WRITTEN TESTIMONY OF
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Introduction: Good morning Chairman Baird, Ranking Member Inglis, and members of the Subcommittee. I am honored to speak with you today regarding the strategic value of the Department of Energy's (DOE) National Environmental Research Parks (NERP). I am Nate McDowell, a staff scientist at Los Alamos National Laboratory (LANL) and director of the Los Alamos Environmental Research Park. To date, LANL has produced 130 peer-reviewed scientific publications based on research conducted at the Los Alamos Environmental Research Park, including many that were high impact largely because they included long-term data sets that captured extreme climatic events.

I obtained my Ph.D. in Tree Physiology from Oregon State University's College of Forestry in 2002, my M.Sc. in Ecosystem Processes from the University of Idaho's College of Natural Resources in 1998, and my B.Sc. in Biology from the University of Michigan in 1994. During these formative years, I learned to think critically about the fundamental regulation of ecosystem function in response to management methods and climate. In the five years that I have been a staff scientist at LANL, my research focus has grown to consider ecosystems from the perspective of national security, in which sustained ecosystem productivity is a critical resource.

A key piece of my research deals with the theory, instrumentation and models needed to monitor and understand how CO_2 moves in and out of an ecosystem. I created and am also the Director of the Los Alamos Tunable Diode Laser Facility located within our Environmental Research Park. This unique Facility is devoted to monitoring and understanding the exchange of carbon dioxide between terrestrial ecosystems and the atmosphere in response to climate variability. The laser measures the isotopic composition of CO_2 exchanged by the plants (Bickford et al. 2009), animals (Engle et al. 2009) and ecosystems we study (McDowell et al. 2008a), allowing us to trace the source and cause of shifts in carbon storage. For example, if an ecosystem undergoes a large emission of CO_2, we can determine why this has occurred. Likewise, we employ our laser facility to determine if specific CO_2 emissions come from biological or from fossil fuel sources; this application may help address a huge technological challenge that lies ahead for any global cap and trade verification system. My team has built strong collaborations with others studying climate impacts, including over 20 academic institutions, other National

Laboratories, the Environmental Protection Agency, the Forest Service and the Agricultural Research Service. Our rate and quality of publications is currently undergoing a dramatic rise due to support from DOE's Office of Science-Office of Biological and Environmental Research and to the growing societal urgency associated with understanding and predicting climate impacts on terrestrial ecosystems.

My testimony will focus on the pressing need to quantify, understand, predict, and manage the response of terrestrial ecosystems to climate, and on the value of the National Environmental Research Parks as an essential American resource for understanding these impacts.

What are the National Environmental Research Parks? The National Environmental Research Parks were formally created in the 1970's following passage of the National Environmental Policy Act (1969). As specified by the Department of Energy in 1976, the charter of the Environmental Research Parks is to assess, monitor and predict the environmental impact of energy use and other human activities. Scientists within the Research Parks are expected to develop methods for observation, experimentation, and prediction of environmental impacts, to inform the public of their results, and to train future environmental scientists. Lastly, the Parks are intended to improve access to non-federal researchers while capitalizing on the protected nature of the DOE land holdings. Current and past research at the Parks includes not only measuring terrestrial ecosystem processes such as carbon and water cycling, but also determining ecosystem management options, and monitoring of endangered species, animal dynamics, virus threats, pollution and hydrology (Dale and Parr 1998).

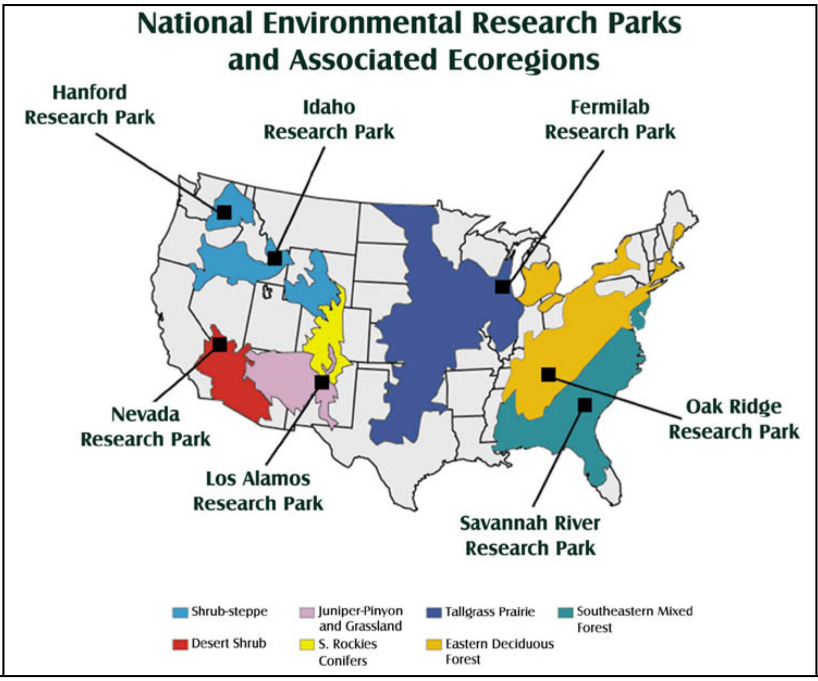

Fig. 1. Distribution of the National Environmental Research Parks

Nearly all of the Parks have formal educational components. At Los Alamos, there are numerous K-12, undergraduate and graduate programs that capitalize on the Research Park for exposing students to environmental science, such as geology, carbon cycling, and climate. There are specific programs directed towards undergraduates, high school students, minorities and Native Americans. Los Alamos staff scientists frequently donate their time to these programs. Additionally, numerous student interns conduct research within the Park under staff supervision each year.

The Research Parks are located in six major vegetative zones, representative of over half of the American landscape (Figure 1). The Research Parks contain large swaths of land--they are five times larger than the National Science Foundation's Long-Term Ecological Research sites (NSF-LTER)--making replication and large scale experiments possible to ensure that the results are meaningful to larger areas. Their large size and broad coverage of both vegetation and climate types allow experimental results to be extrapolated, with care, to much larger areas of the Earth, as might be necessary for monitoring of greenhouse gases and carbon offsets associated with verification of carbon trading and international treaties. Their value as test beds for sensing and prediction of greenhouse gas emissions and terrestrial impacts cannot be over-stated: their lands are protected, they have long-term data sets that capture climate impacts, and they are flexible to experimental manipulations similar to those conducted by DOE's Program for Ecosystem Research and Terrestrial Carbon Process Program (e.g. altering climate change factors such as precipitation, temperature, atmospheric CO_2 to determine the ecosystem impacts, or conducting mitigation experiments such as sustainable forest thinning). It is rare that such protected, yet scientifically important land areas, are available for testing monitoring tools for use in denied or hostile territories, or for testing new theories for climate modeling.

The National Environmental Research Parks have long-term records that are unprecedented in length. These include stream hydrology, soil carbon, and vegetation dynamics records at Oak Ridge; avian virus, isotopic CO_2 exchange, and vegetation water stress and mortality at Los Alamos; grassland rehabilitation studies at Fermi; and numerous other long-term data streams at the four other parks. Notably, the Parks have unique access to skilled scientists with state-of-the-art instrumentation and analysis tools, providing a technical advantage in gathering data and knowledge not available in most countries.

The current threat: The terrestrial impacts of our changing climate are occurring across the Earth in novel, dramatic, and often irreversible ways. These impacts include regional-scale vegetation mortality, changing carbon storage and water availability, and reduced lumber and food production. Human impacts are already widespread and are expected to become both more common and severe globally. Our understanding of these threats has increased dramatically in the last decade due in part to the leadership of DOE's Office of Science-Office of Biological and Environmental Research scientific programs.

Fig. 2. Piñon pine mortality in Los Alamos during a severe drought event, autumn 2002. *Courtesy* C. Allen, USGS

A drastic example of climate impacts on terrestrial ecosystems can be seen by looking no further than outside my office window at the semi-arid woodland that covers much of the Los Alamos Environmental Research Park. In 2002, piñon pine trees died throughout the southwestern United States following a 12 month drought that was considered unusually warm as is consistent with global warming (Breshears et al. 2005). At the Los Alamos Park, the mortality rate exceeded 97% (Figure 2). The rash of dead trees drew significant attention within the region, as many of my neighbors lamented the loss of their favorite trees from their yards, not to mention the economic impacts on commodity production and tourism.

From a scientific perspective, we were fortunate that scientists at the Los Alamos Environmental Research Park had sustained long term water stress and hydrology observations for over a decade proceeding the mortality event, allowing us the first-ever documentation of how trees die (Breshears et al. 2009). In short, trees were unable to photosynthesize for 12 continuous months because of severe water stress, forcing them to starve for carbon. Subsequently they had no resources left for defense against beetle attack. This is similar to starving humans who are often unable to fight off a simple cold virus. This research is critical because during the period of carbon starvation the forests are not absorbing carbon and thus are no longer functioning as a carbon sink. In addition, once trees die they begin releasing carbon back into the atmosphere through the decomposition process.

From the long-term data at Los Alamos we developed the first testable theory regarding the exact causes of tree mortality (McDowell et al. 2008b). We are now testing this theory via a large scale drought manipulation experiment supported by DOE's Program for Ecosystem Research and are examining the consequence of mortality on carbon storage and water yield via DOE's Experimental Program to Stimulate Experimental Research (EPSCoR) as part of the Ameriflux program. We are also testing the new theory for integration into the Community Climate System Model (a joint project funded by DOE and the National Science Foundation, www.ccsm.ucar.edu) for global climate prediction.

But the southwestern piñon pine mortality was only the proverbial canary in the coalmine: catastrophic mortality events are now being observed throughout western North America (Allen et al. *in review*). These regional die-off's are now altering some of America's most cherished places, such as the Colorado Rockies and Yellowstone National Park, where entire mountainsides of pine trees are turning brown. Perhaps even more disturbing is the subtle but insidious doubling of mortality from 1 to 2% in apparently healthy forests over the last three decades (van Mentegm et al. 2009). Though less graphic than the catastrophic die-off's, this doubling of mortality in apparently healthy forests may be a precursor of worse things to come. Notably, increased mortality has also been revealed in wetter areas that are expected to be more resilient, such as at the Oak Ridge Research Park in the Appalachian Mountains (Kardol et al. *in review*). Again, the increase in forest mortality rates reduces the amount of atmospheric carbon that can be absorbed and stored by forests over the long-term.

The challenge: The science challenges are clear: we must understand the changing climate and its impacts on terrestrial systems well enough that we can predict over the next decades what will happen to terrestrial resources such as crop yields, carbon storage, productivity, and water quality. Importantly, this understanding and prediction must be done at regional scales relevant to policy makers. Furthermore, the United States needs a regionally distributed early-warning network of climate impacts. For example, we can presently anticipate weather with near realtime predictions based on a network of weather measurements that feed data into predictive models. Modelers are also making great advances in predicting weather and climate in the upcoming weeks to seasons, which may allow society to plan for events such as heat waves and droughts. We have no such early warning system for climate impacts on ecosystems. The scientists and their associated technology, models, and research sites at both the National Environmental Research Parks and elsewhere, are already available and amenable to development of just this early-warning network for terrestrial impacts.

The Environmental Research Parks are an ideal, yet underutilized network of sites located throughout America that can be used as part of an early warning network, for testing remote techniques for detecting impacts and greenhouse gas emissions, and for conducting fundamental research in line with the original Research Park charter. Unfortunately, they have no formalized funding source, and thus they have only really been used when individual investigators have been able to obtain grants to support work on the Park lands. Thus, there are only rare datasets that have been maintained over sufficiently long time periods to capture extreme climate events and to differentiate short-term variability from long-term trends. Likewise, no integration across parks has occurred, preventing us from determining how ecosystems and their inhabitants respond to climate variation across regions.

Recommendations: It is essential that we have a network of sites for early detection of climate impacts on ecosystems and for testing tools that monitor greenhouse gas emissions and terrestrial impacts. If the National Environmental Research Parks were employed with this charge, they could become a leading entity in the new generation of science in which we not only learn more fundamental science, but also develop and apply tools for verifying international treaties, for predicting consequences on our own soil, and for developing mitigation options. Such a network should be used to build upon existing efforts such as NSF-LTER sites, the Ameriflux network, which monitors CO_2, water and energy exchanges, NOAA's Cooperative Air Sampling Network, USDA's Forest Inventory Analyses and Natural Resources Inventory, which monitor biomass and soil carbon throughout the United States, as well as with existing and future remote sensing tools supported by NASA and the Jet Propulsion Lab. Likewise, capitalizing on existing data management networks, for example, with the North American Carbon Program, is essential.

Support of the Research Parks should be a long-term priority. Decadal-length monitoring is essential for capturing extreme climate events as well as chronic warming. Like fine wines, the few long-term data sets that exist globally have all increased in value with each passing year as they reveal climate change impacts that were not detectable in only three years, the normal proposal funding cycle.

The long-term efforts must include experimental manipulations, such as those supported by DOE-Office of Science. Altering CO_2, rainfall, and temperature over entire ecosystems allows us to see ecosystem response to climate changes that will occur in the future. The manipulations are essential for predicting the response of ecosystems to changes we expect to occur in the next 20 to 50 years. Like long-term observations, these experiments must be decadal in length. For example, in my Office of Science funded study, we are altering rainfall to simulate climate change and determine why trees die and what happens to the ecosystem afterwards, and have found that trees are just starting to die after three years, which is the end of a typical funding cycle. Three years is not sufficient for most ecosystem scale observational or experimental studies of climate change impacts.

Ideally, this research must be integrated spatially and across disciplines. The challenge is complex and exists at multiple scales. Rising air temperature impacts plants at the cellular level, yet it manifests at the tree, landscape, and global scales that affect humans. Observations and experimentation must be integrated with models, such as the Community Climate System Model, if we are to advance our understanding and our forecast accuracy. Only then will our effort be relevant to the American public.

We are at a critical turning point. We know that climate is changing, and we know that terrestrial ecosystems are being impacted. We now have the theory, tools and models to make rapid advances in our ability to forecast impacts that are relevant to human populations. We simply need to integrate these tools and apply them within and beyond the Research Parks.

Thank you for this opportunity to appear before the Subcommittee.

Relevant websites

McDowell Lab at Los Alamos National Laboratory
http://climateresearch.lanl.gov/

DOE EPSCoR Program:
http://www.er.doe.gov/bes/EPSCoR/index.html

DOE Program for Ecosystem Research:
http://per.ornl.gov/

DOE Terrestrial Carbon Process Program:
http://www.er.doe.gov/OBER/CCRD/tcp.html

Community Climate System Model
http://www.ccsm.ucar.edu/

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