Forests, water, climate and disturbance in the Sierra Nevada: critical knowledge gaps

Roger Bales, UC Merced

1. Current water issues
2. Water & forest management
3. Building the knowledge base
1. Current water issues

Photo: Adam Mazurkiewicz
Some recurring questions around water & forests

1. How will the post-fire water yield differ from before?

2. What will be the water yield with climate warming, vs. today?

3. What was the historical water yield prior to fire suppression?

Photos: J. Power & D. Buckley, USFS
Some background questions

1. How different were forests prior to fire suppression vs. today, pre-fire and post-fire?

2. Can we take forests back to pre-fire-suppression conditions?

E. Branch, N. Fork Feather R., 3400’

Photos from G. Gruell
Forest density, Stanislaus NF

1911: 25% of recent

1911: 50% of recent

Collins et al., Ecosphere, 2011
2. Water & forest management

Photo: Adam Mazurkiewicz
Three issues

1. Water use by vegetation
2. Interception losses
3. Timing of snowmelt & runoff

Also climate-warming context
Trees block low-angle winter sun, retarding snowmelt ...

... but intercept snowfall, some of which sublimates ...

... and emit longwave radiation that melts snow ...

... resulting in tree wells
Measuring forest effects on snow accumulation

Eric Knapp, PSW-USFS

1200 measurements

STEF snow survey
March 7, 2013

1200 measurements

Control Even Variable

Legend

Builtup Density Thinning Units
1929 Methods Of Cutting Units

Stanislaus - Tuolumne Experimental Forest
Variable Density Thinning Study
Post-Harvest (2012)
Measuring forest effects on snow accumulation

1200 measurements

Eric Knapp, PSW-USFS

Stanislaus - Tuolumne Experimental Forest
Variable Density Thinning Study
Post-Harvest (2012)
Even thinning
Basic water balance

**Precipitation** = Evapotranspiration + Runoff
Sierra Nevada precipitation & snow water equivalent (SWE) – climatological estimate

Bales et al., 2006
Basic water balance

Precipitation = Evapotranspiration + Runoff
Sierra Nevada watershed research infrastructure

Southern Sierra Critical Zone Observatory (SSCZO)
Co-located w/ Kings River Experimental Watershed (KREW) USFS watershed research site
KREW: 8 instrumented headwater catchments
Increase in water yield with elevation, from rain to snow dominated

Implication for 2°C warmer climate: Reduce runoff by 10-40% in mixed conifer forest (assuming ecosystems adapt)

Decreasing temperature → Increasing snow fraction → Decreasing LAI → Coarser soils

Hunsaker et al., 2013
Basic water balance

Precipitation = **Evapotranspiration** + Runoff

Evapotranspiration refers to evaporation plus water use by vegetation.
Sierra Nevada watershed research infrastructure

Elev., m

600
1200
1800
2400
3000

E-W transect of flux towers

San Joaquin Experimental Range
400 m
1300 ft

Soaproot Saddle
1100 m
3600 ft

CZO P301
2000 m
6600 ft

Shorthair Creek
2700 m
8900 ft

Southern Sierra CZO
(Critical Zone Observatory)

N-S transect of research catchments

MODIS image
Oak savannah
$T_{\text{ave}}$ 14.4°C
P 500 mm
0 d snow
$H_{\text{tree}}$ 11 m
25% tree cover

Pine/oak forest
$T_{\text{ave}}$ 10.9°C
P 850 mm
11 d snow
$H_{\text{tree}}$ 29 m
63% tree cover

Mixed conifer forest
$T_{\text{ave}}$ 8.9°C
P 1000 mm
130 d snow
$H_{\text{tree}}$ >30 m
53% tree cover

Subalpine forest
$T_{\text{ave}}$ 4.1°C
P >1100 mm
184 d snow
$H_{\text{tree}}$ 22 m
31% tree cover
Evapotranspiration (ET) across an elevation transect

Mid-elevation forests show neither summer nor winter shutdown:
- deep rooting & resiliency to moisture stress
- warmer canopy-level temperatures despite snow

Goulden et al., 2012
3. Building the knowledge base

- Past results
- Ongoing studies
- Fire opportunities
- New studies

Photo: Adam Mazurkiewicz
Reducing forest cover by 40% of maximum levels across a watershed could increase water yields by about 9%.

Sustained, extensive treatments in dense Sierra Nevada forests could increase water yield by up to 16%.

These estimates are based on very limited data.

Adapted from Zhang et al., 2001.
Ongoing forest-watershed studies

SNAMP (USFS, CA DWR, UC): 2 sets of paired catchments, Sierra Nevada Framework treatments

KREW (USFS) watershed research site & CZO (NSF, UC): 8 headwater catchments; tree removal:
- 39% for <10 in
- 21% for 10-20 in
- 4% for 20-30 in
Impact of thinning on evapotranspiration & streamflow

Initial estimates – work in progress

30% increase in streamflow for 50% reduction in biomass
Rain-snow transition, 7000 ft elevation, Sierra NF
Headwater catchment, Southern Sierra
CZO/KREW, Sierra NF
Results based on very-detailed pre-treatment data & modeling
What is the slope of this line in different forests???

Saksa et al., in prep
Fire opportunity 1 – American Fire

Government Fire, 2008

American Fire

Extend SNAMP measurements for 5 years
Strategically placed sensors

Snow, temperature, soil
Stream
Fire opportunity 2 – Illilouette basin

- Multiple fires in recent decades
- Regrowth at sustainable forest densities
- Snow dominated
- New JFSP/UCB project

Yosemite NP

Illilouette
Fire opportunity 3 – Rim Fire area

Lower elevation, largely rain dominated – less potential
More sensors added post fire; 2014 upgrades planned – multi-objective research

UCM Ph.D. student, YNP, others
New studies – proposed to address knowledge gaps
Frenchie Project, Tahoe NF

<table>
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<tr>
<th>Name</th>
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<th>Treatment</th>
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<td>Restore</td>
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<td>Control</td>
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<td>Rice</td>
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<td>Control</td>
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<tr>
<td>Dolly</td>
<td>2320</td>
<td>Light</td>
</tr>
</tbody>
</table>
Hemlock Project
Stanislaus NF

All on USFS land,
more treatable area
Other potential project areas that have been discussed

1. Sierra Pacific Industries lands – Central Sierra area
2. Onion Creek, Tahoe NF – very dense, designated experimental area; see UC Phase I report
3. Sagehen area, including Truckee-Donner Land Trust lands – east side of Sierra
4. Scott River, Klamath NF – Phase I evaluation in progress; multi-year planning required
5. El Dorado NF – no specific sites identified
Research Summary

1. High ET across a wide swath of mixed conifer forest
   – Resiliency to water stress – combined snowpack & soil-water storage
2. Low water yield in rain zone, much higher in snow dominated
   – product of longer-tem processes
   – shorter growing season in snow zone
   – Timing & amount of runoff are sensitive to small $\Delta T$
3. Sustained forest management can provide measurable benefits for water supply – will require both investment & verification
4. Better information is critical for water management, especially in a warming & more-variable climate
   – Mountain water cycle is poorly measured
   – The technology is readily available to accurately & routinely estimate water-balance components
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For more information see: criticalzone.org/sierra or email: rbales@ucmerced.edu