Droughts, Floods, and Forest Health

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BIOGRAPHICAL SKETCH

Carol Kennedy graduated from Cal Poly San Luis Obispo in 1980 with a BS in Soil Science. She mapped soils for Bureau of Land Management on the Benton-Owens Valley soil survey and for the Natural Resource Conservation Service on the Lake County Soil Surveys. Carol started working for the Forest Service in 1989 on the Tahoe National Forest. She is still working on the Tahoe as the Watershed Program Manager.

ABSTRACT

The importance of forest ecosystems to human well-being cannot be overstated. The connection between forests and water resources is well established, but the relationships among the components are only partially understood. Drought and floods can impact forest health and the quality and quantity of forest ecosystem services. This talk explores the current and possible changes in forest ecosystems, floods and droughts in response to predicted climate changes, and introduces some potential management options.

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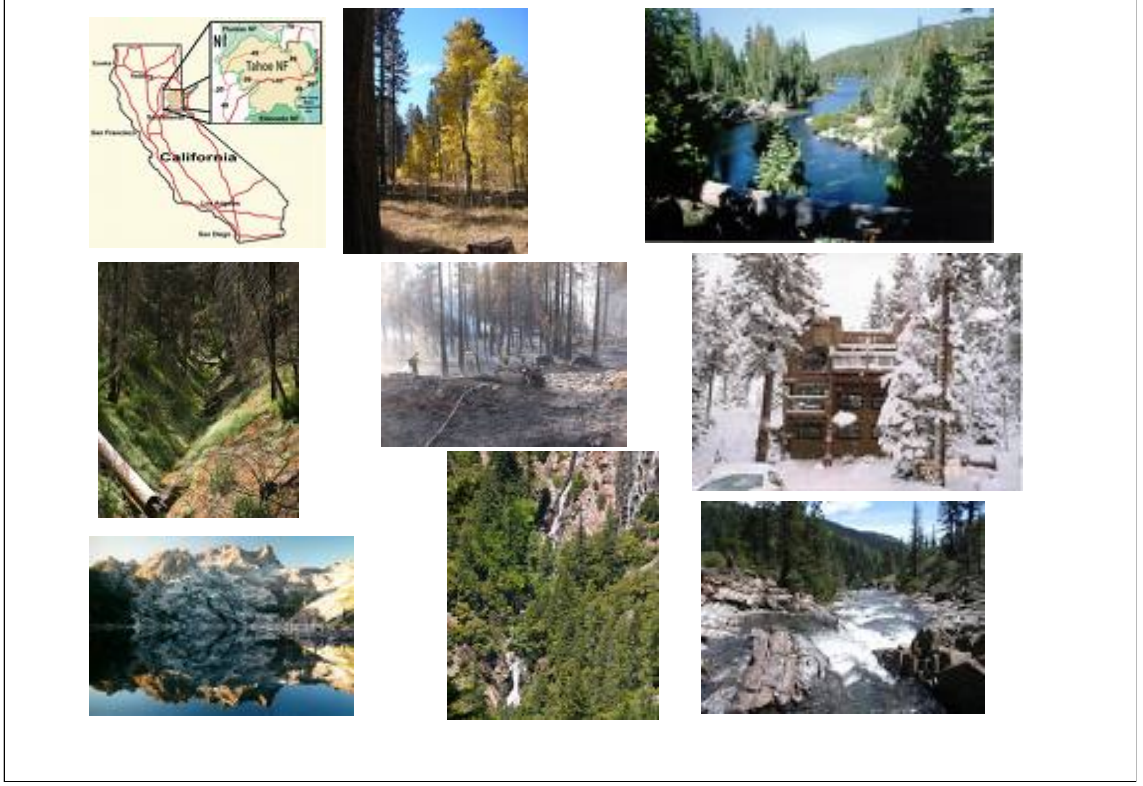
Thank you for the opportunity to stop long enough to do a little research – look to the future – ask questions.

Opportunity to look to the future, see what is predicted to happen, instead of trying to manage for present.

Can't look at drought, flood or forests in CA without throwing in climate change.

Natural resource managers are increasing expected to incorporate climate change predictions into their work.

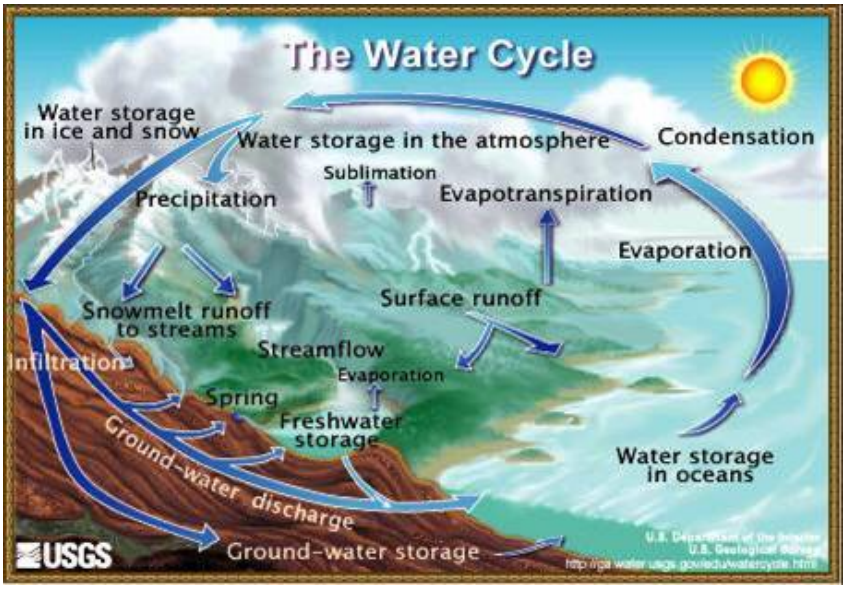


This is my usual view of the world.

Mediterranean climate; water in the winter and annual summer drought; multi-year droughts are “common”.

Floods are generally localized and issues are usually associated with roads, campgrounds, and other human developments.

Water Cycle



It is all about the water cycle. In our part of the world, forests are in the headwaters (at the top of the funnel). Water is transported to the mountains comes down. As we all know snow is a significant component of our yearly water deliver/storage system.

Floods

Floods are pretty easy to recognize – too much water very quickly, sometimes more slowly

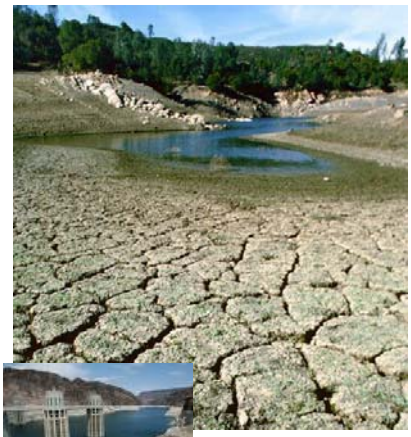
Big floods generally are the cumulative effect of localized flooding in multiple river basins.

Need to say that not all floods are bad. Example, the Nile, farm system supported for thousands of years, floodwaters brought in fresh silt deposits and washed salts from the soils, High Aswan Dam has lead to salt buildup in soils.

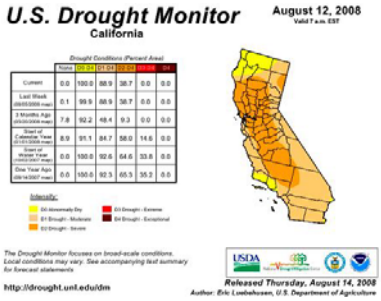
Because forests are more or less at the top of the “hydro-funnel” effects are generally within or adjacent to steam channels. In the valley- at the bottom of the funnel- more widespread effects.

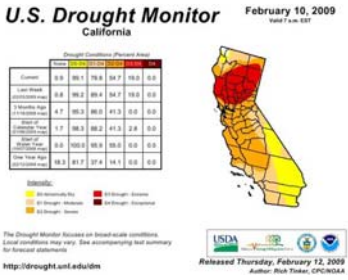
Research results indicate that cutting trees reduces water demand and can affect water yield from forested watersheds primarily during the growing season. Forest road systems may affect hillslope hydrology and flow routing to rivers and streams. Rapid subsequent runoff and increased water yield may in turn affect the frequency and magnitude of local and regional floods, but this remains to be demonstrated in the field.

Connection between forests and water resources is well established, but the relationship among the components are only partially understood. There is some evidence that the frequency of severe flooding may be on the rise due to climate change and permanent large-scale changes in land use. Given the increasing certainty that climate change is occurring and accelerating, we can no longer assume that climate conditions in the future will resemble those in the past. While there are some localized effects from flooding on forest lands, many of the major effects of flooding happen off-forest when storm water reaches valley floors. Droughts and forests – Drought on the other hand has very significant effects on forests.



Drought





. Droughts are a little harder to recognize or define than floods. Droughts can be defined by rainfall amounts, vegetation conditions, agricultural productivity, soil moisture, levels in reservoirs and stream flow, or economic impacts. In the most basic terms, a drought is simply a significant deficit in moisture availability due to lower than normal rainfall. Again severity is defined from a human loss perspective.

But what is the difference between a dry year, a few dry years, and a drought?

Drought and cohorts -- disease-pest and fire. Drought-induced tree mortality exhibits a variety of nonlinear ecological dynamics. Tree mortality occurs when drought conditions cause threshold levels of plant water stress to be exceeded, which can result in the tree to weaken or tree death by loss of within-stem hydraulic conductivity. Insect populations can rapidly build up to outbreak levels in response to increased food supply from drought-weakened host trees. Then wildfire comes in to complete the cycle.

Outline

- Forests and associated ecosystem services
- Forests in CA
  - Existing
  - Predictions
  - Management Implications/Options

Before we get too much further – an outline of the rest of this talk.

Start with general Forest talk, then bring to droughts and floods

Forest ecosystem serrvices

Forests in CA

Will address drought and flood as we go

As key regulators of global hydrologic and carbon cycles, forest are capable of contributing substantial feedbacks to global climate and climate change. Example of process that may be changing – forest carbon storage may be responding to environmentally driven changes in global patterns of tree growth and forest productivity.

Forest Ecosystem Services

- Watershed Services
- Soil Stabilization and Erosion Control
- Air Quality
- Climate Regulation and Carbon Sequestration
- Biological Diversity
- Non-Timber Commercial Forest Products

Importance of forest ecosystems to human well being cannot be overstated. Forests provide raw materials for food, fuel, and shelter. In forests, ecosystem components such as micro-organisms, soils and vegetative cover interact to purify air and water, regulate climate and recycle nutrients and wastes. Without these and many other ecosystem goods and services, life as we know it would not be possible. Some of the major ecosystem goods and services supplied by forests are: …

In addition to these Forests provide recreational and cultural values – basically passive use values, the aesthetic value of forest scenery and solitude and values associated with the region's cultural heritage.

Watershed Services

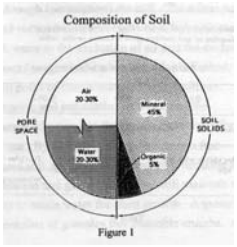
- Capture and store water
- Purify water
- Water supply
  - Agriculture, hydropower generation, municipal water supplies, recreation and habitat for fish and other wildlife species

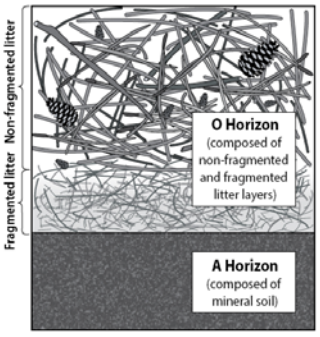
Forested watersheds capture and store water, thus contributing to the quantity of water available and the seasonal flow of water. Forest also help purify water by stabilizing soils and filtering contaminants. The quantity and quality of water flowing from forested watersheds are important to agriculture, the generation of electricity, municipal water supplies, recreation and habitat for fish and other wildlife species.

Water quality is particularly important for municipal uses. The US EPA estimates that as many as 3,400 public water systems serving 60 million people obtain their water from watersheds that contain national forests. The value of the water purification services of forested watersheds is reflected in the costs that some communities incur to protect their watersheds. New York City spent $1.4 billion to protect the quality of water from the 80,000-acre forested watershed that serves much of the city. To protect their watersheds, Portland, Oregon spends $920,000 and Portland, Maine $729,000 per year.

Soil Stabilization and Erosion Control

- Forest ecosystems
  - Soil structure
  - Litter and duff
  - Soil Biodiversity





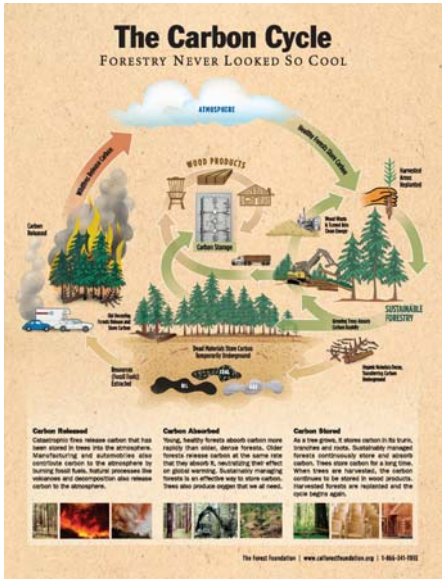
Forest sponge. Breathe of the Earth. True old growth. Species diversity.

Forest vegetation helps stabilize soils and reduce erosion and sedimentation. Forest soils are approximately half air space- pores of different sizes, that form a more or less continuous pore network that moves water down into the soil. The litter and duff layer are also very porous and transmit water rapidly. Result is that rain water and snowmelt can be transported to river systems via interflow in the litter layer (short-term delivery) or via soil water recharge (longer-term delivery). Various types of litter will have different capacities to move water downslope cleanly and without causing erosion. Filters water. Soil also are responsible for nutrient cycling, waste recycling/decomposition.

Estimated values associated with sedimentation range from $1.94 per ton in Tennessee to $5.5 million annually in Oregon's Willamette Valley

Air Quality
Climate Regulation and Carbon Sequestration

- Forests trap
  - Particulate matter
    - Improve air quality
  - Moisture
    - Cools earth's surface
- Forests store carbon



Trees help regulate climate by trapping moisture and cooling the earth's surface. Costanza et.al. (1997) imply the US forests yield $18.5 billion per year in climate regulation benefits. Studies in urban settings conclude that 100,000 properly planted, mature trees in US cities may save as much as $2 billion in heating and cooling costs. Trees also capture atmospheric carbon dioxide, thereby reducing global warming. The US Forest Service estimates that such carbon sequestration services yield benefits of $65 per ton, which totals to $3.4 billion annually for all US forests.

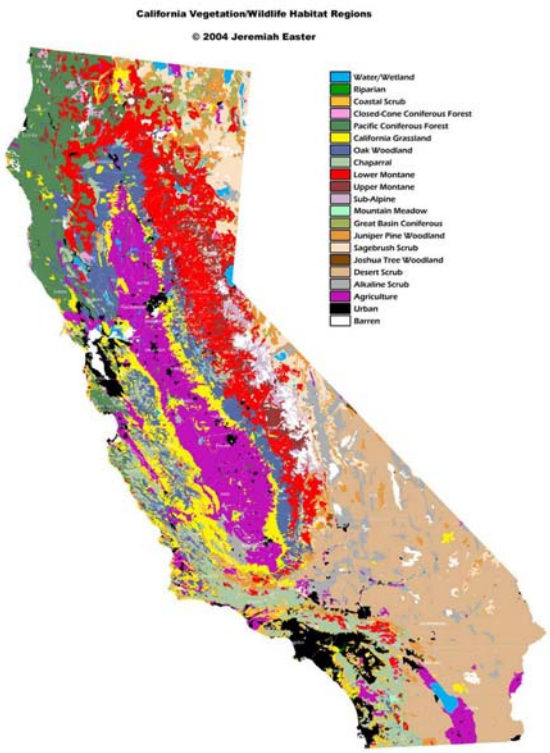
Trees trap airborne particulate matter and thus improve air quality and human health. A study in Tucson, Arizona – plan to plant 500,000 mesquite trees. When mature, they will remove 6,500 tons of particulate matter annually. Tucson spends $1.5 million on an alternate dust control program. Therefore, the air quality value of each tree equals $4.16.

Biological Diversity
Non-Timber Commercial Forest Products

- Wildlife habitat
- Pharmaceutical products
- Edible plants
- Mushrooms

Biological diversity is important for many reasons, including its role as a store-house of genetic material that can be used to selectively breed plants and animals, its contribution to natural pest and disease control and its ability to provide valuable pharmaceutical products.

Existing Forests in California



Shape of state, Mediterranean climate. Effect of species diversity – niche dwellers. Forests cover about 40 percent of California. Trees and forest are adapted to specific climate conditions and as climate warms, forests will change. These changes could include changes in species, geographic extent, and health and productivity. These changes could occur during the lifetimes of today's children, particularly if they are accelerated by other stresses such as fire, pests, and diseases. Some of these stresses would themselves be worsened by a warmer and drier climate. (7)

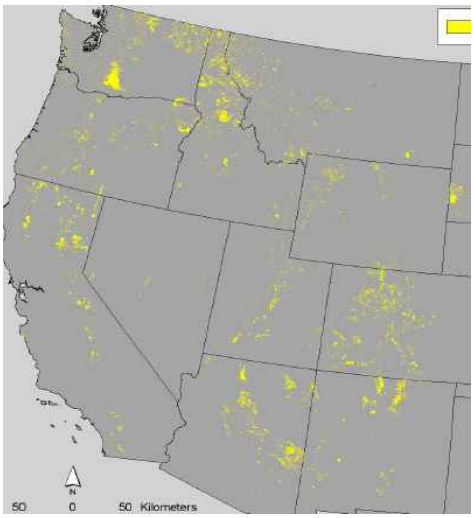
Along the Sierra, drier conditions could reduce the range and productivity of conifer and oak forests. A significant increase in the extent of grasslands and chaparral throughout the state could result. These changes would affect the character of California forests and the activities that depend on them. (7)

Recent warming has been implicated as contributing to episodes of forest dieback (pulses of greatly elevated tree mortality), such as those mediated by bark beetle outbreaks in western North America. Increased length of annual summer drought and increased length and severity of multi-year drought stress.

Forest Mortality

Insects and disease are a normal, even critical, part of the forest life cycle because they help break down plants and put nutrients back into the soil. Drought-stressed trees can't fend off pests and pathogens like healthy trees can. Drought, pests, and diseases are killing trees at an alarming rate across the West, from the spruce trees of Alaska to the oak woodlands near the San Diego-Tiajuana border. Persistent changes in tree mortality rates can alter forest structure, composition, and ecosystem services such as carbon sequestration.

Widespread Increase in Mortality Rates in Western U.S.



- 76 long-term forest plots
- 3 broad regions
- Pacific Northwest:
  - British Columbia, Washington, Oregon
- California
- Interior:
  - Idaho, Arizona, and Colorado
- 130-3353 m elevation

USGS, USFS, 6 universities – data showed that background (non-catastrophic) mortality rates have increased rapidly in recent decades, with doubling periods ranging from 17-29 years among regions. Increases were also pervasive across elevations, tree sizes, dominant genera, and past fire histories. Forest density and basal area declined slightly, which suggests that increasing mortality was not caused by endogenous increases in competition. Because mortality increased in small trees, the overall increase in mortality rates cannot be attributed solely to aging of large trees. Regional warming and consequent increases in water deficits are likely contributors to the increase in tree mortality rates.

Recent warming has been implicated as contributing to episodes of forest dieback (pulses of greatly elevated tree mortality), such as those mediated by bark beetle outbreaks in western North America. Changes in demographic rates, when compounded over time, can alter forest structure, composition, and function. For example, a persistent doubling of background mortality rate (such as from 1 to 2% year) ultimately would cause a > 50% reduction in average tree age in a forest, and hence a potential reduction in average tree size. Additionally, changing demographic rates could indicate forests approaching thresholds for abrupt dieback.

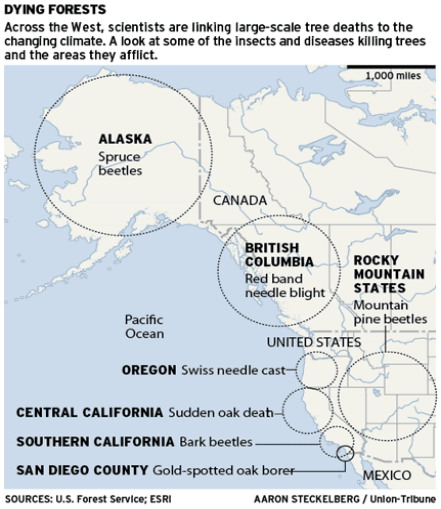
Wanted to determine if systematic changes in tree demographic rates have occurred recently in coniferous forests of the western US, and if so, to identify possible causes. To minimize transient dynamics associated with stand development and succession, we limited our analyses to data from repeated censuses in undisturbed forest stands more than 200 years old. Old forest contain trees of all ages and sizes, and any large, persistent changes in demographic rates over a short period (e.g. a fe decades) are likely to be consequences of exogenous environmental changes. Plots were originally established for diverse purposes, such as to investigate different stages of forest development, document dynamics of certain forest types, explore forest dynamics along environmental gradients, or act as controls for silvicultural experiments. Plot data - 3-7 times/plot. Forest age at original census – 450-1,000 yrs. Bulk of data between 1970s and 2006.

Study shows that forests are losing trees faster now than they were 40 years ago. 76 sites in Pacific NW, Ca, Idaho, Colorado, Arizona. Tree death increased in every plot and every region, at every elevation, in trees of every size and every type. Change is happening fast – estimated doubling times ranging from 17 years in the PNW to 29 years in the Rocky Mountains. In PNW mortality rates jumped from 0.3% in the 1970s to 1.3% today; in CA from 1% in 1983 to 1.7% today; mortality in interior forests climbed to 0.6% from 0.2% in roughly the same period. Recruitment (the number of trees that survive to become mature trees) shows no trends. New growth is often failing to replace dead trees.

Top image stand of dead pine trees off HWY 125 in Grand County, Colorado. – reduced snow pack and prolonged drought are killing forests. Mountain pine beetles have killed about 3.5 million acres of lodgepole pine in NW Colorado over the past decade, wiping out 90% of the pine forests in that area. During the same time period, spruce bark beetle also killed large areas of spruce forest in northern and southwestern Colorado.

Widespread Increase in Mortality Rates in Western U.S.

- Mortality increased in 87% of plots.
- Mortality significantly increased for all plots combined and in each of the three regions.
- Increased at all elevations, for all tree sizes, and in all three of the dominant tree genera studied (Tsuga, Pinus, & Abies)



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British Columbia

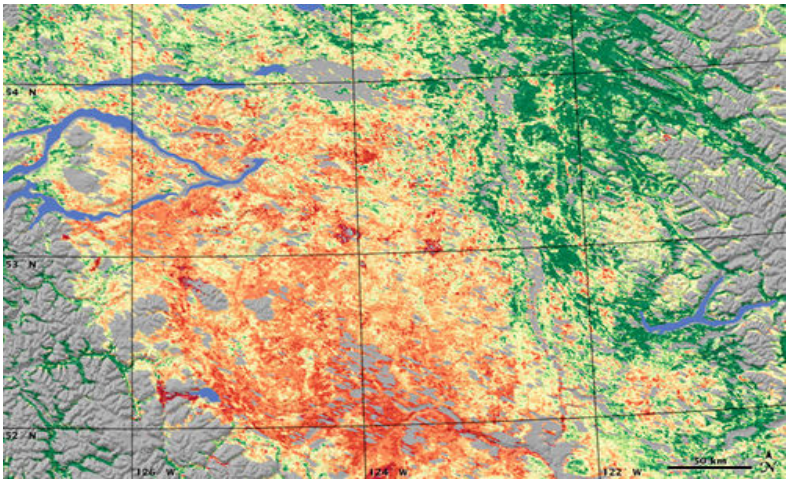
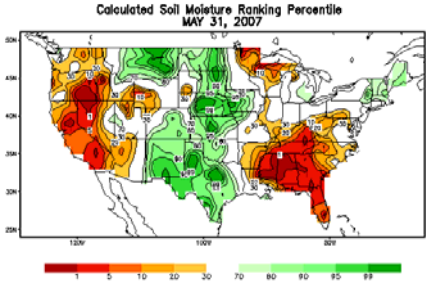


Image from NASA Earth Observatory posted in December showing vast areas of forest in BC now severely damaged or dead from pine beetle infestations. British Columbia has lost 40 million acres of forest to the bark beetle.

United States



- Summers are getting longer and hotter in the West.
  - Greater tree stress from drought
  - Lower spring-summer stream flows
  - Increased insect and disease in forests
  - Increased death rates in trees and forest die-off

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Soil moisture graph. May 22 – fire at Big Sur.

Recent warming in the West has contributed to widespread hydrologic changes, such as a declining fraction of precipitation falling as snow, declining water snow pack content, earlier spring snowmelt and runoff, and a consequent lengthening of the summer drought. Future will probably have sparser forests, with less carbon storage.

USGS study shows that mortality rates in seemingly healthy conifer forests of the American West have doubled in the past several decades. Often new trees are not replacing dying ones. Warmer temperatures and subsequent water shortfalls are the likely cause of the increased death rate.

Trees are dying even close to streams.

Calfire estimates that somewhere around 10 times as many acres are dying from drought etc than are burning each year.

Stream flows are also down, soil moistures in CA have been extremely low. Soil moisture graph. See a large increase in dieoff beginning around 2003- threshold??

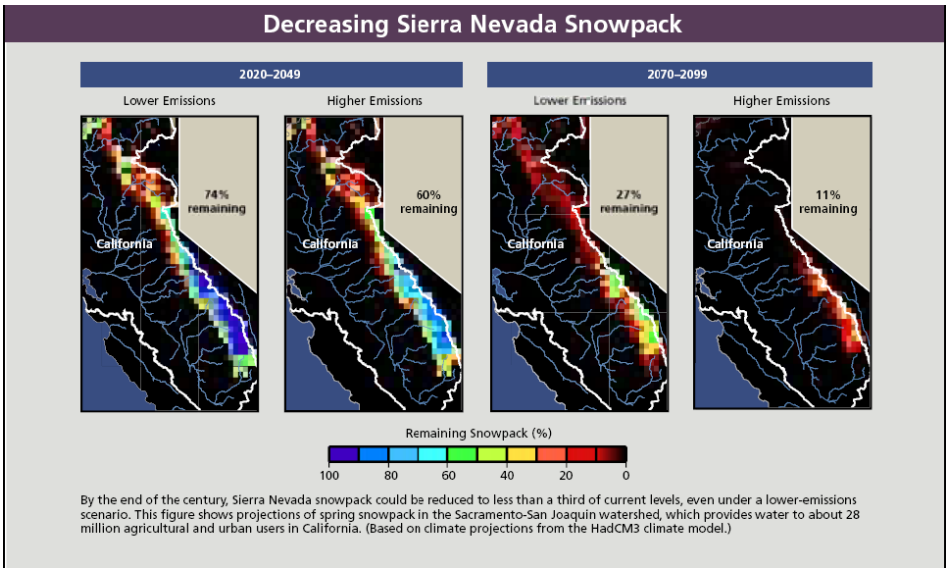
Wildfire

The intensity of fires is linked most closely to the rising temperatures, loss of snowpack, earlier snowmelt and a longer, drier fire season.

The snow melts sooner, the dry season gets longer and rivers crest earlier. That gives more of chance for drying out and therefore a likelihood of more fires.

With warmer and earlier springs, moisture has been uneven, and winter precipitation in some parts tends to come as rain, not snow.

Climate Change



Climate change will directly affects the ecosystem services provided by national forests and will exacerbate the impacts of current natural and anthropogenic stress factors. Wildfires, non-native and native invasive species and extreme weather events are the most critical stress factors that climate change will amplify within national forests. Reduced snowpack, earlier snowmelt and altered hydrology associated with warmer temperatures and changing precipitation patterns will complicate water management, particularly in the western states, and will affect other ecosystem services that national forests provide (eg winter recreation). Drought may become more of a management issue with predicted increased weather extremes.

Important to remember that climate change is non-linear. Rapid climate change.

Forest Response to Climate Variation

In coming decades, global climate changes are expected to produce large shifts in vegetation distributions at unprecedented rates. The shifts are expected to be most rapid and extreme at ecotones, the boundaries between ecosystems, particularly those in semiarid landscapes. Current models don't provide for such rapid shifts that are caused by mortality.

Most rapid landscape-scale shift of woody ecotone ever documented – 1950, northern New Mexico, the ecotone between semiarid ponderosa pine forest and pinon-juniper woodland shifted extensively (2 km or more) and rapidly (<5 years) through extensive mortality of ponderosa pines at direr, lower elevations in response to a severe drought (most severe in 500 years). Further complications were fire suppression which lead to higher than "normal" densities in forests. This shift has persisted for 40 years. Still little evidence of ponderosa pine regeneration. Forest patches within the shift zone became more fragmented and soil erosion greatly accelerated.

Mortality-induced vegetation shifts take place more rapidly than do regeneration-induced shifts associated with plant establishment and migration.

Forest Ecosystem Services

- Watershed Services
- Soil Stabilization and Erosion Control
- Air Quality
- Climate Regulation and Carbon Sequestration
- Biological Diversity
- Non-Timber Commercial Forest Products

Back to Ecosystem services

Climate Change
Forest Service Goals

- Restore, Sustain, and Enhance Nation's Forests and Grasslands
- Provide and Sustain Benefits to the American People
- Conserve Open Space
- Sustain and Enhance Outdoor Recreation Opportunities
- Maintain Basic Management Capabilities of the FS
- Engage Urban America With FS Programs
- Provide Science-Based Applications and Tools for Sustainable Natural Resources Managment

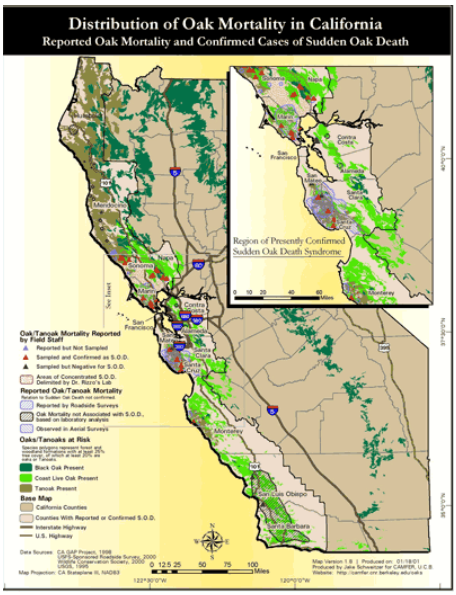
To fulfill its objectives of sustaining ecosystem health, diversity and productivity to meet the needs if present and future generations, the USFS has identified seven strategic goals for 2007-2012. CC will make achieving all 7 goals challenging. In addition all of the 7 goals, have some relation to the current or desired ecosystem condition, which may be difficult or impossible to maintain under the future climate regime.

Managing for Climate and Climate Impacts

- Manage for change without knowing what will change or how it will much change
- Practice ecological management
- Manage for desired future processes
- Toolbox approach

Climate change is already affecting forests and other ecosystems, and additionally, potentially more severe impacts are expected. As a result, forest managers are seeking practical guidance on how to adapt their current practices and, if necessary, their goals. Adaptations of forest ecosystems, in this context means to adjust management (as opposed to “natural” adaptation), to ideally reduce the negative impacts of climate change and help mangers take advantage of any positive impacts.

Confronting Climate Change



- Adaptation Strategies
- Migration Strategies

Adaptation Strategies

Adaptation Options

1. Increase Resistance to Change
2. Promote Resilience to Change
3. Enable Ecosystems to Respond to Change
4. Realign Conditions to Current Dynamics

Migration Strategies

- Maintaining connectivity
- Assisted Migration

Where do we go from here?