Water, forests & climate in the Sierra Nevada

Roger Bales, UC Merced
Topics in this talk

- California hydrology & water resources
  - Drought in the Sierra Nevada
  - Forest water balance
  - Water security
Basic water balance

Precipitation = Evapotranspiration + Runoff

Evapotranspiration refers to evaporation, sublimation plus water use by vegetation.
Calif. water sources

More precipitation & runoff north of Delta
More water use south of Delta

CA Water Plan, 2013
ET in source waters

\[ P = ET + Q \]

\[ P - Q = ET \]

P-Q increases with higher temperature, i.e. longer growing season. Implications for warmer climate, 40 mm per °C.
Applied water use

Water supplies:
- Agriculture: 80%
- Urban: 20%

Precip: 200 MAF
- Applied: 80 MAF
- Agriculture: 33 MAF
- Urban: 8 MAF

Data from DWR, adapted from Nor. Cal. Water Assn.
American Fire one year later, spring 2014
California temperature (°F) and precipitation (inches) anomalies from January 1895 to November 2014, plotted as 3-y anomalies relative to 1901–2000 mean.

Mann & Gleick, 2015
1100 yr drought record

Reconstructed flows of Sacramento R.
Color shading marks below-median periods \( \geq 4 \) yr
1-5 per century

Horizontal line at median

Meko et al. 2014 report

www.wildlandart.com
The outlook for Western drought over the next 50-80 years looks grim.

Current drought may be the new norm, if we’re lucky.
Timber harvest summer 2012, uneven-age thinning & removal of 15-20% of biomass (STEF)

California hydrology & water resources
Drought in the Sierra Nevada
Forest water balance
Water security
UC watershed-scale field programs

- Frenchie & SNAMP - Last Chance
- Hemlock
- PSW - STEF
- YNP – Tioga corridor
- SNAMP - Sugar Pine
- Merced
- E-W transect of flux towers
- Southern Sierra CZO

CZO catchments

- SEKI – Wolverton
- Providence
Field measurements

E-W transect of flux towers

San Joaquin Experimental Range 400 m
Soaproot Saddle 1100 m
CZO Providence 2000 m
Shorthair Creek 2700 m

Ground measurements of precipitation, evapotranspiration, discharge, soil-moisture storage, snowpack storage

(Shorthair not available)
Approach to scaling

Annual ET measured by flux towers, correlated with MODIS NDVI

ET calculated across the Southern Sierra using this calibration

Conceptual
High LAI ↔ High ET & NPP

High LAI → High NDVI

NDVI indicates ET needed to support the current LAI
Kings R. basin water balance

P = ET + Q - ΔS

Before drought

During drought
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
6. Climate warming will increase water use by vegetation, though earlier snowmelt will reduce water availability in some years
7. Sustained forest management that provides measurable benefits for water supply will require investment, verification & maintenance

Some recurring questions
1. How much 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?

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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’
Measuring forest effects on snow accumulation

STEFC 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)
Stanislaus-Tuolumne Experimental Forest

Thinned unit w/ control in background
Southern Sierra Critical Zone Observatory – Sierra NF, Kings R basin
Tree dieoff greatest where recharge to deeper root zone was limited. Regolith storage buffers drought if mean annual precipitation exceeds annual ET.

- Low precip., high biomass & higher ET demand in rain zone $\rightarrow$ one-yr subsurface water-storage buffer at 1100 m

- Higher precip., slightly lower biomass & ET demand in snow zone $\rightarrow$ multi-year subsurface water-storage buffer at 2000 m

Jun 2015
Kings R. basin, Jul 2016
Looking west, 5000’ elevation
California hydrology & water resources
Drought in the Sierra Nevada
Forest water balance

Water security
Making a water-secure California – the three I’s

**INFRASTRUCTURE**

Better & more-accessible INFORMATON to store, transport & treat water

**INSTITUTIONS**

Stronger & more-adaptable INSTITUTIONS

Water security lies at the heart of adaptation to climate change

**INFORMATION**

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
Moving toward sustainability

Sustainable Groundwater Management Act (SGMA) could change everything

Big questions:
Depletion vs. sustainability
Level of sustained supply – storage
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
Forests and water in the Sierra Nevada, next steps

Goals (what)
- Provide **quantitative, credible assessments** of the water-cycle impacts of forest vegetation density, structure, disturbance and management actions in the Sierra Nevada (and other forests)
- Develop **data and tools** for further assessments, of sufficient accuracy to guide investments and build partnerships

Context (why)
- There is indirect evidence that vegetation treatments and disturbance can have both ephemeral and longer-lasting effects on partitioning of precipitation between evapotranspiration and runoff
- **Quantitative information** to enable meeting the goals, across the heterogeneous landscape of the Sierra Nevada, is sorely lacking

Approach (how)
- Carry out **intensive hydrologic and vegetation measurements**, plus hydrologic modeling, of treatment and control catchments, following silviculture prescriptions that provide end-member information for assessments
- **Extend assessments** across the region using lower-intensity measurements, meta-analysis, hydrologic modeling and economic studies

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A modern water information system is a key investment for water management.
Node construction at Alpha site
Science summary

1. High evapotranspiration across a wide swath of mixed-conifer forest
2. Higher water yield & resiliency to moisture stress in snow zone
3. Sustained forest management that provides 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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Bibliography: http://criticalzone.org/sierra
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