Water security in California in the age of drought: linking forest management, water storage, groundwater sustainability & carbon neutrality

Roger Bales, UC Merced
Topics in this seminar

- California hydrology & water resources
  - Drought history in California
  - Climate drivers of drought
  - Drought in the Sierra Nevada
  - Drought impacts
  - Water security

Enterprise Bridge over Lake Oroville, Feather R. July 20, 2011

Oct 23, 2015

DWR/Paul Hames
DWR/Zack Cunningham
Calif. water sources

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

Data from DWR, adapted from Nor. Cal. Water Assn.

Precip: 200 MAF
Applied: 80 MAF
Ag: 33 MAF
Urban: 8 MAF

Water supplies:
Agriculture: 80%
Urban 20%

Aquatic Environment:
- 49%
  - 31% Wild & Scenic Rivers
  - 2% Managed Wetlands
  - 9% Instream Flows
  - 7% Required Delta Outflow

Irrigated Agriculture:
- 41%
  - This water produces food for consumption in urban areas while also providing terrestrial and aquatic habitat for a multitude of species.

Urban:
- 10%
Central Valley groundwater

Sacramento Valley

San Joaquin Valley

Adapted from Faunt et al., 2009
Drought originates from a deficiency of precipitation over an extended period of time – usually a season or more – resulting in a water shortage for some activity, group, or environmental sector (drought.unl.edu)
Development of the drought


Intensity:
- Yellow: D0 Abnormally Dry
- Orange: D1 Moderate Drought
- Tan: D2 Severe Drought
- Red: D3 Extreme Drought
- Dark Red: D4 Exceptional Drought

http://droughtmonitor.unl.edu
1100 yr drought record

Reconstructed flows of Sacramento R.
Color shading marks below-median periods ≥4 yr
1-5 per century

Meko et al. 2014 report

www.wildlandart.com

Horizontal line at median
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
Historical and projected PDSI

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

Current drought may be the new norm, if we’re lucky
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Importance of a few storms

10 periods accounted for 86% of accumulated precipitation averaged over 8 Northern Sierra sites
El Niño effect

Yes, though not quite like past El Niño winters

90-day Accumulated Precipitation % of Normal 01NOV2015–29JAN2016

Data Source: CPC Unified (gauge-based & 0.5x0.5 deg resolution) Precipitation Analysis Climatology (1981–2010)

http://www.cpc.ncep.noaa.gov/
Drought in the Sierra Nevada

American Fire one year later, spring 2014
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

Providence

SEKI – Wolverton

MODIS image
Motivations for research

How does forest vegetation cope with drier than normal years & extended dry periods?
Ground measurements of precipitation, evapotranspiration, discharge, soil-moisture storage, snowpack storage

(Shorthair not available)
Flux tower data

Comparing 2011 (wet) & 2014 (3rd drought yr)

- Providence, mixed-conifer forest, 2000 m, 2152 vs 634 mm precip, 20% drop in ET
- Soaproot Saddle, pine-oak forest, 1100 m, 1320 vs 390 mm precip, 47% drop in ET

Cumulative water-year evapotranspiration

Cumulative water-year gross CO₂ uptake
Matric potential at 2-m depth at Providence showed recharge during drought, but not at Soaproot.

Soil moisture also showed gradual decline during drought, and no recharge below 1-m depth at Soaproot (data not shown).
Southern Sierra averages

Precipitation (P) from PRISM

Evapotranspiration (ET) from NDVI: “canopy-acclimated ET”

P – ET is difference
Forest – interpretation

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 LAI & higher ET demand in rain zone —> one-yr subsurface water-storage buffer at 1100 m.

Higher precip., slightly lower LAI & ET demand in snow zone —> multi-year subsurface water-storage buffer at 2000 m.
Thinned unit w/ control in background

Restore (thin) forest → reduce ET

E. Knapp photo
Sierra Nevada historical photos

Upper Yosemite Valley from Columbia Point, 4800’

Photos from G. Gruell

R. Bales, 11/19/14
Many drought impacts result from the interplay between the natural event (less precipitation than expected) and the demand people place on water supply.
Drought impacts

California’s extensive water-supply infrastructure mitigates the effect of short-term (e.g. single year) dry periods

Criteria used to identify statewide drought conditions – such as statewide runoff and reservoir storage – do not address localized impacts
California hydrology & water resources
Drought history in California
Climate drivers of drought
Drought in the Sierra Nevada
Drought impacts

Water security
A. during the next 10 years, water problems will contribute to instability in states important to US national security interests.

C. We judge that during the next 10 yr the depletion of groundwater supplies in some agricultural areas—owing to poor management—will pose a risk to both national and global food markets.
Making a water-secure California – the three I’s

INFRASTRUCTURE

to store, transport & treat water

Stronger & more-adaptable INSTITUTIONS

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
Infrastructure – storage

Cumulative Groundwater Depletion in California’s Central Valley from USGS and GRACE

From presentation JE Reager, San Gabriel Valley Water Forum held October 2, 2014, Pomona, CA
Managed aquifer recharge system, 7 ac pond, Harkins Slough
A good deal about California does not, on its own preferred terms, add up (J. Didion, *Where I Was From*)
Water rights in Calif. are over-appropriated. Senior water rights get water first.
Limited accurate data & information on water fluxes and stores

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: blending data from satellites, aircraft, wireless sensor networks, advanced modeling tools
American River Hydrologic Observatory

Operational:
11 snow pillows – on flat ground, in clearings, at mid elevations

Index sites

Research:
140+ sensor nodes – spatially representative
Snow-covered portion, ~2000 km²

Prototype, core element of new information system
Node construction at Alpha site
A modern water information system is a key investment for drought management.
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