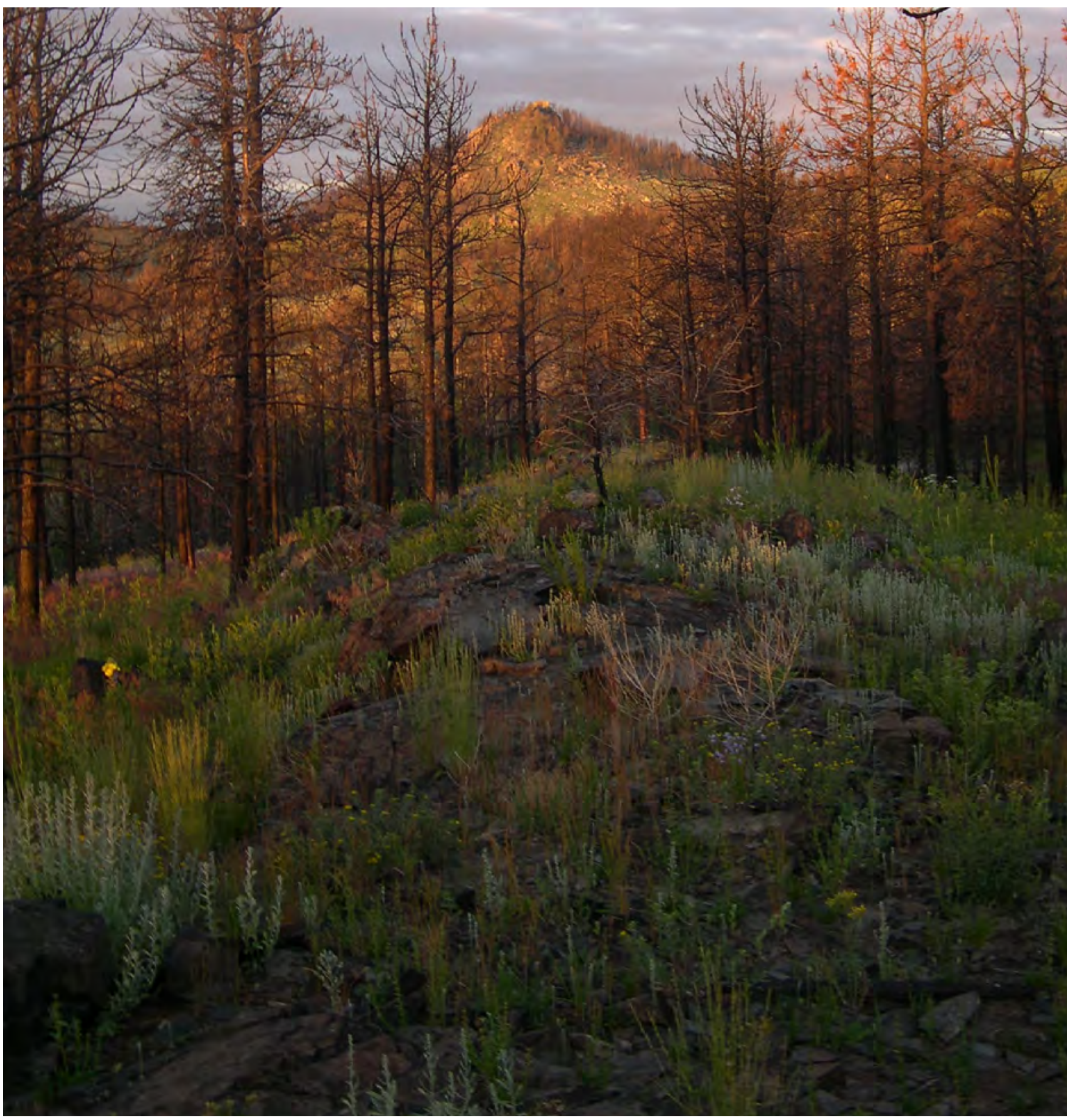


Figure 26. This photo was taken on July 23, 2015, a little over three years following the Arapaho Fire. A variety of grasses and forbs reestablished after the fire. Among the forbs were common yarrow (*Achillea millefolium* L.), the white flower, and blanketflower (*Gaillardia aristata* Pursh), the yellow and reddish flower. (Photo by Michael Curran)

Figure 27. Among the forbs that established after the 2012 Arapaho Fire were cutleaf daisy (*Erigeron compositus*), the white flowers; dwarf mountain ragwort (*Senecio fremontii*), the yellow flowers; and beardtongue (*Penstemon* spp.), the blue flowers. This photo was taken in mid-summer 2015, three years after the fire. (Photo by S. Williams)

Figure 28. The high-intensity 2012 Arapaho Fire burned most of the vegetation at RRS and surrounding lands, dramatically altering the vegetation structure. This photo was taken on March 15, 2013, approximately eight months after the fire swept through RRS. (Photo by S. Williams)

it provides an unbiased third-party assessment of the land cover in 2006. Lower spatial resolution imagery could be used to produce an automated classification using Geographic Information Systems (GIS), ERDAS Imagine®, or similar software.

WILDFIRE DRAMATICALLY ALTERS VEGETATION AT RRS

The RRS vegetation map presented here was completed in 2006; however, in 2012 the Arapaho Fire burned most of the vegetation at the site and surrounding lands, dramatically altering the vegetation structure (Figs. 6, 14–15, 20, 22). Wildfires play a major role in shaping ecosystems across Wyoming, the West, and beyond by changing abiotic (particularly soils) and biotic (e.g., plants, animals, fungi) communities and dynamics (Knight et al., 2014). After a fire, recovery of vegetation (succession) is heavily influenced by factors including the ability of species to recolonize the site, the timing of species' establishment, land-management strategies, changes in the environment, and the legacy of the extent and intensity of the fire.

Priority effects occur when species that are first to colonize new habitat (e.g., post-fire open habitat) facilitate or inhibit the establishment of later species. Invasive species, such as downy brome (aka cheatgrass, *Bromus tectorum*) may benefit from priority effects by inhibiting recolonization of native species to disturbed sites (Perkins et al., 2014). This, in turn, may alter expected or historical successional patterns (Menakis et al., 2003). Monitoring and management strategies of post-disturbance dynamics are, therefore, necessary to determine whether a given disturbance (1) facilitates community shifts in species composition (e.g., invasive species/noxious weed colonization); (2) induces ecological damage due to the change in successional communities (e.g., lower productivity, loss of biodiversity, replacement of keystone species); or (3) promotes succession to a productive state, whether that state is similar to pre-fire or is an alternative ecological state.

BOTH UNDESIRABLE, DESIRABLE PLANTS ESTABLISH AFTER FIRE

To elaborate on these three points, several invasive species—notably cheatgrass and Canada thistle (*Cirsium arvense*), but also common dandelion (*Taraxacum*

Figure 29. Researchers involved in a long-term project at RRS are assessing various methods—and the effectiveness of those methods—of introducing ponderosa pine and grass to a burned site. Here, members of the team place flags where seedling ponderosa were planted in 2015, about three years after the Arapaho Fire. Native grasses, forbs, and invasive species dominated the site when this image was taken. Results of the ponderosa pine research and other studies will be presented in upcoming RRS bulletins. (Photo by S. Williams)

officinale)—began spreading in areas of RRS and surrounding lands shortly after the 2012 Arapaho Fire. In some cases, the weeds formed dense patches (Fig. 24).

Nevertheless, many native grasses, forbs, and shrubs also survived or became established after the fire (Figs. 25–27). Among them bluebunch wheatgrass (*Elymus spicatus*), silky locoweed (*Oxytropis sericea*), cutleaf daisy (*Erigeron compositus*), Pursh's wallflower (*Erysimum capitatum* var. *purshii*), dwarf mountain ragwort (*Senecio fremontii*), lupine (*Lupinus* spp.), dogbane (*Apocynum androsaemifolium*), beardtongue (*Penstemon* spp.), and buckbrush [*Ceanothus velutinus*]) (S. Williams, personal communication, 2016; Williams and Waggener, 2017a). *C. velutinus* is among the fire-adapted species in that their seeds require a heat scarification before they will germinate (Abrahamson et al., 2017; S. Williams, personal communication, 2017).

Some sagebrush is reestablishing at RRS and adjacent lands as well. Though formal surveys had not taken place at the time of this writing, it would be valuable for future researchers to determine which species are present because some sagebrush species are killed by fire while other taxa resprout. Additionally, in many of the meadows at RRS, sagebrush was present pre-fire and did not burn. Rubber rabbitbrush (*Ericameria nauseosa*) is also returning. Antelope bitterbrush is growing as well, but from the seedbank left after the fire. Based on visual inspections of part of the property, there was no regrowth from the original bitterbrush plants because of the intensity of the Arapaho Fire (Figure 28; S. Williams, personal communication, 2017). Literature indicates that bitterbrush is not a fire resistant shrub, but is fire dependent; and light to moderate fires may enhance stands (Noller, 2014). This has been observed with low-intensity prescribed burns in the Laramie Mountains (R. Amundson, personal communication, 2016).

MANY QUESTIONS TO ANSWER

Will the grasses and forbs at RRS and surrounding lands outcompete the established monoculture patches of weeds naturally, or will human intervention be needed to promote native species establishment? How will shrubs and trees respond, including ponderosa pine, which once dominated the landscape? Will tree stands return naturally in great numbers, or will the landscape remain dominated by grasses and shrubs because of such factors as climate change, invasive species establishment, and changes in soils due to past fire intensity? Can humans play a role in managing the soil and vegetation and, ultimately, their effects on wildlife, water, and air quality?

CONCLUSIONS AND FUTURE STUDIES

Research is already underway at RRS to answer some of the questions posed in this paper, including a long-term project assessing various methods—and the effectiveness of those methods—of introducing ponderosa pine and grass to a burned site[26] (Figs. 29–31). Other projects are focused on soil surveys,[27] pre- and post- fire soil comparisons,[28] and soil amendment and microbial community recovery after wildfire.[29] The intent is to publish results from each of these studies in upcoming papers in the RRS bulletin series.

There are many more questions to ask—and, most importantly—to answer. Given the changing nature of the world around us, having historical information is beneficial not only to those researchers conducting projects at RRS, but to others as well, among them scientists, students, landowners and managers, and policy makers. The data and vegetation map presented in this bulletin—coupled with completed[30,31,32] and ongoing research in the Laramie Mountains, across Wyoming, and beyond—will help them to better understand the impact that natural processes and management decisions have on natural resources over time, including soils, vegetation, wildlife, water, and air (Figs. 32*A*–*B*). One of the many valuable components to this work is having long-term weather information. The weather station at RRS that was damaged by mice shortly after being installed in 2013 was repaired in 2017, and weather data can be downloaded on the Wyoming Agricultural Climate Network website at http://www.wrds.uwyo.edu/WACNet/Stations.html (V. Sharma and J. Tanaka, personal communication, 2017). It is our suggestion that the UW College of Agriculture and Natural Resources, WAES, SAREC, and the next RRS management committee work with the National Weather Service (NWS) to become an official cooperative weather observer through the NWS's Cooperative Observer Program.

Future research at RRS—including studies involving forestry, wildlife, and range

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26 Ongoing vegetation studies at RRS will be presented in upcoming papers in the RRS bulletin series. Early results from one of those—restoration of ponderosa pine and native grass at the UW Rogers Research Site following high-intensity wildfire—are expected to be released this year. Leading that project (and the subsequent bulletin) are Mary Elizabeth "Mollie" Herget, Steve Williams, UW Assistant Professor Linda T.A. van Diepen, UW Assistant Professor Derek Scasta, Stephanie Winters, and Robert Waggener. Herget, who earned a master's degree in rangeland ecology and watershed management at UW, worked on RRS projects during 2015, when much on-site activity occurred. Herget is now an agronomist at the Elsberry Plant Materials Center operated by the USDA Natural Resources Conservation Service in Elsberry, Missouri.

27 Another bulletin in the RRS series that should be complete this year will focus on soil surveys at RRS. Leading this effort are Larry Munn, Steve Williams, Michael Urynowicz, and Robert Waggener.

28 A second bulletin dealing with soils—pre- and post-fire soil comparisons at RRS—is also expected to be published this year. It is being compiled by Williams, Urynowicz, and Waggener.

29 A third bulletin focused on soils—soil amendment and microbial community recovery after high-severity forest fire—is also expected to be published this year. It is being compiled by Claire Wilkin, Williams, Urynowicz, and Waggener.

30 The National Cooperative Soil Survey has produced soil data and information for much of the Laramie Mountains. It is provided on the Web Soil Survey operated by the USDA Natural Resources Conservation Service at https://websoilsurvey.nrcs.usda.gov/.

31 The University of Wyoming thesis project by Barbara Packer (Packer, 2000) is an outstanding resource when it comes to vegetation types, their physical environments, species of special concern, and invasive species of the Laramie Mountains. *A Floristic Study of the Laramie Range, Wyoming*, lists 1,061 known taxa in the range.

32 An outstanding guide for wildlife species in the state, including their habitats and distribution, is the WGFD's *Atlas of Birds, Mammals, Amphibians, and Reptiles in Wyoming*, which was updated in 2016 (Orabona et al., 2016).

resources—will help ensure that the gift of Colonel William C. Rogers and the policies and goals established by WAES/SAREC, the College of Agriculture and Natural Resources, UW, and others are successfully implemented and carried out. The data presented here also may be used to compare land-use strategies, biodiversity, temporal dynamics, etc., across a wider geographic area, given the occurrence of similar habitats found in the Laramie Mountains of southeastern Wyoming and northeastern Colorado.

Future work at RRS could examine various vegetational states as they existed pre-fire (Fig. 18), and if post-fire they are transitioning back to those states or are trending to new ecological states. In addition to aerial images such as Figs. 19–20, additional detailed mapping over time could provide researchers with opportunities to study the interrelationships between changing

Figure 30. Prior to planting seedling ponderosa pine trees as part of a restoration study, summer intern Noah Snider[33] measures out a 50×50-meter (164×164-foot) plot at Rogers Research Site on July 23, 2015. (Photo by Mollie Herget)

Figure 31. Field crew members, from left, Lauren Connell, a UW graduate student in ecosystem science and management, UW assistant professors John Derek Scasta and Linda T.A. van Diepen, and Matt King, a UW graduate student in soil science, survey one of the ponderosa pine restoration plots at Rogers Research Site on September 30, 2016. (Photo by Elizabeth Traver)

[33] Noah Snider, from Laramie, Wyoming, is now studying physics at Vassar College in Poughkeepsie, New York. He is on the varsity soccer team and is interested in pursuing a profession in renewable energy.

plant communities and wildlife, as well as how those changes affect soil, water, and air over time. This research ties directly into the wishes of Colonel Rogers, who stated in his will that the land should be used for the "public benefit," and that future studies should focus on improving wildlife and forestry resources on the land that he and his friends grew to love.

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Lastly, we wish future researchers—and those they collaborate with—the very best in their studies at RRS and surrounding lands. Such work should keep the wishes of Colonel William C. Rogers in mind: activities to benefit the public as well as research to improve forestry resources and wildlife habitat at RRS, adjacent lands, and across Wyoming.

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Figures 32*A*–*B*. A variety of forbs reestablished at RRS following the 2012 Arapaho Fire, including ***A***, Gunnison's mariposa lily (*Calochortus gunnisonii* S. Watson), and ***B***, fleabane (*Erigeron* spp.). Both flowers are common to the Laramie Peak area (E. Nelson, personal communication, 2017). These photos were taken on July 23, 2015, about three years after the fire. RRS is home to a wide variety of plants, in part because of the varied terrain, from spring-fed bottoms to open meadows, forested areas, and rocky outcrops. (Photos by M. Curran)

APPENDIX A. PONDEROSA PINE (*PINUS PONDEROSA*) PLANT GUIDE.

Plant Guide

PONDEROSA PINE

***Pinus ponderosa* P. & C. Lawson**

Plant Symbol = PIPO

Contributed by: USDA NRCS National Plants Data Center

Banner, R. 2002.
Utah State University Extension.

Alternate Names

Big heavy, black jack, bull pine, ponderosa white pine, Sierra brown bark pine, silver pine, western pitch pine, western red pine, western yellow pine, yellow pine, Yosemite pine.

Uses

Erosion control: Ponderosa pine is a rapid growing tree with the ability to firmly anchor into most soil types. For this reason, it is suitable for use as a windbreak species. It can also be used with other natives to provide cover and erosion control on rehabilitated sites.

Ethnobotanic: Native Americans used various parts of ponderosa pine for medicinal, building and household, food, and ceremonial purposes. Needles were used as dermatological and gynecological aids.

They were also used to reduce coughs and fevers. The pitch was used as an ointment for sores and scabby skin, backaches, rheumatism, earaches, inflamed eyes, and as a sleeping agent for infants. The boughs of the plant were used in sweat lodges for muscular pain, as decoctions for internal hemorrhaging, and as infusions for pediatric treatments.

The roots of ponderosa pine were used to make blue dye and needles were used as insulation for underground storage pits. The wood was used extensively for fence posts, boards for general construction, and to fabricate snowshoes. Single logs were used to make dugout canoes. Bark was used to cover houses.

Most parts of the plant were used for food, including the pitch, seeds, cones, bark, buds, and cambium. The pollen and needles were used in healing ceremonies.

Ornamental value: Ponderosa pine has a lush green color and pleasant odor that makes it popular for ornamental plantings. It has been planted, sometimes out of its natural range, because of its aesthetic qualities. Ponderosa pine is used as borders of forested highways, but is not planted within the right-of-way. The large stature of the tree limits its use to open spaces.

Wildlife: Red-winged blackbirds, chickadees, mourning doves, finches, evening grosbeak, jays, Clark's nutcracker, nuthatches, rufous-sided towhee, turkeys, chipmunks and squirrels consume the seeds of ponderosa pine. Blue and spruce grouse use ponderosa pine needles for nesting material. Mice, porcupines, and other rodents use the bark for nesting material. The trees are also important to various birds for cover, roosting and nesting sites.

Wood production: Ponderosa pine is one of the most important timber species in the western United States. The annual production of ponderosa pine is ranked third behind Douglas fir and hem-fir. Approximately 1.3 billion board feet of ponderosa pine lumber is produced annually out of Oregon, the largest supplier in the United States. It is popularly used for the construction of buildings.

Description

General: Pine Family (Pinaceae). Ponderosa pine is a large tree that lives 300 to 600 years and reaches heights of 30 to 50 m tall and 0.6 to 1.3 m in diameter. The oldest trees can exceed 70 m in height and 2 m in diameter. The bottom one-half of the straight trunk is typically without branches. The crown of ponderosa pine is broadly conical to round-shaped. The bark is characteristically orange-brown with a scaly plate-like appearance. Twigs are stout, up to 2 cm think, orange-brown, and rough. Needles are 12 to 28 cm long, thin and pointed with toothed edges, occur in bundles of three, and give a tufted appearance to the twig. Buds are up to 2 cm long, 1 cm wide, red-brown with white-fringed scale margins. Male cones are orange or yellow and are located in small clusters near the tips of the branches. The female cone is oval, woody, 8 to 15 cm long, with a small prickle at the tip of each scale. Flowering occurs from April to June of the first year, and cones mature and shed winged seeds in August and September of the second year.

Distribution: Ponderosa pine is distributed from southern British Columbia through Washington, Oregon, and California, and east to the western portions of Texas, Oklahoma, Nebraska, North Dakota, and South Dakota. For current distribution, please consult the Plant Profile page for this species on the PLANTS Web site (http://plants.usda.gov).

Habitat: Ponderosa pine trees occur as pure stands or in mixed conifer forests in the mountains. It is an important component of the Interior Ponderosa Pine, Pacific Ponderosa Pine-Douglas fir, and Pacific Ponderosa Pine forest cover types.

In the northwest, it is typically associated with Rocky Mountain Douglas fir, lodgepole pine, grand fir, and western larch. In California it is associated with California white fir, incense cedar, Jeffrey pine, sugar pine, coast Douglas fir, California black oak, and western juniper. In the Rocky Mountains and Utah, it is associated with Rocky Mountain Douglas fir, blue spruce, lodgepole pine, limber pine, and quaking aspen. In the Black Hills, it is associated with quaking aspen, white spruce, and paper birch. In Arizona and New Mexico, it is associated with white fir, Rocky Mountain Douglas fir, blue spruce, quaking aspen, gambel oak, and southwestern white pine at higher elevations and Rocky Mountain juniper, alligator juniper, and Utah juniper at lower elevations (Oliver & Riker 1990).

Shrubs and grasses typically associated with ponderosa pine within its range include ceanothus, sagebrush, oak, snowberry, bluestem, fescue, and polargrass.

Adaptation
The USDA hardiness zones for ponderosa pine range from 3 to 7. It grows on a variety of soils from shallow to deep, and from gravelly sands to sandy clay loam. It is found growing on bare rock with its roots in the cracks and crevices. It has a low tolerance to alkalinity, preferring soils with a pH of 6.0 to 7.0. It grows best in zones with 30 to 60 cm average annual precipitation on well-drained soils. Once established it also survives hot and dry conditions, exhibiting medium to good drought tolerance. Fifty percent shade reduces the growth rate significantly. It withstands very cold winters.

Ponderosa pine is a climax species at the lower elevations of the coniferous forest and a mid-successional species at higher elevations where more competitive conifers are capable of growing. It generally grows at elevations between sea level and 3,000 m. The populations at higher elevations usually occur within the southern part of its range (Oliver & Riker 1990).

Establishment
Site preparation is needed to control competition, which compromises seedling survival and growth. Seeds are sown in late March to early April. The seed is sown for an initial density of 237 seedlings/m^2 (22 seedlings/ft^2). Transplant stock should be one or two years old, with less than 2 prior transplantings, and 15 to 30 cm in height. Space the plants 1 to 3 m apart depending on the site.

Initial seedling survival is reduced under moisture stress. Older seedlings can tolerate limited moisture. Competition from other vegetation should be controlled for the first three to six years until the trees become well established.

Management
Ponderosa pine can be over-irrigated in poorly drained soils, or drowned out on high water table sites.

It responds well to thinning, which should be done as stands become older to develop larger crowns, resulting in heavier seed crops for wildlife. More forage for deer and elk become available from associated plants by opening the canopy. The use of repellents or other control measures may be necessary to prevent overuse of the trees by rodents.

Ponderosa pine is resistant to fire due to its thick bark. Low intensity surface fires control competitive species like scrub oak and shade-tolerant conifers. Ponderosa pine seedlings can also survive low intensity burns.

Pests and Potential Problems
Approximately 200 insect species affect ponderosa pine from its cone stage to maturity. Pine cone beetles cause tree death by transmitting blue stain fungus to the tree. Their larvae also consume the phloem, restricting the flow of nutrients to the top of the tree.

Western pine beetle is a common cause of death for older trees, drought stressed trees, and even healthy, vigorous trees during epidemics.

Bark beetles are naturally present in all stands. Harvesting methods that leave large amounts of logging slash can allow bark beetle populations to explode and kill vigorous trees up to 0.5 m in diameter.

The ponderosa pine budworm, also known as the sugar-pine tortrix, eats new needles on trees in New Mexico and Colorado. Several years' worth of damage will affect the health of the tree. Early research suggests that some insecticides may help to control infestations.

Dwarf mistletoe is the most widespread parasite that causes branch and stem deformation. It germinates on ponderosa pine branches and forces its roots into the phloem of the host branch, creating stem cankers that leave the wood weak and unsuitable for use as lumber. This weakens the tree and leaves it susceptible to fungal infections and insect attacks. Root diseases, rusts, trunk decays, and needle and twig blights also cause significant damage.

Seeds and Plant Production
Ponderosa pine is propagated by seed. Cones are ready for collection in October and November when they turn reddish brown. Mature seed is firm and brown in color. Cones should be dried on canvas tarp in a well-ventilated area immediately after they have been collected. The seeds will drop from the cones as they dry.

Several germination methods for ponderosa pine have been utilized, each with their own variations. In general, seeds undergo an imbibition treatment before stratification. Seeds are placed in mesh bags and soaked in cold running water for 48 hours. One variation is to soak the seeds in a 40% bleach solution for 10 minutes with hand agitation prior to placing them under running water. The mesh bags are placed in plastic bags and stored at 1^{o}C for 2 to 8 weeks. They should be checked daily for mold. Seeds are sown into containers and covered with media. The media should be kept moist throughout germination. Germination will occur at an average greenhouse temperature of 20^{o}C. Alternating greenhouse temperatures of 21-25^{o}C during the day and 16-18^{o}C at night are an appropriate environment for germinating seeds. Germination will occur in approximately 15 days.

Seedlings are thinned and watered daily throughout the establishment phase. They should not be moved outdoors until after the last frost of the year.

Seeds can be dried to between 5 and 8% moisture and placed in airtight plastic bags, then stored for long periods of time in freezers set at –15^{o}C.

Cultivars, Improved and Selected Materials (and area of origin)
Contact your local Natural Resources Conservation Service (formerly Soil Conservation Service) office for more information. Look in the phone book under "United States Government." The Natural Resources Conservation Service will be listed under the subheading "Department of Agriculture."

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For more information about this and other plants, please contact your local NRCS field office or Conservation District, and visit the PLANTS Web site<http://plants.usda.gov> or the Plant Materials Program Web site <http://Plant-Materials.nrcs.usda.gov>

USDA NRCS

Plant Guide

ANTELOPE BITTERBRUSH
Purshia tridentata (Pursh) DC.
Plant Symbol = PUTR2

Contributed by: USDA NRCS California State Office and Lockeford Plant Materials Center, California Upper Colorado Environmental Plant Center, Colorado


Steve Parr, UCEPC, Meeker, Colorado

Alternate Names
Antelopebrush, buckbrush, quininebrush, bitterbrush, antelope-brush, quinine brush, deer-brush, black sage

Uses
Antelope bitterbrush is one of the most important palatable native shrubs in the western United States. It provides high quality, important spring and winter browse for domestic livestock, antelope, deer, and elk. Its seed is an important source of food for small animals and the plant provides cover for small animals and birds. It is considered medium quality coverage for sage-grouse. The shrub is also used for reclamation and erosion control of mined areas and has the potential for use as a living snow fence, roadside beautification, and xeriscape plantings.

Historic Native American Uses: Western Indian groups used leaf poultice or wash for itches, rashes, insect bites, chickenpox, and measles. Leaf tea was used as a general tonic and for colds, pneumonia, liver disease, to expel worms, and as an emetic and laxative for stomach ache and constipation. Twigs, leaves, and berries were used as a laxative. Root teas were used for coughs, lung and bronchial infections, fever, and to facilitate delivery of placenta.

Status
Please consult the PLANTS Web site and your State Department of Natural Resources for this plant's current status (e.g., threatened or endangered species, state noxious status, and wetland indicator values).

Description
General: Antelope bitterbrush is a slow growing shrub that is moderate to very deep rooted with wide ecotypic variations. It is normally 2 to 6 feet in height and up to 8 feet in width with wedge shaped, three lobed leaves (some are persistent in winter). Leaves can vary in color from grey green to bright green. Some plants have branches near the soil that layer (branches that touch the soil develop roots) providing additional rooting for the plant.

Flowering occurs in late spring to early summer. The spindle-shaped seed shatters easily at maturity. Flowers are small, varying from white to yellow, and produced profusely along each leader. The seeds are large for the species—15,500 per pound. They are about one-fourth inch long and obovate. Seeds, stems, and leaves are nontoxic.

Individual bitterbrush plants exhibit considerable variation for growth form. Bitterbrush's growth forms vary from a uniform, erect growth habit to more decumbent, layering forms. Users are encouraged to consider the various forms of bitterbrush in choosing a strain best suited to their needs.

Distribution: Antelope bitterbrush is an important native browse shrub in the intermountain western United States. It occurs from New Mexico north to Colorado, Wyoming, Montana, and British Columbia, west to Idaho, and Washington, south to Oregon, California, and Nevada. For current distribution, please consult the Plant Profile page for

Plant Materials <http://plant-materials.nrcs.usda.gov/>
Plant Fact Sheet/Guide Coordination Page <http://plant-materials.nrcs.usda.gov/intranet/pfs.html>
National Plant Data Center <http://npdc.usda.gov>

this species on the PLANTS Web site.

Habitat: Antelope bitterbrush occurs most often as part of a mixed shrub community, but occasionally is found in nearly pure stands. It is associated with a variety of understory grasses and forbs. It can also be an understory plant in association with taller growing trees.

Adaptation
Antelope bitterbrush is adapted to a wide range of soils with 8 to 34 inches of annual precipitation. It is normally found at elevations of 4000 to 8500 feet, but has been noted at 11,000 feet in California. The shrub has good tolerance to drought and cold.

In California, bitterbrush is associated with big sagebrush (*Artemisia tridentata*) and rabbitbrush (*Chrysothamnus* sp.). It occurs naturally on dry lake beds, alluvial fans or terraces, and low foothills. It occurs in soils that are deep, gravelly, loamy coarse sands derived from granite, with pH ranging from 6.0 to 7.0. Tests have shown that bitterbrush has high potential for use on deep, coarse, well-drained, neutral to slightly acidic soils in areas that have 12-24 inches of annual precipitation.

Establishment
Natural establishment of antelope bitterbrush occurs in years with good seed production when rodents cache seed and do not use all of the caches. Moisture is necessary the first few years of seedling growth for establishment. Late fall or winter seeding is recommended and competition can be a problem for establishment. Seeds should be drilled about 1 inch deep at a rate of 1/2 to 2 (3) pounds per acre. Rates are doubled if broadcasting and seeds do need to be covered. In California, pretreatment with hydrogen peroxide is required to break dormancy for spring seeding and seedlings are susceptible to late frosts.

Bitterbrush seedlings are often transplanted on critical sites. In such cases, moisture must be adequate to ensure survival in the first year. One-year-old bare-root or containerized seedling stock, 6 to 24 inches tall, is recommended.

Plants should not be used for the first four years and seedlings need protection until they are 8 to 10 inches tall. Rodents normally cache seeds within 50 to 75 feet of an existing seed source. Suitable environmental conditions may allow natural revegetation in only one out of 20 years. Antelope bitterbrush can also be established with tubling plants. These should be planted in the spring or early summer. Establishment can be slow; however, stands tend to be long-lived.

Several insects and diseases are known to damage the foliage, seed, and seedlings of bitterbrush, and are more or less susceptible than other species. High-density populations of grasshoppers can destroy seedlings.

Management
Since antelope bitterbrush is a very palatable shrub for big game and livestock, its use should be controlled or it can be easily eliminated by overuse. The shrub is most often used by big game in the fall, winter, or early spring when other plants are still covered by snow. Livestock tend to use the shrub during the growing season when use is more detrimental to vigor. Stands of bitterbrush can become decadent with no use and mature plants should be browsed for good forage production and vigor. However, no more than 50 to 60 percent of current annual growth should be removed. The literature indicates that bitterbrush is not a fire resistant shrub, but is fire dependent and light to moderate fires may enhance stands.

Pests and Potential Problems
Many species of insects and mites inhabit antelope bitterbrush, several of these are beneficial. It should be noted that bitterbrush is insect pollinated. Insects that cause problems include defoliators such as mountain mahogany loper and western tussock moth. Some of the noted seed insects are bitterbrush seed midge, Say's stinkbug, dark bitterbrush leaf tier, and flower thrips. Large numbers of seedlings and small plants have been destroyed by cutworms and false wireworms. Diseases associated with bitterbrush include root rot, root and stem wilt, and root-stem canker. Seedlings have been damaged by damping off (a disease caused by fungi). A beneficial organism associated with antelope bitterbrush is the nitrogen-fixing endophyte *Frankia purshiae*.

Environmental Concerns
There are no known environmental concerns associated with antelope bitterbrush.

Seeds and Plant Production
In Colorado, seed may not be produced in wildland stands for 8 to 20 years depending on existing conditions. Browsing should be reduced to 30 percent or less to obtain good seed production. Seed may not be produced from mature plants when stressed from drought or late freezes. Seed can be collected by hand by shaking branches and allowing the seed to fall in hand held collectors. Seeds vary in size from

15,000 to 33,000 per pound and germination normally ranges from 85 to 95 percent. A cold moist stratification period of up to six weeks may be required to obtain good germination. Tublings can be grown in a greenhouse for planting in a period of six months to one year.

In California, mature seed must be harvested within 3 to 10 days of ripening because it shatters quickly after reaching maturity. Seed may be harvested into canvas hoppers or aluminum seed collection trays positioned under the shrubs prior to seed fall. Seed collection and orchard maintenance are simplified by the upright growth form.

A 3.6 to 3.6 m to 4.9 x 4.9 m (12 x12 ft to 16 x 16 ft) spacing is recommended for antelope bitterbrush seed orchards. Plants in wildland stands reach full seed production in 8 to 20 years. With appropriate cultural practices, this period may be reduced to about 5 years for seed orchards. Nine-year old shrubs grown at 2.4 m (8 ft) spacings without irrigation or other cultural treatments at the Boise Shrub Garden, produced 118 g (0.26 lbs) of seed per shrub or 199 kg/ha (177 lbs/acre).

Seed is easily cleaned to a purity of 95 percent using a two-screen fanning mill and a barley debearder. Shriveled black seed is nonviable and should be separated with the chaff. Seeds of bitterbrush are relatively large, averaging 34,507 seeds/kg (15,685 seeds/lb) for cleaned seed, with germination averaging about 84 percent. Seeds of bitterbrush remain viable for 15 years or more in open storage.

On rangeland sites antelope bitterbrush is normally seeded in late fall or winter to permit field stratification of the seed. Pretreatment with hydrogen peroxide is required to break dormancy for spring seeding. Seedlings are susceptible to late frosts. Plants develop very slowly and must be protected from competition during the first two seasons. Recommended seeding rates are 1.2 to 3.3 kg/ha (1 to 3 lbs/acre). Bitterbrush may be established on critical sites by transplanting.

Cultivars, Improved, and Selected Materials (and area of origin)
'Lassen' is a cultivar of antelope bitterbrush released in 1984 by USDA Forest Service, Shrub Sciences Laboratory, Provo, Utah, Soil Conservation Service, and Utah Division of Wildlife Resources, Ephraim Utah. Seven other agencies in California, Idaho, Nevada, and Oregon cooperated. Its origin is near Janesville in Lassen County, California.

Fountain Green germplasm is a source identified release of antelope bitterbrush. It was released in 1990 by the USDA Forest Service, Shrub Sciences Laboratory, Provo, Utah, and the Utah Division of Wildlife Resources, Ephraim, Utah. Its origin is north of Fountain Green, Utah.

Maybell germplasm was released in 1997 as a selected class release by Upper Colorado Environmental Plant Center. Five other agencies participated in the release. Maybell's origin is Moffat County in northwest Colorado, near the town of Maybell.

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Release information for 'Lassen' and Maybell Select Class.

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For more information about this and other plants, please contact your local NRCS field office or Conservation District, and visit the PLANTS Web site<http://plants.usda.gov> or the Plant Materials Program Web site <http://Plant-Materials.nrcs.usda.gov>

APPENDIX C. QUAKING ASPEN (*POPULUS TREMULOIDES*) PLANT GUIDE.

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

Plant Guide

QUAKING ASPEN

Populus tremuloides Michx.

Plant Symbol = POTR5

Contributed by: USDA NRCS National Plant Data Center & the Biota of North America Program

Brother Alfred Brousseau
© St Mary's College
@ CalPhotos

Alternate Names
Trembling aspen, golden aspen, mountain aspen, trembling poplar, white poplar, popple, aspen

Uses
Industry: Quaking aspen is an important fiber source, especially for pulp, flake-board, and other composite products. The wood is light and soft with little shrinkage (see Wheeler 2000) and is used for pallets, boxes, veneer, and plywood. Higher grades are used for other solid wood products, such as paneling, furniture components, and flooring. The wood characteristics make it useful in miscellaneous products, including excelsior, animal bedding, matchsticks, toys, beehives, tongue depressors, spoons, and ice cream sticks. It makes good playground structures because the surface does not splinter, although the wood warps and is susceptible to decay.

Conservation: Quaking aspen is valued for its white bark and brilliant fall color, especially when clustered. The species has been widely used in landscaping but is best in sites away from structures that might be damaged by the aggressive roots. The trees provide good visual screening and noise abatement.

Aspen stands are good firebreaks, often dropping crown fires in conifer stands to the ground when they reach aspens and even sometimes extinguishing the fire because of the small amount of flammable accumulation. They allow more ground water recharge than do conifer forests and they also play a significant role in protecting against soil erosion. They have been used in restoration of riparian habitats.

Wildlife: Young quaking aspen provide food and habitat for a variety of wildlife: black bear, deer, beaver, porcupine, elk, moose, ruffed grouse and many smaller birds and animals, including small mammals such as mice, voles, shrews, chipmunks, and rabbits. Bark, buds, new sprouts, twigs from the tops of fallen or logged trees, and fallen leaves all are wildlife foods.

Ethnobotanic: Native Americans used *Populus* bark (including aspen) as a food source. They cut the inner bark into strips, dried and ground it into meal to be mixed with other starches for bread or mush. Catkins were eaten raw, and the cambium was eaten raw or in a soup.

Status
Please consult the PLANTS Web site and your State Department of Natural Resources for this plant's current status, such as, state noxious status and wetland indicator values.

Description
General: Willow Family (Salicaceae): This is a native tree 5-30 m high, typically less than 15 m, with a rounded crown; lateral roots may extend over 30 meters and vertical sinker roots from the laterals may extend downward for nearly 3 m; bark is typically smooth, greenish-white to gray-white, often thin and peeling, becoming thicker and furrowed with age, especially toward the base. Leaves are simple, deciduous, broadly ovate to nearly round, 4–6 cm long, with small, rounded teeth on the margins, on a

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National Plant Data Center <http://npdc.usda.gov>

slender, flattened petiole, dark green and shiny above, pale green below, turning bright yellow, yellow-orange, gold, or reddish after the first frosts. The male (staminate) and female (pistillate) flowers are on separate trees (the species dioecious – or 'polygamodioecious,' because bisexual flowers may be produced at low frequencies on staminate and pistillate trees), each type of flower borne in pendent catkins. The fruits are narrowly ovoid to flask-shaped capsules 5-7 mm long, splitting to release the seeds; seeds ca.2 mm long, each with a tuft of long, white, silky hairs, easily blown by the wind. The common name is in reference to the shaking of the leaves in light wind.

Variation within the species: Considerable genetic and morphological variation exists over the range of quaking aspen. A number of species and varieties have been described but none are currently recognized. Entire stands are often produced as a single clone from root sprouts – this sometimes easily observable on a single mountainside in different timing in leaf appearance or in different hues and timing of fall coloration. Distinctively large triploid trees are sometimes found.

Quaking aspen hybridizes naturally with bigtooth aspen (*Populus grandidentata*), narrowleaf cottonwood (*P. angustifolia*), curly poplar (*P. canescens*), balsam poplar (*P. balsamifera*), eastern cottonwood (*P. deltoides*), and white poplar (*Populus alba*, a naturalized European species), and hybrids with black cottonwood (*P. trichocarpa*) occur rarely in Alaska. Quaking aspen, bigtooth aspen, European aspen (*P. tremula*), and three Asian species are closely related and sometimes classed together as a single, circumglobal superspecies (see Peterson and Peterson 1992).

Distribution
Quaking aspen is the most widely distributed tree species in North America. It grows from Alaska across the Northwest Territories to Quebec and Newfoundland, south to West Virginia and Virginia, and in all of the western North America US states (except Oklahoma and Kansas) -- in all Canadian provinces and all but 13 US states (absent from the Southeast). It occurs in both the eastern and western sierras of Mexico, into the south-central part of the country. Outside of the main range, it is represented by a huge number of disjunct populations. For current distribution, please consult the Plant Profile page for this species on the PLANTS Web site.

Adaptation
Quaking aspen occurs in a wide variety of habitats (including soil type and moisture conditions) and at a great range of elevation, matching its extensive geographic range. It characteristically forms pure stands or mixed stands with bigtooth aspen, but it occurs with scrub oaks and sagebrush at lower elevations and as a prostrate form above timberline and exists as a dominant species in many communities at mid elevations. It is a shade-intolerant, disturbed site species and is quickly replaced in succession by more tolerant species.

Some trees are self-pruning, dropping numerous small twigs with excess fall foliage and returning nutrients to the soil. Leaves decay relatively rapidly, and a characteristic "aspen soil," with a higher pH than on conifer-dominated soils, develops on sites that have supported aspen for a number of generations.

Flowering occurs March–April (East) or May–June (West), before the leaves appear and fruiting in May–June (–July), often before the leaves are fully expanded. Temperatures above 12° C for about 6 days apparently trigger flowering. Female trees generally flower and leaf out before male trees.

Establishment
Quaking aspen commonly establishes from seed in Alaska, northern Canada, and eastern North America. Seedling establishment is less common in the West but occurs there in moist sites such as kettles and other topographic depressions, seeps, springs, lake margins, and burnt-out riparian zones. Drought stress kills seedlings, as does standing water.

Young trees first flower at 2-3 years but production of large seed crops begins at about 10-20 years; maximum seed production occurs at 50-70 years. Heavy seed crops are produced at 4-5-year intervals. Seeds are wind-dispersed for distances of 500 meters to several kilometers.

Germination generally begins nearly immediately after moisture is received and can occur across a broad temperature range, with optimal germination at 15-25° C. Surface placement or a very shallow depth of burial on exposed mineral soil (such as burned or scarified sites) apparently provide the best environment for germination. Continuous moisture is required.

Asexual reproduction and clones
Reproduction of quaking aspen is primarily by root sprouts, and extensive clones of root-interconnected

trees are characteristic of the species. Most root sprouts develop within 10 meters of the parent stem, although some are produced at 30 meters or more. They develop from roots within 2-10 centimeters of the surface. Growth in primordia and buds is suppressed by apical dominance but resumes after stems are top-killed by fire, harvest or wind-breakage, or after defoliation and many thousands of sprouts per acre may be produced. Removal of the above-ground plant portion in June or July after maximum auxin production (the chemical agent of apical dominance) results in fewer suckers than top-removal during the dormant season. Sprouts produced in a closed stand usually die unless in a canopy gap. Saplings may begin producing root sprouts at 1 year of age.

Stands of quaking aspen may consist of a single clone or represent a mosaic of different clones. Even in a small area, wide variation in genetic traits exists between clones – differences may be seen in leaf shape and size, bark colour and texture, branching habit, resistance to disease and insect attack, sexual expression, growth rate, and phenology. The most conspicuous differences may be in the timing of spring leaf flush and in autumn leaf coloration.

The staminate-pistillate ratio of clones is 1:1 in most localities, but in the eastern US staminate trees may outnumber pistillate ones by 3:1. Some clones alternate between staminate and pistillate forms in different years or produce combinations of perfect, staminate, and pistillate flowers.

Individual trees of quaking aspen are short-lived (maximum age in the Great Lakes states is 50–60 years, up to 150 years in the West). Stands may be even-aged (after a single top-kill event) or only broadly even-aged (from sprouting of a gradually deteriorating stand). The clones are much older: many in the Rocky Mountain and Great Basin regions are at least 8000 years old, persisting since the last glacial retreat. A male clone in the Wasatch Mountains of Utah occupies 17.2 acres (43 ha) and has more than 47,000 stems – this clone is estimated to be 1 million years old and may be the world's most massive known organism. Clones east of the Rocky Mountains usually cover no more than a few acres.

Management
The thin, soft bark of quaking aspen makes it susceptible to many diseases and insect infestations as well as mechanical and fire damage. Fires may kill trees or cause basal scars that serve as entry points for wood-rotting fungi, which are common in older stands. The wood decays easily. Fires may also kill surface roots that could reduce sucker regeneration.

The poplar borer beetle, one of the most common wood borers of aspen, weakens trees by boring galleries in the trunk near the lower portion of the crown. Outbreaks of forest tent caterpillar may last 4-5 years and result in serious defoliation -- cold weather in the spring shortly after the eggs hatch and above-average fall temperatures can cause a rapid decline in caterpillar populations by killing eggs and larvae. Overgrazing by livestock or big-game animals disturbs roots and compacts soil, limiting sucker formation. Heavy grazing of young sucker stands by cattle for three years in a row may destroy them.

Quaking aspen can be propagated by seed, following cold stratification. Germination of fresh seed may be 80-95%, but viability lasts only 2-4 weeks under favorable natural conditions (low temperature and humidity). Seeds dried for 3 days and stored at cool temperatures may retain good viability for up to a year.

The species roots poorly from woody stem cuttings, but newly initiated (softwood) shoots can usually be induced to root by dipping in IBA (indolebutyric acid) or other commercially available rooting powders. A more preferred method uses root sprouts. Collect dormant lateral roots in early spring -- plant root cuttings 1-2 in diameter and 3-5 centimeters long in vermiculite and place in the greenhouse for 6 weeks. Excise the young sucker shoots and root in perlite/vermiculite (2-3 weeks, using IBA), misting frequently. Transplant the developing plants to peat/vermiculite mix and grow at 15-25^{o} C. Or, the root cuttings may be planted directly into the perlite mix, with the top of the cutting just below the media surface.

Cultivars, Improved and Selected Materials (and area of origin)
Contact your local Natural Resources Conservation Service (formerly Soil Conservation Service) office for more information. Look in the phone book under "United States Government." The Natural Resources Conservation Service will be listed under the subheading "Department of Agriculture."

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For more information about this and other plants, please contact your local NRCS field office or Conservation District, and visit the PLANTS Web site<http://plants.usda.gov> or the Plant Materials Program Web site <http://Plant-Materials.nrcs.usda.gov>

APPENDIX D. REQUEST FOR AEROCAM IMAGERY FOR THE UNIVERSITY OF WYOMING FLETCHER PARK RESEARCH SITE, 2006.

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JUSTIFICATION

The University of Wyoming established the Fletcher Park Research Site[2] in Albany County, near Laramie Peak, in 2005. Colonel William C. Rogers bequeathed the land to the university in 2002 with the stipulation that it be utilized for research purposes within five years of the gift. The site is managed by the Wyoming Agricultural Experiment Station (WAES) and is composed of about 320 acres (~129 hectares) of ponderosa pine forest and woodland.

Research at Fletcher Park will probably focus on ecosystem processes and forest and rangeland ecology and management. Currently, Rik Smith of the Department of Plant Sciences is measuring nitrogen fixation by a rosaceous shrub, *Purshia tridentata* (antelope bitterbrush), on the site.[3] AEROCam imagery will be very beneficial in mapping bitterbrush cover in the plant communities at Fletcher Park as well as in future ecosystem studies that may include ecosystem recovery from fire,[4] spread of disease and insect infestations, effect of timber management and grazing on plant community health, and restoration of ecosystem structure and function.

OTHER DETAILS

SPATIAL RESOLUTION

Standard spatial resolution of 1–2 meters (3.3–6.6 feet) is requested.

WAVELENGTHS

Standard CIR (color-infrared) acquisition is requested.

DATA ANALYSIS

Data will be analyzed using ERDAS IMAGINE® and ArcGIS. The Wyoming Geographic Information Science Center (WyGISC), an independent center at UW that is generously housed by the UW College of Agriculture,[5] will provide facilities, support, and training to personnel using the data. Imagery from Fletcher Park will be made available to students enrolled in "Remote Sensing 4112/5112," UW Department of Botany, for their class projects.

1 Rik Smith is now an associate professor at Columbia Basin College in Pasco, Washington.

2 Fletcher Park Research Site was later officially named the Rogers Research Site (RRS) in memory of Colonel Rogers.

3 A lightning-caused wildfire (Arapaho Fire) swept through nearly 100,000 acres of the Laramie Mountains in 2012, including RRS lands. It burned much of the vegetation at RRS and surrounding areas, including ponderosa pine. This changed much of the focus at the site to post-fire research, teaching, and extension.

4 One of the initial proposals was to study ecosystem recovery from prescribed fire. That plan changed because of the 2012 Arapaho Fire.

5 In 2009, the University of Wyoming Board of Trustees approved renaming the college the College of Agriculture and Natural Resources.

APPLICATIONS

AEROCam data will be used in several ways. Initial application will be for collecting baseline resource inventory data: for example, the extent of ponderosa pine cover, meadow and riparian habitat, and shrub density. This baseline data will be very useful before management changes are implemented to assess timber stand health and density. Probable management in the future will include the use of prescribed fire, stand thinning, rangeland improvement, weed control, and even timber harvest to correct approximately 20 years of patchy, resource extractive management.

AREA TO BE COVERED

The area to be covered is about 320 acres (~129 hectares) lying fully within Township 26 North, Range 71 West, Section 10 (Sixth Principal Meridian), in northeastern Albany County, Wyoming.

OTHER USES FOR DATA

Once the imagery is processed it will be accessible through the WyGISC website.[6] Users of the data may include the following University of Wyoming departments and offices: WAES, Department of Plant Sciences, Department of Renewable Resources,[7] WyGISC, Department of Botany, Department of Zoology and Physiology, Department of Animal Science, Facilities Planning, Real Estate Operations, and Cooperative Extension Service.[8] As the site is surrounded on three sides by U.S. Forest Service lands, cooperative planning and management efforts may also include the Medicine Bow-Routt National Forests.

SIDELAP

The planned 35% sidelap is acceptable.

DESIRED DATES IN ORDER OF PRIORITY

June 1, 2006, ± one week
August 15, 2006, ± one week

NUMBER OF FLIGHTS

Two flights are requested to monitor seasonal changes in vegetation.

GEO-REFERENCING

We do not require geo-referenced images. WyGISC will provide this service.

FEEDBACK

We will be happy to provide feedback to the Upper Midwest Aerospace Consortium (UMAC)[9] including data, shapefiles, and PowerPoint slides. We plan to attend the UMAC conference to present results. The remote sensing student awarded the WyGISC/WAES scholarship will be encouraged to attend and present results.[10]

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6 Results from this project are presented in a paper that went through a formal review process in 2016, and that paper is the focus of this bulletin. The bulletin is posted on the University of Wyoming Extension publications website at http://www.wyoextension.org/publications/ (type Rogers Research Site in the search bar).

7 In 2011, the UW trustees approved renaming the department the Department of Ecosystem Science and Management.

8 In 2011, the trustees voted to change the University of Cooperative Extension Service to University of Wyoming Extension.

9 The former AEROCam was part of a NASA-funded project called the Upper Midwest Aerospace Consortium (UMAC), which is headed by the University of North Dakota.

10 Mathew Seymour was awarded the scholarship (Appendix E). He was not able to attend the UMAC conference, but he presented his research to a UW Geographic Information Systems class. Further, he wrote a paper on the research, and that paper is presented in this bulletin.

APPENDIX E. UNIVERSITY OF WYOMING STUDENT AWARDED SCHOLARSHIP TO CREATE VEGETATION MAP OF THE ROGERS RESEARCH SITE.

INTRODUCTION

WyomingView[11] focuses on remote sensing data and technologies in support of applied research, K-16 education, workforce development, and technology transfer.

WyomingView—or WyView—is part of AmericaView, a program partially funded by the U.S. Geological Survey (USGS).

WyView is headed by the Wyoming Geographic Information Science Center (WyGISC) at the University of Wyoming, Laramie, Wyoming.

INTERNSHIPS

WyView internships are aimed at promoting educational opportunities in remote sensing and workforce development. These semester-long internships provide opportunities for UW undergraduate and graduate students to address natural resource management issues using remote sensing science and technology. These scholarships are part of a grant provided by AmericaView and USGS to WyView.

SCHOLARSHIP AWARDED FOR VEGETATION STUDY AT RRS

During the 2006–2007 academic year, the WyView program offered four scholarships in support of undergraduate and graduate students using remotely sensed data in their research. These scholarships were made possible by generous support from USGS and AmericaView Inc., which collectively fund WyView.

Figure 1. While working on two B.S. degrees at the University of Wyoming, Mathew Seymour earned a scholarship during the 2006–2007 academic year to map vegetation at the Rogers Research Site. He is now a postdoctoral researcher at Bangor University in the United Kingdom. (Photo by Ken Driese)

One of the four scholarships was awarded to Mathew Seymour (Fig. 1) to map vegetation at the University of Wyoming's Rogers Research Site (RRS) in the Laramie Mountains, northeast Albany County, using high spatial resolution photography and heads-up digitizing. Seymour was an undergraduate student at UW double-majoring in wildlife management and environment and natural resources.[12]

STUDENT TESTIMONIAL

"The USGS and Wyoming Agricultural Experiment Station provided me an opportunity to work closely with an outstanding group of professionals. With AEROCam photographs, and professional help, I created a vegetation map of the Rogers research area in northeastern Albany County using heads-up digitizing[13]. This experience has taught me valuable lessons in remote sensing and professionalism that will further my academic and professional career. I would like to thank WyomingView and my project mentors for their dedication and patience throughout this project."

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11 More about WyView—including news, internship information, publications, and contact information—is at http://wyomingview.blogspot.com/p/interns.html.

12 Mathew Seymour earned two bachelor's degrees from UW in 2007 and went on to complete his master's and doctorate studies at Hólar University College in Iceland (2011) and ETH Zurich in Switzerland (2014), respectively. He is now a postdoctoral researcher at Bangor University, Bangor, Gwynedd, United Kingdom.

13 The results of Seymour's project are presented in this bulletin.

When lead author Mat Seymour conducted his vegetation mapping project at Rogers Research Site in 2006, the 320-acre parcel and surrounding lands in the Laramie Mountains were covered with various age classes of ponderosa pine, along with mixed grass/shrub lands and quaking aspen. In 2012, the lightning-caused Arapaho Fire burned nearly 100,000 acres in the Laramie Peak area, including RRS lands, dramatically altering the land cover. The vegetation map presented in this bulletin is, therefore, of great importance for ongoing and future research associated with RRS and the Laramie Mountains as a whole. This photo, taken in 2015, shows grasses and forbs that reestablished within three years of the fire. Also present is the noxious weed, Canada thistle. (Photo by Steve Williams)

University of Wyoming
Agricultural Experiment Station

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