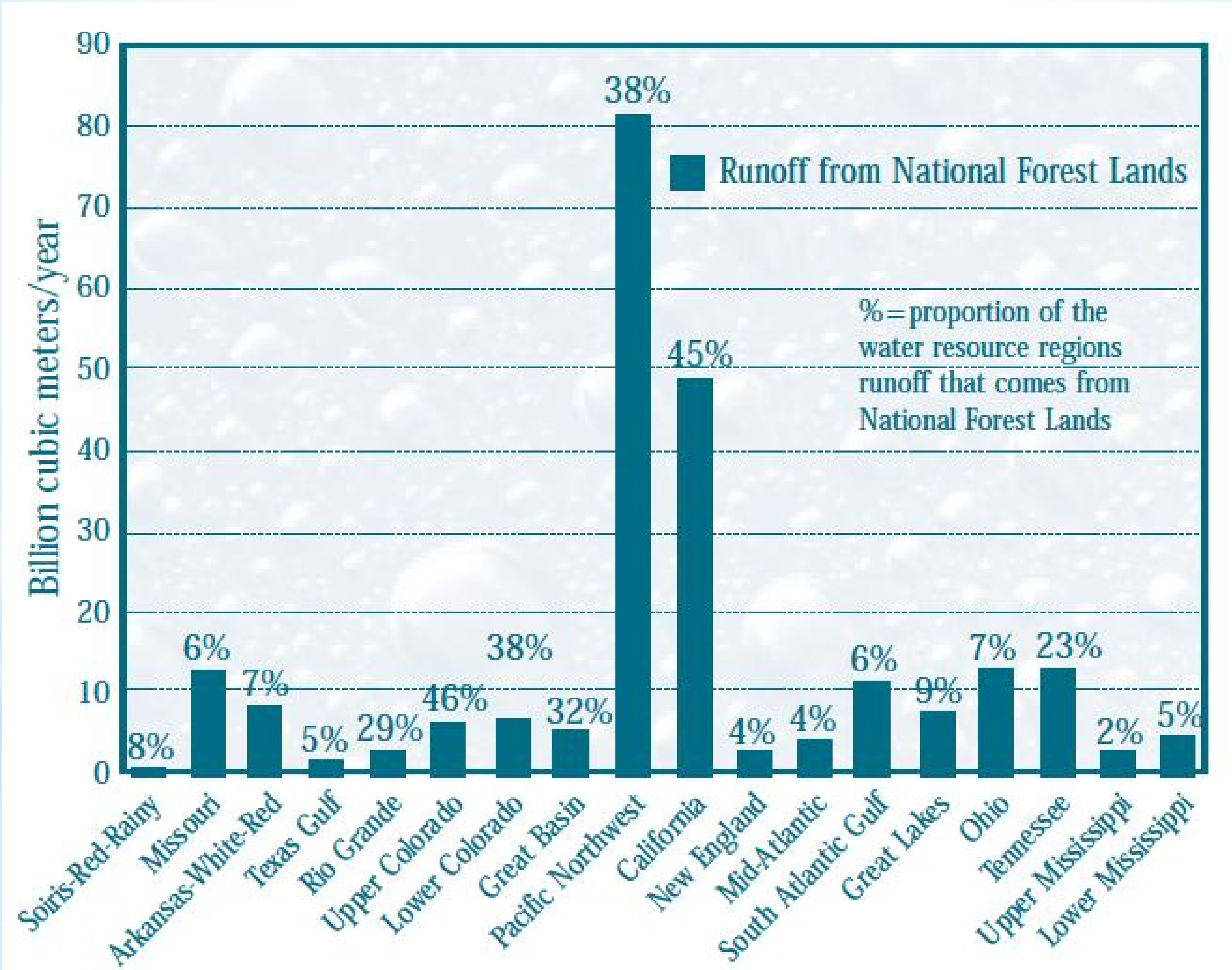
Forests and Water in the Sierra Nevada: Kings River Experimental Watershed and Ecosystem Monitoring Project

Mohammad Safeeq

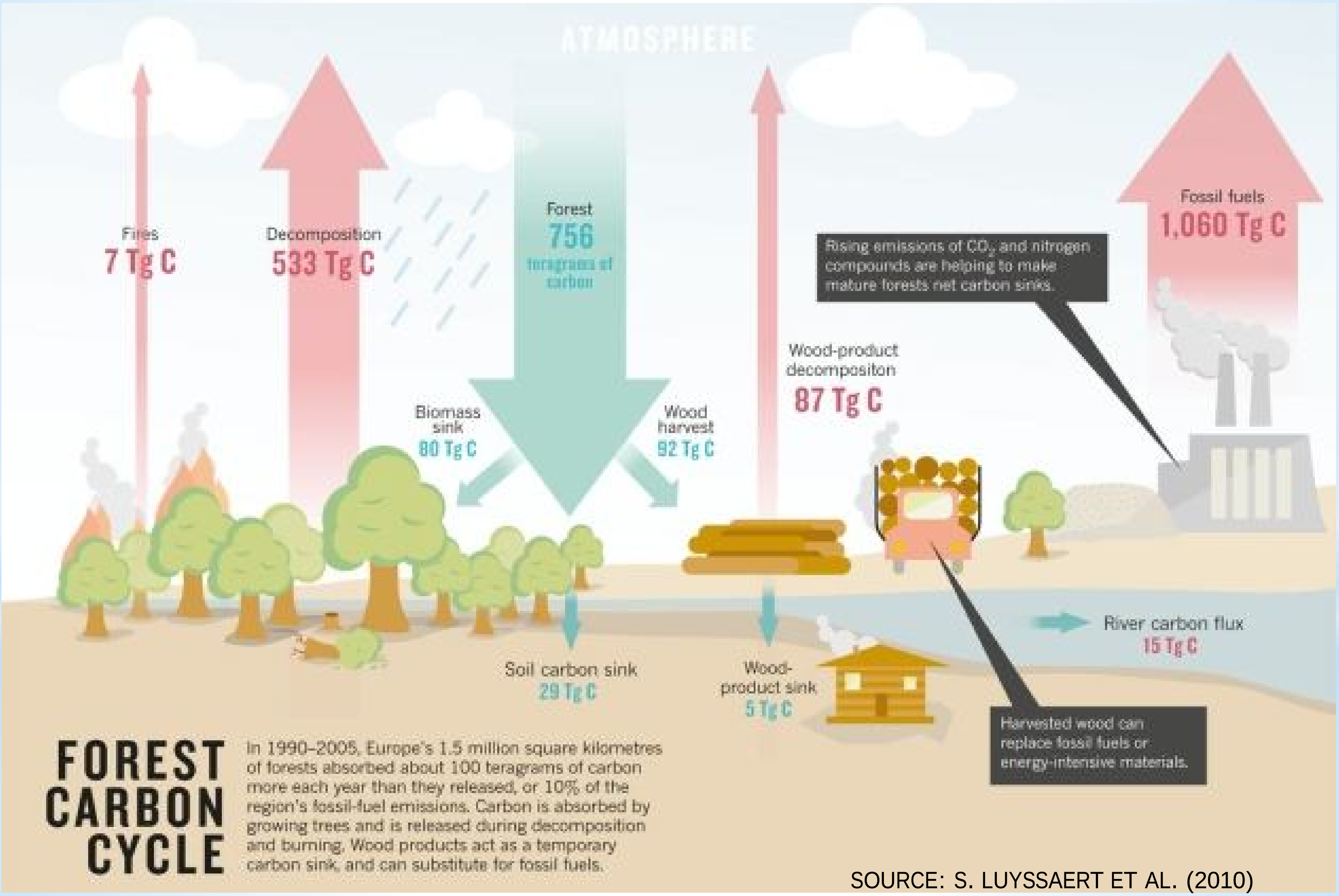
Research Scientist
&
Assistant Adjunct Professor

University of California Merced
Email: msafeeq@ucmerced.edu
Phone: 209-228-2459

Contribution of water runoff from national forest lands (Sedell et al., 2000)

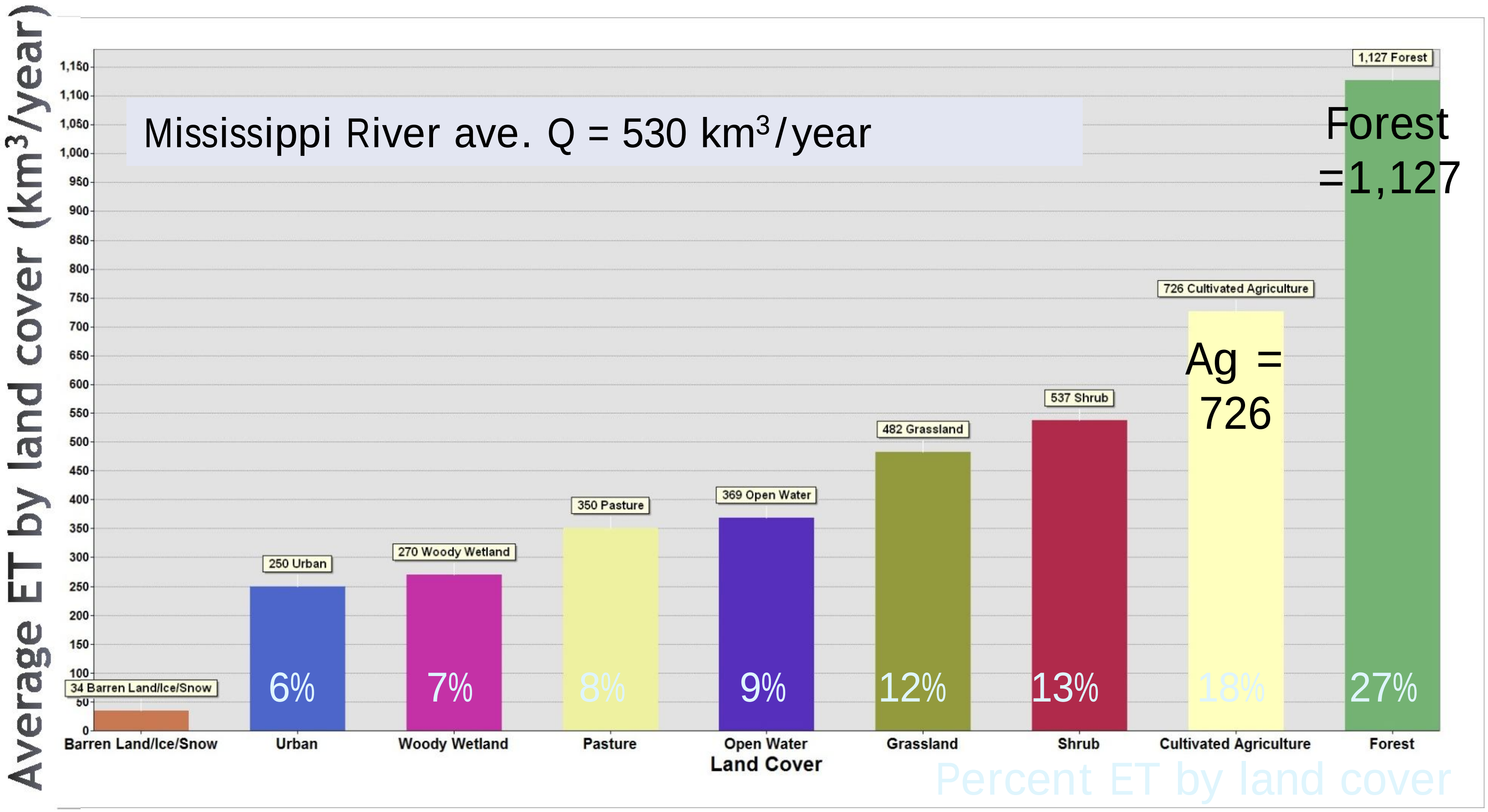


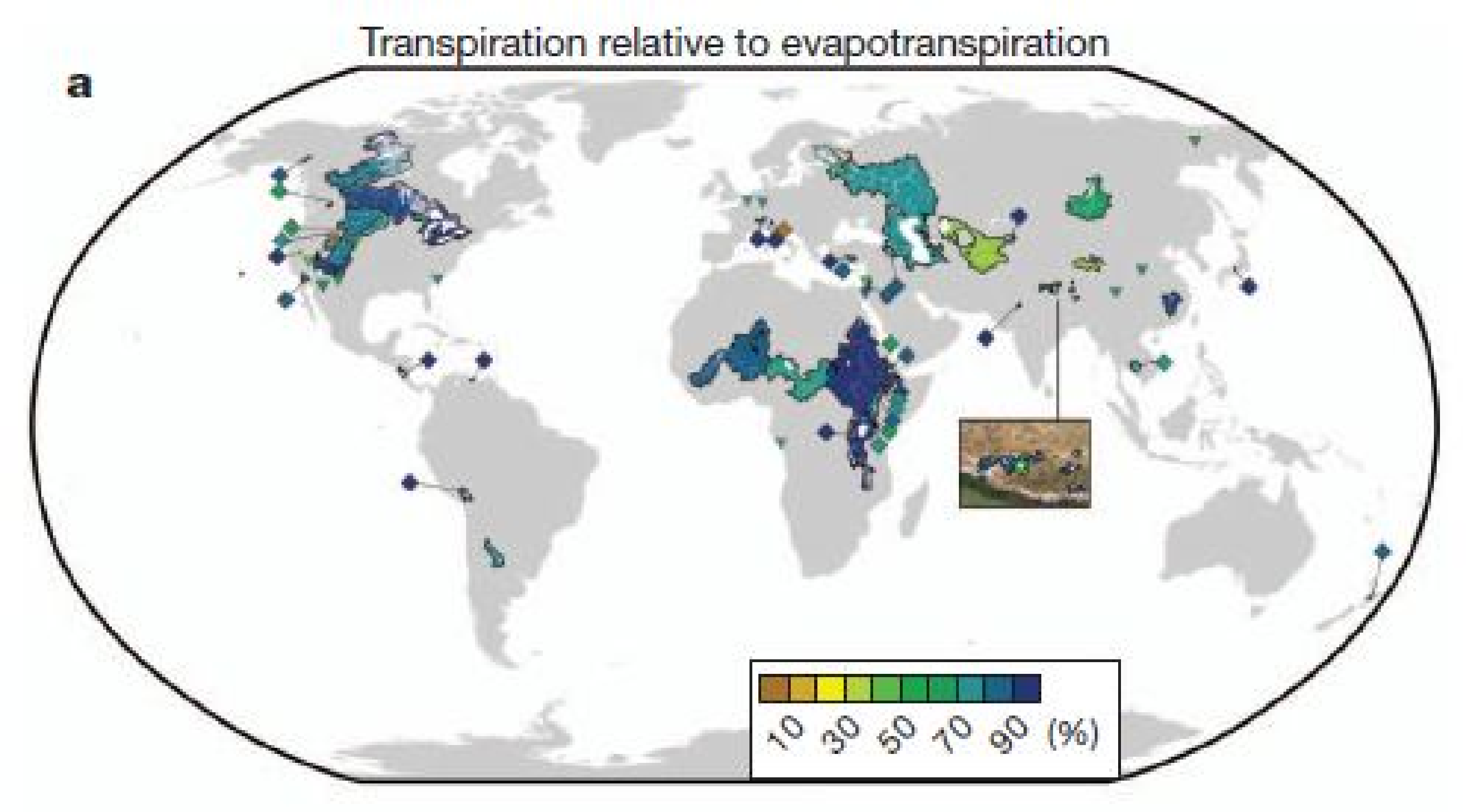
World's forests have absorbed as much as 30% of annual global anthropogenic CO_2 emissions



SOURCE: S. LUYSSAERT ET AL. (2010)

Trees and forests use prodigious quantities of water: account for 25% of the US land & 27% of the total ET





Most of the flux in ET is "T"

Figure 3 | Transpiration and carbon fluxes within 73 lake catchments. **a**, Transpiration losses as a percentage of total evapotranspiration. **b**, Transpiration rates. **c**, Gross primary productivity for 10% of Earth's continental area. Coloured diamonds are shown for small basins as a visual aid. Inverted triangles represent compiled *in situ* transpiration measurements (for example sap flow[9]).

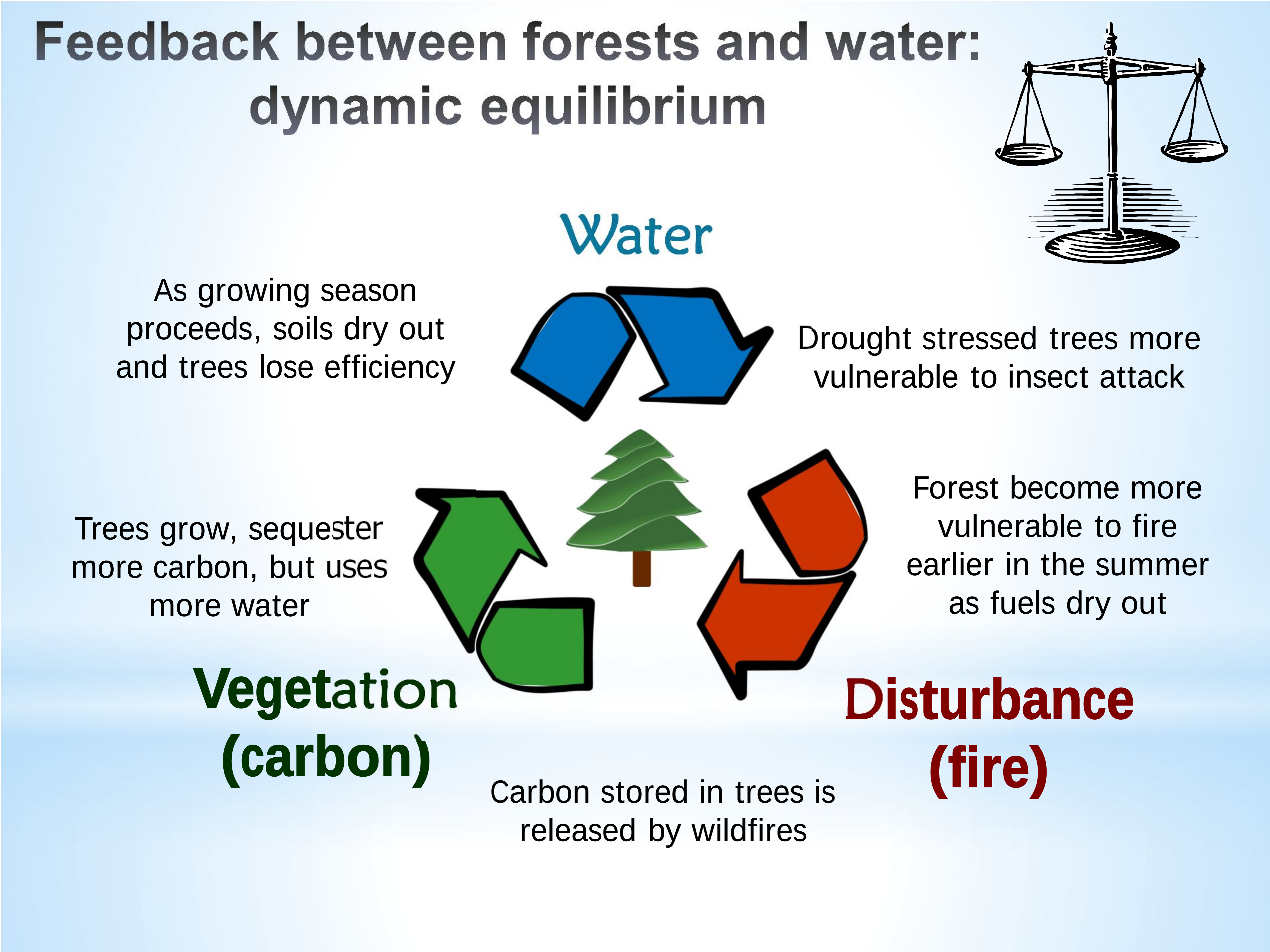
Jasecho et al., 2013

When this large demand is not met, forests become susceptible to a wide range of disturbances

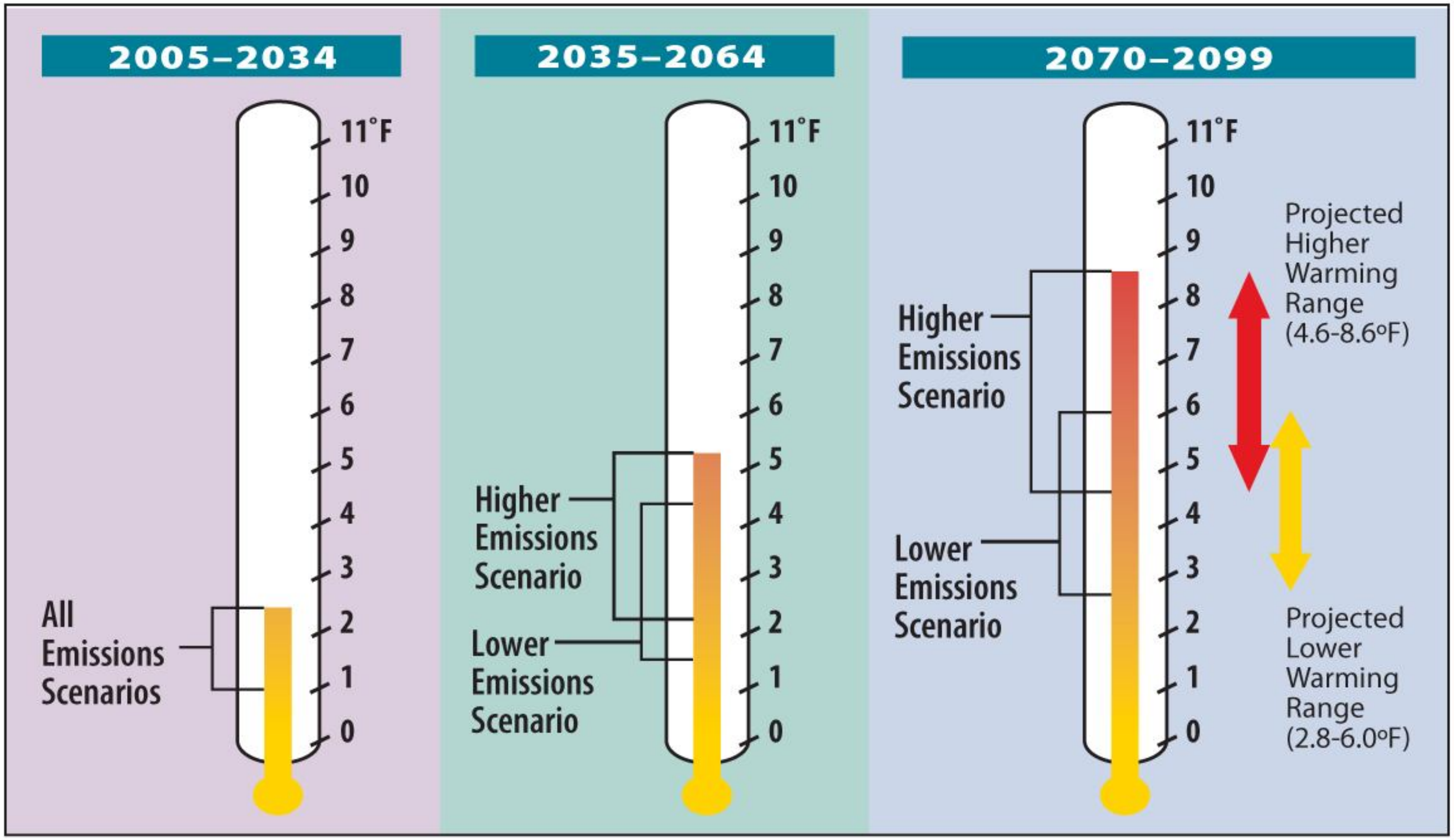
- Dieback/ Mortality
- Fire
- Bugs
- Species changes

Southern Sierra Critical Zone Observatory, showing forest dieback at ~1500 m elevation, June 2015.

Image from rough fire near Kings Canyon.


Feedback between forests and water:
dynamic equilibrium
Water
As growing season proceeds, soils dry out and trees lose efficiency
Drought stressed trees more vulnerable to insect attack
Trees grow, sequester more carbon, but uses more water
Forest become more vulnerable to fire earlier in the summer as fuels dry out
Vegetation (carbon)
Disturbance (fire)
Carbon stored in trees is released by wildfires

Increasing temperatures: Since 1895, average temperatures in CA have increased by 1.5°F

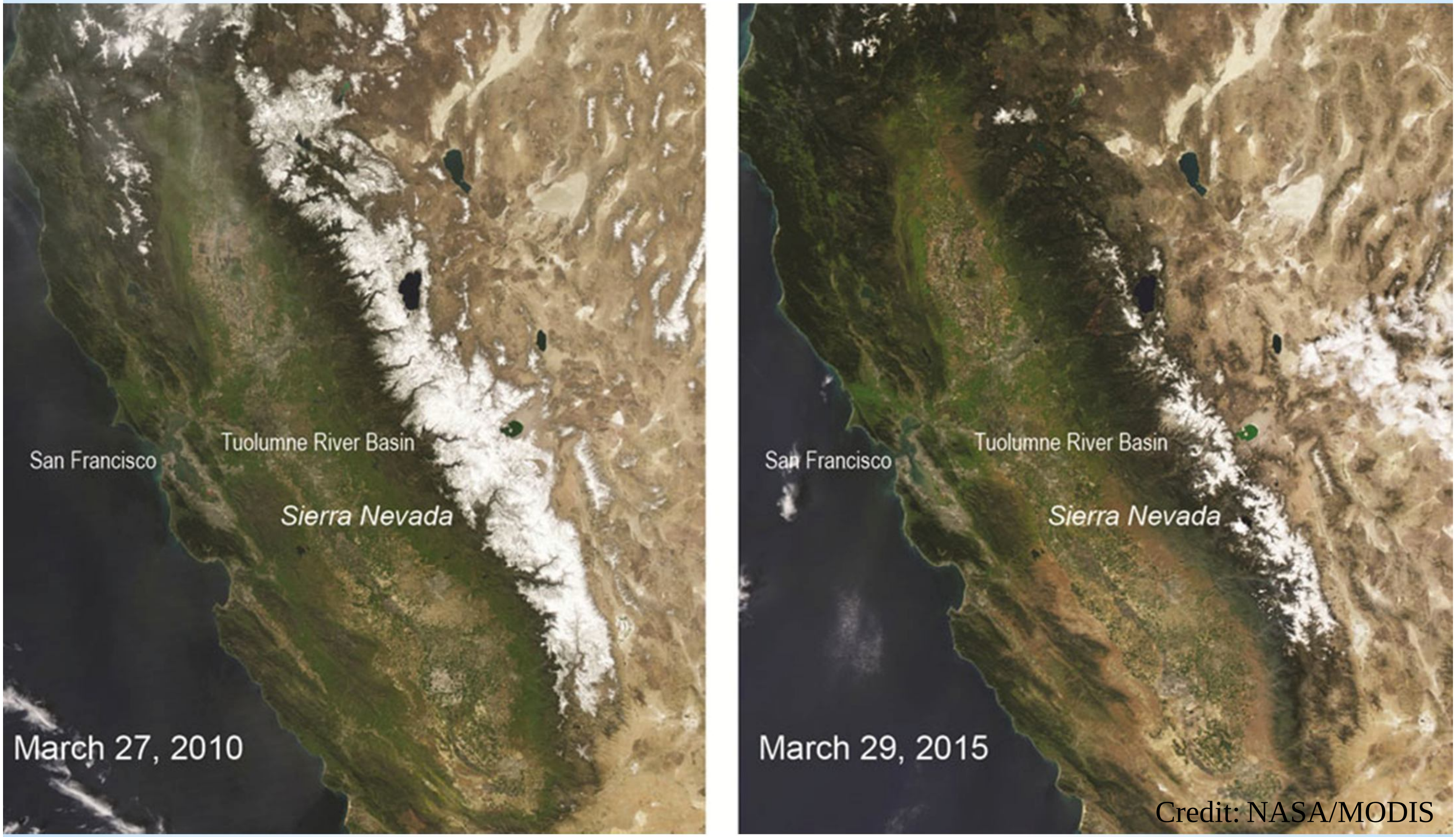


California is expected to experience dramatically warmer temperatures during this century. The figure shows projected increases in statewide annual temperatures for three 30-year periods. Ranges for each emissions scenario represent results from state-of-the-art climate models.

Increase above 1961-1990 average

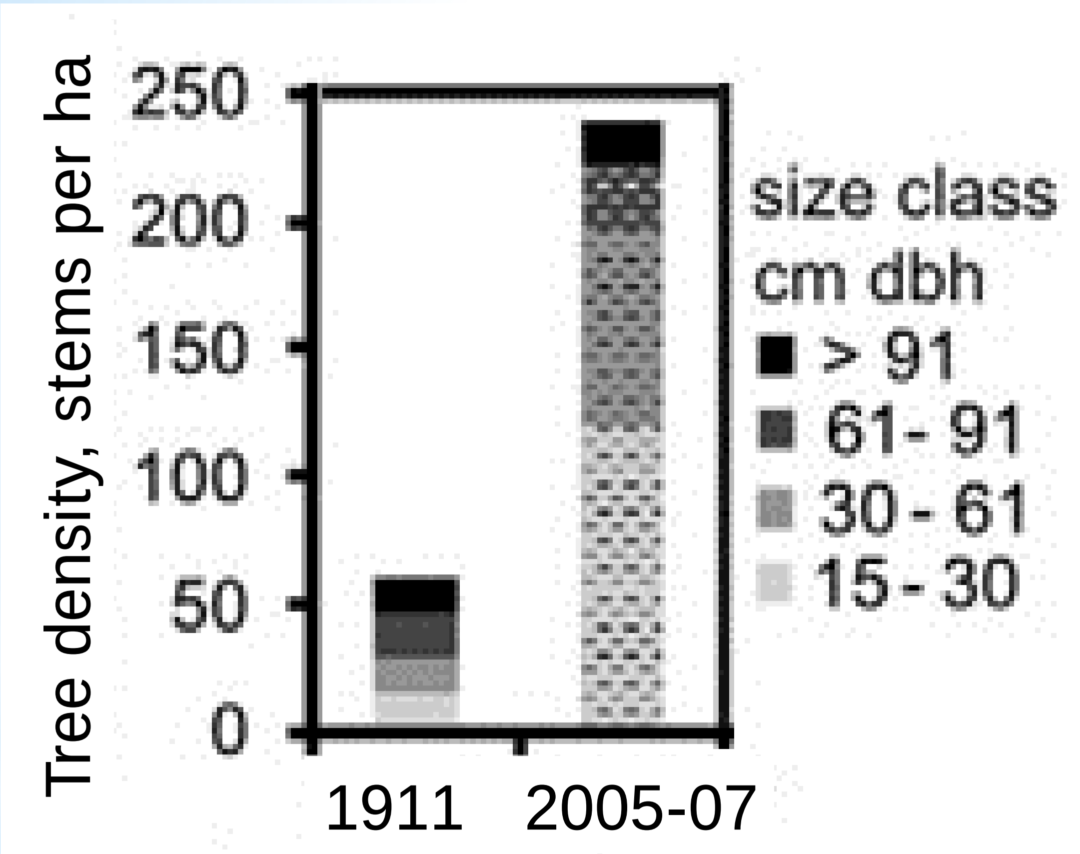
Source: CA Climate Change Center

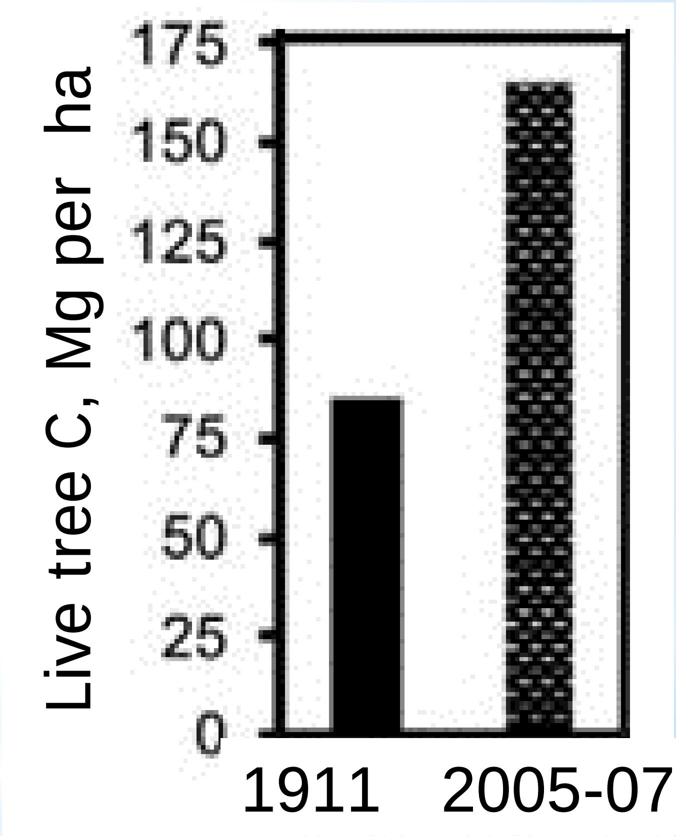
Sierra Nevada Snowpack Shrinks to Lowest Level in 500 Years (Belmecheri et al., 2015)



Credit: NASA/MODIS

Significant increase in the forest density and live tree carbon: Stanislaus NF



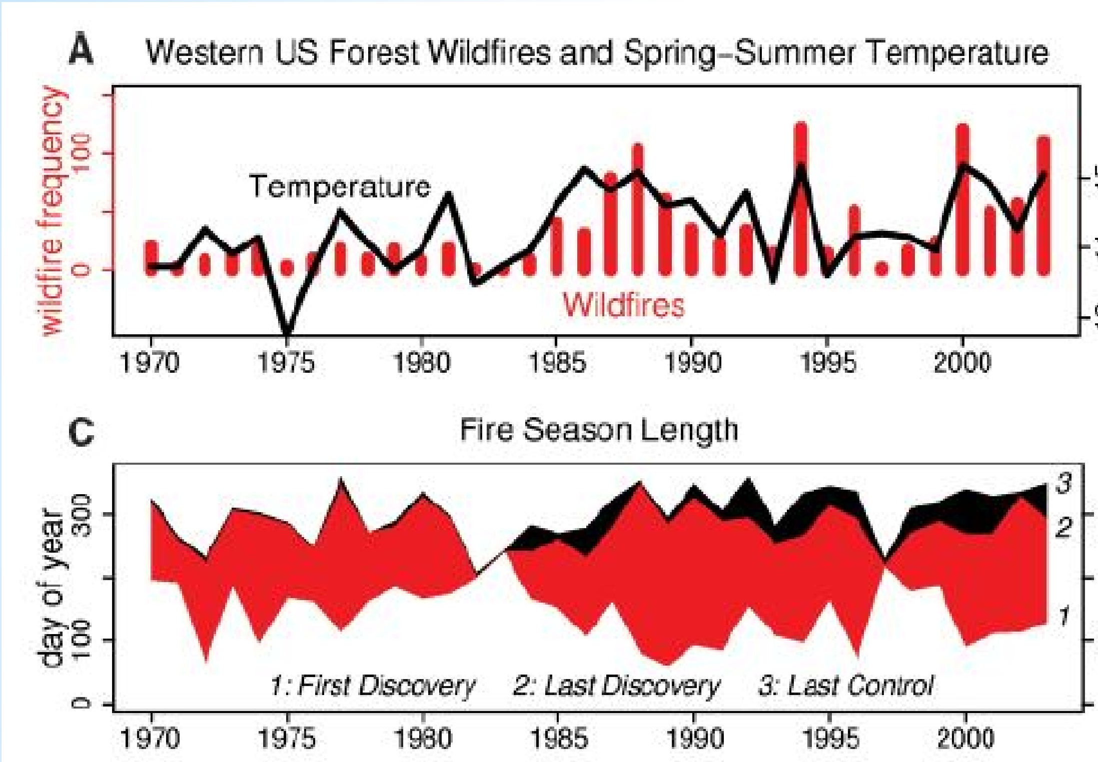


1911: 25% of recent

1911: 50% of recent

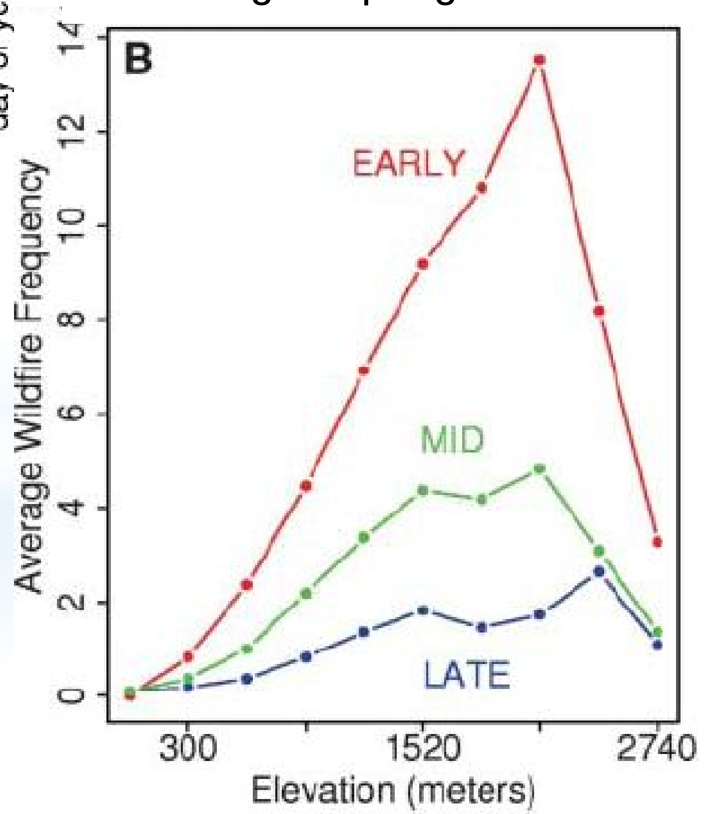
Collins et al., Ecosphere, 2011

Fire



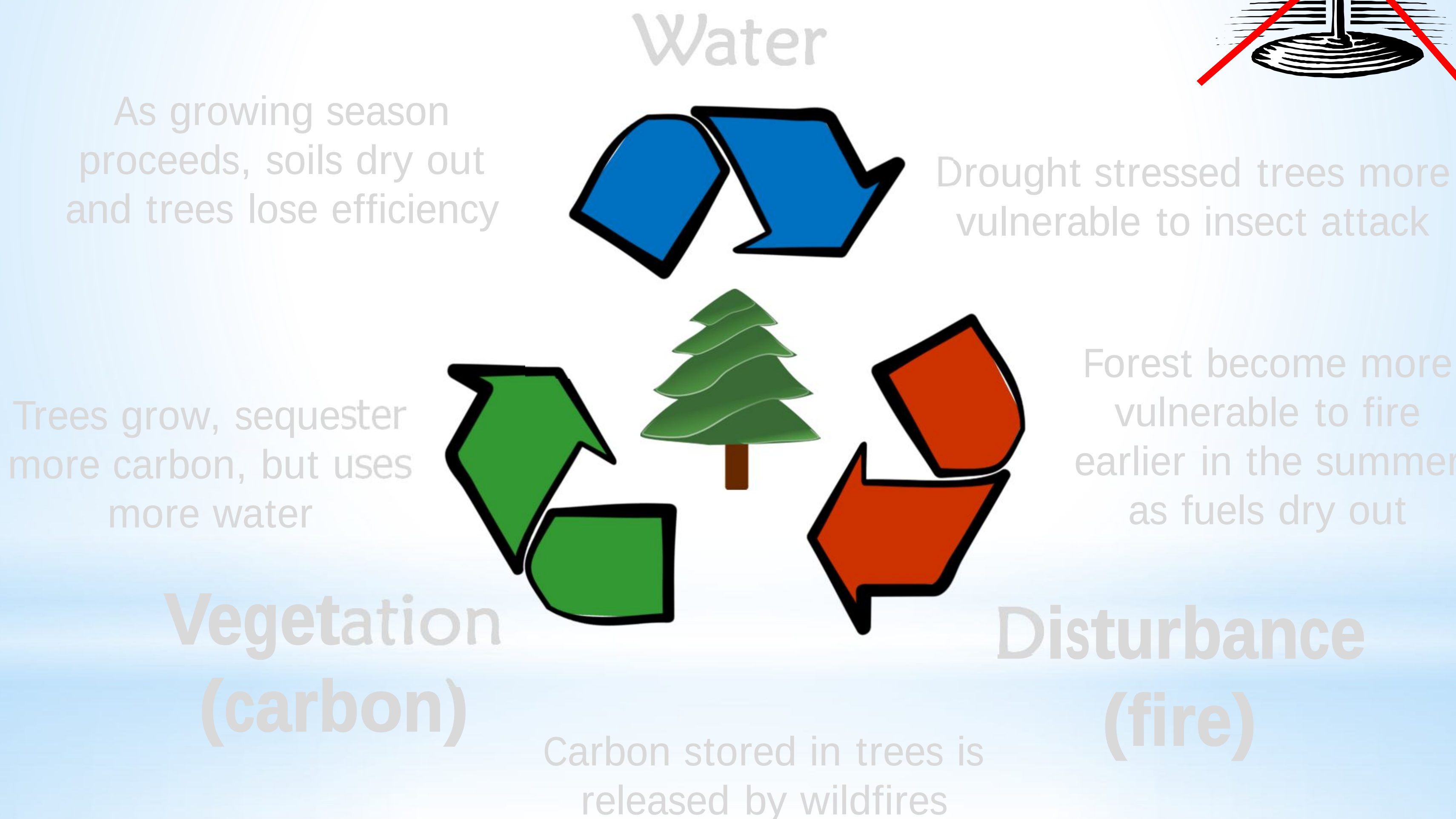
Westerling et al. (2006)
Figures 1a,c and 2b

Timing of Spring snowmelt



Fire frequency and length is increasing AND more fires in earlier snowmelt years;

Feedback between forests and water: dynamic equilibrium



Can we restore the natural dynamic equilibrium?

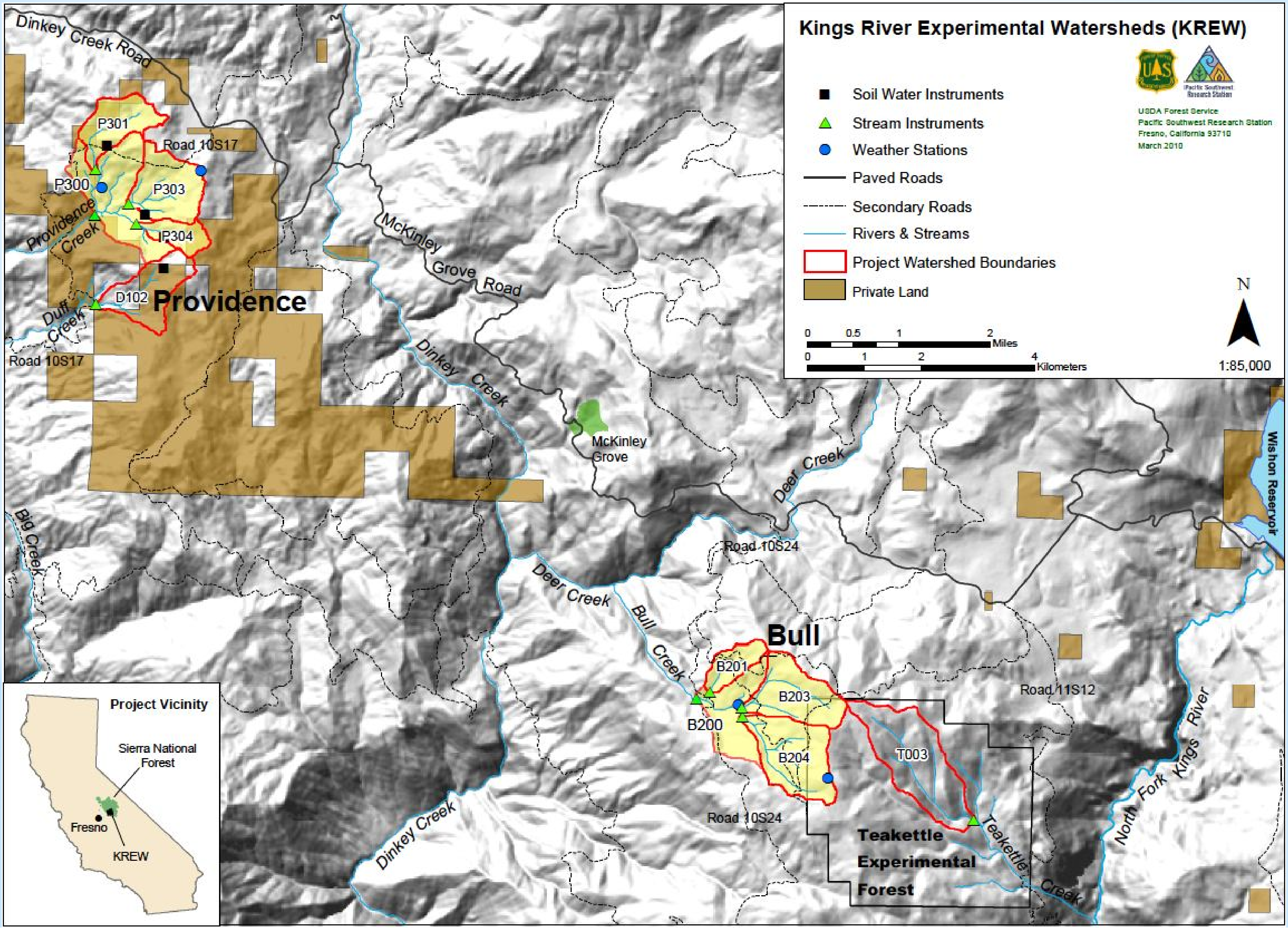
Goals of the Experimental Watershed Study

* Understand processes and quantify variability of headwater stream ecosystems

* Evaluate the effects of forest management for healthy forests

* Apply models to predict & understand

KREW Study Area



KREW Catchments

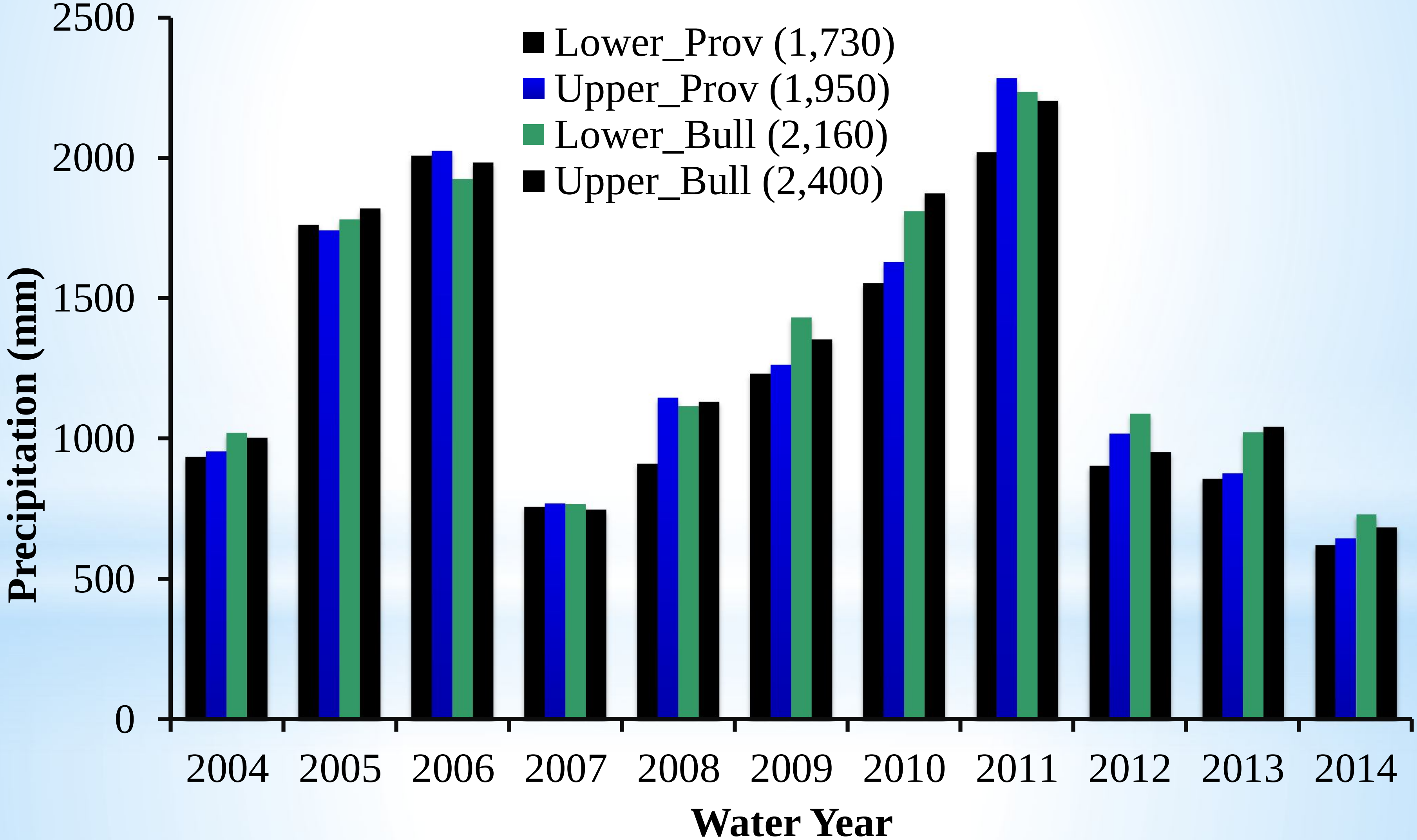
Watershed Code	Area (ha)	Mean Elevation (m)	Data Collection Begins	Treatment Year	Treatment
Providence Site					
P300	461	1883	2005	2012 thin; 2014/15 burn	Combination of Thin, Burn, and no Treatment
P301	99	2005	2002	2012 thin; 2014/15 burn	Thin and Burn
P303	132	1937	2002	2014/15	Burn only
P304	49	1935	2002	none	Control (no treatments)
D102	121	1833	2002	2012	Thin only
Bull Site					
B200	474	2323	2006	2012 thin; 2013 burn	Combination of Thin, Burn, and no Treatment
B201	53	2287	2003	2012	Thin only
B203	138	2413	2003	2013	Burn only
B204	167	2394	2003	2012 thin; 2013 burn	Thin and Burn
T003	228	2309	2003	none	Control (no treatments)

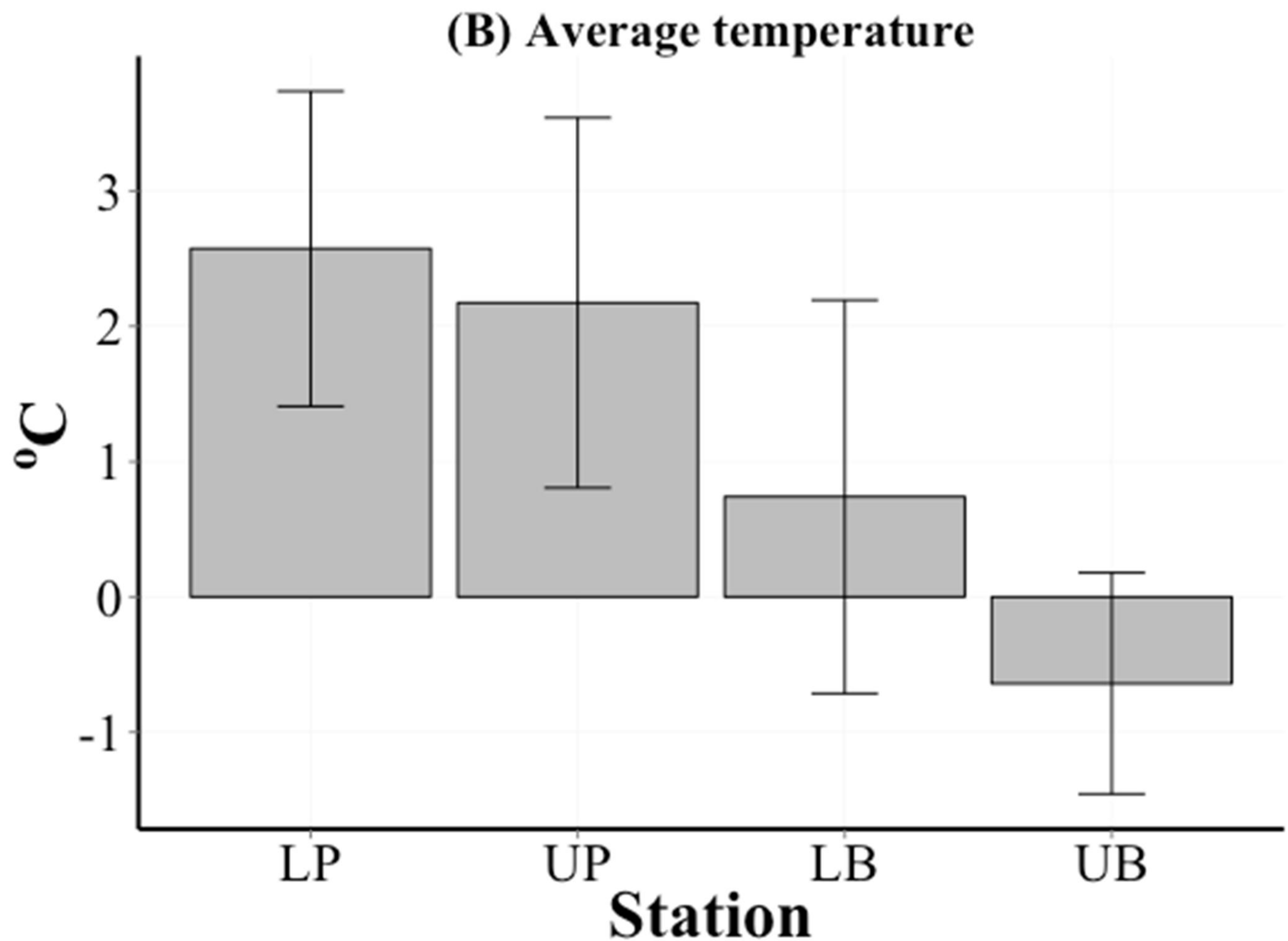
Integrated Watershed Research

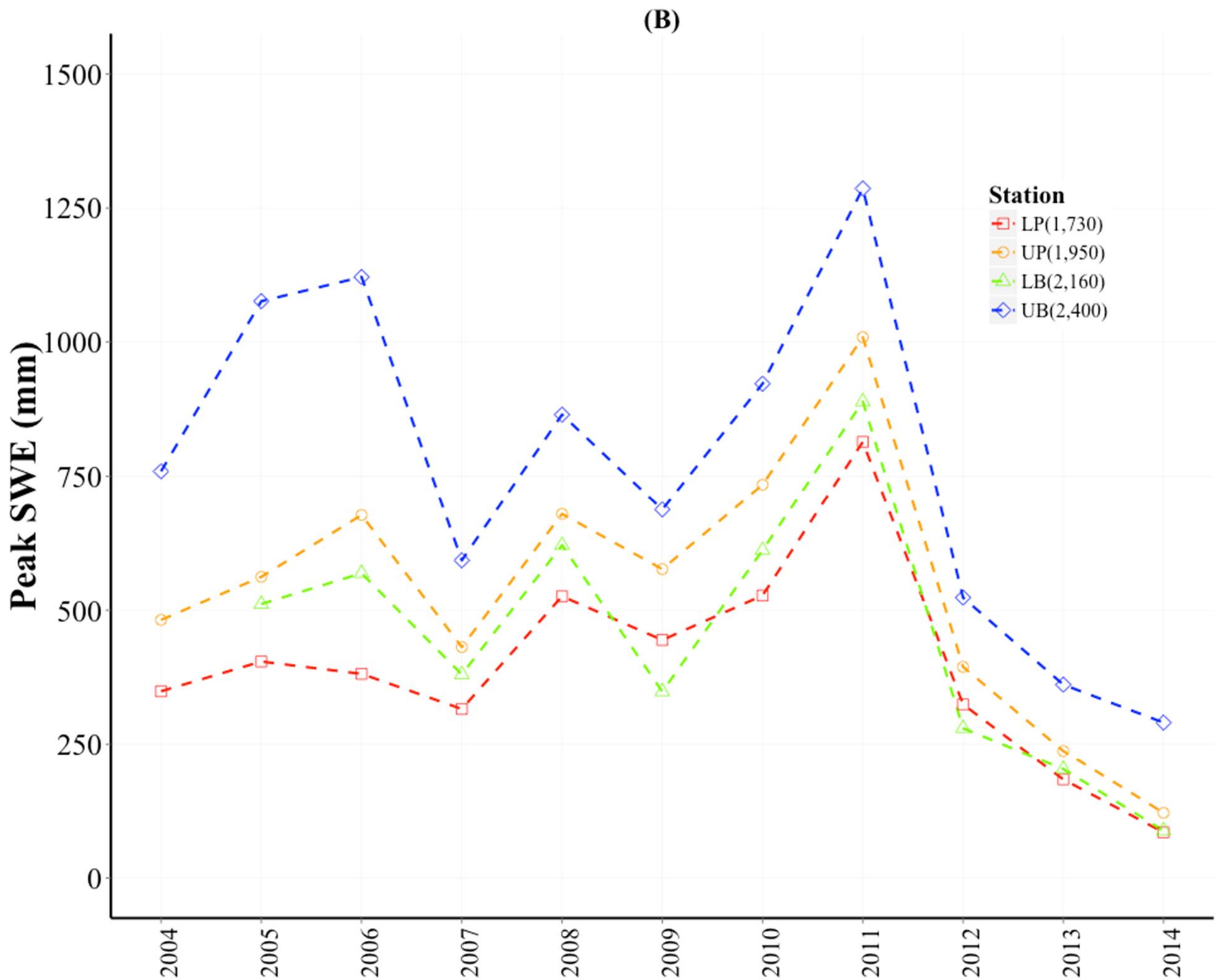
* Hydrology
* Meteorology
* Air quality
* Sediment & turbidity
* Soils & geomorphology
* Water chemistry
* Fuels

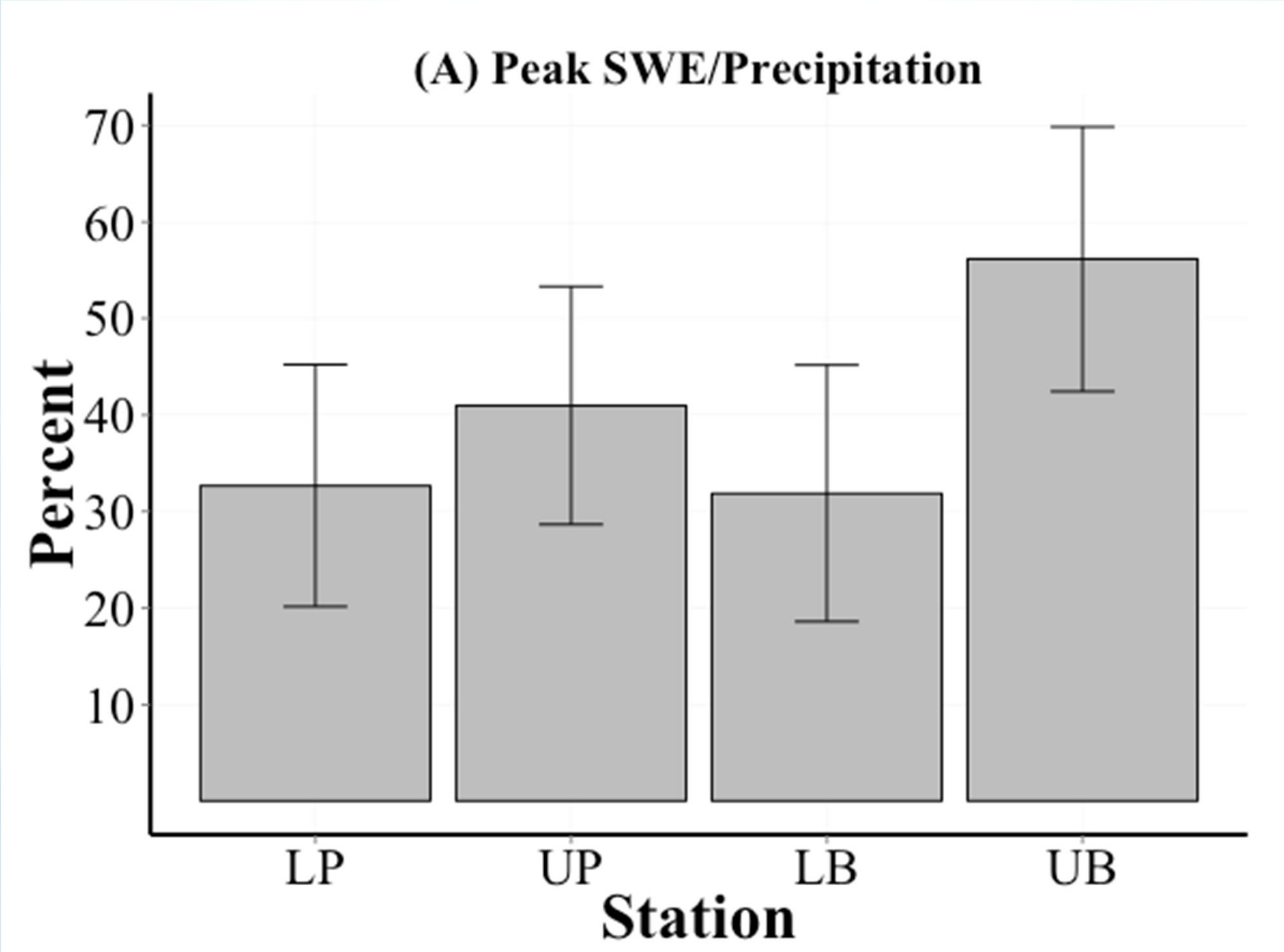
* Biology
  * Stream macroinvertebrates
  * Stream algae
  * Riparian & upland vegetation
  * Yosemite toad

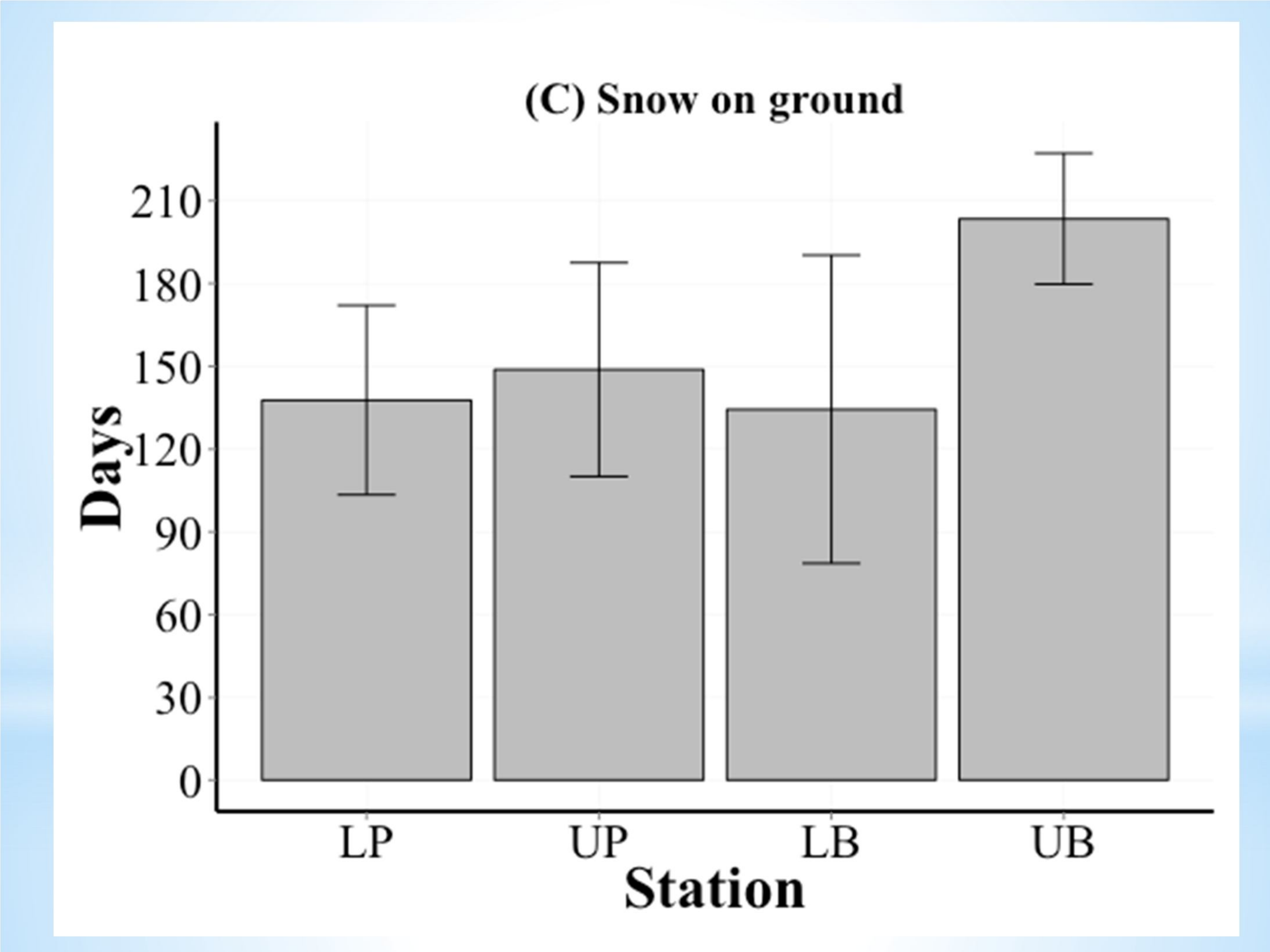
Annual precipitation across the four sites

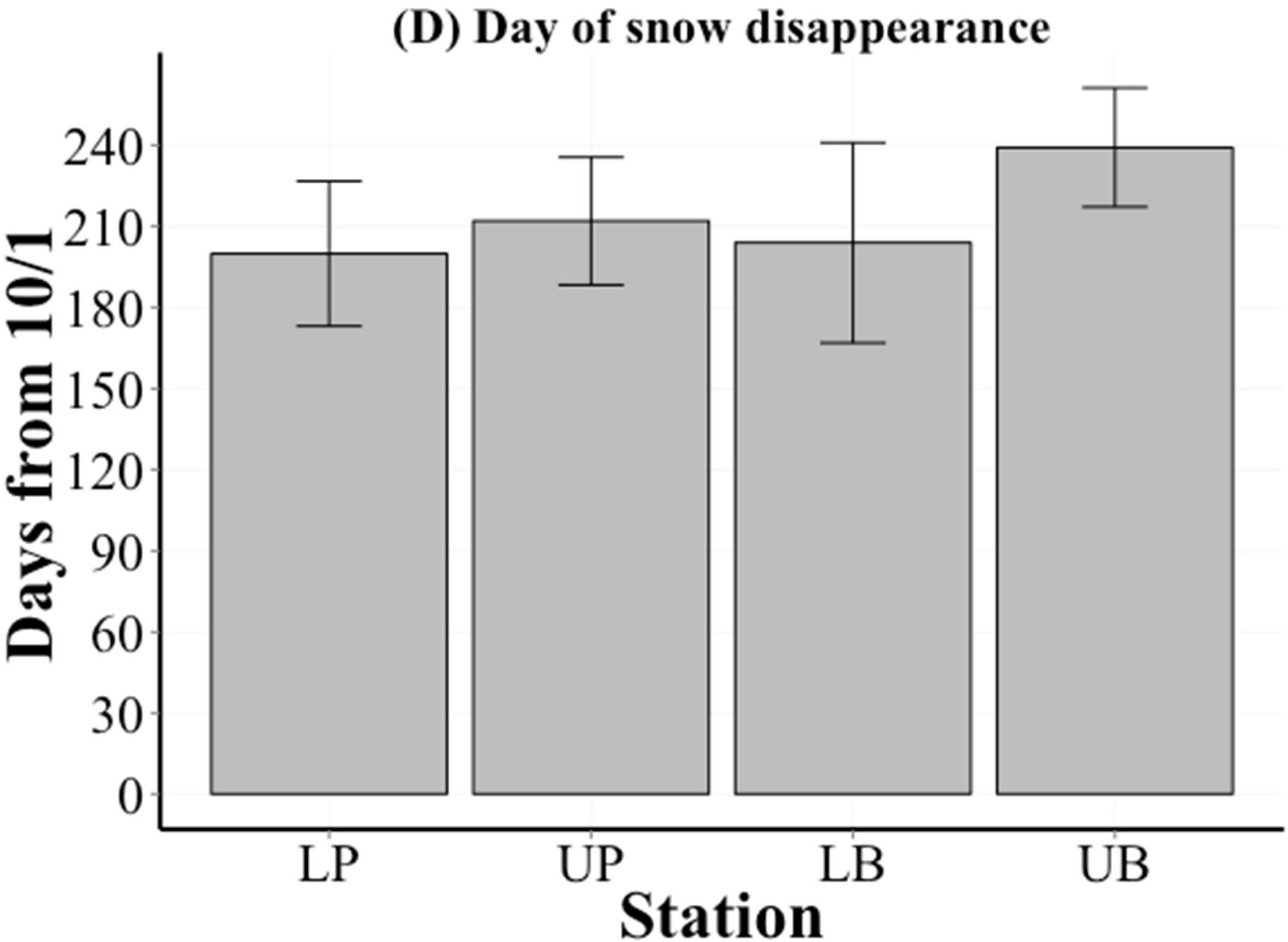



(B) Average temperature
°C
3
2
1
0
-1
LP
UP
LB
UB
Station

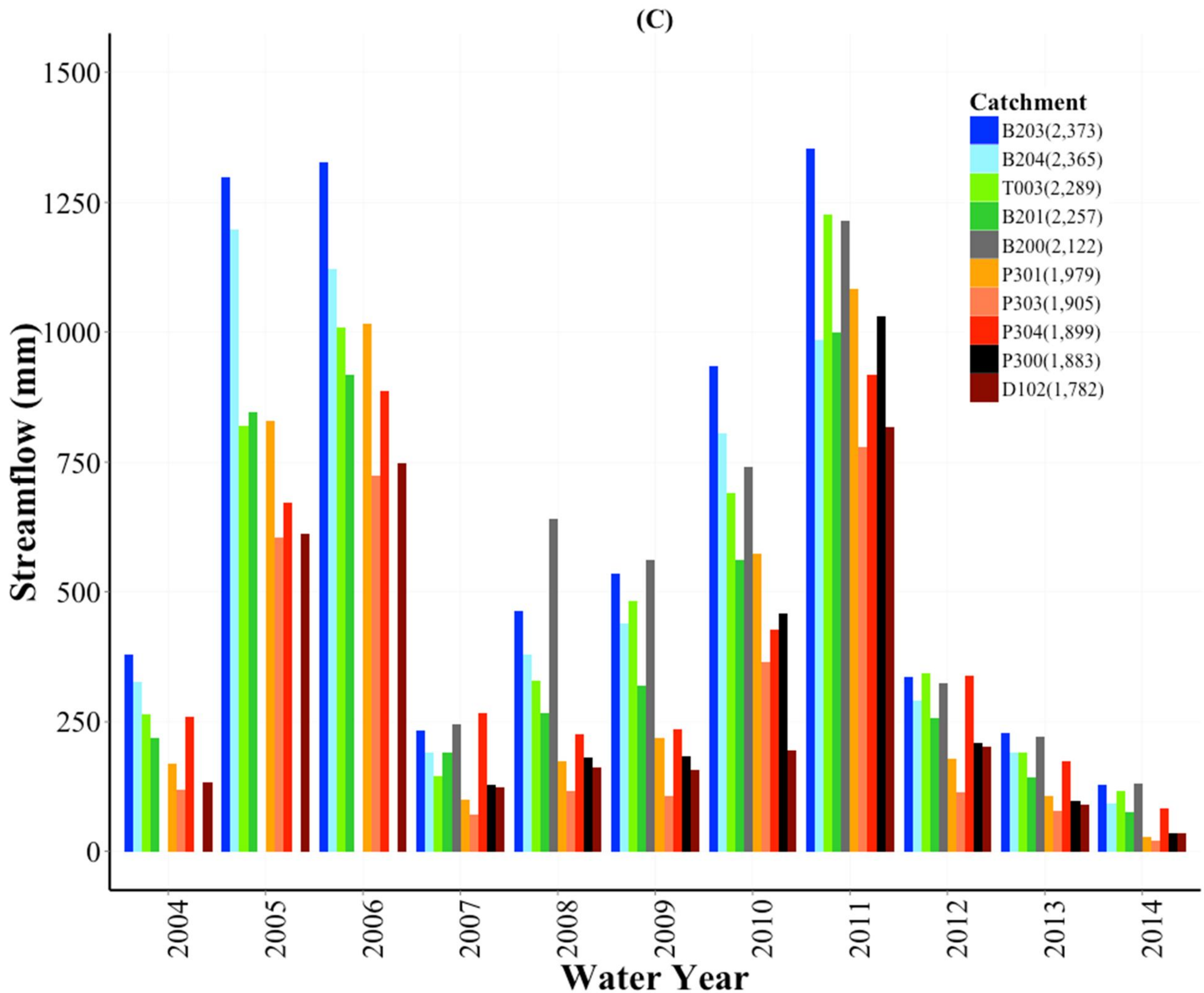

(B)
Peak SWE (mm)
1500
1250
1000
750
500
250
0
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Station
LP(1,730)
UP(1,950)
LB(2,160)
UB(2,400)


(A) Peak SWE/Precipitation
Percent
70
60
50
40
30
20
10
LP
UP
LB
UB
Station


(C) Snow on ground
Days
210
180
150
120
90
60
30
0
LP
UP
LB
UB
Station

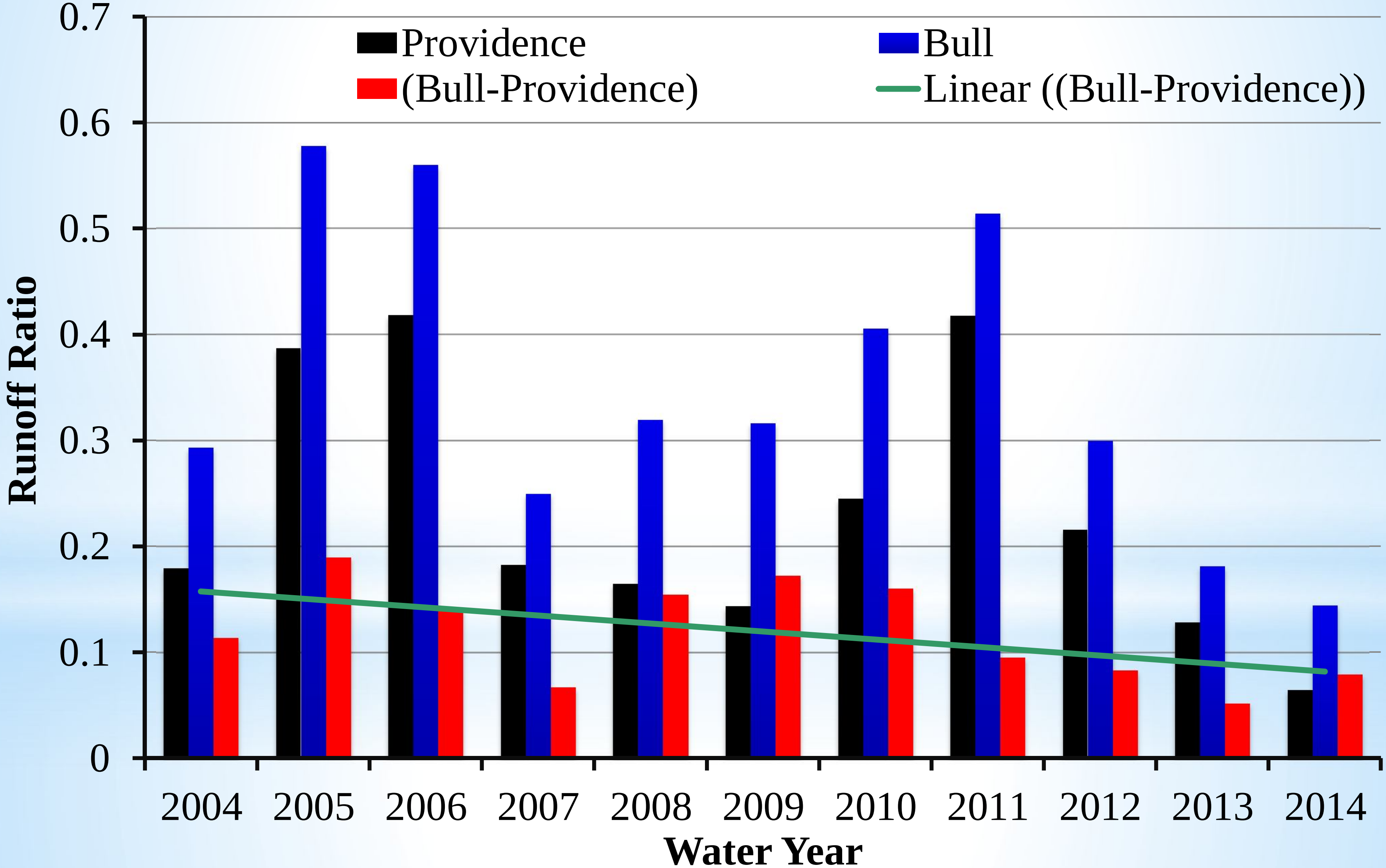


(D) Day of snow disappearance
Days from 10/1
240
210
180
150
120
90
60
30
0
LP
UP
LB
UB
Station

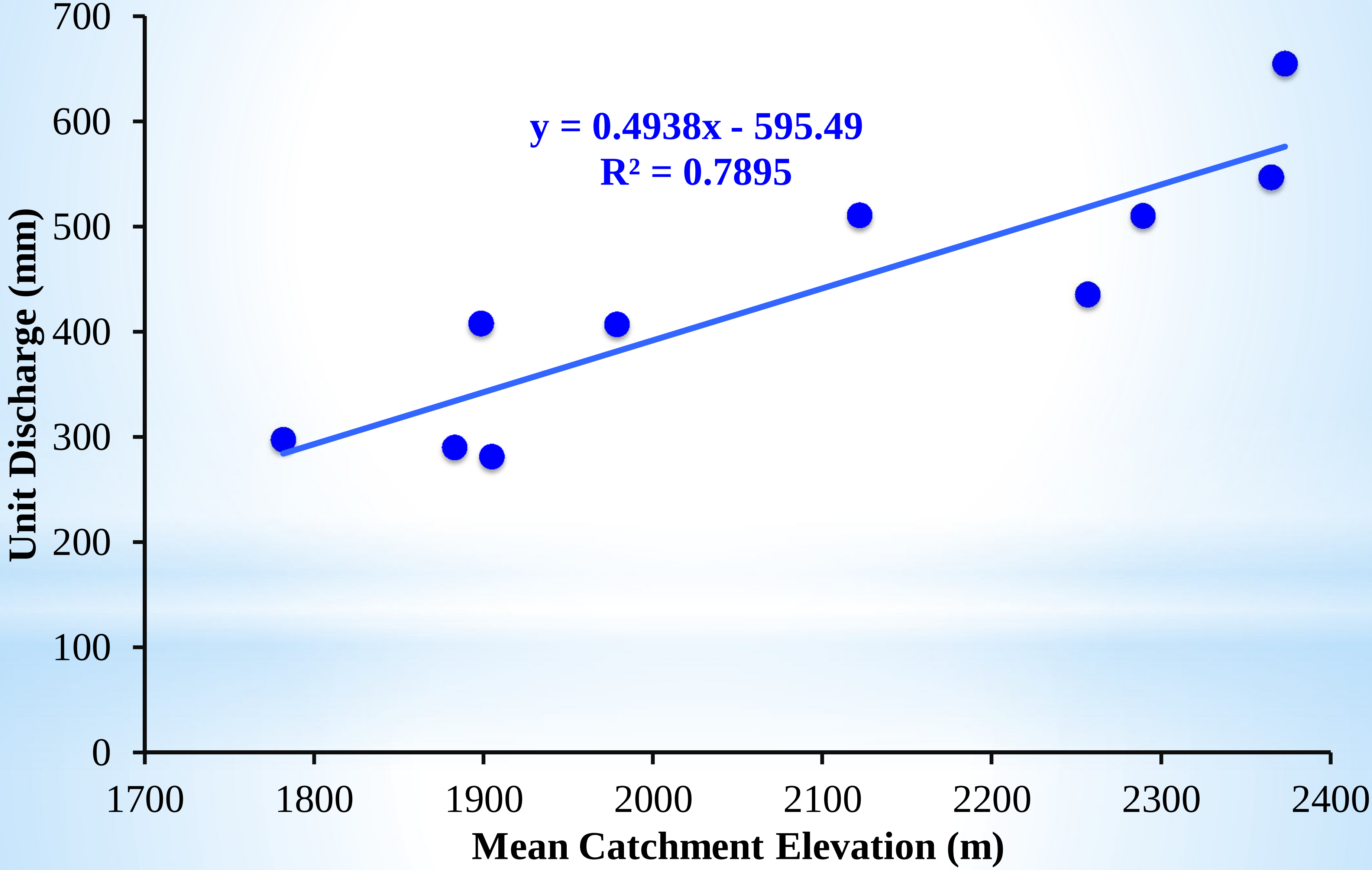


(C)
Catchment
B203(2,373)
B204(2,365)
T003(2,289)
B201(2,257)
B200(2,122)
P301(1,979)
P303(1,905)
P304(1,899)
P300(1,883)
D102(1,782)
Streamflow (mm)
0
250
500
750
1000
1250
1500
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Water Year

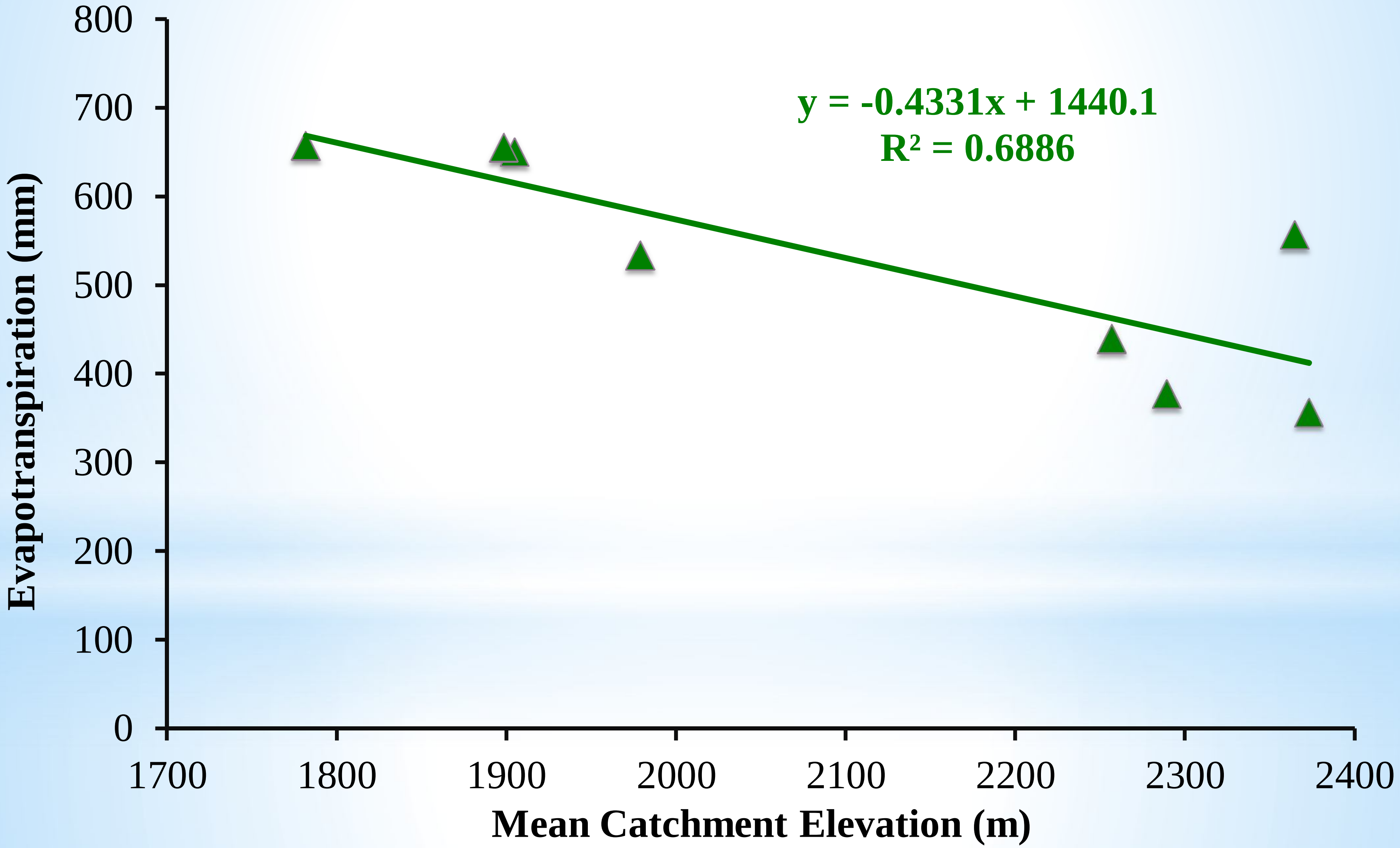
~ Runoff ratio is higher in high elevation Bull catchments



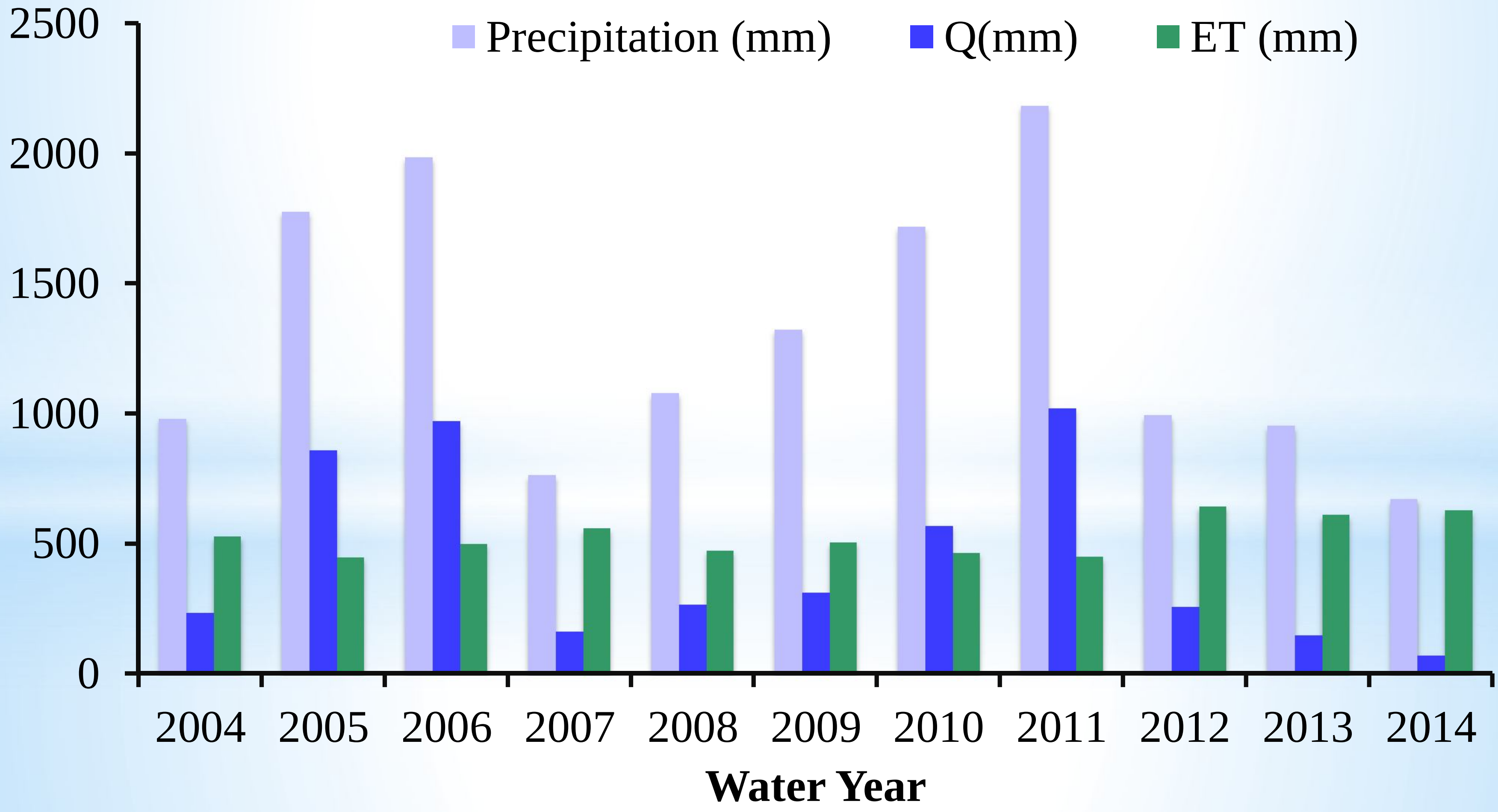
~ 50 mm **increase** in discharge with 100-m elevation gain



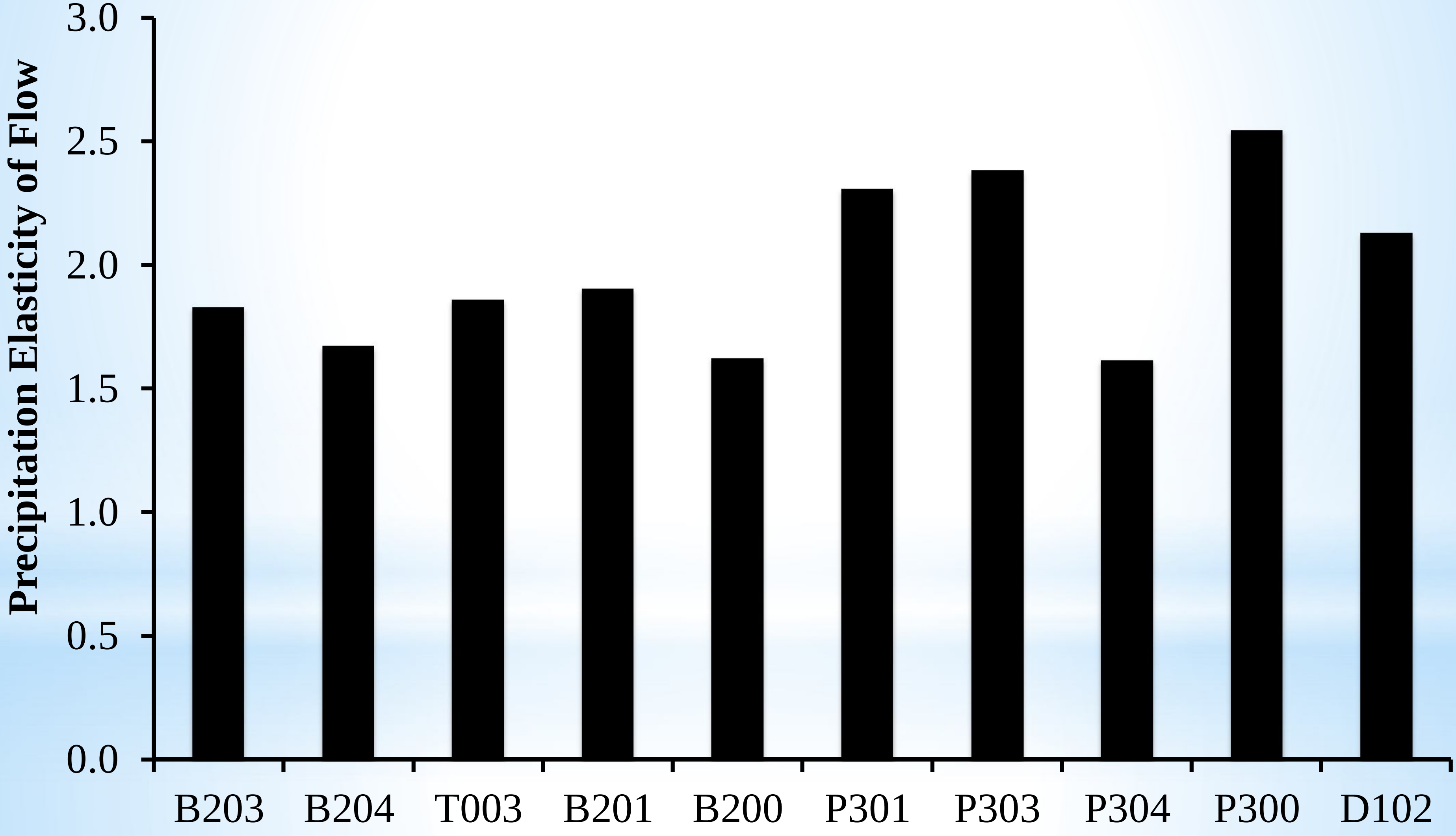
~ 43 mm **decline** in evapotranspiration with 100-m elevation gain



In response to precipitation, annual evapotranspiration is less variable than the streamflow



High elevation Bull catchments are less susceptible to variability in annual precipitation



Summary

- No increase in precipitation with increasing elevation. Temperature is the main driver of snowpack dynamics.
- Streamflow increases by ~ 50 mm / 100 m elevation gain – attributed to decline in evapotranspiration (ET) .
- Spatial variability in streamflow is significant and largely driven by the ET and precipitation state (rain vs. snow).
- High elevation catchments show less susceptibility to drought despite shallow soil depth – delayed snowmelt and lower ET mediates the carryover storage.