Forest Dynamics & Climate Change

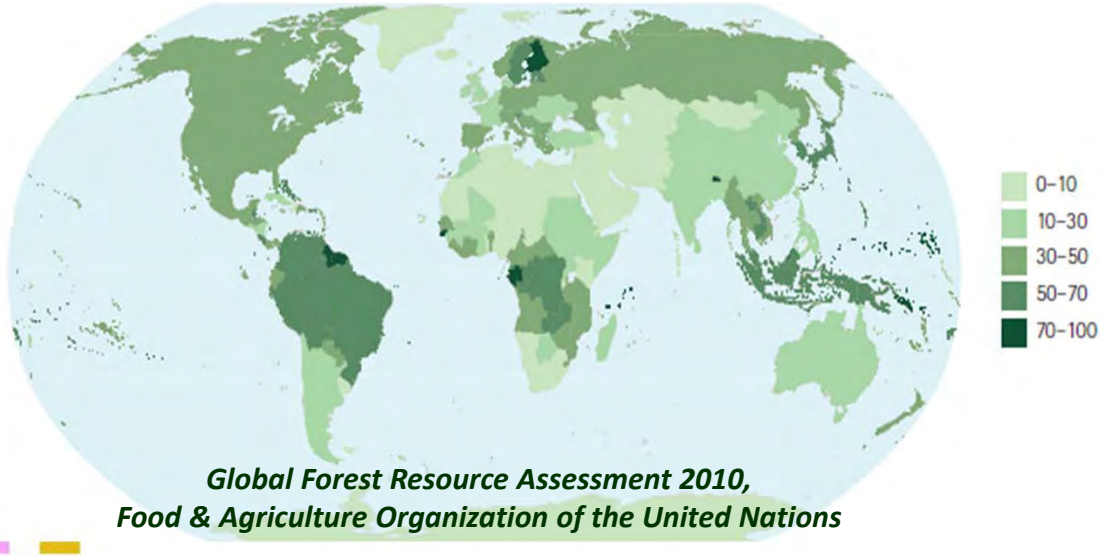
Bill Smith

CCS203

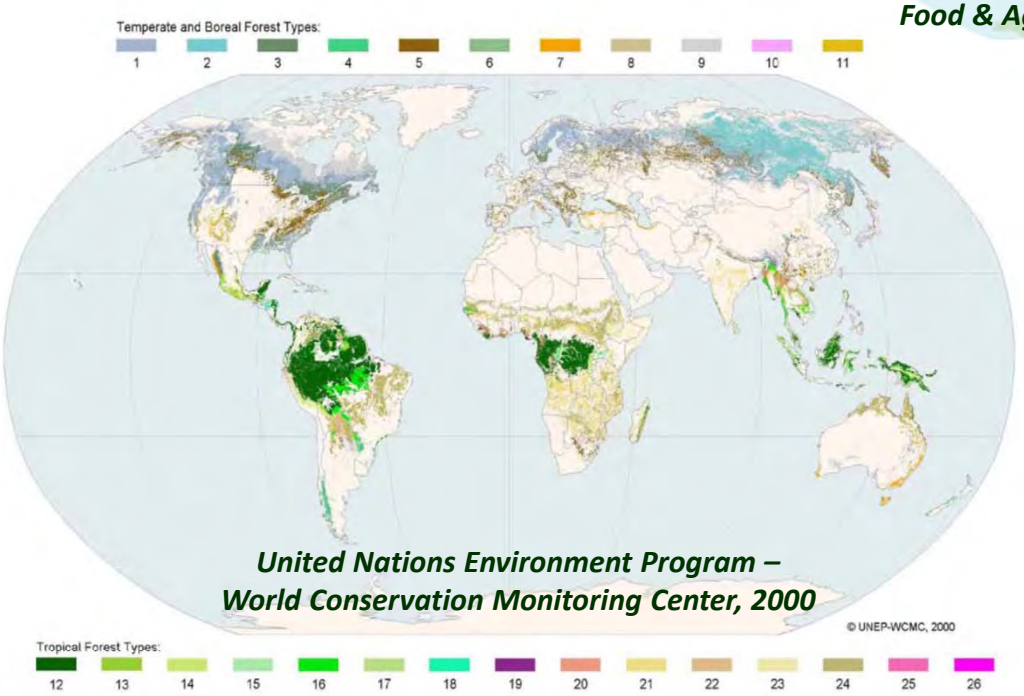
September 29th, 2010

Global Forest Extent

- 30% of land area
- ~40 Mkm^2
- 6200 m^2 / person



Global Forest Resource Assessment 2010,
Food & Agriculture Organization of the United Nations



United Nations Environment Program –
World Conservation Monitoring Center, 2000

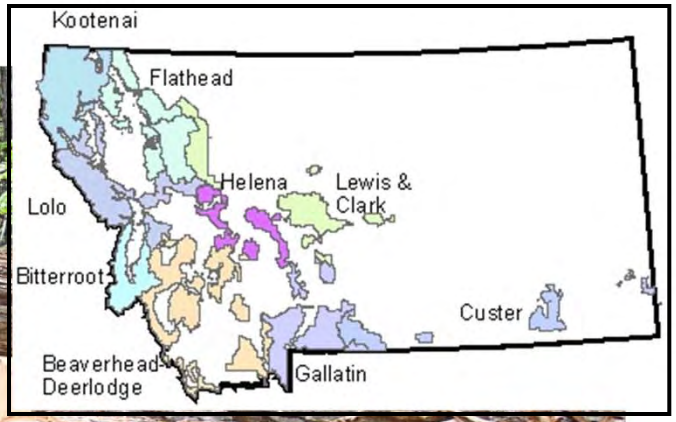
Forest Classification:

- Boreal
- Temperate
- Tropical

Only ~36% of forest is classified as primary forest

Forest Ecosystems as Sources of Goods and Services

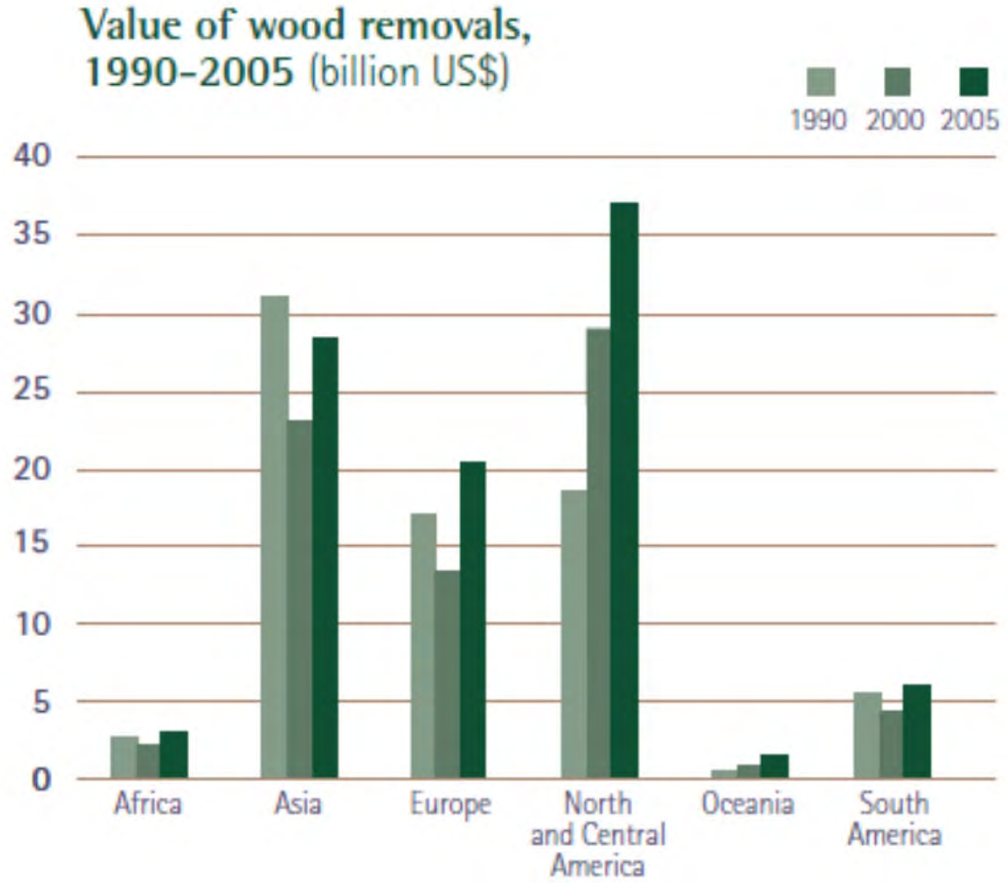
Montana's Forest Industry



Regardless of what Montana's timber industry eventually becomes, it currently employs approximately 9,000 people across the state, earning $400 million in labor income annually and accounting for 10 percent of the state's economic base, according to Todd Morgan, director of forest industry research for UM's Bureau of Business and Economic Research. **Flathead Beacon, 10/8/08**

Global Forest Industry

- **Global wood removals valued just over $100 billion annually.**
- **Non-wood forest products valued at $18.5 billion.**
- **Montana contributes only slightly over 1% to North and Central American Forest Industry.**



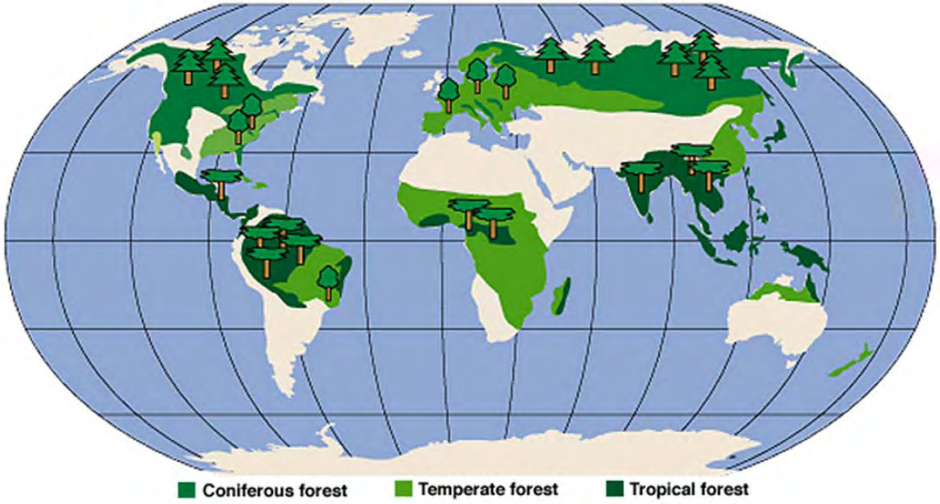
Global Forest Resource Assessment 2010, Food & Agriculture Organization of the United Nations

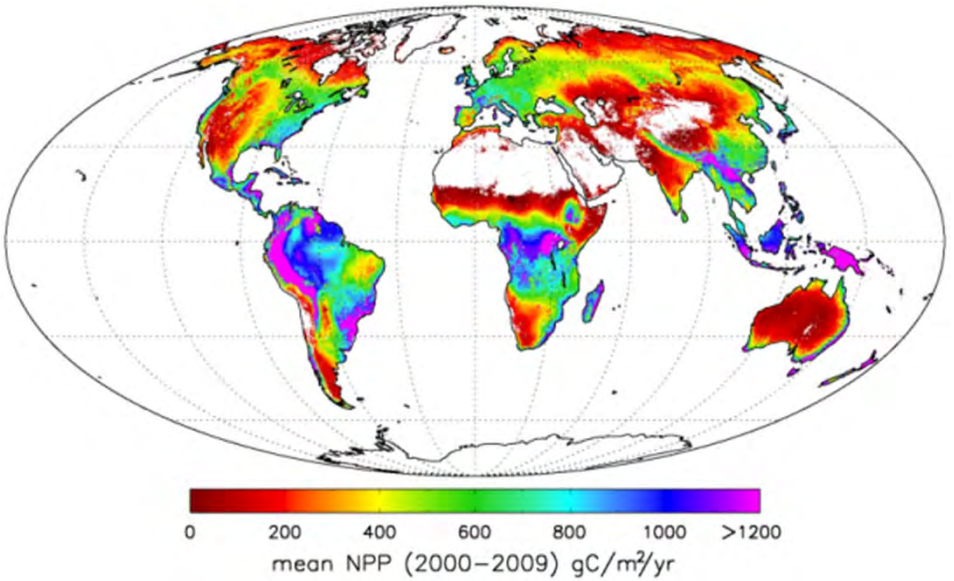
Montana's Soci-Economic Utilization of Forests

- *Approximately 10 million people are employed in forest management & conservation.*
- *More that 60,000 university students graduate in forestry annually.*

Glacier Park's visitation exceeded 2.083 million visits in 2007, the highest in 13 years. Yellowstone National Park's visitation increased nearly 10 percent in 2007 to 3.151 million visitors, surpassing the previous record set in 1992.

Forests Also Store A LOT of Carbon in Their Biomass…



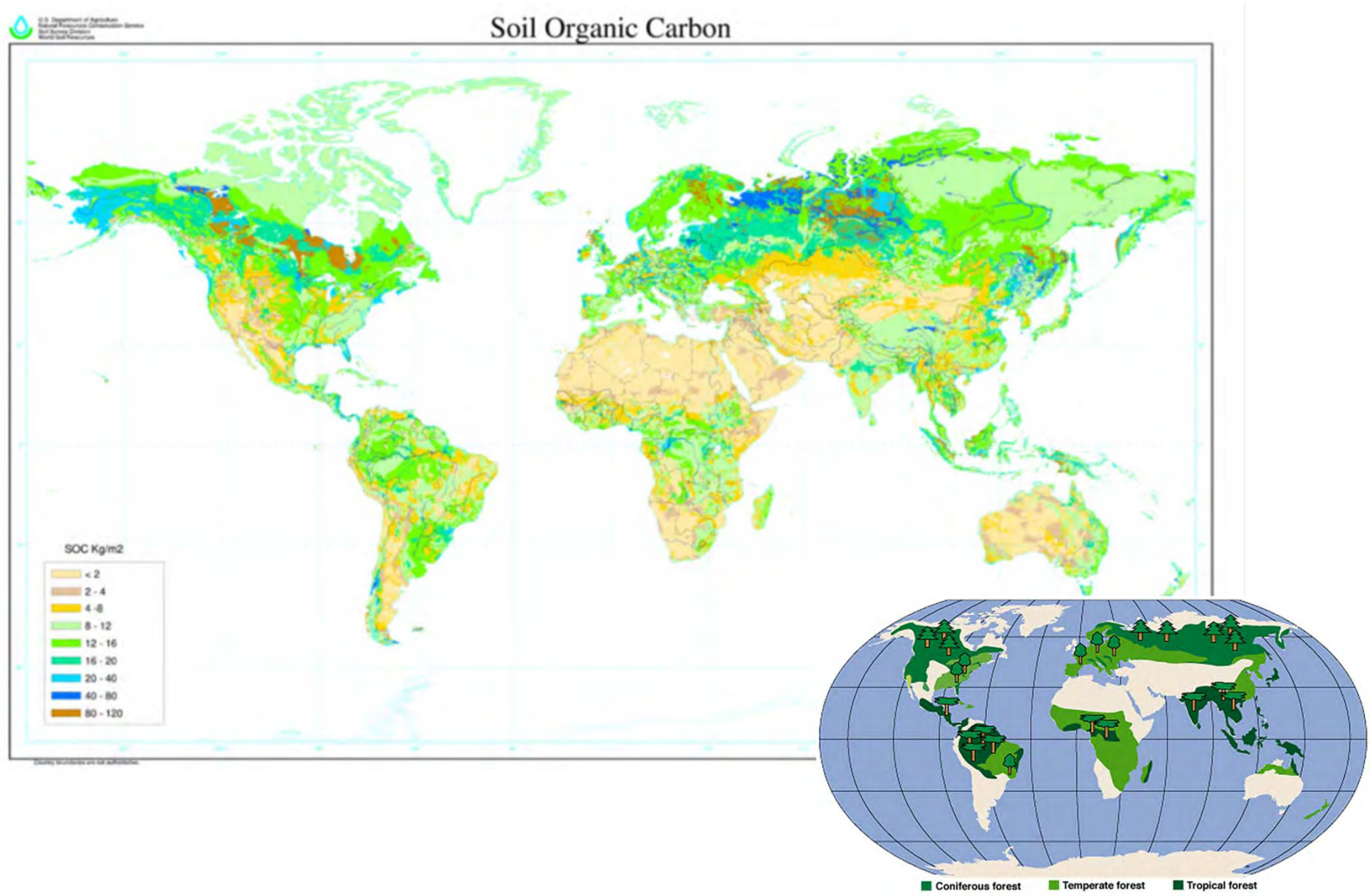


For the 1.42 billion hectares of Northern forests, roughly above the 30th parallel, we estimate the biomass sink to be 0.68 billion tons of carbon per year.

—Myneniet al (2001), PNAS

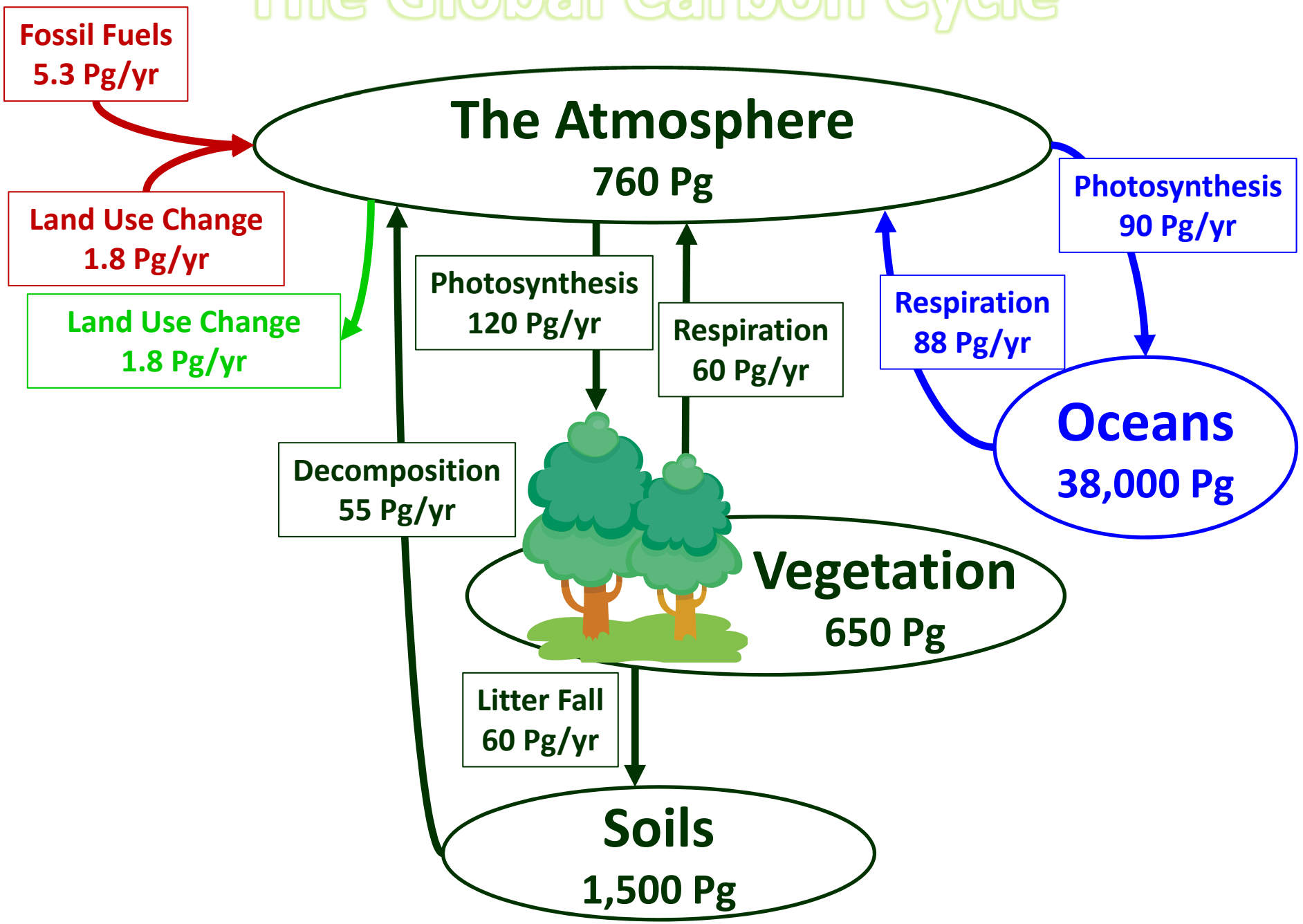
Image from: Zhao & Running, Science 2009

…And In Their Soils

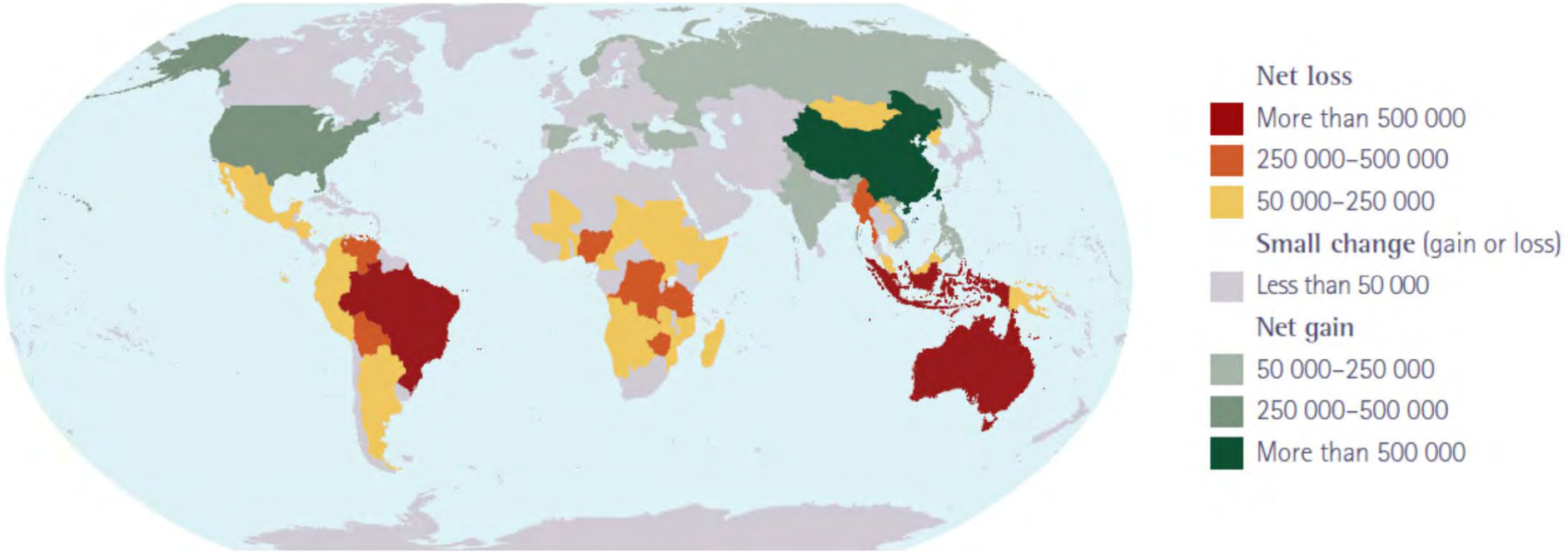


FAO-UNESCO, Soil Map of the World, digitized by ESRI. Soil climate map, USDA-NRCS, Soil Survey Division, World Soil Resources, Washington D.C.

The Global Carbon Cycle



Net Change in Forest Area 2005-2010



For the world as a whole, carbon stocks in forest biomass decreased by an estimated 0.5 Gt annually during the period 2005–2010, mainly because of a reduction in the global forest area.

What Regulates Forest Tree Distribution?

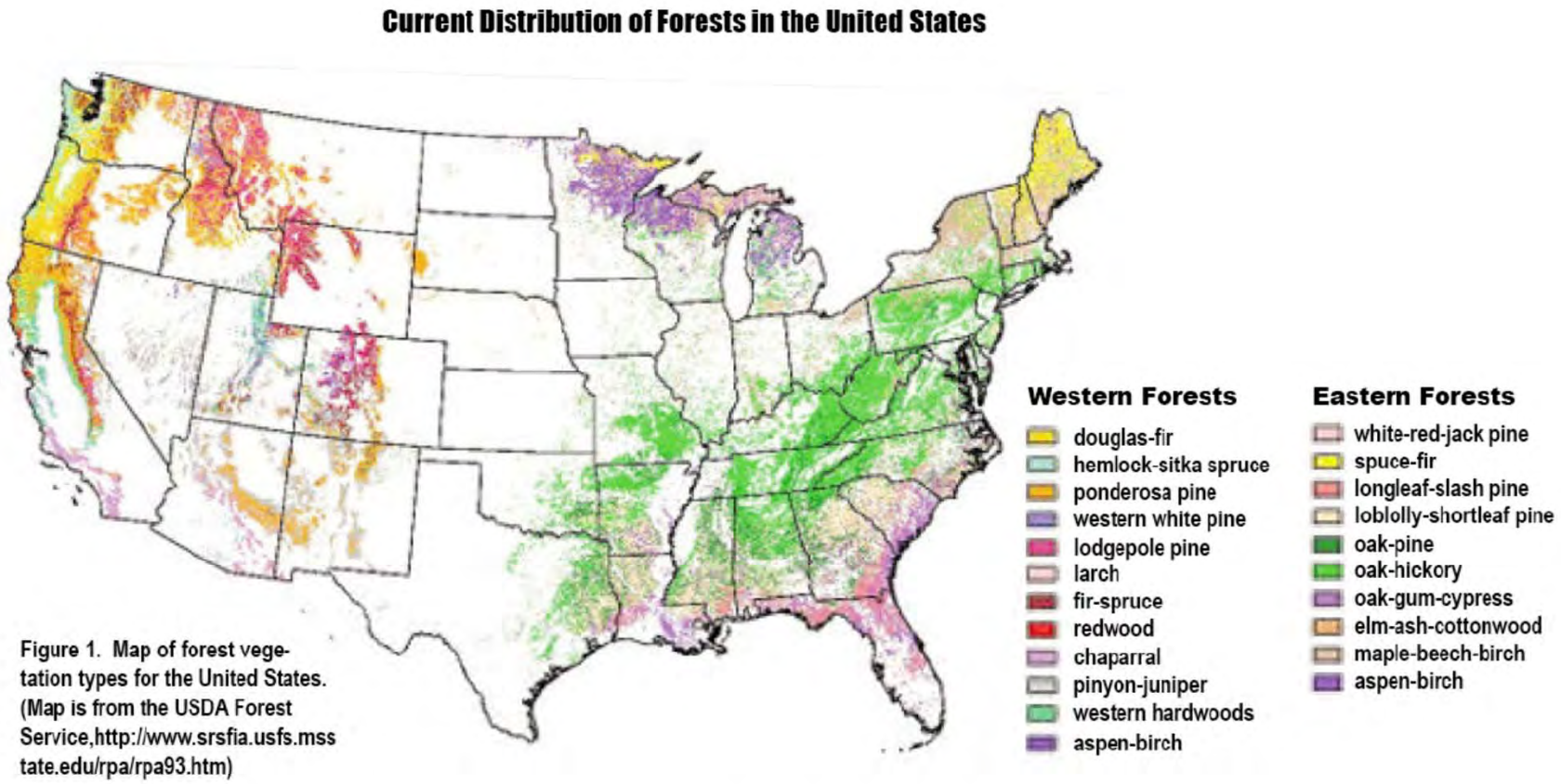
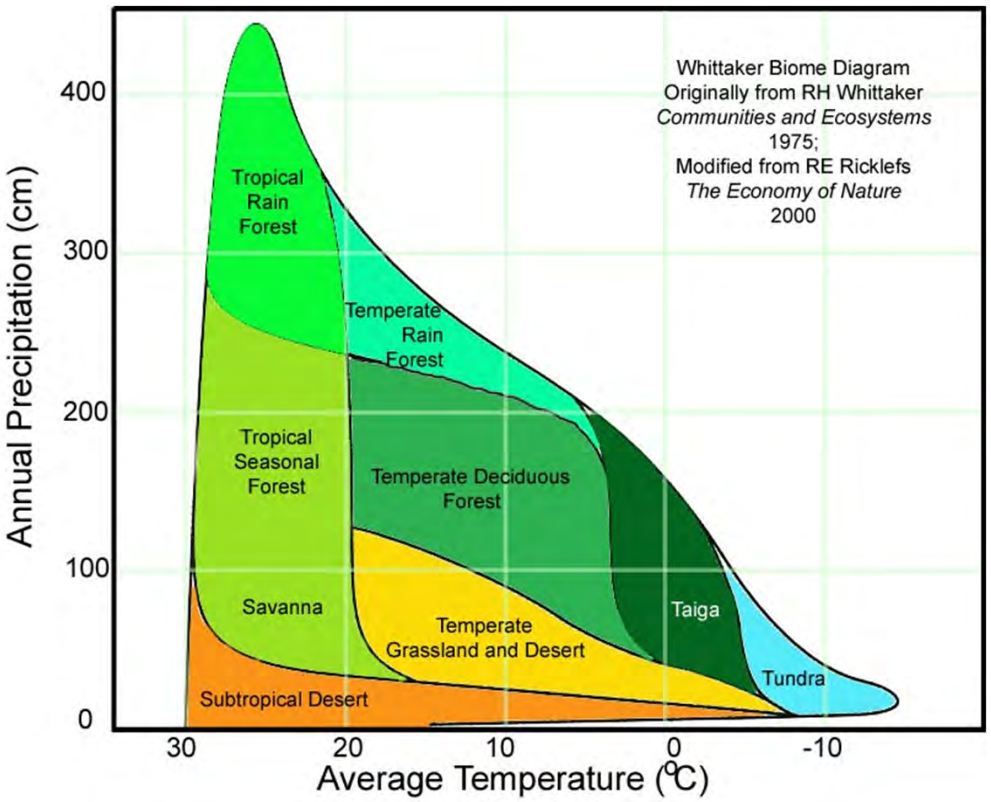
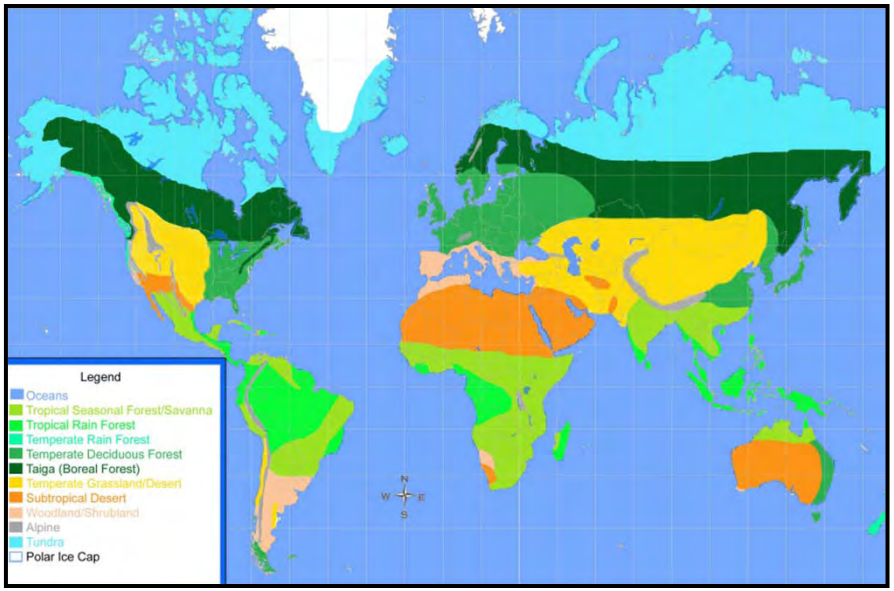


Figure 1. Map of forest vegetation types for the United States. (Map is from the USDA Forest Service,http://www.srsfia.usfs.msstate.edu/rpa/rpa93.htm)

The Relationship Between Climate & Vegetation

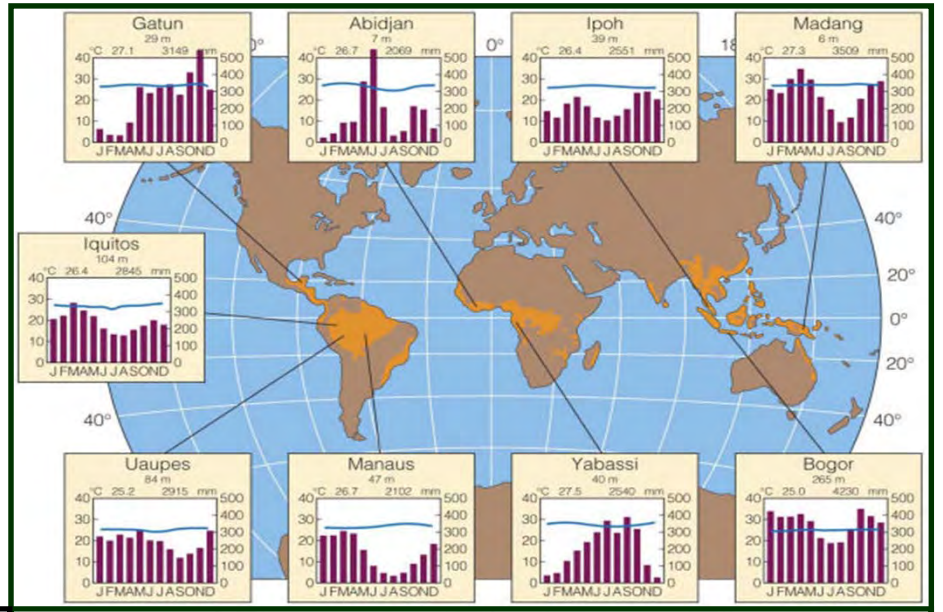


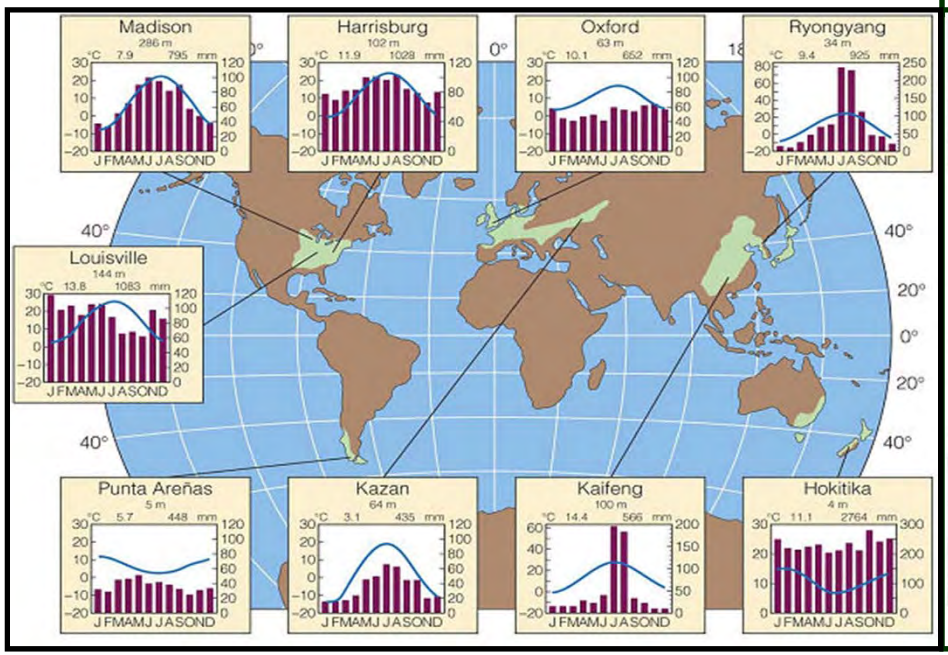


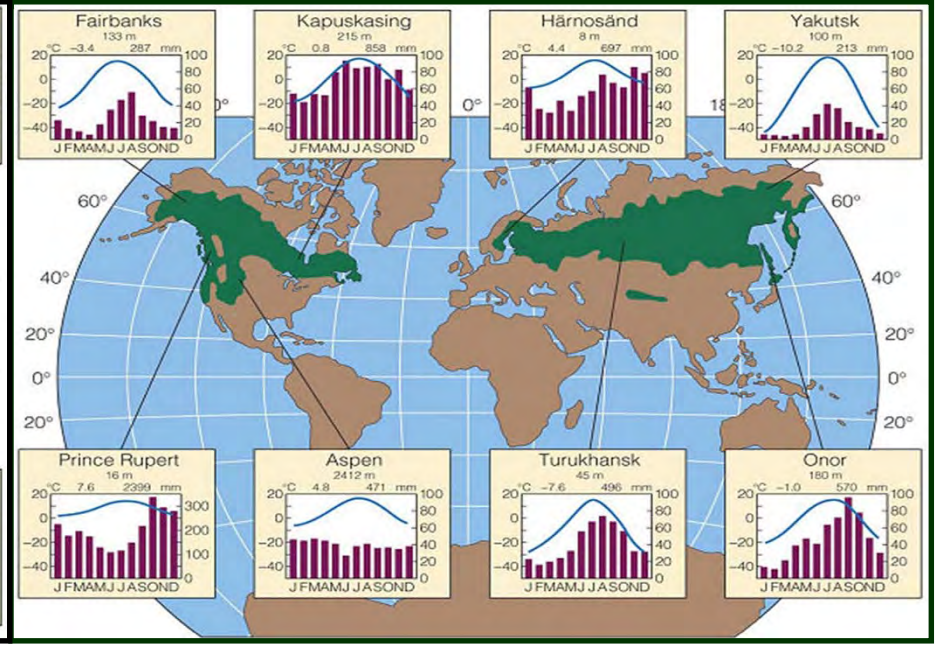
Climate & Vegetation

Climate & Distribution:

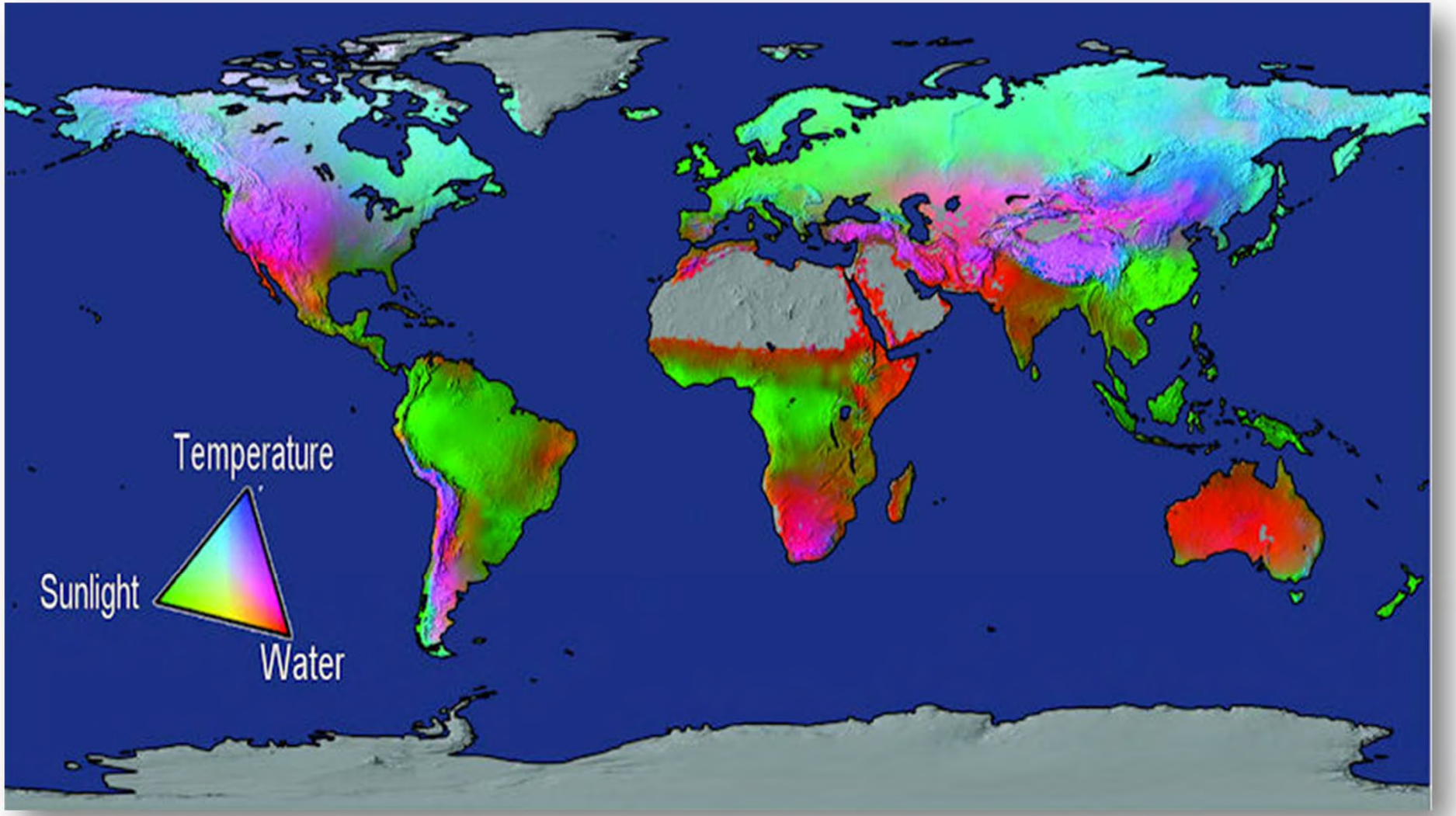
- Tropical
- Temperate
- Boreal





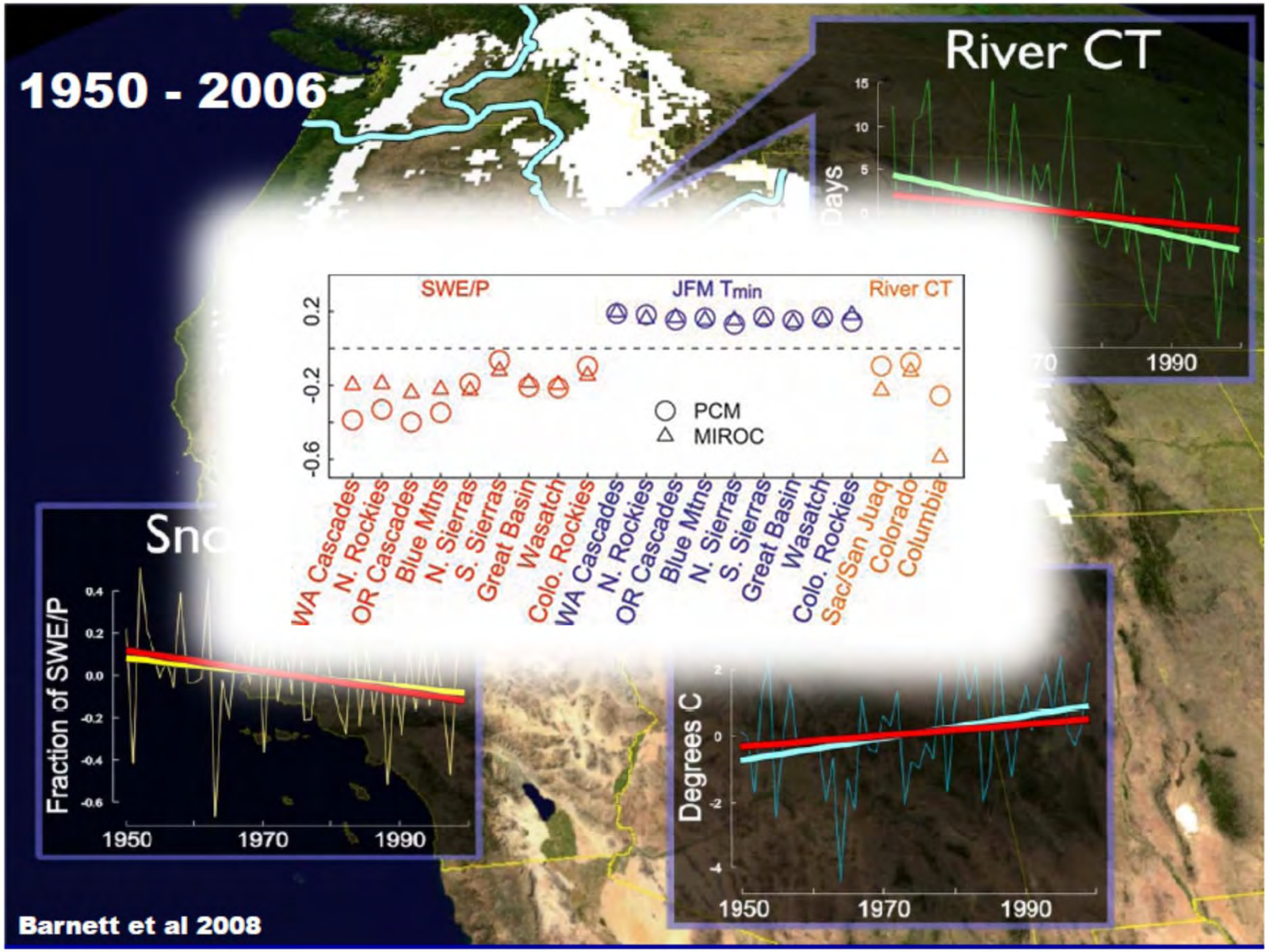


Biophysical Limits to Productivity

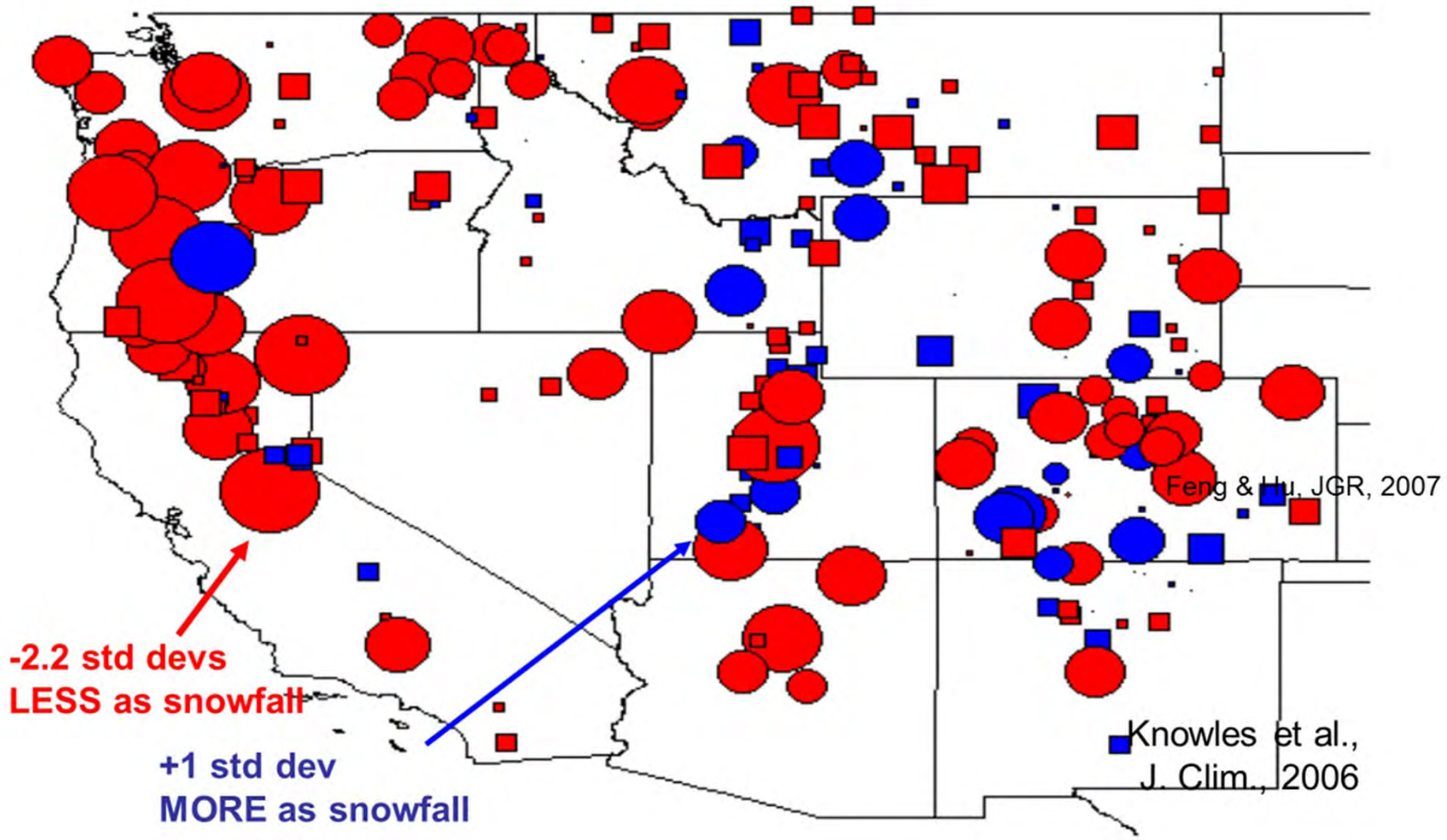


(Churkina & Running, 1998; Nemani et al., 2003; Running et al., 2004)

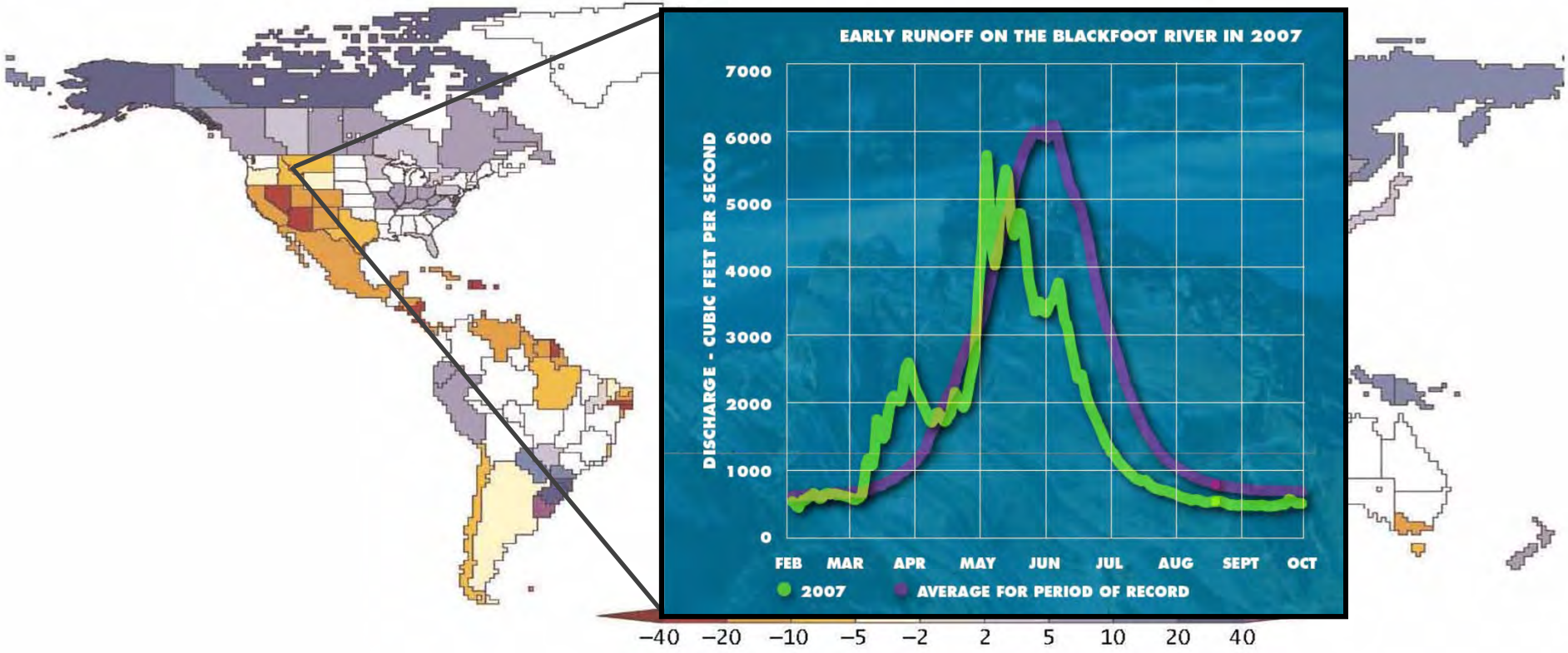
Climate Change & Forest Dynamics



Climate Change & Forest Dynamics



Spring Runoff Dynamics



Milly et al., Science 2008

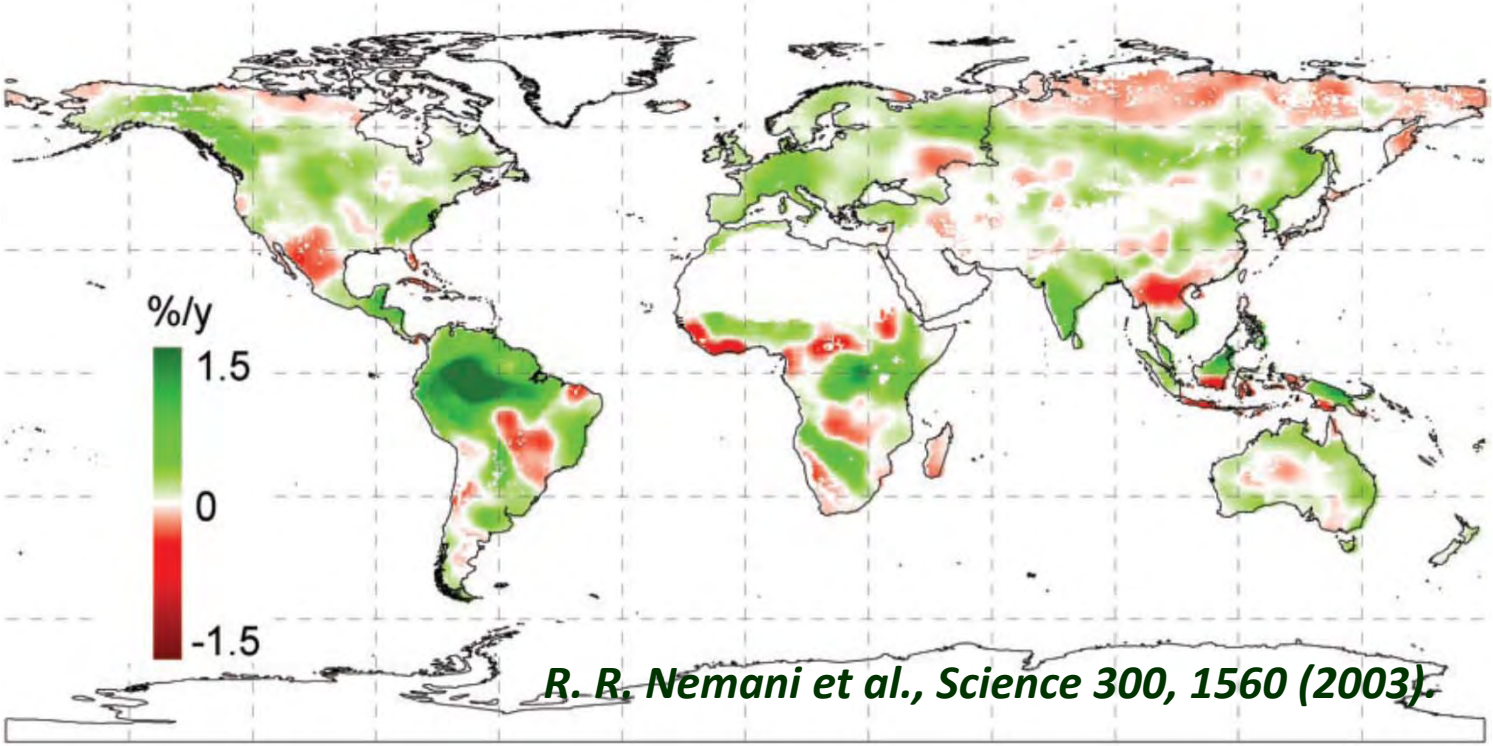
Projected change in annual runoff volume by the middle of the 21st century, relative to the historical period 1900-1970. Presence of color indicates that at least 8 of 12 models agreed on the direction (increase or decrease) of runoff change under the Intergovernmental Panel on Climate Change (IPCC) "SRES A1B" emissions scenario.

The strong relationship between forest cover and climate suggests that climate change could have profound consequences for forest dynamics.

1. Forest Growth/Mortality
2. Forest Pest Dynamic
3. Wildfire Dynamic
4. Carbon Storage Dynamic

Is there evidence that climate change is affecting forest dynamics: Forest Decline?

Climate-Driven Increases in Ecosystem Productivity from 1982 to 1999



From 1982 to 1999, climate constraints were relaxing with increasing temperature and solar radiation, allowing an upward trend in NPP.

The past decade has been the warmest since instrumental measurement which could imply continued increases in NPP.

BBC NEWS

Yosemite's giant trees disappear

Matt Walker
Editor, Earth News

The oldest and largest trees within California's world famous Yosemite National Park are disappearing.

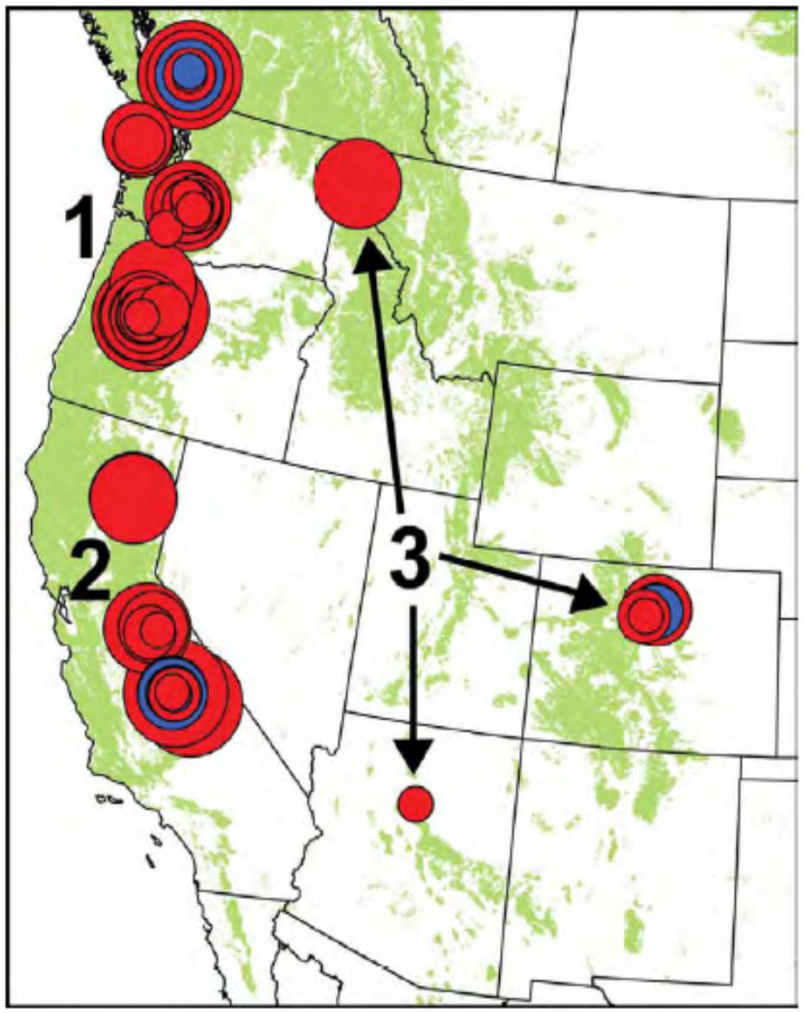
Climate change appears to be a major cause of the loss.

The revelation comes from an analysis of data collected over 60 years by forest ecologists.

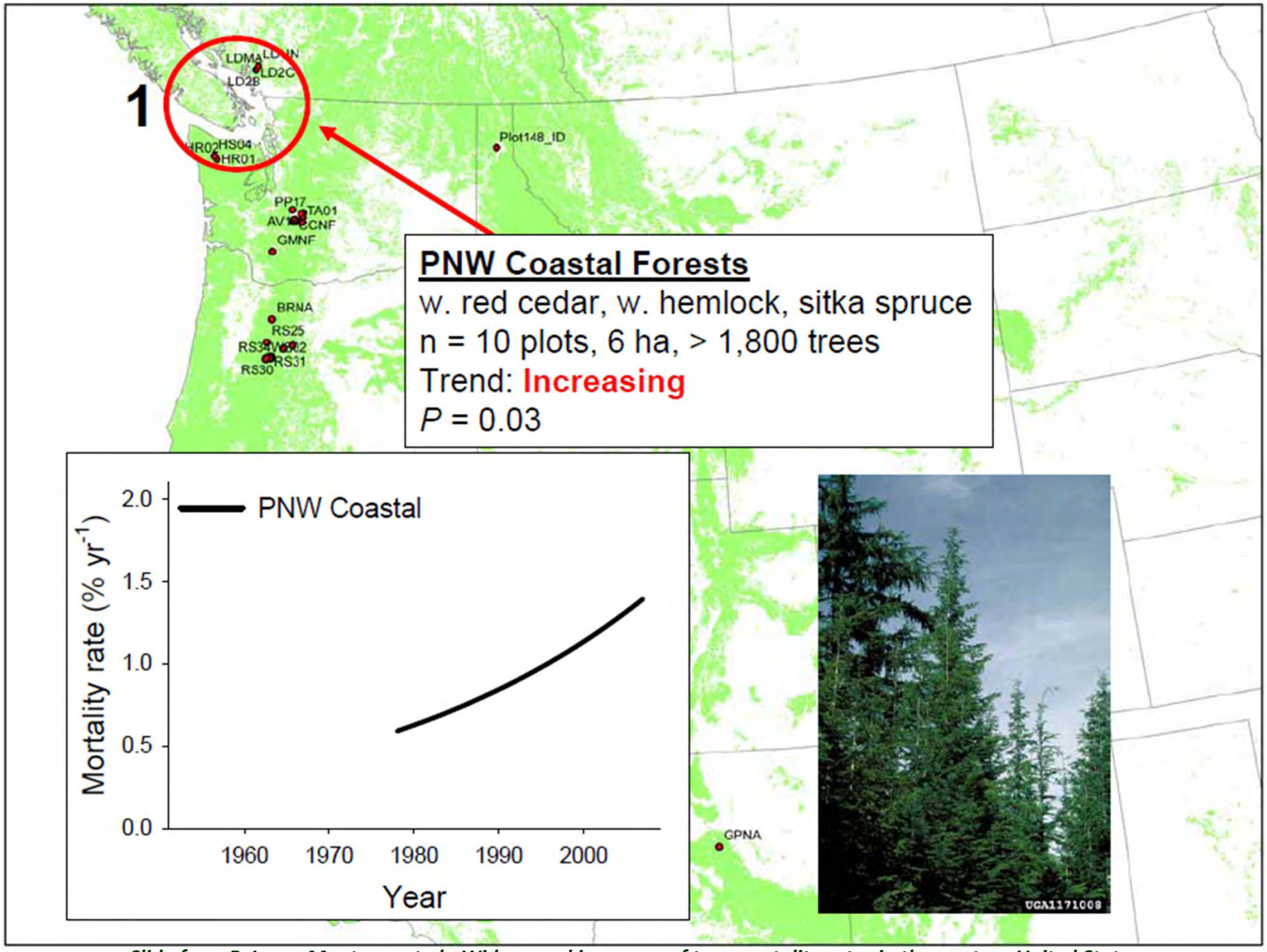
They say one worrying aspect of the decline is that it is happening within one of most protected forests within the US, suggesting that even more large trees may be dying off elsewhere.

Forest Mortality

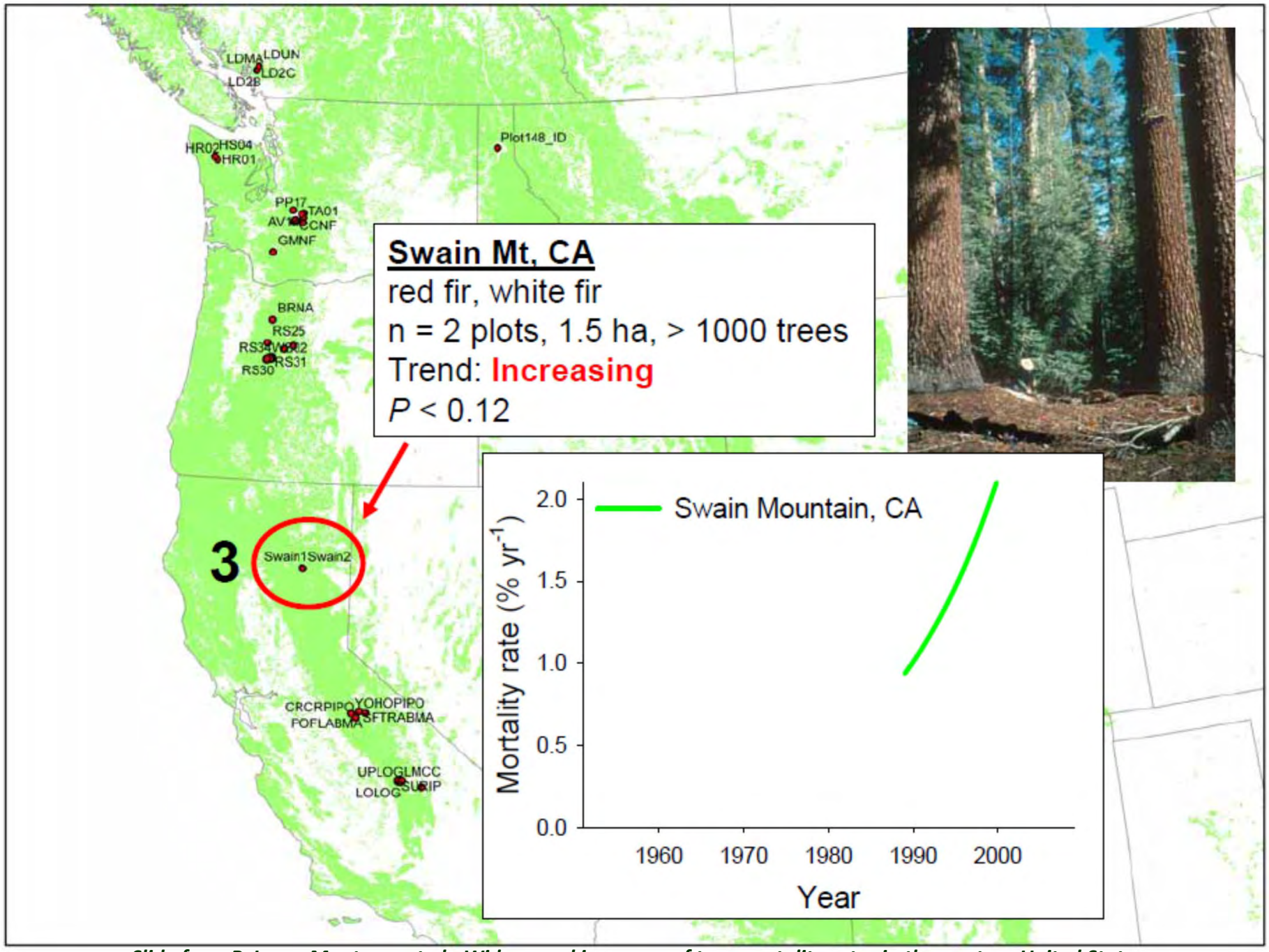
- **Background Mortality: Non-catastrophic mortality.**
- **87% of plots showed increased mortality rates.**
- **Regional Warming and consequent increases in water deficit are likely contributors to this trend.**



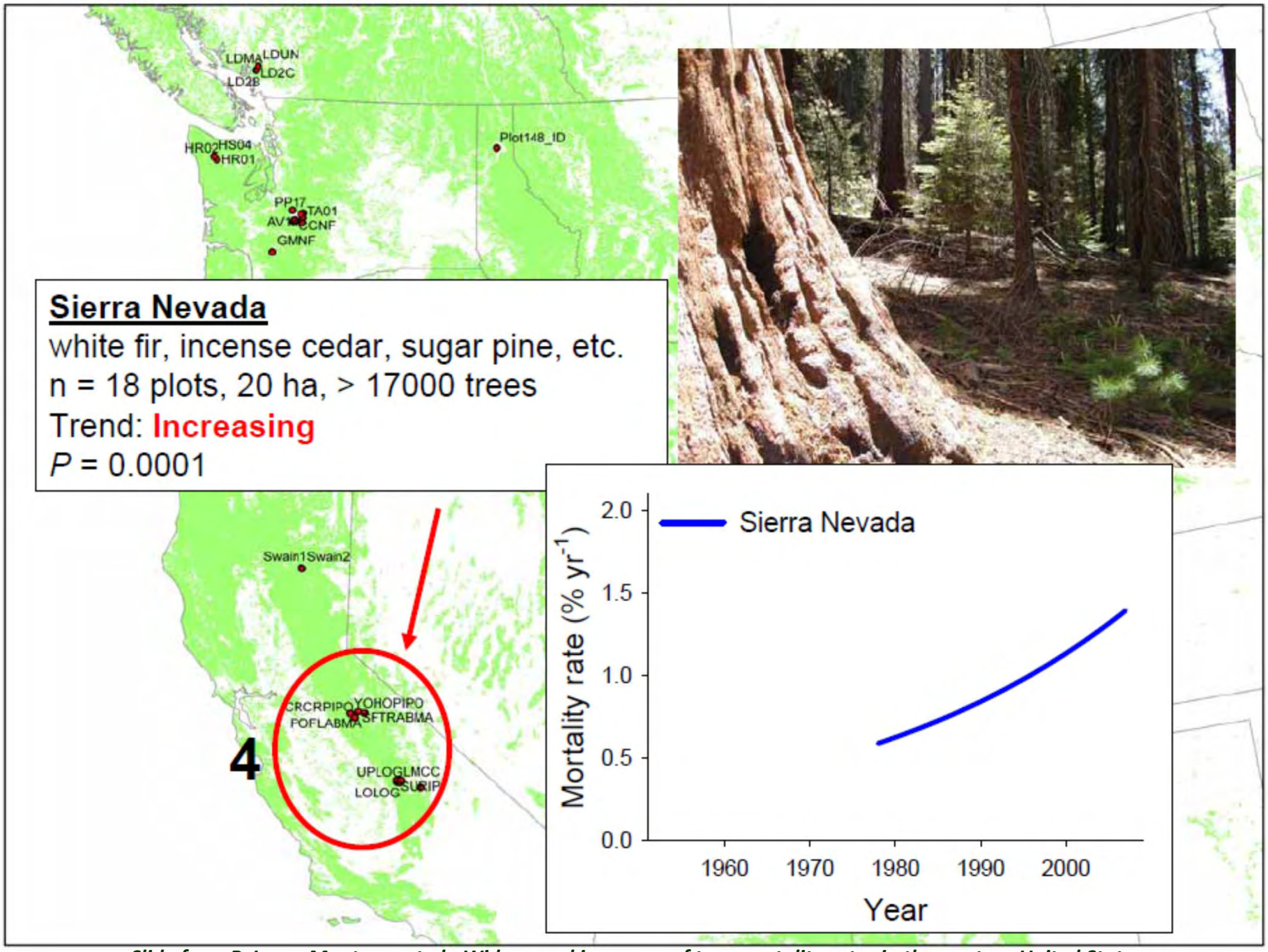
P. J. van Mantgem et al., Science 323, 521 -524 (2009)



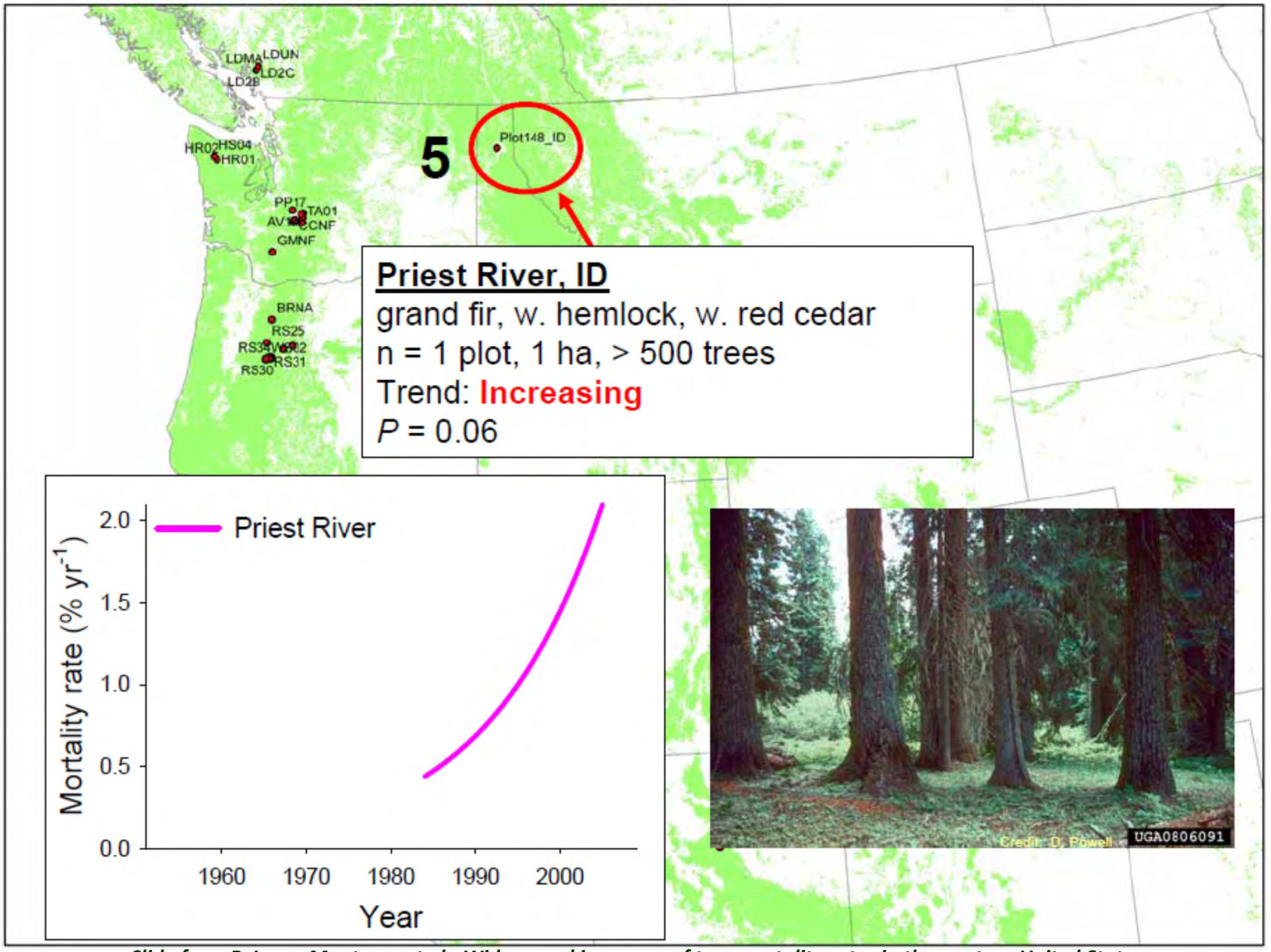
Slide from P. J. van Mantgem et al., Widespread increases of tree mortality rates in the western United States



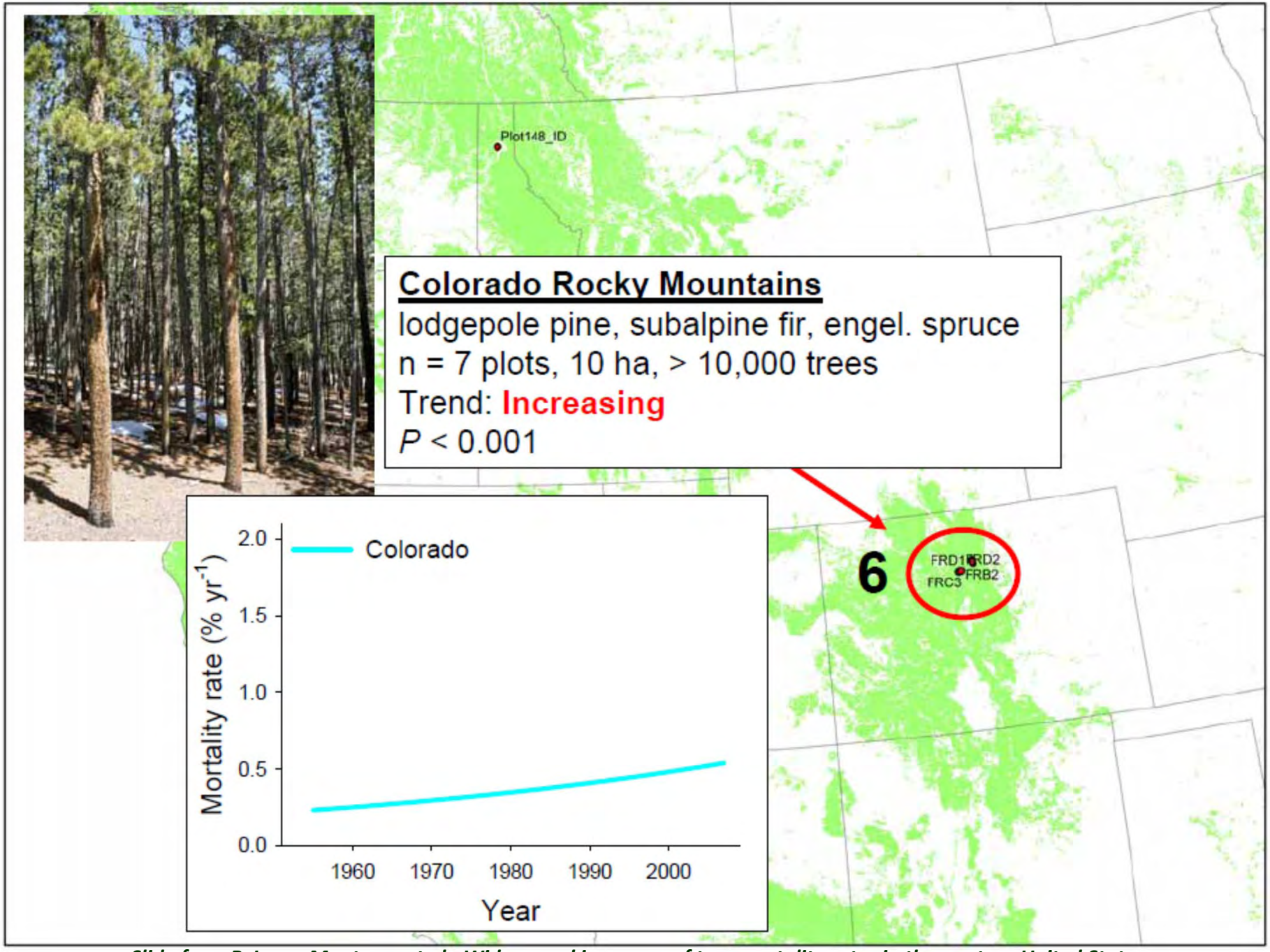
Slide from P. J. van Mantgem et al., Widespread increases of tree mortality rates in the western United States



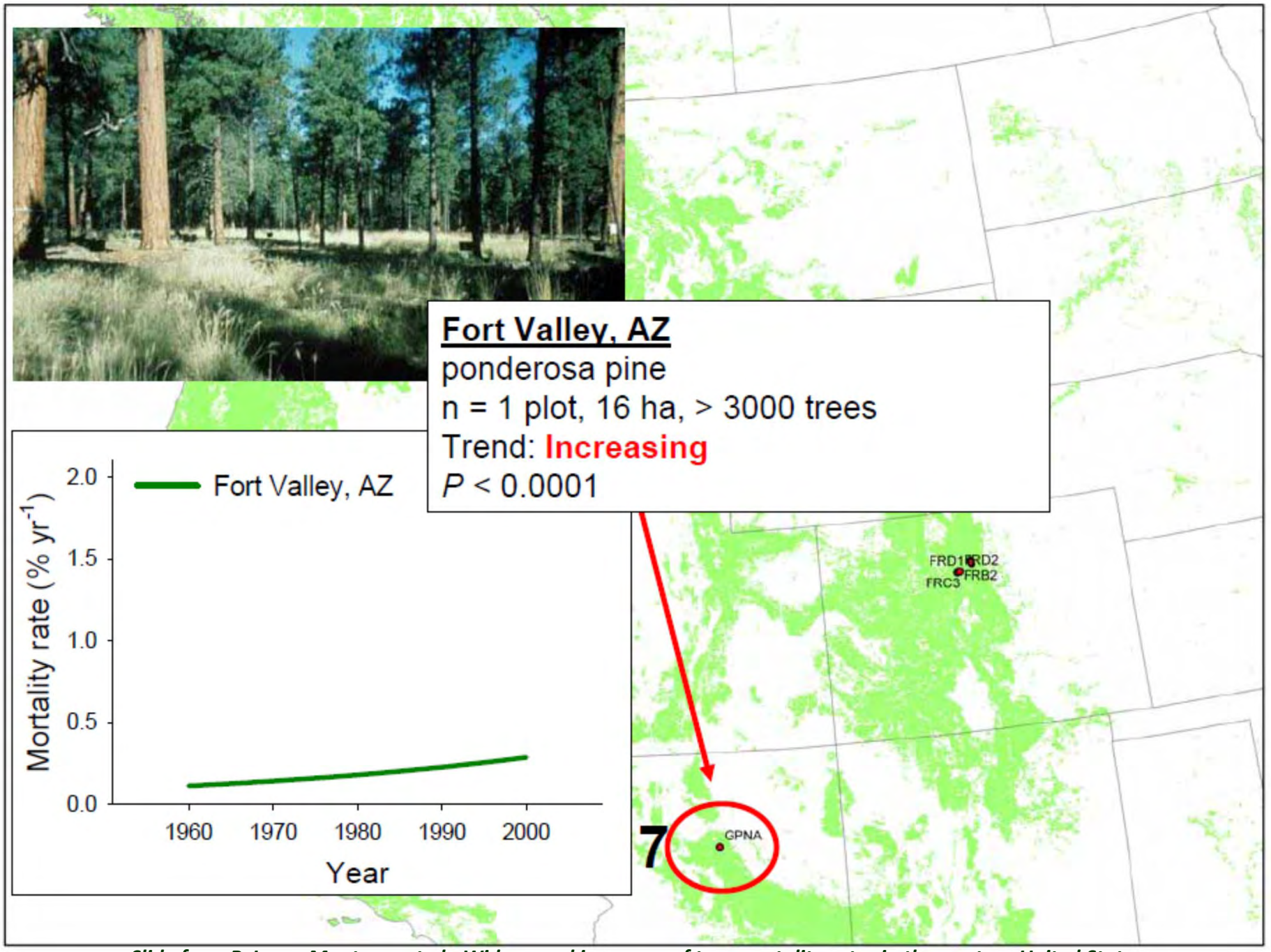
Slide from P. J. van Mantgem et al., Widespread increases of tree mortality rates in the western United States



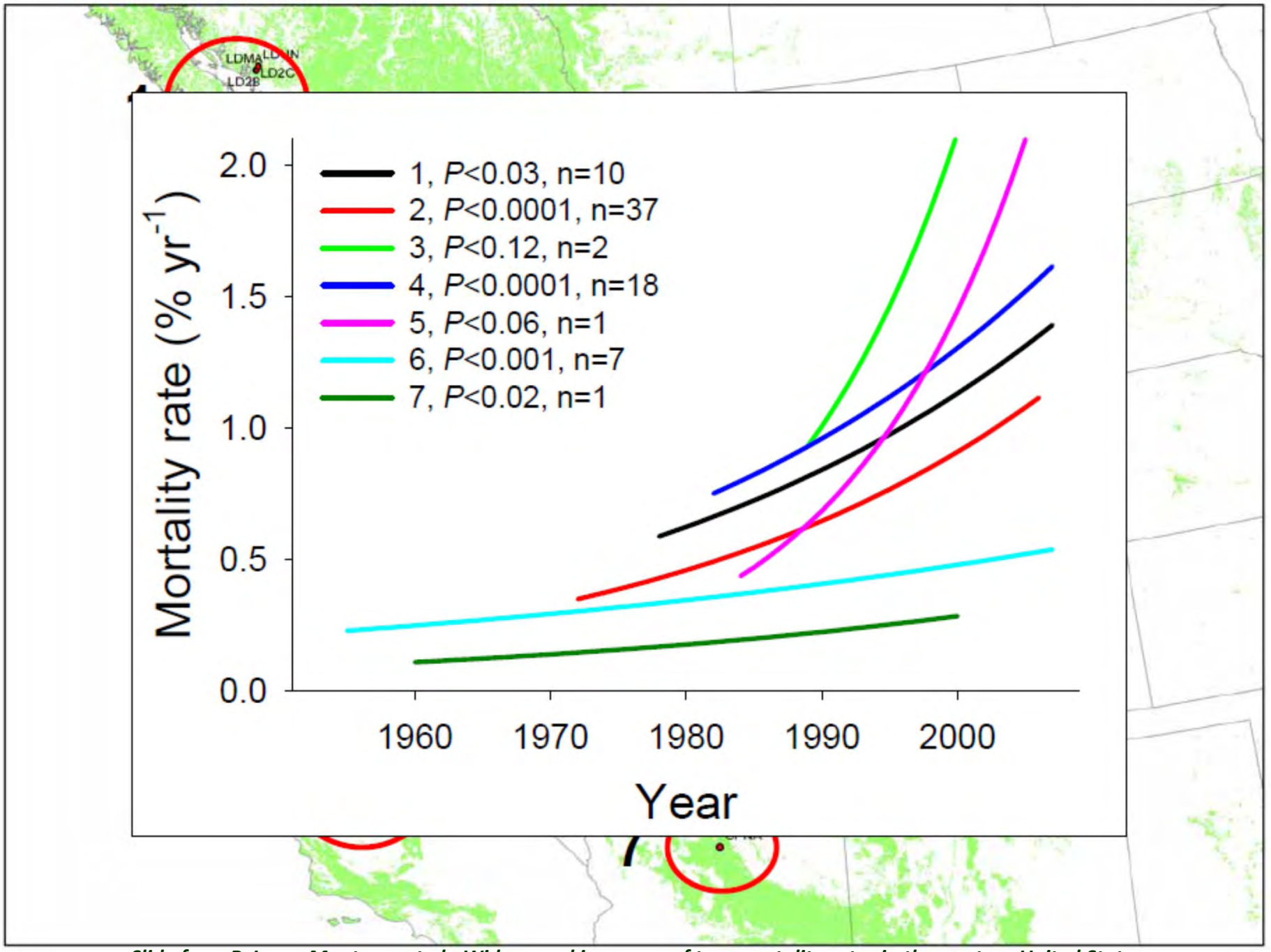
Slide from P. J. van Mantgem et al., Widespread increases of tree mortality rates in the western United States



Slide from P. J. van Mantgem et al., Widespread increases of tree mortality rates in the western United States

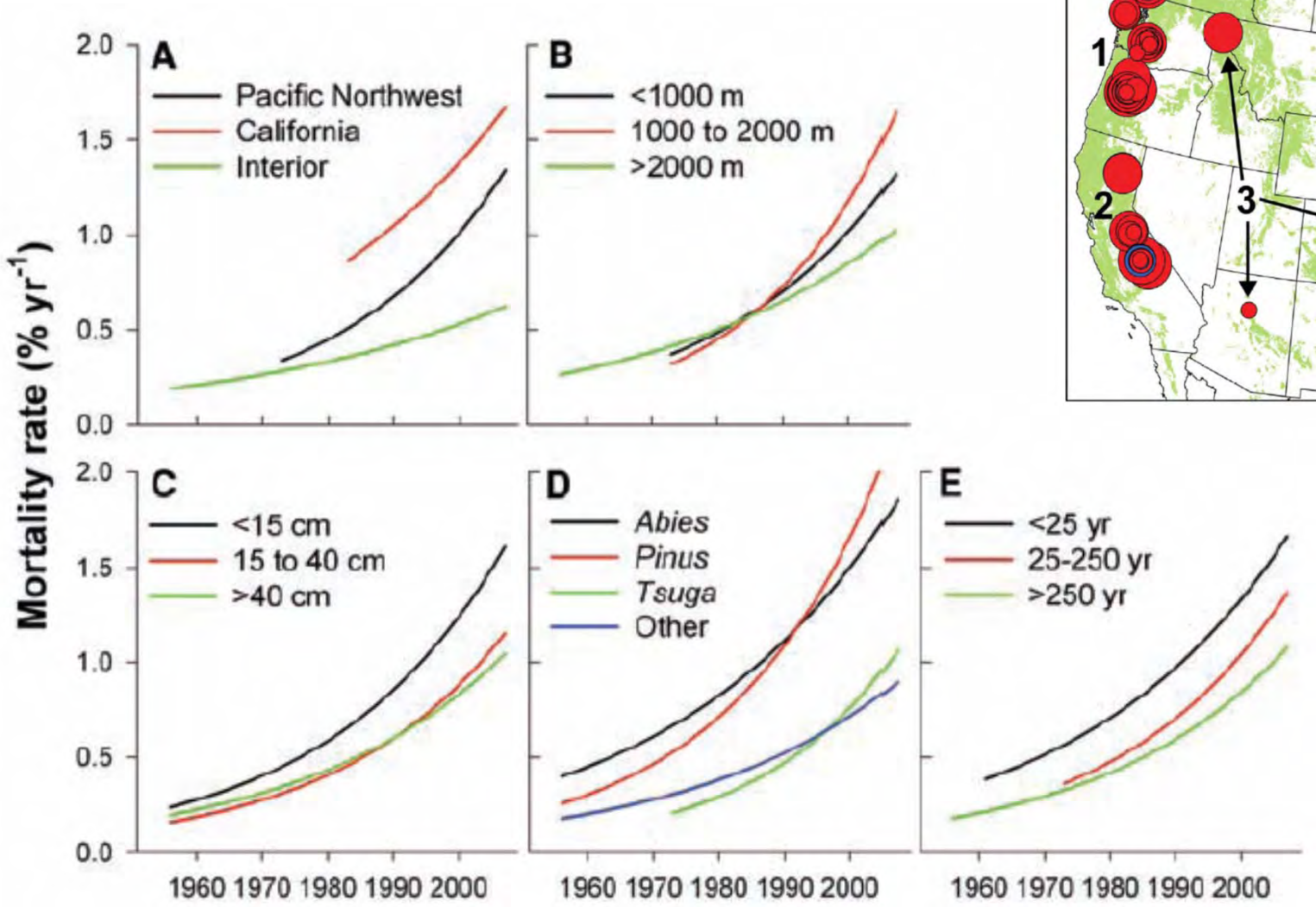


Slide from P. J. van Mantgem et al., Widespread increases of tree mortality rates in the western United States



Slide from P. J. van Mantgem et al., Widespread increases of tree mortality rates in the western United States

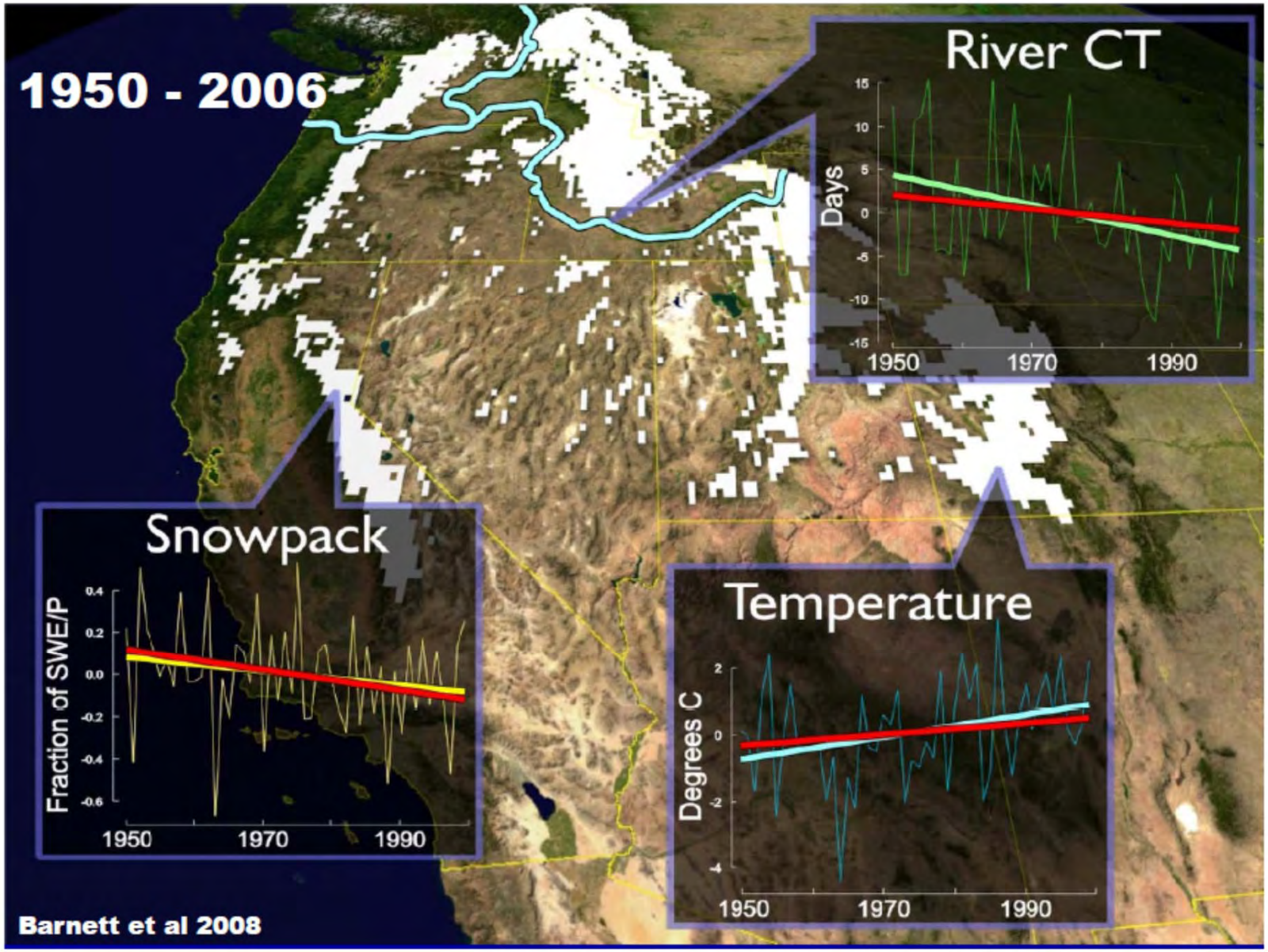
Forest Mortality



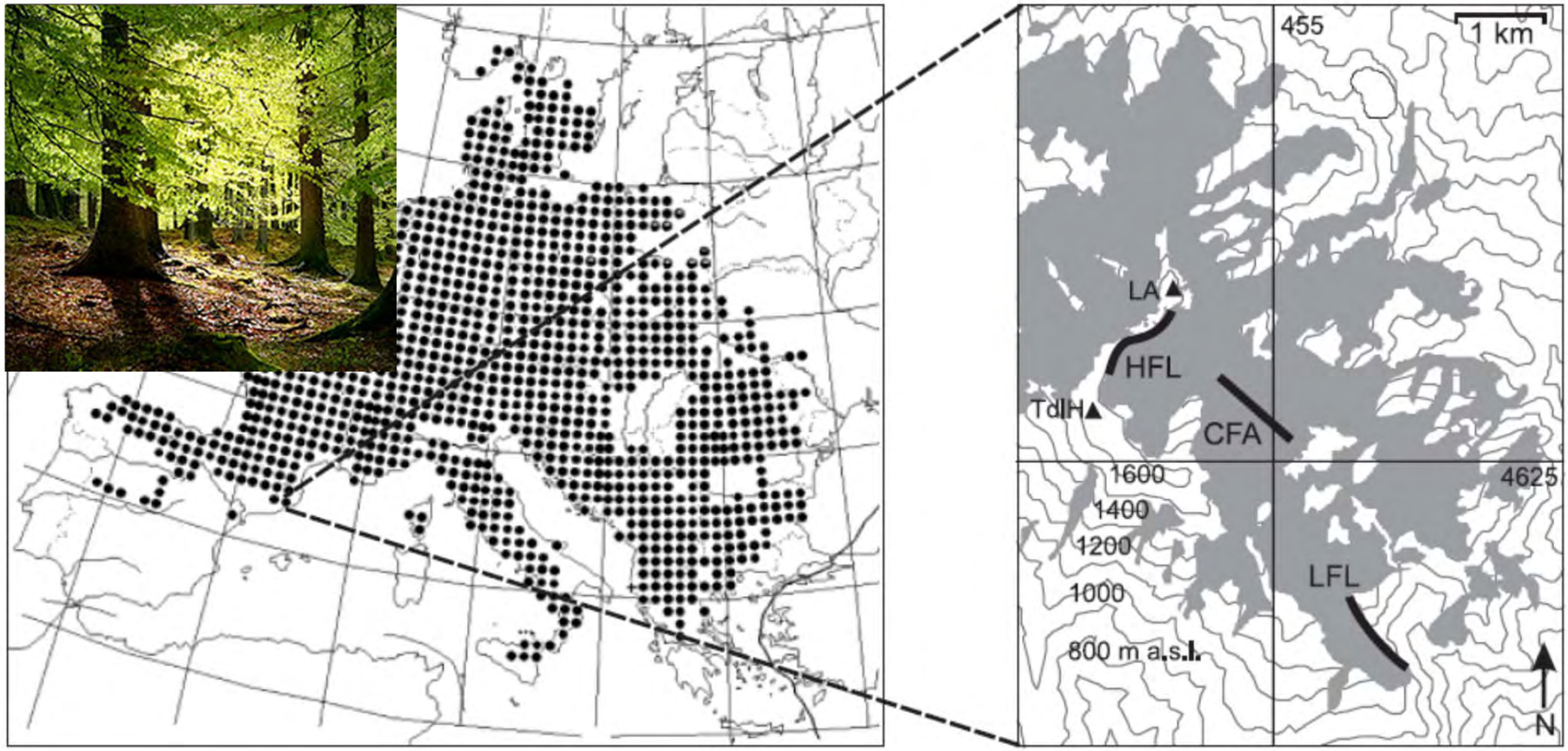
Modeled trends in tree mortality rates for (A) regions, (B) elevational class, (C) stem diameter class, (D) genus, and (E) historical fire return interval class.

Image from *P. J. van Mantgem et al., Science 323, 521 -524 (2009)*

Forest Mortality



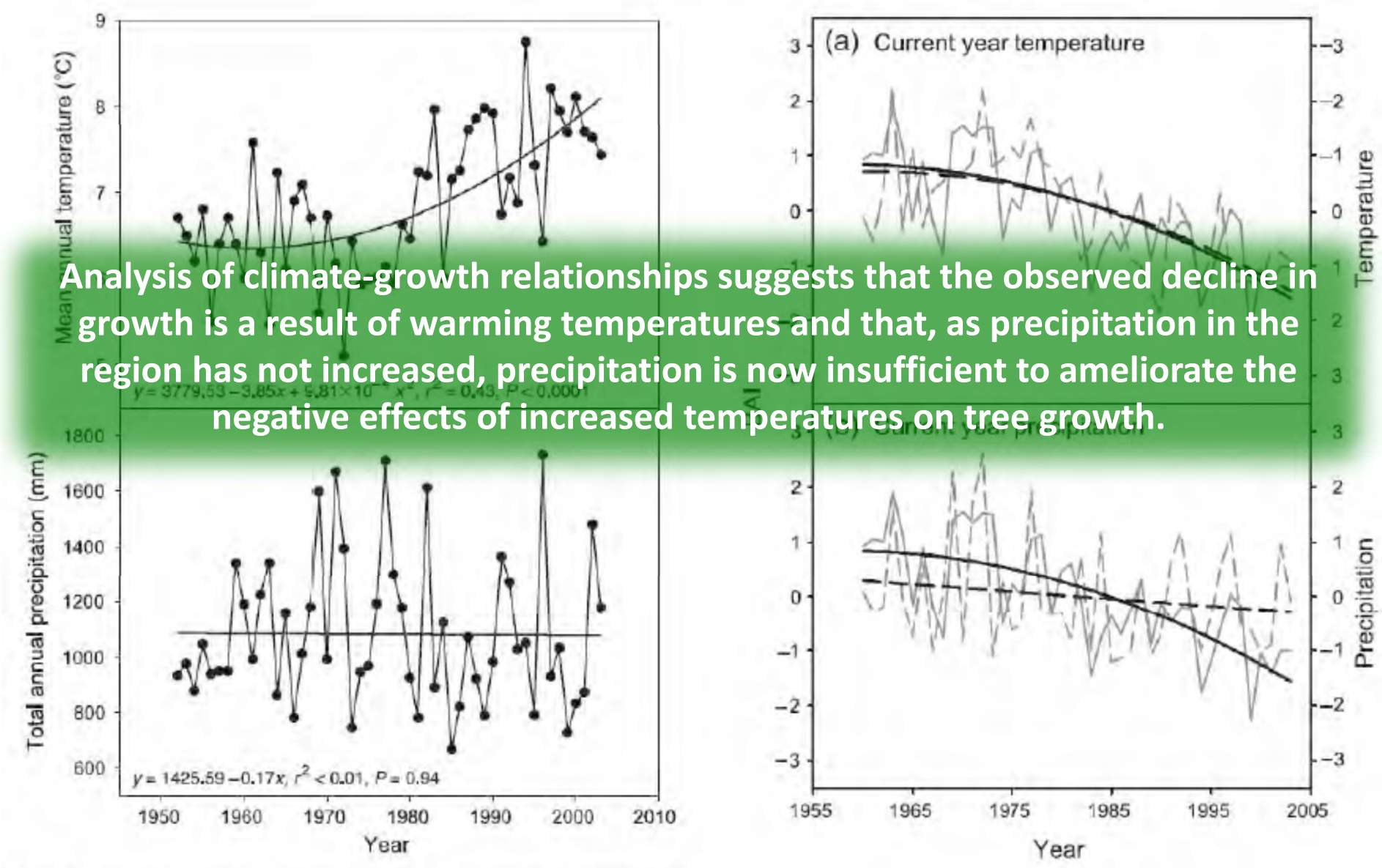
Forest Mortality



- European Beech distribution is largely drought limited similar to many deciduous forests.
- Recently, significant growth declines have been observed at the lower growth limit.

Image From Jump et al. (2006), Global Change Biology

Forest Mortality



Analysis of climate-growth relationships suggests that the observed decline in growth is a result of warming temperatures and that, as precipitation in the region has not increased, precipitation is now insufficient to ameliorate the negative effects of increased temperatures on tree growth.

Image From Jump et al. (2006), Global Change Biology

Is there evidence that climate change is affecting forest dynamics: Forest Decline?

Yes, Compelling Evidence

Is there evidence that climate change is affecting forest dynamics: Forest Pest Dynamic?

The New York Times
nytimes.com

November 18, 2008

Bark Beetles Kill Millions of Acres of Trees in West

By JIM ROBBINS

HELENA, Mont. — On the side of a mountain on the outskirts of Montana's capital city, loggers are racing against a beetle grub the size of a grain of rice.

From New Mexico to British Columbia, the region's signature pine forests are succumbing to a huge

"Montana lost a million acres of trees to beetles [in 2007]"

the situation is worse.

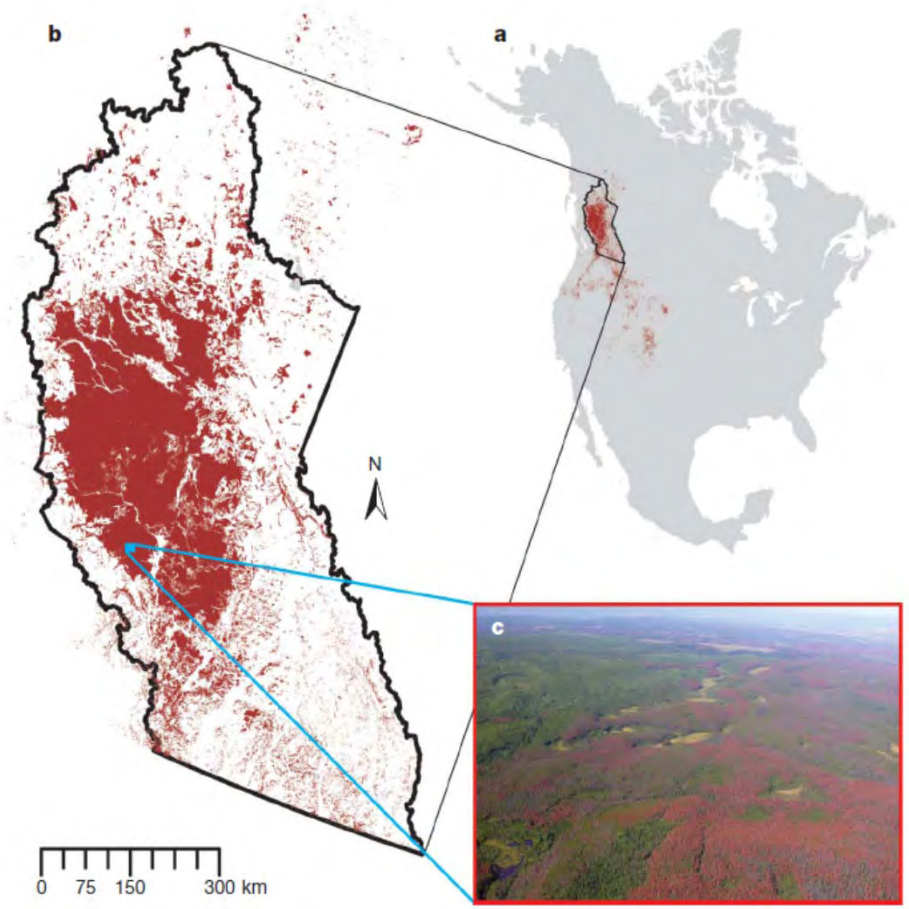
"In Wyoming and Colorado in 2006 there were a million acres of dead trees. [2007] it was 1.5 million. [2008] it totaled over 2 million"

year it is expected to total over two million. In the Canadian provinces of British Columbia and Alberta, the problem is most severe. It is the largest known insect infestation in the history of North America, officials

"British Columbia has lost over 33 million acres of lodgepole pine forest …"

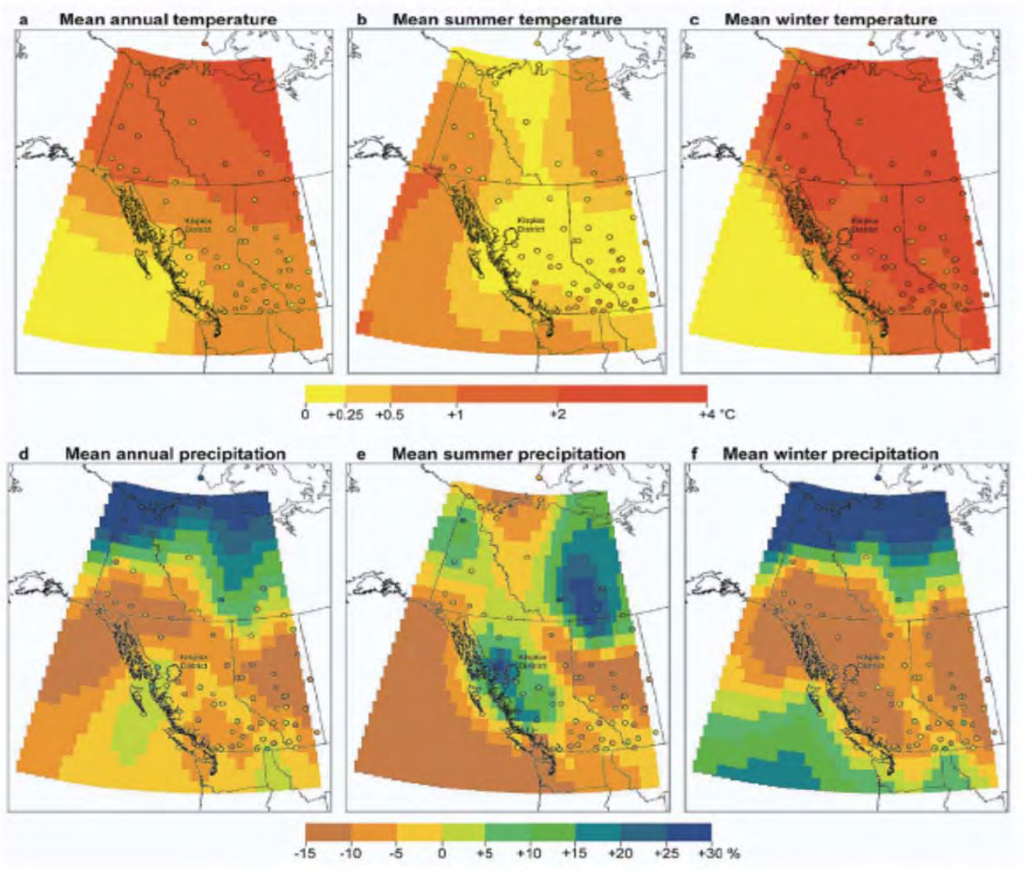
Climate & Pest Dynamic

- The mountain pine beetle is a native insect of the pine forests of western North America.
- The current outbreak in British Columbia is an order of magnitude larger than all previously recorded outbreaks.
- Maximum annual beetle impact (20 Mt C) is of similar magnitude to forest fire emissions from all of Canada during 1959–1999 (27 Mt C).



W. A. Kurz et al., Nature 452, 987 (2008).

Climate & Pest Dynamic



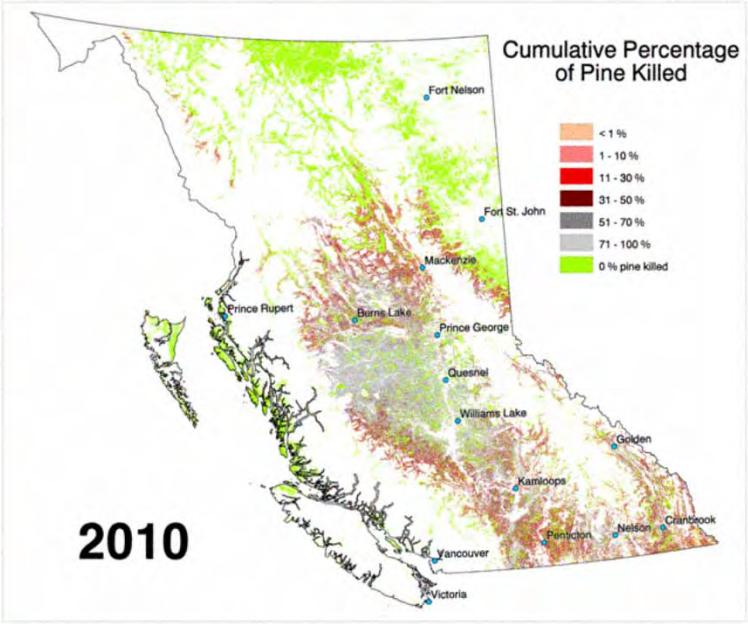
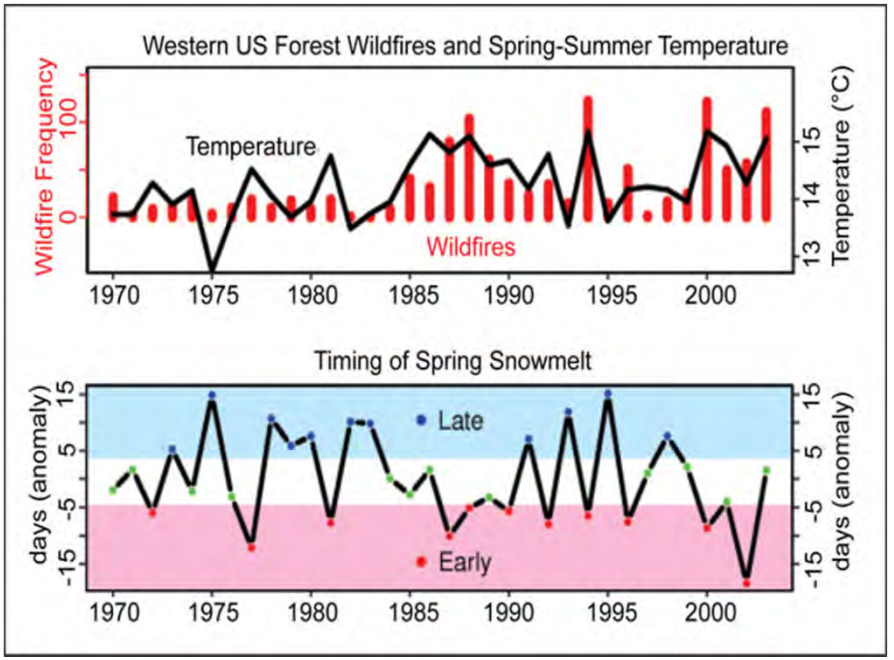


Figure 3. Changes in temperature and precipitation from the 1960–1991 normal period to the 1998–2002 average, observed by weather stations (circles) and interpolated using thin plate spline techniques (colored areas).

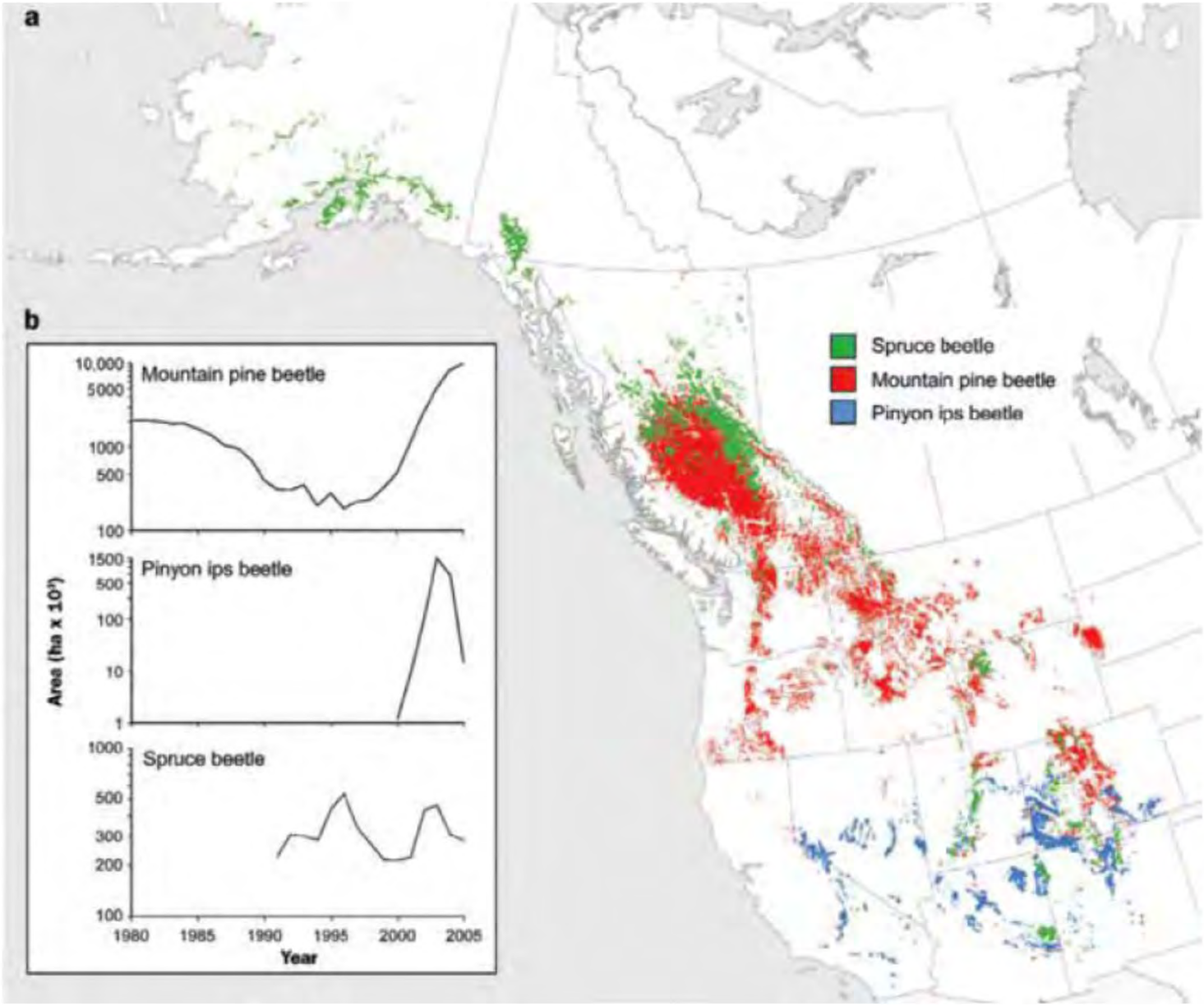
Woods et al., Bioscience 2005

How Does Climate Influence Pest Dynamic?

- **Climate change influence frequency, intensity, and distribution of outbreak.**
- **Elevated Temperature:**
  - **Reduces wintertime bark beetle mortality.**
  - **Reduces the time needed to complete a lifecycle.**
- **Drought Stress:**
  - **Weakened tree defense.**
  - **Younger trees become susceptible to infestation.**



Climate & Pest Dynamic



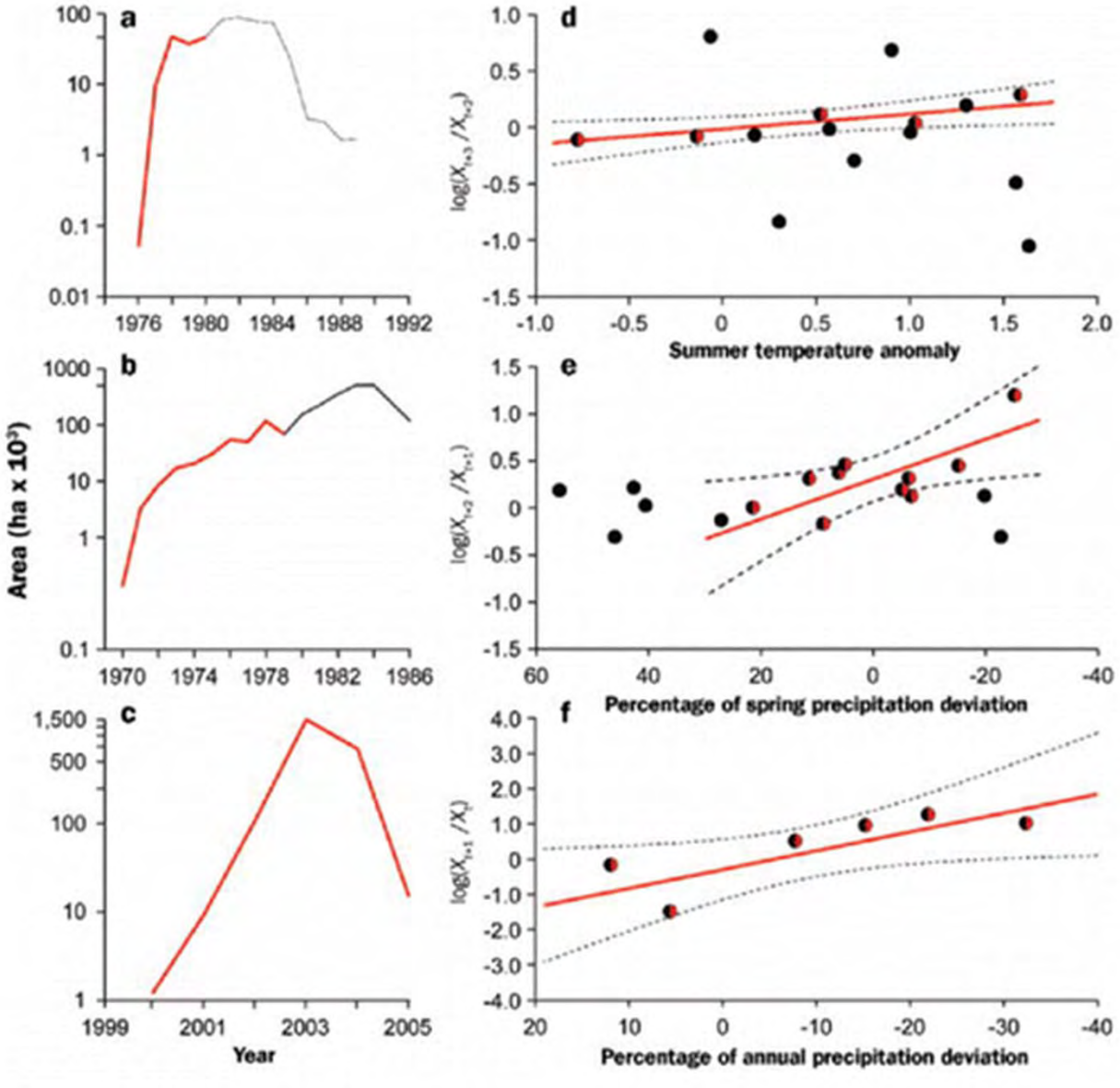
Raffa et al Bioscience 2008

Climate & Pest Dynamic

(a) spruce beetle in central British Columbia, Canada

(b) mountain pine beetle in southern British Columbia

(c) pinyon ips beetle in the US Southwest



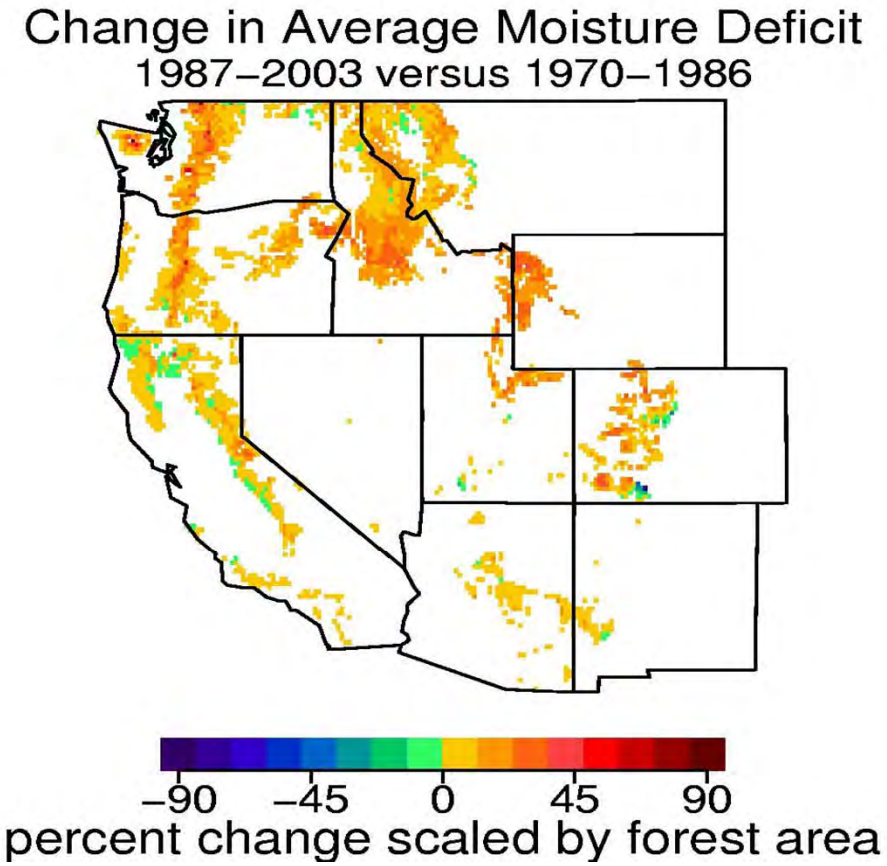
Raffa et al Bioscience 2008

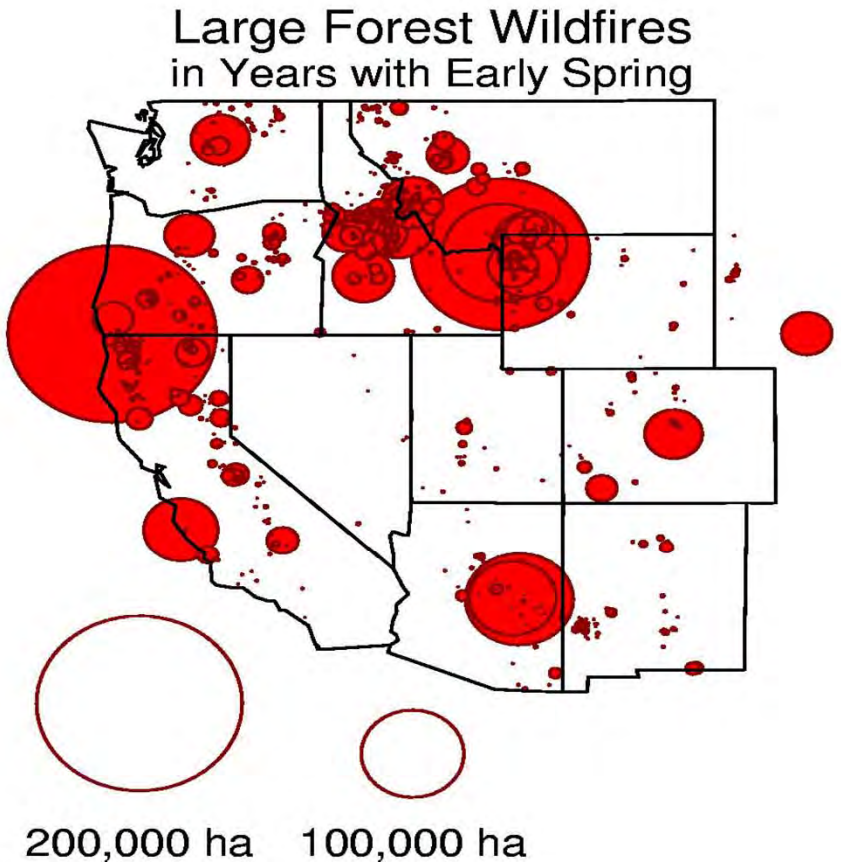
Is there evidence that climate change is affecting forest dynamics: Forest Pest Dynamic?

Yes, Compelling Evidence

Is there evidence that climate change is affecting forest dynamics: Wildfire Dynamic?

Wildfire Dynamic





Less moisture—more fires. Between 1970 and 2003, spring and summer moisture availability declined in many forests in the western United States. During the same time span, most wildfires exceeding 1000 ha in burned area occurred in these regions of reduced moisture availability.

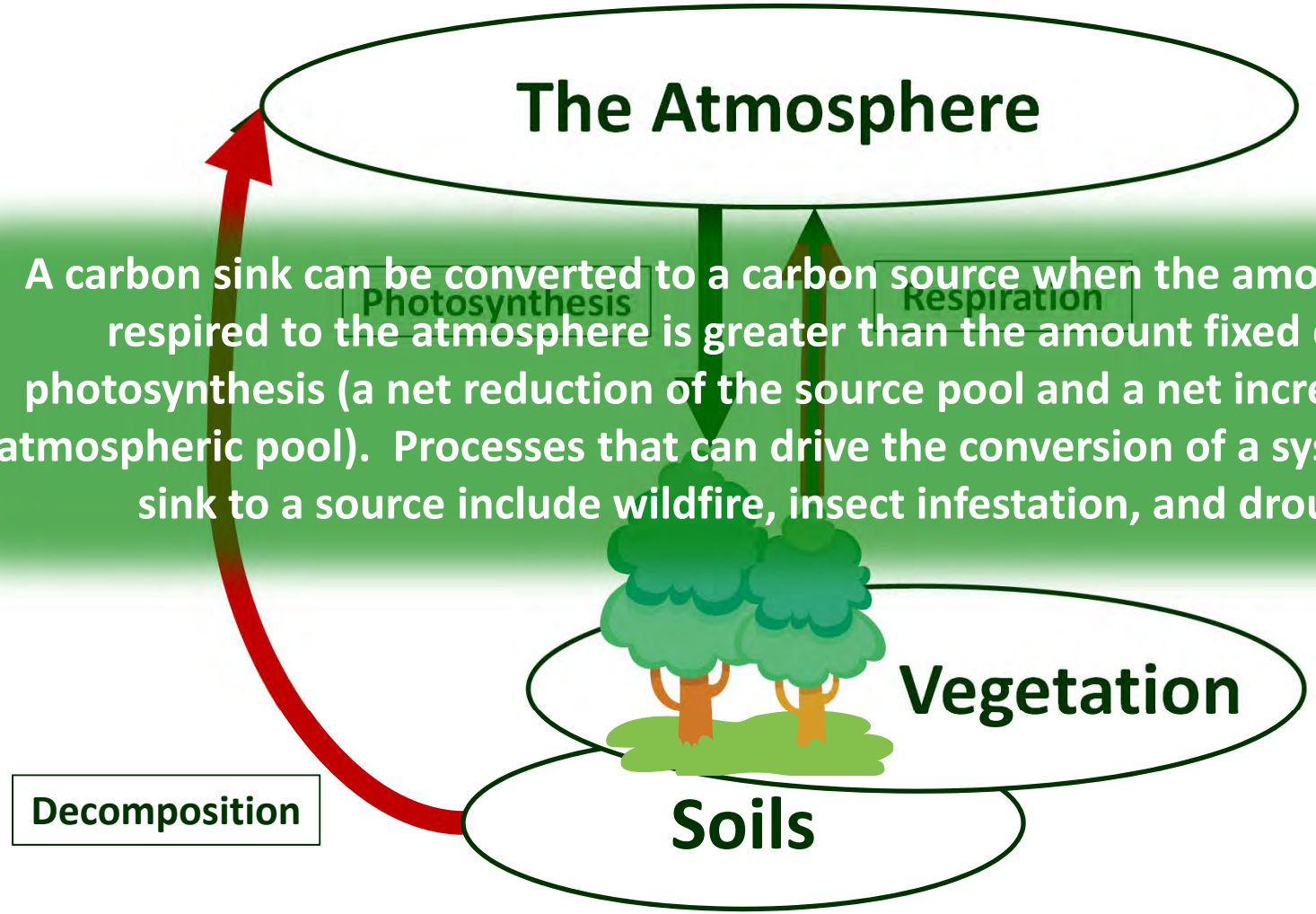
Westerling et al. Science 2006; Running, Science 2006

Is there evidence that climate change is affecting forest dynamics: Wildfire Dynamic?

Yes, Compelling Evidence

Is there evidence that climate change is affecting forest dynamics: Carbon Storage?

What Would Cause a Shift from Carbon Sink to Source??



A carbon sink can be converted to a carbon source when the amount of CO_2 respired to the atmosphere is greater than the amount fixed during photosynthesis (a net reduction of the source pool and a net increase in the atmospheric pool). Processes that can drive the conversion of a system from a sink to a source include wildfire, insect infestation, and drought.

Carbon Sink to Source

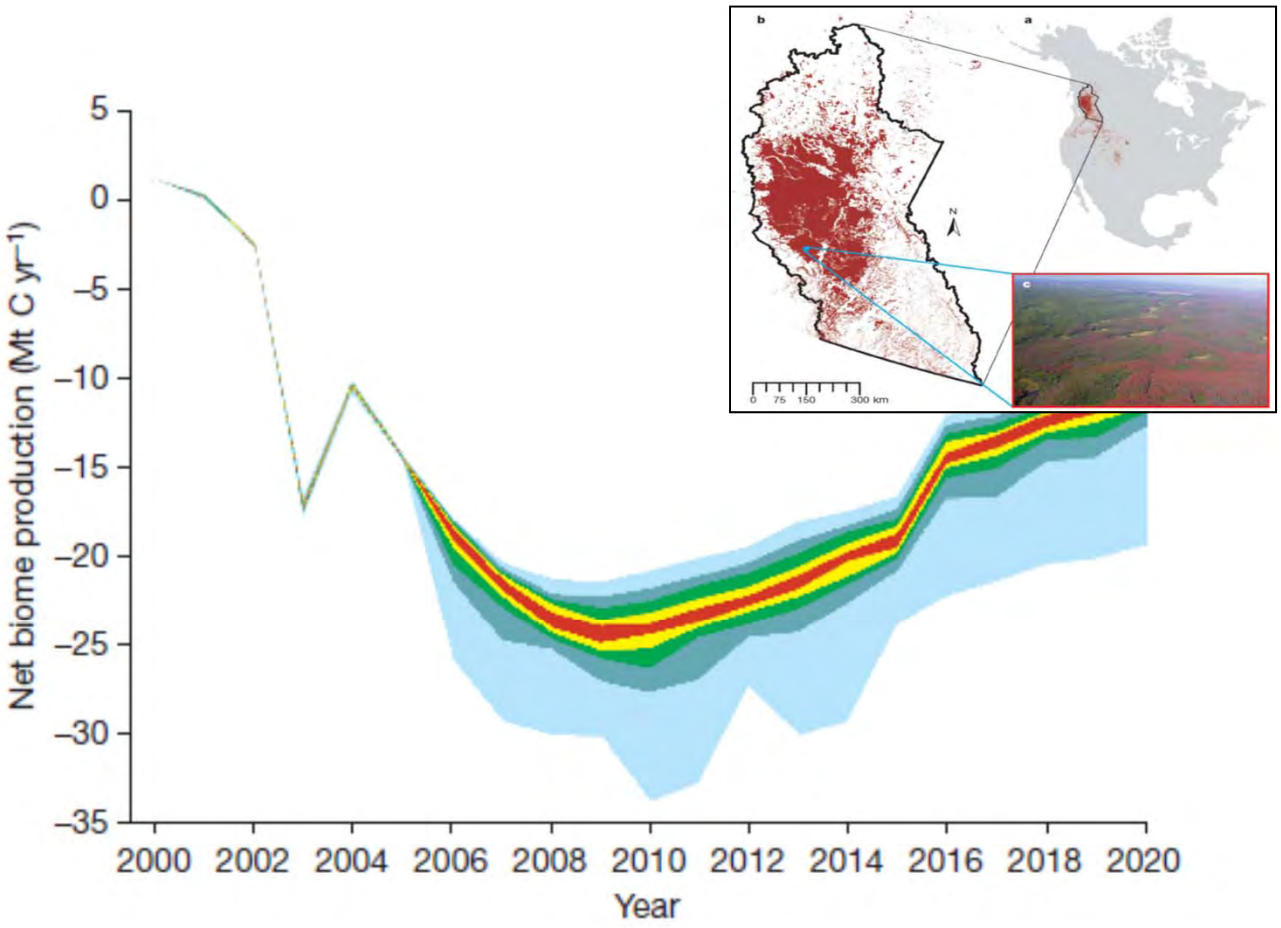
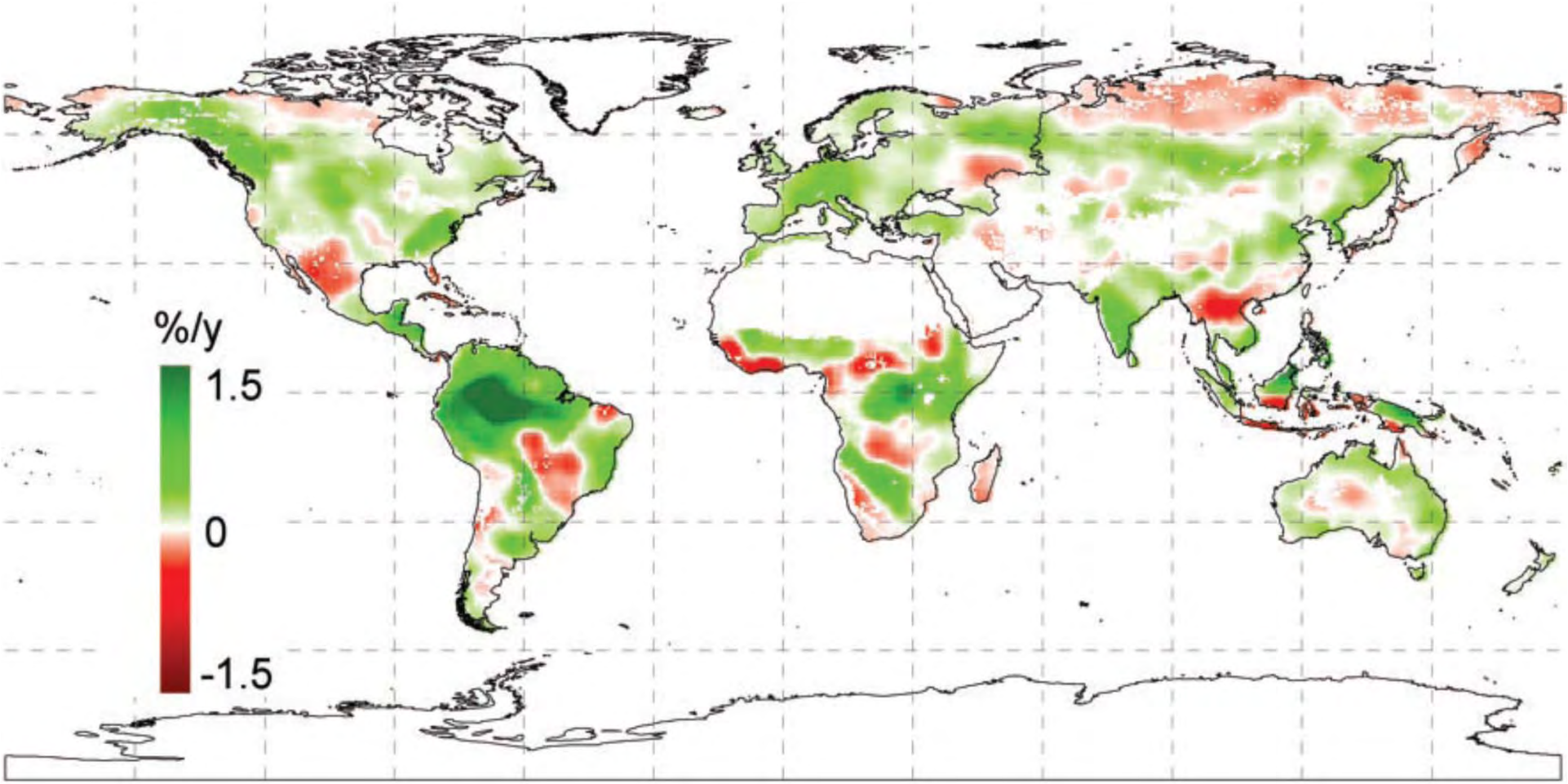


Figure 2 | Annual NBP by percentile from the Monte Carlo simulations. The model results are based on statistics from 2000 to 2006 and projections from 2007 to 2020. Negative values represent fluxes from the forest to the atmosphere (a net source of carbon). Asymmetry of the range of estimates of NBP in any single year is a function of the area burned and the associated direct carbon emissions.

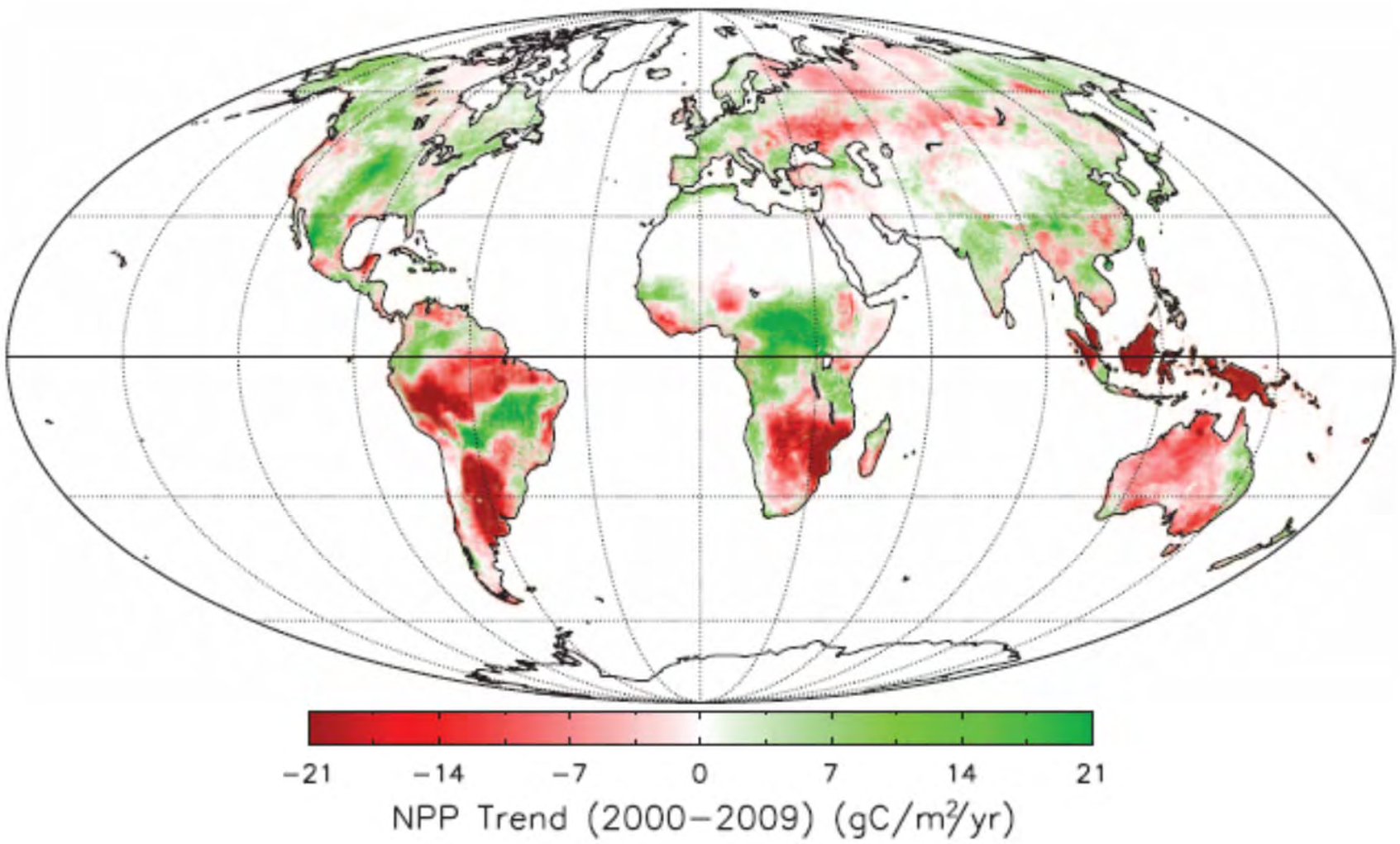
Image From W. A. Kurz et al., Nature 452, 987 (2008).

Climate-Driven Increases in Global Terrestrial Net Primary Production from 1982 to 1999



Nemani et al., Science 2003

Drought-Induced Reduction in Global Net Primary Production from 2000 Through 2009

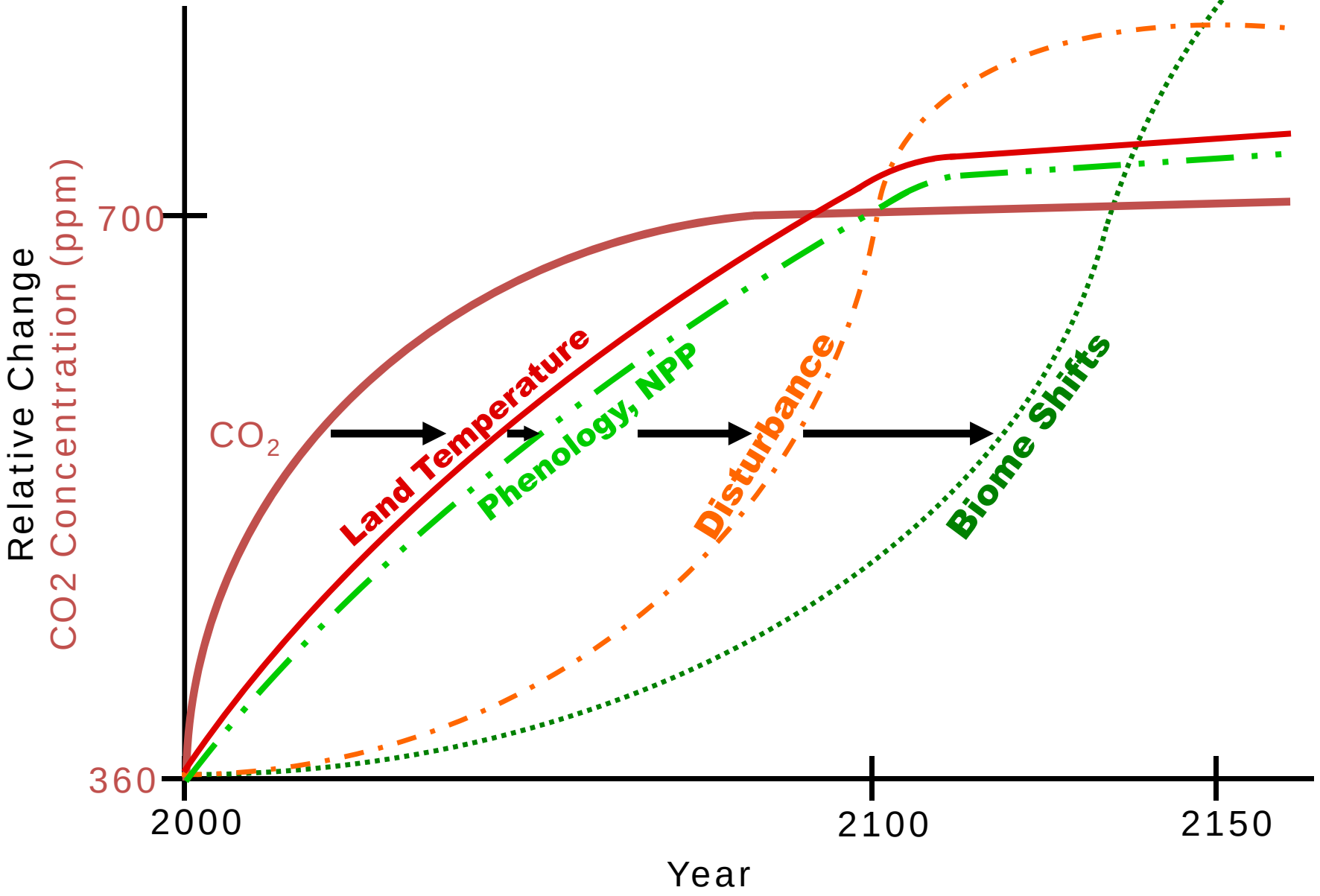


Zhao & Running, Science 2009

Global Net Primary Production

- From 1982 to 1999, climate constraints were relaxing with increasing temperature and solar radiation, allowing an upward trend in NPP.
- The Past decade has been the warmest since instrumental measurement which could imply continued increases in NPP.
- However, research suggests large scale droughts have reduced NPP.
- A continued decline in NPP would weaken the terrestrial carbon sink

Time Lag in Biospheric Responses to Changing Climate



Summary

- **Evidence from long-term forest plots that forest mortality rates are increasing, and warming seems to be the dominant contributor.**
- **Pest infestations are becoming more common, and climate change appears to be partially responsible, although there are multiple interactions.**
- **3. Climate change indices are correlated with increases in fire frequency and magnitude, but there are also other controlling factors (e.g., fire suppression).**
- **4. A little bit of global warming could be good for northern hemisphere forest C storage (with some important caveats).**