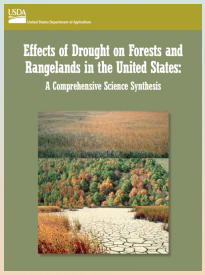
Effects of Drought on Forests and Rangelands in the United States:

A Comprehensive Science Synthesis

James M. Vose, USFS R&D
James S. Clark, Duke University
Charles H. Luce, USFS R&D
Toral Patel-Weynand, USFS R&D

IPCC process

77 authors from federal agencies, national labs, universities



Topics Addressed in This Assessment

- Characterizing Drought for Forested Landscapes and Streams
- Physiological Responses of Forests to Future Drought
- Impacts of Drought on Forest Dynamics, Structure, Diversity, and Management
- Forest Biogeochemistry in Response to Drought
- Insect and Pathogen Responses to Drought
- Fire and Drought
- Rangeland Drought: Effects, Restoration, and Adaptation
- Detecting and Monitoring Large-Scale Drought Effects on Forests: Toward an Integrated Approach
- Ecohydrological Implications of Drought
- Economics and Societal Considerations of Drought in Forests and Rangelands

Chapters in Special Issues of Scientific Journals

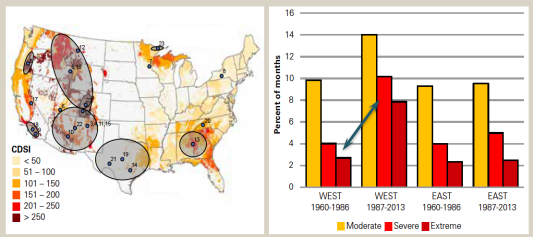
Global Change Biology
Forest Dynamics
Fire
Biogeochemical Cycling

Forest Ecology & Management
Ecohydrology
Characterizing Drought
Insects and Pathogens
Physiology
Monitoring Drought

Why a synthesis?

- *Recent widespread drought, potentially getting worse*
- *Forest and rangeland responses differ from agriculture*
- *Scientific foundation needed to manage for resilience and adaptation*

Big increases in western wildfire



Clark et al. 2016 – Chapter 4

Forests and Drought

Drought impacts….

- *Widespread forest mortality – especially the west*
- *Increased costs of fighting large fires*
- *Water scarcity*



Key Messages

- Drought is now affecting all ecosystems, could get worse
  - *Changes most obvious in the west, impacts in eastern forests through morbidity, slow decline*
- Impacts both immediate and long-lasting
  - *Plant stress, drought-tolerant species*
  - *Habitat shifts*
  - *Some invasive species can benefit*
  - *Reduced carbon storage and water supplies*
- Manage to increase resiliency and resistance

Drought

"A period of uncharacteristically dry weather for a given location."

Drought Types

- **Meteorological**
  - Variations in Precipitation and Temperature imputing evaporation and soil moisture balance
- **Hydrological**
  - Outcome of a period of meteorological drought on streamflow or reservoir storage
- **Ecological**
  - Outcome of a period of meteorological drought on forest, rangeland, aquatic ecosystems.

Drought and associated weather characteristics important for forests and rangelands

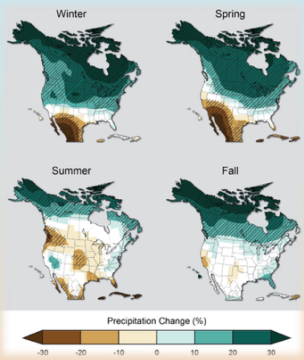
Lower rainfall, but also…

- Less snow
- Dry air (low humidity)
- Longer dry spells
- Higher temperatures during droughts

Seasonal precipitation projections

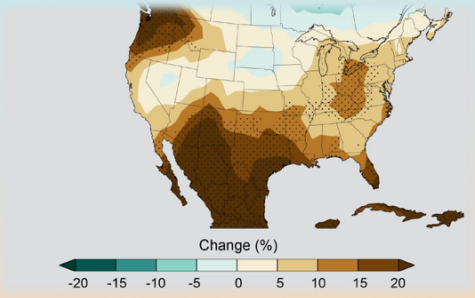
White = models disagree

Hatched = models agree



GCRP 2014, Our Changing Climate

Change in Maximum Number of Consecutive Dry Days



GCRP 2014, Our Changing Climate

Effects of Drought on Trees and Forests

- Changing biodiversity
  - *Large species differences in drought effects*
- Forest productivity
  - *Balance of effects on growth, survival, reproduction*
  - *differs for each species*
- Carbon sink in forests
  - *large and dependent on productivity*

Interactions critical and poorly understood

- Warming and drought
  - *Growing-season benefit vs drought-stress cost?*
  - *How much worse is 'hot drought'?*

Interactions critical and poorly understood

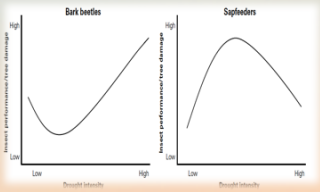
- Will moist habitats be the future drought refuges?
  - *Drought-hydrology interactions*
  - *The poorly understood rooting environment*
- Species interact
  - *Costs/benefits through drought effects on natural enemies, competitors, pollinators, seed dispersers*
- Rising atmospheric CO_2
  - *Interaction with photosynthesis*

Effects of Drought on Forests – Indirect Effects

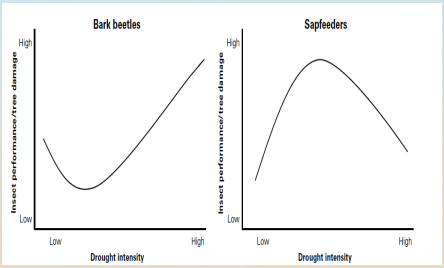
Insect outbreaks and drought*… complex*

Moderate drought *can increase resistance to some, decrease resistance to others*

Severe drought *can promote widespread outbreaks*



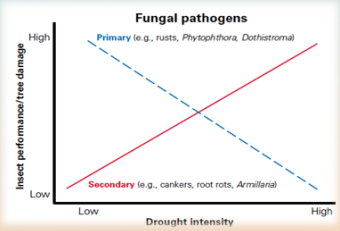
Response varies by insect type…..



Kolb et al. 2016 – Chapter 6

Effects of Drought on Forests – Indirect Effects

Pathogens….*some more harmful under drought, others less*



Kolb et al. 2016 – Chapter 6

Effects of Drought on Forests – Indirect Effects

Wildfire… *increase frequency, size, severity*

- *Annual area burned projected to increase by >200% in most of western US*
  - *- suppression costs*
  - *- risk to wildland-urban interface*

Littel et al. 2016 – Chapter 7

Stress complexes

Littel et al. 2016 – Chapter 7

Effects of Drought on Ecosystem Processes

Nutrient Cycling…. *water stress = nutrient stress*

- *- reduced nutrient uptake*
- *- premature leaf loss*
- *- declining microbial activity*
- *- losses to due to fire and postfire erosion*

Schlesinger et al. 2016 – Chapter 5

Effects of Drought on Ecosystem Processes

Carbon Cycling…..

- Potentially large losses with fire

- Reduced C uptake due to lower growth

- Increased C loss with higher mortality

Schlesinger et al. 2016 – Chapter 5

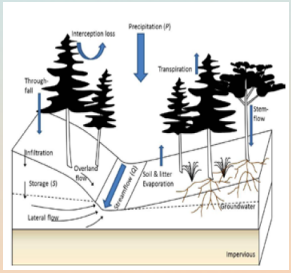
Effects of Drought on Ecosystem Processes

Hydrologic Cycling*…. Declining streamflow, reservoir storage*

Vegetation

Infiltration rate & soil storage

Groundwater access



Vose et al. 2016 – Chapter 10

Effects of Drought on Ecosystem Processes

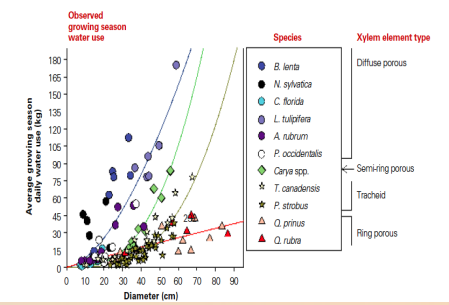
Hydrologic Cycling….

Atmospheric drought = precipitation deficits
Hydrologic drought = streamflow deficits

Not a necessarily a 1:1 relationship due to interaction between watershed characteristics (biological and physical) and precipitation inputs!

Vose et al. 2016 – Chapter 10

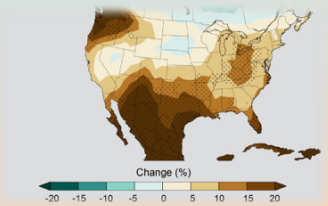
Tree species use different amounts of water and have different sensitivities to drought…



Vose et al. 2016 – Chapter 10

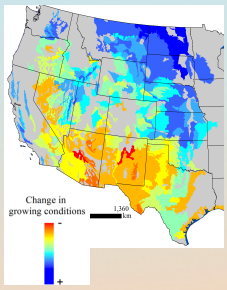
Drought Effects on Rangelands

- *Range ecosystems respond to drought*
- *Can expect increased drought*

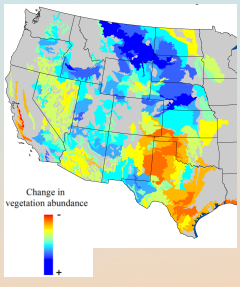


Historical Changes in Western Rangelands

Weather Trends: 1998-2012



Vegetation (Satelite NDVI) Trends: 2000-2012



Rangeland impacts

- *Reduced vegetation, increased erosion*
- *Loss of moist microsites*
- *Seasonal changes affect species composition/productivity*
- *Advantages for invasives*
- *Increased wildfire*
- *Reduced tree cover*

Challenges for the Future

- Detection
- Predicting impacts
- Managing for drought

Drought is hard to detect

- *Unlike agricultural crops, forests impacts hard to detect with remote sensing*
- *Ground detection requires intensive monitoring*

Prediction challenges

- *Uncertainty in predicting changes in precipitation*
- *Limited understanding of:*
  - *extreme events*
  - *rooting zone*
  - *species interactions*
  - *stress complexes are poorly understood*

Managing for Drought

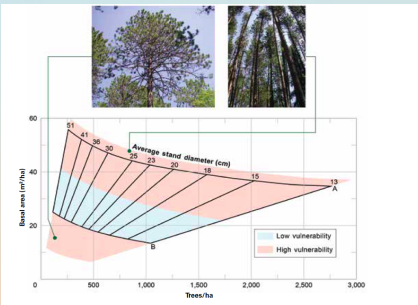
Can we make forests less vulnerable?

direct effects – growth, reproduction, mortality

indirect effects – fire, insects, pathogens

Can we reduce impacts on water supply?

Different ways to think about managing size and density



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Managing for Drought

Keeping trees alive during extended droughts…

- lower density (but not too low?)
- drought resistant species
- diversity hedge against uncertainty

Productivity—resilience tradeoffs

Managing for Droughts

Impacts on stream water quality and quantity…

- *Reduce fire risk in those areas where WQ critical*
- *Maintain riparian ecology*
- *Avoid compensating for flow loss through harvest*
- *Resilience through information and intelligent response*

Priorities: where to focus effort?

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