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Introduction

Chairman McClintock and Ranking Member Tsongas, my name is Dr. Shane Burgess and it is an honor to be providing this testimony. Of relevance to this hearing, I am a product of America's greatest single innovation—the democratization of education first exemplified by the Land-Grant University system created in 1862. I am testifying about the Land-Grant Universities' impact on the use and stewardship of our nation's natural resources.

I am the Vice President of Agriculture, Life and Veterinary Sciences, and Cooperative Extension, Dean of the College of Agriculture and Life Sciences, Interim Dean of the School of Veterinary Medicine, Director of the Arizona Experiment Station, Professor of Animal and Comparative Biomedical Sciences and Professor of Immunobiology, at the University of Arizona, an 1862 Land-Grant University.

I came to The University of Arizona five years ago after 10 years' service at Mississippi State University, another 1862 Land-Grant University. I graduated in 1989 as a doctor of veterinary medicine from Massey University in New Zealand, one of many universities worldwide using the U.S. Land-Grant University model.

The Land-Grant Universities: History

The land-grant universities were established in 1862 under the Morrill Act through a mechanism of federal land grants to each state not then in rebellion. The purpose of the Act was:

> *[the] support, and maintenance of at least one college where the leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to agriculture and the mechanic arts, in such manner as the legislatures of the States may*

respectively prescribe, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life.

This innovation was transformational. Today we see public universities as normal. In 1862, they were truly a unique experiment enabling the United States to become the first nation to take advantage of its single most valuable asset: its people's intelligence and motivation.

Until then, nations had invested only in education of the few—in aristocrats and the clergy. This model provided only linear returns to a nation's culture, economy and political system. Via the Morrill Act, the United States invested a tiny fraction of its natural resources to get a disproportionate and massive return. The establishment of the land-grant universities directly correlated with unprecedented exponential growth in U.S. gross domestic product to the point where the United States became a global superpower within 60 years.

Two other acts were critical to the land-grant universities' impact. The Hatch Act of 1887 connected a research mandate and infrastructure to these universities. The Smith-Lever Act of 1914 explicitly "extended" by mandate that the research findings be moved rapidly into the economy, driving innovation in commerce and other everyday activities. Today, the Hatch Act is carried out in the land-grant university Experiment Stations and the Smith-Lever Act by the Cooperative Extension System.

This American innovation, democratizing education and facilitating economic growth through research and extending discovery into the economy, has been emulated worldwide.

Today's land-grant universities adhere to the original intent of the Morrill Act of 1862; they have the broadest mission of any set of institutions in American higher education. They are as critical to America's future now as they were in 1862. In Arizona, The University of Arizona, a top 20 public university and member of the elite Association of American Universities, is the 1862 land-grant university. Based in Tucson but with sites in all 15 Arizona counties, The University of Arizona provides a vast array of programs, including: two separately accredited medical schools; a law school; and colleges of humanities, fine arts, social sciences and architecture, to name just a few. Of course, we still have a college of engineering, we are home to the Reserve Officers' Training Corps, and we are leading in the commitment to education for veterans.

I lead the founding college, the College of Agriculture and Life Sciences. Today we provide education, research and Extension, not only to the agricultural sector but to sectors as diverse as engineering, education and the $2.6-trillion retail sector. Today, women comprise 71% of our undergraduate students. Minorities comprise 45%, and 37% of our undergraduates are first-generation college students. We are as committed to implementing the Morrill Act's intentions today as were the Arizonans who established us as Arizona's first university in 1885. We are still breaking the cycle of generational poverty for American families.

We are stepping up today to meet another challenge as we add our new School of Veterinary Medicine and an expanded educational commitment to Arizona's bio-economy sectors.

For 153 years, land-grant universities have provided research, Extension and teaching that have empowered the U.S. economy to make the most of its natural resources. We and our peer universities are one of the primary reasons why Americans live in the world's most affluent society, with the most affordable and safest food supply the world has ever seen. And we need our land-grant universities today more so than ever to address the needs and challenges of our growing world populations—and maintain worldwide stability.

America's land-grant universities are the world's leading innovators in natural resources use, including agriculture. The real rate of return on agricultural research and development (adjusted for inflation) is between 8% and 11%, depending on the state; in Arizona, it averages an annual rate of 10.4%[1,2]. This compares very favorably with the return on the S&P 500 Index of 9.8% since 1928, three-month Treasury Bill of 3.56% since 1934, and the 10-year Treasury Bond of 6.4%[3].

The world is hungry for the products of U.S. primary economic sectors, and agricultural products are particularly resilient to global shocks. During the 2007-2009 Great Recession, agriculture was the only sector to maintain a continual positive trade balance. With 21st-century globalization and technological revolution, U.S. agricultural productivity will continue to be a source of revenue that will serve as a critical underpinning of our economy.

The ability of the United States to be a central part of global trade is vital for American agriculture. Our land-grant universities are a critical component of a system that ensures both these successes.

Land-Grant Universities and the Responsible Stewardship of Natural Resources

Today I will discuss nine examples of research programs from our university that are relevant to this subcommittee. The following examples focus only on a limited subset of what we do on our forested lands and in our water programs. I will touch specifically on wildfire management and the greater use and stewardship of natural resources for the public good.

Led by Dr. Tom DeGomez and Agent Stephen Campbell, our ***Wildfire and Forest Thinning*** program has protected and mitigated forested areas in northern and eastern Arizona from the damage and the monetary and human cost of wildfires, and, in doing so, maintaining the watersheds so critical to urban water supplies. They are also boosting biodiversity. The program's Natural Resource Working Group - a collaboration of local and state governments, state and federal land management agencies, forest product and livestock industries, environmentalists, recreation industries and

universities, including our employees - was launched more than 20 years ago to address the devastation of forest fires.

By identifying and implementing science-based solutions, our program has reduced the number and intensity of wildfires, saving lives, property and watersheds, and returning forests to healthy, diverse and economically productive ecosystems. With the assistance of then-State Sen. Jake Flake and then-Navajo County Supervisor Lewis Tenney, the U.S. Forest Service provided the working group with access to 12,000-forested acres in 1998 to try new forest restoration concepts. The effort eventually evolved into the White Mountain Stewardship Project and realized success: 70,000 acres of previously dense degraded forest were on the road to healthy diversity and thinned effectively to help mitigate low-intensity, ground and crown wildfires.

Since the program's inception, several large wildfires have affected the White Mountains, and the managed areas did much better than the unmanaged. When the San Juan Fire reached this treated area in June 2014, it changed abruptly from a high-intensity, super-destructive crown fire to a low-intensity, less destructive ground fire.

In 2013, Navajo and Apache counties took over the working group, ensuring the work would continue and be managed by the local community. This program, and programs like it, serve as a national model and should be expanded for use in other fire-vulnerable states.

Our ***Rangeland Monitoring*** program, led by Dr. Doug Tolleson, and in collaboration with the Bureau of Land Management (BLM), promotes rangeland health while also enhancing the productivity, profitability, and sustainability of ranching enterprises. It applies best available science to enhance our economy and environment. After the Wallow Fire, which burned 538,000 acres in eastern Arizona in June 2011, all livestock were removed from public grazing allotments. Our faculty participated in monitoring rangeland recovery from the fire, providing critical information for supporting the Forest Service's decision to allow grazing to resume on allotments much earlier than planned. Estimated benefits to ranchers range from $12,241 to $52,835 per allotment. Estimates of total benefits to Arizona's economy range from $477,410 to $2,060,577.

Our ***FireScape*** program, led by Dr. Donald A. Falk, is a transformational landscape-scale approach to fire and forest health in Arizona's "sky islands"—forested mountain ranges separated by vast expanses of desert and grassland plains. The relationship between fire and ecosystems has been altered or disrupted by human activities since the late 1800s. Resulting build-up of fuels has led to much more severe wildfire behavior in many ecosystems. Most fires continue to be suppressed, making the fuel problem, and eventual fires, much worse. Though land managers do small-scale forest thinning treatments and prescribed burns—a few tens of acres here, a couple hundred acres there—the problem is making an impact on the landscape scale. That's what really matters for wildfire.

FireScape's underlying premise is that fires are a natural part of sky islands: they are going to occur whether we like it or not, no matter how much money and effort is spent on trying to eliminate them. Fire is an essential behavior of sky island ecosystems. Preventing one wildfire means simply building up the fuel so the next fire is bigger and much more destructive. FireScape connects our scientists with the Forest Service, The Nature Conservancy, BLM, National Park Service employees, as well as private sector southeastern Arizona land managers, to manage each sky island landscape as a unique biophysical setting with its own management challenges. Consequently, the FireScape plan for each mountain range is appropriate for its particular needs. Importantly, this research connects back to our undergraduate and graduate education.

Our ***Santa Rita Experimental Range*** *(SRER)*, founded in 1903, was originally contained within the Santa Rita Forest Reserve, as established by Presidential Executive Order of April 11, 1902, by President Theodore Roosevelt. Santa Rita, today led by Dr. Mitchell McClaran, is the oldest research area maintained by the Forest Service and has been a principal site for pioneering research on the improvement and management of semiarid grasslands in the Southwest. This "landscape laboratory" provides a unique source for long-term ecological research and its results have been applied over the 20 million acres of semiarid rangelands in the United States and to another 20 million acres in northern Mexico. It is also a public-private partnership with a local rancher—creating local income and jobs as well as state tax revenue.

Santa Rita is world-class because of the long-term historical and biological databases maintained since its creation. This was only possible because of the vision behind the Morrill Act. The experimental range has undergone major vegetation changes due to natural plant processes and management practices. Santa Rita is an essential member site of the *National Ecological Observatory Network (NEON)* strategically located across the United States.

NEON has 20 ecoclimatic domains of distinct landforms, vegetation, climate and ecosystem dynamics. NEON collects data that characterize terrestrial plants, animals, soil and the atmosphere at 20 core terrestrial sites (http://www.neonscience.org/science-design/field-sites/field-site-types). Core NEON sites are designed to remain for 30 years. The network statistically captures terrestrial wildland conditions across the continent, such as stream flow data per minute, and coordinates local measurements in the field with high-resolution airborne remote sensing.

Everything I have described so far has required analysis of complex datasets. A major bottleneck in research is the general inability of today's scientists, and traditional computing technology, to meet the massive analytic challenges and support the cross-discipline collaboration needed to solve our world's most pressing contemporary biological and ecosystem challenges. In 2008, we were awarded a unique $100-million, 10-year project (the biggest single project ever funded by the National Science Foundation) called ***CyVerse***. Directed by Dr. Parker Antin, CyVerse takes advantage of

our nation's massive open access public high-performance computing capacity and trains people in the for- and not-for-profit sectors in the use of cloud computing.

The CyVerse vison is "Transforming science through data-driven discovery"; its mission—"to design, deploy, and expand a national cyberinfrastructure for life sciences research and train scientists in its use." Cyberinfrastructure is the hardware, software and people needed for science, complementary to physical infrastructures like laboratories, DNA sequencing centers, greenhouses and land laboratories that make it possible to collect data. Cyberinfrastructure makes it possible to store, share, analyze and identify solutions from massive datasets. CyVerse includes data storage; an interactive, web-based, analytical platform; a cloud infrastructure to use remote servers for computation, analysis, and storage; Web authentication and security services; support for scaling computational algorithms to run on high-performance computers; education and training in how to use cyberinfrastructure; and expert people. But most importantly, CyVerse was designed from the outset for "drag and drop" use so that, if you can use a personal computer, then you can use a super-computer—this has never been done anywhere before. This program, too, fulfills Morrill, Hatch and Smith-Lever Act mandates. Like our land-grant universities, CyVerse is a democratizing force.

Of relevance to this committee, CyVerse cyberinfrastructure is germane to all life sciences disciplines. It works equally well with data from plants, animals, and microbes at individual and ecosystem scales. Our CyVerse scientists understand how the world's organisms contribute to food and fuels, and how ecosystems are the emergent properties resulting from extremely complex physical and biological interactions. With a team of collaborators from around the world, for the first time, CyVerse enables researchers to answer questions that previously were unapproachable because the computational requirements were too large, too complex, or simply unknown to domain-expert researchers.

The science and engineering programs I have described above are only a sampling of the innovative and industry-changing research taking place at the nation's land-grant universities. **Yet it is our laws and policies that are the most critical elements to optimal and rational natural resource management and use**—regardless of whether they are being created in Washington, D.C., or at the state and local levels. Because sound public policies and good laws are essential to natural resource management, I have launched four initiatives directly focused on law and policy with state and nationwide impact.

The first pertains to our ***V Bar V (V-V) Ranch*** program located on 70,000 acres in the Coconino National Forest. This forest is part of the watershed that supplies two-thirds of the water needed by metro Phoenix's 5 million residents, taking pressure off of the Colorado River. The Coconino National Forest is also part of the 4 Forest Restoration Initiative, a 2.4-million-acre project accelerating restoration to restore watershed health and function, improve wildlife habitat, conserve biodiversity, protect old-growth, reduce the risk of super-fires and restore natural forest resilience. Business and industry are to have key roles.

Though the V-V is part of our Experiment Station, we have undercapitalized on it. In part, this was because we and our Forest Service landlords have not collaborated as well as we should have with our complementary missions. In the summer of 2015, I began what has been a very constructive negotiation with the Forest Service to build a collaborative agreement to utilize the V-V more quickly and in a more meaningful manner to come up with better practices that can be applied on working ranchlands statewide. This is proving to be a very complex process but we now have a memorandum of understanding (MOU) to guide our collaborative efforts in developing a permitting instrument to provide "rapid approval" of research, teaching, outreach and Extension activities on Walker Basin Allotment. Our goal is to complete a final draft MOU entitled "Developing a Collaborative Research Agreement for Walker Basin Allotment" by May 2016 that will then be reviewed by our respective contracting and legal counsels. Our intent is that the MOU facilitate work at V-V that will have the same longstanding, far-reaching contribution to range science and the health of grazing lands as has research at Santa Rita.

The second initiative is the ***Case Study in Efficiency-Agriculture and Water Use in Yuma County, Arizona***, led by University of Arizona Cooperative Extension economist Dr. George Frisvold, collaborating with a broad swath of industry experts in Yuma. Yuma County produces 95% of the nation's winter vegetable crop, is 4th nationally in the production of high value export durum wheat, and has the highest alfalfa yield nationally. Arizona is 2nd nationally – after only California, which has six times the agricultural land and four times as many farms – in vegetable and citrus production. This case study detailed for the first time how Yuma agriculture uses water today more effectively and efficiently than any time in the past. Response to the study has been overwhelmingly positive and it was a key element in the BLM Colorado River Basin Study. It has been a seminal resource for Yuma-area agriculture, government and elected officials, and conservation groups involved in agriculture production or seeking an understanding of the relationship between efficient, highly productive agriculture and water use.

The third project is Dr. Mark Apel's ***Solar Development Modeling*****.** Between 2011 and 2013, Dr. Apel completed a Renewable Energy Opportunity Analysis (REOA) for all Arizona counties. Solar and other renewable electricity generation has always been central to economic growth in the West and will be of growing importance, especially now that coal is economically unsustainable for power generation. Very little land in the West is privately owned, which means solar energy facilities will likely need to be placed on public lands in cooperation with private ventures, using our current models of public land use for ranching, recreation and tourism.

For the first time, elected and appointed public decision-makers and the private sector have maps and geographic information system shapefiles identifying the areas in their jurisdiction best suited for utility-scale solar power generation facilities. These maps have been accessible online since November 2014 (http://cals.arizona.edu/reoa/). The project has had two specific impacts so far:

1. In April 2014, the REOA was used by planners in Arizona's Cochise County in their analysis, support and approval of the Houston-based Torch Renewable Energy's Red Horse II wind and solar project, which is needed to keep Tucson Electric Power (TEP) on track to supply 15 percent of its energy from renewable sources by 2025. This target is required by Arizona's Renewable Energy Standard. Located in southeastern Arizona, Red Horse II has 250,000 solar panels over one square mile of land. It hired 150 laborers, installers, electricians and heavy equipment operators who completed the project in August 2015. Red Horse II is TEP's largest renewable energy resource.

2. Pima County, Arizona, has used REOA results to create a Solar Incentive District, which identifies specific properties considered nearly "shovel ready" for photovoltaic development and provide streamlined development processes.

The fourth initiative targets law and policy directly. After many conversations with two key Arizona thought leaders, I initiated a partnership between our Cooperative Extension system and the University of Arizona's James E. Rogers College of Law and we launched the ***Natural Resource Users Law and Policy Center*** in the winter of 2015. Led jointly by our Cooperative Extension System Director Dr. Jeff Silvertooth and Dean of the Rogers College of Law, Marc Miller, Esq., this is the first such entity of its kind in the world dedicated to economically, environmentally and socially sustainable natural resource use. Not only does it focus on our farmers and ranchers, but also our miners, as natural resource users. We will educate lay and legal students, fill a gap in legal services, and serve as a judicial and legislative resource for decision makers.

Conclusion

The research projects described above are only a glimpse into how this nation's land-grant universities contribute to the prudent use and stewardship of natural resources on federal lands. A more thorough review of the activities undertaken by all of the land-grant institutions would reveal that these most innovative of universities are fulfilling their missions as originally envisioned in 1862.

In Arizona, and the rest of the west, our land grant university's future contributions to federal lands face two existential challenges. The first is the disconnect between the rapid-turn around cycles of funding agencies and the time it takes to get approval to do landscape scale studies on federal lands. This is partially a management issue between the universities and the federal agencies and that is my motivation for initiating the novel cooperation agreement with the US Forest Service at our V-V station. The second is limitations at federal funding agencies—not only in amounts of funding *per se* but in authorized agency priorities to fund the kind of work needed for our federal lands to better serve the nation.

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