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CLIMATE CHANGE ON WILDFIRE ACTIVITY

HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

TO

CONSIDER SCIENTIFIC ASSESSMENTS OF THE IMPACTS OF GLOBAL CLIMATE CHANGE ON WILDFIRE ACTIVITY IN THE UNITED STATES

SEPTEMBER 24, 2007

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CLIMATE CHANGE ON WILDFIRE ACTIVITY

MONDAY, SEPTEMBER 24, 2007

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The committee met, pursuant to notice, at 3:04 p.m. in room SD–366, Dirksen Senate Office Building, Hon. Jeff Bingaman, chairman, presiding.

OPENING STATEMENT OF HON. JEFF BINGAMAN, U.S. SENATOR FROM NEW MEXICO

The CHAIRMAN. The hearing will come to order.

Thank you all for being here. The likelihood that global warming would result in increased wildfire activity and fire-suppression costs was discussed at a hearing in this committee more than 27 years ago. Since then, we've had numerous hearings to consider the science of climate change and also the science related to wildfires. But this is the first hearing, I'm aware of, to consider the impact of global warming specifically on wildfire activity.

A report, released earlier this month by the GAO, reported that a group of experts convened by it and by the National Academies of Sciences, quote, "generally agreed that the scientific community has reached consensus that climate change will cause forest fires to grow in size and severity," end quote. That consensus is reflected in the fourth assessment of the Intergovernmental Panel on Climate Change. It concludes that, quote, "An intensification and expansion of wildfires is likely, globally, and that—with that, an extended period of high risk—high fire risk and large increases in area burned in North America as a result of global warming." Despite the enormous efforts of firefighters, and while—wildfires have become larger, they've become more intense, they've become more difficult, and they've become more expensive to control in recent years.

We've often discussed the role that past wildfire suppression and other land uses have had on fueling wildfire activity in some areas in recent years. It's clear, from the science, that climate change is driving the dramatic growth in wildfire activity, and that it is likely to get worse. A number of studies predict that global warming will increase the number of acres burned by wildfires in the United States by 25 to 75 percent by the middle of the century. Alaska, the Southeast, the Southwest, and the northern Rockies appear to be at particularly high risk. This information is important to this committee because of our work on global warming and on wildfire policies. For example, the wildfire situation is a stark reminder of the enormous current and potential costs of not acting on global warming. That's a point that was made in the Stern report that we received earlier in the year. Along with rising temperatures, Federal wildland fire spending has more than tripled in less than 10 years. It's risen from 800 million in 1996 to 3 billion this year. It also is a reminder that, while the Forest Service's work to contain its wildland firefighting costs is critical, those efforts will not solve the growing budget crisis that it faces.

We have four distinguished scientists testifying before the committee today, and let me just mention who they are and then defer to Senator Domenici for any opening statement that he has.

Our three witnesses today are Dr. Ann Bartuska, who is the Forest Service's deputy chief of research and development. Thank you very much for being here. She's accompanied by Dr. Susan Conard, who is the Forest Service's national program leader for fire ecology research; Dr. Thomas Swetnam, who is the director of the Laboratory of Tree-Ring Research, and professor of dendrochronology at the University of Arizona; and also Dr. John A. Helms, who is professor emeritus at the University of California, testifying on behalf of the Society of American Foresters. So, we welcome all of you.

Now let me turn to Senator Domenici for any opening statement he would like to make.

[The prepared statements of Senators Barrasso and Salazar follow:]

PREPARED STATEMENT OF HON. JOHN BARRASSO, U.S. SENATOR FROM WYOMING

Wildfire and its implications for people and resources are of great interest in Wyoming. Fires are growing increasingly larger and more frequent in our state and across the Rocky Mountain West.

This trend raises questions of how we as a Nation should provide for the safety of our people and the sustainability of our land.

We know that our state has sustained a drought for almost a decade in some areas. We know wildfires are increasing in size and scope—as they do in hot and dry years.

We know that forests continue to stockpile fuels without proper harvesting. They suffer infestation of bark beetles and other invasive species that increase fuel loads.

We also know an active program of harvesting and thinning forest lands can combat these conditions.

The people of Wyoming need to see action—action that will allow for responsible harvesting of public and private lands to reduce fire risk.

Thinning stands and treating forests to reduce fuel loads is the only proven method of reducing the scope and intensity of wildfire before problems occur.

Fires ravage overgrown, hot, dry fuel loads, but thinned stands in healthy forests withstand lightning strikes and drought years.

The right path of action is clear. We need to manage our lands responsibly.

So, where are the Forest Service regulations implementing an active program of forest management? Where is Congress' call to public agencies and private citizens to manage their forests appropriately?

The citizens of Wyoming deserve an active management plan.

I will be interested to hear the witnesses testimony not in regard to climate change, but in regard to addressing the threat of hot, dry years by mitigating the increased wildfire risk.

We've experienced stretches of devastatingly dry years in the past. We will see similar events in the future.

Making one issue the scapegoat for all of our woes is easy and grabs a headline in the paper. Finding the will to make sound policy decisions based on common sense is the challenge.

PREPARED STATEMENT OF HON. KEN SALAZAR, U.S. SENATOR FROM COLORADO

I want to thank Chairman Bingaman and Ranking Member Domenici for holding today's hearing on global climate change and its effects on wildfire activity in the United States. I would also like to thank our witnesses for taking the time to share their expertise with us today.

Climate change is a very serious problem. In June, the Senate passed an energy bill that has the potential to curb the progression of climate change by promoting the use of renewable energy and by reducing the amount of greenhouse gas emission released into the atmosphere. I look forward to working with my colleagues as this legislation is considered by the House-Senate conference committee.

However, we are constantly learning more about the effects of climate change. What we are learning is that we are experiencing the impacts of climate change now, and that it is not something that will just impact us in the future. Climate change is increasingly being cited by scientists as the cause for our more frequent and severe wildfires.

Today's hearing is of interest to me as studies have shown that Western states are particularly vulnerable to more frequent and severe wildfires due to climate change. Studies have shown that fire season itself is even longer in the West than it was twenty years ago.

In my state of Colorado, the Hayman wildfire that began in June of 2002 was the largest wildfire in Colorado's history and burned nearly 138,000 acres over the course of three weeks. Over 40,000 people living outside of Denver were forced to evacuate their homes, and 133 homes were lost.

Today's hearing is critical in helping us to understand the impacts of climate change and the increased fire danger that is now posed. It is also important to help us understand the necessary measures we must take to prevent further damage to our lands and communities and how we can best serve the people of our states in the face of wildfires.

I want to thank Chairman Bingaman and Ranking Member Domenici once again for holding this important hearing so that we can understand the best way to address this important issue.

STATEMENT OF HON. PETE V. DOMENICI, U.S. SENATOR FROM NEW MEXICO

Senator DOMENICI. Thank you, Mr. Chairman, and good afternoon.

I doubt that much of the information we will hear today is going to surprise most members who've participated in hearings in this committee over the last decade. I anticipate our witnesses today will refine our understanding of what may be occurring, and will help us to begin to focus on the areas of greatest risk. For that, I thank them for taking the time to come to testify.

It seems to me that we have always had years of drought, warm summers, early runoffs of snowpack, and when we have the right weather conditions, we experience spectacular fires. I've no doubt that we will see the convergence of these events again in the future.

At least three cataclysmic fires come to mind, and they all occurred during a period of changing climate conditions. They are: one, the afternoon of October 8, 1871, when the township of Peshtigo and parts of Green Bay, Wisconsin, were destroyed. A prolonged and widespread drought and high temperatures, capped off by a cyclonic storm, resulted in a fire covering about 2400 square miles in Wisconsin and upper Michigan. Between 1200 and 2400 lives were lost that afternoon, but it didn't get much press, because it was also the day that the city of Chicago burned.

On Sunday, September 1, 1894, a great firestorm destroyed Hinckley, Minnesota, and five other nearby communities. The fire covered 400 square miles, consuming nearly everything in its path. It is estimated that between 420 and 800 people died. Thankfully, over 500 people were evacuated from Hinckley on two trains that happened to be in the area at the time.

Finally, the third was on August 20 and 21, 1910. Fires raged across 3 million acres of northern Idaho and western Montana, an area the size of Connecticut. The fires went on runs of more than 50,000 acres, 78 square miles, and threw fire brands 10 miles in front of the main fire. The wind blew at up to 80 miles per hour. In this event, 86 people are known to have perished.

I expect our witnesses today are all going to tell us that we are in for more warming, and, therefore, more fires. They are likely to tell us that when these fires occur, they will be very damaging, and, yes, that these fires will result in more carbon dioxide being released into the atmosphere, which will impact our environment. Some of the impact may be beneficial, and some may be damaging.

I think that we all understand that. But what we are struggling with is this: whether anything can be done about changes to our forests; and, if so, how much the remedial actions may cost.

In the short run, there are only two variables that we can influence, those being hazardous fuel removals from Federal lands, and private development in and around our Federal forests. I hope that Congress will address these two issues. I'm sure today's witnesses will have more suggestions.

In closing, I very much appreciate this hearing and these witnesses coming to testify.

Thank you very much, Mr. Chairman.

The CHAIRMAN. Thank you very much.

Let me just indicate, we have a good number of Senators here, as well as our witnesses. Let me ask if any Senator has a short statement they would like to put in the record, at this time, or briefly summarize for us. Let me call on Senator Wyden.

STATEMENT OF HON. RON WYDEN, U.S. SENATOR FROM OREGON

Senator WYDEN. Thank you very much, Mr. Chairman. I'll be brief.

I think you've made it very clear that there is an emerging scientific consensus that climate change and the growing number of wildfires are related. What we're going to particularly need to do in government is to see if we can get in front of the trends and reduce the number of forest fires. My sense is, with some of the practices at the land management agencies, we're going to have to make some changes to get ahead of the problem. For example—this'll be my last point—members of this committee worked very, very hard in a bipartisan way on the forest health legislation, and one of the key components there was to get critical thinning work done in our forests in order to prevent fires in those forests, but what has happened is, there has been, in the administration, a—I guess you could call it dragging their feet on completing this critical, you know, thinning work. Until attention is turned squarely to this, we're going to have hundreds of thousands of acres of choked second-growth plantation forests all across the West, and we're going to have global warming as a greater and greater risk to these critical public resources.

So, I'd like to suggest that we get on with the bipartisan work that's been the tradition of this committee, particularly in the thinning area, as a way to get out in front of some of this very, very serious problem.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you very much.

Senator Craig.

STATEMENT OF HON. LARRY E. CRAIG, U.S. SENATOR FROM IDAHO

Senator CRAIG. Mr. Chairman, I'll make my comments during the question period.

Let's put this fact on the table. We spent about 650–700 million this year in healthy forests. We've spent to date, 1.6 billion fighting fire, and probably it'll go to 1.8 or 1.9 before the snow falls. If we dedicated that much resource to healthy forests, by the end of the decade, my guess is, we'd be spending a lot less fighting fires.

Thank you.

The CHAIRMAN. Thank you very much.

Senator Tester.

STATEMENT OF HON. JON TESTER, U.S. SENATOR FROM MONTANA

Senator TESTER. Yes, thank you, Mr. Chairman.

I'd like to thank the panelists for being here today. You know, about 800,000 acres—in fact, I think it's a little more than that—burned up in the State of Montana this fire season, and we're just about at the end of it, I hope. That, combined with, as I read in the paper, the Northwest Passage now exists, along with the changes in the land that my grandparents homesteaded and we've been farming for nearly 100 years—it's inarguable, the climate has changed.

The issue for me is figuring out what we can do to help remedy the situation, because doing nothing is not an option, in this case. Doing nothing, whether it's on global warming or whether it's on the Forest Service ability to manage their forests in a way that makes sense, is simply not a solution at all.

So, with that, I look forward to this hearing. I want to dovetail on something—what Senator Domenici said, you know, that over the last decade, I believe—you guys have probably had a lot of hearings on climate change, and maybe you hear the same thing over and over again—but I think it's really time that we take proactive steps to help solve the problem.

Thank you.

The CHAIRMAN. Thank you very much.

Senator Corker.

STATEMENT OF HON. BOB CORKER, U.S. SENATOR FROM TENNESSEE

Senator CORKER. Thank you. I've enjoyed my colleagues' comments. I'm actually more interested in the panel, no offense to anybody, and I think we'll move on with them.

So, thank you.

[Laughter.]

The CHAIRMAN. That's a great example for us all.

Senator DOMENICI. You mean everybody?

[Laughter.]

The CHAIRMAN. He——

Senator DOMENICI. "All of us."

The CHAIRMAN [continuing]. He meant your comments, as well as mine.

Senator DOMENICI. Yours, too?

The CHAIRMAN. I think he did.

Senator DOMENICI. Oh, well, then we'll all shut up.

[Laughter.]

The CHAIRMAN. Dr. Bartuska, please go right ahead.

STATEMENT OF ANN BARTUSKA, DEPUTY CHIEF, RESEARCH AND DEVELOPMENT; ACCOMPANIED BY SUSAN CONARD, NATIONAL PROGRAM LEADER, FIRE ECOLOGY RESEARCH, FOREST SERVICE, DEPARTMENT OF AGRICULTURE

Ms. BARTUSKA. Mr. Chairman and members of the committee, thank you very much for the opportunity to talk with you today about climate change and wildfires.

As you've mentioned, I'm accompanied by Dr. Conard, who is our national fire ecologist, who will be providing the details on the science of the interactions of climate change and wildfire. But I wanted to provide some context, in the sense of describing what the overall R&D program is for Forest Service research, and to provide that background.

In 1908, we established our very first experimental watershed in Colorado. That became the basis for, now, nearly 100 years of forestry research within our organization, and we are all about the science of trees, forests, and forest ecosystem, and all the interactions associated with that. So, our ability to look at climate change and wildfire and the interactions in forest ecosystems has a very long history, and it's something that we are very proud of.

Our climate change research priorities currently involve three areas. One is adaptation; that's providing options to increase forest resilience, to reduce threats, and to provide managers tools associated with that. The second is in mitigation: increasing options through carbon sequestration and soils—and forest soils, and forest biomass itself. Then, the third is in decision support for practitioners and policymakers. We think all three of those are essential for a healthy research program.

To do this, we're relying on our extensive network, the infrastructure of our research laboratories that are nationwide, our long-term research studies, building upon the 80 experimental forests and ranges that we have—and, again, the first one in—from 1908, soon to have our centennial of that effort. But we also have our rich and nationwide forest surveys. Some of you are aware of our Forest Inventory and Analysis Program. We also call it the Nation's Forest Census. We're coming up on 75 years of continuous survey of forests. So, we have a very large data set to work from.

In addition to that, we have over two decades of focused climate change research, three decades of air pollution research, and long experience with scientific assessments which provide a basis for making decisions about climate change and forest management. We are integrating that piece of climate change upon a solid foundation of our traditional disciplines—entomology, pathology, silviculture—but we're also integrating our climate change research with fire ecology, with wildland fire research, as well as the complex interactions of dealing with fuels research, which are some of our strongest programs. So, all of those, together, provide, again, a very solid foundation from which to operate.

We have been active—our scientists have been active with the U.S. Climate Change Science Program, as well as have participated in the assessments of the recent IPCC, the Intergovernmental Panel on Climate Change.

Finally, I just have to point out, Forest Service R&D can't do the work alone. We rely on our associations and partnerships with many universities, represented here, as well as elsewhere; other Federal agencies that deal with science and management; as well as nongovernmental organizations. We believe, all together we really have—to get a very important science together.

But we also know that we have more work to do. Just last week, about 75 of our scientists came together with several scientists from other communities to revise and look at what gaps we have in our climate change portfolio, and to develop a new research and development strategy. So, we believe, again, we're turning the corner on that.

But I think the other aspect that is critically important for us is, How do we get our science into the hands of the practitioners? If we just do—if we're just about science and doing research, then we're really not meeting our obligation in providing the tools that are needed to take the science and translate it into practice, working with our managers to come up with more options that they can use, build into their planning activities, build into their management strategies, so that they can really integrate the linkage between climate change and wildland fire into their overall programs. This is something that we are increasingly going to be spending our time on. It is a critical strength of the Forest Service that we have our research entity—or research enterprise embedded within a management agency, and it really creates for a very good integration of those two.

There are science-based adaptative management approaches that we are taking now that we believe will help reduce the impact of wildfires on climate change and mitigate the impacts of climate change on our Nation's forests and grasslands. For example, specifically, as has been referenced here, increasing our fuel reduction work over the past several years can lead to reducing the threat of large wildfires and may increase the resilience of forests to the effects of climate change. We intend to build upon that and continue to study those interactions.

Mr. Chairman, thank you for being able to make a few remarks. I'd like to now turn it over to Dr. Conard to provide some of the technical details about our program.

Mr. CONARD. Thank you.

The CHAIRMAN. Go right ahead, Dr. Conard.

Mr. CONARD. Mr. Chairman and members of the committee, thank you for the opportunity to discuss with you what scientific research tells us about the potential interplay of climate change and wildfire.

According to data from the National Interagency Fire Center, annual burned areas have exceeded 7 million acres only seven times since 1960; six of those have been in the past 20 years. In recent years, we have seen particularly severe droughts in the western United States, Alaska, and Florida. Not coincidentally, these regions have accounted for a majority of increased wildfire activity in the United States.

The IPCC has reported clear patterns of temperature increase and long-term trends in precipitation changes since 1900. For North America, the greatest future increases in winter temperatures are projected for boreal and Arctic zones, with summer temperature increases the greatest across the lower 48 States.

Precipitation is projected to decrease in the southwestern United States. We can expect these changes to lead to longer and more severe fire seasons in many areas.

The frequency and severity of fires vary greatly due to differences in weather, topography, and fuels. For example, in Ponderosa Pine and Loblolly Pine Forests, which historically had high-frequency, low-severity fires, reduced fire frequency beginning in the late 19th century has led to substantial fuel accumulation. These fuels increase fire hazard, a condition that can be exacerbated by warming climate and longer fire seasons. Fuel treatments and active forest management can help to mitigate such increases in fire hazard.

A number of studies indicate that variations in cyclic weather patterns and in climate over time are factors in how fire patterns change from year to year. The extent and severity of wildland fires correlate with drought patterns, timing of spring snowmelt, and changes in ocean circulation patterns, as I'm sure you will hear more about from Dr. Swetnam.

Research indicates that a warming climate will increase fire hazard, likely leading to increases in the annual area burned, as well as in the severity of fires. We expect such changes in fire regimes to affect geographic distributions of trees, other plant species, and animals.

Global general circulation models provide coarse scale projections of changes in temperature, precipitation, and other factors as greenhouse gas increases. These models project varying trends in climate patterns across the country. Scientists are developing tools that adjust these model outputs for local variations in terrain, temperatures, precipitation, and vegetation.

A number of these models developed by Forest Service researchers and their collaborators predict large changes in fire regimes and vegetation patterns across North America and in many regions of the country. Other models project potential future distribution of suitable habitat for tree species and for animal species. Improved models will help us to better project and anticipate the potential effects of changing climate on vegetation and species distributions, and on interactions with fire and other disturbances. The higher resolution provided by these types of models provides essential information for site-specific planning and decisionmaking.

I would now like to talk briefly about effects of fire on climate and carbon. As long as the incidence and severity of wildfires remains constant, the removal of carbon through the atmosphere through—from the atmosphere through a regrowth of vegetation in burned areas equals the carbon emitted through fires. There is growing scientific concurrence, however, that climate change will increase burned areas and fire severity, resulting in increased wildfire emissions.

Fire produces many emissions besides carbon dioxide. Some of these compounds trap more radiation than CO_2, while others reflect heat and light. Impacts of fire-induced vegetation changes on how the surface of the Earth reflects or absorbs the sun's rays will also influence the effects of fire on climate.

Research has shown that hazardous fuel-reduction treatments in the appropriate type of fire regime are often effective at decreasing the severity of subsequent fires. If the fuels that are removed are used for bioenergy or in wood products, they also provide benefits by offsetting the use of fossil fuels or entering carbon into semi-permanent storage. Subsequent lower-severity wildfires will emit less carbon to the atmosphere than would occur in untreated stands. Forest Service scientists are working with partners to develop better estimates of various components of the forest carbon cycle that include these alternate uses of materials and account for the various processes involved as forests are harvested or burned and as they regrow.

In summary, the net effect of changing fire regimes on climate and carbon storage will be influenced by many factors. Changing emissions, carbon dioxide uptake by regrowing vegetation, the use of potential fuels for bioenergy or in wood products, and changes in vegetation will all play a role.

In the United States, the magnitude and effects of climate change and its impact on fire regimes will vary in different regions of the country. We need to understand more about fuels, about the effects of changing burn severity on carbon release, and about how these effects will vary regionally.

I'd now like to turn to Dr. Bartuska for concluding remarks.

Ms. BARTUSKA. So, just a few key points—sorry—a few key points, to reiterate.

One is that we have made an investment, in the Forest Service, for over—nearly 100 years, rather—in understanding forest and rangeland science, and we believe this is foundation upon which we can look at our climate change processes.

We also believe that we should be taking that into account looking at adaptation strategies, mitigation options, but also the decision-support tools that are needed to address the issue of climate change and wildland fire.

But, finally, it doesn't make sense, if we're just going to do the science, if we don't put it in a form and in a way that is available to practitioners and helping managers make better decisions. That really is the foundation of the work that we're moving into.

Mr. Chairman and members of the committee, thank you for the opportunity to discuss the science of the interactions of climate change and wildfire. Dr. Conard and I will be available for questions at the end of the panel.

Thank you.

[The prepared statement of Ms. Bartuska follows:]

PREPARED STATEMENT OF ANN BARTUSKA, DEPUTY CHIEF, RESEARCH AND DEVELOPMENT; ACCOMPANIED BY SUSAN CONARD, NATIONAL PROGRAM LEADER, FIRE ECOLOGY RESEARCH, FOREST SERVICE, DEPARTMENT OF AGRICULTURE

Mr. Chairman and members of the Committee, thank you for the opportunity to talk with you today about the interactions of climate change and wildfire. I will give you a brief description of the Forest Service research programs in climate change and wildfire. I am accompanied today by Dr. Susan Conard, our scientist who leads the national fire ecology research program, and she will discuss the science of the interactions between climate change and wildfire.

The Earth's climate is changing and will continue to change for many decades. Decisions being made today by policymakers and public and private sector resource managers will have implications through the next century. Forest Service Research and Development provides long-term research, scientific information, and tools that can be used by managers and policymakers to address climate change impacts to forests and rangelands.

Forest Service climate change research priorities involve three areas: adaptation (increase forest stress resilience); mitigation (increasing carbon sequestration through storage in soils, living plants and wood products); and decision support for practioners and policymakers. To do this, we maintain an extensive infrastructure of research laboratories, long-term research studies, and continuous data from nationwide forest surveys and experimental forests. Several long-term data sets—the Nation's Forest Census (Forest Inventory and Analysis) and the Experimental Forests—provide several decades worth of information on forest and rangeland trends. Over two decades of focused climate change research, three decades of air pollution research, and long experience with scientific assessments provide a firm foundation for addressing climate change and forest management. The Forest Service climate change research program is supported by strengths of its more traditional research in areas such as ecophysiology, landscape ecology, watershed hydrology, vegetation modeling, nutrient cycling, and forest management. Further support comes from partnerships with universities, federal and state agencies, non-governental organizations, and the forest industry here and abroad.

Scientists from the Forest Service are active in the United States Climate Change Science Program (CCSP) and participate in CCSP and Intergovernmental Panel on Climate Change (IPCC) assessment activities. In addition, the Forest Service climate change research, fire ecology, wildland fire, and fuels research programs combine to provide a rich source of information, data, and scientific discoveries. The science is essential to underpin predictive models and adaptation and mitigation techniques. Important aspects of the research are the effects of fire on carbon storage, atmospheric chemistry and warming potential, water supply, and ecosystem health and resilency. Forest Service scientists and colleagues funded by the National Fire Plan and the Joint Fire Science program—managed jointly by the Forest Service, US Geological Survey, Bureau of Land Management, National Park Service, US Fish and Wildlife Service, and the Bureau of Indian Affairs—are studying wildfire and climate interactions, predicting and monitoring wildfire emissions, and looking at factors that affect fire behavior and fuel consumption. This research allows us to better understand fire and water supply issues, perhaps two of the most critical issues for western states.

I would like to say a few words about the scientific process. Science can describe the connections between human and ecological systems, develop methods to forecast the occurrence of damaging fire events and other disturbances, and characterize the possible outcomes of alternative management options. Scientists can help managers interpret what they are seeing on the ground and can help evaluate the environmental effects, social and economic costs and benefits, and effectiveness of potential management programs towards reaching management objectives. This scientific information can help managers and policymakers to decide the most appropriate management strategies for specific situations.

As scientists, we know that the scientific basis for understanding fire and climate change interactions is more complete for some interactions than for others. We have important knowledge gaps that we must address. For example, current estimates of fire emissions vary widely. While we have information for a few systems, we do not have good information broadly on burn severity or on how burn severity will cause emissions to fluctuate. We also do not know how much we can increase carbon storage without causing unacceptable increases in fire hazard in fire-dominated ecosystems.

The interaction of climate change with ecosystems is also the subject of the Synthesis and Assessment Report (SAP) 4.3, The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity, is one of 21 synthesis and assessment products being produced by the CCSP. These reports summarize scientific understanding of various aspects of climate change for government and private sector decision-makers. USDA participates in CCSP and is the lead agency for SAP 4.3. The direct and indirect climate effects on wildfires is one topic addressed by SAP 4.3, and when the report is finalized, will help to provide the necessary scientific basis for assisting decision and policy makers.

As we continue to integrate results from various scientific studies, we increase our understanding of where and why results differ, as well as where results can be generalized. Scientists' ability to provide this kind of information will aid decision-makers.

Although policy questions may often be framed as science questions, many non-scientific considerations must be part of the answer to these policy questions. While science can provide a foundation for management and policy decisions, science alone is not sufficient to determine policy. Adaptive management by land managers is a useful tool that combines emerging research with evaluation of management practices. This approach enables managers to modify practices as our understanding of management impacts improves. This is an important concept in dealing with active application of science by practitioners and policymakers.

While we still have much to learn about the interactions among climate change, carbon emissions, and wildfire, there are science-based adaptive management approaches we are taking today that can help reduce the impact of wildfires on climate change and mitigate the impacts of climate change on our nation's forest and grasslands. For example, the Forest Service has increased our fuel reduction work over the past several years, which reduces the threat of large wildfires and may increase resilience of forests to the effects of climate change.

Mr. Chairman, Dr. Susan Conard will now address in greater detail the science of the interactions between climate change and wildfire activity. Following her testimony and my concluding remarks, we would be happy to answer any questions you might have.

SCIENTIFIC RESEARCH ON THE IMPACTS OF CLIMATE CHANGE ON WILDFIRE ACTIVITY

Mr. Chairman and Members of the Committee, thank you for the opportunity to discuss with you today what scientific research tells us about the potential interplay of climate change and wildfire. Today I will talk about the current scientific understanding of historical interactions of climate and wildfire, how climate is changing fire regimes, how wildfire affects climate change, some of the research-based knowledge and tools being developed that help us understand how climate change is likely to affect wildfires, and ways in which this knowledge can help support managers and policymakers.

BACKGROUND

A number of recent scientific studies indicate that variations in cyclic weather patterns and climate over time are factors in the increase in large, severe fires and how fire patterns change from year to year. According to data from the National Interagency Fire Center (NIFC), annual burned areas have exceeded 7 million acres only 7 times since 1960; 6 of those have been in the past twenty years. One possible outcome of climate change is an increase in the incidence and severity of wildland fire in some parts of the continent and in Alaska. Fuel treatments and active forest management have reduced fire hazard and can help to mitigate these increases in fire hazard.

Recent data and projections from the Intergovernmental Panel on Climate Change (IPCC) provide some context for this discussion. IPCC reports (IPCC 2007) show that there have been clear patterns of temperature increase and long-term trends in precipitation change around the world since 1900. Results from over 20 different global models project strongly increasing temperatures for much of the globe, with the greatest increases generally projected for northern latitudes. For North America the greatest increases in winter temperatures are in the boreal and arctic zones, with summer temperature increases the greatest across the lower 48 states in the United States. Precipitation is projected to decrease in the southwestern United States, and increase in some areas of the northeast. We can expect these temperature and precipitation patterns to lead to longer and more severe fire seasons in many areas of the United States and Canada, which underscores the need to continue to engage in active forest management as a mitigation measure.

HISTORICAL WILDFIRE

Natural disturbance—whether by fire, insects, disease, hurricanes, ice storms, floods, or tornadoes—is a fact of life for all ecosystems. For most forests and rangelands, fire is a relatively regular occurrence, although the typical frequency, behavior, and severity of the fires (the fire regime) vary greatly from one forest type to another. This difference in fire regimes is a function of the combination of weather, topography, stand structure (fuels), and occurrence of ignitions that characterize specific ecosystems (e.g. Pyne et al. 1996). For example, many prairies and grasslands historically burned every few years, or even annually. Dry pine forests burned primarily in frequent, low intensity surface fires. Cool, moist conifer forests, such as coastal Douglas-fir in the Pacific Northwest of the United States have burned in high intensity stand replacement fires only every few hundred years (Heinselman 1978, Heyerdahl et al. 2001, Leenhouts 1998, Schmidt et al. 2002). While each ecosystem has a typical fire regime, the characteristics of individual fires may vary widely as a function of specific fuel structure, weather conditions during the fire, and weather and climate patterns in the weeks (and even years) before a fire occurs (Leenhouts 1998, White et al. 1996).

In forest systems, the highest severity fires (where severity refers to the level of ecological impact) are in fire regimes with stand replacing fires, which typically kill all or most of the living vegetation, and burn deeply into surface litter and duff layers. Ecosystem recovery is generally slow (100 to 300 years) as is the return to pre-fire levels of fuel loadings and fire frequency. In some forest and shrub systems, as well as in perennial grasslands and savannas, fires may top-kill most of the above-ground biomass, but native species are adapted to recover through re-growth from live roots, basal sprouting or regeneration from seed. Such systems recover rapidly—and typically undergo shorter interval between fires.

The lowest severity fires in forest systems burn only surface fuels and low-growing vegetation, and have little impact on overstory trees. These surface fire regimes are most typical of forest types on dry sites or with fairly open canopies, and with grassy or shrubby understories, such as ponderosa pine and loblolly pine. Such surface fires typically occur much more frequently (every 3 to 30 years) than stand replacement fires.

In mixed severity fire regimes, there may be a pattern of relatively frequent surface fires, with less frequent stand replacement fires, or patches of high fire severity, that are a function of either unusually severe weather or reduced fire frequency that leads to greater than normal fuel accumulation. This appears to be the pattern in many conifer forests in the west and can also occur in some of the Southeast.

In some systems in North America (such as ponderosa pine and loblolly pine forests which historically had high frequency, low severity fires) reduced fire frequency beginning in the late 19th century has led to substantial fuel accumulation. These fuels increase fire hazard and burn severity, a condition that can be exacerbated by a warming climate and longer fire seasons (e.g Westerling et al, 2006).

EFFECTS OF CLIMATE ON FIRE REGIMES

While climate has always been variable, the suite of climate models evaluated by IPCC project an increased frequency and intensity of drought and high-intensity rainfall events, particularly in the boreal and temperate zones of the northern hemisphere. These predictions take into consideration the larger land mass in the northern hemisphere as compared to the southern hemisphere. The largest changes in temperature are projected for high latitudes in both the northern and southern hemispheres; however, water has a moderating effect on changes in temperature and precipitation; hence the northern hemisphere, with its relatively larger land mass, will likely see more frequent and intense weather patterns (IPCC 2007).

Historically, the extent and severity of drought, timing of spring snowmelt, and changes in ocean circulation patterns have all correlated with the extent and severity of wildfire on forests and rangelands. The impacts of climate change may be most noticeable in the short-term on fire regimes typified by low or mixed severity fires because fuel structure in these systems reacts more rapidly to fire exclusion and drought is more frequent.

Warmer winters also exacerbate summer drought because of reductions in winter snow pack depth and duration that alter both the timing and volume of runoff, leading to longer summer droughts, larger water deficits, and more severe fire seasons (e.g. Westerling et al. 2006). Wet years of climatic cycles lead to high rates of vegetative growth (fuel production), often in the forest understory. Drought stresses trees and other vegetation, causing increased flammability of live and dead fuels and increased susceptibility to a number of insects (most notably bark beetles) and some pathogens. Warmer winter temperatures can increase the reproductive rates of insects, resulting in a second generation in one year. In addition, warmer temperatures can extend the ranges of some insect populations, as has happened with the mountain pine beetle in the western United States (Logan et al, 2003). Recent research shows clear relationships between warmer temperatures and drought on extensive insect outbreaks in southwestern forests and Alaska.

A number of studies published over the past two decades suggest that a warming climate will cause increases in fire hazard, likely leading to increases in the annual area burned as well as in the severity of fires (Brown and Smith 2000, Flannigan et al. 1998, Fosberg et al 1996, Lenihan et al. 1998, Stocks et al. 1998, Wotton and Flannigan 1993). These studies in general do not take into account mitigating measures such as fuel reduction. These projections are supported by numerous studies that relate inter-annual or multi-year changes in fire patterns to regional patterns of climate variability (e.g. Swetnam and Betancourt 1990, 1998; Fauria and Johnson 2006; Kitzberger et al. 2007; Murdiyarso and Adiningsih, 2007; Swetnam and Baisan 1996; Westerling et al 2006).

As climate warms and becomes more variable, some of the greatest effects on fire regimes are expected to occur in the boreal zones of North America (primarily Alaska and Canada) and in Eurasia (Fosberg et al. 1998, Flannigan et al. 1998, Fauria and Johnson 2006). The effects of climate on fire regimes in systems with deep organic layers such as peat bogs, are predicted to be large but are poorly understood (Morrisey et al 2000, Turetsky et al. 2006). This is tremendously important because of the large carbon stores that can be released from these ecosystems if fire frequency and the depth of burn increase.

In recent years, we have seen particularly severe periodic seasonal droughts in the western United States, Alaska, and Florida. Not coincidentally, these regions have accounted for a majority of increased wildfire activity in the United States. Climate models, which I will speak more of later, project increased drought in the southwest United States. The same models project increased rainfall in the upper Midwest, Great Lakes and New England.

Changes in fire regimes and in wildfire occurrence and severity have implications for atmospheric chemistry, the influence of smoke on air quality, the quality of our drinking water, and the ability of forests and grasslands to store carbon. These changes could both facilitate and force changes in the structure and composition of ecosystems, with feedback loops that are largely unknown. Ultimately, changes in fire regime can be expected to result in substantial alterations to the geographic distribution of trees, other plant species, and animals (e.g. Heinselman 1978).

CIRCULATION PATTERNS AND WILDFIRES

The severity of fire seasons in different parts of North America has been shown to be highly correlated with annual and multi-year weather patterns (such as those resulting from changes in El Niño, La Niña or other ocean circulation patterns). (e.g. Swetnam and Betancourt 1998, Kitzberger et al. 2007). In mountainous areas of the western United States, one of the key factors associated with severe fire seasons is the timing of snow melt in the spring, with earlier snow melt often being a precursor to longer summer drought periods (e.g. Westerling et al. 2006). High temperatures and low rainfall (or longer dry seasons) together produce increases in area burned and numbers of large, intense fires.

The El Niño-Southern Oscillation provides the south and southwestern United States with abundant winter rains every 3-7 years, supporting luxuriant growth of grasses and forbs the following growing season. If this season in turn is followed by drought, the abundant surface fuels increase the probability of stand-replacing fires to develop in open woodlands, parklands and dry pine (ponderosa) forests (Swetnam and Baisan, 1990). Recent research indicates that the warm phase of the Atlantic Multidecadal Oscillation has coincided with 40-60 year periods of increased fire frequencies throughout the western United States, and that the West appears to be entering such a period now (Kitzberger et al., 2007).

The effects of these multi-year weather patterns may well amplify climate change-induced effects to forests and grasslands. Seager et al (2007) recently projected severe drought conditions for much of the 21st century in the southwestern United States. This supports projections of multiple models for decreased summer rain and increased temperatures in this region (IPCC 2007).

TOOLS FOR ASSESSING INTERACTIONS BETWEEN CLIMATE CHANGE AND WILDFIRE

Scientists are developing and using a number of tools to assess the interaction of climate change and fire. Under a changing climate, fire occurrence and patterns of ecosystem recovery after a fire may also change, leading to changes in vegetation structure and composition and in the ability of those ecosystems to store carbon.

Global General Circulation Models (GCMs) are used to project climate effects on temperature, precipitation and other factors and generally do not incorporate disturbances such as wildfire except in a very coarse way. Their predictions are primarily useful for long-range and large-scale (e.g. national or broad regional) thinking and planning. Even at a coarse scale, however, it is clear that the mechanisms and expected magnitude of impacts of changing climate will vary greatly across the country.

To develop landscape-scale projections of impacts of climate change on ecosystems or on fire that are useful for management and planning, scientists adjust General Circulation Model outputs for local variations in terrain, temperatures, precipitation, and vegetation. While Forest Service scientists are not generally involved in developing General Circulation Models (this being largely the realm of physicists and atmospheric chemists), they use General Circulation Model outputs to project changes in vegetation, fire hazard, wildlife habitat and water supply both at coarse scale and at scales more appropriate to local and regional resource management planning. Information from field studies and landscape-level models can also be used by General Circulation Model developers to help make their models more realistic, especially in terms of incorporating major landscape processes such as fire.

There are several types of vegetation models that are useful for assessing the potential interactions among climate change, vegetation, and wildfire. These range from global to regional or landscape-scale, and they take a range of approaches (See Keane et al. 2004 for an extended discussion). Some models are based on biogeochemical processes and focus on overall plant productivity in a given climate, but often without regard to the likely presence or absence of vegetation, or of individual species (e.g., Neilson et al, 2005). Other models use detailed knowledge about how individual species grow currently to project viability, and growth, and changes in species composition (Bugmann and Solomon, 2000; Busing et al, in press). Still other types of models evaluate current climatic limits of species or ecosystems and use that information to project areas where habitat may be suitable in the future (Iverson et al, 2004; Rehfeldt et al, 2006). Further, some of these models are landscape-level models (Mlandnoff and Liu, 2003) and others model individual stands and use statistical information on distribution of forest types to develop projections.

Models give us projections of species environmental potential but not actual capability to move on the landscape. Scientists are working hard to realistically represent vegetation change and species migration given that the capability of many long-lived plant species to migrate may be slower than the projected rate of change in distribution of suitable habitat (Neilson et al. 2005).

One example of a biogeochemical model that looks at fire, which is under development by Forest Service researchers, is the Mapped Atmosphere-Plant-Soil System. The MAPSS simulates potential impacts of changes in the physical environment on vegetation dynamics for major ecosystems (Bachelet et al. 2003). The fire module predicts substantial increases in burned area and emissions from wildfires, particularly in the boreal zones and in the western United States (e.g. Lenihan et al. 2003).

Keane et al. (2004) discuss and compare over 40 landscape fire models from around the world that are able to incorporate climate into their simulations. A number of landscape-scale models developed by Forest Service researchers and their collaborators predict large changes in fire regimes and vegetation patterns in areas as diverse as Glacier National Park, California, the Ozark Plateau, and the North-Central United States. Landscape vegetation fire models have been developed for nearly every region of the United States, including Alaska. However, these models vary greatly in design and in sensitivity to climate, terrain, and other parameters (Cary et al. 2006), and in general they are still being evaluated for use in predicting effects of changing climate on vegetation and fire. Many of these models are currently in use to support forest management decisions and the development of planning alternatives.

Other kinds of models combine current distribution of individual tree species based on data from the Forest Service Forest Inventory and Analysis program (FIA) with climate model outputs to project potential future distribution of suitable habitat for tree species (Iverson et al, in press, for the eastern US; Rehfeldt et al. 2006, for the western United States) or for bird species (Matthews et al. 2004 for the east). The outputs from such models have potential to help managers as they make decisions about appropriate approaches to reforestation under a changing climate.

Depending on the landscape model, the potential effects of fire, insects, other disturbance regimes, fuel treatments, or other management practices over time or at multiple scales can be evaluated. The interactions of disturbance (primarily fire in the western United States) with vegetation and climate can be incorporated into landscape models such as LANDIS, SIMMPLE, and MC-FIRE to compare effects under different management scenarios. Most of these models are currently operating at regional levels, and are not yet in nationwide application. Forest Service researchers are currently examining how best to incorporate climate change effects on tree growth into the Forest Vegetation Simulator (FVS), which is currently used by silviculturists and planners to simulate forest growth and dynamics, as well as responses to fire and fuel treatments and to insect and disease, at a stand level (http://www.fs.fed.us/fmsc/fvs/).

The large assortment of models mentioned above give scientists a wide range of important information to compare and evaluate. Models need to be tested at the local level and strengths and weaknesses sorted out. Cushman et al. (2006) discuss the future needs for improving the capabilities and utility of landscape models. Improved landscape models will enable us to better project and anticipate the potential effects of changing climate on vegetation and its interactions with fire and other disturbances such as insects and diseases. The resolution provided by these types of models provides essential information for site-specific planning and decisions.

THE INTERACTION OF FIRE, FIRE BEHAVIOR, AND CLIMATE CHANGE

While current fire behavior modeling tools do not explicitly incorporate climate change, they all use data on weather and fuel condition to develop predictions. Thus fire behavior modeling tools can be used to evaluate multiple scenarios, such as the effects of extreme drought or higher temperatures that might be expected in a changing climate. Our knowledge of how fire behavior affects forests and rangelands comes from a combination of experimental studies (often using prescribed fire) and observations before, during and after wildfires. Such observations can occur at a range of scales from satellite remote sensing of fires and burned areas, to aircraft-based remote sensing or smoke sampling, to measurements of fluxes or changes in ecosystem properties made on the ground. Each year, seasonal severity projections include expected weather patterns over the fire season, including the known influences of changes in atmospheric circulation patterns, temperatures, and rainfall brought about by El Nino or La Nina, and other ocean oscillation patterns.

Good data on current and past fuel conditions as well as patterns of fire on the landscape provide a foundation to better understand the interactions between fire and climate. Ongoing monitoring is also essential. Two recent national projects being implemented under the auspices of the interagency Wildland Fire Leadership Council will help to provide this foundation. The LANDFIRE project (http://www.landfire.gov/index.php), a collaboration with the US Geological Survey and the Nature Conservancy, is mapping at the 15 meter resolution for fuels, vegetation, fire regime, condition class, terrain, and other important parameters. The Monitoring Trends in Burn Severity Project (http://svinetfc4.fs.fed.us/mtbs/) is mapping burn severity and perimeters for all large fires in the United States (over the past 20 years and into the future). Information from the burn severity project will eventually be integrated with LANDFIRE as part of the mechanism for updating LANDFIRE for fire and other disturbances. The two projects will provide essential baseline data layers which can be used for improved monitoring as well as modeling of changing fire regimes, effects of fuel treatments, fire behavior, fuel consumption and emissions, and potential interactions with climate.

FEEDBACKS BETWEEN FIRE AND CLIMATE CHANGE

There is growing scientific concurrence that climate change will increase areas burned, which will result in increased emissions of carbon dioxide and other greenhouse gases from wildfires—both through increases in area burned and through increased emissions. Mitigation measures such as hazardous fuel reduction can help to reduce these effects (e.g. Johnson et al. 2007). Fire produces many emissions besides CO_2 (including methane, particulates, and other aerosols; Andreae and Merlet 2001). Some of these compounds are much more efficient at trapping radiation than CO_2 while others reflect heat and light. In addition, there are great variations among ecosystems in how fires affect the release of CO_2 from soil which normally stores about twice as much carbon as above ground parts of forests. In some systems, post-fire emissions from soil respiration are greatly reduced, while in others they may increase or remain relatively unchanged (Amiro et al.2003). Another factor that will affect the regional and perhaps global effects of fire on climate is the magnitude of the impacts of fire-induced vegetation changes on how the surface of the earth reflects or absorbs the sun's rays.

A number of recent papers have addressed this issue, but it is extremely complex, and current data are not adequate to evaluate the potential net affects. Smoke from wildfires can also cause severe local and regional air pollution. Smoke from large fires often travels great distances, and may affect local temperatures and air quality thousands of miles from its origin (e.g. Colarco et al. 2004, Damoah et al. 2004).

While it is clear that increases in burn area and fire severity will increase greenhouse gas emissions, it is the balance among the influences of these various emission changes, the uptake of CO_2 by regrowing vegetation, the utilization of potential wildfire fuels for bioenergy or in wood products, and changes in vegetation composition, albedo and other factors that will determine the net effect of changing fire regimes on carbon storage and on climate.

IMPLICATIONS OF CHANGING FIRE REGIMES FOR CARBON STORAGE

There is increasing attention being paid by scientists to the significant role that wildfire plays in the global carbon cycle (Schimel and Baker 2002). As long as the incidence and severity of wildfires remains constant, removal of carbon from the atmosphere through regrowth of vegetation in burned areas equals the wildfire carbon products emitted. An increase in wildfire will increase emissions of carbon gases and particulates and other greenhouse gases (IPCC 2007). Many forest management techniques, such as prescribed burning or thinning dense vegetation in appropriate fire regimes, can be used to make forests more resilient to wildfire, particularly in ecosystems typified by short intervals between fires or mixed severity fire regimes.

Research has shown that hazardous fuel reduction treatments in the appropriate type of fire regime are often effective at decreasing the severity of subsequent fires (e.g. Johnson et al. 2007). If the fuels that are removed are used either for bioenergy or in wood products, they are providing benefits in terms of overall carbon balance, either by offsetting use of fossil fuels or entering carbon into semi-permanent storage. Subsequent lower severity wildfires fires will emit less carbon to the atmosphere than would occur in untreated stands. Forest Service scientists are working with partners to develop better estimates of various components of the forest carbon cycle that include these alternate uses of materials (Smith et al. 2006) and account for the various processes involved as forests are harvested or burned, and as they regrow.

In the United States, the magnitude and effects of climate change, and its impact on fire regimes will vary in different regions of the country. We need to understand more about fuels, the effects of changing burn severity on carbon release, and how these effects will vary regionally.

I would like to turn to Dr. Bartuska for a discussion of science in support of managers and policymakers.

SCIENCE IN SUPPORT OF MANAGERS AND POLICYMAKERS

Scientists can assist managers and policymakers by providing knowledge and tools that support adaptive management in response to our changing climate. Adaptive management combines emerging research with evaluation of management practices. This enables managers to modify practices as our understanding of the science of these complex systems improves.

Research, such as that mentioned earlier, tells us that fire regimes are changing and will continue to change across North America, and that some of this change is due to changing climate, although measures such as fuel reduction can help to mitigate these effects. These changes may complicate fire management activities and suppression operations, alter ecosystem characteristics and increase potential fire risk and other losses to communities and infrastructure. We can also expect that new vegetation communities will develop over time as a reflection of the tolerances and adaptations of individual species.

Changes in vegetation and fire regimes will affect our ability to store carbon in forests and rangelands, and will affect atmospheric chemistry and climate. Scientists across the United States and around the world are developing new knowledge and new approaches to quantifying these impacts and improved methods of adaptation and mitigation to lessen the impacts of these changes.

There is good scientific basis for vegetation treatments in appropriate fire regimes to reduce wildfire severity; treatments will reduce stress and crowding of vegetation and increase resistance to severe drought and to bark insects. Because climate in many areas will change more rapidly than long-lived plant species can migrate, moderate to severe fires can be seen as opportunities to facilitate migration, either by planting a mix of species that may be better adapted to current and future climates, or by selecting seed from trees that grow in warmer seed zones or at lower elevations.

Because we can not predict precisely what species or genotypes will be best able to tolerate changing environments, managers may want to ensure a diverse mix of species on the landscape. Forest biomass from fuels reduction can be used for bioenergy and wood products—this will decrease the net effective emissions from wildfires, offset fossil fuel emissions, and help to increase carbon storage. Scientists are evaluating options for incorporation of organic matter from forest fuels into the soil, where it will decompose slowly, and not add to fire hazard as much as if left on the surface. While wildfire is a part of the problem of climate change and carbon storage, management of fire and fuels and thoughtful restoration of burned areas can be a part of the solution.

CONCLUSION

As we have presented, science can describe the connections between human and ecological systems. Scientists can help policymakers and managers evaluate options and interpret the effectiveness of potential management alternatives. Science can provide a solid foundation for the many non-scientific considerations that managers and policymakers must take into consideration. I hope the information we have provided has been helpful.

Mr. Chairman and members of the Committee, thank you for the opportunity to discuss the science of interactions of climate change and wildfire. Dr. Conard and I would be happy to answer any questions you might have.

The CHAIRMAN. Thank you very much.

Dr. Helms, why don't you go right ahead.

STATEMENT OF JOHN A. HELMS, PROFESSOR EMERITUS OF FORESTRY, UNIVERSITY OF CALIFORNIA, BERKELEY, CA

Mr. HELMS. Thank you, Chairman Bingaman and Ranking Member Domenici, for—and members of the committee—for the opportunity to come and talk to you this afternoon on this topic.

But the first remark I'd like to make is that it must be remembered that forests have responded to climate change throughout the last millennia, and they adapt very strongly. They have moved in species distribution, they have evolved, and they've also suffered from extermination as the climate has changed. So, this is something that is ongoing. What we are concerned about is the increased rate at which this is happening.

But I might also comment that the forests are adaptable, and one can see that, when you look at forests that grow both on a north slope and a south slope in an area. They are obviously growing well, even though the climate might be different by several degrees.

The projections are—vegetation change, in precise, has been mentioned earlier, due to differences in model assumptions on temperature change, temporal patterns of rainfall, et cetera; but, in general, it can be summarized that the changes most likely to be seen in the northern latitudes, where there will be loss of meadows, a conversion of forests to grasslands, and probably tree invasion into areas that previously were too cold. Forests are expected to move northwards in latitude and upwards in elevation, and probably this indicates that the pine forests are mostly subject to change. The shift in boundaries are—can be quite large. It has been estimated that a temperature change of about 3 and a half degrees in the Rocky Mountain area is equivalent to the vegetation habitat moving upwards: 2,000 feet upslope or 200 miles further north.

Climate change will also have an effect on growth, which may increase or decrease, depending upon the way in which the climate changes, and the particular species, the tree ages, et cetera.

Within a given forest, there will be changes in ecosystem structure due to changes in species interaction and competitiveness. But, in general, climate change is expected to lower productivity in some forests, such as in parts of the West, and higher productivity may occur in the Northeast, lake States, and parts of the Southeast.

But we also must remember that carbon dioxide may also enhance growth. Experimentally, it's been demonstrated that, if you increase levels of CO_2, it's been commonly shown that tree growth can increase by around about 20 percent if the site is fertile, but that this increase is then subjected to other limiting factors in the environment, such as water supply or other nutrients. Interestingly, as a consequence of industrial pollution, it's being demonstrated, in many parts of the world, that the forests are increasing in growth. So, when we come to the point of examining the way in which climate change is affecting growth, there are complications that will require quite sophisticated analysis.

But as forests are placed under increasing stress, the most observable characteristic will be loss of vigor and increased mortality. Some of the species will no longer be able to grow or compete. This decline in health and vigor will be resulting in increased carbon to the atmosphere, and, in some cases, this will be quite substantial. It may be equivalent to what might happen under deforestation. As these species die, it exposes the soil, and, as you are aware, there are substantial quantities of carbon in the soil, which, as it becomes exposed, subjected to increased temperature, it will again be a source of release of carbon to the atmosphere, compounding the effects of climate change.

So, already in North America, forests are showing evidence of stress. A prime example is that of the mountain pine beetle epidemic in British Columbia. Although the beetle is endemic and a natural part of the ecosystem, and, indeed, and important component in the functioning of the system, once the populations develop to a great extent, you end up with increased mortality. The B.C. Ministry of Forests reports that about 23 million acres have been subject to increased beetle attack. Of particular concern is that, as the winter conditions are made more mild, this insect may move into other provinces and attack other species.

A second example is that in the Southwest, where some States have experienced a die-off of pinyon pine of about 90 percent. The Forest Service has estimated that about—almost 4 million acres over six States have been affected. Here again, the precipitous decline in pinyon pine is associated with climate change, particularly reduced temperatures in the wintertime.

So, again, evaluating the effects of climate change on forests is made difficult. It appears that the impact on insects may, indeed, be greater than the impact on potential wildfire.

Now, in evaluating the effect of climate on wildfires, I would like to mention that there are three issues that are important. One is the levels of prehistoric burning by Native Americans. The second is the importance of human ignitions in—as sources of wildfire. The third is the changed forest structures that have occurred over time.

It's well documented that Native Americans have used fire extensively. One example is in California, that prior to the 1800s it's estimated that they burned about 400—4 and a half million acres annually. In the period of the 1800s, 1825 to the very early 1900s, it's estimated by the Interagency Fire Center that there's about seven fires that were 1 to 3 million acres in extent. Although these fires are—both Native American and in the early 1800s—were large in extent, it's probable that the modern fires are much more destructive because of their intensity.

I'd like to comment on the role that humans have played in fire. Again, the Interagency Fire Center reports that in 2006 there were over 96,000 fires nationwide, of which 83 percent were human-caused, and that, if you divide the country up into 11 regions, that human ignitions exceeded lightning ignition in five out of those 11. So, clearly, it's difficult to separate out the effects of climate change from other factors such as human ignitions and fire conditions.

So, finally, I'd like to comment on what role mitigation might play. Since the severity of wildfires are, to a large extent, influenced by human ignitions and changed forest conditions, it's important to consider the extent to which the social sciences and forest management could contribute to both understanding and mitigation.

Monitoring climate change and forest conditions should be aimed at separating out all these complex factors and interactions that result in wildfires. Since growth and mortality on national forests greatly exceeds that from removal from harvest in the building up of fuels, it would be prudent to consider treatments and incentives aimed at fuel reduction and, where possible, using that excess biomass for socially needed products and energy production.

So, the aim of treatments on forests would be to create, as far as possible, conditions in the forest that are suited to current and future uses by society so that these forests can better withstand what will inevitably be an increase in wildfires that will be enhanced through climate change.

Mr. Chairman, thank you very much for the opportunity to comment.

[The prepared statement of Mr. Helms follows:]

PREPARED STATEMENT OF JOHN A. HELMS, PROFESSOR EMERITUS OF FORESTRY, UNIVERSITY OF CALIFORNIA, BERKELEY, CA

INTRODUCTION

Chairman Bingaman, Ranking Member Domenici, and members of the Senate Committee on Energy and Natural Resources. Thank you for the opportunity to give testimony on scientific assessments of the impacts of global climate change on wildfire activity in the United States. My name is John A. Helms, Professor Emeritus of Forestry at the University of California Berkeley where I served as Head of the Department of Forestry and Resource Management. I am here today representing the Society of American Foresters for which I served as President in 2005. The Society has 15,000 members who are forest managers, consultants, academics, and researchers and promotes sustainable forest management for balanced and diverse values.

LIKELY MAGNITUDE OF CLIMATE CHANGE

This topic has been discussed at previous hearings, so I will not elaborate here. However, since there is a direct relation between climate and forests, and between the structure of forests and wildfire, it is important to understand the likely magnitude of changed climate.

Due to the complexity of General Circulation Models there is considerable uncertainty regarding the precise changes in climate. However, there is general agreement that temperatures will increase 1-4°C in the next century resulting in less snow, more heat-absorbing exposed ground and sea water, which lead to less reflectance or albedo and provide positive feedback. On the other hand, there is continuing uncertainty regarding the extent to which changes in clouds and precipitation patterns may ameliorate increased temperatures. Average temperatures have already changed several degrees especially in northern latitudes. Maritime climates are already becoming wetter and interior of continents drier. Glaciers and ice sheets are diminishing.

EFFECT OF CLIMATE CHANGE ON FOREST ECOSYSTEMS

Throughout millennia, climate has been the principle determinant of vegetation distribution throughout the world. Animal and plant species are in a constant state of flux—continuously adapting, changing distribution, evolving, and becoming extinct. At a finer scale, forests have considerable adaptive capacity and can, for example, grow well on both north-and south-facing slopes that have several degrees difference in climate.

Scientific literature clearly documents changes in growing season, phenology, and modified distribution of animals, plants, and insects. Of particular concern is the extent to which likely increases in temperature will cause changes in species distribution, how much climate changes are being affected by human activities, and whether the rate of change can be mitigated.

Projections of vegetation response to climate change are imprecise due to differences in model assumptions on temperature change, temporal patterns of rainfall, and likely responses of species to these changes. However, in general, effects of climate change are more likely to be seen in northern latitudes with loss of meadows, conversion of forest to grassland, and tree invasion into areas that were previously too cold. Forests are expected to move north in latitude and upward in elevation. Pine forests at low elevation are likely to be replaced by woodlands and grasslands. These shifts in biome boundaries are expected to be large. It has been estimated that a temperature change of +3.5°C in the Rocky Mountain zone is equivalent to vegetation habitat moving 2,000 feet up slope or 200 miles further north (Ryan 2003).

Climate change will have considerable effects on forest growth, which may increase or decrease depending on tree age, species, site quality, and location. Within a given forest there will be changes in ecosystem structure due to changes in species interaction and competitiveness. In general, climate change is expected to lower productivity in the west, and Alaska with higher productivity in the Northeast, Lake States, and parts of the Southeast.

Carbon dioxide in the atmosphere can also limit growth. Experimentally increasing atmospheric levels of CO_2 have commonly shown that tree growth increases up to 20 percent on fertile sites. Growth declines over time since other factors such as nutrient availability or water then become limiting. Interestingly, forest growth has increased in many areas of the world due to added nitrogen from industrial pollution, which further complicates analyses of tree growth responses to climate change.

As forests are placed under increased temperature and water stress the most observable feature will be loss of vigor and increased mortality as species are no longer able to survive in the changed climate. This decline in health and increased mortality and decay will add substantially to carbon emissions—equivalent in some instances to that due to deforestation. As species die and are replaced, soils will be exposed, become warmer and subject to erosion, again releasing substantial amounts of carbon to the atmosphere and compounding climate change effects.

Already North American forests are showing evidence of stress and apparent effects of climate change. A prime example is the mountain pine beetle epidemic in lodgepole pine forests of British Columbia. Although this beetle is endemic and, overall, is a positive and useful component in the functioning of natural ecosystems, it appears that unusually hot, dry summers and mild winters have increased beetle attacks and in 2006 about 23 million acres were affected (BC Ministry of Forests and Range 2007). Of particular concern is that, due to climate change, the mountain pine beetle is likely to spread to Jack pine forests in Alberta thus causing potential for increased wildfire.

A second example is pinyon pine in the Southwest where in some states dieoff has reached 90 percent. The USDA Forest Service estimated in 2003 that about 3.8 million acres over six states were affected. Here again, the precipitous decline in pinyon pine is associated with climate change and drought. It seems that the winters have not been sufficiently cold to restrict build-up in bark beetle populations. In addition, the extensive tree mortality has been accompanied by a major decline of pinyon jays and other ecosystem changes. In evaluating the effects of climate change on forests, therefore, it appears that the area impacted by insects are greater than that affected by wildfire.

A third cause of catastrophic change in forest ecosystems is hurricanes. Increasing sea water temperature in the Gulf of Mexico is expected to cause increased hurricane frequency and severity. Again, in the context of climate change, the sudden removal of forests by hurricanes is likely to increase opportunities for species to invade that are more adapted to warmer conditions.

EFFECT OF CLIMATE CHANGE ON WILDFIRES

Lightning-caused fires have always been a major component of forest ecosystems in the West. In addition, it is well documented that Native Americans used fire extensively in controlling game, regenerating desired plants, and for preventing surprise attacks from enemies. Prior to the 1800s, it has been estimated that Native Americans in California burned about 4.5 million acres of wildlands annually (Stephens et al. 2007). The National Interagency Fire Center estimates that during the period 1825-1918 there were seven fires that were 1-3 million acres in extent. Although these historic fires were very large, they probably differed from contemporary fires which are more intense, crown fires that result in stand replacement. This difference is primarily due to past harvesting, regeneration, and fire suppression practices that have resulted, especially on national forests, in stands having a high proportion of shade-tolerant species, younger age classes, and higher density of smaller trees than were characteristic of forests prior to settlement. Similarly, major changes have occurred in plant species and structure of the nation's grasslands due to grazing.

The National Interagency Fire Center also reports that humans have had a major role in fire ignitions. In 2006, there were 96,380 wildfires of which 83 percent were human-caused and human ignitions exceeded lightning ignition in five out of 11 regions. Expressed in terms of area, 9.8 million acres burned in 2006 of which 45 percent were human-caused with human ignitions exceeding lightning ignitions in eight out of 11 regions.

Clearly, then, it will be difficult to separate the effects of climate change on wildfire occurrence from the effects of rapidly increasing human populations in forested areas and the change in forest conditions due to past forestry, urbanization, and other activities.

Never-the-less, weather is fundamentally important in influencing the incidence and severity of wildfires, which due to climate change are expected to increase in frequency and intensity (Keene et al. 1997, USFS PNW 2004). One estimate is that wildfires will increase 50 percent by 2050 and double by 2100, with estimates varying depending on the climate models used (Liu et al. 2004).

Higher temperatures and low humidity are important because they increase the drying rate of fuels and increase the likelihood of drought and length of fire seasons. Increased wind increases the rate of fire spread. And climate change will likely increase the incidence of thunderstorms and lighting. However, some areas will no doubt experience decreased fire frequency. Areas of increased precipitation may moderate fire behavior, but greater vegetation growth may also add to wildfire potential. Further complicating predictions is that wildfires emit considerable quantities of particulates that result in short-term cooling by reducing solar heating. At the same time, wildfires exacerbate climate change by emitting greenhouse gases to the atmosphere. In 2005, wildfires in the U.S. resulted in 126.4 Tg CO_2 (140 million tons) being emitted to the atmosphere (EPA 2007).

Although interactions among climate change, vegetation, human actions, forest conditions, and insect and disease vectors are highly complex and uncertain, wildfires will certainly be a major factor accelerating species change and changes in plant distribution.

RESPONSIBILITY TO MITIGATE THROUGH FOREST MANAGEMENT

Since incidence and severity of wildfires are to a large extent influenced by human ignitions and forest conditions, it is important to consider the extent to which social sciences and forest management can contribute to both understanding and mitigating wildfire occurrence and intensity.

Monitoring climate change and forest conditions should be aimed at separating out the complex factors and interactions that result in wildfires. Since both growth and mortality on national forests greatly exceeds harvest resulting in a build-up of fuels, it would be prudent to consider treatments and incentives aimed at fuel reduction and using excess biomass for societally-needed products and energy production. The aim of such treatments on national forests would be to create, as far as practicable, forest densities more suited to current societal usage so that forests can better withstand the inevitable increase in wildfires that climate change will cause.

The CHAIRMAN. Thank you very much for your testimony.

Dr. Swetnam, we're glad to have you here. Please go right ahead.

Mr. SWETNAM. OK.

STATEMENT OF THOMAS SWETNAM, DIRECTOR, LABORATORY OF TREE-RING RESEARCH, AND PROFESSOR OF DENDROCHRONOLOGY, UNIVERSITY OF ARIZONA, TUCSON, AZ

Mr. SWETNAM. Chairman Bingaman, thank you so much for inviting me, and thanks to the ranking member, Senator Domenici.

By way of a little further introduction, I'm a professor of dendrochronology, which is the use of tree rings. We use the tree rings to study all kinds of history—climate history and ecological history and human history. Just a little personal note, also, I just want to say I—in addition to being a scientist for the last 20 years, I was a firefighter before that for several years. My father was a district ranger with the U.S. Forest Service for 35 years in New Mexico, and he taught me quite a lot about fire. He's been on my mind recently. He passed away a year ago, and, last night, watching Ken Burns's new war documentary, he came to mind, also.

Key points of my presentation here. I think you may have some handouts here, where you can see these graphics* a little more detailed. The first key point is that warming temperatures clearly have begun to influence fire activity in the western United States, with increasing numbers of large fires well correlated with both the interannual and the decadal changes that we see in temperature throughout the western United States. Now, we also see—we know that there are many other factors involved, including forest changes, increasing fuels, and also things like invasive species; cheatgrass in the Great Basin, for example, have also been involved. We also know that more people have been moving into these environments. So, all of these things are coming together in a kind of perfect firestorm.

That's the main point I'm going to make, and I'm going to hold that til the end of my presentation.

I'm going to talk a little bit about the historical perspective of fire—using tree rings and other records, we've been able to look far back in time—and to see what the role of fire has been in forest ecosystems over centuries and millennia. Several things that we see right off is that there's a lot of variability, historically, with some ecosystems not burning very frequently in the past, and some ecosystems having burned very frequently, until recent century. About 100 years ago, with the beginning of livestock grazing and then fire suppression, the fire regimes were disrupted in some forest types. We also see, from the historical record, that fire and climate were very well correlated going way back in time, so warming temperatures and droughts have been related to big fires for a long time.

I'm also going to talk a little bit about some natural climate factors that control forests and also fire activity, particularly the El Nino southern oscillation and these other two major ocean and atmosphere patterns of Pacific decadal oscillation and the Atlantic multidecadal oscillation.

Fire-scarred trees are one of the main ways that we get these long histories of fire from our paleoecological records. One of the main things we see on these scars—there are injuries at the bases

*Graphics have been retained in committee files.

of trees, and what we see is that, very commonly, there are many fire scars right until about 1890, and then a lack of fire scars for about 100 years. The last fire scar typically occurs when livestock grazing began—that's when the sheep and cattle begin to eat the grasses which were carrying fires—and then fire suppression by government agencies.

We also have been able to use long records, like charcoal in lake sediments and bogs. This is an interesting example of a core sediment—core sample from a bog at Valles Caldera National Preserve, which Senator Bingaman knows well. This bog shows charcoal presence all the way down 9,000 years, and it's only the top 20 centimeters of this core has no charcoal on it. That's the last century. So, it's a truly extraordinary change in the last 9,000 or 10,000 years, with lack of fire relation to fire suppression.

We also see from these records that there's a lot of variability, as I said. In some forest types—the wetter, cooler, higher-elevation forests, like spruce and fir and lodgepole pine, in Idaho and Montana—typically, the fires only occurred every 100 years to 400 years in those forest types before this century. You move over to the Ponderosa pine-dominated ecosystems, and there you had surface fires burning once or twice per decade, in some cases, in the Southwest. So, very different kinds of fire histories. It's likely that fire suppression has had much less effect in the wetter, cooler types, because they were longer intervals anyway, so fire suppression has had less influence there.

We have a long history of fire from giant sequoias, more than 3,000 years of fire-scar record from the Sequoia National Park and King's Canyon. We are able to get fire-scar records there and compare them with our tree-ring records of temperature. So, here we have a fire-scar-based history from these trees, and then we have ring-width patterns from bristlecone pine and foxtail pine. These are trees growing right at tree line, and their growth is controlled by how warm the growing season is. So, if it's a very warm year, you get a thick ring; if it's a cold year, you get a narrow ring. When we compared the foxtail pine and bristlecone records, you see this match—a pretty good match between the fire-history record and the temperature record over the last 1500 years.

One thing I'd point out is, about at the very end of the record, you see that the fire-scar record drops off, with very few fires after about 1850. That's when fire suppression began. But you see the temperatures rising up in the tree-ring record. My colleagues and many other dendrochronologists have put together records like this from around the northern hemisphere, and they show that this warming episode in the last decade or so is warmer than the temperatures over at least the last 1,000 years, including this medieval warm period here, which was quite warm, and there was a lot of fire.

Now, the El Nino and these other ocean atmosphere patterns are also important to climate and fire. I'm not going to go into detail on this. There's quite a bit more of this in the written testimony, of how they're important. We know a lot more about the El Nino and La Nina than we do this Pacific decadal oscillation or the Atlantic multidecadal oscillation. But we are learning that they control interannual to decadal-scale climate patterns. One of the things we see when we look at the El Nino record relative to our tree-ring, fire-history, and also documentary records, is that there's a strong relationship in the Southwest with the El Nino. Typically, El Ninos bring more moisture to the Southwest and also to the Southeastern United States, and there's less fire. But, at the same time, there is an inverse relationship in the Northwest—so, the northern Rockies and the Pacific Northwest is usually dry during El Ninos, and there's more fire—and that the converse is true of La Ninas. The pattern tends to switch back and forth. This is of some use, actually, for potential predictive uses, is—are these patterns over the long term.

The other thing I would say is, this Pacific decadal oscillation has some effect on climate in the West and also fire activity, and it's shifted to a state that's more typical of drought; that is, colder ocean temperatures. At the same time, the Atlantic—North Atlantic has shifted to warmer temperatures, which is also more conducive to drought. So, there are some changes that are not good right now with regards to fire.

But these don't seem to explain the big fires that we're occurring—we're seeing. Over the western United States, we've had more and more of these recordbreaking fires, over 100,000 acres—one in Oregon, you know, the Biscuit Fire Complex in 2002, a half a million acres, and Rodeo-Chediski, in Arizona. This year, actually, we may be breaking records, I believe, in Idaho, Utah, Nevada, and maybe California, as the year goes on, with more large fires that are really extraordinary.

When we look at the total record of fire over this past 30-some-odd years, this is the paper we published last year with my colleague Tony Westerling in Science, where we looked at numbers of large fires over the whole West. We were focusing on forest landscapes on Federal lands, primarily. You can see a clear trend of rising numbers of large fires. In fact, a 300-percent increase in the last decade and a half or so, relative to the prior period.

If you go to lower elevations, there's not such a clear trend. The lower elevations, below 5,000, 4,000 feet, there's not such a clear trend of increasing numbers of large fires, except maybe, in the recent years, there may be more and more of those large fires since 2003.

You can see a real shift here, if you look at the size of these pie charts*. Since 1986, there's 6.7 times more area burning. Notice that the size of the red portion, which is area above 5,500 feet, there's more high-elevation forest burning, which is leading us to this conclusion that this is not just fire suppression, this is also climate variability. Remember, it's those high-elevation forests that only burn at long intervals and have less of a fire-suppression effect.

The trends are very similar. When you look at temperature in relationship to the area-burned record, there's a very good correlation there, the interannual. Then, there's a nonlinear relationship, as well, perhaps, as temperature is rising, numbers of fires is increasing faster and faster.

*Charts have been retained in committee files.

Then, last, there's—when we look at the record, there's many more of these early snowmelt years. That is, spring is arriving earlier. There's many more of these early snowmelt years in the last decade than in the previous two decades. If you sort out when the big fires are occurring, they're occurring in those years when there's early snowmelt.

Finally, I don't mean to simplify this at all. There's many different factors involved, besides climate. There's changing fuels in forest structures, and invasive species are very important—cheatgrass in the Great Basin. In southern Arizona, we have a problem with this African buffel grass that's burning, and now causing more wildfire in the Sonoran Desert. On top of that, we have the warming conditions and people—more people moving into these landscapes. So, there's a whole suite of problems coming together for our fire problems.

Thank you.

[The prepared statement of Mr. Swetnam follows:]

PREPARED STATEMENT OF THOMAS SWETNAM, DIRECTOR, LABORATORY OF TREE-RING RESEARCH, AND PROFESSOR OF DENDROCHRONOLOGY, UNIVERSITY OF ARIZONA, TUCSON, AZ, AND ANTHONY L. WESTERLING, ASSISTANT PROFESSOR, ENVIRONMENTAL ENGINEERING AND GEOGRAPHY, UNIVERSITY OF CALIFORNIA

Chairman Bingaman, ranking member Domenici, and members of the Committee, I thank you for the opportunity to be here and testify on the matter of climate change and wildfires. My name is Tom Swetnam, and I am Professor of Dendrochronology (which is the study of tree rings) and Watershed Management at the University of Arizona. I am also Director of the Laboratory of Tree-Ring Research. Please note that my co-author of the written testimony is Dr. Anthony Westerling of the University of California, Merced. Tony is Assistant Professor of Environmental Engineering and Geography.

Senators Bingaman and Domenici may recall that we met and talked some years ago when I was appointed by President Clinton to the first Board of Trustees of the Valles Caldera National Preserve in New Mexico. Part of the reason I was appointed to that Board was because I was raised in northern New Mexico and I know that landscape very well. I have spent a great deal of time studying forests and fires in New Mexico and elsewhere in the West—originally as a fire fighter, and for the past 27 years as a scientist.

EXECUTIVE SUMMARY

Fire is a natural and necessary part of most terrestrial ecosystems. Prior to Euro-American settlement of North America, enormous areas burned as a consequence of lightning and Native American-set fires. The largest areas burned during the warmest and driest years. However, recent fires and damages caused by them are often outside the historical range of variability, and in some cases these impacts are ecologically unsustainable. This is particularly the case in many ponderosa pine-dominated forests and drier mixed conifer forests that formerly sustained primarily frequent, low-severity surface fires. The changes we see in some of these areas now are a consequence of a "perfect fire storm"—the combination of a number of causes contributing to catastrophic fire. The ecological and watershed damages caused by some of these fires are extreme and probably irreversible. The threats to human lives and properties are increasing.

The key points of our testimony are:

- Increasing numbers of large forest fires and total area burned in the western United States are significantly correlated with warming and drying trends.
- Historical land uses and management practices disrupted natural fire patterns in many western forests about a century ago, and these changes have led to dense forests and fuel accumulations that are also contributing to unusually large and severe fires in some places.
- Natural climate oscillations (for example the El Niño-Southern Oscillation) have also affected fire activity, but they do not fully explain the recent surge in burning.

- Studies using coupled global circulation and wildfire models consistently predict increased burning under scenarios of future increased greenhouse gas concentrations.

LONG-TERM PERSPECTIVES OF WILDFIRE AND CLIMATE HISTORY

From many detailed studies of fire scars in tree rings, sampled in ponderosa pine-dominated forests across the West, we have learned that low severity forest fires used to burn through the understory of these forests at intervals of about 5 to 30 years. This pattern of repeated burning continued for centuries until the late 1800s, when Native American burning practices were eliminated, large herds of sheep and cattle were introduced, and government-sponsored fire suppression began. My colleagues and I have developed very similar histories of frequent, low severity forest fires from fire scars and tree rings in giant sequoia trees in California, extending back to 3,000 years before the present (Figure 1)*. Other scientists and colleagues have drilled core samples from wet meadows, bogs and lake bottoms in many places in the west. They have reconstructed more than 10,000 years of fire history by carbon-14 dating and counting the number of charcoal particles of various sizes deposited in the sediments.

Fire history studies typically find a broad range of past fire frequencies in different forest types and elevations. As you might expect, the relatively wet forests of high elevations and more northerly latitudes generally show much longer intervals between past fires (on the order of 100s of years) than the relatively dry, lower elevations where ponderosa pine dominates. Although the frequencies of past fire varied substantially from one ecosystem type to another, a general finding has been that the changes in past fire activity were well-correlated with independent reconstructions of climate history. In particular, increased fire occurrence corresponded with warming and drying conditions. Our studies of giant sequoia fire scars and comparison with temperature-responsive tree-ring width chronologies shows that these long-term associations have existed for many centuries (Figure 1).

Warmer, drier conditions are likely to promote drier fuels, which may be more readily ignited by lightning or people. Drier fuels also carry fire more rapidly across the landscape. Another general pattern of wildfires is that, the longer the typical interval between fires, the more severe and intense the fire when it occurs. For example, lodgepole pine and spruce-fir forests of high elevations in the Northern Rockies typically burned only once per 150 to 400 years. When they did burn, they burned intensely during hot, dry years. Recall the 1988 Yellowstone fires, for example. In contrast, Southwestern ponderosa pine and relative dry mixed conifer forests (like giant sequoia groves) usually burned once or twice per decade for thousands of years, and these fires were typically of low severity. The key factor here is fire frequency. At low fire frequencies fuels accumulate in increasingly dense forests over long periods, while at high fire frequencies the fuels are consumed and open forests with little fuel accumulation are maintained. Hence, suppression of the frequent, low severity fires in forests where this type of fire regime predominated has led to unusually high fuel accumulations and increasingly large and severe wildfires.

Although warm and dry conditions were important to increased fire occurrence, another aspect of climatic control was also important, especially in the drier, lower-productivity forests. That is the role of prior wet conditions, which served to reduce fire activity and allow fuel accumulation. Our paleoecological and modern studies have indicated that wet/dry lagging patterns are important to regional fire patterns in some parts of the West, both in the past and today.

Based on these findings, it is evident that both climate variations and human land uses in the past have directly and indirectly affected forest fuels and fire frequencies. Despite local and sub-regional differences among ecosystems with different land-use histories, at the broadest-scale of the western states, including Alaska, increasing numbers of large forest fires in recent years are significantly correlated with warming and drying. I will come back to this key point about recent broad-scale trends in a moment, but first, I will briefly review what else we have learned about historical and natural climate and fire patterns from tree rings and documentary records.

MULTIYEAR TO MULTI-DECADAL CLIMATE VARIATIONS: ENSO/PDO/AMO

Just about everyone has heard of “El Niño” since the very large event in 1982 and 1983 resulted in worldwide climate effects. This general awareness marks a revolution in climatology that has occurred in the past few decades. Thanks to many

* Figures 1–6 have been retained in committee files.

observations of ocean and atmosphere patterns and computer models, we have increasing knowledge that ocean surface temperatures, related atmospheric pressure patterns, and the jet streams have tremendous effects on climatic patterns over the continents. These patterns go through changing "cycles", or oscillations. The word "oscillation" is used because the intervals between the highs and lows, and the magnitudes of the highs and lows are highly variable, and not fixed like the cycle of a pendulum clock. The El Niño/La Niña pattern is also known as the El Niño-Southern Oscillation—or ENSO, for short. ENSO is the best known of the ocean-atmosphere oscillations, and it operates over variable periods of about 2 to 7 years. ENSO appears to most strongly affect rainfall and forest fire patterns in the West and Southeast, but two other ocean-atmosphere oscillations have also been identified in recent years that appear to be quite important: The Pacific Decadal Oscillation (PDO), and the Atlantic Multi-decadal Oscillation (AMO). As implied by the names, these last two oscillations operate on decadal time spans, that is, the high and low parts of the oscillations persist for 10 years or longer.

From a combination of centuries-long tree-ring records, and careful analyses of modern climate histories and documentary records of forest fires from government agencies, a number of studies have revealed the following key findings:

- The ENSO has important effects on wildfire occurrence, especially in the Southwest and Southeast. In these regions, El Niño typically brings increased cool season rainfall, and forest fire activity is reduced in the subsequent fire season. Conversely, during La Niña events conditions are generally drier and wildfire activity is increased. These patterns have some predictability to them months in advance of the fire season. Consequently, the state of the ENSO is now being used by the Predictive Services group at the National Interagency Fire Center for developing seasonal wildfire "outlooks".
- The Pacific Northwest and northern Rocky Mountains (in the U.S.) typically have an opposite, though weaker response to ENSO relative to the Southwest and Southeast. This means that during El Niño events it is typically drier in these regions and more fires occur, and during La Niña events it is wetter and fewer fires occur. However, it appears that during some strong La Niña events, it is generally dry throughout the West and Southeast. The typical inverse pattern of ENSO response between the Northwest/Northern Rockies and the Southwest/Southeast has potential strategic applications in the allocation and pre-positioning of fire fighting forces, and/or emphasis on prescribed fire use in the different regions.
- The Pacific Decadal Oscillation was first noted, in part, because of its important effects on salmon fisheries in the Northwest. The pattern itself is measured by sea surface temperatures in the Pacific Ocean, especially the northern part. Recent studies indicate the most pronounced sub-regional effect of the PDO is in the Pacific Northwest and northern California, both in terms of rainfall patterns and forest fires. However, there are interesting interactions of the PDO and ENSO affecting fire and climate across the West, as might be expected because both oscillations are based on changes in the Pacific Ocean. For example, drought conditions and more wildfires appear to occur in parts of the West during combinations of positive (warm) phases of the PDO and negative (cool, La Niña) phases of the ENSO. Again, there may be some predictive utility of these patterns for long-term "outlooks" and forecasting wildfire hazard.
- Findings to date suggest that the positive phase of the Atlantic Multi-Decadal Oscillation (AMO), generally corresponds with more widespread droughts and wildfires in the western US than during the negative phase. These associations are less well understood than the ENSO and PDO patterns.
- Finally, an important implication of the PDO and AMO patterns described above is that both of these ocean-atmosphere patterns appear to have shifted to states that favor more drought and wildfire in some sub-regions of the western US (i.e., cool PDO, warm AMO phases). These climate patterns may have contributed to the recent surge in area burned and increased numbers of large fires in the west, but it is unlikely that they are primarily responsible. A chief reason for this conclusion is that fire-promoting decadal phases of the PDO and AMO occurred before in the past century (e.g., the 1950s and 60s), but we did not see the magnitude of increases in burning that we have witnessed recently accompanying the warming.

MODERN CLIMATE AND FIRE TRENDS

Most of the climate-wildfire patterns I have just described have been studied extensively using a combination of paleoecological, paleoclimatic, and modern documentary records. Although the paleo-records are insightful, and are the best data we have for long-term perspectives on climate and wildfire, the recent several decades is the period of time when we have the most comprehensive records for assessing climate and fire patterns. Government agencies have been keeping records on wildfire statistics since the early 1900s, but unfortunately, these records are often lacking in completeness and reliability before the 1970s. Nevertheless, this recent period has proven useful for assessing contemporary changes.

Our current understanding of recent wildfire changes in North America derive from a set of studies in Canada, Alaska, and the Western US. First, I am going to summarize the findings of the study led by my colleague Tony Westerling that we published in July of last year in the journal Science, along with our co-authors Drs. Dan Cayan and Hugo Hidalgo from Scripps Institution of Oceanography, University of California, San Diego. Next, I will briefly mention the published findings on climate change and wildfire in Canada, Alaska, and elsewhere.

The Westerling et al. (2006) study utilized fire occurrence records for the period 1970-2003 from federal lands in the western US, and the time series used was the number of large wildfires (i.e., exceeding 400 hectares, or about 1,000 acres). Most of the area (80%) included in this database was above 4,500 feet elevation. Hence, these data primarily reflect forested landscapes across the western US. It is important to note that these data do not necessarily reflect general wildfire patterns in the many lower elevation, non-forest ecosystem types.

The main findings are as follows:

- There is a clear upward trend in the area burned and numbers of large forest fires in the western US, especially since the mid 1980s (Figure 2, Figure 3, upper two plots). The area burned by large forest fires is 6.7 times higher in the latter period 1987 to 2003 than in the earlier period from 1970 to 1986 (Figure 4). Note, however, in a separate compilation of lower elevation, non-forest fire occurrence data that no clear trend through 2003 shows in these data (Figure 3, lower two plots). It is particularly notable that the largest wildfires in 50 to 100 years have occurred in a number of states in the past five years (i.e., Arizona, Colorado and Oregon in 2002, Texas 2006, Idaho and Utah 2007).
- The trend and year-to-year variation in numbers of large forest fires is well-correlated with spring and summer temperatures over the same time period (Figure 5).
- The trend and year-to-year changes in number of large forest fires generally matches changes in the timing of spring onset, as indicated by the timing of peak runoff from extensive streamflow data in the western US. Many more large fires occurred during years in which spring arrived relatively early than during years when spring arrived relatively later (Figure 6). Additionally, there are significantly more early spring occurring years after 1986 than before that time.
- The largest increase in numbers of large wildfires has occurred at middle elevations, with much of the increase above 5,500 feet (Figure 4). About 60% of the large fires in the recent period occurred in the Northern Rockies and another 18% in the Oregon Cascades, Sierra Nevada, and northern California. This concentration of many large fire events in northern mountain areas in relatively wet forest types suggests that forest structure changes because of past land management may be less important in these areas than the effect of warming and earlier springs. That is because these northern, wetter areas contain a large proportion of spruce-fir, lodgepole pine, and other forest types where natural fire intervals were already quite long (centuries), and so fire suppression has had less effect there on changing fuel accumulation patterns.

In addition to the Westerling et al. study, several other recently published studies point to the importance of warming temperatures in observed trends of increasing fire occurrence in the western US including Alaska (McKenzie et al. 2004, Duffy et al. 2005, Kasischke and Turetsky 2006), Canada (Flannigan et al. 2005, Gillett et al. 2004),), and possibly Russia (Goldammer 2006). Furthermore, a number of these studies have employed global circulation model (GCM) simulations of future climate under increasing greenhouse gas scenarios as input to wildfire response models. The GCM-fire studies have consistently concluded that increasing areas burned are to be expected in coming years and decades (Brown et al. 2004, Fried et al. 2004, Gillett et al. 2004, McKenzie et al. 2004, Flannigan et al. 2005, Westerling and Bryant 2006).

Finally, both the Arctic Climate Impacts Assessment (http://www.acia.uaf.edu/), and the ecosystem impacts assessment of the 2007 Intergovernmental Panel on Climate Change Report identified increasing wildfire occurrence as a likely response to global warming. The 1,000-plus member Association for Fire Ecology (composed of fire scientists, students, and fire managers) recently issued a declaration on climate change and wildfire, strongly expressing their professional and scientific concern over current and anticipated wildfire responses to regional and global warming http://www.fireecology.net/pdfs/san—diego—declaration—final—29—nov—2006.pdf).

CONCLUSION

Increasing wildfire problems are related to an interacting set of causes, including (1) increased forest density and fuels because of a century of fire exclusion, (2) warming climate and increasing frequency and magnitudes of droughts, (3) invasive species, such as cheat grass and African buffel grass allowing fires to spread more readily across elevation gradients, and (4) the increasing presence of people and built structures in these areas that are fire prone (i.e., the wildland-urban-interface).

Although the combination of causes listed above exist together on some landscapes, it should be emphasized that there is tremendous variability across the US, and not all of these causes and problems are present everywhere. Indeed, there are some landscapes where warming trends apparently have had little effect, so far, on fire activity. Some forests and other ecosystem types have been unaffected or little affected by fire suppression. Moreover, the importance of invasive grasses (or other non-native species), urbanization and its consequences to habitat fragmentation, and increasing ignitions by humans are paramount in some areas, and these factors may exceed the effects of climate change now and the foreseeable future.

"Natural" oscillations of the climate system, such as ENSO, PDO, and AMO will continue to operate and have important effects on drought and wildfire in the US. These ocean-atmosphere patterns impart some degree of predictability to climate and wildfire hazard months in advance of fire seasons. For example, the most recent National Oceanic and Atmospheric Administration reports on the ENSO status indicate an increasing trend toward La Niña conditions, which could spell increased drought and wildfire problems next summer, especially in the Southwest and Southeast. The effects of long-term warming trends caused by greenhouse gases on ocean-atmosphere oscillations are not well understood. Some modeling studies addressing these questions are not encouraging, suggesting that increased amplitude of ENSO might occur. Alternatively, ocean and atmospheric patterns might lock into states promoting more-or-less permanent "dust bowl" like conditions in the Southwest (Seager et al 2007).

A recent influence of warming climates and increasing drought is apparently manifest in the rising areas burned and occurrences of "megafires" (>100,000 acre burns) in many places across North America and elsewhere. Under increasing greenhouse gas scenarios, the available evidence points to a likely continuation of rising areas burned, more megafires, greater damages and costs incurred, and additional human lives lost. Not least of the mounting concerns about these trends is the likely effect of releasing more carbon into the atmosphere, and the possibility of shifting temperate and boreal forests from a net carbon sink to a net source.

The CHAIRMAN. Thank you very much, all of you, for your testimony.

Let me start, and we'll do 5-minute rounds of questions here.

Dr. Swetnam, let me start with you. It would seem that, based on the charts—and I didn't pick up all of the information on each of these charts that you put up, but maybe you could interpret it a little bit for us. To what extent can we make policy about which ecosystems we ought to be concentrating our forest restoration dollars on——

Mr. SWETNAM. Right.

The CHAIRMAN [continuing]. As a result of the research you've done? I don't know all the factors that go into deciding where we put that forest restoration money, but if we were going to try to put it where it would do the most good, based on your research, what would you conclude?

Mr. SWETNAM. I think it is very important to be cognizant of the different kinds of fire regimes that occurred in the past, and, indeed, we see in these higher- elevation forests, that they only burned at very long intervals in the past, and there's likely to be less changes in those places because of fire suppression. So, the really big problems with regards to forest structure and ecosystem changes are in those forest types and other ecosystem types that burn frequently in the past, but then those fire regimes have been disrupted. So, commonly it's Ponderosa pine—Ponderosa-pine-dominated ecosystems in the West, and other dry mixed-conifer forest types—as where there's been the greatest structural changes and the greatest shifts in fire behavior and fire risk, I think.

So, those have a real key, I think, priority for treatment. Of course, it's also where people have moved in and—people have, you know, moved into harm's way—are a lot of these same landscapes. So, I think there is some basis of using the fire history, our understanding of these different fire-regime types, to focus the energies and the efforts where the ecosystems have changed the most, and where the fire behavior has shifted outside of its historical range of variability the most.

The CHAIRMAN. To your knowledge, is that kind of a calculation being factored in to decisions about forest restoration priorities, at this point, or not?

Mr. SWETNAM. To some extent. I believe some of the mapping work that's being done—for example, LANDFIRE, which perhaps Dr. Conard could talk about a little bit more—there are some large-scale mapping efforts for the whole United States that are aimed at identifying which ecosystems have changed the most, and which ones—which—where are the fuels located? I think that is one approach to getting at this, is understanding where the high priorities are. But there is a need for more work on this, I think, and more use of historical information, to try to zero in on where the changes have been most severe.

The CHAIRMAN. Because where those changes have been most severe is where you believe the forest restoration work would do the most good?

Mr. SWETNAM. That's right.

The CHAIRMAN. That's what——

Mr. SWETNAM. That's right.

The CHAIRMAN [continuing]. I'm taking you to say.

An issue that I've raised with some other witnesses in earlier hearings is this whole business—you know, one of our policies here in Washington is that we budget fire suppression funds on the basis of the average over the last 10 years. Whatever was required over the last 10 years, we take the average, and that's what we budget for the next year. When I look at your charts, it seems like there is a fairly clear pattern of increased fire activity. I think Dr. Conard talked about how—I think you said six of the seven worst fire seasons were—since what year was it?

Mr. CONARD. Since 1980. Oh, I'm sorry—actually, a high percentage of them have been in the past 10 years, so I have another graph here that shows that in the past 10 years we've had 5—well, we've actually had, now, 7 years, over 7 million acres a year burning.

The CHAIRMAN. I guess the obvious question is, Does it make any sense, given this pattern of increased fire activity that we've experienced and are continuing to experience, to continue budgeting, on the assumption that an average over the last 10 years will get us where we need to be? I don't know, is that something you've looked at, Dr. Swetnam?

Mr. SWETNAM. I haven't really looked at the economics of this. I would defer to Dr. Conard and——

The CHAIRMAN. All right.

Mr. SWETNAM [continuing]. Dr. Bartuska.

The CHAIRMAN. Dr. Bartuska, did you have any thoughts on that?

Ms. BARTUSKA. I think you've hit one of our more significant challenges—budgeting based on the increasing level of fire suppression is really eating into our overall programs. What we're trying to look at is different types of approaches, risk-based management approaches, being able to reduce our costs, being able to put our efforts into greater priority so that we have—where we have the greatest risk, where we have the greatest probability of success. But the escalating cost is something that we're very concerned about, and, I know, has been talked about in various hearings in the last several months.

The CHAIRMAN. All right. My time is up.

Senator Craig.

Senator CRAIG. Mr. Chairman, based on what Dr. Helms said, with fires moving north, I would suggest we invest in Idaho and not in New Mexico.

[Laughter.]

The CHAIRMAN. Based on what Dr. Swetnam said——

[Laughter.]

The CHAIRMAN [continuing]. I think he said it's a waste of money up in Idaho, and——

[Laughter.]

The CHAIRMAN [continuing]. We really should concentrate in the Southwest.

Senator CRAIG. All right.

The CHAIRMAN. That's what I thought I heard.

Senator CRAIG. I was just trying to put it in the context of those who've testified today.

Let me thank all of you very much for your testimony. I read a great deal of what you do, and spend a good deal of time with this issue. Thank you for these reports, coming out, and the University of Arizona, their work.

What I said earlier—and let me do this now—I want to make a statement, because, you know, I think it's very consistent, but it takes us to a slightly different dimension, Mr. Chairman, as it relates to how we look at what we're doing, or not doing.

I say that in this context. Earlier this year, we had a hearing to discuss wildfire management and preparedness. During that hearing, I discussed the Angora fire at Lake Tahoe. The reason this was a significant time to discuss it, Mr. Chairman, was because, about a decade ago, this committee, along with Senator Reid and others and I, looked at the dead and dying problem of Tahoe, and we put the resources into the budget, but we were denied activity in that watershed by certain interests, who simply said, "No, you're not going to come in and thin and clean and change the character of that forest." That was then. So, what happened this year was, 254 homes in the biggest travesty—that was potentially preventable.

Dr. Swetnam continually talks about adding man to the ecosystem. Those large homes that we're seeing spread across the West right now definitely change things.

It's estimated that 90 percent of the trees in that fire scenario, in Tahoe, burned. Now, that's a—3,100 acres. It released 190,000 tons of carbon dioxide. Right now, there are two fires burning in Idaho that are 100 times the size of that fire. The Cascade Complex still burns, at 300,000 acres. The East Zone Complex still burns, at 300,000 acres. It's an unimaginable release of those two release that is phenomenal in carbon into the atmosphere.

So, where do we stand now? Mr. Chairman, over a century ago, to intervene on behalf of nature, we decided to make a stand against wildfire. Many folks here today have testified to that. We took fire out of the equation, whether it was with man's presence or with grazing, or a variety of other activities that were human-induced, and we replaced it with land management.

Now that we are not able to actively manage our public lands, we have taken both out of the equation. But the problem is, man has more intensively come to the land by his presence, and those—and so, to simply step back and say, "Let it burn," is no longer possible. We spent $130 million in Idaho alone this year on fire. Part of it was to save a great nationally known resort, called Sun Valley. We had to save it, or we would have lost tens of billions of dollars worth of property. Seems to me that we've rejected land management, and nature is replacing it with fire in this scenario.

I don't know about the folks in your State, Mr. Chairman, but I know that the folks in my State got a very bitter lesson this year. Here's why they got the lesson. In 2004, Idaho was one of the cleanest States in the Nation. We released 15,000—15.56 million metric tons of CO_2 in Idaho in 2004. This year alone, by fire, we released 12 million metric tons of CO_2. So, for all of the commercial and industrial and residential and transportation and electrical power, it was minuscule. My State was nearly gray all summer, because its skies were filled with smoke and with carbon.

Let me go on, just a little more. Fires are lending—are leading producers of CO_2 in the environment. On average, 6 million tons of CO_2 are released for every acre burned. Up to 100—excuse me, 6 tons—up to a 100 tons of CO_2 per acre can be released, depending on the intensity of the fire, the number of trees per acre and so on and so forth. To date, roughly 8.4 million acres have burned in the United States, meaning a—at least 50 million tons of CO_2 have been released due to catastrophic fire.

Last year alone, 10 million acres. We've had that debate about what was the bigger year. I was out in Idaho in August, saying, "It's one of the greatest fire years ever," and a prominent person in the Forest Service called me and said, "Larry, you're wrong. We had much bigger burns before the turn of the century than we have today, but it's the decade that we're in, where we're having the largest burns of recent memory." It's of recent memory that we're talking about. Dr. Conard just talked about the last decade and these acreages. But we were burning at, or above that, before the turn of the century.

Here is the point I want to get to. If you stop burning in the forest today, if you stopped at the 8 or 10 million burned, and backed it off substantially—and I'm talking about climate change now, Mr. Chairman, your struggle, and others, to look at comprehensive climate change legislation that might produce a result—that would be roughly the equivalent of removing 12 million automobiles from the roads. If we stopped the forests from burning today, it would be equivalent to removing 12 million automobiles.

Now, you and I both know we can't remove 12 million automobiles. But if we decided to engage fire once again, both in stopping it, where we can, and creating a healthy forest environment where we could—if we were dedicating way more than we are now to healthy forests—my guess is, we would come closer to removing those automobiles from the road, in a sense of pollution, than ever before.

Now, I've gone on beyond my time. I'll add the rest to the record.

Senator CRAIG. But we know the triangle of fire, Mr. Chairman. We know that it's oxygen, we know that it's heat, and we know that it's fuel. We have great scientists out there working on it. But our hands are tied today because we do not have the political will to change the equation necessary to do one of those three things in the triangle, and that's to remove the fuel. If we had the political will to intervene and engage active management again to remove the fuel, we change the equation dramatically as it relates to fire, we change the equation to a healthy forest coming earlier than 2035, we change the style of sink that brings us back to a much more positive sink for our healthy forests than a negative sink.

In 2000, I was at The Hague stopping the Clinton administration—and this just isn't politics, this is reality of climate change at that time—from trading off our ability to use our national forests as sinks. We stopped 'em. We said, "No, you don't go there." It's one of our great options in climate change, is to re-create a healthy forest environment, and to do so that it can once again sink.

I'll close by saying this. As we work, as you struggle, you and Senator Specter, to—and you've been thoughtful and workable; and, potentially, the work you're doing has some application—but when? Would you like to move 12 million automobiles off the roads? You do that by stopping our forests from burning, short term. But, long term, you create a much healthier environment in which those forests begin to sink and grab up the carbon in the atmosphere and become a positive force instead of a negative force. I think that makes good sense. We ought to be at that business.

Thank you.

The CHAIRMAN. Senator Wyden.

Senator WYDEN. Thank you.

I thank all the panel. It's been an excellent afternoon.

I think it's obvious that Senators understand that we are dealing with a worsening spiral. We've got these hundreds of thousands of acres, in the West, of, you know, choked second-growth plantation forests. This leads to more fires. That increases global warming, which, in turn, worsens the fires. So, we have this spiral that we're dealing with.

I'm interested in hearing your thoughts about what the barriers are to active management. Now, that's what we have worked very hard on, as a part of the forest health legislation, to address. I've heard litigation is always cited. As far as I can tell, most of the litigation involves issues relating to old growth and various matters involving, you know, timber sales, and not barriers with respect to getting thinning projects off the ground.

But I'd like to go right down the line and get a sense of what each of you thinks are the barriers to active management. That's what we want, that's what we think is critical to get on top of this issue of cleaning out overstocked plantations.

So, Dr. Bartuska—let's just go down the row—barriers to active management?

Ms. BARTUSKA. Speaking, of course, as the head of our research organization, our real focus is on, How do we make sure we have the right tools in the hands of the managers to make the best decisions they have? The subject of wildland fire and its interaction with climate change, what we're hearing from the people on the ground is, they need to know, What are adaptation options? What can they do about these changes that are taking place? What do they need to do to be able to manage for a resilient forest that allows for multiple stresses? Then, what are the mitigation options they have with regard to carbon and carbon management? So, what are the tools, and how do they get there with——

Senator WYDEN. What is the——

Ms. BARTUSKA [continuing]. In their context?

Senator WYDEN [continuing]. The backlog on those thinning projects? Because what I hear, at home, is that there's a huge backlog on the very, kind of, of thinning projects that you're talking about. Do you have information on that?

Ms. BARTUSKA. I do not know what our backlog on thinning projects is. We could certainly get that to you and provide it at a later time.

Senator WYDEN. Would ya? That would be very helpful.

Would your colleague like to add anything on this point? Barriers to active management, and the very projects that your colleague was talking about.

Mr. CONARD. I don't think I have anything specific to add, except just to emphasize that, while research is providing managers with some tools that they can use in making decisions on how best to manage, certainly the more we can understand, regionally and locally, the impacts of fire and better ways of managing fire and managing carbon, that that will certainly improve the manager's ability to do a good job.

Senator WYDEN. Doctor.

Mr. HELMS. Senator Wyden, I think the issue is not a matter of lack of knowledge or lack of technology. In my view, the issue is one of—it's a sociopolitical issue. It's lack of trust. It's different agenda of different parts of society. I think one of the solutions is to—we have to increase the amount of information that's available, and understanding of the natural processes so that society at large can better understand the issues that it faces. It's basically a matter of choice among very difficult and competing values. What—the job we have in front of us, I think, is to seek some sort of sensible balance that seeks to find some middle ground among the people who different views on the way in which the problem should be addressed.

Senator WYDEN. You're being too logical. We got 80 votes for the forest health legislation because we were trying to achieve exactly the kind of balance you're talking about, and it was built around the idea that we would get the resources for the thinning projects that Dr. Bartuska is correctly identifying. Those resources have not been forthcoming from the administration. I want to get the bipartisan spirit of the forest health bill back on track.

Dr. Helms.

Mr. SWETNAM. I——

Senator WYDEN. Excuse me—Dr.—excuse me—I got my "Dr.'s" mixed up.

Mr. SWETNAM. Yes.

Senator WYDEN. Thank you.

Mr. SWETNAM. I would echo some previous comments. I would point, sort of, what's lacking and needed more is more collaboration. I'll say a little bit more about that. We need more funding, obviously, to do a lot of this work. Ultimately, we need to begin working at broader scales. I, personally, don't think that we can thin our way out of this problem in the western United States. I don't think there's either enough funding or time necessarily to thin enough of the landscape actually to prevent the losses that we're worried about. So, one of the things we need to do——

Senator WYDEN. But you don't think thinning is unimportant.

Mr. SWETNAM. Thinning is important, especially smaller-diameter trees, focusing on the dense forests, the forests that have changed the most. Strategically, we can focus those in particular areas to protect communities. But, ultimately, we need to think, and start working at the landscape scales. By that, I mean watersheds and mountain ranges, tens of thousands to hundreds of thousands of acres. When you get to that scale, I think you're also talking about other kinds of treatments besides thinning. You've got—we've got to move back toward using fire as a tool in these landscapes, using prescribed fire. There is risk and there is smoke involved in doing that, but it is a less expensive alternative, and it's a more realistic one, an appropriate, ecologically. So, collaboration is how we're going to get there, is working with communities——

Senator WYDEN. No——

Mr. SWETNAM [continuing]. I think——

Senator WYDEN. No question about it.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

Senator Domenici.

Senator DOMENICI. Mr. Chairman, I went back to my office for a minute—and, you know, it's quite unique to go all the way back to my office, try to, all the way, walk back, but I watched you all, and you were so—it's so exciting that I came back.

[Laughter.]

Senator DOMENICI. I want you to know.

The CHAIRMAN. We appreciate it.

Senator DOMENICI. If anybody was watching the television, they would all have been watching, today.

The CHAIRMAN. They had to either watch us or Ahmadinejad, and we made it.

[Laughter.]

Senator DOMENICI. Good. Don't close me off too quick, here, because I really have come with a purpose, and I don't know that I can put it together here.

I'm directing my attention at you two ladies, because you, presumably, can go back to the Department and get information, and that's what I'm looking for.

Could you find out, and furnish the committee with, information, first, about the number of acres of forestland that are infested by bark beetles? Like in New Mexico, and up in Alaska? Could you get us information as to how many thousands of acres, or whatever, are infested? Could you get that for us?

Ms. BARTUSKA. Absolutely, we could provide that.

Senator DOMENICI. Second, could you get us information as to how much infested forest has been removed—over any increment of time—last year, for 12 months? Could you get us that information?

Ms. BARTUSKA. I believe so.

Senator DOMENICI. Could you do that? We'd like to have that.

Third, could you get us information as to how much of that kind of forest was sought to be cleaned, and was prevented by some kind of court action? Could you get that for us?

Ms. BARTUSKA. I can bring it back to the office and see what is available, certainly.

Senator DOMENICI. OK. Try that, if you would. OK.

Now, the Doctor mentioned cleaning the forests. Of course, he's a good environmentalist, so he's right on the ball. He knows what kind you ought to cut. He mentioned the right one so they wouldn't hook him for cutting the forest. What size are they supposed to be?

Mr. SWETNAM. Smaller-diameter stems we need to focus on in many forests, but not always, not in all cases.

Senator DOMENICI. What is the diameter? Tell me, so we'll have it, it'll be in the record. You stated it a while ago.

Mr. SWETNAM. This is also an issue. Should we fix on a particular fixed diameter? I don't think that's——

Senator DOMENICI. Didn't you, a while ago, use it, just as you spoke? You said——

Mr. SWETNAM. No. No. "Small diameter."

Senator DOMENICI [continuing]. Small diameter? Is that good enough?

Mr. SWETNAM. That's the—that should be the main focus of——

Senator DOMENICI. OK, small diameter.

Mr. SWETNAM. Yes.

Senator DOMENICI. Can you get that down, normally, when you have an argument, where you stop arguing and agree that "small diameter" means something? Will that normally happen?

Mr. SWETNAM. That's when the argument begins again, is, "Well, what do you mean by 'small'?"

Senator DOMENICI. I understand.

Mr. SWETNAM. Of course, it's—a small tree in Sierra Nevada is a huge tree in the Southwest.

Senator DOMENICI. Yes. Now, here's the point. Either you or—you don't work for the government, do you?

Mr. SWETNAM. No, sir. I work for the State of Arizona.

Senator DOMENICI. Yes, that's right. Used to go up there and take care of that ranch a little bit, and then got up there in northern New Mexico.

Mr. SWETNAM. The Valles Caldera National Preserve, yes, sir.

Senator DOMENICI. Yes. Then you stopped that and——

Mr. SWETNAM. Yes, I'm no longer on the board.

Senator DOMENICI. Right, we were just——

Mr. SWETNAM. I was on the first board that you—both you and Senator Bingaman appointed me to, and——

Senator DOMENICI. Yes, that's right. Then you didn't get appointed the second time. I don't want to talk too much about that.

[Laughter.]

Senator DOMENICI. Now, let me come back over here to you ladies for the last question.

Now, you know, you're supposed to be able to clean up the forest, I assume. We've even passed bills that focused on cleaning up the forest that is close to housing and buildings, and all you remember that. What was—we called it Happy Forests or something—Healthy and Happy—I named it "Happy," and you all called it "Healthy."

[Laughter.]

Senator DOMENICI. I said, why couldn't it be happy? When it burns and has a place to go, it's very happy forest.

But, anyway, what I'm trying get, along with these facts, is a set of facts that has to do with how much forestland do we clean up? Because I'm firmly of the opinion that the answer is: for the money we put out, and for what Congress says we should be doing, we're doing far too little cleanup of the heavy-laden—and I don't know how to define it for you to bring me back something, so let me try. How much forest acreage do we clean up in a period of time, using whatever prescribed means are legal and appropriate? Can you try to get me that?

Ms. BARTUSKA. Let me clarify "cleanup." Your first question had to do with insect or——

Senator DOMENICI. Yes, you're right.

Ms. BARTUSKA [continuing]. I would say, the bark beetle issues in the West. We certainly can lay out where those forests are that have been affected by beetle, and where we have the management. Then I'm also assuming where—we could provide—acres on where we have done fuels reduction projects associated with the Healthy Forest Restoration Act or, in general, where we have hazardous fuels. That, I think, is also very available.

Senator DOMENICI. Right.

Ms. BARTUSKA. Is that sufficient, sir?

Senator DOMENICI. Now, this last one——

Ms. BARTUSKA. OK.

Senator DOMENICI. Did you define the last one, about just cleanup?

Ms. BARTUSKA. I'm—what I'm—I was—or assuming that you were referring to both the insect disease issue and then fire issues as being a priority for our active management.

Senator DOMENICI. OK. If you can give us that, where it's understandable to us—what some of us would just like to know—is our sensitivity, that not much is going on, right or wrong, with reference to beetle-infected forests and with reference to forests that are overladen and going to burn, just as sure as we're sitting there?

Ms. BARTUSKA. I can say that we—since the beginning of the National Fire Plan, we have treated 200 million acres with hazardous fuels reduction, so we—we feel like we have had some accomplishment.

Senator DOMENICI. Great.

Ms. BARTUSKA. We believe that we have been showing some good progress. But we can get you the data that supports the larger acreage.

Senator DOMENICI. Very good, thank you.

The CHAIRMAN. Senator Tester.

Senator TESTER. Thank you, Mr. Chairman.

I want to thank the panelists that are here today. A lot of my questions revolve around forest management. That's probably not your bailiwick, but we'll see if we can get through it.

First of all, I want to thank all your comments, but especially when we were talking about what some of the problems were when you have competing interests that want to have it done one way, and another group wants to have it done another way, when you try to achieve common ground, and balance, and exchange information. I can just tell you, from my perspective, I think what's happened in the past is that there's been a "my way or the highway" kind of attitude. That is not how you get things done. You get things done by finding common ground.

But I want to talk about thinning versus fire prevention, first of all. I'll ask Dr. Bartuska this question, and that is—what I've read—and, make no mistake about it, we've got to do some thinning—but from what I've read, thinning isn't going to eliminate the fire problem. It may help, but is it going to eliminate it?

Ms. BARTUSKA. I think what was mentioned earlier is that we—it is really a complex set of competing issues and competing of stresses that need to be addressed. So, certainly, management for wildfire is one piece of that. But I think there is clearly—within the climate change context, we have other issues that we are working toward.

Senator TESTER. I mean, because you can thin a forest, and, if you have a big undergrowth of grass, your fire potential is going to go through the roof, is that not correct?

Ms. BARTUSKA. In fact, I believe Dr. Swetnam pointed to the buffalo grass issue—or buffalo grass, rather—that is a problem in some of the southwestern areas. Cheatgrass is another one.

Senator TESTER. Yes.

Ms. BARTUSKA. That is certainly—invasive species is part of this equation, and how you manage that, and whether or not you can address some of that problem—has to also be taken into account.

Senator TESTER. But even grass species that are native to the area—if you get heavy rains in the spring, and it grows up, it doesn't have to be cheatgrass, it could be any kind of grass. You're going to have a fuel there that is going to be easily touched off by a lightning strike or somebody careless with a campfire or whatever.

Ms. BARTUSKA. Actually, I'd like to see if Dr. Conard could respond to that.

Senator TESTER. Sure.

Mr. CONARD. I think what I'd like to do is back up a little bit and——

Senator TESTER. Sure.

Mr. CONARD [continuing]. Maybe talk about different ways in which fires burn in different ecosystems. The kinds of systems that Dr. Swetnam was talking about—the Ponderosa pine, for example; loblolly pine in the East—were historically typified by these fairly frequent fires that burned the low-growing fuels, but didn't damage the trees. As you get into cooler and wetter kinds of tree systems, those were historically characterized by crown fires that had very long intervals in between them.

I think that's where we're beginning to see some of these effects in the northern forests, in forests that are crown-fire systems, but where more often you're getting those severe conditions, where those fires can occur. Now, thinning in those systems has—would have the effect of essentially changing the ecosystems, because these are ecosystems with closed-canopy forests. If you begin to open it up enough to prevent crown fire across the landscape, which I think would probably not be feasible, what you begin to do is change it to an ecosystem where those shade-tolerant species, which normally would be regenerating, can't regenerate, and other species would start to come in. So, you'd be changing the system.

Senator TESTER. OK. I want to rip over to Dr. Swetnam, because you talked about thinning the large-diameter trees, and I don't want to be too specific, but we did talk about the pine beetle in B.C., which also happens to be in Montana, that that dies when it gets into small-diameter trees, because the winters get cold enough it can still kill it in the small diameter trees. In the bigger diameters, we don't get cold enough winters to kill it, so it infects the bigger trees.

So, in those kind of situations, isn't it fair to look at a more global way of—I mean, if you cut all your small-diameter trees, you're not going to have a forest left, the big ones are dead.

Mr. SWETNAM. That's right. You need to have a balanced design. If you're going to do thinning or forestry treatments, you have to be considerate of the age structures of the forests, and how the forests regenerate naturally. With regards to beetle outbreaks, something that we might be able to do is to break up the landscape into a more heterogenous type of landscape, with different ages and different species, might be helpful. When you've got these really expansive areas of one species, and they're all being stressed by climate change, then you're set up for these really enormous kinds of events.

Senator TESTER. OK. I've got more questions, but I'll wait for the next round, Mr. Chairman.

The CHAIRMAN. Senator Salazar.

Senator SALAZAR. Thank you very much, Senator Bingaman, for holding this hearing on this very important issue.

A comment, first, and that is, I think it is very important for us to keep moving forward with our energy legislation that we crafted out of this committee, also working with the Finance Committee; because, at the end of the day, if we can move forward with biofuels, with efficiency, with carbon sequestration in the way that we fashioned our legislation out of this committee, I think it'll help us move forward in a significant way on the global warming issue. So, I appreciate what you've done there, and I appreciate you also putting a focus here on our forests and what's happening with fire danger in the West.

I Dr. Swetnam, thank you for including, in your two—in your megafires in the Western United States, a picture of the Hayman Fire that burned in my State with 138,000 acres, back in July 2002. I actually was the attorney general of the State at that time, and was very involved in the criminal aspects of that case for a period of time, and saw the disaster that occurred out there with the burning of over 100,000 acres.

I have a question for you, Dr. Helms, with respect to a part of your testimony where you say that, since both growth and mortality on national forests greatly exceeds harvest, resulting in a buildup of fuels, it would be prudent to consider treatments and incentives aimed at fuel reduction and using excess biomass for societally needed products and energy production.

My question—starting with you, Dr. Helms, and to all of you, is—as we look at what's happening in the West and in my State, we have, in Colorado, approximately 2 million acres of forests that have been infected by bark beetles. So, you can travel through hundreds of miles, and you see the disaster that's about ready to happen. I've often referred to that as the Katrina of the West ready to happen with some of these forests ready to go up like a tinderbox. So, my question to you, Dr. Helms—if you look at the possibility of biomass, bioenergy coming off with some of these forests, what kinds of policy changes would you recommend to us to further that goal? I would ask the same question of you, Dr. Bartuska, in terms of what the Department of Agriculture might be recommending to us.

Dr. Helms.

Mr. HELMS. The policy direction should be oriented toward trying to secure ways and means by which these forests can, indeed, be treated, because it—the way in which beetles attack is primarily through those stands which are the densest. So, we understand that, ecologically. The issue how to effect ways in which to do that—not technologically, but through social and political means.

Senator SALAZAR. OK. Dr. Bartuska, how would you respond to that question?

Ms. BARTUSKA. Actually, first, I'd like to take a moment to correct the record. I got enthusiastic and forgot the decimal point on my million acres of treatment. We're at 20 million acres. I think I overstated that a bit.

But, also, with regard to biomass-to-energy, I'm not sure that a policy change is needed, so much as we have some really fundamental scientific breakthroughs that are needed for an effective woody biomass-to-energy portfolio. Our group and the Forest Products Lab has been working on several of the enzymes that are needed to really move us into a true biorefinery, bioenergy context, and are part of a—the recent DOE-funded projects at University of Wisconsin. So, we think that is the big breakthrough that's needed. The billion-ton report speaks to that woody biomass can provide up to 30 percent of the bioenergy of this country currently in use as a substitution for fossil fuel. So, being able to have biomass as a principal starting point for the energy program is absolutely critical. That's what I think we need to be——

Senator SALAZAR. Is it mostly, though, a technological breakthrough that is needed for woody biomass, or do we already—have we already developed some of the technology? Are we putting enough money into the research and development of—for woody biomass? What more could we do to try to get us there faster?

Ms. BARTUSKA. There are several different pathways of biomass to energy, some in the ethanol production is—we probably have the technology and the ability to move in that pathway. But some of the big breakthroughs in the cellulosic ethanol, really using wood in a more effective way, require, still, several enzyme paths that have not been worked out. That is where we just need to have the community working much more effectively together. I think that is actually happening right now.

But you also have the biomass into just fuel use. That, I think, has also been developing more technologies. The Fuel for School program, for example, where you have biogenerators locally placed, and it—whether it be schools, hospitals—so, you have this balanced portfolio, and those are multiple steps.

I just believe wood has to be part of the solution, and I think that's what we're all trying to identify, is that pathway.

Senator SALAZAR. I'll only make this—my time is up, but I'll make this comment. I think, in Colorado, we struggle with the opportunity, and try to figure—trying to figure out the pathway forward. There are a number of different demonstration projects where we are trying to use woody biomass in a good way with respect to pellets, and even a high school in one county that wants to become the first energy-independent county in my State, Jackson County, through using woody biomass. But I think we're searching for the pathway to make—so that we can have effective programs with respect to using woody biomass.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you very much.

Why don't we go ahead with any additional questions in a second round.

Senator Craig.

Senator CRAIG. I'll be very brief.

A couple of comments and observations based on some of my colleagues' questioning and response from the—our panelists.

Obviously, thinning and changing the structure of a forest as it relates to fuel loading, whether you get laddering effects from small trees getting to big trees, or whether it's grass and certain types of grass—and Senator Tester mentioned that—I'm sitting here looking at a scenario that was—is somewhat historic. Probably in the State of Montana and Idaho, we graze our land 50 to 60 percent less than we did a decade or two or three ago, so that fuel buildup on the floor, if it's just grass and some forbes and small bushes, is now rapidly growing, in part because we no longer graze the land, or we graze it substantially less. I flew over a fire complex in Idaho this year unlike any I have ever experienced. I've been fighting fires, or on fires, since I was 15 years of age, in the back of our ranch, on BLM lands. This was a 600,000-acre piece of black land. Now, that's all of Connecticut and probably Rhode Island together. It had burned, 2 years before. A lot of it had been rehab'd and seeded, but it had not been grazed because of a variety of reasons, and decisions and lawsuits that would disallow even the lightest of grazing. We talk about cheatgrass as an invasive species that is very fire prone, but is very graze-able, early. If you hit it early and thin it and get it down, and then get your livestock off from it, you change the whole fire equation. But slick-spot pepper grass and a fear for the spike-tail grouse disallows that in a lawsuit that denies the grazing of that area. A problem. Now it's a 600,000-acre burn, once again. Four ranchers wiped out, and grazing and some livestock. The great tragedy was the canyons—this is high country, high plateau country—beautiful canyon lands filled with trees and water and wildlife—gone, gutted, like a torch gone through—in some instances, not all, and in some.

So, when we look at reality, believe it or not, as hostile as public policy has been to grazing over the last five decades, in the scenario that the Doctor started talking about, in the late 1800s, when we began to change things, grazing, properly managed, also became a fuel reducer in some instances. I found that, really, very intriguing. You're right, Dr. Bartuska, I've done a couple of Fuels to Schools projects. We've got one on the Payette Forest, in Council, Idaho. The Payette Forest has got dead-and-dying. It's a very fire-prone forest in some instances, but it's now suggesting it just may not be able to find the fuels for the school. It's ironic that they were the promoters of it, but now, policywise, doesn't quite allow us to get to where we need to get, to get the hog fuels, to get to the burners, and so on and so forth. Policy begets policy, and it must work together. We, here in Washington, have dramatically tied the hands of our land managers into some scenarios that are a lot more political than they are scientific, I suspect. I guess that's my frustration. We'll work our way through that. Woody biomass and cellulosic ethanol and, you're right, a few more works at the lab table, and maybe we've got a stand-up commercial operation that could significantly, as Senator Salazar mentioned, help us change some of those equations. But it really needs to be a broadbrush picture, narrowed, specified as it relates to the situations we're all dealing with. My guess is, here, we try to get it too broad at times, and we tie the hands of those who have the wise science behind them in the management.

Anyway, Mr. Chairman, thank you very much for, I hope, a valuable hearing coming out of a very bad fire season.

In Idaho, while the rains are coming and the snow is coming in the high country, we're still burning. We're now—we've knocked off about 2 million acres of land, most of it in the timbered areas. It's a great tragedy. Now the mudslides, and the water quality in those regions is beginning to rapidly decline as we get into our wet season, and that's going to be the next step and problem we deal with.

Thank you.

The CHAIRMAN. Senator Tester.

Senator TESTER. Thank you, Mr. Chairman.

Dr. Bartuska, if we do nothing, if we don't do any thinning, if we don't do anything different than we're doing now, and climate change continues along the same upward ramp, as one of the charts showed, have you done any projections on what the Forest Service budgetary needs are going to be over the next 10 or 20 years, just to fight fire, alone?

Ms. BARTUSKA. No, I have not done that, and I don't believe our agency has done that, based on the climate change projections.

Senator TESTER. OK. I know it would just be projections, but do you think it would be wise to do that? Just over the short term, it might give us, as policymakers, some sort of idea on what to expect if policies aren't put in place that could help impact the forest.

Ms. BARTUSKA. We actually have just began looking at, what are the management activities that are needed in response to climate change, based on the science that we've done. So, we believe we'll be improving our estimates over time. I can't tell you when that will——

Senator TESTER. OK.

Ms. BARTUSKA [continuing]. Happen, but we have——

Senator TESTER. OK.

Ms. BARTUSKA [continuing]. Our very first documentation of our strategy right now.

Senator TESTER. That's good.

Dr. Helms, you talked some on invasive species. We have invasive weed species that are incredible problem in our forests and in the grassland, too, in the State of Montana. I guess the question I have is that—Is there a connection between the invasive species in our forests, and global warming? Or is the invasive-species issue due to something else?

Now, let me give you an example. I live in north central Montana. It's flat as this table, right up here. If I overgraze my ground, cheatgrass will come in. If I don't overgraze my ground, if I treat it in a way that's sustainable, I'll never have a problem with cheatgrass. Is that the same thing that's happened in the forestland, or is it because of global warming or some other issue, that we find invasive grasses and invasive species—more along the line of invasive grasses, because the invasive weeds are a whole 'nother animal?

Mr. HELMS. When you have a change in vegetation, any kind of disturbance, the—you know, nature abhors a vacuum. So, what plants come in there are those plants that have a competitive advantage.

Senator TESTER. Gotcha. So it does have a——

Mr. HELMS. It's often the invasive, testimony those exotic plants aren't accompanied by other organisms, insects or whatever, that hold them in check. So, once you create change, it's the pioneering species that have the advantage. In the context of climate change, it's going to exacerbate that, and it will give, perhaps, invasive exotics an advantage over the native plants.

Senator TESTER. OK, good to know.

You talked a little bit about forest lands turning to grasslands, and I didn't hear what you said at the beginning. What happens to the grasslands with climate change?

Mr. HELMS. The grasslands could move into desert.

Senator TESTER. Really? That's a nice thought. You also talked about the fact that they take off the forested vegetation, for whatever reason, and you have higher soil temperatures and——

Mr. HELMS. Yes.

Senator TESTER [continuing]. A greater potential for the CO_2 to——

Mr. HELMS. Yes.

Senator. TESTER [continuing]. Come out of the ground. Is there anything being done to address that issue—and that can be either you, Dr. Helms, or to Dr. Conard, or anybody on the panel, I don't care—to deal with the issue of exposed ground, higher temperatures, more CO_2 potentially coming out of the ground? Because it's going to happen.

Mr. HELMS. Yes. In the context of forest management, given that likelihood, the response would be to reduce the amount of cutting such that there is canopy—shade—so that you don't raise the temperature of the soil.

Senator TESTER. OK.

Mr. HELMS. So, it would be prudent, then, to recognize that the soil, in the highest sites, have about 40 percent of the total carbon content. So, you need to be prudent about how you handle that.

Senator TESTER. OK. I just want your opinion on this, because, like I said before, a lot of these questions revolve around forest management, and I'm not a forester, I'm a farmer. But the question about low or no snowpack and a let-it-burn policy is an issue that comes up a lot in Montana, where we have a lot of acres that burned this year. What is your perspective on a year that has very low snowpack, so we know it's going to be a dry summer and, for the most part, the heat comes with it—what is your perspective on the let-it-burn policy on a fire that starts in June, per se, when you have snowpack that's way below normal? Any of you can answer it. If none of you want to answer it, I understand, because it's kind of a political hot button.

Mr. HELMS. If I can initiate a comment.

Senator TESTER. Sure.

Mr. HELMS. Where the precipitation comes in the form of snow, the forest does two things. One, the canopy itself collects that snow and prevents it from getting to the ground, and it oblates and moves back to the atmosphere. But if the forest canopy is not closed, and the trees provide partial cover, then the trees play a crucial role in protecting that snow that's on the ground from melt. So, I think one of the issues that face our concerns around the forest, whether it be through climate change or insects or disease, is to recognize the extreme importance of the Nation's forests in relationship to water supply, because water is going to be a particularly critical factor, and, in the context of climate change, we need to be very concerned about the important role that forests play in protecting our watersheds.

Senator TESTER. OK.

Do you have any comment on that, Doctor?

Ms. BARTUSKA. Actually, I think Dr. Helms has done a very good job at——

Senator TESTER. Yes.

Ms. BARTUSKA [continuing]. At summarizing where we are.

Senator TESTER. Yes. Thank you very much.

I appreciate your guys's perspective, and I know that there's questions about forest management, and there's been head-knocking. But from my perspective, nothing's ever going to change in the forests until we get together and find common ground. Nothing's ever going to change. There is common ground to be found, and we can manage the forests right, and we can take care of our watersheds, and we can take care of the invasive species. But, if we continue to kick people out of our offices that differ with us in opinion, it's never going to happen.

Thank you guys very much for your comments.

The CHAIRMAN. I think it's been useful testimony. We appreciate you all being here. I think we will try to gain some lessons from what you've said and put them into application.

That'll end our hearing.

[Whereupon, at 4:37 p.m., the hearing was adjourned.]

APPENDIXES

APPENDIX I

Responses to Additional Questions

DEPARTMENT OF AGRICULTURE,
FOREST SERVICE,
Washington, DC, December 3, 2007.

Hon. JEFF BINGAMAN,
Chairman, Committee on Energy and Natural Resources, 304 Dirksen Senate Office Building, Washington, DC.

DEAR SENATOR BINGAMAN: Thank you for your letter of September 28, 2007, in which you provided the questions submitted for the record by the Committee for the September 24, 2007, hearing on Scientific Assessments of Global Climate Change on Wildfire Activity in the United States. The responses to the questions are enclosed.

Sincerely,

DOUGLAS W. CRANDALL
Director, Legislative Affairs.

[Enclosure.]

RESPONSES OF ANN BARTUSKA AND SUSAN CONARD TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. Can you summarize the available science regarding which particular regions in the country are likely to see the most significant increases in wildfire activity resulting from global warming?

Answer. The recent report of the Intergovernmental Panel on Climate Change (IPCC 2007) developed projections of the most likely future changes in temperature and precipitation for different regions around the world. These projections were based on the outputs of 21 different global climate models. For North America the largest increases in summer temperatures are projected for the western and central US, and the largest increases in winter temperatures for the boreal zones of Canada and Alaska, and to a lesser extent the northeastern US. Winter precipitation is expected to decrease in the southwestern US and in Florida, and summer precipitation is projected to decrease across much of North America (with greatest decreases perhaps in the northwest and in Florida), and to decrease along the eastern seaboard and in the north (Alaska and Canada).

These data suggest that increased fire hazard may occur in many regions of the US, primarily the western US, Florida, and the boreal forests. Projections based on regionalized climate models (Brown et al. 2004) suggest that in the western US the greatest impacts on fire hazard will be in the northern Rockies, Great Basin and the Southwest, with less impact the on Front Range of the Rockies and the High Plains regions.

Question 2. Your testimony indicates that the Forest Inventory and Analysis program is an important program when it comes to monitoring and understanding the impacts of global climate change on our forests. Can you give me a better idea of the role and importance of the FIA program in the Forest Service's global warming and other research?

Answer. The Forest Inventory and Analysis program (FIA) uses a scientifically sound monitoring design to provide forest resource baselines and trends. The program makes use of remote-sensing data and field-based data to monitor forests and provide an inventory in every State every year. The FIA program provides critical information for interdisciplinary ecosystem research including climate change. Since 1930, FIA has collected, analyzed, and reported information on the status and trends of America's forests by tracking how much forest exists, where it exists, who owns it, how it is being managed, and how it is changing, as well as how the trees and other forest vegetation are growing and how much has died or been removed. This long term data set is important to tracking changes in forest and tree species distribution as well as determining the amount of carbon sequestered in forests.

Question 3. Your testimony repeatedly mentions that vegetation treatments "in appropriate fire regimes" may reduce wildfire severity. Would you expand on which fire regimes are appropriate for such a treatment strategy?

Answer. Fire regimes describe the general relationships between a given ecosystem and its expected disturbance in terms of average return interval, burn intensity and severity. Treatments are most appropriate in those ecosystems that have historically burned frequently with low intensity and little mortality to the overstory species. This type of fire regime is found in dry ponderosa pine forests and dry mixed conifer ecosystems of the west and southwest, as well as the frequent burning pine ecosystems of the southeastern United States.

In addition, other ecosystems may benefit from appropriately designed treatments even though fire has historically been less frequent. The need for treatments in these areas might be to reduce hazardous fuels in the wildland urban interface, protect wildlife habitat, control insect and disease outbreaks, create a mosaic of age classes across the landscape, or for other reasons related to ecosystem restoration.

Question 4. Would you please provide a list of all of the Forest Service projects over the last ten years that were designed to reduce hazardous fuels within the area burned by the Angora Fire and that were appealed or litigated? Please include the name and a brief description of each such project; whether it was appealed, litigated, or both; the outcome of the appeal or litigation; and the length of time between when the appeal was filed and when it was decided by the Forest Service.

Answer. No fuel treatment projects within the Angora Fire were appealed or litigated within the last ten years. Over the last ten years, seventeen fuel treatments were implemented in and adjacent to the Angora Fire on National Forest System lands (excluding the urban lot treatments). One of these treatment units (unit 20) was partially complete (trees thinned and hand piles created but not burned).

Please see the chart and map* on the following pages for specific information.

* Map has been retained in committee files.

ANGORA FIRE AREA PRE-FIRE TREATMENT UNIT PRESCRIPTIONS

Unit	Acres Treated	Year Completed*	Activity
6	78	1995	Pre-commercial Thinning/Activity Fuels Pile Burn.
7	33	2007	Commercial and Pre-commercial Thinning/Salvage/Activity Fuels Pile Burn.
8	91	2007	Commercial and Pre-commercial Thinning/Activity Fuels Pile Burn.
11	14	1997	Commercial and Pre-commercial Thinning/Salvage/ Activity Fuels Pile Burn.
12	12	2006	Commercial and Pre-commercial Thinning/Salvage/ Activity Fuels Pile Burn.
13	8	2007	Commercial and Pre-commercial Thinning/Salvage/ Activity Fuels Pile Burn.
14	17	2007	Pre-commercial Thinning/Activity Fuels Pile Burn.
16	27	2006	Pre-commercial Thinning/Activity Fuels Pile Burn.
17	18	2006	Commercial and Pre-commercial Thinning / Activity Fuels Pile Burn.
18	11	2006	Commercial and Pre-commercial Thinning/Salvage/ Activity Fuels Pile Burn.
19	25	2006	Pre-commercial Thinning/Activity Fuels Pile Burn.
20	60	**	Commercial and Pre-commercial Thinning/Salvage/ Activity Fuels Pile Burn.
21	87	2005	Pre-commercial Thinning/Salvage/ Activity Fuels Pile Burn.

ANGORA FIRE AREA PRE-FIRE TREATMENT UNIT PRESCRIPTIONS—Continued

Unit	Acres Treated	Year Completed*	Activity
22	123	2005	Commercial Thinning/Salvage/ Activity Fuels Jackpot Burn.
28	21	2006	Pre-commercial Thinning/Activity Fuels Pile Burn.
29	26	2005	Commercial and Pre-commercial Thinning/Salvage/ Activity Fuels Pile Burn.
30	35	2005	Commercial and Pre-commercial Thinning/Salvage/ Activity Fuels Pile Burn.

* This year represents the year the burning was completed. Thinning was completed in previous years.
** All activities completed except pile burning.

Question 5/6. A recent Forest Service assessment of the fire behavior during the Angora Fire indicated that slash piles left behind after fuels reduction projects burned during the fire. What is your best estimate of the number of slash piles that burned during the Angora fire?

a) When were those piles made?

b) Did the project decisions or descriptions specify a time-frame for the treatment of those piles?

c) Does the Forest Service have any general guidance regarding removal of slash piles, and, if so, was the guidance followed in the area burned during that fire?

Answer. More than 850 acres of hand piles[1] were burned within Lake Tahoe Basin Management Unit (LTBMU) last fall, winter, and spring. However, there were not enough available burn opportunities due to a short, dry winter and air quality concerns to burn all "cured" hand piles within the Basin. Opportunities to burn are dictated by the presence of appropriate weather and fuel conditions for meeting burn controllability and smoke management objectives.

The hand piles within unit 20 were among those that were not burned. Hand piles within treatment units are not counted. However, estimates indicate that hand pile units within the Basin average about 15-20 piles per acre. Treatment unit 20 totaled sixty acres.

a) The hand piles in treatment unit 20 were created in 2005.

b) No.

c) The Forest Service has no general guidance regarding removal of hand piles.

RESPONSES OF ANN BARTUSKA AND SUSAN CONARD TO QUESTIONS FROM SENATOR CANTWELL

We are observing serious wildland fire conditions such as an increasing number of large and severe wildfires, lengthened wildfire seasons, increased areas burned, and increasing numbers of large wildfires in fire-sensitive ecosystems. The annual number of acres burned on public lands has been increasing over the last couple of decades. Recent research suggests that these trends are, in part, related to shifts in climate. For example, a warming climate is contributing to longer wildland fire seasons with more extreme wildland fire events, which greatly increase the risk to human lives and infrastructures, particularly within the wildland urban interface. Without taking action to manage fire-dependant ecosystems today and in the absence of thoughtful preparation and planning for the future, wildland fires are likely to become increasingly difficult to manage. To this extent, I have the following questions:

Question 7. The San Diego Declaration on Climate Change and Fire Management was ratified at the Association for Fire Ecology's Third International Fire Ecology and Management Congress, a gathering attended by 1,200 delegates from 26 different countries across six continents, and represents the broadest agreement to date among wildland fire scientists and managers of the effects of global warming on wildfires and fire regimes. What is the Bush Administration's and the U.S. Forest Service's position on the San Diego Declaration? What has the Administration and agency been doing to incorporate the document's scientific conclusions and action items into land and fire management?

Answer. We are familiar with the San Diego Declaration on Climate Change, which was developed by the Association for Fire Ecology and endorsed by the membership and other signatories at the 3rd International Fire Ecology and Management Conference in Sand Diego in November, 2006. In general, the Declaration addresses the role that climate and weather patterns play in shaping fire regimes and the potential for changing climate to significantly alter future fire patterns, and encourages managers to consider these potential impacts as they develop and implement management strategies for fire affected ecosystems.

In the recently issued Forest Service Strategic Plan for 2007-2012, climate change is recognized as an important factor that "will impact forest, range, and human well-being by potentially altering the ability of ecosystems to provide life-supporting goods and services. The implication for natural resource management is to be flexible and adapt management strategies to help mitigate the effects of climate change. In short, we need to develop new knowledge so that we can manage for future change, ensuring the continued provision of goods, services, and values from forests and rangelands."

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[1] The piles that burned on the Angora Fire were hand piles, created after hand thinning and piling of much smaller amounts of material than would be found in a typical slash pile. Slash piles refer to machine-generated by-products, often from timber operations or large-scale thinning.

Question 8. One of the key findings of the San Diego Declaration is that wildfire seasons are lengthening and wildfire size is growing. In the absence of thoughtful planning and preparation for future changes in climate and weather, wildland fires will likely be increasingly difficult to manage—-a point apparently verified by the current wildfire season. What is the Forest Service doing to incorporate climate change projections and mitigations into Land and Resource Management Plans and Fire Management Plans?

Answer. The Forest Service is developing a strategic approach to address climate change in forests and rangelands. By developing and implementing this strategy, we anticipate that field managers will address the effects of climate change by managing for healthy, resilient ecosystems.

Question 9. The San Diego Declaration proposes several action items for management, research, and education to help adapt public land management to cope with wildland fire in a changing climate, including holding conferences and symposia to enhance communication among managers and researchers, and engage the general public. What is the Administration and Forest Service doing to educate citizens about the effects of climate change on wildland fire? What is the Administration and Forest Service doing to enhance communication and collaboration among fire and climate scientists, fire and land managers?

Answer. The Chief of the Forest Service has identified climate change as one of three key themes for the agency to address, along with water issues and encouraging children to get outdoors. Chief Kimbell has delivered several recent speeches that have addressed climate change and has been interviewed on numerous occasions on the subject. The themes are spotlighted on the Forest Service webpage (http://www.fs.fed.us/), and climate change is further highlighted by Research and Development (http://www.fs.fed.us/research/fsgc/climate-change.shtml).

Within Research and Development, fire and climate scientists collaborate closely on an ongoing basis. Over 75 Forest Service scientists, with several colleagues from other agencies and academia, met in September to identify gaps in the Forest Service Research and Development program in climate change. The results will be used to develop an updated Climate Change Research and Development Strategy.

In addition, the Forest Service research community provides peer-reviewed science for application on the national forests and grasslands, including extensive research on climate change effects on those ecosystems. This information is provided to land managers through training, conferences and other technology transfer efforts.

RESPONSES OF ANN BARTUSKA AND SUSAN CONARD TO QUESTIONS FROM SENATOR SALAZAR

Question 10. What types of adaptation management strategies have been found to best deal with managing the expected increased threat of wildfires?

Answer. The most effective measures for dealing with an increased threat of wildland fire are:

Homeowner utilization of Firewise and other guidance to:

- Ensure house and deck construction material is fire resistant.
- Ensure vegetation adjacent to houses and other structures is either removed or exhibits low flammability characteristics (e.g.: broadleaf versus conifer trees).
- Ensure combustibles are kept away from structures (needle litter, firewood, scrap lumber, etc.).

Ensure adjacent fuel within the wildland-urban interface is maintained in a low hazard condition, through a combination of mechanical treatments and prescribed fire.

Maintain a high percentage of lands outside the wildland-urban interface in a resilient, sustainable fashion, through the use of prescribed fire, wildland fire use, and mechanical treatments.

Question 11. One of the most enduring ad campaigns in our country's history are the Smokey the Bear public service announcements. There probably isn't a person in the room who hasn't heard the slogan "Only you can prevent forest fires." Given that the majority of wildfires are caused by human activity, are there plans to increase efforts to reach the public on climate change and expected increased wildfire activity, and ways to prevent wildfires?

Answer. The Cooperative Forest Fire Prevention (CFFP) Program, commonly known as the Smokey Bear Program, was created to maintain public awareness of the need to prevent human-caused wildfires. In cooperation with the Advertising Council and the National Association of State Foresters, new campaigns are developed every few years. In calendar year 2008, a new campaign will be launched to spread Smokey's message of reducing human-caused wildfires.

Fire and Aviation Management is actively involved with Forest Service Research and other staff groups to educate the public in the reasons for wildfire causes and increases in severity.

Question 12. The link between climate change and fire is clearly strong, but since this linkage has come to light, some people suggest that climate is more critical than fuel as a driver of fire behavior, and there is no reason to treat fuels to protect communities or restore ecosystems. What are the implications of climate change for fuel treatment and forest restoration?

Answer. Both field observations and fire behavior models demonstrate the central importance of fuel loads, fuel structure (the vertical and horizontal distribution of fine fuels, in particular), and fuel moisture as important determinants of fire behavior. Weather patterns during and preceding a fire also have strong effects on fire behavior, as does terrain. In general, decreased fire intensity and ecosystem impacts will occur as fine fuel loads decrease, fuel moisture increases, and where wind speeds are low, humidity is low, and slopes are more shallow.

In situations where fuels are overly dense, or where understory vegetation development has led to fuel continuity from the ground to tree crowns, a number of studies have shown that fuel treatments can effectively modify fire behavior, increase the effectiveness of suppression actions, and decrease the likelihood of crown fire.

Warming climate, as it increases intensity of droughts and length of fire seasons, is expected to lead to higher fire hazard in many parts of the country. Maintenance of healthy forests and rangelands, control of invasive species such as cheat grass, and fuel reduction treatments all can play a part in reducing this threat and in improving the ability to manage wildfires across the landscape. Recent papers also suggest that severe fires can be seen as opportunities to facilitate ecosystem adaptation to changing climate. For example, by planting tree species or genotypes more adapted to warmer climates, or by adjusting planting densities, forests recovering after a fire may be made more resilient to future changes in climate (e.g. Spittlehouse et al. 2003).

Question 13. Fires are becoming increasingly harder to fight and are releasing huge quantities of carbon dioxide. Wildland Fire Use, the practice of allowing some lightning-ignited fires to burn under less extreme conditions, has been suggested as a way to mitigate fires and ensure they release less carbon dioxide. Do you see a role for Wildland Fire Use in changing future fire behavior so it is less extreme, thereby releasing fewer greenhouse gases?

Answer. Careful use of unplanned ignitions (Wildland Fire Use) has great potential to reduce severity and intensity of future wildfires by creating patterns of vegetation which are less prone to large, high severity fire events. In these areas, reduced burn severity and emissions occur through reduced consumption of fuel, thus enabling the site to retain material which in a severe wildfire would have otherwise been released as carbon dioxide and other emissions.

Withholding fire from fire-adapted ecosystems increases the potential for severe, high intensity fires. In some parts of central Idaho wilderness areas, there is evidence that the previous implementation of wildland fire use (1972-2006) resulted in reduced burn severity and emissions from the fires of 2007.

Question 14. It has been suggested that because young forests grow fast and older forests grow slowly, we can cut down old forests and replace them with fast-growing plantations to maximize the uptake of carbon dioxide and reduce global warming. What is the current scientific understanding of the effects of logging older forests on the uptake or release of greenhouse gases?

Answer. Answering this question requires consideration of the net greenhouse gas outcome of the options in the question—it requires thinking about what the atmosphere sees rather than thinking only in terms of carbon on a particular acre.

Actively managing rapidly growing forests and converting the wood to long-lived products, substitutions for fossil-fuel intensive products, and biofuels provides substantial greenhouse gas benefits. Older forests can be significant pools of carbon, but the pool size is neither increasing nor decreasing when considered across time and disturbance cycles (fire, insect, disease, wind events). In the systems studied, a life cycle analysis shows that substantially more carbon can be sequestered and greater greenhouse gas benefit realized by actively managing the stand and using the wood over multiple rotations than is sequestered by older stands of the same type.

A mosaic of ages and stand types across the landscape can be important depending on the goals and objectives of the landowners or managers. Old forest stands that may be important with regard to other environmental values often do not help in overall greenhouse gas reductions. The relative value of desired outcomes must be considered.

RESPONSES OF ANN BARTUSKA AND SUSAN CONARD TO QUESTIONS FROM SENATOR DOMENICI

Question 15/16. Dr. Conard, near the end of your written testimony you said: "Because climate in many areas will change more rapidly than long-lived plant species can migrate, moderate to severe fires can be seen as opportunities to facilitate migration, either by planting . . . or by selecting seed from trees that grow in warmer seed zones or at lower elevations." What is the current reforestation backlog facing the Forest Service?

Answer. At the end of fiscal year 2006, the Forest Service declared a total of approximately 1.1 million acres needing reforestation. These needs will be updated with new information following the end of fiscal year 2007.

Question 17. How much of that backlog was the result of fires and insect outbreaks and how much was caused by past harvesting?

Answer. We estimate that the 1.1 million acres of reforestation needs consist of approximately 704,000 acres resulting from wildfires, 33,000 acres caused by insect and disease, and 120,000 acres from previous harvest treatments. Reforestation after a timber harvest is a legal requirement that is paid for through the timber sale, whereas no funding source outside of appropriated funds is available following a fire unless there is a salvage sale.

Question 18. In the absence of a dramatic increase in reforestation funding, what are the other ways the Forest Service has to pay for the work needed to address the reforestation backlog?

Answer. Partnerships with external organizations are a way that the Forest Service uses to provide additional funding for reforestation work. For example, the Forest Service receives contributions from organizations such as American Forests, The Arbor Day Foundation, National Forest Foundation, the National Association of Garden Clubs, the Batesville Casket Company, and the Forest Service Plant-a-Tree programs. These contributions currently provide less than 5% of the annual reforestation accomplishments but we are working with the partners to increase the program.

Question 19. Given current funding availability and the projected increase in fires that you've suggested could happen, is it realistic to believe the Forest Service has the capability of undertaking the kind of work you suggested in your testimony? If not, what changes would have to occur to facilitate that kind of work?

Answer. As with all decisions regarding expenditures of funds, this would be a matter of evaluating priorities among many competing needs.

Question 20. Dr. Conard, I have been reading a Pacific Northwest Research Station publication from January 2004 titled Western Forests, Fire Risk, and Climate Change. The author of the paper was Ron Neilson. I found a number of the statements in that document quite interesting. In the summary, Mr. Neilson said, "In six of seven future scenarios run through one model, the Western United States gets wetter winters and warmer summers throughout the 21st century (as compared to current climate), with expanded woody growth across the West and thus, increasing fire risk." Several of the witnesses today told us that early spring run-off followed by a dry summer leads to severe fire seasons. In fact, the paper I am talking about said: "Large fires associated with climate patterns including the 1910 Idaho fires, 1988 Yellowstone fires, and 2002 Biscuit Fires in Southwest Oregon" were strongly related to climate variability. Are Forest Service researchers suggesting we will be more likely to experience dry springs followed by warmer summers and therefore more fires due to climate change? Or are the models suggesting that increased forest vegetation over a larger landscape will make more acres susceptible to forest fires?

I am also interested in another comment in this paper, which said: "Computer models can forecast the likely effects of different scenarios, giving people a chance to compare outcomes. Computer models cannot predict specific events." We heard lots of dire predictions, most based on computer models at our Climate Change and Wildfire hearing. Yet, the authors of this Forest Service report are warning us that these models have limited capabilities.

Answer. Current global change models, and regional analyses based on these models, suggest that much of the US will experience warmer summers, earlier snowmelt, and longer, more severe summer drought. As shown in recent papers, such as that by Westerling (2006) in Science, these factors can be associated with the occurrence of severe fire seasons and more large fires in the West over the past several decades. Fire patterns in Florida and other areas of the country have also been associated with severe drought and other factors related to multi-year climate variability.

Based on model projections, the environmental conditions associated with high fire hazard are likely to increase in many regions. The effects of climate and fire/climate interactions on vegetation are more difficult to predict. Newer model projections (IPCC 2007) suggest that the southwestern US will be both drier and warmer, as opposed to earlier projections that suggested the area would be wetter and warmer.

If the new projections are correct, we might expect fewer trees in these regions, with a transition from forest to savanna to desert grasslands. Because projections of individual models vary, the IPCC uses ensemble forecasts (developed by comparing the results from over 20 different global models) to increase the robustness of their projections. Climate models are improving greatly, and generally are much more capable at reproducing past events than they were even 5 years ago. This calibration to past events provides higher confidence in the accuracy of projections of future changes.

Question 21. Understanding these limitations, is the Forest Service suggesting that we should predicate future forest policy on these predictive models?

Answer. Clearly we believe climate change has serious implications for the long-term health and sustainability of the nation's forests. But, as we have already noted, predictive models have their limits when it comes to developing long-term forest policy. In the near term, modeling results will be useful in informing management strategies developed in forest plans. In the longer term, as the real world effects of climate change become more apparent, other environmental policy changes may be needed to protect the national forests. Adaptive management strategies are being used, but will be even more important and useful as more information comes in and models improve.

Question 22. I gather from the past testimony of Chiefs Dale Bosworth, and Abigail Kimbell, and Undersecretary Mark Rey that the Forest Service believes we must manage for change, including increased management of forest vegetation. Is that correct?

Answer. We are already starting to see the impacts of climate change on forests with fires burning hotter and bigger, larger insect outbreaks, and warmer winters with smaller snowpacks. The agency is working to increase the resilience of National Forests and Grasslands by adapting to changing ecosystem conditions, and working to mitigate future effects of climate change. Management of forest vegetation and disturbance processes are the essential tools we use to adapt to a changing climate and mitigate further impacts to the forests and grasslands.

Question 23. Dr. Bartuska, I have a data set provided by the Forest Service that shows the number of acres burned by year from 1916 through 2006. When I look at that data set, I see that 2006 is only the 37th worst year in the 90-year data set. Two years (1931 and 1933) showed more than 5 times the number of acres burned than we had in 2006. Four other years (1928, 1929, 1933 and 1934) showed more than 4 times the number of acres burned than we had in 2006. What do you think caused the number of acres burned each year between 1916 and 1954?

Answer. First, we would like to frame the data in question. Several years ago the Forest Service compiled available historical federal and state wildfire occurrence data back to the early 1900's. However, the Agency cannot provide a full accounting for field methods used to collect the data, so the accuracy of the data during this time period cannot be verified.

The data do indicate that significant acres were burned during the 1920's through the 1940's; the maximum number of burned acres reported in a single year was 52 million acres in 1930. The data further indicate that the acres burned were predominantly in the southern and eastern US (states of VA, WV, NC, SC, TN, GA, FL, AL, LA, MS, TX, AR, & OK) with most of the burned acres occurring on unprotected forested and non-forested lands, for example:

Year	Total Acres Burned	Acres Burned within States Above
1927	38 million	34 million
1930	52 million	47 million
1933	44 million	41 million
1947	24 million	21 million

As to the general cause of the acres burned, there appears to be a combination of factors including climatic conditions on a national scale such as the “dust bowl” of the 30's combined with a tradition of woods and field burning and fire reporting protocols which contributed to the high number of acres reported. The Agency has initiated an effort to better understand and interpret the historical data and would be willing to provide a follow-up report at conclusion of that effort.

Question 24. I know you heard my opening statement when I mentioned the 1871 Peshtigo fire, the 1894 fire in Hinckley, Minnesota, and the 1910 fires in Montana and Idaho. What do you think primarily caused any of those fires?

Answer. The primary underlying factors for the fires in question appear to be the accumulation of fuels, management practices, drought, and wind and weather conditions. An account of the specific incidents follows:

Peshtigo Fire.—Many months of extreme drought combined with the land-clearing practices of the time ("slash and burn") caused many small fires to be whipped into a huge forest fire when a cyclonic storm blew up on the night of October 8, 1871.

One example from survivor accounts is that railroad workers clearing land for tracks that Sunday evening started a brush fire which somehow became an inferno. It had been an unusually dry summer and the fire moved fast. Some survivors said it moved so fast it was "like a tornado."

Hinckley Fire.—The fire occurred on September 1, 1894 and was centered at Hinckley, Minnesota. After a two-month drought, several fires started in the pine forests of Pine County, Minnesota. The main contributor to the fire was apparently the then common method of lumber harvesting, which involved stripping trees of their branches, littering the ground with such detritus. Another contributing factor was a temperature inversion that trapped the gases from the fires.

1910 Fires.—1910 was the driest year in memory. Snows melted early and the spring rains were lacking. An electrical storm the night of July 15 touched off more than 3,000 fires. Then, on August 20, hurricane-force winds roared into Idaho and Montana dry forests. In a matter of hours, fires became firestorms.

Question 25. Do your models suggest that we will have more years with the specific causal agents that occurred in these mega fire incidents?

Answer. The primary causal agents of the incidents described above were rooted in land management practices, such as relatively uncontrolled burning of logging slash, and burning for land clearing. Today, these practices are much more closely managed. Widespread burning without knowledge of impending weather changes (such as high winds) was often the critical confluence of events that led to these megafires of the past. Once the fires started, often in many places at once, there was little capability in place to suppress them. We utilize fire behavior science and fire weather forecasting to manage fire effects and maintain controllability of our prescribed fires. In addition, fire weather predictive services allow for better preparation for weather changes and identification of long-term weather trends.

As climate changes, the weather conditions that lead to increased fire hazard are likely to become more frequent, and the annual burned areas are likely to continue increasing, at least in the short-term. Current land management practices, including reduction in hazardous fuels and the existence of extensive fire suppression capabilities, should help to mitigate these effects of changing climate on fire regimes.

Question 26. If the low elevation and southern ponderosa pine forests are likely to migrate to higher elevations and to the north, as suggested by Dr. Swetnam, do you believe it would be wise to ignore the fires at higher elevations in the northern Intermountain States?

Answer. Our policy is never to "ignore" fires regardless of the location. Each fire receives an appropriate management response that balances resources at risk, potential fire behavior and effects, cost, and potential resource benefits from the fire (in areas where the use of fire to achieve resource benefits is permitted by the Land and Resource Management Plan) to determine the best management approach while always providing for the safety of our firefighters and the public. As climates change and conditions favor species that may be better adapted to dry, warm conditions, our appropriate management response approach will not change. The specific actions taken to ensure our approach is appropriate will be determined based on risk, probability, safety, cost, and benefits (where appropriate).

Question 27. Do you know of any research that examines the ability of tree species to invade and reforest lands that have been heavily impacted by fires, including how various species respond to the loss of soil and the changes in moisture regimes after high intensity fires?

Answer. There are multiple research studies that have looked at recovery after individual fires in a wide range of vegetation types. Each ecosystem type has different characteristic patterns of recovery after fires, and both the rate of recovery and the species composition after a fire can vary as a function of fire adaptation of individual species, the availability of seed, the size and severity of the burn, and the weather patterns in the seasons after the fire.

The rate of regeneration of tree species after a fire is a case in point. Some tree species, such as aspen, oaks, and maples, have the capacity to sprout from roots or living stem bases following even fairly severe fires. Most conifer species, on the other hand, must reproduce from seed. Some conifer species are well-adapted to reproducing after high-intensity fires, while others, such as ponderosa pine in the west and loblolly pine in the east, may have their seeds burned up in a severe fire. These species will need to reinvade from living trees within the burn or at the edge; a process that can take decades depending on local conditions.

There are a number of studies that have evaluated the geographic changes in habitat suitability that might be expected for various tree species based on various climate change scenarios. The Climate Change Tree Atlas provides maps of potential changes in habitat suitability for over 100 tree species in the eastern US. Models developed by Forest Service researchers provide similar projections for key tree species in the western US. Such information can be used by managers to help them make decisions about appropriate strategies for regeneration following severe disturbances, including wildfires.

RESPONSES OF ANN BARTUSKA AND SUSAN CONARD TO QUESTIONS FROM SENATOR CORKER

Question 28. I understand that a number of models predict that the Southeast is likely to experience the greatest increases in wildfires in the continental United States. Will you please describe why this is the case and describe what changes are predicted to occur and how they will increase the risk of wildfires?

Answer. In general the eastern seaboard is projected to experience less warming than the rest of the country, and is projected to experience similar or higher precipitation than what we have today. The exception is Florida, where models suggest that temperatures will warm slightly and rainfall may decrease substantially. This pattern is likely to lead to increased frequency of periods of high fire hazard. We are not aware of published models that predict large increase in wildfires in the rest of the Southeast.

Question 29. Do we need to reconsider forest management policies or other mitigation activities?

Answer. We believe the Forest Service currently has forest management policies and authorities that allow the agency to mitigate and adapt to the impacts of climate change. For example, we currently conduct thinning treatments in conifer forests to improve forest health and make the forest more resistant to insect attacks.

Question 30. Are there currently obstacles to forest management that could significantly reduce the damage caused by fires that will only continue to compound the problem if temperatures continue?

Answer. The Healthy Forests Initiative, launched in 2002, has helped to reduce the time it takes to administratively plan and implement projects that reduce the impact of wildfire on the landscape. The Forest Service received additional assistance in removing administrative barriers through the Healthy Forest Restoration Act, which improved the procedures and processes for planning and implementing fuel reduction projects, especially near at-risk communities. The Forest Service continues to work to streamline planning processes and remove administrative barriers to accomplish fuel reduction work as quickly and efficiently as possible.

RESPONSES OF ANN BARTUSKA AND SUSAN CONARD TO QUESTIONS FROM SENATOR BARRASSO

Question 31/32. Doctors, your testimony mentions the importance of forest treatments to reduce stress and crowding. Your research details the opportunity for positive results presented to forest managers by these methods. What is your agency's approach to implementing your findings? What steps have been taken to put these findings into practice to actively meet forest management needs?

Answer. The Forest Service research community provides peer-reviewed science for application on the national forests and grasslands, including extensive research on climate change effects on those ecosystems. Among other applications, Forest Service research is used to plan and visualize stand level vegetation treatments and evaluate forest plan strategies for promoting healthy forests. The computer models used for these purposes are being retooled to account for the latest climate change research. The latest research information is also disseminated through publications, conferences, and the ongoing collaboration between national forests and the regionally based research stations.

Question 33. When will we see results on the ground?

Answer. The Forest Service approach to vegetation management already promotes the resilience of forest ecosystems in the face of climate change. Under the National Fire Plan, the Forest Service has accomplished 11.9 million acres of hazardous fuels and restoration treatments from 2001 through 2006. This includes 6 million acres in the wildland-urban interface and 2.1 million acres of restoration treatments. Final numbers for FY07 are still being compiled, however, an estimated 2.9 million acres of hazardous fuels and restoration work was accomplished. The Forest Service will continue its work on fuel reduction projects and insect treatments in FY 2008.

RESPONSES OF JOHN A. HELMS TO QUESTIONS FROM SENATOR SALAZAR

Question 1. What types of adaptation management strategies have been found to best deal with managing the expected increased threat of wildfires?

Answer. Wildfires require a combination of fuel, temperature, and oxygen. Of these, the only factor that can be managed is the presence and distribution of fuels. Given that the most intense and catastrophic fires occur in dense forests, and since experience has shown that when wildfires encounter less dense and more open stands fire intensity commonly drops (USDA PSW 2007), it seems clear that increased efforts must be made to thin overly-dense stands. In doing so, irregular mosaics of stand density should be created that remove ladder fuels to reduce opportunities for fire to burn into tree crowns.

Since it is clearly impossible to rapidly treat all 180 million acres the Forest Service estimates are in hazardous condition, current efforts to create "Defensible Fuel Profile Zones" (DFPZs—Quincy Library Group/USDA FS, California), "shaded fuelbreaks" (Agee et al. 2000) and "Strategically Placed Landscape Area Treatments" (SPLATS or SPOTS in California's Sierra Nevada—USDA FS) are all worthwhile exploring. These are areas 1/4-1/2 mile wide, usually along roads or strategically placed in which fuel loadings are reduced to reduce potential for crown fires, interrupt fire spread, and to provide defensible space to fight the fires.

Although not free from criticism, these efforts are initial steps in the right direction. More adaptive management and pilot studies (such as the Fuels Management National Pilot Project 2007 funded by the Forest Service) are needed to demonstrate efficacy and cost effectiveness and to communicate lessons learned from these and other projects and forest treatments (Wildland Fire Lessons Learned Center 2007).

Question 2. One of the most enduring ad campaigns in our country's history are the Smokey the Bear public service announcements. There probably isn't a person in the room who hasn't heard the slogan "Only you can prevent forest fires." Given that the majority of wildfires are caused by human activity, are there plans to increase efforts to reach the public on climate change and expected increased wildfire activity, and ways to prevent wildfires?

Answer. There is considerable current effort aimed at providing the public with information regarding wildfires, hazardous fuels, and the need to provide defensible space around homes. Some of these are the Fire Safe Council, Firewise, Rural Fire Assistance, and Landfire. National programs are coordinated through the National Fire Plan. Fire-prone states such as California have aggressive programs of public information.

However, the fact that catastrophic wildfires are due to hazardous fuel loadings and over-dense public forests and thus can be addressed by forest management seems to be either little understood or rejected.

Increased effort in technology transfer and outreach is needed, particularly at K-12 education levels where perceptions are formed, to provide the public with science-based information regarding the need to restore public forests to densities that do not support catastrophic, stand-replacing fires or insect outbreaks. It is generally not appreciated, for example, that current mature mixed conifer stands in the Sierra Nevada of California are carrying over 1,000 trees per acre; by comparison, natural forests in which low-intensity fires were common carried only about 40 mature trees per acre.

Priorities to move forward are: 1) enhance collaboration among federal and state agencies in partnership with industrial, tribal, and non-industrial family forest owners, 2) streamline legal and regulatory frameworks to encourage restoration of forest health and responsible stewardship of the nation's forest lands, and 3) provide better communication to the public and decision makers indicating that restoring and maintaining forest health is key to mitigating likely effects of climate change.

Question 3. The link between climate change and fire is clearly strong, but since this linkage has come to light, some people suggest that climate is more critical than fuel as a driver of fire behavior, and there is no reason to treat fuels to protect communities or restore ecosystems. What are the implications of climate change for fuel treatment and forest restoration?

Answer. Wildfires are driven by both fuel and temperature and are made particularly devastating when combined with low humidity and high winds. Modeling shows that, in general, changing climate will likely result in more wildfires. However, fires won't burn without fuel, and fire intensity increases with fuel loading. A prudent steward of forest lands would therefore reduce hazardous fuel loads and remove a portion of trees that provide ladder fuels that enable flames to reach the canopy.

The amount of fuels in a forest can reach 15-70 tons per acre (Sampson 2004) and this fuel loading cannot be removed by prescribed burning without incurring substantial risk. Therefore some preliminary mechanical treatment is required. This could be cost-effective if the smaller-dimension biomass could be used for cellulosic ethanol production and the larger material converted into wood products that store carbon. A major hurdle on public lands is to make this material available through long-term contracts that provide a sufficiently stable investment climate that will enable industry to construct the necessary processing plants for both ethanol and wood products.

Question 4. Fires are becoming increasingly harder to fight and are releasing huge quantities of carbon dioxide. Wildland Fire Use, the practice of allowing some lightning-ignited fires to burn under less extreme conditions, has been suggested as a way to mitigate fires and ensure they release less carbon dioxide. Do you see a role for Wildland Fire Use in changing future fire behavior so it is less extreme, thereby releasing fewer greenhouse gases?

Answer. Yes, the Wildland Fire Use system in which lightning fires are managed to achieve resource benefits is a worthwhile approach to reintroducing natural fire into forest ecosystems. Wildfires are indeed increasingly hard to fight and release 75-80 tons CO_2 or more per acre (Sampson 2004). Fires that can be several hundred thousand acres in size are clearly emitting millions of tons of CO_2 and other greenhouse gases into the atmosphere. Once forest stands are restored to more natural density levels, prescribed fires can be used which emit about 18-20 tons CO_2 per acre (Sampson 2004).

Decisions to permit natural fires to burn are based on diverse criteria that assess the risk to private property, ecological systems, and societal values. The Wildland Fire Use approach is commendable, however one must accept the likelihood that, initially at least, some ecological and societal values will be damaged and air quality will be affected. This points to the importance of providing the public with quality information regarding the goals, risks, and benefits of the program.

Question 5. It has been suggested that because young forests grow fast and older forests grow slowly we can cut down old forests and replace them with fast-growing plantations to maximize the uptake of carbon dioxide and reduce global warming.µWhat is the current scientific understanding of the effects of logging older forests on the uptake or release of greenhouse gases?

Answer. It is true that fast-growing, younger forests sequester carbon at a higher rate than slower growing, older forests. When older forests become mature or overmature, the rate of carbon accumulation may become zero or negative due to loss of vigor, tree mortality and decay of organic matter. The total accumulation of carbon in older forests is greater than in younger forests.

It is well documented, however, that young forests managed by utilizing a series of harvests will, in time, sequester or store more carbon than unmanaged forests left for several hundred years (Birdsey and Lewis 2002, Krankina and Harmon 2006, IPCCa 2007). This is because, over successive rotations or cutting cycles, managed forests maintain high rates of CO_2 uptake. The superiority of managed forests in sequestering carbon is especially evident when the harvested wood is used for both energy production and wood products that store carbon for long periods. The situation is made even more compelling when renewable wood products are used instead of alternative materials such as concrete, steel, aluminum, and plastic that are non-renewable and have been shown by life cycle analyses to consume far higher amounts of energy in manufacture (Perez-Garcia et al. 2005). In this context it should be mentioned that "managed forests" are not necessarily single-species, uniformly-spaced "plantations". They could be if this was desired, but they could also be managed to have multiple species, several age classes, and understory vegetation such that are indistinguishable from naturally-occurring forests.

The following figure* from the IPCCa 2007 report illustrates the principle.

* Figure has been retained in committee files.

Forests and forest management have an important role in mitigating climate change. As reported by the Intergovernmental Panel on Climate Change (IPCC 2007b):

> Forestry can make a very significant contribution to a low-cost mitigation portfolio that provides synergies with adaptation and sustainable development. However this opportunity is being lost in the current institutional context and lack of political will and has resulted in only a small portion of this potential being realized at present (high agreement, much evidence).

RESPONSES OF JOHN A. HELMS TO QUESTIONS FROM SENATOR DOMENICI

You have testified that ". . . in general, effects of climate change are more likely to be seen in northern latitudes with loss of meadows, conversion of forest to grassland, and tree invasion into areas that were previously too cold. Forests are expected to move north in latitude and upward in elevation. Pine forests at low elevation are likely to be replaced by woodlands and grasslands." Dr. Swetnam suggested that it might be too late to manage in high-elevation long fire rotation stands and that it might be wiser to focus management in the Ponderosa Pine forests of the Southwest.

Question 6. If the low elevation and southern Ponderosa Pine forests are likely to migrate to higher elevations and to the north, as suggested by Dr. Swetnam, do you believe it would be wise to ignore the fires at higher elevations in the northern Intermountain States?

Answer. Decisions on when and how to deploy fire suppression resources depend on professional analyses of potential fire behavior, duration, cost, and risk to ecological, environmental, and societal values, life, and property. This approach is appropriate when considering fires within any ecosystem or biome. The mountain tops of the Southwest are especially at risk to climate-induced vegetation changes and replacement by species that are more adapted to hotter and drier conditions. Thus these unique ecosystems may warrant special attention to reduce the likelihood and severity of wildfires.

Question 7. What does the field of forestry tell us about the ability of tree species to invade and reforest lands that have been heavily impacted by fires, including the loss of soil and the changes in moisture regimes after high intensity fires?

Answer. In general, rates of germination, establishment, and growth of trees after wildfires are slower than those of shrubs and grasses—in particular sprouting shrubs and hardwoods. It is therefore common for pioneering shrubs and grasses to rapidly colonize and dominate burned areas for many decades. This is less true for the "fire-type" conifers such as lodgepole pine that have serotinous cones evolved to open from the heat of fires. Forestry research and experience shows that vegetation growth after fires varies from brushfields to successful tree regeneration depending on such factors as the availability of seed. Surveys in California's Sierra Nevada have shown that mature true fir forests having no shrubs in the understory can have 2 million viable seeds of shrub species per acre that remain dormant in the soil until heat from fires cracks their seed coats and stimulates germination. In contrast, tree seeds do not commonly remain viable in the soil after two years and seed crops have periodicity from one to seven years.

After a wildfire, a prompt assessment is needed of post burn conditions to determine the likelihood that desired vegetation of diverse species will become established. The desired mix of vegetation cover needs to be defined and the timeframe in which preferred conditions of tree cover, habitat, and soil cover should be attained needs to be identified. Experience has shown that those areas likely to become brushfields or have high potential for erosion need to be promptly planted to return them to forest conditions. Brushfields often have conifer seedlings underneath them, but it can take 50-100 years for the trees to overtop the brush and form a forest canopy. Burned areas that may regenerate satisfactorily to the desired species mix without treatment or are ecological reserves not needing treatment should be identified in the post-burn assessment.

In all cases, the post-burn analysis should identify the costs, benefits, and risks associated with action or no action. Decisions should ensure that society is best served by using treatments where necessary to rapidly restore the preburn mix of forest values, habitats, uses, and watershed protection.

Question 8. Dr. Helms, you have also testified that " . . . since both growth and mortality on national forests greatly exceeds harvest resulting in a build-up of fuels, it would be prudent to consider treatments and incentives aimed at fuel reduction and using excess biomass . . ." In your estimation, what type of effort would it take to mitigate the potential impacts of the change to our forests that you and the other witnesses have suggested could happen? That is, how can we prepare those forests for the changes that may occur?

Answer. Efforts are already being made by agencies within Interior and Agriculture under existing programs and policies such as the Healthy Forests Restoration Act of 2003 to reduce fuels that have built up in over-dense federal forests. However, current efforts are small relative to the magnitude of the problem. The main impediment to progress is that segments of the public distrust and challenge analyses and plans to thin forests. To prepare forests for climate changes, emphasis must be placed on identifying ways and means by which high-risk stands and forests can be thinned and fuel reduction carried out to restore and maintain forest health and vigor in a societally-acceptable manner.

The Forest Service estimates that 180 million acres of national forests are in need of treatment and all this area cannot be readily treated in a short timeframe. However, the spread of catastrophic wildfires can be limited by shaded fuel breaks such as described in my response to Question 1.

In 2006 a joint agency comprehensive fuels treatment strategy was initiated aimed at reducing fuels buildup in forests in an efficient and effective manner (USDA and USDI 2006). This mix of policy and management approaches is an important step and warrants enhanced support and further development.

Question 9. Do you recommend we start now, or do we have time to fight and fuss over what environmental protections and analysis must be completed before we begin to take action?

Answer. Because wildfires are increasingly devastating and costly there is an urgent need to address forest condition problems and societal impediments to mitigation. This task has already commenced and excellent programs are beginning to reduce fuels on public lands (e.g., USDA and USDI 2006, National Fire Plan 2007). About 20 million acres have already been treated under the Healthy Forest Restoration Act, with special emphasis on the wildland/urban interface. But accomplishments to date represent only a small fraction of the 180 million acres of national forests needing attention, thus losses to catastrophic wildfire and costs of suppression are increasing. Overly-dense national forests need to be thinned, which would not only reduce hazards of wildfire but would also enhance wildlife habitat and water yields.

National forests are owned by the people who necessarily must have a say in how their forests are managed. In addition, treatments under any policy or plan must conform with current laws and regulations. To address controversy and opposition by some segments of the public to thinning public forests, increased efforts are needed to provide factual information through technology transfer such that children, adults, and decision makers have adequate science-based information to help shape opinion regarding the balance that needs to be struck between competing uses and values of forests. This is especially important in the context of climate change because the likely increases in forest mortality and wildfires are undoubtedly going to negatively impact the diverse benefits that forests provide society.

Moving forward will require policies and incentives aimed at increasing collaboration among landowners and stakeholders such that sustained thinning projects can be developed at the scale and duration necessary to effectively address the wildfire problem.

Question 10. Dr. Helms, during questions by Senator Tester, you suggested that timber management could help to maintain sufficient crown cover to help hold the accumulated snow pack in place for longer than in open areas. If trees sometimes have a more difficult time regenerating after high intensity fires and water retention and run off are negatively impacted in the absence of tree cover; and we do experience higher temperatures, are we more likely to see brush fields, or stands of new trees as species have to migrate up in elevation and to the north through these heavily burned lands?

Answer. Maintaining and enhancing the nation's water supply for residential, agricultural, and environmental needs is a critical priority. The nation's future supply of water is in jeopardy in the context of changed climate and precipitation patterns, particularly in the Southwest. Most of the nation's water comes directly from forested watersheds or indirectly through recharged ground water systems. It is imperative, therefore, that forests be evaluated in terms of how their structure and composition affect hydrological cycles and the extent to which management can enhance the supply and quality of water and the timing of distribution to streams.

Where precipitation is in the form of snow, forest cover is critical in enhancing water yields by providing shade over snow, delaying snow melt, and preventing erosion. These effects are enhanced where the forest has a discontinuous canopy cover, a condition that may have to be maintained by thinning.

Given likely higher temperatures, uncertain precipitation patterns, and possible species change, it would be prudent to examine whether thinning treatments can maintain forest health, delay transition to better-adapted vegetation such as shrubs, and thus help ensure adequate water yields for environmental and societal needs.

The potential of forests to revert to brushfields, either following wildfire or as the result of climate change, is important because once an area is dominated by brush it often takes many decades before trees can break through and the area returns to forest. As brushfields commonly reburn, the area can remain dominated by brush indefinitely. The importance of considering ecological succession and forest/brush dynamics in any management strategy is mentioned in my response to Question 7.

RESPONSE OF JOHN A. HELMS TO QUESTION FROM SENATOR BARRASSO

Question 11. I notice that your testimony includes an emphasis on our "responsibility to mitigate through forest management." Could you elaborate on that point, specifically fuels treatment?

Answer. Healthy forests and their associated wildlife habitats and watersheds are priceless assets providing the nation with critical values and uses. The sustainable management and conservation of forests is crucial to societal welfare. When forests are allowed to become overly dense the trees lose vigor and become susceptible to insects, disease, mortality, and fire. This is exacerbated under conditions of overall rise in temperature, drought, and storms. It is therefore in society's best interest that, apart from ecological reserves, wilderness or similar areas, forests be sustainably managed to maintain forest health and provide the balance and diversity of values and uses that society needs.

The argument that forests, especially national forests, should be left unmanaged and that "nature knows best" is understandably appealing. However it does not recognize that the condition of our national forests is far from "natural". People are an integral and often dominant part of ecosystems and rapidly increasing human populations have drastically changed forest structure and composition through harvesting, development, infrastructure, and wildfire suppression policies. Forests could be allowed to "develop naturally", but nature's way of reducing stand density is through tree mortality through competition, suppression, insect/disease attacks, and wildfire. Natural forests start as tens to hundreds of thousands of seedlings per acre and at maturity may only have fifty dominants. The natural process of forest succession is therefore characterized by natural agents continually causing tree mortality. However, in today's context, these forest successional processes represent loss of critical forest values, risk to life and property, and are most certainly societally unacceptable. The difficulty is that human timeframes of what is important and acceptable are far shorter than nature's long-term cycles of ecological succession. Actually, our only realistic option is to manage our forests to reduce risks and to sustain the values and uses upon which we are dependent.

The challenge is how to accomplish this in a socially acceptable and economically feasible way. Societal acceptance can probably only be achieved through a combination of Congressional leadership and science-based information outreach. In particular, decision-making processes are needed that emphasize stakeholder common interests in restoring healthy forests to reduce wildfires, mitigating the effects of climate change, and striking a balance among competing values and viewpoints. The overall policy goal should be to restore and sustainably manage the nation's forests for the welfare of society at large. Since fuels treatments and thinning are costly, it is critical to explore ways and means by which these costs can be offset by utilizing the biomass in the form of energy or renewable wood products. The desirability of this option becomes apparent when one appreciates that using wood can reduce carbon emissions where it is used in place of alternative materials that life cycle analyses show have higher energy requirements in manufacture.

I used the word "responsible" in my testimony in the context that failure to restore forest health and reduce impacts of wildfire and insects on wood supply, wildlife habitat, and water supply is to abdicate current society's responsibilities to present and future generations.

RESPONSE OF JOHN A. HELMS TO QUESTION FROM SENATOR CORKER

Question 12. Do we need to reconsider forest management policies or other mitigation activities? Are there currently obstacles to forest management that could significantly reduce the damage caused by fires that will only continue to compound the problem if temperatures continue to rise?

Answer. Forests are a critical national resource. They are owned by state and federal agencies, industries, tribal groups, and non-industrial family owners having diverse goals and objectives. Issues of climate change transcend property boundaries.

It is important, therefore, to examine current laws and regulations to determine opportunities for coordinated policies and cooperative management at the landscape level. Flexible policies, regulations, and incentives are needed to readily accommodate mitigation opportunities that are time-sensitive and likely to be ownership-, location- and forest-specific.

The major obstacle to forest management on national forest lands is the strong perception by some that no trees should be cut to provide wood products needed by society. It seems imperative that society understand and support the need to reduce the density of trees on national forests that are so susceptible to mortality, fuel build-up, wildfires, and insect attack. This situation will be exacerbated as temperatures rise, storms increase in frequency, and changed precipitation patterns lead to droughts. Society must recognize that the enormous funding needed to address the problem and to thin the national forests is simply not available and that it is in society's best interests to carry out the needed thinning treatments through the sale of biomass for energy and for wood products that store carbon. It is important that the public and decision makers consider whether it is environmentally, ethically, or strategically appropriate that the US, although having the capacity to be self-sufficient in wood, imports 36 percent of wood consumed and that California, for example, imports 80 percent of its wood needs from other states or countries.

RESPONSES OF THOMAS SWETNAM TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. A number of the witnesses mentioned that logging and grazing have contributed to the accumulation of fuels that are contributing to these fires. Can you briefly explain the process by which logging and grazing results in the accumulation of fuels?

Answer. Intensive livestock grazing was an important cause of reduction in surface fire occurrence in many Western forests. This effect occurred primarily during the late 1800s and early decades of the 1900s. Very large herds of sheep, goats, cattle and horses removed the grass cover in under stories of ponderosa pine and mixed conifer forests. In 1890, for example, there were more than 5 million sheep and 1.5 million cattle in New Mexico! Prior to this intensive livestock grazing era, more-or-less continuous grass cover promoted fire ignitions by lightning and people, and extensive spread of these fires. Grazing and the creation of livestock trails and "driveways" effectively disrupted the fire ignition and spread process. The sheep industry declined after the First World War, and after 1910 the U.S. Forest Service also began to fight forest fires aggressively, and to reduce overgrazing on federal forest lands. During the subsequent century, lack of frequent surface fires in ponderosa pine and mixed conifer forests allowed many trees to establish and dead fuels (tree needles, branches, logs, and snags) to accumulate. This general history did not occur everywhere in the West, but it was fairly typical in the Southwest and in many pine-dominant and mixed conifer forests of the Sierra Nevada, and inter-mountain regions (Swetnam and Baisan 2003). This effect of livestock grazing, fire suppression, and subsequent fuel accumulation was generally not important in relatively higher elevation, wetter forests, such as spruce-fir and lodgepole pine forests. Grass cover was much less extensive in these forest types, and typically large fires only occurred at long intervals (>100 years), so fire suppression has had less or no effect here in lengthening the intervals between fires (Schoennagel et al. 2004).

Logging (tree harvesting) has a highly variable effect on fire activity. Again, the effects depend on forest type, region, and the kind of management practices employed. It is generally thought that extensive, unregulated logging practices in the late 19th century and early 20th century were a contributing factor to the enormous and destructive wildfires that occurred during this part of the settlement era in the Lake States and West. Some of these massive, historic conflagrations were noted by Senator Domenici in his statement at the beginning of the hearing (for example the Peshtigo Fire of 1871). The unregulated 19th century harvesting, and some modern harvesting in the 20th century, produced massive quantities of surface fuels, deriving from untreated residual branches, tree leaves/needles and boles. These fuels contribute to fire ignition, spread, and unusual fire severity. Although this type of logging—where residual fuels are generated and untreated—has contributed to increased fire extent and severity in some places and times, logging (and thinning) practices can lead to reduced fire hazards when the residual fuels are treated, e.g., by hauling them away or burning in situ in piles or by broadcast burning. There is a building body of scientific evidence supporting the general strategy of forest thinning and prescribed fire as a means of reducing wildfire severity and damaging effects in some western forests (e.g., Schoennagle et al. 2004, Finney et al. 2005, Cram et al. 2006, Omi et al. 2007). The recent Omi et al. study, in particular emphasized the importance of treating surface fuels, and not just reducing overstory tree densities. Again, I would emphasize that such fuels treatments (e.g., thinning) are ecologically appropriate in forests that formerly sustained frequent surface fires, had relatively low tree densities and low accumulated surface fuels, but now have much higher tree densities and accumulated dead fuels. From an ecological perspective, however, such treatments are not justified in wetter, higher elevations forests where frequent surface fires were not a natural occurrence (Schoennagle et al. 2004).

Another effect of logging on fire activity is related to the extensive road building associated with logging. Vast networks of roads built to accommodate logging have allowed many more people to travel into remote areas, and it is likely that this greater access has allowed more human-set fires to occur in these places.

Question 2. You mentioned at the hearing that you believe that thinning should generally focus on small-diameter trees. What is the scientific rationale for focusing on small diameter trees?

Answer. To reduce fire hazards in forests that previously sustained frequent surface fires (i.e., before intensive livestock grazing and active fire suppression began) the primary emphasis should be on thinning relatively smaller diameter (often younger) trees (Allen et al. 2002). This emphasis is a rather obvious and logical strategy in most of these forest types where past management practices have led to extreme forest structure changes and hazardous fuel accumulations. For example, many ponderosa pine and mixed conifer forests in the Southwest and elsewhere in the West have extraordinarily dense "thickets" of relatively small diameter trees. It has been shown in studies that the vast majority of these small diameter (and often stunted) trees established in these forests as a consequence of and following the disruption of frequent fire regimes by land use practices (e.g., livestock grazing and active fire fighting) (e.g., Fulé et al. 2002). In some cases the stem densities of these stunted tree thickets exceed 5,000 stems per acre (Falk 2004). Moreover, it is clear from fire behavior modeling and observational studies that these dense thickets are an important contributing factor in generating unnaturally severe crown fire behavior in some forests (Cram et al. 2006, Cruz et al. 2006, Allen 2007). It is also generally the case that larger diameter, older trees, are relatively rare in most forest types as a consequence of natural mortality patterns, and because of extensive harvesting of large trees in the past century. Hence, there are ecological, silvicultural, esthetic, and scientific reasons to focus primarily on thinning smaller diameter trees, and to thin (or harvest) larger diameter, older trees sparingly and judiciously (if at all) in these forest types I am referring to.

In my view, it is an unnecessary and counter-productive point of contention for federal agencies, timber industry interests, or forest scientists to insist that specific diameter caps should never be imposed in thinning treatments. It is quite clear that a focus on thinning of the relatively small diameter stems will often and substantially reduce the risk of unnaturally severe fires in these forest types. Importantly, focus on the smaller diameter trees will also reduce contention and challenge of such treatments by concerned citizens and non-governmental organizations. Moreover, it is critical that resulting fuels generated by such thinning be treated by removal (by burning or hauling off site) (Omi et al. 2007). It is important to note here that I use the phrase "small diameter" trees in a relative sense, and specific to forests where natural surface fire regimes were disrupted. The diameter range of trees in high density groups in productive Sierra Nevada forests may be considerably larger than the diameter range of thickets in lower productivity Southwestern forests.

I would also clarify that I am not opposed to traditional forestry practices that involve either even aged or uneven-aged management or rotation-based silvicultural designs in appropriate areas and circumstances. I am trained as a forester myself, and my father was a District Ranger with the U.S. Forest Service for 35 years. However, I believe that in the context of reducing fire hazard in forests where thickets of small diameter trees are a primary cause of increased hazards (i.e., a substantial part of the problem in the West), a focus on small diameter trees makes eminent sense.

Question 3. Your testimony mentions the possibility that global warming could result in "more-or-less permanent 'dust bowl'-like conditions in the Southwest." Are there any indications in the historical or pre-historical records of what that might mean for wildfire activity in New Mexico?

Answer. My reference to the potential for a transition to "more-or-less permanent 'dust bowl'-like conditions in the Southwest" was based on the recent paper published in the journal Science by Seager et al (2007). They hypothesized this potential under a scenario of increasing greenhouse gases and continued global warming, and the modeled and observed effects of ocean-atmosphere patterns on regional climate.

The most extreme droughts in the past century in New Mexico were the "turn of the century drought" (1890s), the "Dust Bowl drought" of the 1930s, the "1950s drought" (late 1940s to about 1957), and the current drought (since about 1998). The tree-ring record of drought in the Southwest is very extensive, and perhaps the best documented drought history of this type for anywhere in the world. Good quality tree-ring-based drought reconstructions cover all of New Mexico and the broader Southwest over the period from about AD 1500 to present, and some locations have histories extending back nearly 2,000 years (Ni et al. 2002, Cook et al. 2004). These long-term histories show that some pre-20th century droughts exceeded in magnitude and duration any drought experienced during the 20th century. Notable examples include the so-called "megadroughts" of the mid 1100s, and the 1580s. Many of these droughts undoubtedly had profound impacts on human populations and ecosystems. For example, a "Great Drought" at the end of the 13th century AD was a contributing factor in the Anasazi abandonment of the Colorado Plateau, and the migration of many of the ancestors of modern New Mexico Pueblo peoples to the Rio Grande valley.

We have limited knowledge about the impacts of past megadroughts on ecosystems and fire. However, it is likely that some past droughts led to very large wildfires, bark beetle outbreaks, and direct drought-induced mortality of trees and other plants—much as recent drought effects. Moreover, extreme amplitude "switching" of wet years and dry years during the late 1700s apparently led to many widespread fires in the Southwest (Swetnam and Betancourt 1998). We think the 1580s megadrought probably caused widespread burning and drought/bark beetle-related tree dieoff. This interpretation is based on observations that very few living or dead trees can be found in the Southwest that pre-date this major event. Hence, it appears that a major forest and woodland dieoff occurred, followed by extensive regeneration during a wetter and cooler period in the early 1600s (Swetnam and Betancourt 1998).

During the 20th century, the 1950s drought stands out as the most severe event. Notably, a number of very large forest fires erupted in Southwestern forests during this period. Also, a very extensive bark beetle outbreak and tree mortality occurred in parts of New Mexico during the 1950s drought (Swetnam and Betancourt 1998, Breshears et al. 2005, Allen 2007). However, even though the 1950s drought was more extreme in some areas of the Southwest than the recent drought, both forest fires and bark beetle outbreaks were considerably smaller in extent than during the recent drought. For example, the largest recent fires (i.e., the Rodeo-Chediski in Arizona, 467,000 acres) were almost an order of magnitude larger in size than the largest forest fires during the 1950s in this region. The extraordinary size of both bark beetle outbreaks and wildfires in the recent decade in the Western US (including Alaska) and Canada is a chief reason that I and many of my colleagues have concluded that recent warming temperatures and earlier springs are likely a key factor in these patterns, and not just reduced rainfall (Breshears et al. 2005, Westerling et al. 2006).

Responses of Thomas Swetnam to Questions From Senator Senator Salazar

Question 4. What types of adaptation management strategies have been found to best deal with managing the expected increased threat of wildfires?

Answer. Fuels treatments using mechanical thinning and prescribed fires are appropriate and effective in some forest types, particularly forests that formerly sustained frequent surface fires in the 19th century and earlier. Climate change increases the urgency to get on with these treatments at much larger scales than has been accomplished so far. A general goal should be to increase the resiliency of these forests to the coming climate "shocks", i.e., drought-induced wildfires, insect outbreaks, and other disturbances. By "resiliency" I mean the ability of ecosystems to resist damaging effects and to recover from disturbances. I would emphasize a need to act at broader spatial scales, and especially to increase the use of fire as a management tool and a key element of ecological restoration. We can not hope to keep fire out of our forests. Fires will happen; the question is: Will they be fires that we have planned for and managed, and are ecologically beneficial, or will they be unplanned, uncontrolled and destructive to ecosystems and human values?

One adaptive strategy I have advocated is utilizing recently burned landscape "mosaics" as an opportunity to engage in landscape-scale follow-up treatments. Most recent, large wildfires have resulted in complex mosaic patterns of high, moderate, and low severity burned areas (proportions of overstory trees killed), and unburned patches. These large mosaics of burned/unburned areas provide an excellent opportunity to engage in large-scale forest restoration/fire use treatment programs. The high severity burned patches and fire lines constructed during the suppression efforts offer safety zones and control features for use of prescribed surface fires. Local communities are energized in these areas and ready to move forward with proactive restoration efforts at improving sustainability and resiliency of forests surrounding their homes. A partnership of federal agencies, community groups, and University scientists are currently engaged in planning such an effort in southern Arizona, where I live and work.

Question 5. One of the most enduring ad campaigns in our country's history are the Smokey the Bear public service announcements. There probably isn't a person in the room who hasn't heard the slogan "Only you can prevent forest fires." Given that the majority of wildfires are caused by human activity, are there plans to increase efforts to reach the public on climate change and expected increased wildfire activity, and ways to prevent wildfires?

Answer. I understand that the U.S. Forest Service is planning to engage in a new effort to reach out to children to help them understand climate change effects and the importance of forests and natural resources. I am unaware of other specific plans by federal agencies to focus on public communication/education on the wildfire and climate change issue.

Although it is true that the majority of fires are ignited by people nationally, in most mountain and forest regions of the West there are more lightning ignited fires than human ignited fires. Moreover, lightning ignited fires dominate the total area burned in most forest landscapes of the West. In general, more than 95% of total area burned is accounted for by fewer than 5 percent of the fires. Hence, total area burned (or numbers of the very large fires) is a much more relevant statistical factor to consider in terms of wildfire trends, impacts and costs than total numbers of fires ignited. Ignitions by people are important, particularly in some sub-regions, and in some ecosystem types. But the effect of high numbers of human set fires in some sub-regions does not outweigh the dominant role of lightning, fuels and climate change at the scale of the entire Western United States.

I do not mean to imply, however, that there isn't a strong need for public education and fire prevention programs. Careless ignition of fires by people can be extremely destructive, and is a part of the fire problem. Smokey Bear's message is still needed. At the same time, however, I believe we need to greatly increase the public's understanding that not all fire is bad, and in fact, the use of fire as a tool by knowledgeable managers (e.g., prescribed fire and wildland fire use) is essential to maintain the functioning of some ecosystems. Landscape-scale fire use will also be necessary to maintain fuels at safe levels. This is one of the great challenges of land management, I believe, in the coming century: How can we restore fire-dependent ecosystems using fire as an ecological restoration and management tool, while also protecting human property and lives? How can we use fire as a management tool, while also managing smoke and carbon dynamics?

Question 6. The link between climate change and fire is clearly strong, but since this linkage has come to light, some people suggest that climate is more critical than fuel as a driver of fire behavior, and there is no reason to treat fuels to protect communities or restore ecosystems. What are the implications of climate change for fuel treatment and forest restoration?

Answer. The implications are twofold. First, warming temperatures, earlier springs, and increasing severity and duration of droughts—and related wildfire responses—increases the urgency of forest restoration and appropriate fire management. Forest and fuel changes because of land uses are very important in some forests (and not in others). Furthermore, invasive species and expanding human populations all point to the necessity to better manage our forests to reduce fire hazards where feasible and ecologically justifiable. Second, there are some forest areas where forest and fuel changes are not outside the historical range of variability, and human land uses have had relatively little effect on the fire regimes or fire severity occurring in these types. In these places fuels treatments (thinning or prescribed surface fires) may or may not mitigate current or future fire hazards, and there is little or no ecological justifications for such treatments. In these cases, development and implementation of land use policies (e.g., wildland fire use, land use zoning, fire fighting and post-fire remediation policies) may be more appropriate local responses than fuels treatments.

Question 7. Fires are becoming increasingly harder to fight and are releasing huge quantities of carbon dioxide. Wildland Fire Use, the practice of allowing some lightning-ignited fires to burn under less extreme conditions, has been suggested as a way to mitigate fires and ensure they release less carbon dioxide. Do you see a role for Wildland Fire Use in changing future fire behavior so it is less extreme, thereby releasing fewer greenhouse gases?

Answer. Smart, effective wildland fire use will be essential in managing carbon dynamics in our forests in coming years. The issue is not whether we will generate smoke and carbon inputs to the atmosphere via fire, but how much, and to what extent can we manage such inputs? A general hypothesis is that planned, frequent low severity fires (in appropriate ecosystems) will result in less smoke and carbon input than uncontrolled, high severity wildfires. I am not very familiar with published literature on this topic, but my impression is that there is limited information on the short and long-term effects of fire use practices versus wildfires, particularly at the scales of landscapes (i.e., multiple watersheds and mountain ranges). I think more research is needed on this subject.

Question 8. It has been suggested that because young forests grow fast and older forests grow slowly we can cut down old forests and replace them with fast-growing plantations to maximize the uptake of carbon dioxide and reduce global warming. What is the current scientific understanding of the effects of logging older forests on the uptake or release of greenhouse gases?

Answer. The specific role of older forests versus younger forests in sequestering carbon is beyond my knowledge and expertise. I suspect that there is some scientific literature on this topic, but I doubt that there is a scientific basis for such a drastic step as removing old forests for this purpose. In general, old growth forests are a quite small proportion of the remaining forests in U.S., and so harvesting them for the purpose of planting young trees would unlikely be a significant benefit to carbon sequestration. The losses of the special values of old growth forests would also be great (e.g., wildlife habitat, esthetic, and scientific values). On the other hand, it may well be that expanding plantations in some previously harvested lands, or perhaps converting grasslands or other ecosystem types (where feasible) to forests for carbon sequestration may be a useful approach in the future.

RESPONSES OF THOMAS SWETNAM TO QUESTIONS FROM SENATOR DOMENICI

Dr. Swetnam you suggested that it might be too late to manage in high-elevation long fire rotation stands and that it might be wiser to focus management in the Ponderosa Pine forests of the Southwest.

Question 9. If the low elevation and southern Ponderosa Pine forests are likely to have to migrate to higher elevations and to the north, do you believe it would be wise to ignore the fires at higher elevations in the northern Intermountain States?

Answer. During the hearing I stated that prioritization of management treatments, such as forest thinning and prescribed burning, should be focused in areas where forest structures and fuel levels have changed the most as a consequence of past land use practices (e.g., livestock grazing and fire suppression). High severity fires are a much larger problem—from an ecological and sustainability perspective—in these forests (e.g., ponderosa pine dominated and drier mixed conifer forests) than in some higher elevation, northern forests (e.g., spruce-fir and lodgepole pine forests). Also, there are extensive areas of ponderosa pine and mixed conifer outside of the Southwest that have experienced disrupted surface fire regimes, increased forest densities and fuel accumulations, and are in need of fuels treatments to reduce risk of large unnaturally high severity fires. Current federal agency approaches and tools for mapping, and assessing fire hazards and treatment prioritization (e.g.., LANDFIRE and Fire Regime Condition Class assessments) do in fact consider such historical and natural aspects of fire and forest changes.

Perhaps climate change (e.g., warming) will eventually establish more landscape areas in the higher elevations and northern Western states suitable for ponderosa pine. If this happens on a large-scale there will probably be many negative repercussions that will outweigh concerns about whether or not ponderosa pine can migrate to or grow in these places. For example, what will we do if the vast forests of spruce-fir, lodgepole pine, western hemlock, Douglas-fir etc. in the northern, Western states convert en masse to other ecosystem types as a consequence of extraordinarily large fires, forest insect outbreaks, and direct drought-induced mortality? Extreme watershed impacts, such as reduced water quality and rapid sedimentation of municipal reservoirs will likely occur in this scenario, as well as loss of critical wildlife habitat, and loss of human lives and built structures in the wildland urban-interface.

Given this worrisome potential scenario, I do not at all believe we should "ignore" the changes occurring in high elevations, or northern forests. The key question is what can we do about these changes, if anything? It is possible that some kind of forest management might mitigate future changes in these forests. However, broad-scale forest thinning or the use of prescribed surface fires within these forests (i.e., long-interval fire regime types), has much less (or no) ecological basis or justification. Open, low-density forests and frequent surface fires were generally not a historical, ecological condition of most of these forests in the past; they are not evolutionarily adapted to this type of fire regime or forest condition. It is not at all clear that thinning treatments or surface fire use will help maintain or sustain these forests in the face of climate changes. It is possible that high severity fires, which are occurring more frequently in the recent decade, will begin to "self limit" the extent of future high severity fires. By "self-limit", I mean that formerly burned areas (n previous years and decades) may begin to limit the spread and extent of future fires.

In the near-term, and at the much broader global-scale, I believe the most important thing we can do to reduce future negative impacts in our high elevation and northern forests is to proceed rapidly to significantly reduce our greenhouse gas emissions.

Question 10. What does the field of forestry tell us about the ability of tree species to invade and reforest lands that have been heavily impacted by fires, including the loss of soil and the changes in moisture regimes after high intensity fires?

Answer. There is a considerable scientific literature on post-fire responses of vegetation and soils. I am not an expert in these areas, or very familiar with all of the recent literature. However, I will comment on the case of ponderosa pine in the Southwest, which I know best. A recent published study of post-fire forest recovery in Southwestern ponderosa pine landscapes (Savage and Mast 2005) found that re-establishment of forests in high severity burned areas was highly variable. In some cases trees did re-establish, and in other areas, burned areas have not recovered to forest—even 50+ years after the fire. Ponderosa pine produces large seed crops only erratically, and the seeds are heavy and do not travel very far by wind. Hence, large canopy holes created by severe fire may not recover for centuries. Where seedlings do establish following severe fires, Savage and Mast found that sometimes very dense stands regenerated. If these dense stands are not subsequently thinning by surface fires or mechanical treatments, they may create conditions that will generate additional high severity fires in the future.

Regarding soil effects, it has been observed that soil loss and erosion is sometimes extreme following high severity crown fires in the Southwest. For example, a recent crown fire in the Chiricahua Mountain of Southern Arizona resulted in a 30 foot deep, 60 foot wide gully at about 9000 feet elevation in this mountain (personal observation). Sheet erosion of soils, flooding and debris flows have occurred widely in Southwestern mountain ranges following recent fires (Allen 2007). In some cases, thin ancient soils in some burned areas in Southwestern Mountain ranges have been completely eroded away, and it is unlikely that soils or trees will re-establish on these sites for centuries, and possibly millennia.

Question 11. If trees sometimes have a more difficult time regenerating after high intensity fires and water retention and run off are negatively impacted in the absence of tree cover; and we do experience higher temperatures, are we more likely to see brush fields, or stands of new trees as species have to migrate up in elevation and to the north through these heavily burned lands?

Answer. We are already seeing some ecosystem-type conversions as a consequence of high severity fire and erosion in some Southwestern forests, as I described in response to the previous question. An example that Senator Domenici is familiar with is the Bandelier-Los Alamos area in the Jemez Mountains of northern New Mexico. A series of high severity crown fires in this landscape (including the 1977 La Mesa Fire and the 2000 Cerro Grande Fire) has resulted in conversion of ponderosa pine and mixed conifer landscapes to grasslands and shrub fields over significant areas (Allen 2007). At this point, it seems that grasslands and shrub fields are likely to be the most common ecosystem type replacing forests in the Southwest, and perhaps elsewhere in the West.

Question 12. Dr. Swetnam, much of your testimony was focused on the Pacific Southwest and Southwest, yet many of the climate change models suggest that in the short and middle term the tree species composition in the upper Great Lakes and the Southeast are likely to see the largest changes, while the Western U.S. could even see an expansion of forests due to wetter winters. If one assumes that increased global temperatures will result in drier climates in these areas and that these areas may also experience increased fire activity, what steps can the land managers in these states take to mitigate the changes, or to prepare for the changes?

Answer. It is only relatively recently that down-scaled, regional climate models have become sufficiently accurate to assess with some confidence what may occur climatically in regions of U.S. under different scenarios of increasing greenhouse gases in the atmosphere. I am not familiar with results of forecasts in most U.S. regions, but information on the Southwestern U.S. (e.g., Seager et al. 2007, Hoerling 2007) are not encouraging. Precipitation forecasts are still much less consistent and reliable that temperature estimates. However, even in models showing some increases in winter precipitation, warming temperatures and consequent increased evaporation and evapotranspiration are likely to override rainfall increases, resulting in a net decrease in soil moisture and river flows (Hoerling 2007).

Regarding what to do to mitigate and prepare for these changes, I would refer to my answer to a similar question (#6) by Senator Salazar. In summary, I think climate changes (warming and increased droughts, in particular), increase the urgency of forest restoration and fuels treatments, but these should be focused in landscapes where forests have changed the most and have become more conducive to crown fires because of past management actions, and where large, high severity fires are generally outside the historical range of variability. It also makes sense to focus fuels treatments at the wildland-urban-interface, but not exclusively.

Question 13. Dr. Swetnam, in the most aggressive models of increased temperature and moisture changes can you describe where forests might exist in Arizona and New Mexico, as well as what the species composition might be at various altitudes say 50 years from now? And in 100 years?

Answer. This is a critically important question, not only for Arizona and New Mexico, but also for the rest of the U.S., and the globe, i.e., what forest and ecosystem changes will occur due to warming and drought trends, when and where? I frankly do not think anyone has reliable answers to these questions yet. As I pointed out in the previous question (#12) there are improved regional climate change model results that are useful in addressing this question. There are also dynamic vegetation models that are beginning to address these questions (e.g., Bachelet et al. 2001). Some of the vegetation models do contain wildfire-climate submodels, and some include insect outbreak dynamics. However, I don't think the important combined effects of fires and insect outbreaks have been addressed, and I know of no such results for Arizona and New Mexico in particular. I do think this is an important topical area needing much further research.

RESPONSE OF THOMAS SWETNAM TO QUESTION FROM SENATOR CORKER

Question 14. Do we need to reconsider forest management policies or other mitigation activities? Are there currently obstacles to forest management that could significantly reduce the damage caused by fires that will only continue to compound the problem if temperatures continue to rise?

Answer. As I have articulated in response to previous questions by Senator Salazar (#4, 6, 7) and Senator Domenici (#9, 12), I believe we need to increase our forest restoration and fuels treatments substantially in forest types that have undergone major changes in tree density and fuel loads because of past management activities. We especially need to re-introduce surface fires as an ecological process in many of these forests. This will require planning and implementation at landscape-scales (i.e., watersheds to mountain ranges), and it will especially require collaboration with local communities. As I describe in response to Senator Salazar's question (#4), I think utilization of recently burned landscape "mosaics" is an outstanding opportunity to carryout much larger treatments, especially using prescribed fire. Moreover, there is urgency in quickly moving to landscape-scale treatments in these areas because it has been demonstrated in recent studies (Finney et al. 2005, Omi et al. 2007) that there is a fairly short window of time (10 years or less) that these treatments can effectively mitigate the effects of future wildfires.

There are many obstacles to carrying out ecological restoration and mitigating/adapting to climate change and future wildfires using thinning and prescribed fire treatments. A few examples include smoke emissions, risk of escaped prescribed fires, liabilities in the use of fire as a management tool, public/agency conflicts over goals and means of carrying out restoration programs, etc. Dealing with all of these obstacles is daunting, but doable, I think, so long as collaborative approaches involving all concerned are a central part of the process.

I would mention one obstacle in particular at this point: The professional capacity for fire management must be increased substantially within the federal agencies if we are to meet the challenge of creating more resilient and sustainable ecosystems in the face of coming climate changes. By this I mean that we need a much larger corps of well-trained, experienced, year-round fuels and fire managers. The task of fire fighting must not continue to overwhelm the ability to manage fuels and forests. An investment in much greater personnel capacity and expertise to plan and implement thinning and prescribed burning in the context of building ecological resiliency is essential to move beyond the current reactive mode of management in response to increasingly severe wildfire seasons (see the recent GAO report, 2007).

APPENDIX II

Additional Material Submitted for the Record

STATEMENT OF THE NATIONAL ASSOCIATION OF CONSERVATION DISTRICTS

On behalf of the nation's 3,000 conservation districts, the National Association of Conservation Districts (NACD) is pleased to provide comments to the Committee on climate change and wildfires. Established under state law, conservation districts are local units of government charged with carrying out programs for the protection and management of natural resources at the local level.

In carrying out their mission, districts work closely with the USDA's Forest Service and Natural Resources Conservation Service and the Interior Department's Bureau of Land Management to provide the technical and other help private landowners need to plan and apply complex conservation treatments on forest, range and other working lands.

Conservation Districts play an important role in the areas of hazardous fuels reduction, woody biomass utilization and forest planning.

Though changing climate may have an effect many agree that because of past management practices and fire suppression, many of our forests administered by Federal agencies have accumulated fuel loads and developed stand structures susceptible to catastrophic fires that destroy the stands and increase the risk of insect and disease attack. Silvicultural practices such as prescribed fire, density control and harvest of commercial forest products can reduce the frequency and intensity of extreme fire events, while benefiting local, regional, and national economies.

Conservation districts across the country are actively involved in implementing the National Fire Plan that was developed in 2000. Conservation Districts:

- Serve as a catalyst to assemble major stakeholders to work together to solve wildfire and any other environmental problems on a community or watershed level.
- Provide education and information about critical local natural resource issues.
- Play a direct role in implementing wildfire protection plans such as hazardous fuel reduction and prevent a catastrophic fire or in restoration plans to stabilize a site after a wildfire has occurred.

Conservation districts applaud Congress for passing the Healthy Forests Restoration Act (HFRA) in 2003. The funding for HFRA and implementation through the National Fire Plan provide opportunities for local communities and organizations, including conservation districts, to become engaged in community wildfire protection projects, fuels reduction projects, and state and local Firewise education efforts. Continued commitment from Congress and the administration to this end is crucial to if we are to make our forests more healthy and our communities safer places to live and work.

Conservation districts and resource conservation and development councils (RC&Ds) already have in place a number of cooperative agreements with federal land management agencies to promote, and improve the utilization of woody biomass in order to reduce the build-up of hazardous fuels, lessen the threat of catastrophic wildland fires and restore forest, woodland, and rangeland health.

Conservation districts' efforts offer tremendous opportunities to reduce catastrophic wildland fires and restore forest, woodland, and rangeland health. In recognition of these opportunities, NACD entered into a cooperative agreement with the Bureau of Land Management and Forest Service to develop, promote, and improve woody biomass utilization.

Other partners in this effort include the Interior Department's Bureau of Indian Affairs, National Park Service, Fish and Wildlife Service, the National Association of Resource Conservation & Development Councils, and State Forestry Agencies.

Under this agreement, NACD is providing resource materials and information to local conservation districts to educate landowners and others on the issue. The goal of this initiative is to help increase public understanding of the social, economic, environmental and aesthetic benefits gained by using woody biomass as a means of reducing the buildup of hazardous fuels.

We believe more cooperative efforts such as this are needed. Involving local communities and landowners is the ideal way to ensure the success of the Healthy Forests Restoration Act, the National Fire Plan and other efforts in wildland fire management.

Conservation districts also support other collaborative efforts of the Interior and Agriculture Departments in conducting fuel reduction treatments in the urban wildland interface on federal lands that are at risk from wildfire. To maximize their effectiveness, we believe these collaborative hazardous fuel reduction efforts should include:

- A landscape scale approach with the support and involvement of local constituents;
- Cross boundary mitigation;
- Coordination of Federal, state and local government priorities, project design and implementation strategies to maximize effectiveness and minimize costs; and
- Project designs that consider restoration of ecosystem structure, native composition and natural fire regimes.

The drought, which is expected to continue unabated for several more years—especially in the West—adds to the wildland fire issue by contributing to insect and disease problems on our Nation's National Forests, BLM lands and private woodlands, as well. Not only is the damage costly to timber, but it also adds to the fuel load and endangers lives, homes, and entire communities as we have recently seen in South Lake Tahoe.

The nation's conservation districts believe that there are many more opportunities to develop the potential to use woody biomass and turn hazardous fuels into useful and valuable products such as renewable energy. We look forward to continuing our partnerships with the various federal agencies that are responsible for managing the nation's public forests and rangelands.

NACD encourages support for policies and programs that prevent the buildup of hazardous fuels and rehabilitate those lands damaged by wildfire. Such efforts should be coordinated with biomass utilization projects and include criteria for enhancing watershed health. We look forward to continuing to work with the Committee on these issues and working at the state and local level to explore opportunities to partner with federal, state and local emergency response agencies to address natural resources recovery.

STATEMENT OF LAURA MCCARTHY, INTERIM CO-DIRECTOR, GLOBAL FIRE INITIATIVE, THE NATURE CONSERVANCY

The Nature Conservancy is providing written testimony to add to the record of the Energy and Natural Resources full committee held September 24, 2007. This written testimony summarizes work by The Nature Conservancy's Global Fire Initiative and Global Climate Change Initiative to understand the impacts of climate change on fire management at a global scale and to work with public land managers in the Western U.S. to adapt to changing climate and fire regimes in specific landscapes.

The Nature Conservancy is an international, nonprofit organization dedicated to the conservation of biological diversity. Our mission is to preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive. Our on-the-ground conservation work is carried out in all 50 states and in more than 30 foreign countries and is supported by approximately one million individual members. The Nature Conservancy has protected more than 117 million acres of land and 5,000 miles of river around the world. Our work also includes more than 100 marine conservation projects in 21 countries and 22 U.S. states.

The Conservancy owns and manages approximately 1,400 preserves throughout the United States—the largest private system of nature sanctuaries in the world. We recognize, however, that our mission cannot be achieved by core protected areas alone. Therefore, our projects increasingly seek to accommodate compatible human uses, and especially in the developing world, to address sustained human well-being in a changing world.

Climate change and altered fire regimes pose serious long-term threats to healthy ecosystems that support people, plants, and animals. Prompt action is needed to address these threats to minimize future harm to nature and to the social and economic fabric of our society. The effects of a changed climate, including increases in global average air and ocean temperatures, increased precipitation in some areas and more frequent and severe droughts in others, an increase in the occurrence of intense weather events and a change in wildfire patterns and intensity, are already evident. This testimony will focus on adaptation strategies, in order to avert the most extreme effects.

IMPACTS OF CLIMATE CHANGE ON FIRE MANAGEMENT AND FOREST HEALTH

Fire is a key process in many ecosystems around the world[1] and in the majority of U.S. ecosystems.[2] The Nature Conservancy's recent global fire assessment found that over half of global lands have degraded fire regimes from urban development, livestock ranching, agriculture and mining.[3] The alternation of these natural fire regimes through excessive wildfire suppression or, at the other extreme, catastrophic wildfire, can impair ecosystem function, emit greenhouse gases above natural levels, open pathways for invasive species, and place biodiversity conservation and human life and property at risk.

Climate change is also altering key factors that control wildfire: temperature, precipitation, humidity, wind, biomass, vegetation species composition and structure, and soil moisture. Human activities have increased atmospheric concentrations of carbon dioxide and other greenhouse gases, causing global mean temperature to increase 0.7[degree] C in the 20th Century.[4]

Projections of future climate predict that natural fire frequencies will increase around the world,[5] although fire may decrease in areas of higher precipitation. Warmer temperatures, decreased precipitation over land, increased convective activity, increased fuels from dying vegetation, and large-scale vegetation shifts may increase fire globally.

Wildfires may create a positive feedback for global warming through significant emissions of greenhouse gases. Wildfires currently contribute approximately 7% of global greenhouse emissions.[6] Global fire data indicate that carbon emissions from fire increased significantly in the last century—from 1.5-2.7 billion tons C y^{-1} in 1900 to 2.7-3.3 billion tons y^{-1} in 2000—mainly as a result of tropical deforestation.[7]

In mid-altitude conifer forests of the western U.S., an increase in spring and summer temperatures of 1°C since 1970, earlier snowmelt, and longer summers increased fire frequency 400% and burned area levels 650% from 1970 to 2003.[8] Low levels of human activity in those forests, however, suggest that climate change may cause different impacts where there are high levels of human intervention.

Across much of North America, fire suppression during the 20th Century depressed fire frequencies below natural levels. In these areas, prescribed burning and wildland fire use could return ecosystems to an ecologically-appropriate fire regime, particularly if favored by future climate. Although prescribed burning may release

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[2] Shlisky, A.,J. Waugh, P. Gonzalez, M. Gonazlez, M. Manta, H. Santos. E. Alvarado, A. Ainuddin Nuruddin, D.A. Rodriguez-Rejo, R. Swaty, D.Schmidt, M.Kaufmann, R.Myers, A.Alencar,F.Kearns,D.Johnson, J.Smith, D.Zollner and W.Fulks.2007.Fire, Ecosystems and People: Threats and Strategies for Global Biodiversity Conservation. GFI Technical Report 2007-2.The Nature Conservancy. Arlington, VA.

[3] Shlisky,A.,J. Waugh,P. Gonzalez, M. Gonazlez, M. Manta, H.Santos. E. Alvardo, A. Ainuddin Nuruddin, D.A.Rodriguez-Trejo, R.Swaty, D.Schmidt, M.Kaufmann, R.Myers, A.Alencar, F.Kearns, D.Johnson,J .Smith, D.Zollner and W.Fulks. 2007. Fire, Ecosystems and People: Threats and Strategies for Global Biodiversity Conservation. GFI Technical Report 2007-2. The Nature Conservancy. Arlington, VA.

[4] Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: The Physical Science Basis. Cambridge University Press. Cambridge, U.K.

[5] Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: The Physical Science Basis. Cambridge University Press. Cambridge, U.K.

[6] Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: The Physical Science Basis. Cambridge University Press. Cambridge, U.K.

[7] Mouillet, F.,A. Narasimha, Y.Balkanski, J.F. Lamarque, and C.B. Field. 2006. Global carbon emissions from biomass burning in the 20th century. Geophysical Research Letters 33:L01801.doi10.1029/2005GL024704.

[8] Westerling.A., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and earlier spring increase western U.S. forest fire activity. Science 313: 940-943.

greenhouse gases in the short-term, re-growth in biomass results in no net loss of carbon. Prescribed burning can also increase numbers of large-diameter old-growth trees (and standing biomass per unit area), thus reducing net greenhouse gas emissions in the long term.

LAND TREATMENTS TO IMPROVE RESILIENCE IN FIRE-DEPENDENT ECOSYSTEMS

Questions to witnesses on September 24 revealed some of the Committee members' interest in the role of mechanical fuels reduction treatments to increase forest resilience to large-scale fires triggered by climate change (specifically less snowpack and higher summer temperatures). During the question and answer period, Dr. Thomas Swetnam made a point that was captured by the press as, "We can't thin our way out of this." However, Dr. Swetnam's answer was actually much longer, as he explained how thinning is a necessary part of a landscape approach that addresses forest health at a scale of 100,000 acres or more. Specifically, Dr. Swetnam suggested that entire landscapes may not need to be mechanically thinned, but rather that such treatments could be strategically placed in the landscape, and fuels on the rest of the lands treated with prescribed burning and wildland fire use.

The Nature Conservancy is already applying this landscape approach through a partnership program called the Fire Learning Network carried out with the Department of the Interior and USDA Forest Service. The Fire Learning Network consists of 76 multi-jurisdictional landscapes in 36 states, ranging in size from 1,200 to 12 million acres. The landscapes are organized into regional networks that generally use collaborative approaches to large scale ecological restoration, and the four Western networks include several examples of the strategic approach discussed by Dr. Swetnam.

The lessons learned from the Fire Learning Network experience with collaborative landscape restoration indicate that land managers and partners in some places are successfully developing strategies to restore forest health in fire-dependent ecosystems impacted by climate change. These land managers are developing landscape restoration plans before they begin treatments. The landscape restoration plans are based on a collaboratively developed vision of the desired future landscape condition, expressed quantitatively with data derived from LANDFIRE and related sources. The plans include an assessment of current ecological conditions and the treatments necessary to move toward the desired future condition. As a result, most implementation fits the description offered by Dr. Swetnam—that is strategically placed mechanical treatments and a program of prescribed burning and wildland fire use to restore ecological conditions across a large landscape.

SUMMARY AND RECOMMENDATIONS

Two conclusions emerge from the above summary of climate change impacts on fire management at a global scale that are important to incorporate into forest and fire management policy:

1. Attempts to exclude fire from forests that are adapted to low-intensity, frequent fire can result in a net increase in carbon release because eventually, unnaturally severe, damaging fires can occur as a result of a build-up of vegetation.
2. The ecologically appropriate use of prescribed burning and wildland fire use in fire-dependent ecosystems does not contribute to increased carbon emissions in the long run.

The Nature Conservancy recommends that the Senate Energy and Natural Resources Committee steer the agencies to develop climate change adaptation strategies through existing agency land and resource management planning, research programs, and new initiatives that may be launched to address climate change.

STATEMENT OF THOMAS R. ARMSTRONG, SENIOR ADVISOR, GLOBAL CHANGE PROGRAMS, GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR

Mr. Chairman and Members of the Committee, thank you for the opportunity to provide this statement for the record on climate change and its impacts on wildfire activity in the United States. My name is Thomas R. Armstrong, and I am the senior advisor for global change programs at the U.S. Geological Survey (USGS). I also represent USGS and the Department of the Interior (DOI) as a member of the U.S. Climate Change Science Program (CCSP).

Climate change is perhaps the most complex and multi-faceted challenge facing public land managers. Although climate change is a natural, continuous Earth process, changes to the Earth's climate are related to human activities as well. Whether the causes are natural or from human influence, the USGS climate change focus is on understanding its impacts and the potential adaptive strategies for managing natural resources and ecosystems in the face of these changes.

Climate change affects biota, water, ecosystems, cultures, and economies. To effectively manage its public lands and trust resources, the DOI, working within the broader U.S. interagency climate change science framework, must advance the scientific understanding of climate change processes and impacts. The USGS, a DOI bureau, has a long and distinguished history of conducting research, monitoring and modeling of climate change and its physical and biological impacts. The USGS conducts scientific research to understand the likely consequences of climate change, especially by studying how climate has changed in the past and using the past to forecast responses to shifting climate conditions in the future; distinguishing between natural and human-influenced changes; and recognizing ecological and physical responses to changes in climate. For example, USGS scientists and colleagues have created sophisticated models that relate wildland fire patterns to decadal climatic variability (Swetnam and Betancourt 1998). USGS researchers have also investigated plant, animal, soil, and water responses to fire through field-based empirical investigations for more than 40 years (Van Wagtendonk 1983, 1994; Keeley 2004). These capabilities and strengths allow the USGS to play a critical role in conducting climate change science across the Nation's terrestrial, freshwater, and coastal systems and in providing objective science to assist decision makers.

The DOI has taken bold steps to coordinate and focus its efforts in climate change. Secretary Kempthorne has convened a Climate Change Task Force to address the land management and stewardship challenges presented by a changing climate. The task force includes three subcommittees—one on legal and policy issues; a second on land and water management issues; and a third, which I chair, dealing with climate change scientific issues specifically related to the DOI's responsibilities. This latter subcommittee is exploring development of regional scale models to better forecast location-specific changes to the landscapes we manage. In addition, it is evaluating information needs to determine whether more extensive and integrated monitoring might strengthen the understanding of on-the-ground trends in the forces of climate and how they influence water availability, vegetative patterns (including proliferation of invasive species and the health and integrity of native plant communities), wildlife habitat, the future viability of threatened and endangered species, and wildfires.

A changing climate may profoundly shape future impacts of wildfires throughout the United States, North America, and the rest of the planet (Westerling et al. 2006). A changing climate is expected to produce major shifts in the timing and magnitude of local to regional precipitation patterns, the types and distribution of vegetation, including invasive species, and the types and volumes of fire fuel loads-and thus fire frequency, severity, and intensity. For example, as precipitation patterns in desert ecosystems change, opportunistic species such as red brome and cheatgrass invade. USGS research shows that these invasive species alter the natural ecosystems and fire regimes, leading to hotter burning fires that further alter soils and ecosystems (Whisenant 1990; Knapp 1996; Young and Evans 1978; Brooks and Pyke 2001; Suring et al. 2005; Miller and Tausch 2001).

While DOI bureaus have management responsibility for both forest and rangeland habitat, a large portion of that habitat is in rangeland. Natural and human-caused disturbances have interacted over the past several decades to change rangelands and pinyon-juniper ecosystems across as much as one half of the Great Basin's one hundred million acres (McIver et al. 2004). Protracted drought coupled with invasive species, altered fire regimes, grazing, human settlement and recreation, and energy exploration and development have yielded suites of vegetation that often cannot support wildlife species. Increasing annual temperature and decreasing precipitation regimes have exacerbated these ecological changes, and climate change will continue to interact with plant and animal dynamics on dry lands. As a result of these rapid and widespread changes, the sagebrush biome is becoming widely recognized as among North America's most "at-risk ecosystems" (Noss 1995).

Encroachment of native conifers such as juniper on the more mesic or moisture-balanced lands of the sage biome has shifted fire regimes from frequent, low-and mixed-severity fires to infrequent, high-severity fires. Fuel loads have increased as much as six-fold (McIver et al. 2004). Changes in the size and severity of wildfires and in the type and patterns of precipitation, whether snow or rain, falling on burned areas may have significant effects on the biological and hydrological response of large areas of the landscape (Omi 2005). One unknown is the impact of climate change on the distribution of State or federal listed noxious weed species.

Expansion of some invasive species, particularly cheatgrass and red brome which can serve as highly flammable fuels, have changed fire return intervals on the more xeric or dry interior rangelands from more than 50 years to less than 10 years (Miller and Tausch 2001). Another recent study found that cheatgrass biomass increases are stimulated by increasing carbon dioxide levels (Ziska et al. 2005). This study also found that cheatgrass will become more coarse (e.g., lignin content will increase) in the future, reducing the time that it is palatable to livestock and wildlife and causing fuel loads to accumulate due to reduced decomposition rates.

USGS research supports land-management agencies by working to discover the site-specific conditions where management actions, such as fire suppression and mechanical treatments, can restore rangeland vegetation to habitat suitable for critical wildlife species such as the sage grouse. Better decision making tools mean better management of land resources, and they provide the support necessary to manage wildland fuels and wildfires through more cost-effective means.

The USGS, in some cases in collaboration with universities or management agencies and with the support of the Joint Fire Science Program, conducts fire-related research to meet the varied needs of resource managers and to understand the role of fire on the landscape. This research includes fire management support, studies of post-fire effects and habitat restoration, and a wide range of studies on fire history and ecology. The ongoing mountain pine beetle epidemic, a consequence of long-term drought, perhaps related to climate change, has devastated forests throughout the West, thus creating a potential for catastrophic wildfires that may affect the natural ecosystems, homes and communities, including municipal water supplies, and local economies. The USGS is involved in multi-agency efforts to identify the bark beetle spread, tree mortality, and the potential for post-fire debris flows and water-quality effects. These efforts include the Colorado Front Range Fuels Treatment Partnership and the Northern Colorado Bark Beetle Cooperative, partnerships that include not only USGS but also the U.S. Forest Service, the National Park Service, the Bureau of Land Management, the U.S. Fish and Wildlife Service, and other State and local agencies.

To better understand the interaction between climate change and fire, and provide the science needed by resource managers and decision makers, the USGS is working to develop:

- A better understanding of fire's ecological role over the full range of biophysical settings and ecosystems. Basic fire ecology identifies biological sensitivities and dependencies, guiding management in prediction of post-fire consequences and in engineering the proper application of fire for long-term management. This understanding extends to physical processes within burned watersheds that affect restoration, runoff, erosion, sedimentation, debris-flow generation and water-quality issues. Recent USGS research efforts include collection and analysis of samples from the June 2007 Angora Fire on the shores of Lake Tahoe to determine potential water-quality and health effects of ash. Additionally, models developed by USGS scientists can be used to predict the probability and quantity of debris flows after wildfire.
- Means for securing better and more timely empirical data on fire effects and responses. This includes the development of new methodologies, technologies such as remote sensing, or approaches for quantifying and mapping active fires and post-fire effects, as well as standardizing field sampling.
- A better scientific understanding of the factors that influence fire regimes and post-fire effects, such as climate, precipitation, change in vegetation type and pattern, fuel, and insect and pathogen invasions.
- Methods to integrate the preceding topics to address emergency response, treatments and prescriptions, priority setting, fuel reduction, risk assessment, safety, public information, and cost effectiveness.

Also, in partnership with the USDA Forest Service and the Nature Conservancy, USGS continues to provide a pivotal role in developing the LANDFIRE project—mapping and modeling of vegetation, fuel conditions, and a suite of other data. These products benefit landowners and land managers throughout the country.

In summary, wildfires are a serious and growing hazard over much of the United States. They threaten life and property, particularly when they move from forest or rangeland into developed areas. This situation may be exacerbated by a changing climate. USGS fire-related research that includes fire management support, studies of post-fire effects, and studies of fire history and ecology are essential to understanding and forecasting the impacts of climate change on forest and rangeland ecosystems. An improved understanding and the ability to forecast future impacts can serve as the scientific foundation upon which fire management and land management decisions can be based.

Mr. Chairman, we appreciate your continued interest in this challenging land management issue, and we thank you for the opportunity to present this statement.

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