Water, forests and climate

Roger Bales, UC Merced

1. Water & fire
2. Water & forest management
3. Securing the future
1. Water & fire – issues to consider

- Forest structure
- Water yield
- Snowpack storage
- Wildfire
California wildfires – area burned per year

Given dense forests & climate warming, we expect future years to follow an increasing trend

Area burned has implications for water & other ecosystem services
SFPUC Report: The economic impact of the 2013 Rim Fire on natural lands

**Ecosystem services:** benefits people obtain from ecosystems

<table>
<thead>
<tr>
<th>Ecosystem Service</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetic Information</td>
<td>$28,290,426</td>
<td>$334,324,867</td>
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<tr>
<td>Biological Control</td>
<td>$775,534</td>
<td>$792,153</td>
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<tr>
<td>Moderation of Extreme Events</td>
<td>$43,970,557</td>
<td>$45,605,922</td>
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<tr>
<td>Air Purification</td>
<td>$1,558,478</td>
<td>$31,382,368</td>
</tr>
<tr>
<td>Habitat and Biodiversity</td>
<td>$125,029</td>
<td>$65,015,130</td>
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<tr>
<td>Pollination</td>
<td>$10,069,509</td>
<td>$32,791,479</td>
</tr>
<tr>
<td>Recreation and Tourism</td>
<td>$450,299</td>
<td>$211,241,045</td>
</tr>
<tr>
<td>Soil Retention</td>
<td>$14,371</td>
<td>$97,805</td>
</tr>
<tr>
<td>Waste Treatment</td>
<td>$14,762,870</td>
<td>$14,762,870</td>
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<tr>
<td><strong>Total Annual Ecosystem Services Lost to the Rim Fire by Ecosystem Service</strong></td>
<td><strong>$100,017,074</strong></td>
<td><strong>$736,013,639</strong></td>
</tr>
</tbody>
</table>
Brief review: fire suppression on public lands

For most of the 20th century, any form of wildland fire, whether it was naturally caused or otherwise, was quickly suppressed for fear of uncontrollable and destructive conflagrations.

– When the U.S. Forest Service was established in 1905, a primary task was to suppress all fires on its lands
– Early fire suppression had limited success, until the advent of vehicles, equipment & roads during the 1940s
– In 1978, the Forest Service changed to a policy that encouraged the use of wildland fire by prescription.

Can fire be re-introduced as a natural part of the landscape, given the current mosaic of built capital (homes, businesses, roads) spread throughout the forest?
2. Water & forest management
USFS estimates that 6-9 million ac of FS lands need restoration

Funding is inadequate to meet the need for forest restoration; critical projects don’t “pay for themselves”

Sierra is critically important for water supply, climate change, decreasing greenhouse gas emissions, Delta sustainability

Use the IRWM program for regional collaboration in managing water-related issues, e.g. economic vitality, water-supply reliability, flood management, water quality, ecosystem enhancement
Some recurring questions around water & forests

1. What was the historical water yield prior to fire suppression?
2. What will be the water yield w/ climate warming, vs. today?
3. How will the post-fire water yield differ from before?

Upper Yosemite Valley from Columbia Point, 4800’
Basic water balance

Precipitation = Evapotranspiration + Runoff

(Evapotranspiration is mainly water use by vegetation)
Evapotranspiration

Pine/oak forest
E: 4000’
P_{ave}: 28”
ET: 33”

Mixed conifer forest
E: 7000’
P_{ave}: 33”
ET: 30”

Subalpine forest
E: 9000’
P_{ave}: 36”
ET: 18”

Oak savannah
E: 2000’
P_{ave}: 16”
ET: 20”
Water balance – Kings R. basin

Precipitation

Runoff

Evapotranspiration

Goulden & Bales, 2014
Runoff declines w/ higher temperature

- Longer growing season w/ temp. increase $\Rightarrow$ more ET
- Average: 14% drop in runoff per 2$^\circ$C
Evapotranspiration is currently lower in colder basins

Goulden & Bales, 2014
Water & Sierra Nevada forests

What we know
1. Vegetation removal generally results in more runoff, initially
2. Vegetation regrowth means less runoff
3. Clear cutting or wildfire means more sublimation & earlier snowmelt – runoff could go up or down
4. Less-dense forests (up to a point) can retain snow longer
5. Colder, snow-dominated areas produce more runoff that lower, rain-dominated areas
Major issues facing forest management

1. Information needs
   a. Studies to understand the effects of forest management on water over the wide range of physiographic conditions in California
   b. Pathways for precipitation reaching stream channels
   c. Methods for estimating evapotranspiration across vegetation types
   d. Erosion and sediment transport

2. Coordination between land owners

3. Limited funding for forest watershed restoration

4. Regulatory requirements
3. Securing the future

Constraints
- Growing population
- Increasing demand for food, energy & materials
- Warming & variable climate
- Restoring ecosystems
Making a water-secure world – the three I’s

**INFRASTRUCTURE**

to store, transport & treat water

**INFORMATION**

Better & more-accessible

**INSTITUTIONS**

Stronger & more-adaptable

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Water security lies at the heart of adaptation to climate change.

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Water security: the reliable availability of an acceptable quantity & quality of water for health, livelihoods & production, coupled w/ an acceptable level of water-related risks
The bottom line is that we need to expand our state’s storage capacity, whether surface or groundwater, whether big or small. Today, we need more storage to deal with the effects of drought and climate change on water supplies for both human and ecosystem needs. Climate change will bring more frequent drought conditions and could reduce by half our largest natural storage system—the Sierra snowpack—as more precipitation falls as rain rather than snow, and as snow melts earlier and more rapidly.
Water storage reservoirs

- Clouds
- Reservoirs
- Snowpack
- Upper Watersheds
- Rivers & Streams
- Floodplains
- Soils
- Groundwater
- Aquifers
- Canals
- Farm Ponds
- Wetlands
- Oceans

California Roundtable on Water and Food Supply, 2012
Monthly dry season evapotranspiration at mixed conifer site (Providence Creek) – drought effects
Water security: from storage to retention

Comprehensive, timely, accurate, accessible, and transparent data and resulting information about our water resources is an essential foundation for effectively managing water storage in California.

California Roundtable on Water and Food Supply, 2012
Envisioning a new water information system for California

Example – seasonal forecasts – uncertainty can be high
– Mainly monthly, manual measurements
– Few automated, but non-representative measurements
– Statistical forecasts, vs. hydrologic models

New, mature technology available now: blending data from satellites, aircraft, low-cost wireless sensor networks, advanced modeling tools
Integrate these sensors with remotely sensed data, forecasting tools & decision support

American R. basin hydrologic observatory (in progress)

Platform for research & core element of new water information system

Strategically place low-cost sensors to get spatial estimates of snowcover, soil moisture & other water-balance components
Node construction at Alpha site
Integrate these sensors with remotely sensed data, forecasting tools & decision support

Platform for research & core element of new water information system
Strategically place low-cost sensors to get spatial estimates of snowcover, soil moisture & other water-balance components

American R. basin hydrologic observatory
ACWA Policy Principles on Improved Management of California’s Headwaters

“... managing California’s headwaters is integral to optimizing ... water supplies ... Increasing water yield and quality; reducing the risk and impacts of catastrophic wildfire; and enhancing natural features and functions; are all benefits to be derived, locally and statewide, from improved headwaters stewardship. Enhancing the resiliency and adaptability of headwaters is overdue.

California can no longer afford to relegate management of its headwaters to the margin.”
Measuring forest effects on snow accumulation

1200 measurements

STEF snow survey
March 7, 2013

1200 measurements

Legend

- Variable Density Thinning Units
- 1929 Methods Of Cutting Units

Stanislaus - Tuolumne Experimental Forest
Variable Density Thinning Study
Post-Harvest (2012)
The scientific foundation for natural infrastructure investments is imperfect, but robust.

“Harnessing the water-related services provided by forests, wetlands, floodplains, and working lands—known as ‘natural infrastructure’—has a major role to play .... Investing in integrated water management strategies that combine engineered solutions with natural ... is the future of water management.”
Urgent action is needed in the Sierra Nevada to avoid devastating impacts on California’s environment and economy.

Research needs
– How management that improves ecological resilience can enhance the snowpack, thereby increasing water supply reliability
– The water use of overgrown forests and the potential increase in water yield that will result from forest thinning treatments

Implementation
Use the IRWM program for regional collaboration in managing water-related issues, e.g. economic vitality, water-supply reliability, flood management, water quality, ecosystem enhancement
Research Summary

1. High evapotranspiration across a wide swath of mixed conifer forest
2. Resiliency in the snow zone to water stress – combined snowpack & soil-water storage
3. Higher water yield in snow zone owing to shorter growing season – climate vulnerable
4. Research is critically needed on several basic hydrologic, social-science, management questions around forests & water
Some concluding points

1. Sustained forest management that provides measurable benefits for water supply will require investment, verification & maintenance
   – **Next step**: do scalable demonstration project in Sierra Nevada

2. Better information is a critical foundation for water security, especially in a warming & more-variable climate
   – **Next step**: incorporate research products into scalable water information system

3. With better management, California’s existing water supply could go further to meeting the needs of the state’s urban & agricultural uses.