Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II

5 Land Cover and Land-Use Change

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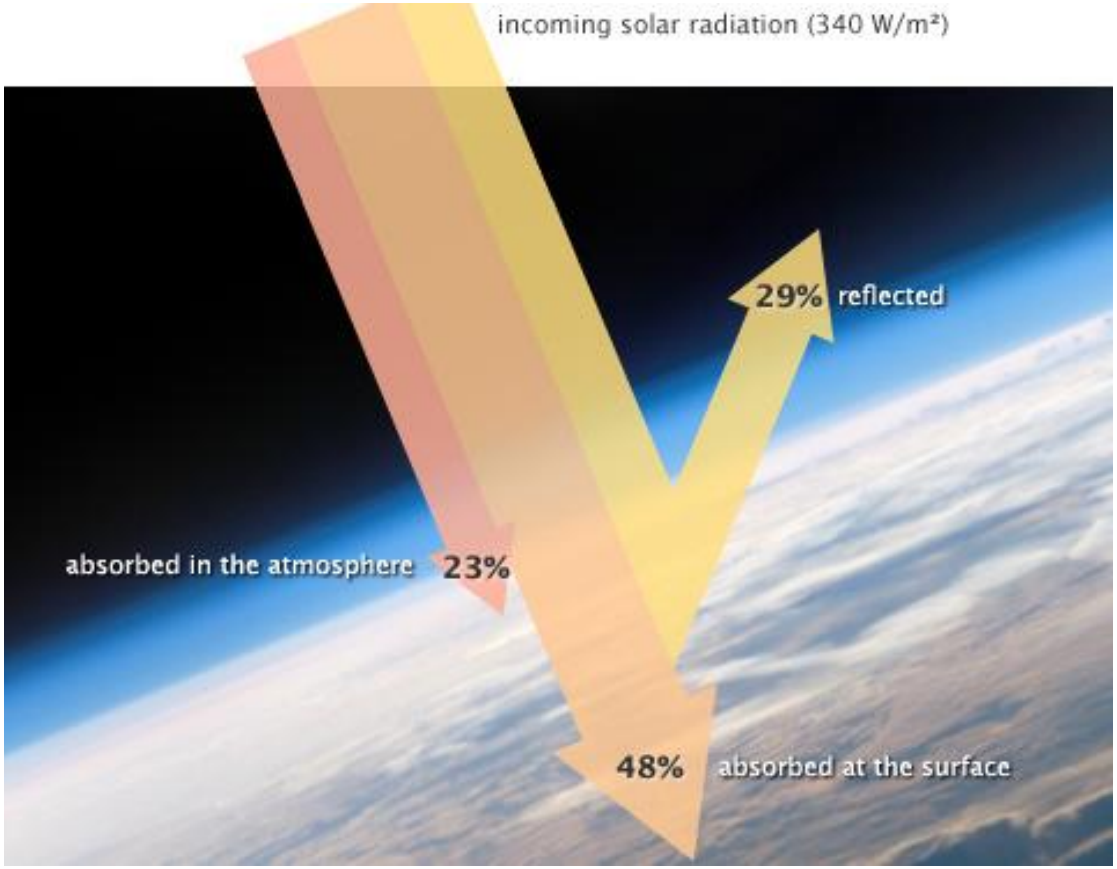
Why Land Cover?

This assessment was written to help inform decision-makers, utility and natural resource managers, public health officials, emergency planners, and other stakeholders by providing a thorough examination of the effects of climate change on the United States.

https://nca2018.globalchange.gov/chapter/front-matter-about/

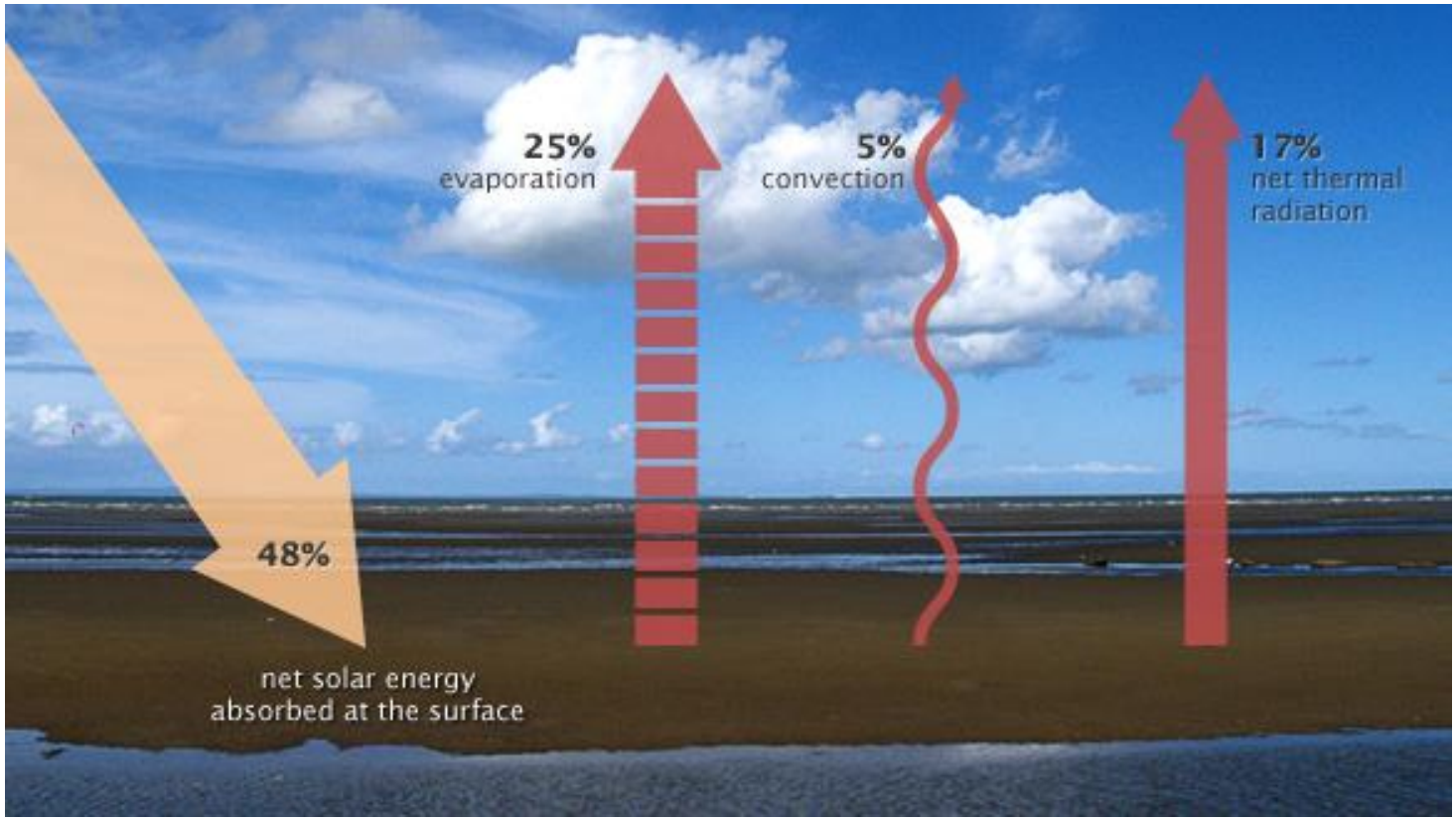
Why Land Cover?



https://earthobservatory.nasa.gov/features/EnergyBalance/page4.php

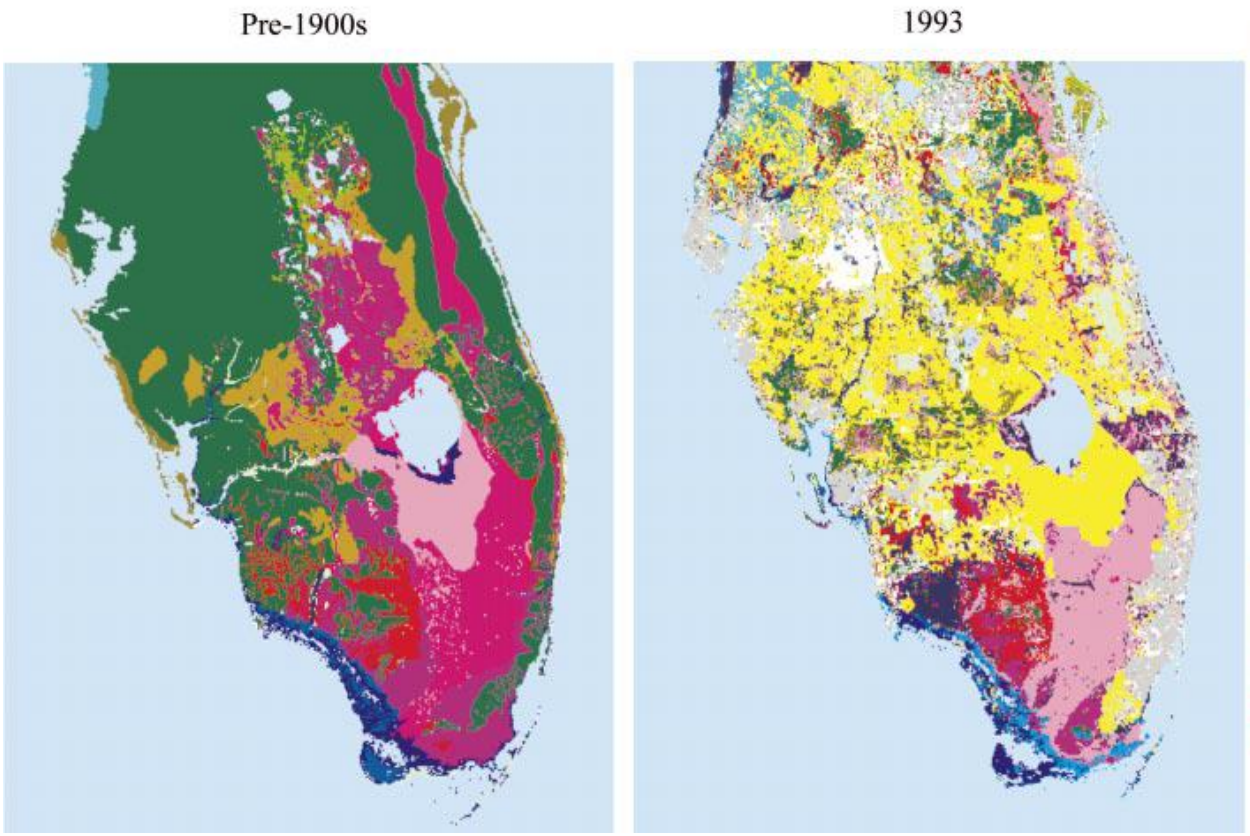
~ 70% of atmospheric energy (heat) is from the earth

Why Land Cover?



https://earthobservatory.nasa.gov/features/EnergyBalance/page5.php

Land cover composition influences the relative proportions of heat released to the atmosphere by E, C, and TR

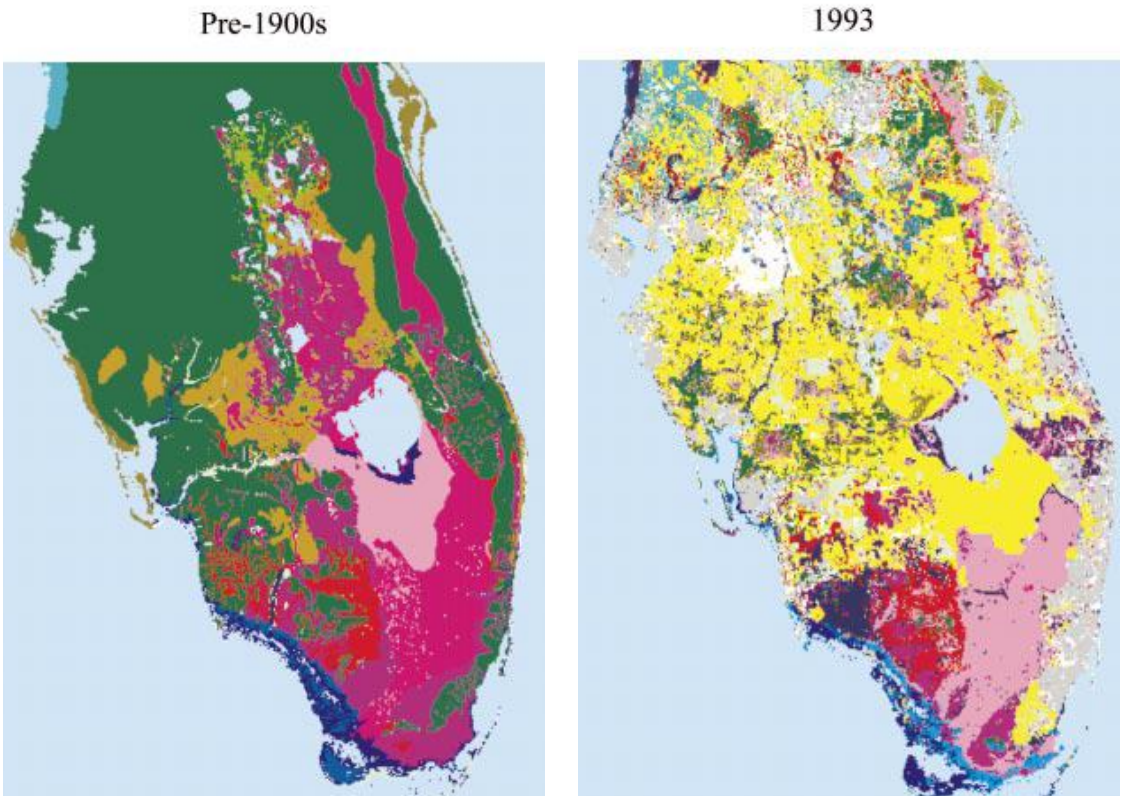


LCC produced …

- Δ sea breeze structure & strength
- Δ spatial distribution of convective rainfall
- ↓ 2-mo precip total
- ↑ 2-m diurnal T range
- ↑ T max
- Consistent over 3 simulated periods
- Robust to model parameter Δs
- model = observation

Marshall, Pielke Sr, Steyaert, Willard (2004) The impact of anthropogenic LC change on the FL Peninsula sea breezes & warm season sensible weather. Monthly Weather Review 132:28-52.

Land cover change has changed the climate

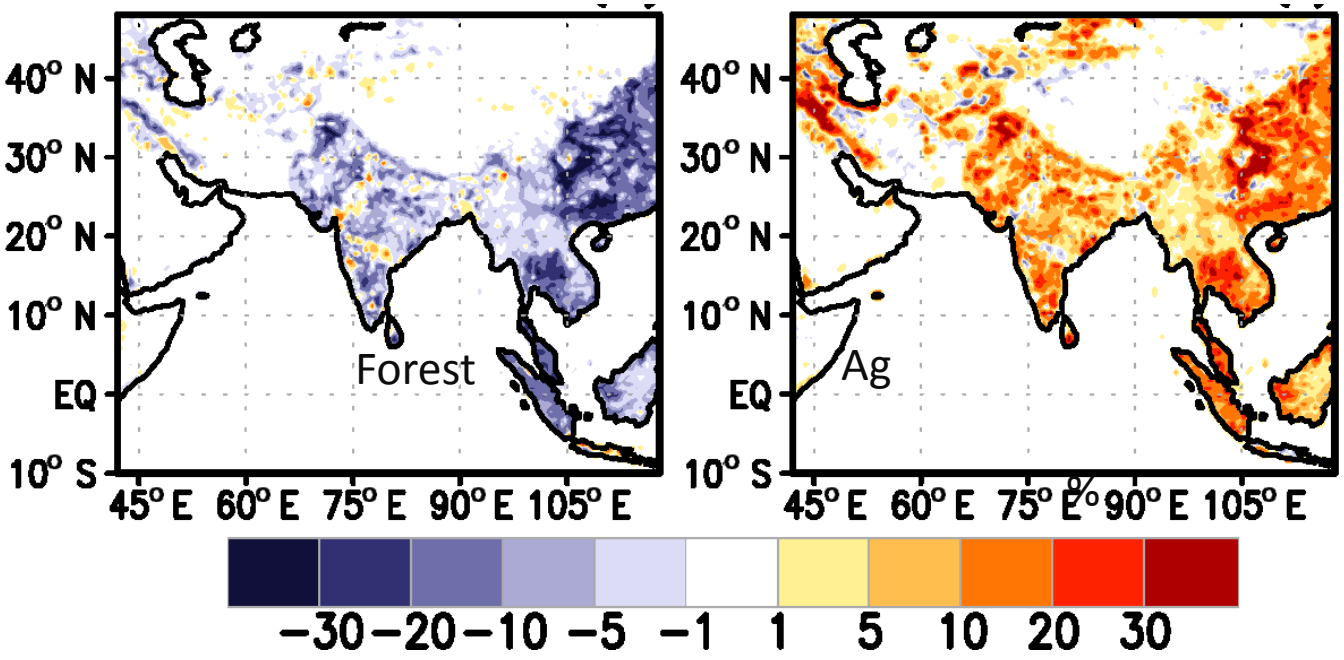


Marshall, Pielke Sr, Steyaert, Willard (2004) The impact of anthropogenic LC change on the FL Peninsula sea breezes & warm season sensible weather. Monthly Weather Review 132:28-52.

Why Land Cover?

"Daily moderate rainfall events, … a major portion of seasonal summer monsoon rainfall over …, have decreased significantly [from] 1951 through 2005," coinciding with forest ↓in & ag ↑.

Source: Halder et al. (2016) Hydrol. Earth Sys. Sci. 20:1765-1784



Land Cover Change (National Land Cover Database [NLCD])
-2001 to 2016 -

Units = ha	2016 →									
2001 ↓	Water	Urban	Barren	Forest	Shrub	Grass	Ag	Wetland	Total	Loss
Water	*12,769,881*	17,330	247,818	45,926	37,460	213,292	51,292	479,820	13,862,820	1,092,939
Urban	14	*39,973,199*	56	56	22	85	917	25	39,974,374	1,175
Barren	81,998	81,641	*7,821,982*	5,208	8,690	17,562	14,852	23,149	8,055,082	233,100
Forest	76,756	701,410	18,394	*188,608,904*	7,143,831	6,878,774	253,724	42,071	203,723,864	15,114,960
Shrubland	63,186	362,460	20,135	4,309,097	*164,774,281*	5,352,124	656,480	22,435	175,560,199	10,785,918
Grassland	142,149	392,851	30,800	3,141,003	3,603,131	*98,641,509*	3,290,855	52,034	109,294,332	10,652,823
Agriculture	133,501	1,185,625	74,236	1,220,744	426,732	682,352	*177,680,408*	185,589	181,589,188	3,908,780
Wetland	434,327	120,396	5,033	39,311	17,295	45,025	118,464	*46,132,366*	46,912,217	779,851
Total	13,701,813	42,834,912	8,218,454	197,370,249	176,011,442	111,830,723	182,066,993	46,937,489		
Gain	931,932	2,861,712	396,472	8,761,345	11,237,161	13,189,214	4,386,585	805,123		
Net Δ	-161,006	2,860,538	163,372	-6,353,615	451,243	2,536,391	477,805	25,272	0	

- 50% of land cover Δ & 43% of urbanization in coastal region (NOAA C-CAP)
- Nearly 3 million ha of urbanization
- 6.3 million ha of forest *cover* loss (PNW & southeast)

Key Message 1

Land-Cover Changes Influence Weather and Climate

Changes in land cover continue to impact local- to global-scale weather and climate by altering the flow of energy, water, and greenhouse gases between the land and the atmosphere. Reforestation can foster localized cooling, while in urban areas, continued warming is expected to exacerbate urban heat island effects.

Key Message 2

Climate Impacts on Land and Ecosystems

Climate change affects land use and ecosystems. Climate change is expected to directly and indirectly impact land use and cover by altering disturbance patterns, species distributions, and the suitability of land for specific uses. The composition of the natural and human landscapes, and how society uses the land, affects the ability of the Nation's ecosystems to provide essential goods and services.

Key Message 1

Land-Cover Changes Influence Weather and Climate

KM 1 topics

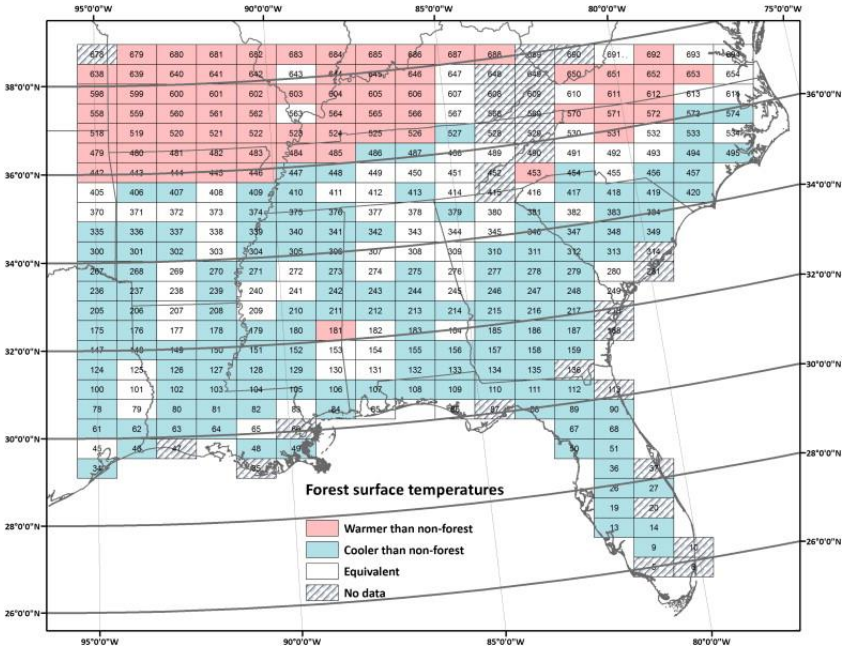
- Temperate forests promote cooling rather than warming
- Influence of fire on climate
- Effect of urbanization on climate
- Irrigated agriculture

KM 1 topics (forests)

- Temperate deforestation → warming
  - Wickham et al. (2013) Glob. Ecol. Biogr. 22:62—629 (review of ~20 GCM studies)

- Temperate forests → cooling not warming

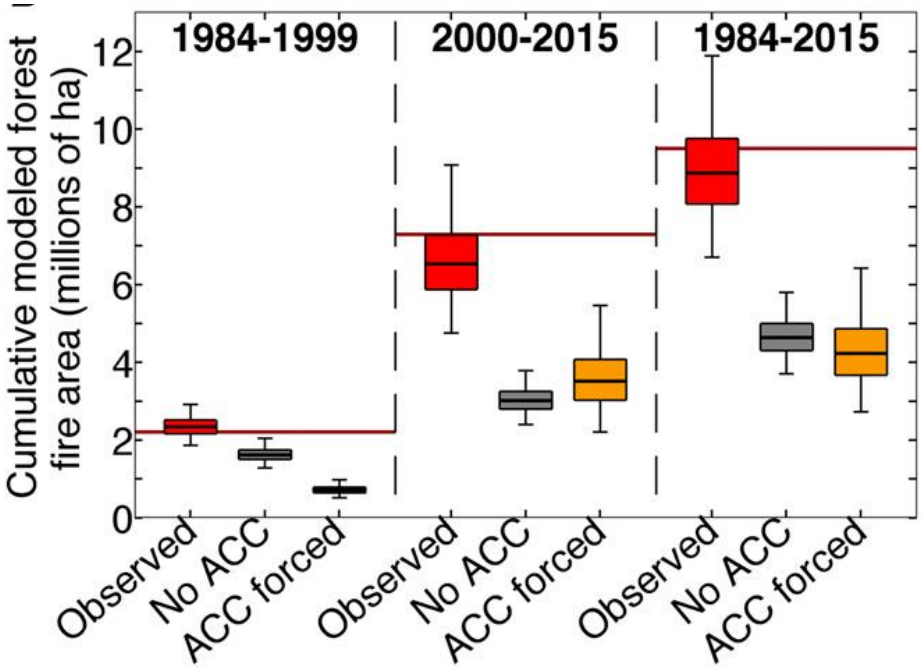
Source: Bonan (2008) Science 320:1444-49



Source: Wickham et al. (2014) Glob. Plan. Change 120:46-53

KM 1 topics (fire)

- Fire releases C and other GHGs to atmosphere, promoting warming
- Fire tends to reduce surface albedo, at least temporarily, promoting warming
- Fire releases aerosols to atmosphere, promoting cooling



ACC = anthropogenic climate change

Source: Abatzoglou & Wiilliams (2016) PNAS 113:11770-75
[cited in Climate Science Special Report]

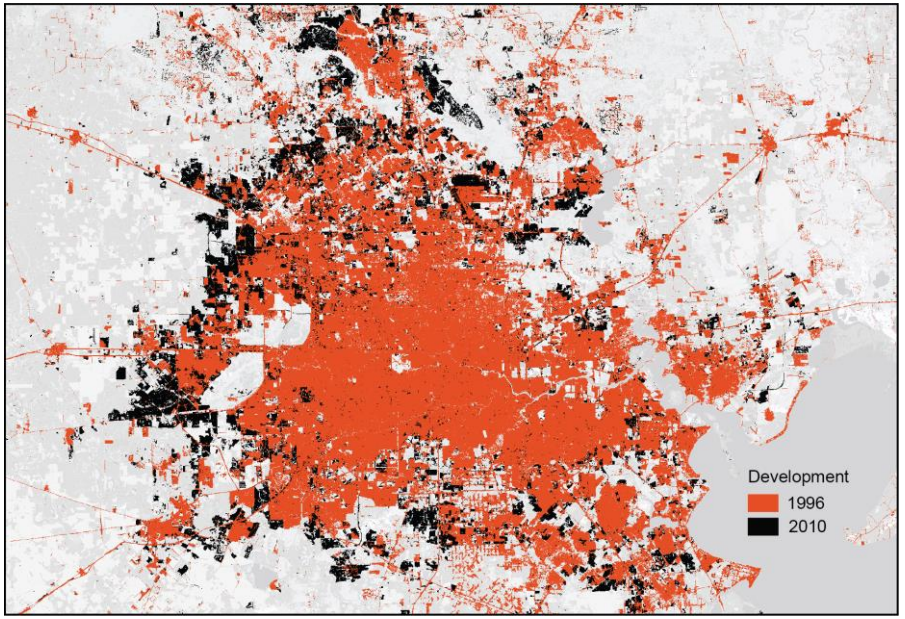
KM 1 topics (urbanization)

- Urbanization is climate change (UHI effect)
  - Heat capacity of construction materials < veg & soil
  - Impervious cover (↓ ET)
  - Canyon-like architectures traps heat
  - Heat emissions from building and vehicles
  - ↑ surface roughness
  - Δ boundary layer (UBL)
- Greater impact on eastern U.S. cities
- May influence downwind precipitation patterns
  - Low certainty (too few studies)
- Widespread urbanization can effect regional climate
  - e.g., China (citation)

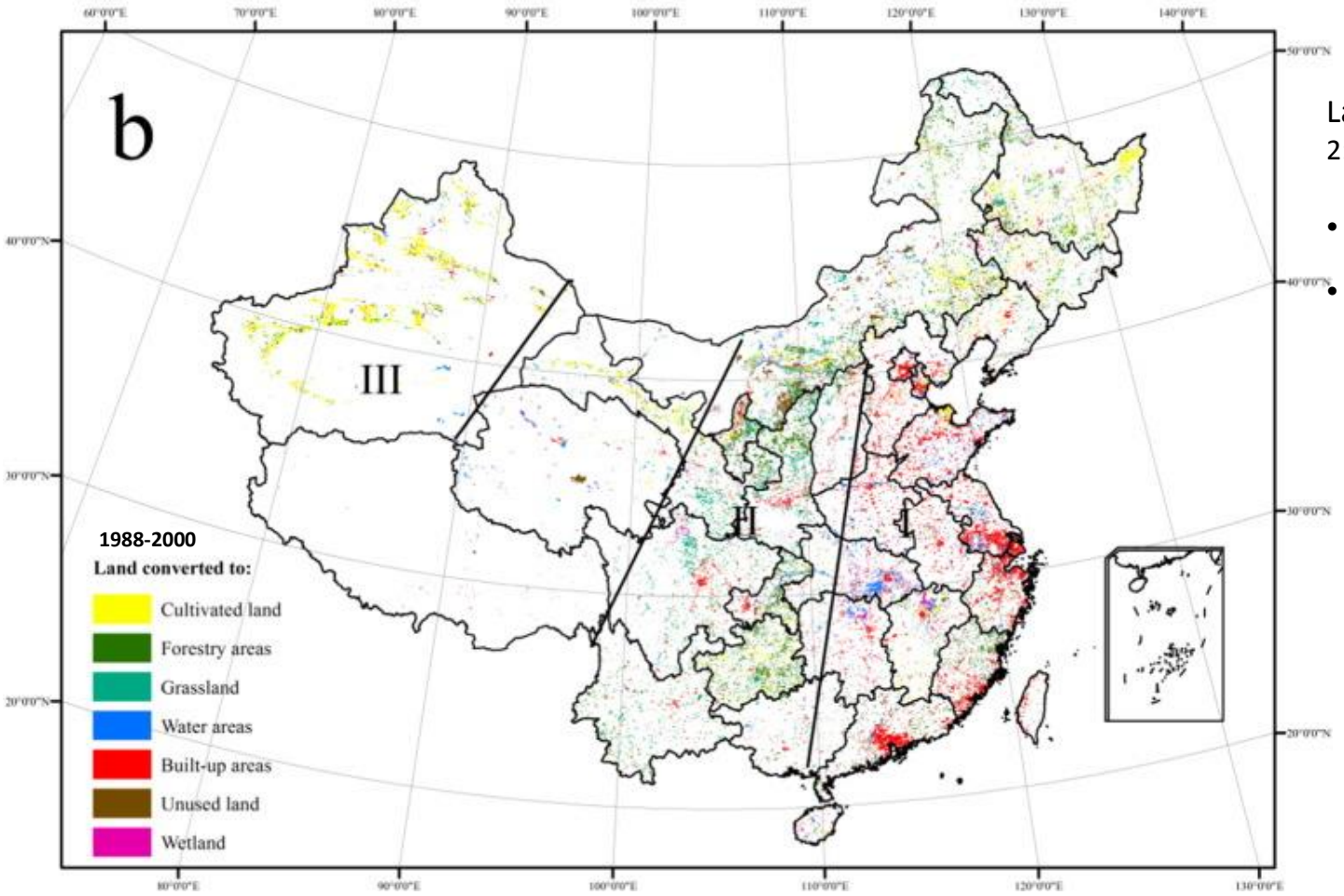
Jankovic, Hebbert (2012) Hidden climate change – urban meteorology and the real scales of weather. Climatic Change 113:23-33

Urban = singularity within the regional weather system

Houston, TX



Source: NOAA C-CAP; Land Cover and Land-use Change Fig. 5.3)



Song & Deng (2017) Sci. Total Env. 576:705-719

Lai et al. (2016) Sci. Adv. 2:e1601063

- Urban ↑: $6.87*10^6$ ha
- 1.45 Pg C of total emissions (‘90 – ‘10)

Key Message 2

Climate Impacts on Land and Ecosystems

KM 2 topics

- Agriculture and food security
- Wildland fire
- Forest to shrubland conversion in the western U.S, and poleward migration of forests in eastern US.

KM 2 topics

Agriculture and food security

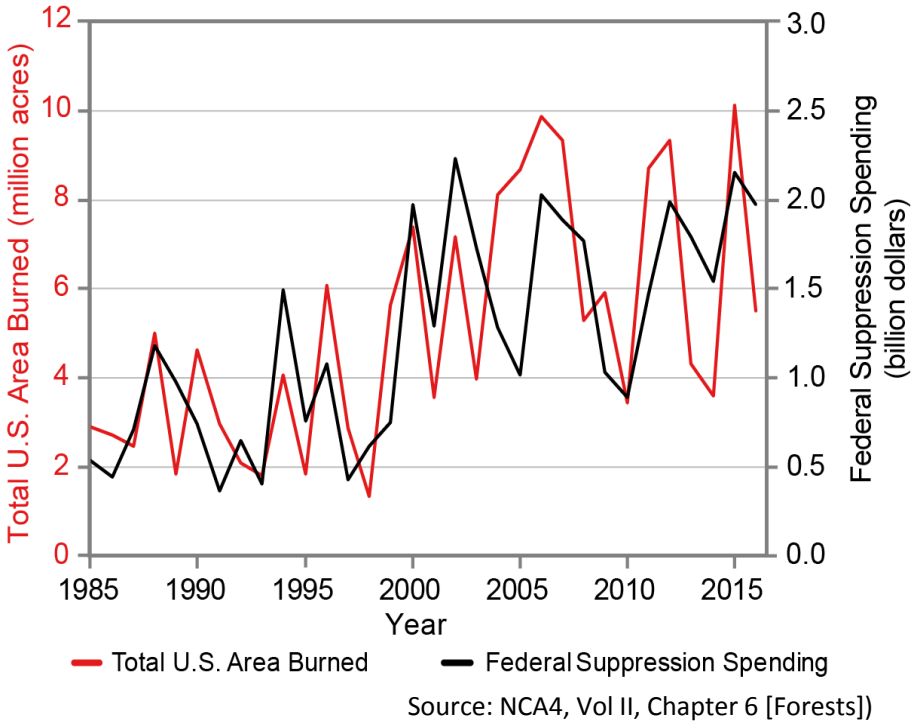
1) Introduced notion of geographic shifts in cropland location
   - Deryng et al. 2011; citation 170])
2) Shift to irrigated agriculture in Great Plains.
3) Negative impact of warming on yields
   - Rosenzweig et al. 2016; Zhou et al. 2017

Source: FMR.org

KM 2 topics

Wildland fire

- Anthro climate Δ = 55% ↑ fuel aridity
- Anthro climate Δ = 2x area burned
- Anthropogenic climate Δ will continue to be a driver of wildland fire while fuels are not limiting (Vose/Peterson)



Source: NCA4, Vol II, Chapter 6 [Forests])

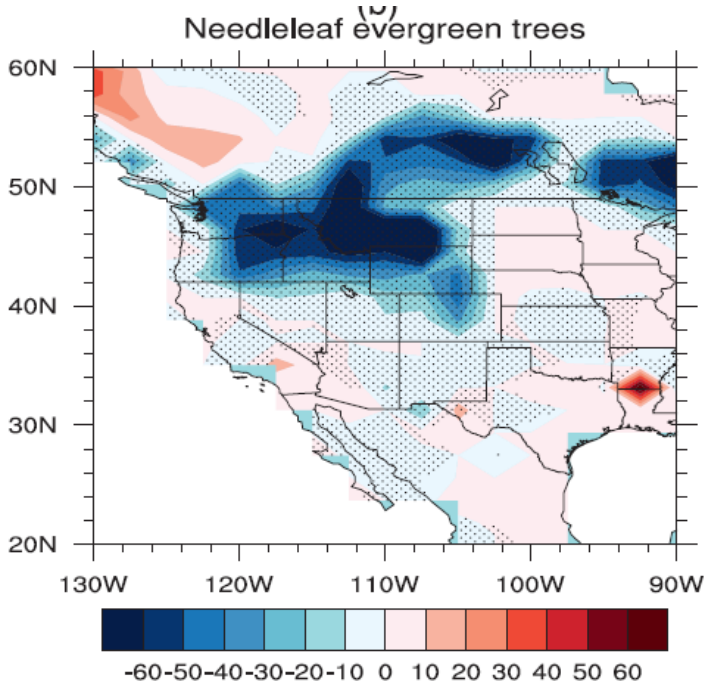
- Forest & wildland fires are likely to increase in the southeast US (Vose/Peterson)

Abatzoglou & Williams, 2016, PNAS, 113:11770-75

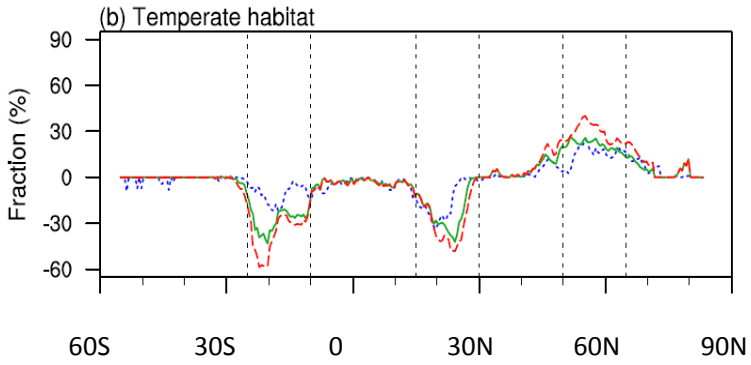
KM 2 topics

Vegetation distribution

- Conversion of forest to shrub from warming, drought, pests, fire
- Poleward migration at ecological transition zones

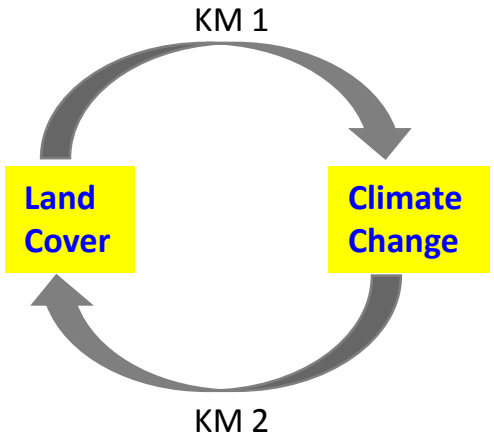


Source: Jiang et al. (2013) J. of Climate 26:3671-87 [145]



Source: Park et al. (2015) J. of Climate 28:2884-87 [148]

NCA 4



Biogeophysical focus

NCA 3

Key Messages

1. Land use decisions effect vulnerability and resilience to climate change (NCA 4, KM2)

2. Land cover change affects climate locally, regionally, and globally (NCA4, KM1)

3. Society has the capacity to make LULCC-related decisions that adapt to climate change (NCA 4, KM2)

4. Land cover decisions can ↓ GHG emissions (NCA 4, KM2)

Societal focus

New in NCA 4

- Emphasis on the influence of land cover on climate
  - Managing land cover composition (or not) is management for climate change mitigation (or not)

- Temperate reforestation promotes cooling
  - Forests in the southeast are cooler than surrounding herbaceous (cropland, grassland) cover year round

- Urbanization is climate change

- Climate change may change the spatial distribution of agriculture

What should be on the radar for NCA 5?

(an idiosyncratic list)

- Are western forests recovering from disturbance?
  - MTBS, LANDFIRE, LCMAP, NLCD
  - (Vose/Peterson)
- Has the spatial distribution of cropland changed?
  - USDA-CDL, FORE-SCE
- Urbanization's effect on precipitation patterns
- Coastal land cover change attributable to sea level rise
- Permafrost (NCA 4, Alaska chapter KM2)
  - Societal impact (Alaska) versus extent (LULCC)?
- Affect of dramatic urbanization in China on US climate?

Thanks

Climate change effects on forests and ecological disturbance

Highlights from the *Forests* chapter of the Fourth National Climate Assessment

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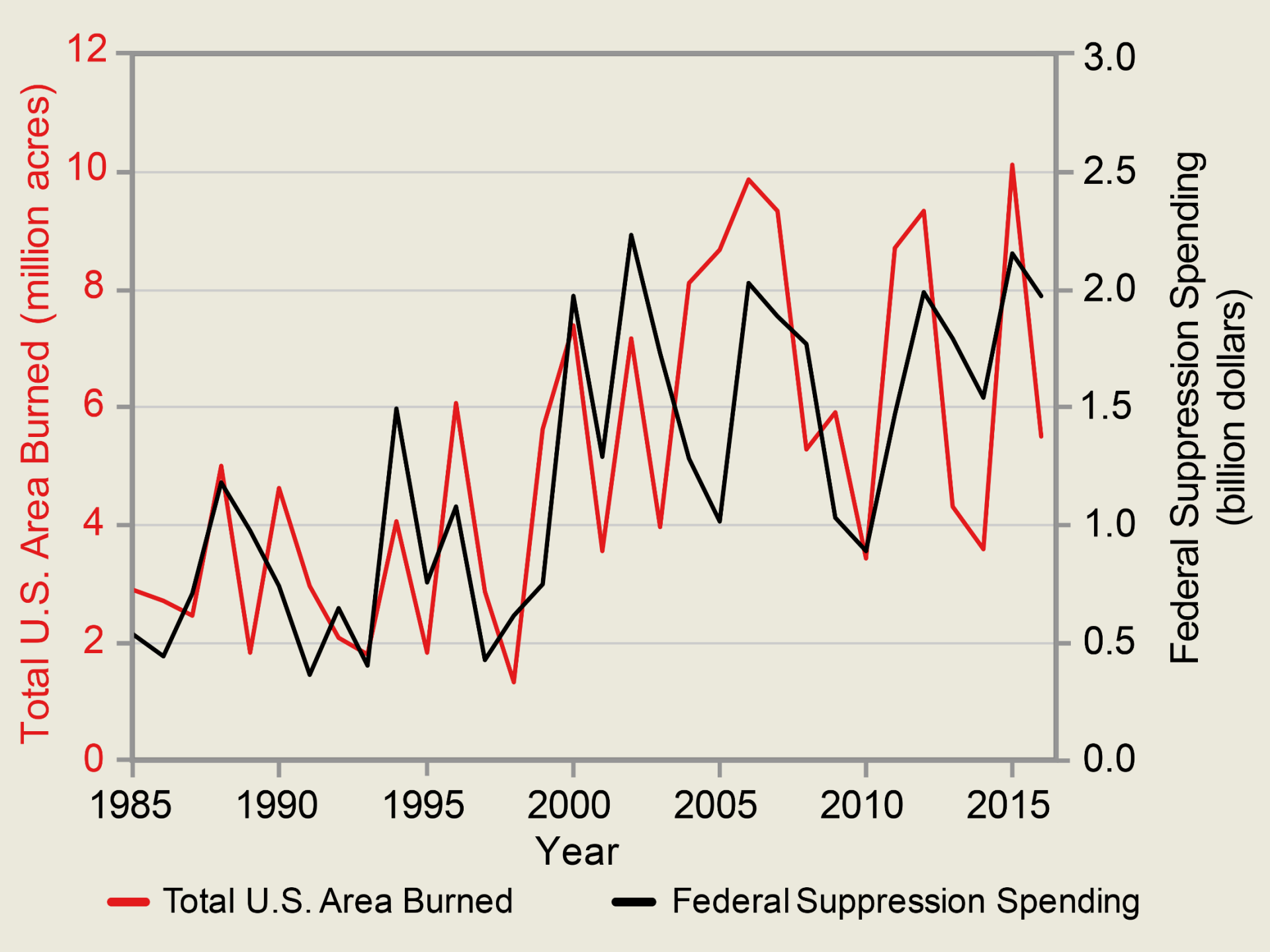
- **Jessica Halofsky, University of Washington, Climate change adaptation**

Key Message 1: Ecological Disturbance and Forest Health

- The frequency and magnitude of ecological disturbances will likely increase
- These disturbances will drive rapid and often persistent changes in forest structure and function
- Gradual climate change and less severe disturbances will likely alter forest productivity and the distribution and abundance of species at longer timescales (decades to centuries).

Climate change and wildfire

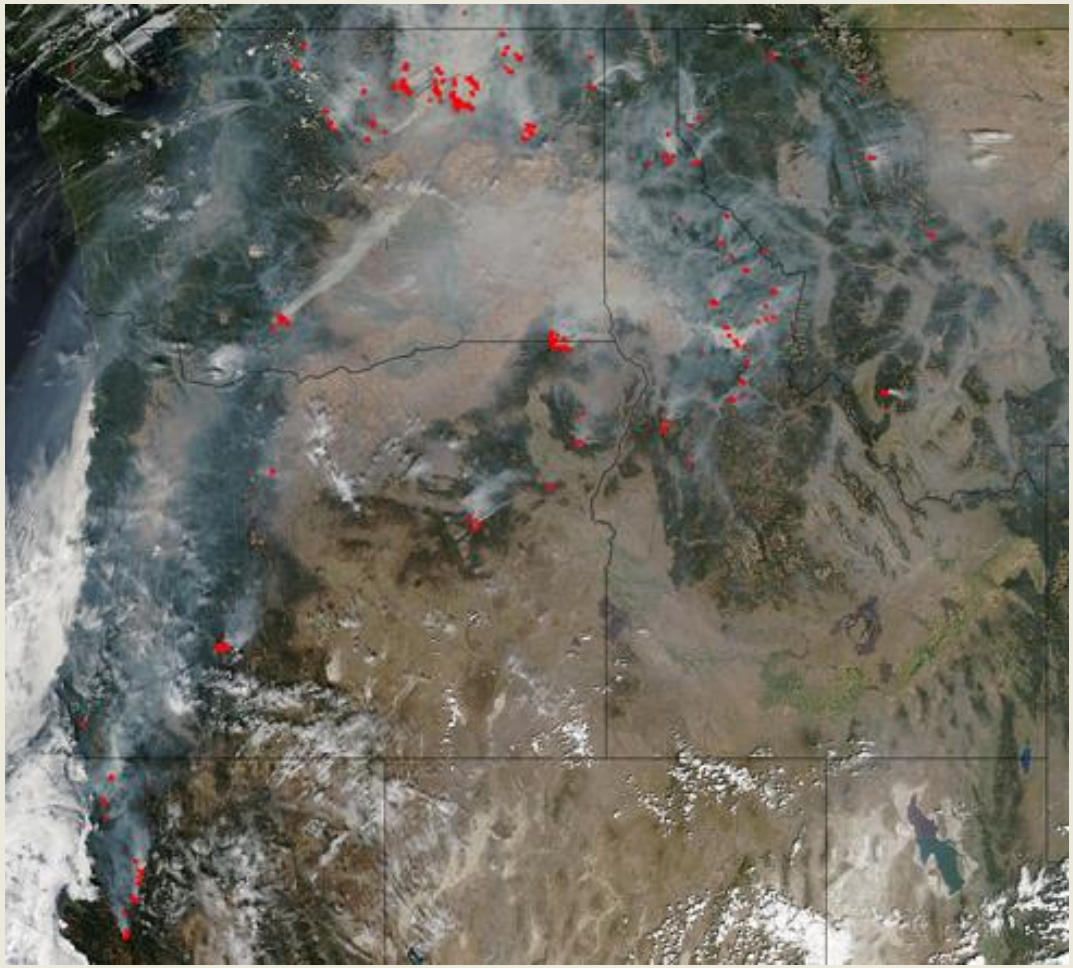
- Warmer and drier spring and summer conditions lead to:
  - Early snowmelt
  - Lower summer fuel moisture
  - Longer fire seasons
  - Increased fire frequency and extent
- Fire intensity and severity may also increase


Total U.S. Area Burned (million acres)
12
10
8
6
4
2
0
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Federal Suppression Spending (billion dollars)
1985
1990
1995
2000
2005
2010
2015
Year
Total U.S. Area Burned
Federal Suppression Spending

Climate change and regional wildfires

In 2015 and 2017, over 9 million acres burned in the western United States; in 2018, over 7 million acres burned.

Pacific Northwest, August 30, 2015

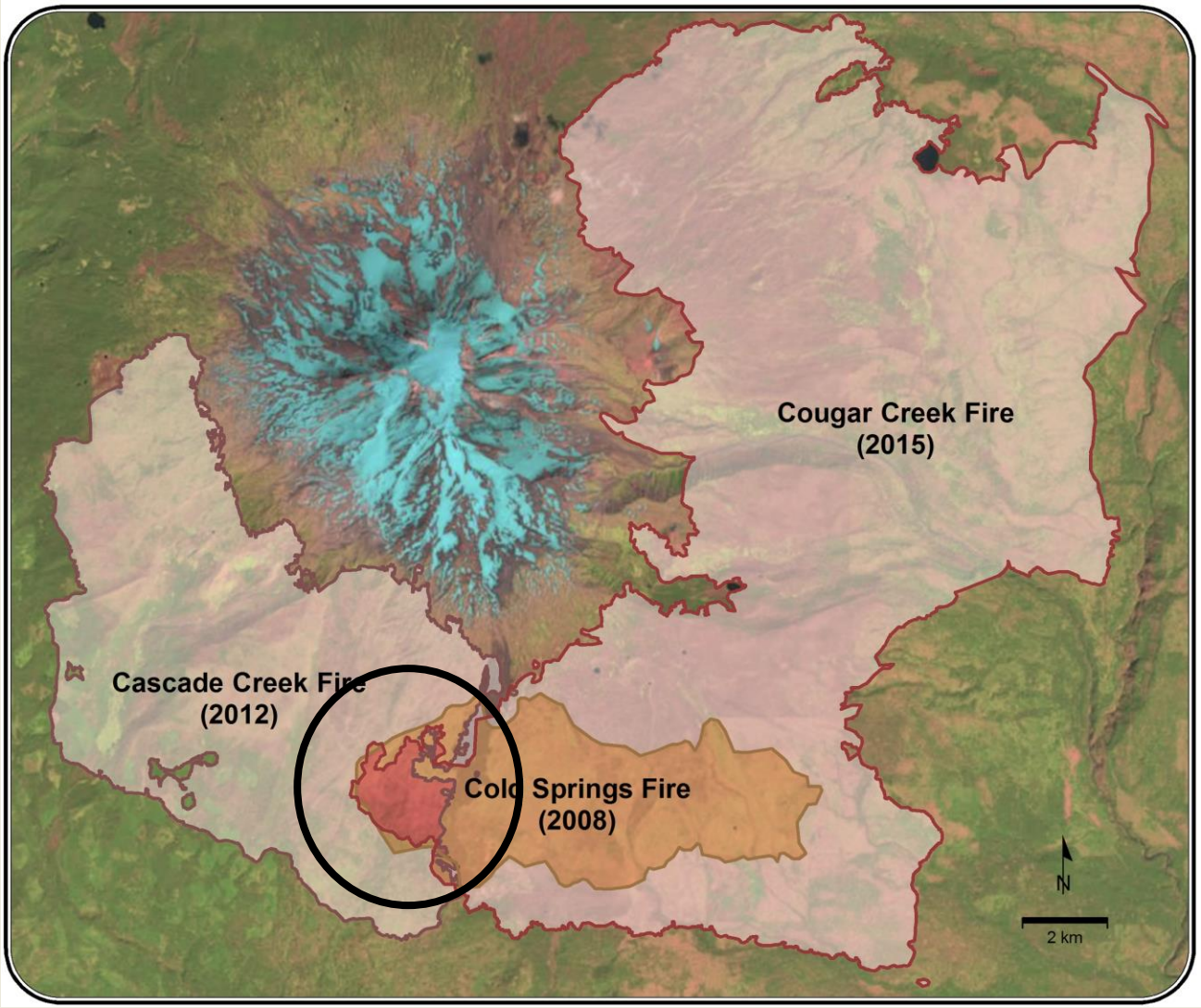


MODIS, NASA

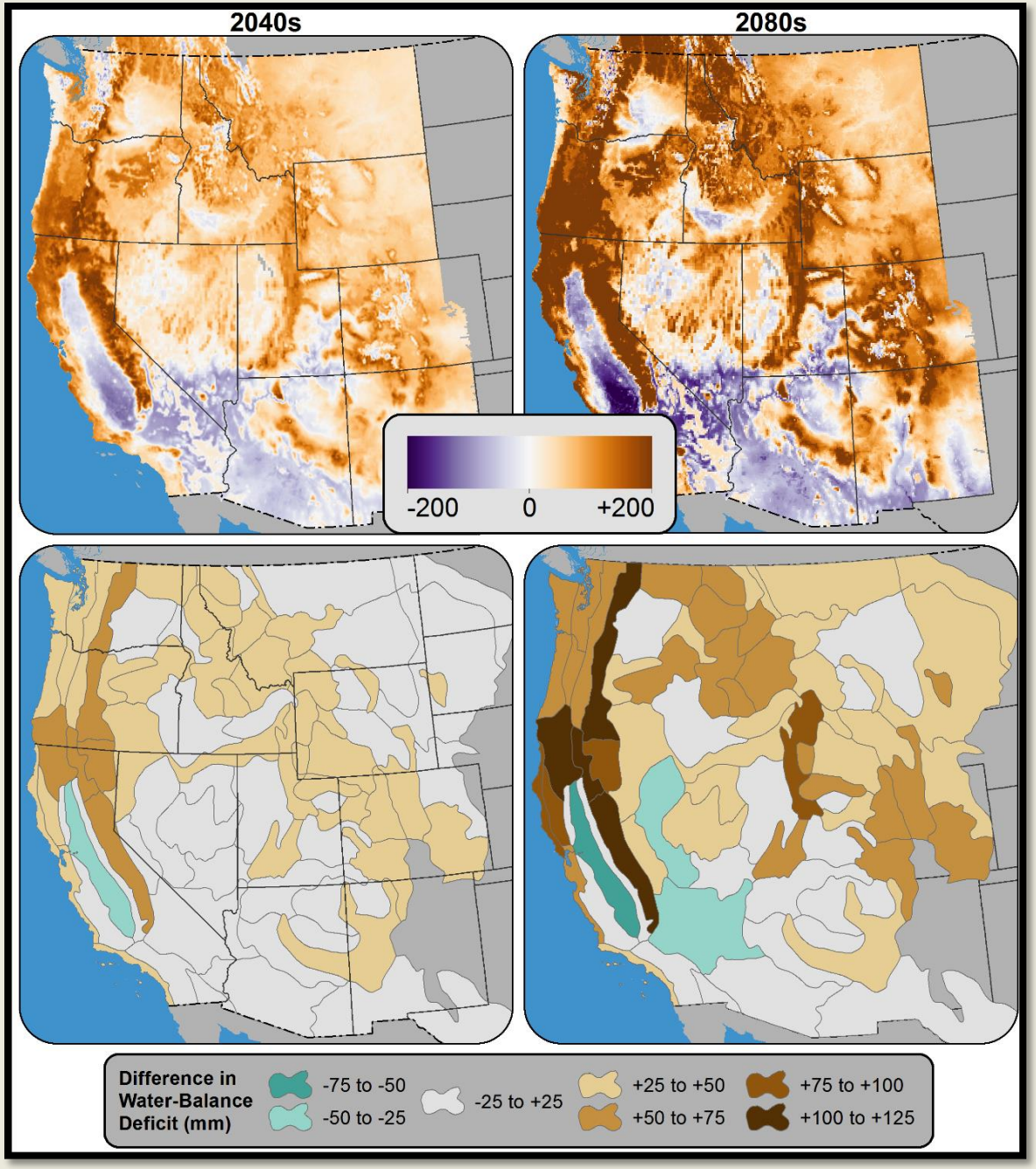
Wildfires are colliding

<u>Southwest Washington</u>

Fires have burned some areas 3 times since 2008



Map by R. Norheim



Projections for changes in summer water-balance deficit

McKenzie & Littell, 2017
Map by R. Norheim

Wildfire risk increasing in eastern US

- **In the southeast US**, by 2060, median annual area burned by lightning-ignited wildfire is projected to increase by 34%.

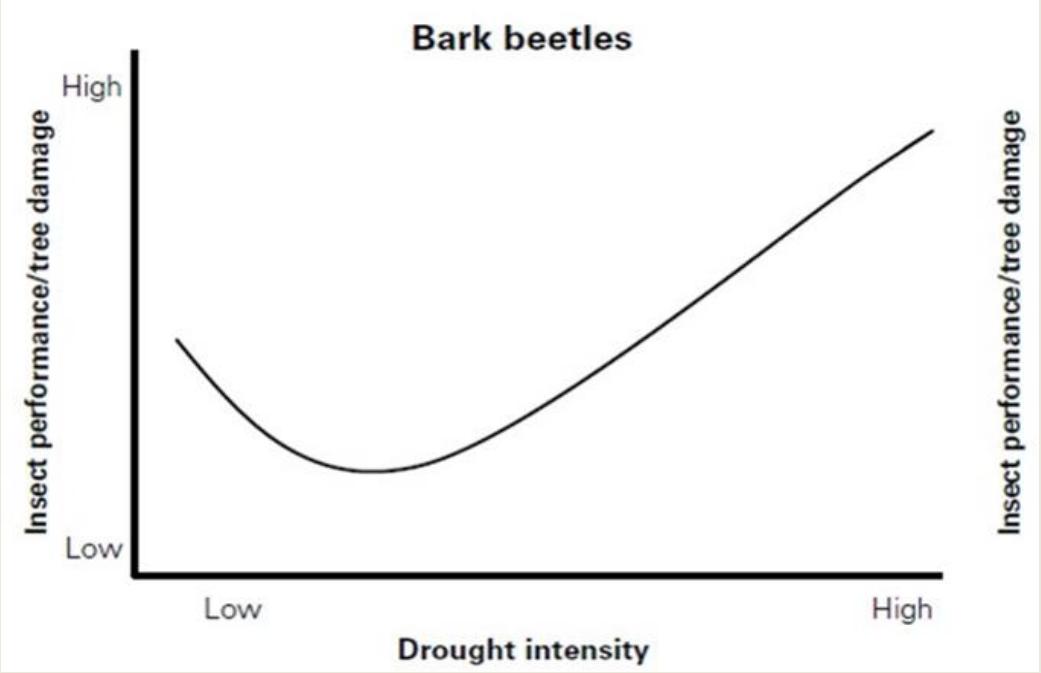
- Extensive wildfires in the Southeast during the past 5 years, including **near urban areas**, may corroborate these projections.

- Concerns of **WUI and smoke management** with prescribed burning

Rapid forest change: Insects

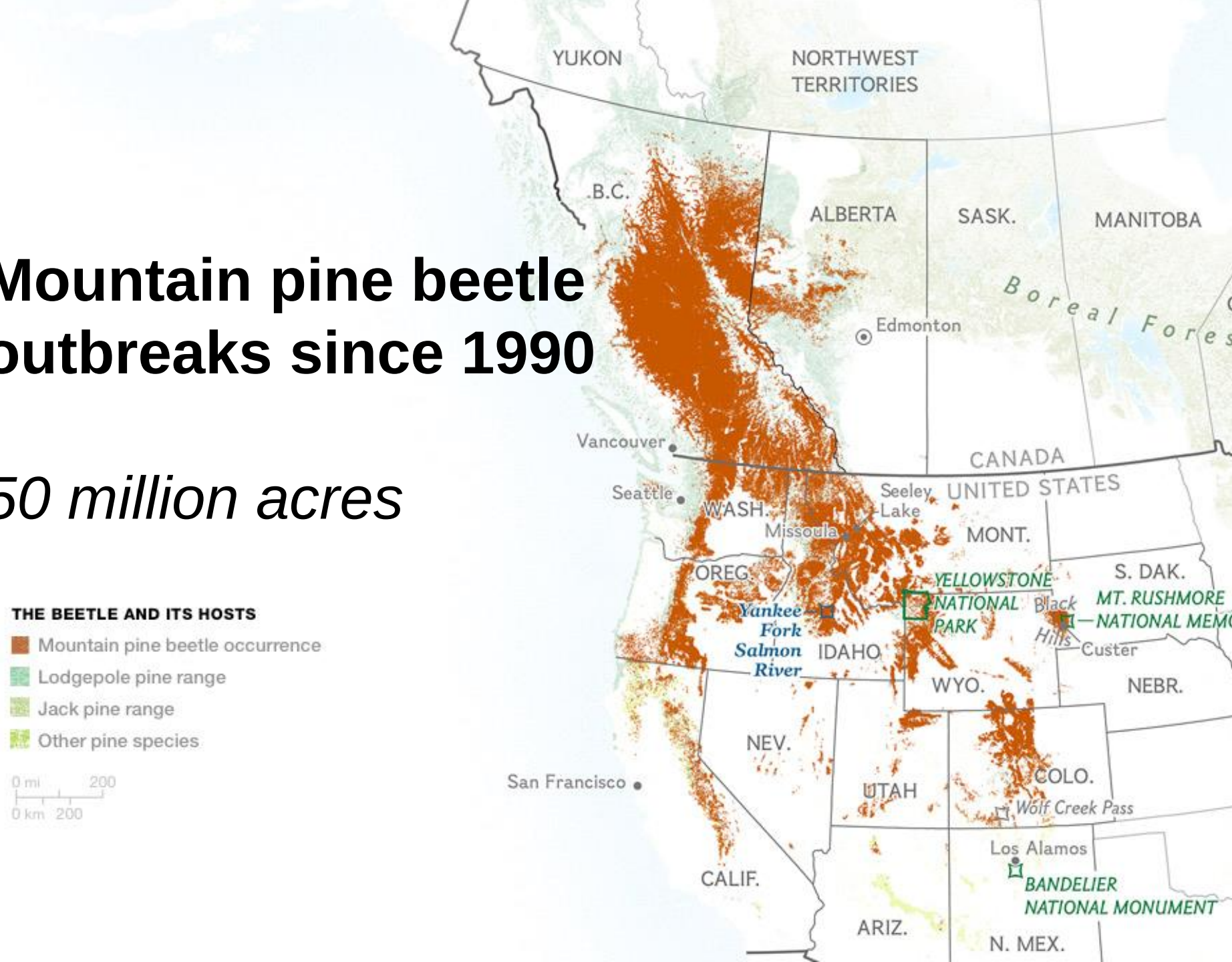
During the past 30 years, **bark beetle-caused tree mortality** in the western U.S. has exceeded that of wildfire.

By 2016, more than 102 million drought-stressed trees were killed by western pine beetle in the central and southern Sierra Nevada.



Mountain pine beetle outbreaks since 1990

50 million acres



Southern Pine Beetle Range Expansion

Southern pine beetle is expanding (red symbols) into new areas of the Northestern United States

Expansion correlated with warmer temperatures

Dodds et al. 2017
J. For. 116(2):178-191

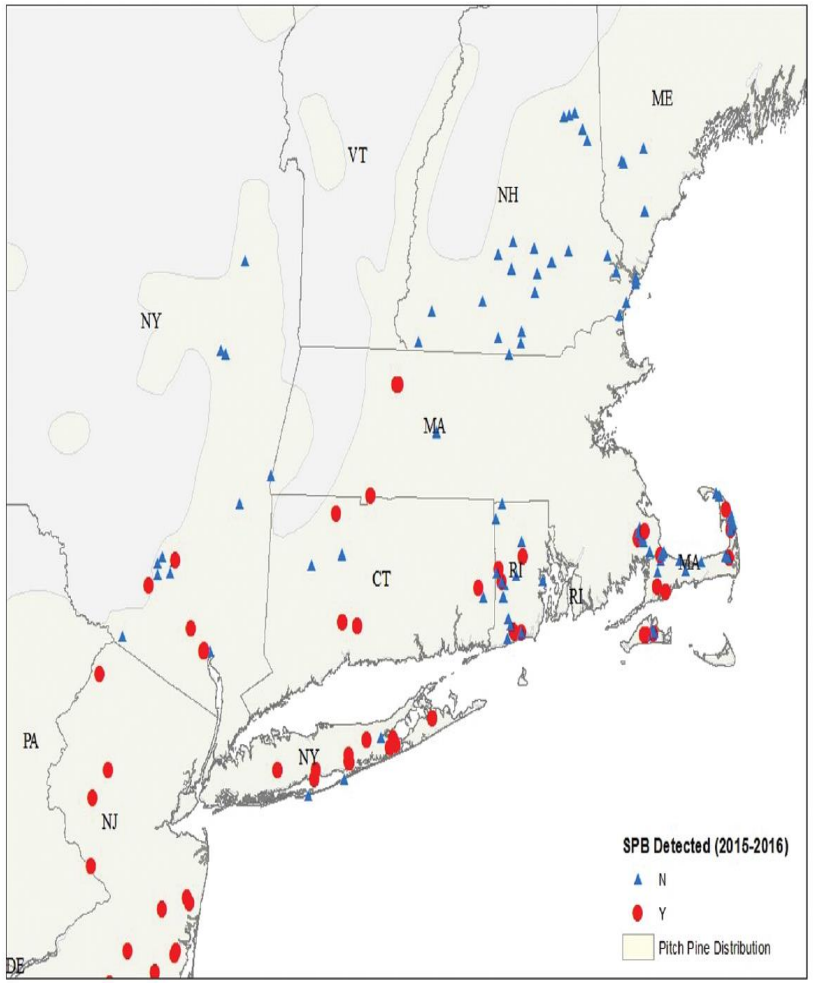


Figure 4. Results from southern pine beetle detection and monitoring traps deployed throughout the northeastern United States in 2015 and 2016.

Disturbances will interact

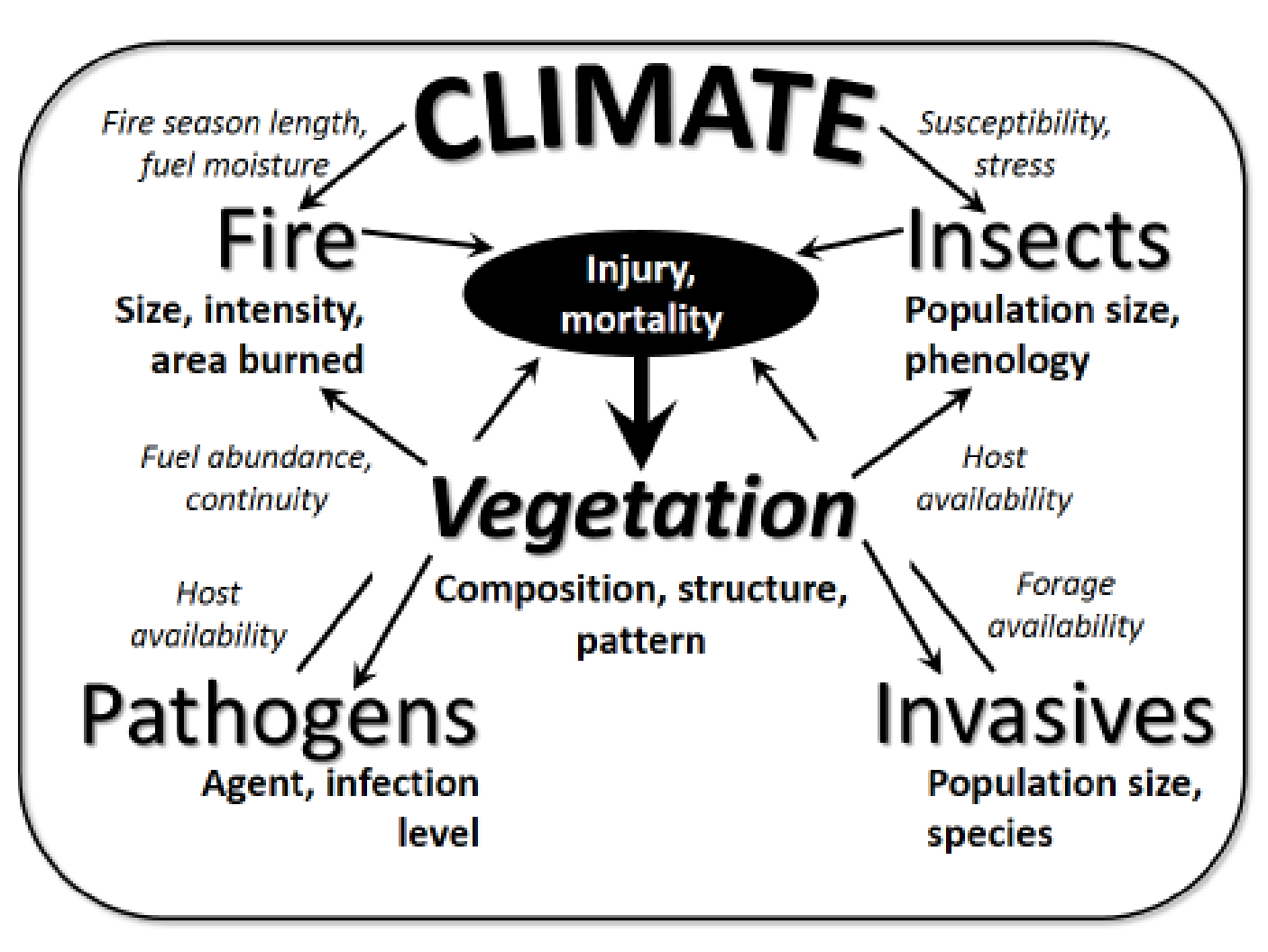


Figure by R. Loehman

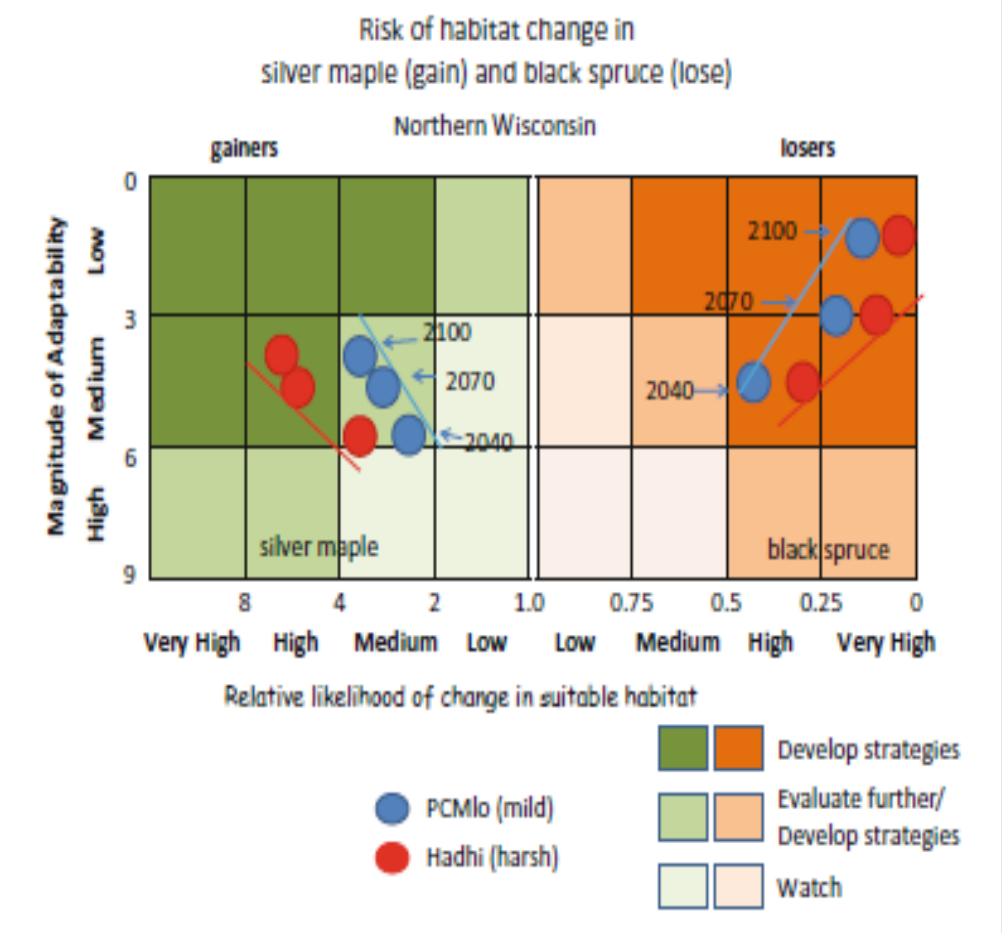
Drought, insect outbreaks, and fires will likely interact

Rapid and persistent changes are likely

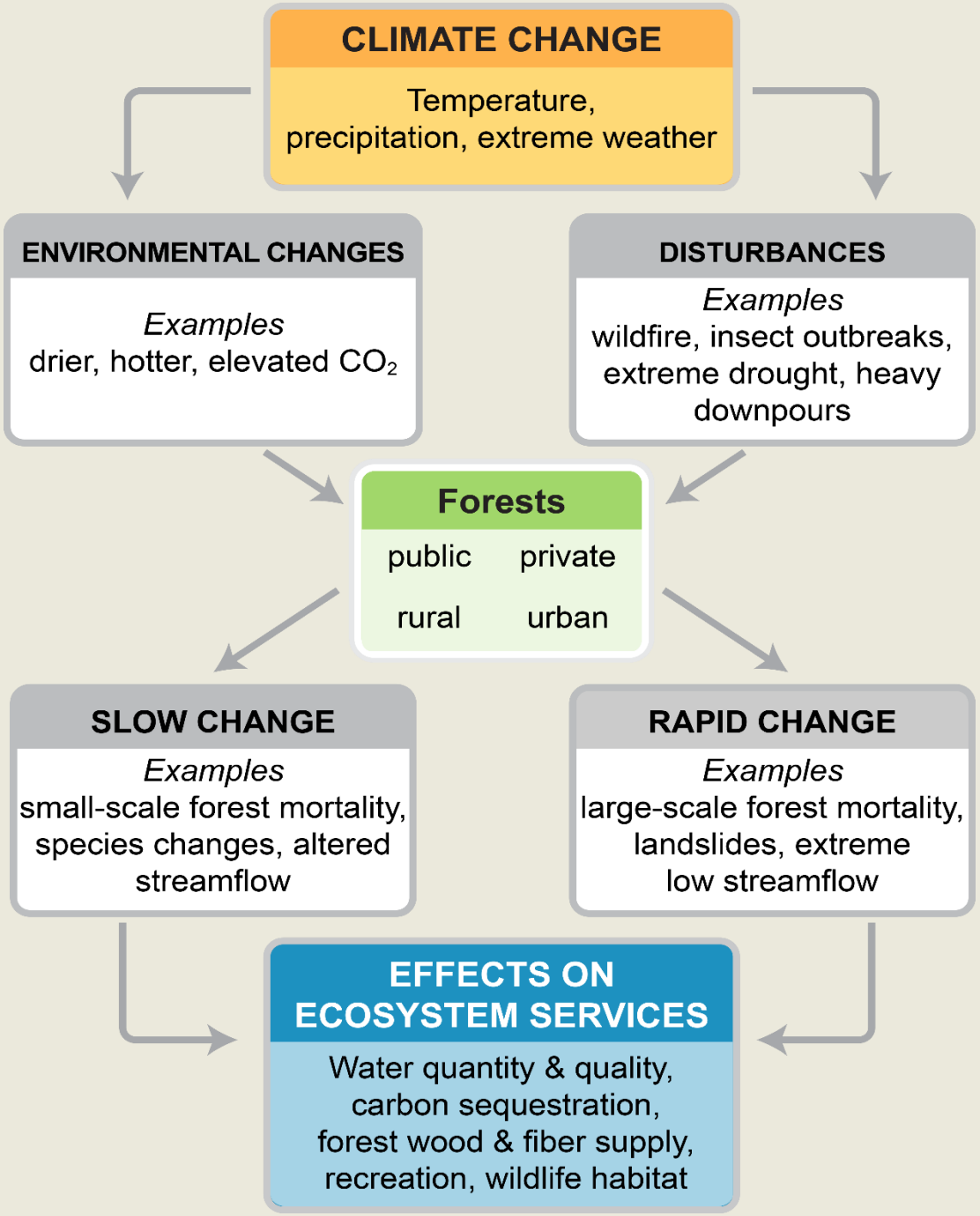
Forests will change in species composition and structure, and in some places will transition to non-forest.

Long-term forest change

- In some locations, the rate of climate change may be outpacing the capacity of tree populations to adjust.
- Failure of some tree species to track changing climate can reduce forest health and competitiveness with other species.



Key Message 2: Ecosystem services



Tree growth

- Effects will differ in energy-limited versus water-limited forests.
- Increased atmospheric CO_2 could increase biomass growth.
- Heat-related stress may exacerbate drought effects, and in some cases cause lower forest productivity and higher mortality.

Carbon sequestration

- Disturbances are expected to make it difficult to retain carbon within forests.
- Forests are projected to continue to sequester carbon, but at declining rates because of land use and aging forests.

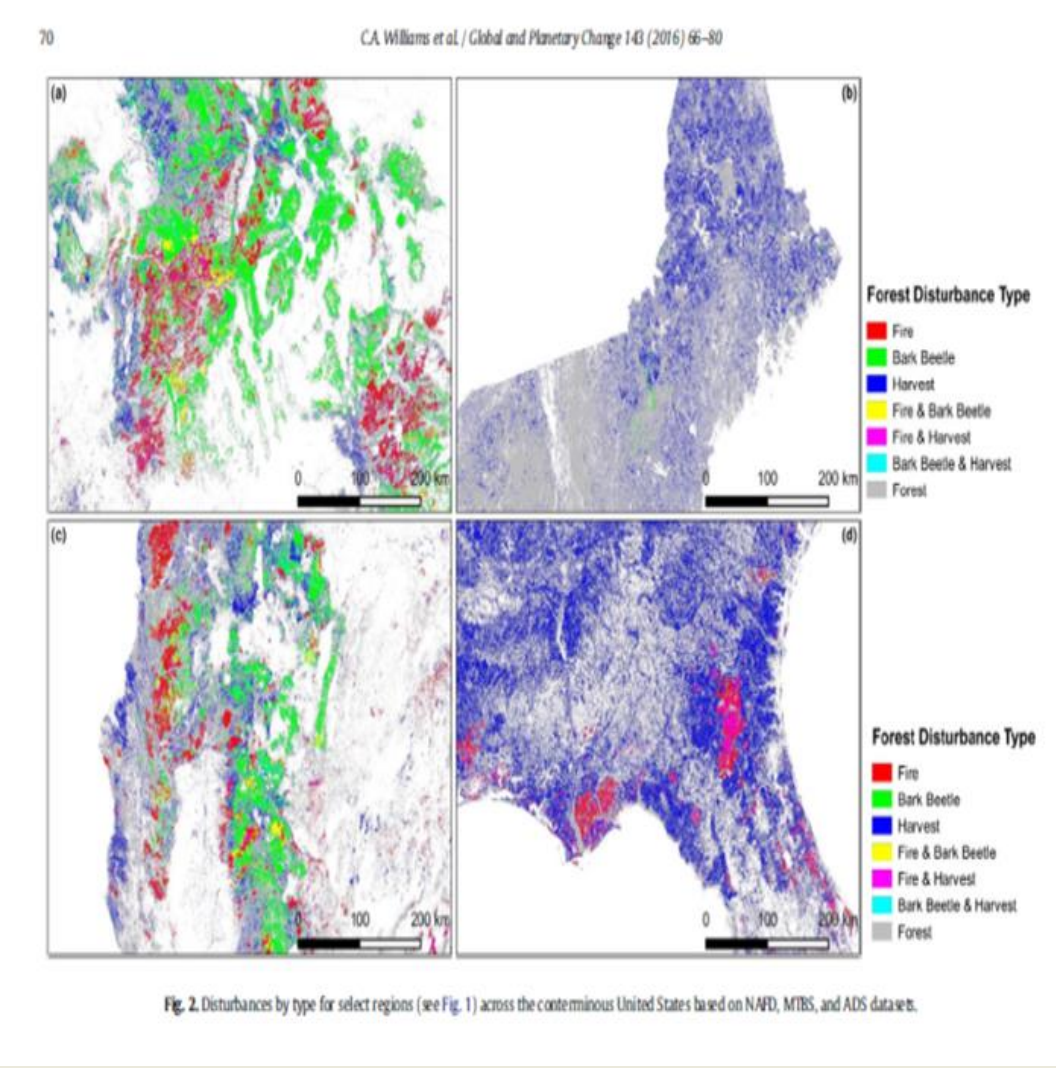


Fig. 2. Disturbances by type for select regions (see Fig. 1) across the conterminous United States based on NAFD, MTBS, and ADS datasets.

Water resources

- Water quality and quantity will be affected by increased temperatures, disturbance, and reduced snowpack.
- Less snowpack and earlier snowmelt will cause lower summer low flows.
- Water demand is high in the summer, and surface water shortages are likely in dry years in some locations.

Key Message 3: Adaptation

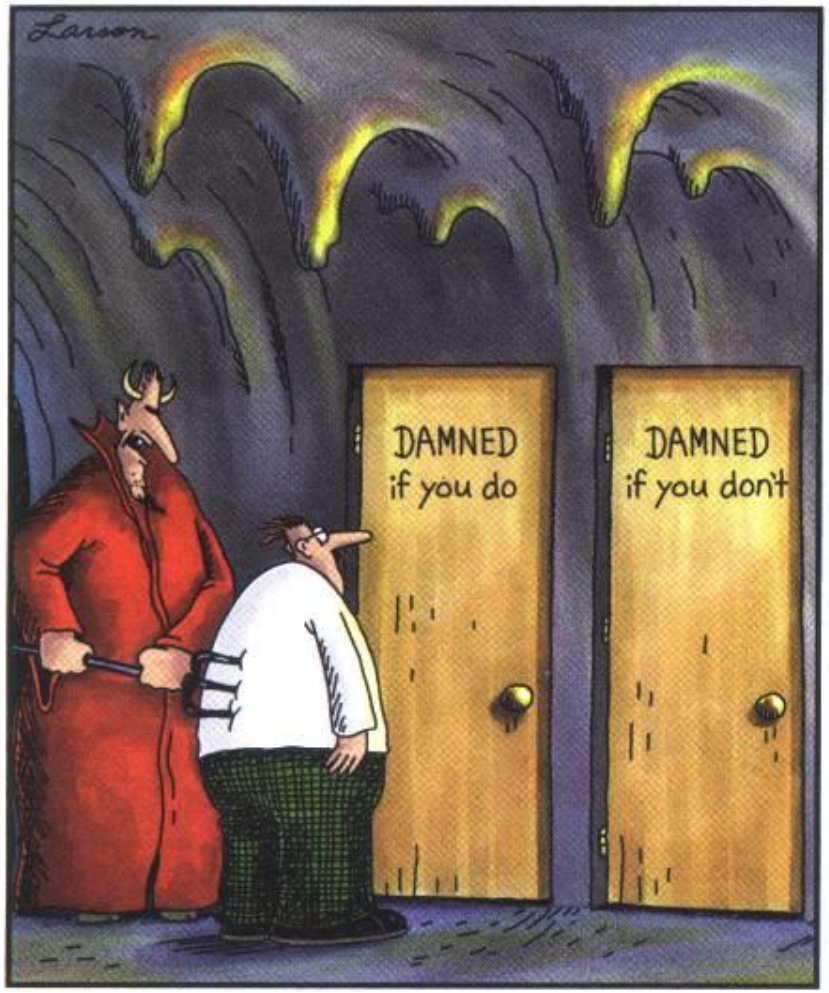
- Forest management activities that increase the resilience of U.S. forests to climate change are being implemented, with a broad range of adaptation options for different resources.
- The future pace of adaptation will depend on how effectively social, organizational, and economic conditions support implementation.

Adaptation – working definition

An effort to lower the potentially negative consequences of climate change

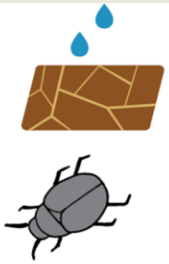
AND transition ecosystems and natural resources to a warmer climate.

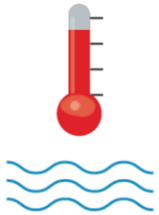
= building <u>resilience</u>?



"C'mon, c'mon – it's either one or the other."

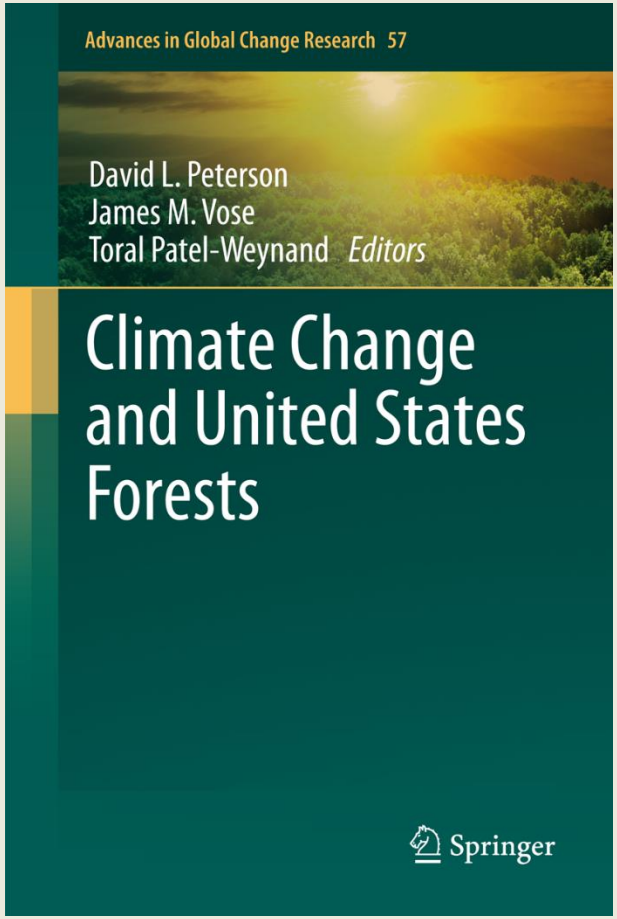
Climate change vulnerability assessments set the stage for adaptation

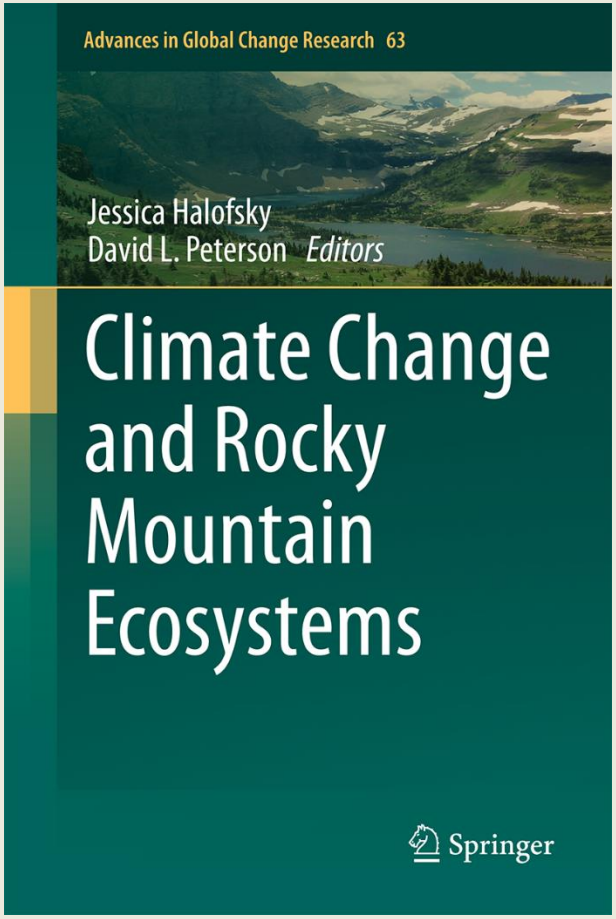




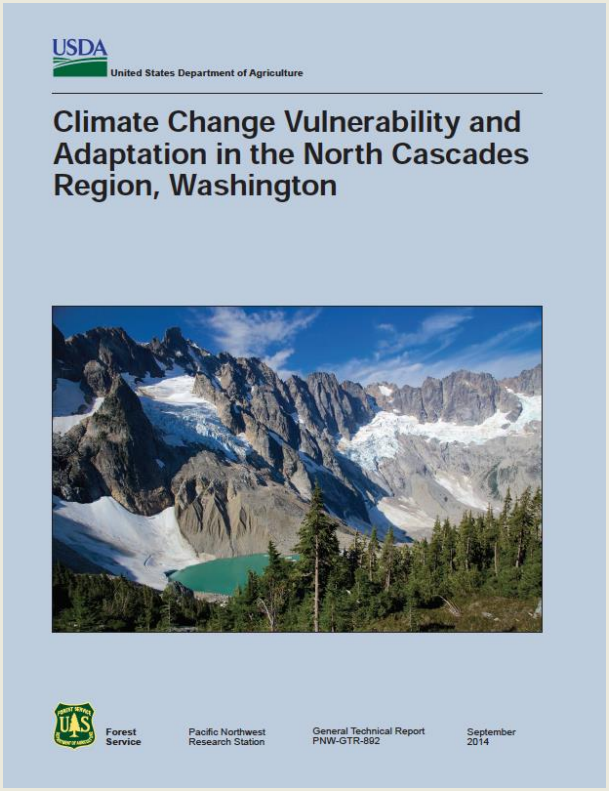
Climate Change Vulnerabilities	Increasing wildfire area burned and fire season length	Increasing drought severity and incidence of insect outbreaks	Lower snowpack, increasing precipitation intensity, and higher winter peakflows	Lower summer streamflows and increasing stream temperatures
Adaptation Options	Reduce hazardous fuels with prescribed burning and managed wildfire	Reduce forest stand density to increase tree vigor; plant drought-tolerant species and genotypes	Implement designs for forest road systems that consider increased flooding hazard	Use mapping of projected stream temperatures to set priorities for riparian restoration and coldwater fish conservation

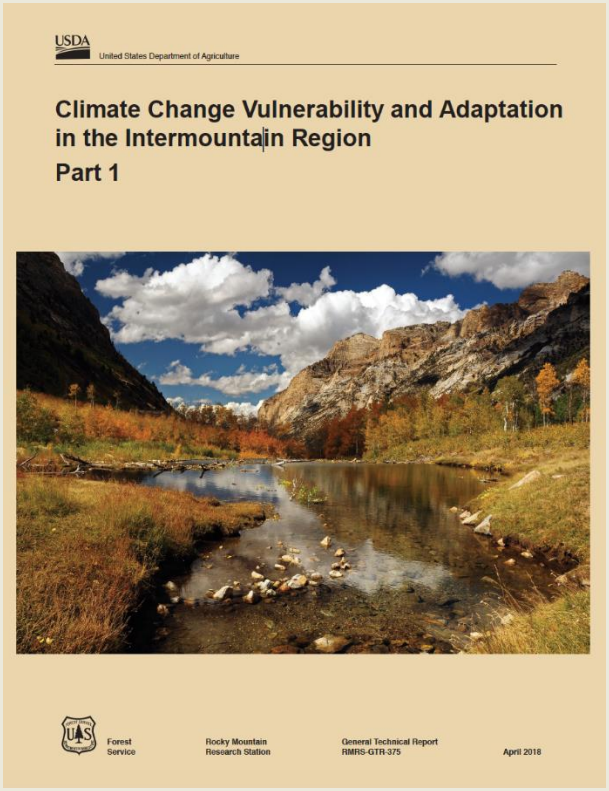
Scientific documentation and assessments

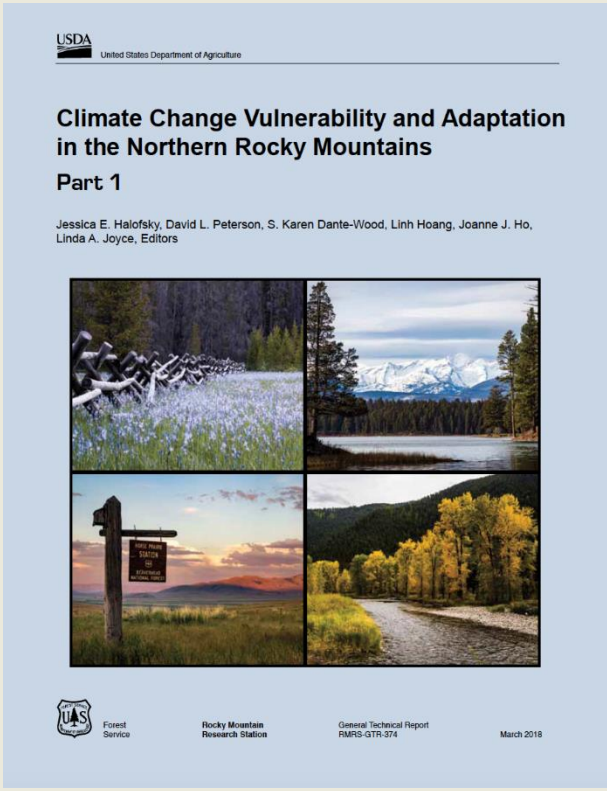




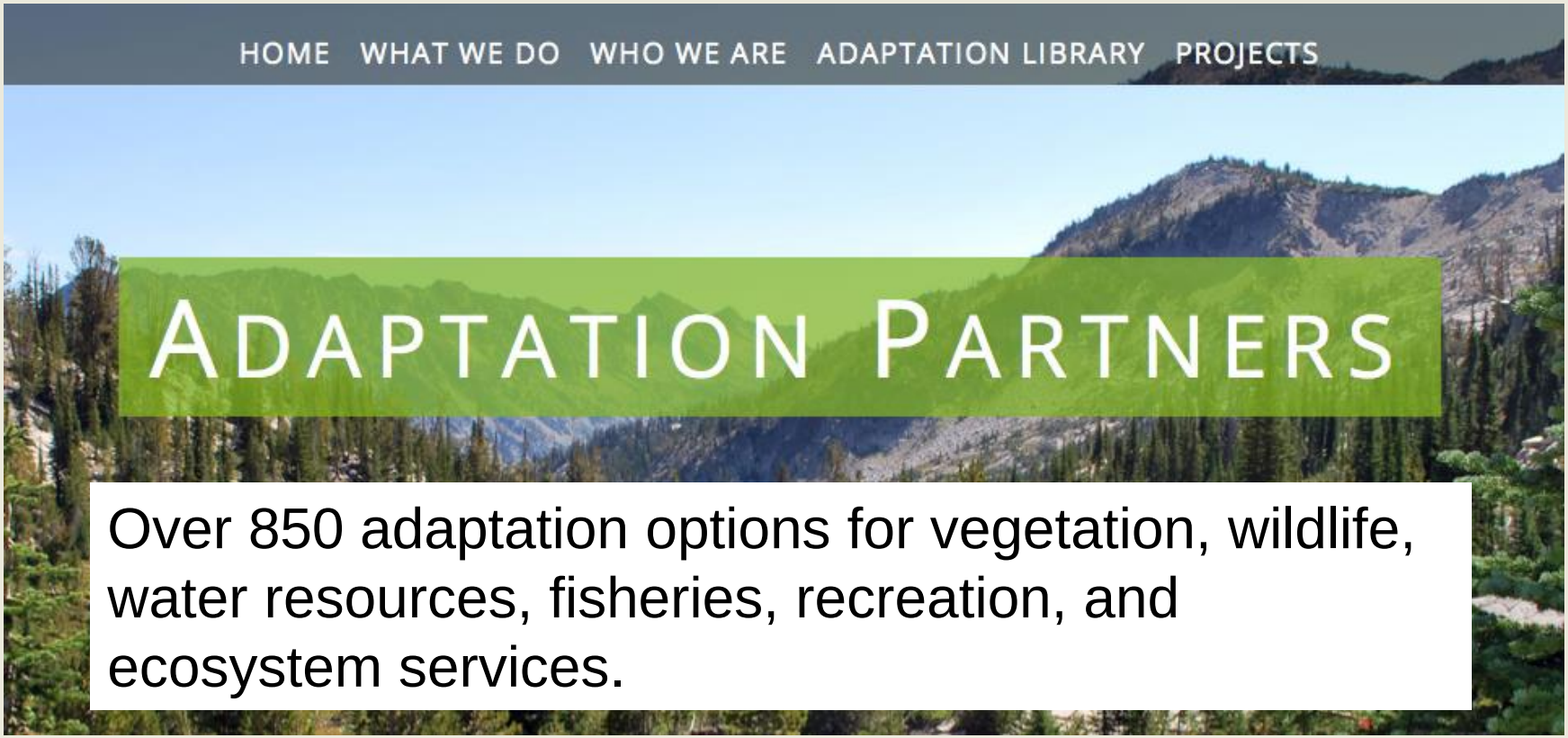
Scientific documentation and assessments







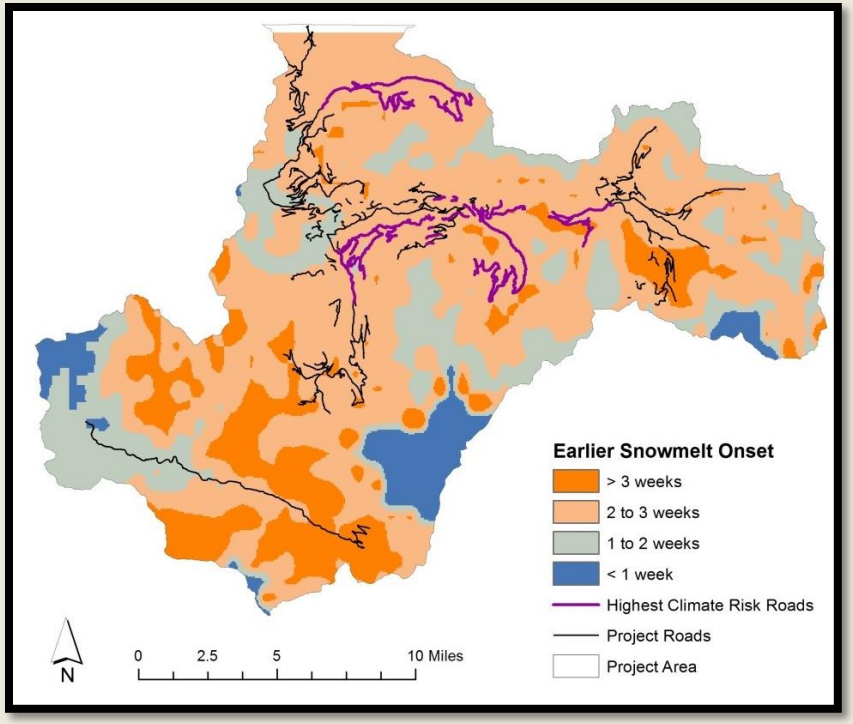
Climate Change Adaptation Library



http://adaptationpartners.org/library.php

Example: Climate change, hydrology, and road management

- Mount Baker-Snoqualmie National Forest used a vulnerability assessment to analyze effects on travel management projects.
- Analyzed climate change risks and potential changes in use for roads.
- This informs decisions on future road maintenance and decommissioning.



Questions?

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