Can forest management to reduce fire risk in the high Sierra result in more streamflow at the mountain front?

UC Merced Research Week Symposium: California Drought & Effects
Topics in this talk:

1. Southern Sierra Nevada CZO
2. The mountain water cycle – recent results
3. Water security & managing ecosystems
Motivating questions

How will this landscape & the hydrologic processes connecting it alter with climate warming & landcover change?

How do regolith development & properties control, limit or modulate effects of climate change, management or disturbance on hydrology, biogeochemistry & ecology?
Mountain hydrology – fluxes

How well can we estimate any of these fluxes & stores?

My biases:
Improved predictions require better process understanding

The basis for process understanding is new measurements
Processes are coupled & best studied together

Reservoirs:
- Snowpack storage
- Soil-water storage
SSCZO site location, gradients & infrastructure

4 instrumented sites along steep climate gradient: 12°C, 60 km

Co-located w/ USFS watershed research site: 8 headwater catchments ~ 100 ha each

Lower SSCZO site proposed for NEON core

Winter access to upper sites over snow

Encourage collaboration
SSCZO conceptual model

Feedbacks across time scales: regolith-atmosphere coupling along elevation transect

- Glacial
  - Subalpine forest 2700 m
- Millennial
  - Mixed conifer forest 2000 m
- Century
  - Pine/oak forest 1100 m
- Decadal
  - Oak savannah 400 m
- Annual

Feedbacks across spatial scales

- Pore to plot
- Hillslope to catchment
- Basin to regional

3000 m elevation gradient
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
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Basic water balance

Precipitation = Evapotranspiration + Runoff

Evapotranspiration refers to evaporation plus water use by vegetation
Sierra Nevada precipitation & snow water equivalent (SWE) – climatological estimate

Bales et al., 2006
American River basin

Despite these limitations, snow pillows are widely used by modeling community as ground truth.

Few representative precipitation measurements

2 snow pillows in N. fork, 1 in Middle Fork, 8 in S. Fork

Non-representative network – index sites

Stations are on flat ground, in clearings, at mid elevations.
What elevations provide the most snowmelt?

Values estimated from time series of satellite snowcover depletion & daily snowmelt. Most snowmelt comes from elevations above most measurement of precipitation or snowpack.

Rice & Bales, 2013
Comparison of SWE measured by LiDAR w/ indirect estimates of SWE & precipitation, Kaweah R. basin

Future: data from distributed, wireless sensor networks, blended w/ remote sensing data

Kirchner et al., in prep.
Basic water balance

Precipitation = Evapotranspiration + Runoff

Evapotranspiration refers to evaporation plus water use by vegetation
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
Basic water balance

Precipitation = Evapotranspiration + Runoff

Evapotranspiration refers to evaporation plus water use by vegetation
KREW: 8 instrumented headwater catchments
Increase in water yield with elevation, from rain to snow dominated.

50% more runoff in snow dominated vs. mixed rain-snow catchments.

Decreasing temperature
Increasing snow fraction
Decreasing LAI
Coarser soils

Hunsaker et al., 2013
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Making a water-secure world – the three I’s

**INFRASTRUCTURE**
to store, transport & treat water

**INFORMATION**
Better & more-accessible

**INSTITUTIONS**
Stronger & more-adaptable

HARD SOFT

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

Better & more-accessible

**INFORMATION**

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
Making a water-secure California

INFRASTRUCTURE: planning

INSTITUTIONS: collaboration & integration in planning, management

Ecosystem services: managing forests, wetlands, rivers

More INFORMATION-intensive decision support

Water management translates into managing ecosystem services. Adapting to climate change also means managing ecosystem services.
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 are Rim Fire area

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
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?

Strawberry, S. Fork American R., 5800’
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?

Upper Yosemite Valley from Columbia Point, 4800’
Forest density, Stanislaus NF

Tree density, stems per ha

1911  2005-07

Live tree C, Mg ha

1911  2005-07

Collins et al., Ecosphere, 2011
Thinned unit w/ control in background
Forest management – estimated water yield potential, quick “back-of-the-envelope” calculation based on very limited data

Based on DWR, Bulletin 120

Average annual increment for 40% LAI reduction
  – American R. basin: 120,000 AF
  – Feather thru San Joaquin: 730,000 AF

For 60% LAI reduction
  – American R. basin: 180,000 AF
  – Feather thru San Joaquin: 1,100,000 AF

These numbers are a starting point for analysis, not results that can be cited
1. High ET across a wide swath of mixed conifer forest

2. Low water yield in rain zone, much higher in snow dominated

3. Sustained forest management can provide measurable benefits for water supply – will require both investment & verification

4. Better information is a critical foundation for water security, especially in a warming & more-variable climate
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For bibliography of research presented see http://criticalzone.org/sierra