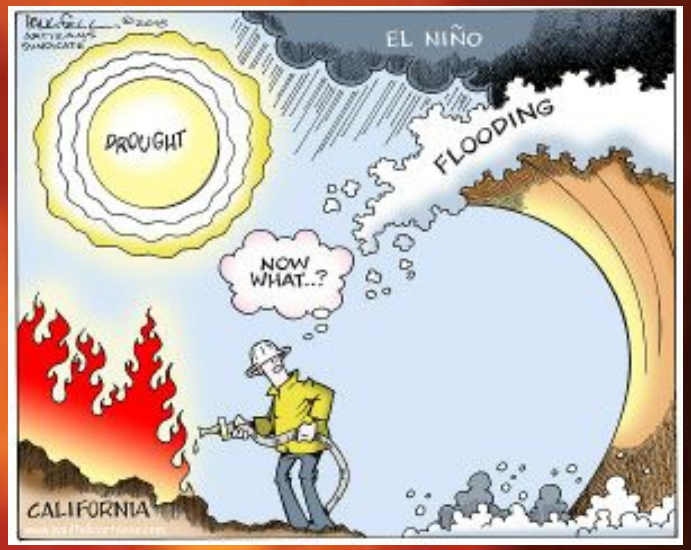
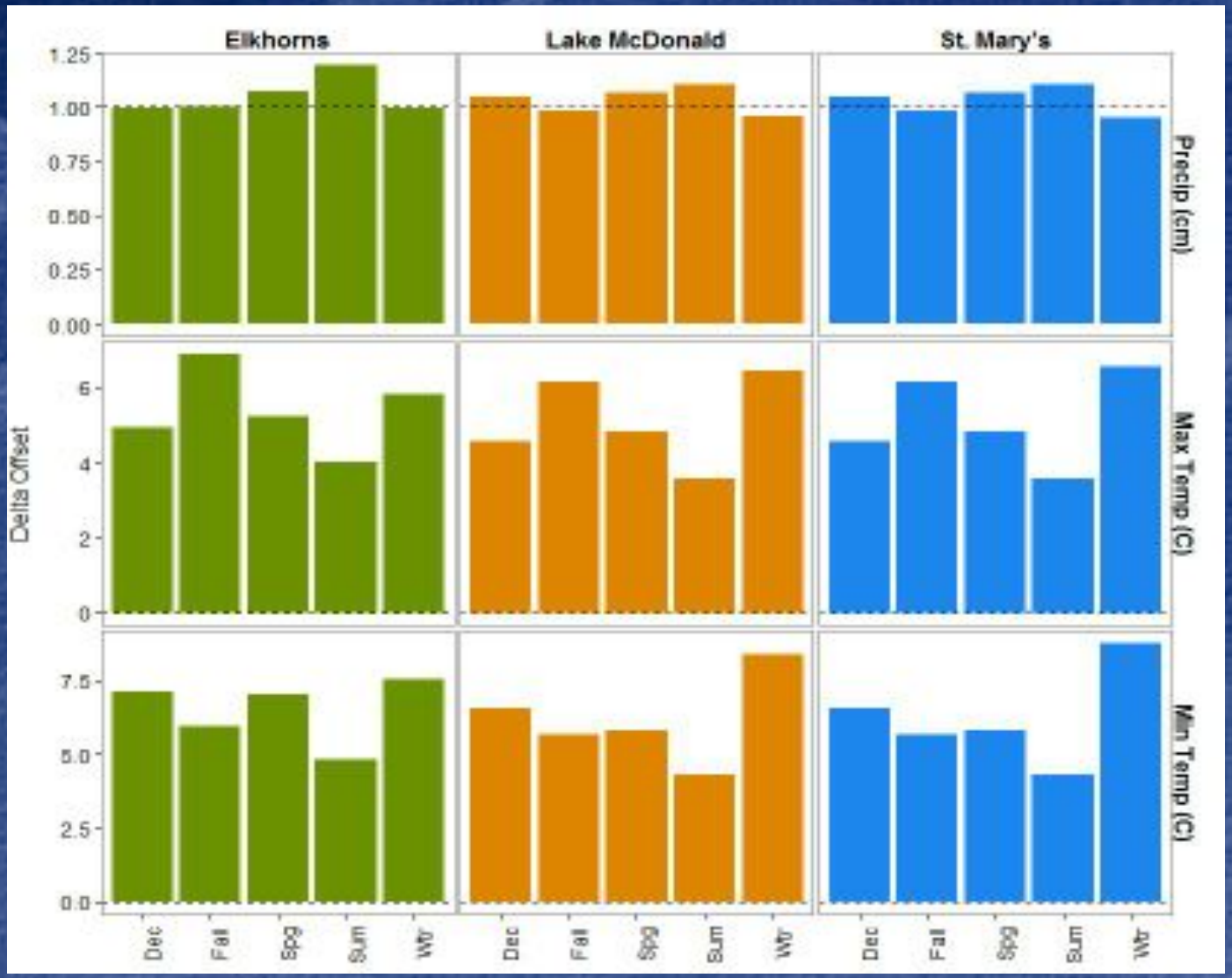
The drivers of drought and fire in northern Rocky Mountain forests: interactions of vegetation, climate, and disturbance



Bob Keane
USDA Forest Service
Rocky Mountain Research Station

Fire, Fuel, and Smoke
Science Program

Extrapolation to fine scales – CMIP5 800 m daily RCP8.5- Temperature and precip increases for three Crown landscapes



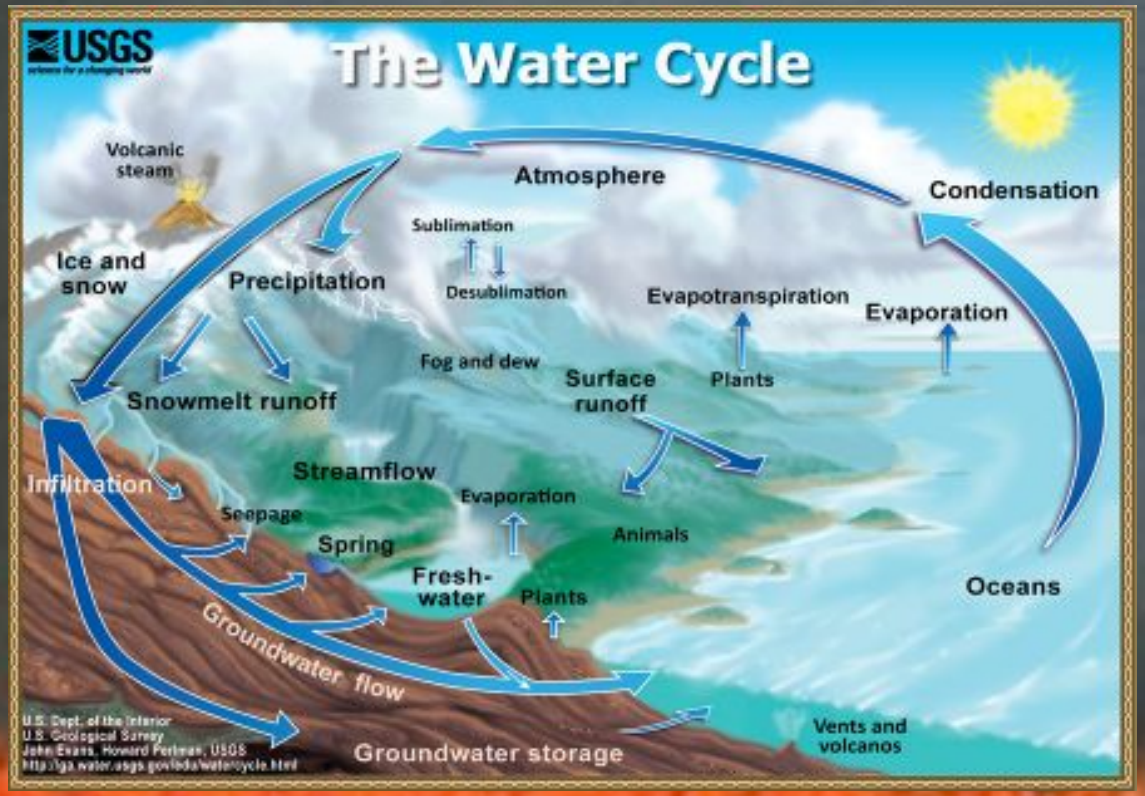
CNRM GCM

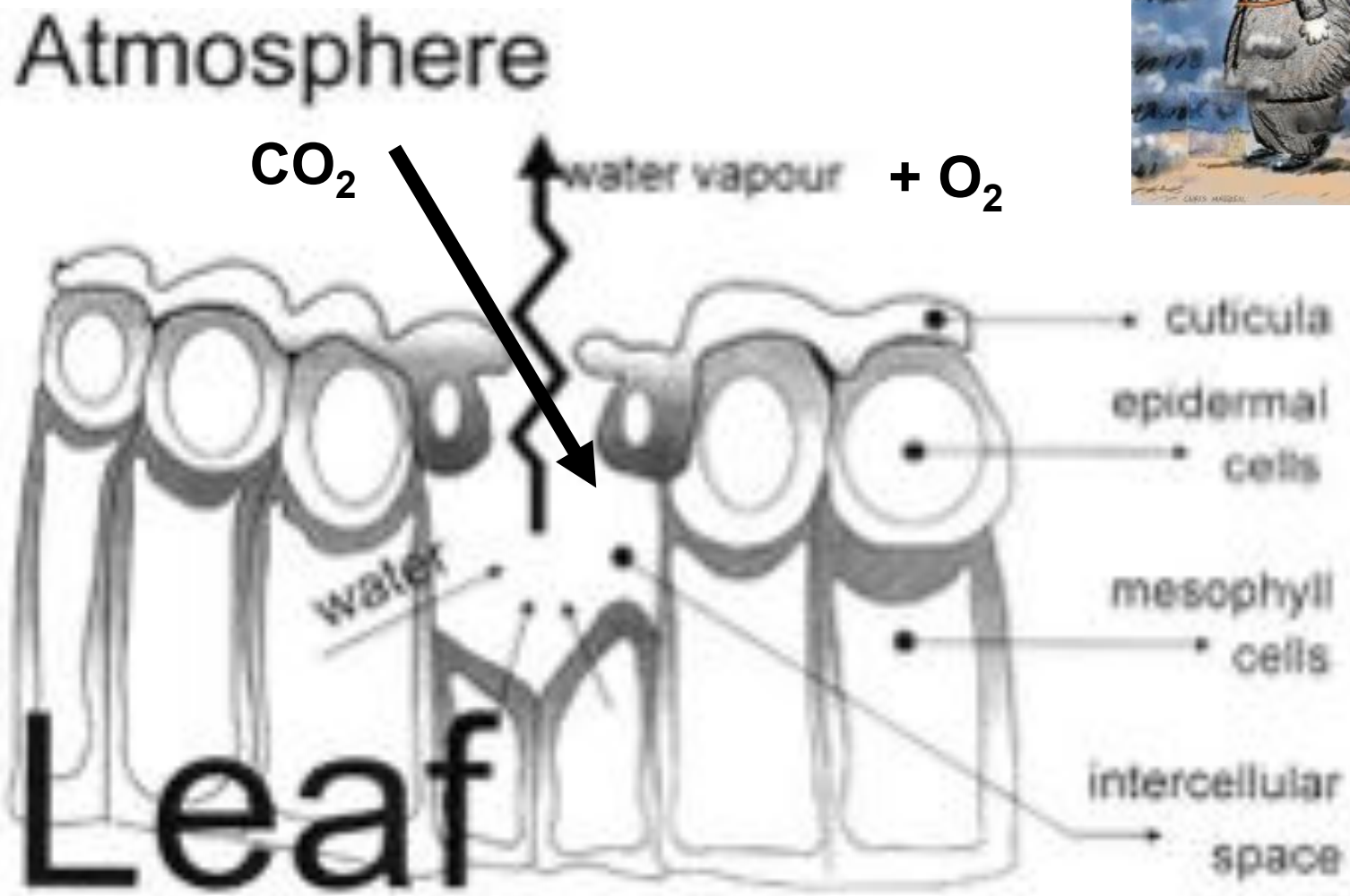
Peters and others 2013

What are the drivers of drought and fire in NRM landscapes?

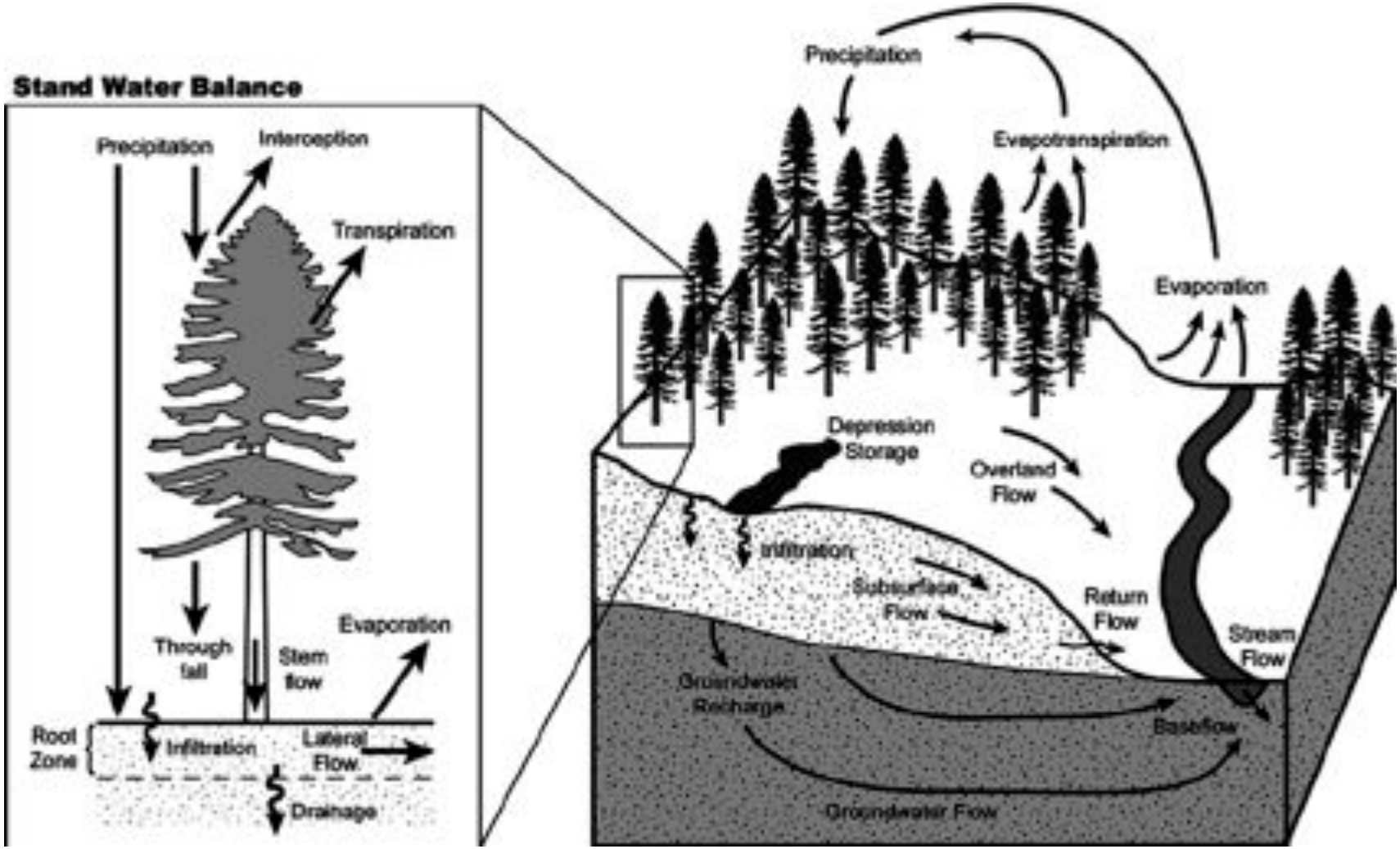
This presentation:

- Discuss climate, vegetation, and fire interactions in the hydrological cycle
- Present modeling results of the interactions of climate, vegetation, and disturbance under historical and future climates
- Discuss possible mitigation or "adaptation" strategies for minimizing drought impacts

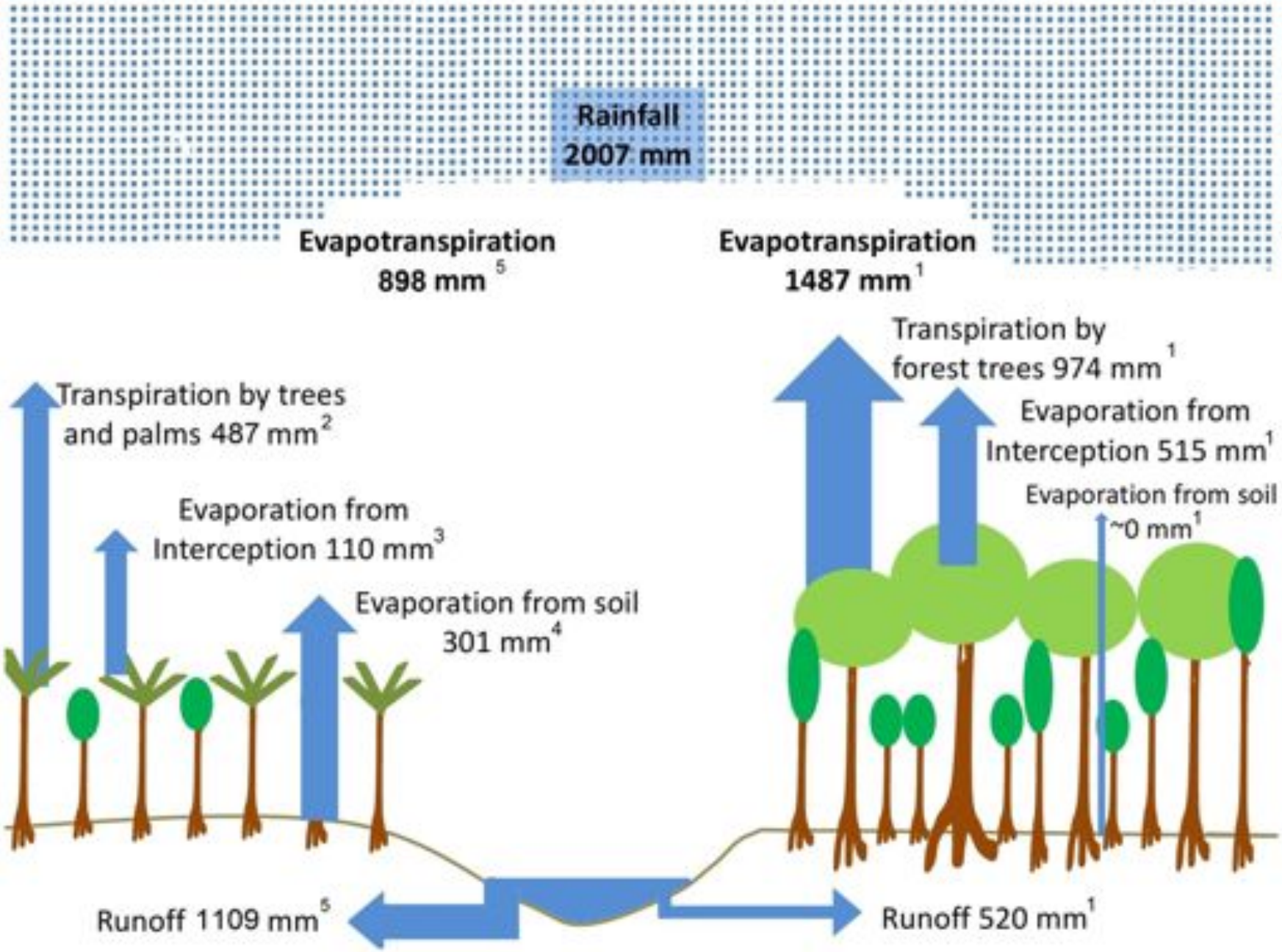


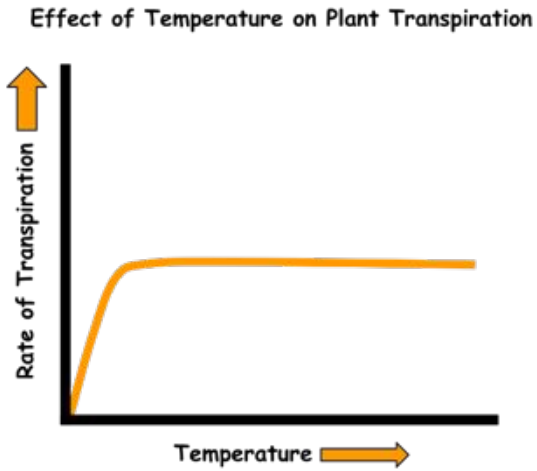

Atmosphere
CO_2
water vapour
$+ O_2$
cuticula
epidermal cells
mesophyll cells
intercellular space
water
Leaf

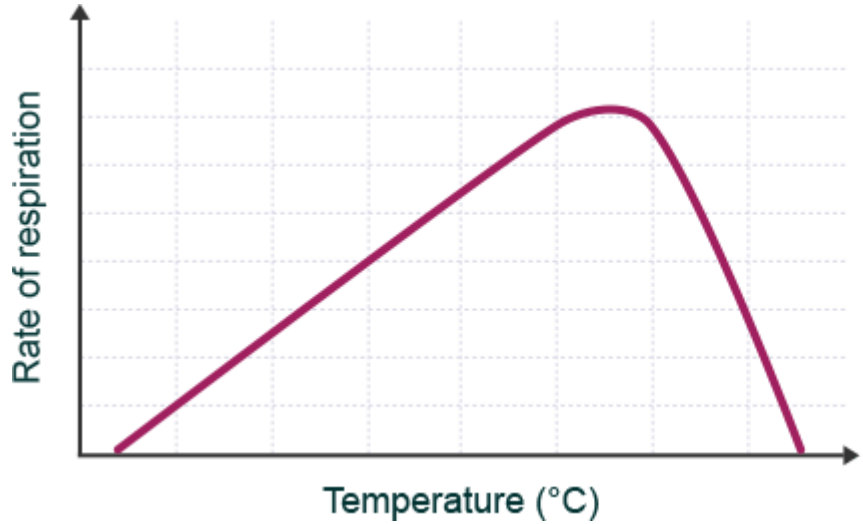
Hydrologic Cycle



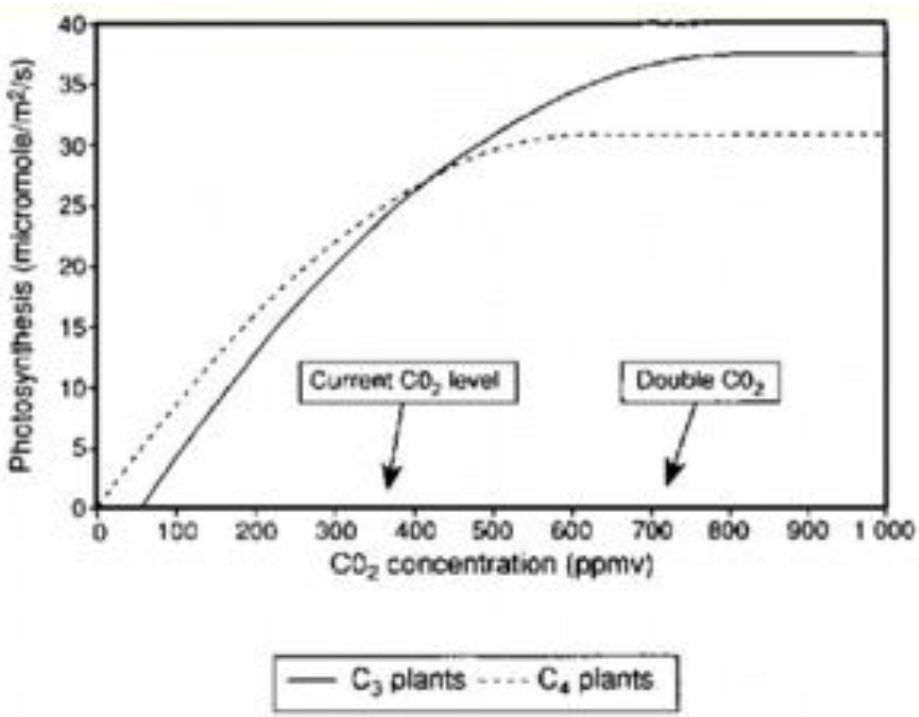
Great differences between tree species


Rainfall
2007 mm
Evapotranspiration
898 mm 5
Evapotranspiration
1487 mm 1
Transpiration by trees
and palms 487 mm 2
Evaporation from
Interception 110 mm 3
Evaporation from soil
301 mm 4
Transpiration by
forest trees 974 mm 1
Evaporation from
Interception 515 mm 1
Evaporation from soil
~0 mm 1
Runoff 1109 mm 5
Runoff 520 mm 1





Double Whammy of Higher Temperatures



There is a bright side:
CO2 fertilization increases
Water use efficiency

Vegetation interactions with drought

Plants constantly grow and add more leaf area

- **Higher LAI**
  - More ET
  - Less overland flow
  - Less throughfall
  - Less sunlight
  - Less wind
  - Lower surface temperatures
- **Indirect effects**
  - More competition
  - Higher and longer water deficits
  - Lower growth rates
  - Higher plant stress
  - Greater insect and disease susceptibility

Vegetation-drought interactions with wildland fire

Dry conditions will foster more fires

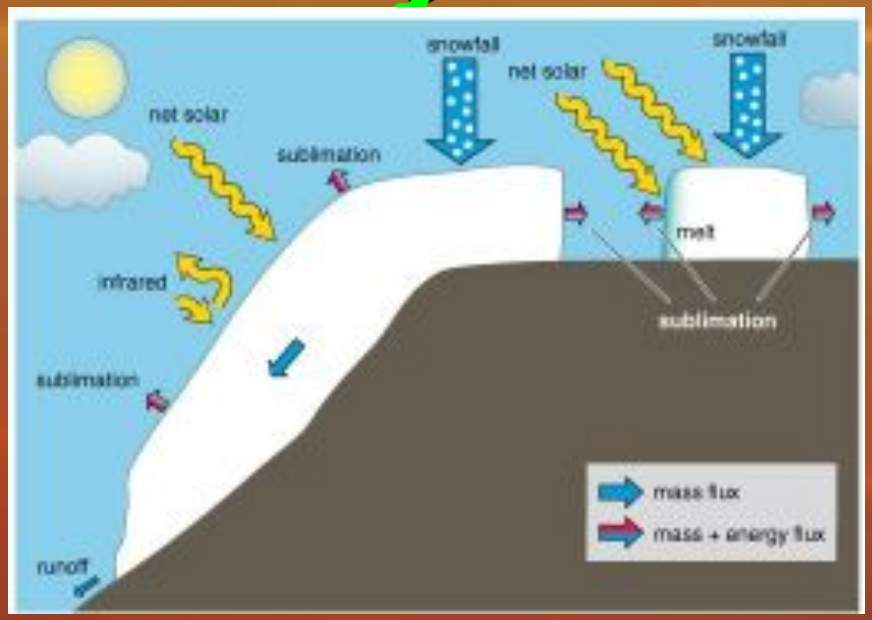
- **Higher LAI**
  - More canopy fuels
  - More surface fuels
  - More ET
  - High canopy cover
- **Indirect effects**
  - More crown fire
  - Higher intensities
  - Earlier and longer periods of low fuel moistures
  - Less wind, low radiation and temperature, higher moistures

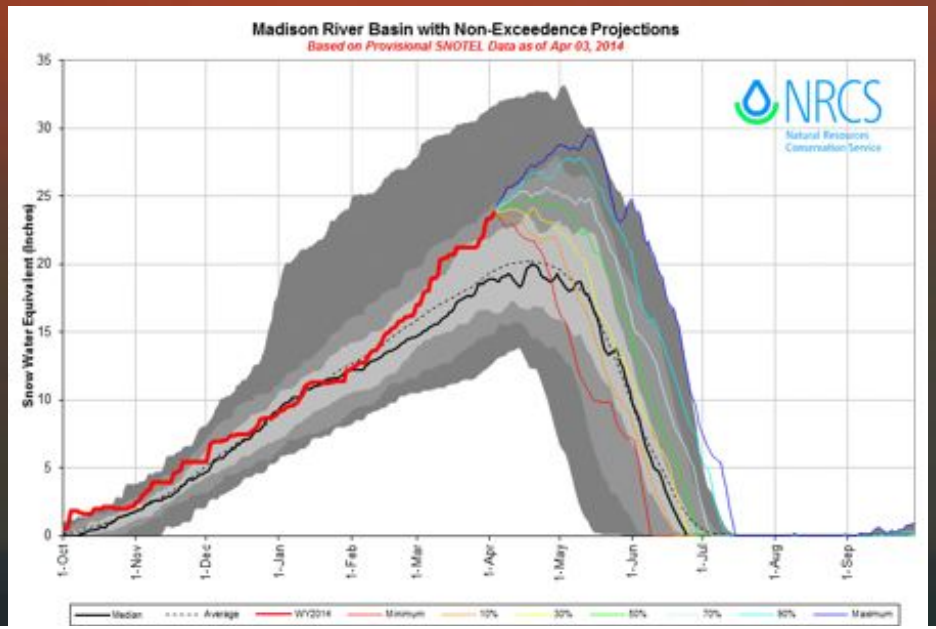
Disturbance interactions with drought

Disturbance kills plants, removes biomass and lowers leaf area

- **Lower LAI**
  - Less ET
  - More overland flow
  - More throughfall
  - More sunlight
  - More wind
  - Higher surface temperatures
- **Indirect effects**
  - Reduced competition
  - Reduced water deficits
  - Increased growth rates
  - Reduced plant stress

Snow dynamics





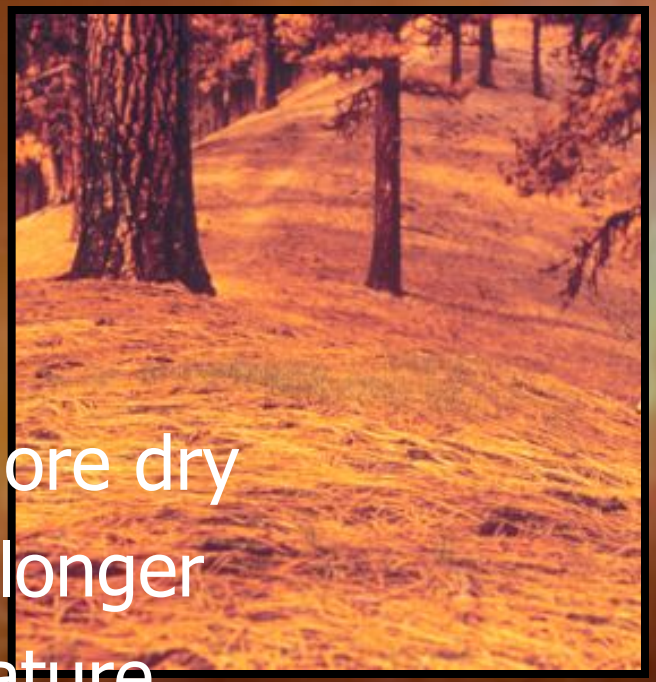
Wildfires and climate change

- Why are fires expected to increase?

Climate Change and Wildland Fire – Western MT

Longer Fire Seasons

currently 78 days longer



- Early snowpack melt off
- Late snowpack accumulation
- Deeper droughts
- Fuels will be drier longer and more dry
- More of landscape will be drier longer
- Lower humidity, higher temperature

Increased Lightning and Wind

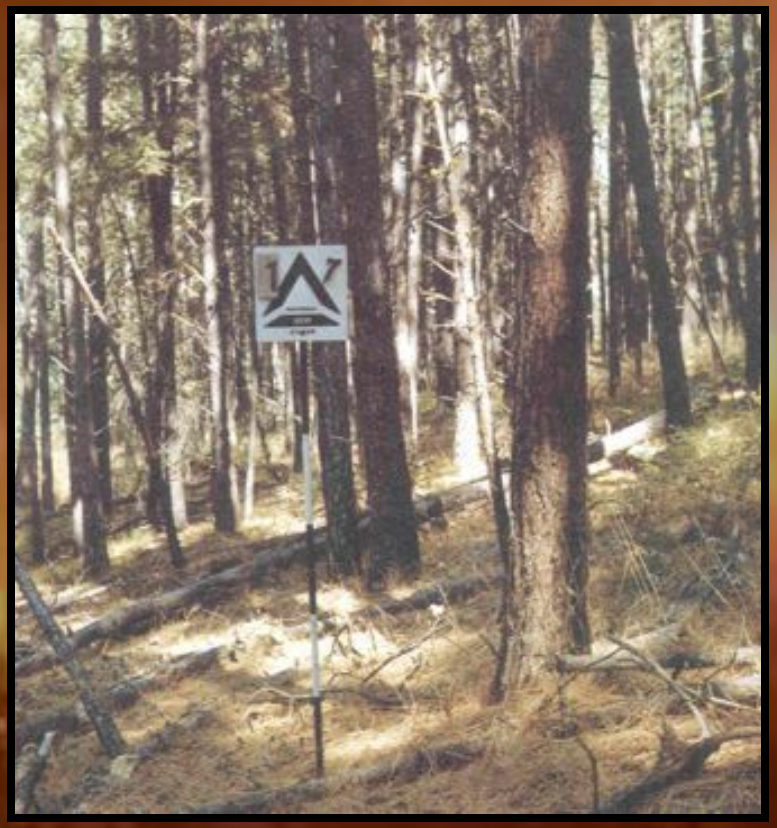
No indication of change

- More convective storms
- Greater storm intensity
- 30% increase in global lightning
- Greater occurrence during drought
- Higher cloud to ground strikes
- Greater number of positive strikes
- More wind

Climate Change and Wildland Fire

Increased fuel production

- Higher productivity results in an increase in burnable biomass, especially in subalpine environs
- Increased fuels will be more contagious and connected
- Productivity will increase both surface and canopy fuels
- Continued suppression will exacerbate situation

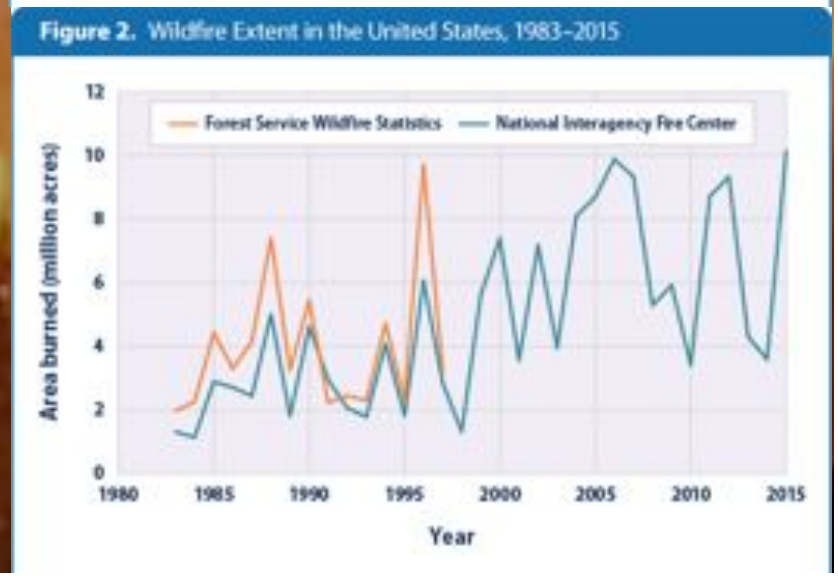


More and larger fires

Maybe not more, but larger

Fires are predicted to be more numerous and larger for the following reasons:

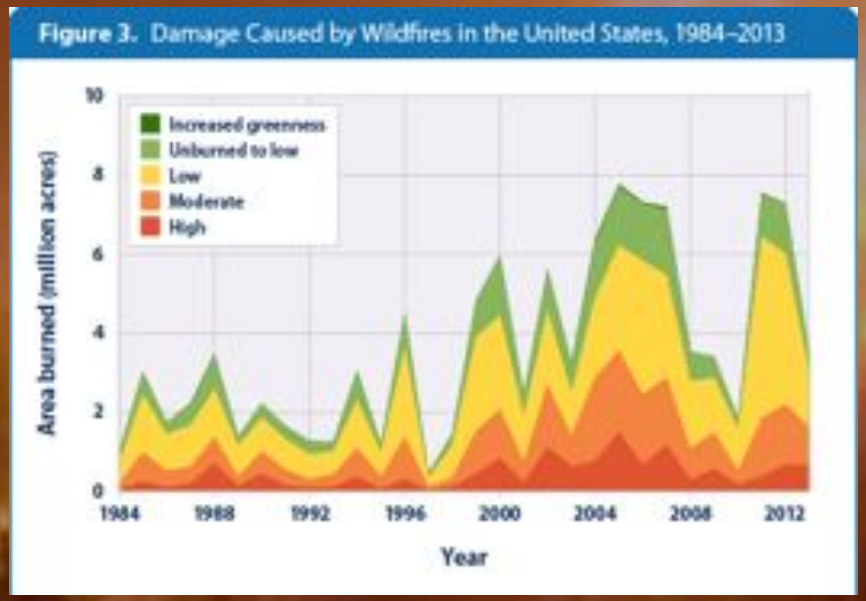
- Greater fuel accumulation
- Continuous flammable fuel beds
- Higher winds
- More of landscape in drought
- Burn longer with long fire seasons



Climate Change and Wildland Fire

Greater fire intensities & Higher fire severities

- **More intense fires are expected because of the following:**
  - High accumulated fuels
  - Denser tree canopies
  - Widespread drought conditions
  - High wind events
  - Previous fire management -- Exclusion



Putting all the interactions together

Modeling climate change

FireBGCv2:
A research simulation platform for exploring fire, vegetation, and climate dynamics

Keane, Robert E.; Loehman, Rachel A.; Holsinger, Lisa M. 2011. **The FireBGCv2 landscape fire and succession model: a research simulation platform for exploring fire and vegetation dynamics. Gen. Tech. Rep. RMRS-GTR-255. Fort** Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 137 p.

CLIMET
Climate-Landscape Interactions on a Mountain Ecosystem Transect

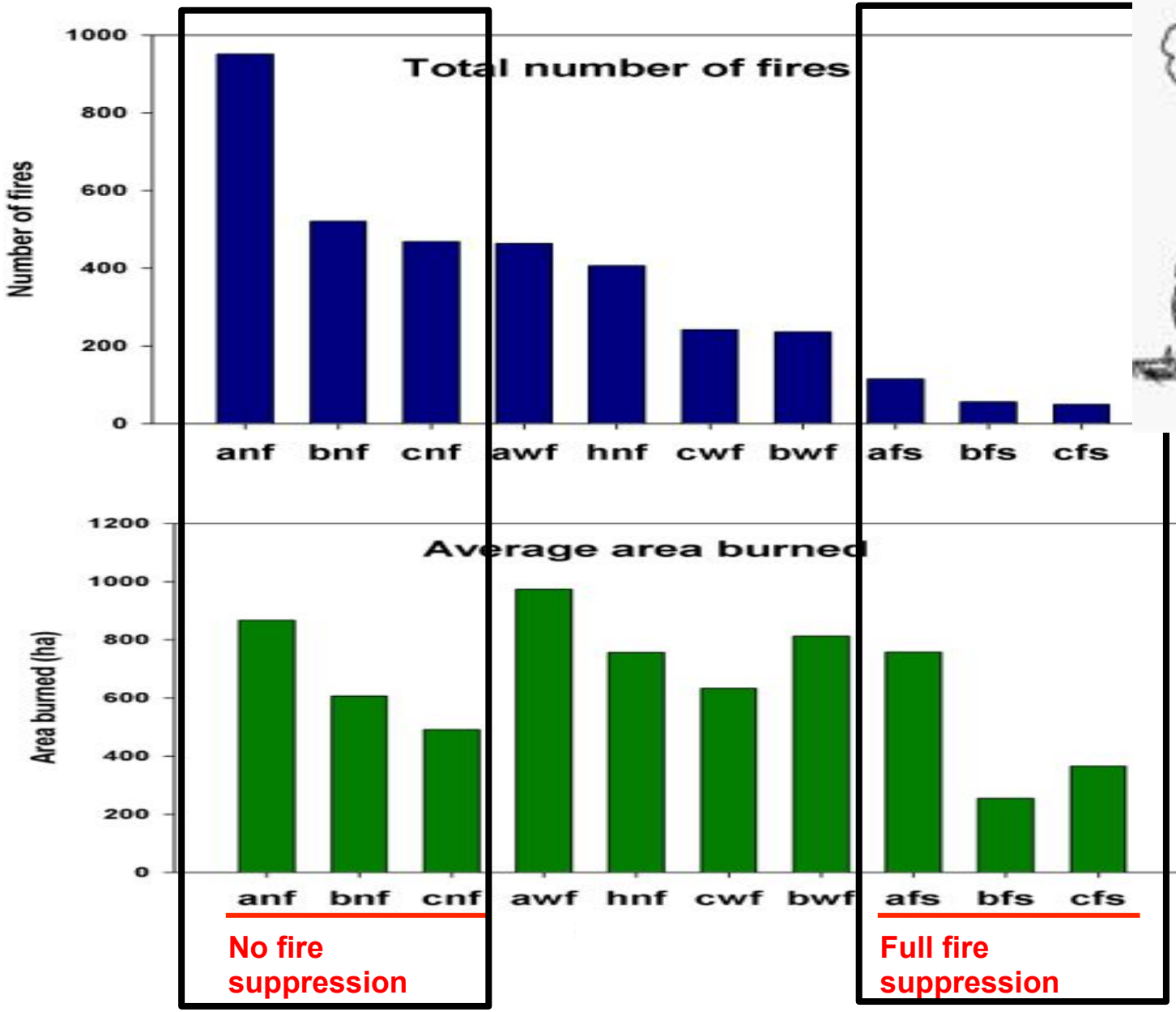
FireLab
MISSOULA, MONTANA

Old Climate scenarios (***HadCM3 GCM - Mote 2003, Mote et al. 2007)***

- **H-Historical climate (recorded weather)**
- **B2 (A1B): WARM AND WET (+1.6ºC; +9% ppt)**
- **A2: HOT AND DRY (+4ºC; -7% precip.)**

Based on IPCC (2007) projections

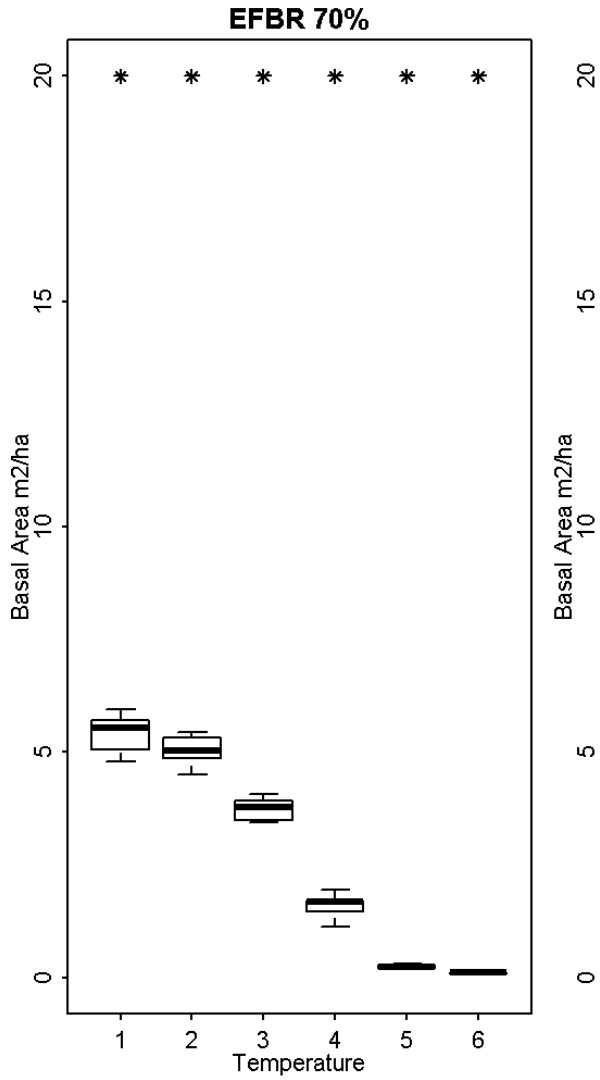
Number Fires vs Area Burned



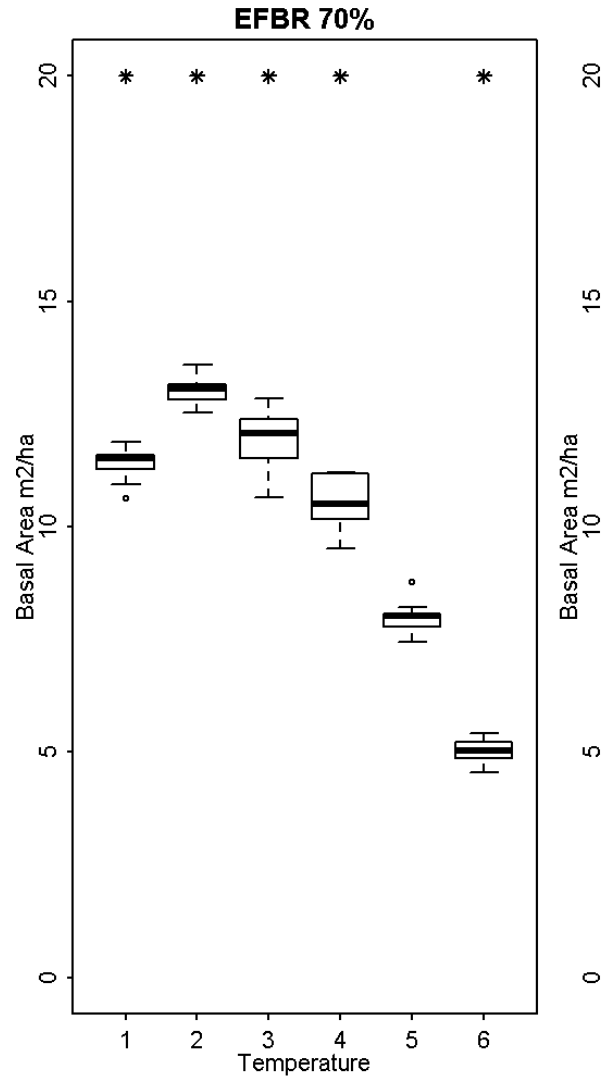
Dominant species changes

Bitterroot NF

- Ponderosa pine
- Douglas-fir
- Lodgepole pine
- Subalpine fir
- Englemann spruce
- Whitebark pine
- Cottonwoods
- Western red cedar
- Western hemlock
- Western larch
- Shrubs
- Grasses
- Water

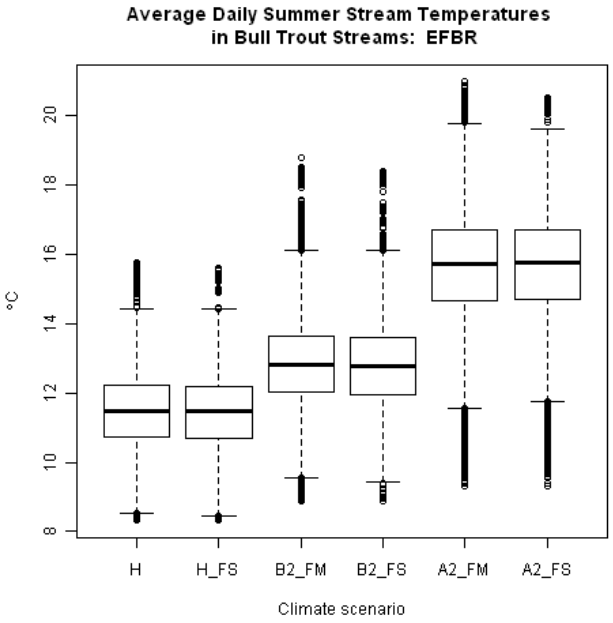


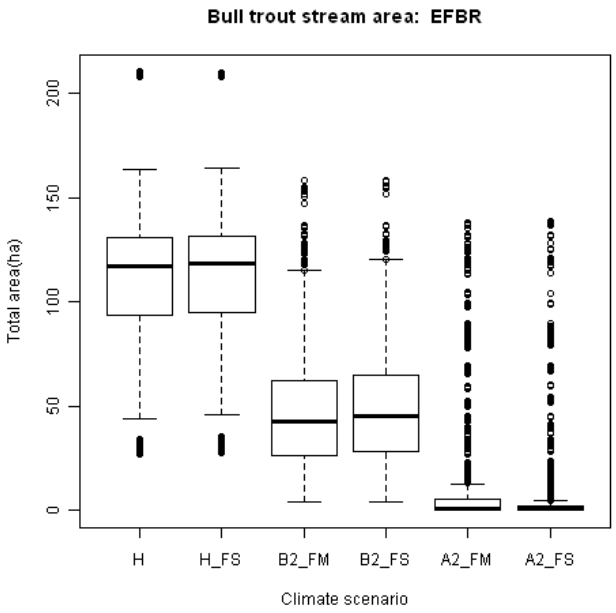
Lodgepole pine

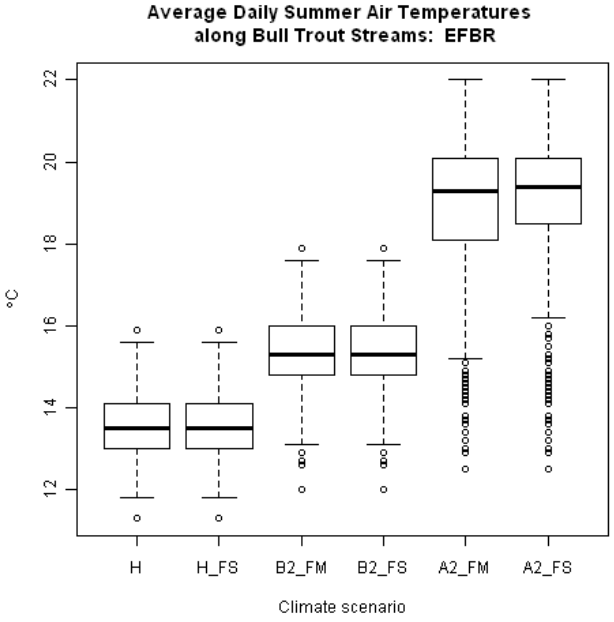


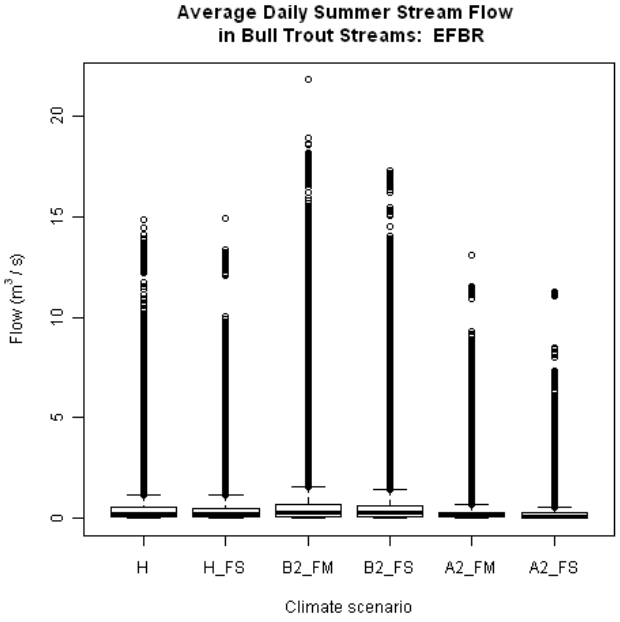
Douglas-fir

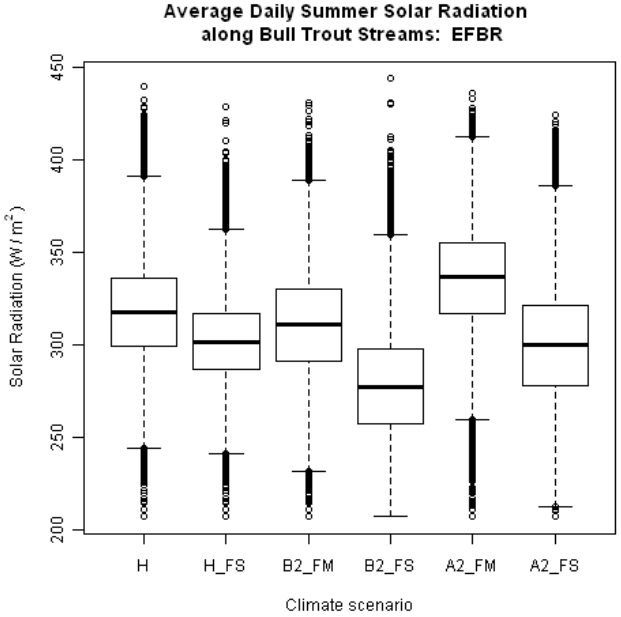
Simulation Results: East Fork Bitterroot River





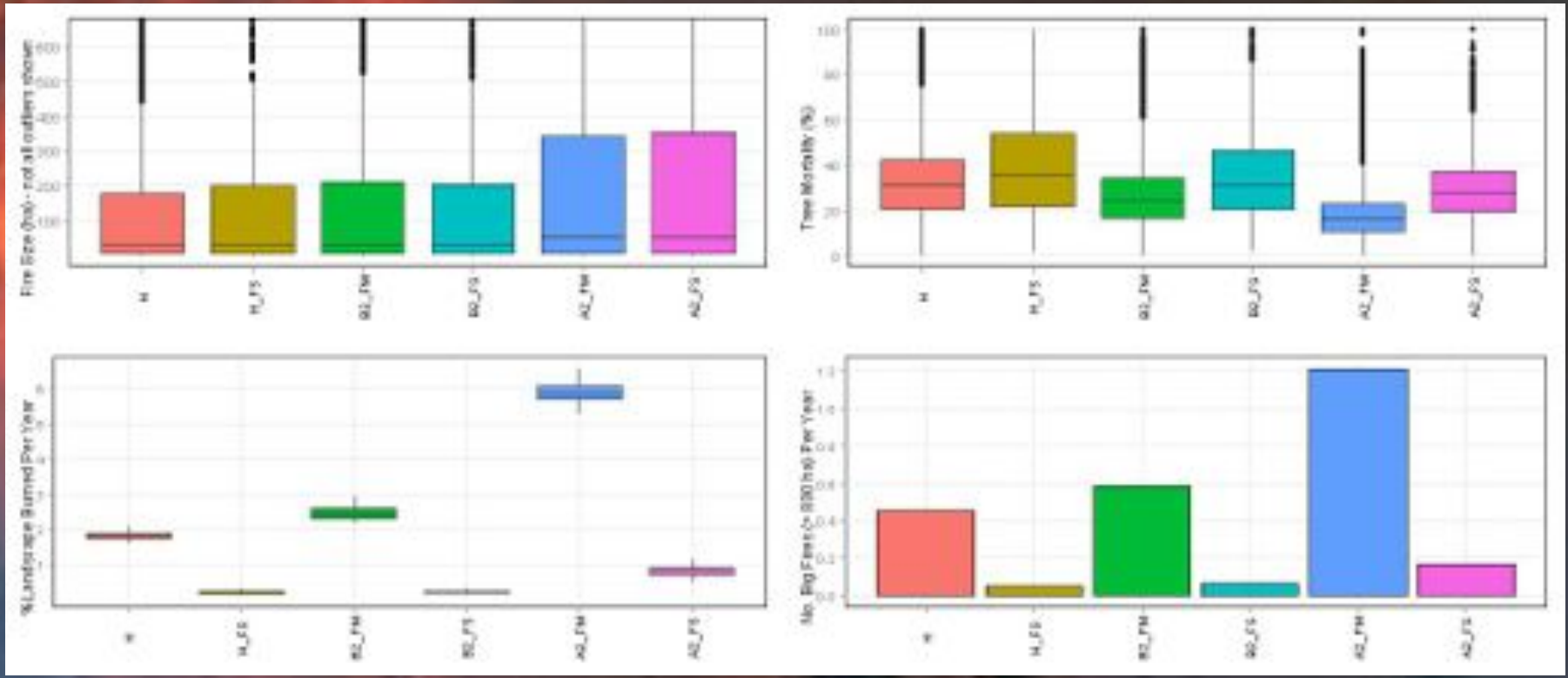






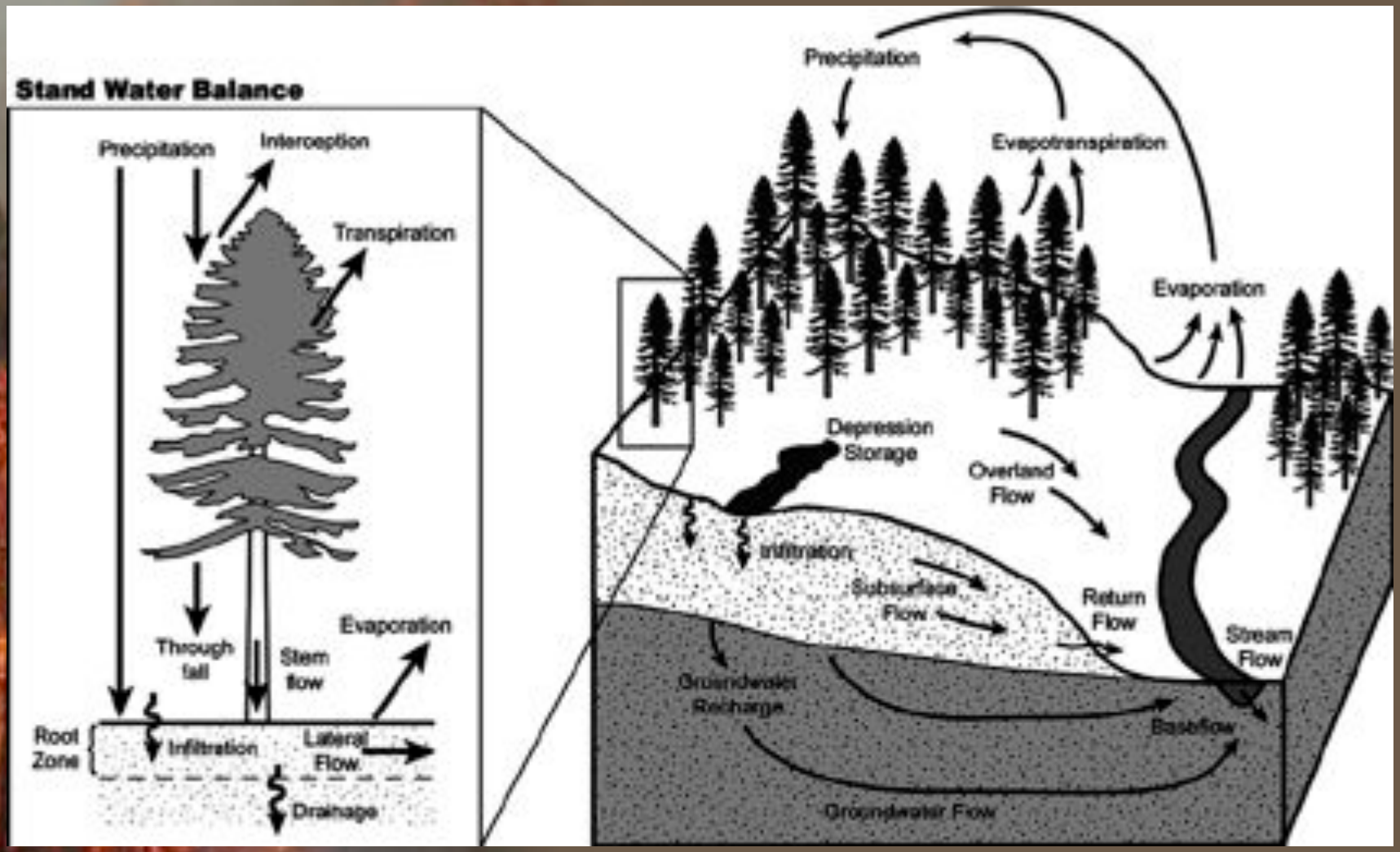
East Fork Bitterroot River

Fire dynamics in a changing climate



Adapting to Climate Change, Drought, and Fire

Our toolbox is limited…



Reducing LAI is our most effective strategy…

How?

- Silviculture
- Prescribed fire
- Wildfire
- Wildland fire use
- Other disturbances

Design implementation using ecological context

Design for multiple objectives

Disturbance will happen, so how do we maintain resilience in the face of drought

How?

Plan for future disturbances and proactively treat areas with the highest vulnerability to change

- **Use HRV**
- **Use modeling**
- **Use experience**