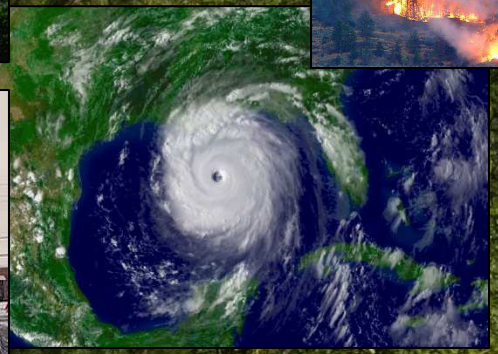
Hydrologic Effects of a Changing Forest Landscape








Paul K. Barten, Ph.D.
Associate Professor of Forest Resources
University of Massachusetts Amherst

Presentation Outline

- The National Academies
- Sponsors ...and Charge to Committee
- Expanded scope adopted by the Committee
- Summary of US Water Management

Focusing on prospects for water yield augmentation

- Key patterns and processes
- Findings ...Conclusions ...Recommendations
- Questions and discussion

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

- National Academy of Sciences (1863)
- National Research Council (1916)
- National Academy of Engineering (1964)
- Institute of Medicine (1970)

National Research Council

- Divisions (e.g., Earth and Life Sciences)
  - Boards (e.g., Water Science and Technology)
    - Committees (assisted by NRC staff)

COMMITTEE ON HYDROLOGIC IMPACTS OF FOREST MANAGEMENT

Sponsors

- Bureau of Reclamation (USDI)
  - irrigation
  - hydropower
  - municipal & industrial (M&I)
  - recreation

  (Appropriation Doctrine)
  (Irrigation allotments)

- US Forest Service (USDA)
  - National Forest System
  - State and Private Forestry
  - International Forestry
  - Research

Land: BLM > USFS > National Park Service > Private

Statement of Task (Charge to Committee)

1. What is the state-of-the-science of forest hydrology?

2. What are information and research needs

3. What new issues need to be addressed to ensure clean and plentiful water?

4. How well are forest hydrologic impacts [*effects, influences*] understood over short- and long-term temporal scales ...and small and large spatial scales?

1. relatively good;
2. institutions, public engagement, mapping, modeling, forecasting;
3. forest loss [sprawl] and climate change;
4. sufficient/insufficient and sufficient/insufficient.

COMMITTEE ON HYDROLOGIC IMPACTS OF FOREST MANAGEMENT

PAUL K. BARTEN, *Chair*, University of Massachusetts, Amherst
JULIA A. JONES, *Vice-Chair*, Oregon State University, Corvallis
GAIL L. ACHTERMAN, Oregon State University, Corvallis
KENNETH N. BROOKS, University of Minnesota, St. Paul
IRENA F. CREED, The University of Western Ontario, Canada
PETER F. FFOLLIOTT, University of Arizona, Tucson
ANNE HAIRSTON-STRANG, Maryland Department of Natural Resources, Annapolis
MICHAEL C. KAVANAUGH, Malcolm Pirnie, Inc., Emeryville, CA
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RONALD C. SMITH, Tuskegee University, Tuskegee, AL
DANIEL B. TINKER, University of Wyoming, Laramie
SUZANNE B. WALKER, Azimuth Forest Services, Shelbyville, TX
BEVERLEY C. WEMPLE, University of Vermont, Burlington
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Hydrologic Effects of a Changing Forest Landscape

National Research Council Staff

LAUREN E. ALEXANDER, Study Director
ELLEN A. DE GUZMAN, Research Associate
JULIE VANO, Consultant

Short Course in US Water Resource Management

1. Water is a renewable natural resource ...*but* effective supply is finite and temporally variable.

2. Water is an essential natural resource.

   ~20 liters/person/day in 1900 (80,000,000)

   ~300 liters/person/day today (305,000,000)

3. Water flows downhill.

4. Water can flow uphill to power and money.

"We have only two modes – complacency and panic."

Sec. James R. Schlesinger, Dept. of Energy, 1977

Water 2025:
Preventing Crises and Conflict in the West

Water 2025 Status Report

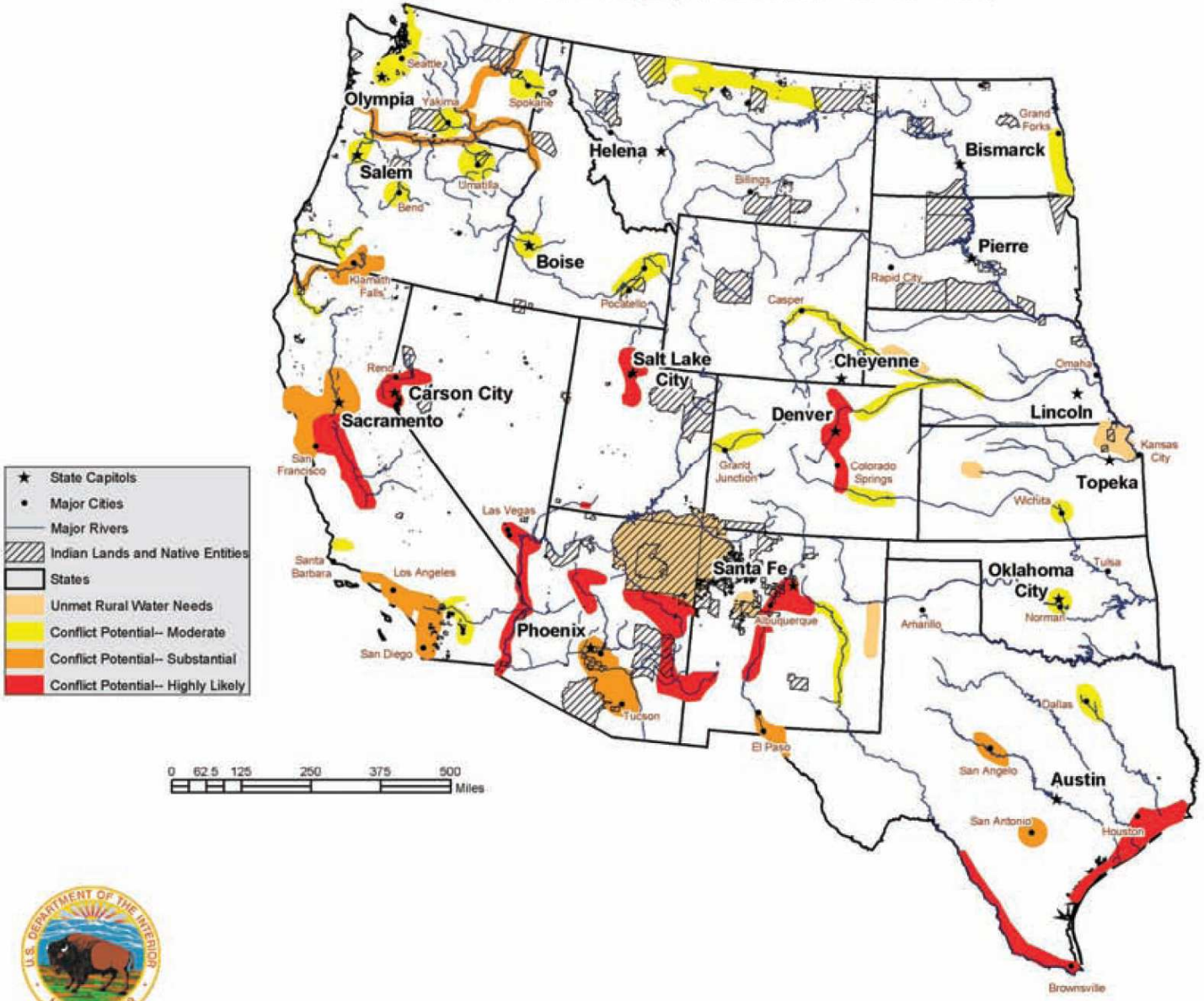
August 2005

U.S. DEPARTMENT OF THE INTERIOR
MARCH 3, 1849

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

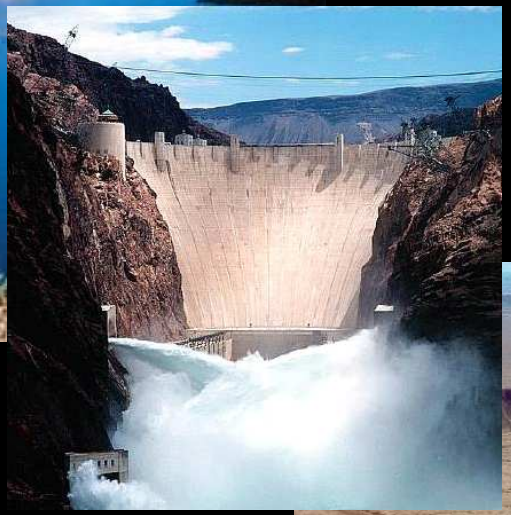
Potential Water Supply Crises by 2025

(Areas where existing supplies are not adequate to meet water demands for people, for farms, and for the environment)



May 2003

Lake Mead

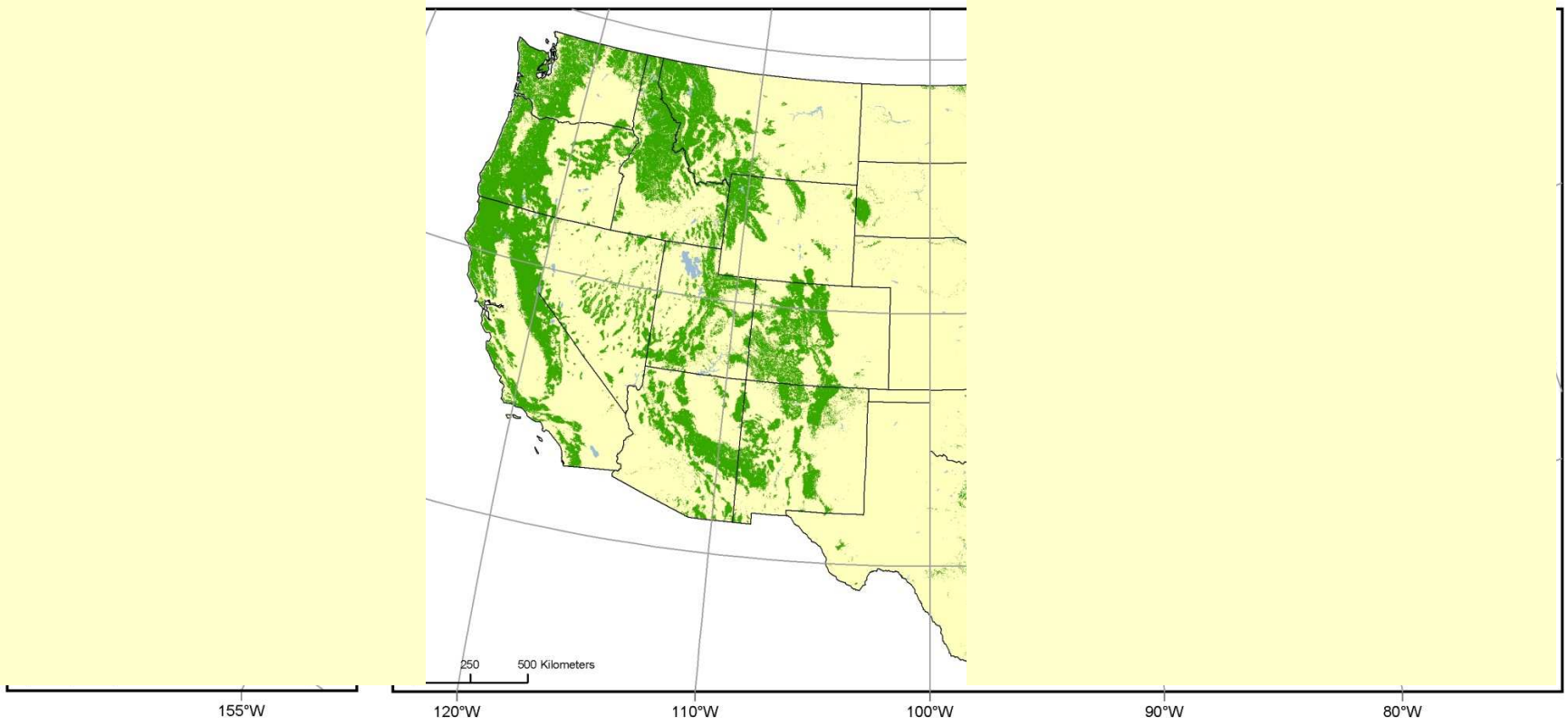


Hoover Dam

Mgt. Paradigm?

- ~~Supply Augmentation~~
- ~~System Efficiency~~
- Demand Management
- Source Protection

Central ↑ Arizona Project



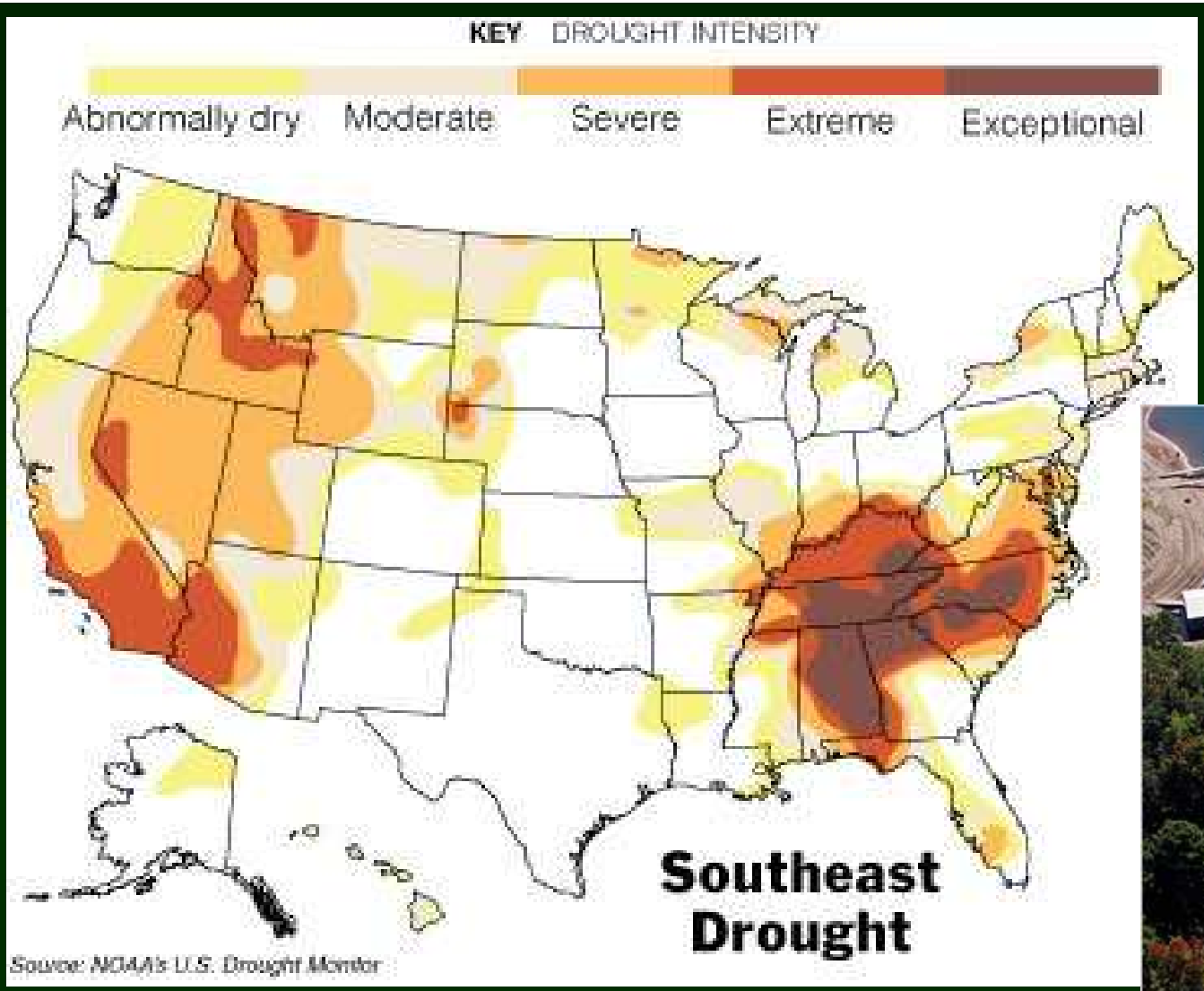
Forest Cover

- Forest
- Non-forest
- Water

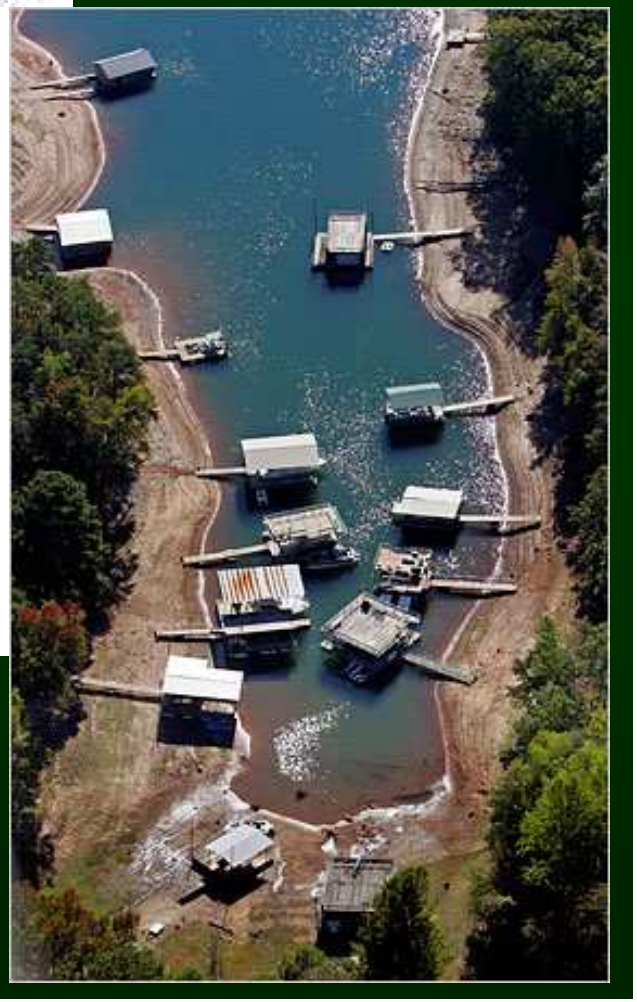
Data source: Forest cover types - U.S. Geological Survey (USGS) and the U.S. Department of Agriculture (USDA) Forest Service , Forest Inventory and Analysis Program.

Map projection: Lambert Azimuthal Equal-area

Map created by the Catchment Research Facility, The University of Western Ontario.



New York Times (October 2007) and NOAA



Lake Lanier
Atlanta, Georgia

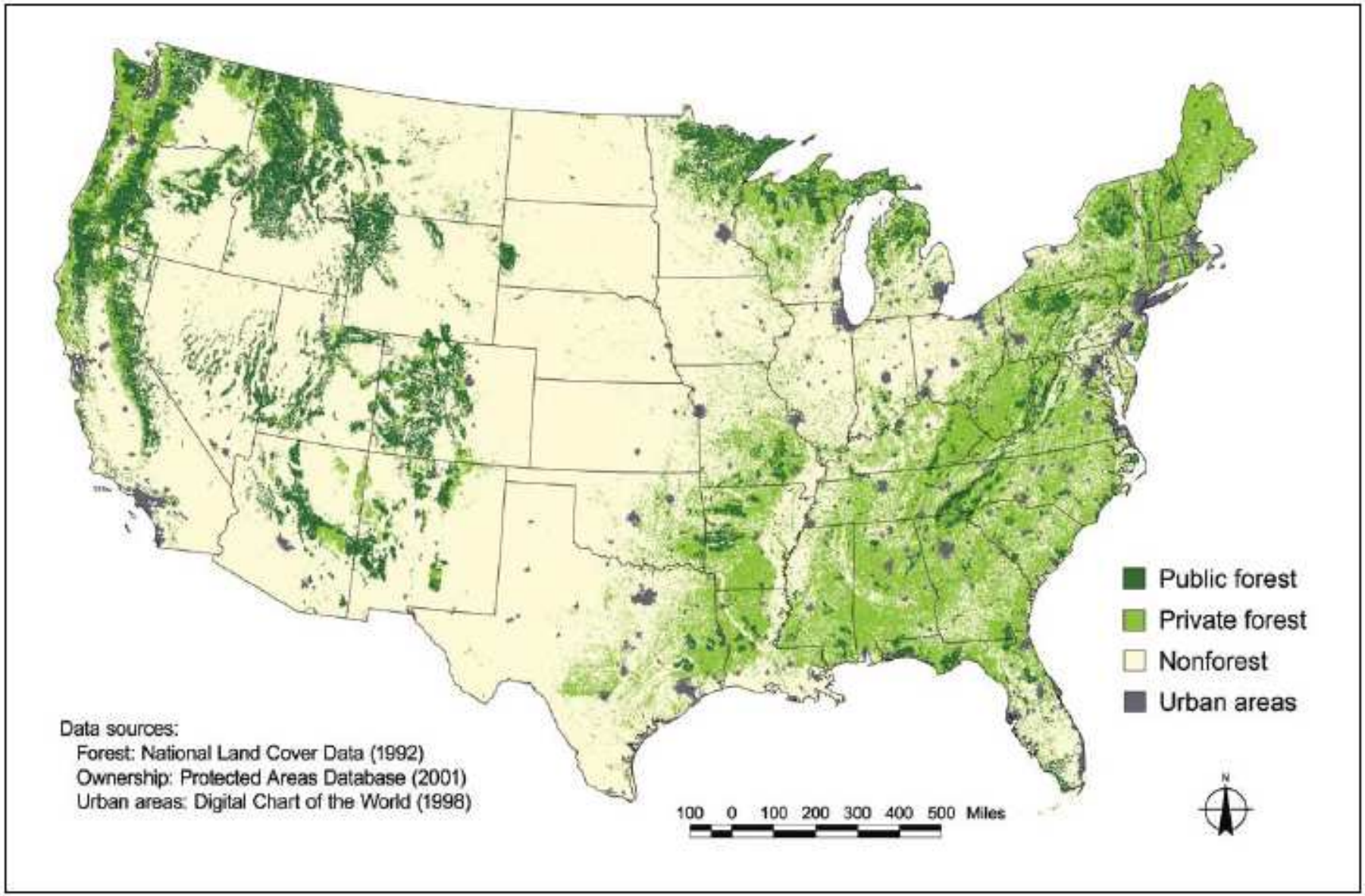
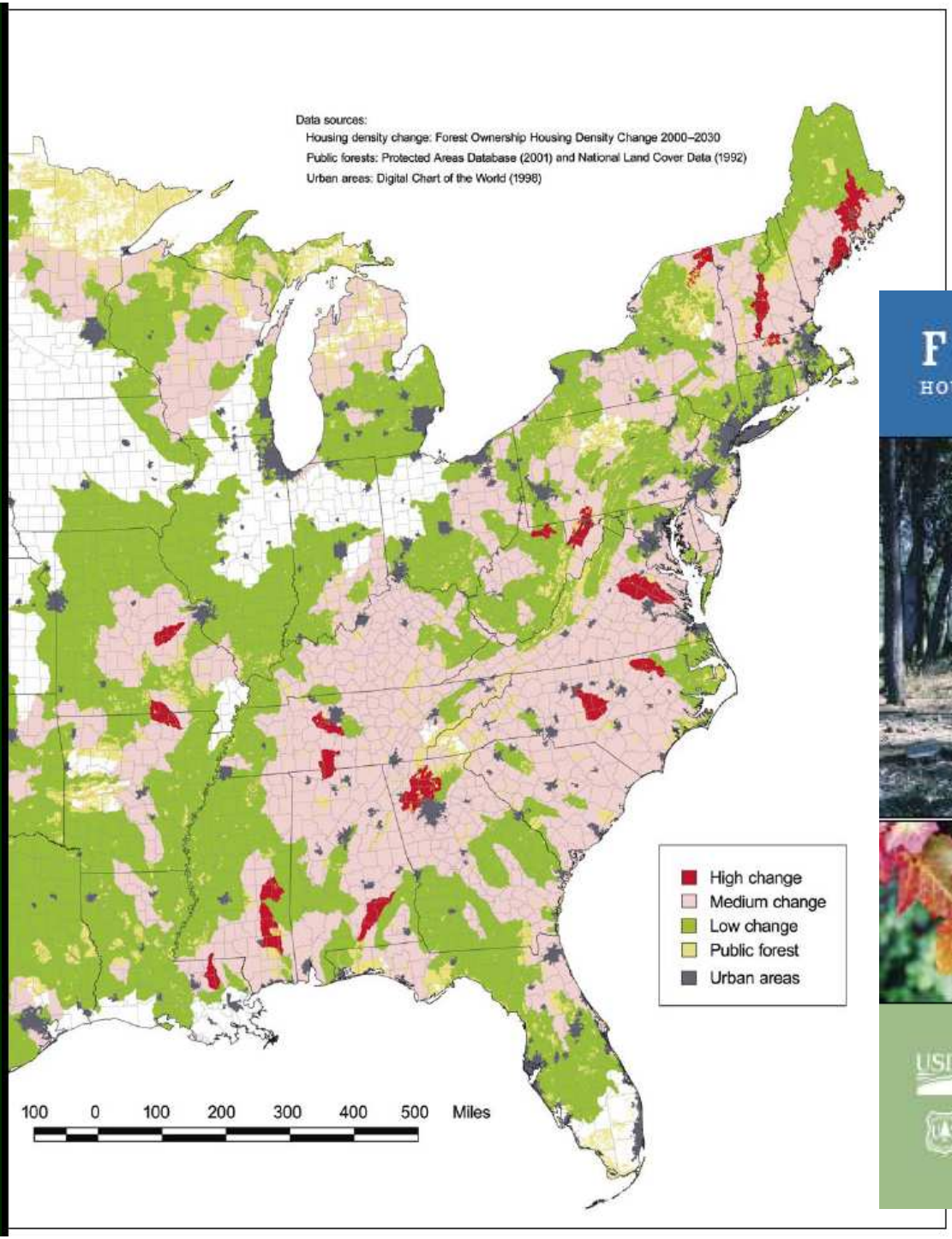
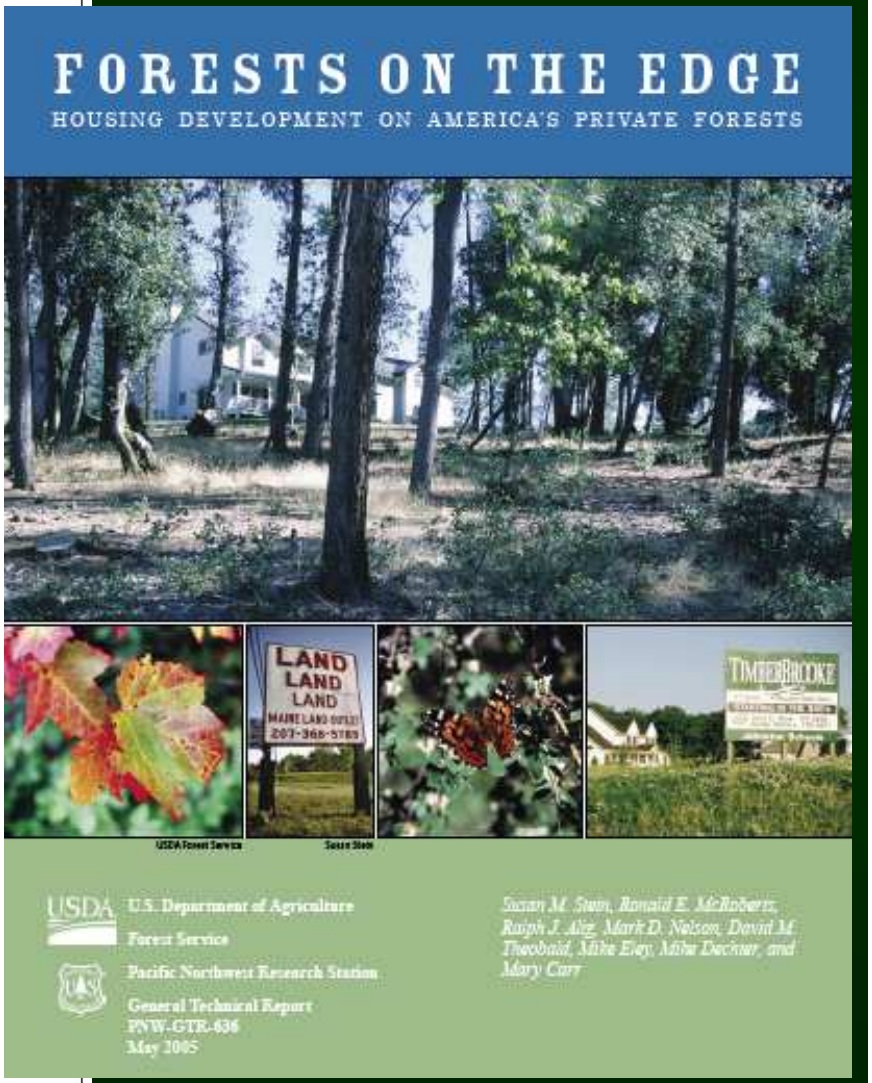


Figure 1—Location of private and public forest, nonforest, and urban areas. About three-quarters of America's private forests are in the East.

Stein *et al.* 2005. Forests on the Edge: Housing Development on America's Private Forests

Forest Conversion by 2030 US Pop. ~364,000,000





"Climate Change Effects on Natural Resources: Avoiding the Unmanageable and Managing the Unavoidable on America's Federal Public Lands."

V. Alaric Sample
Pinchot Institute for Conservation (Spring 2008)

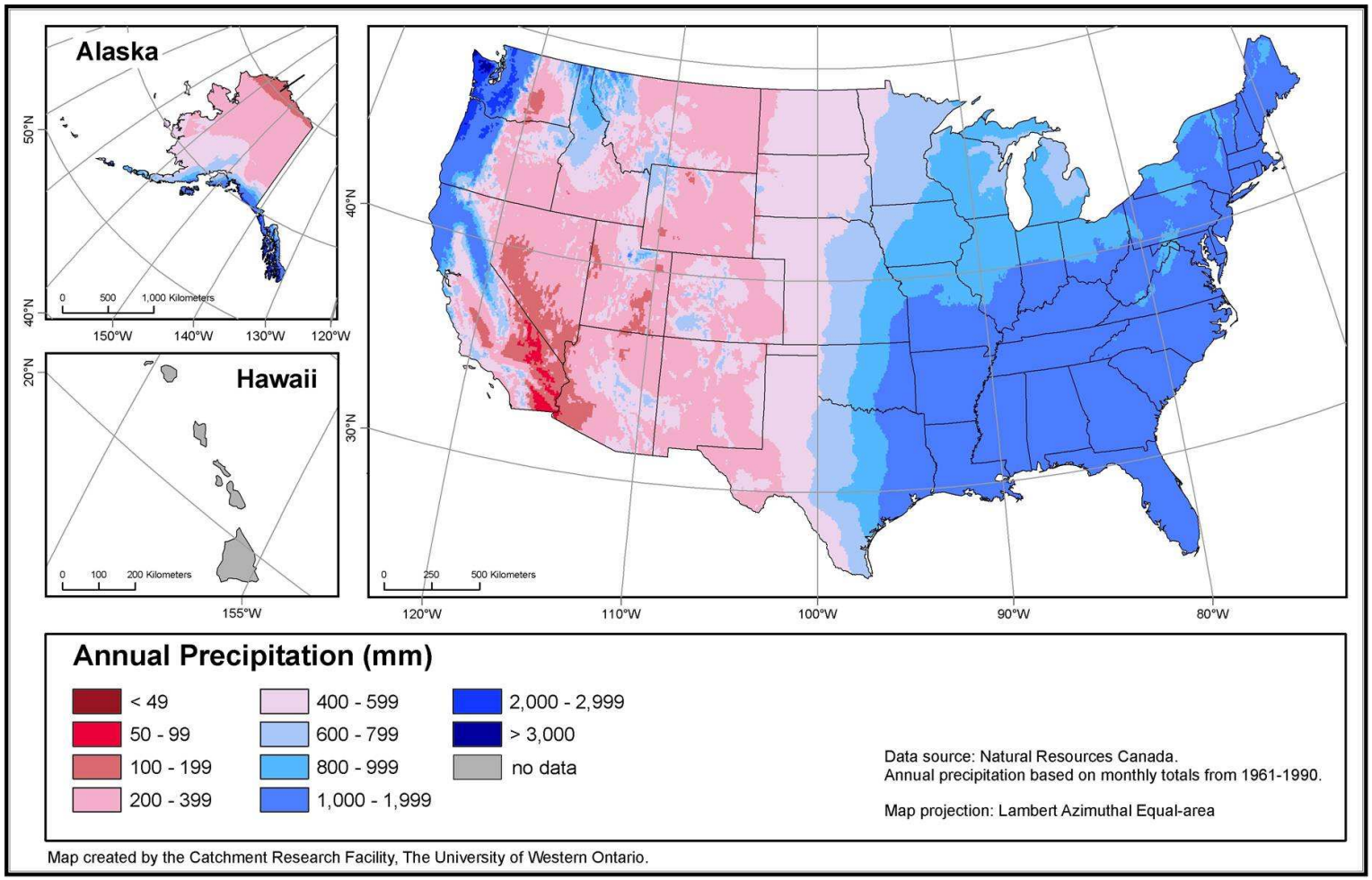
Avoiding the Unmanageable

- irreconcilable conflicts w/r to land and resource use
- development in high risk areas (wildfire and floods)
- untenable public expectations and political demands

and Managing the Unavoidable

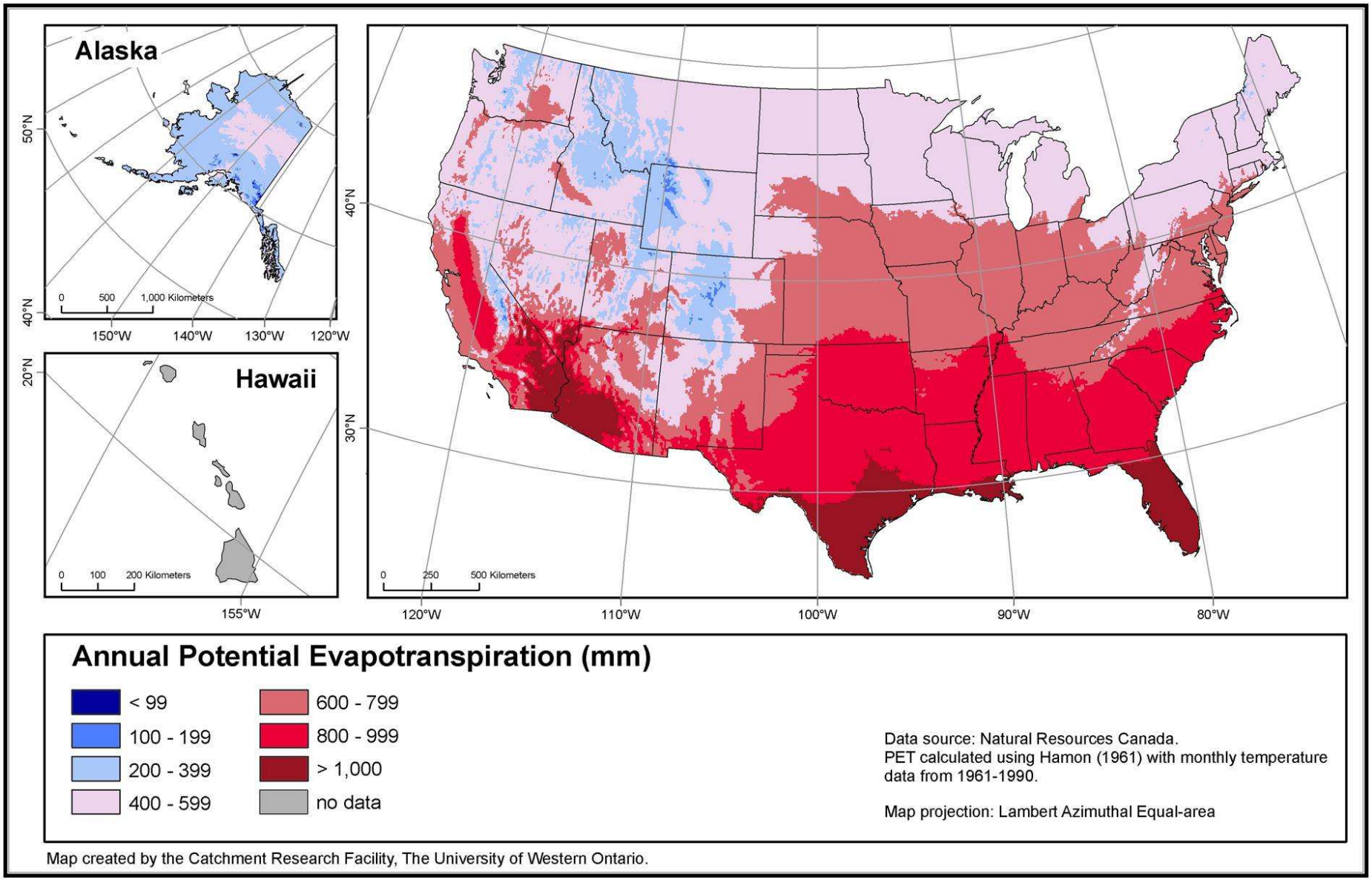
- more water and energy use by a growing population
- development (...if it leads to forest loss)
- threats to public water supplies

Precipitation

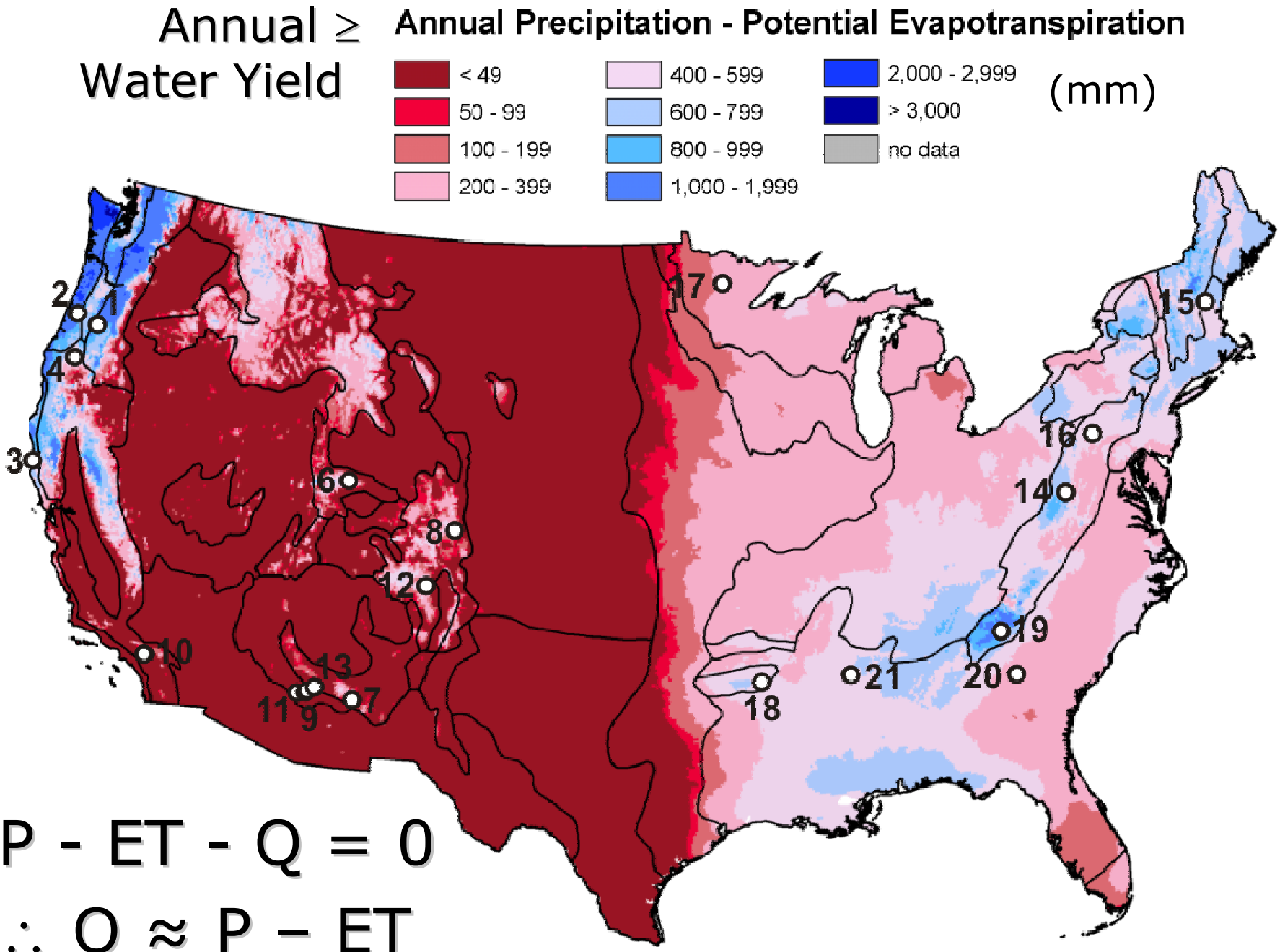


Creed et al., Univ. of Western Ontario, Canada

Potential Evapotranspiration

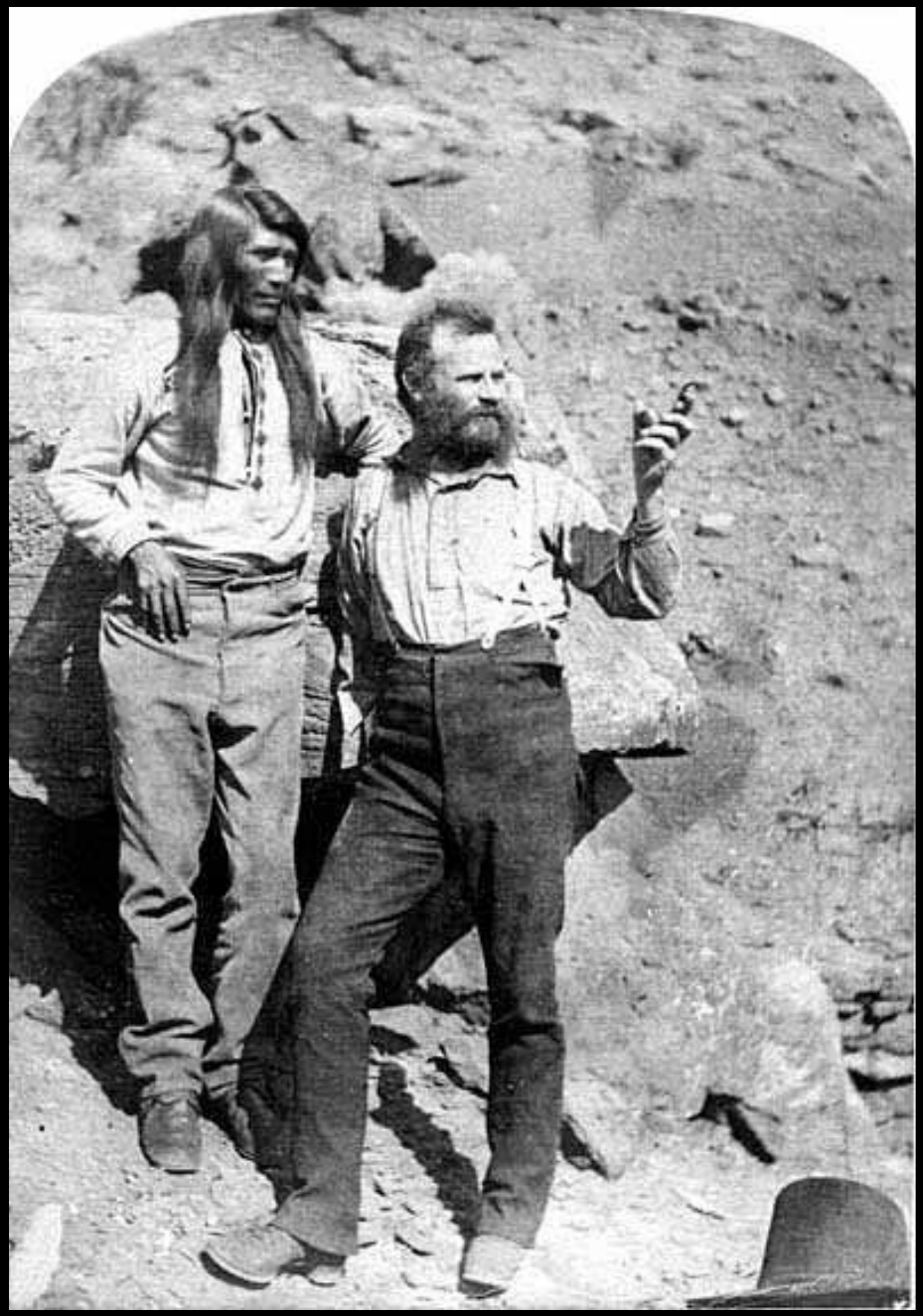


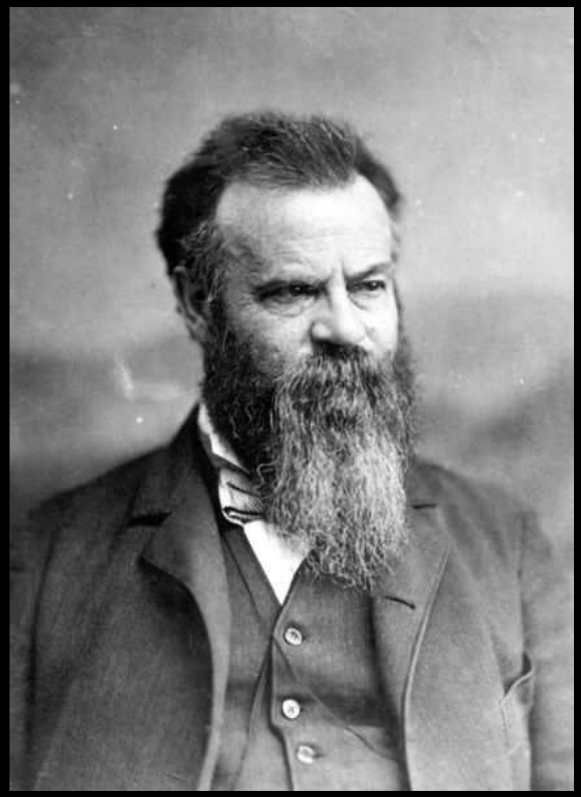
Annual ≥
Water Yield



$$P - ET - Q = 0$$

$$\therefore Q \approx P - ET$$



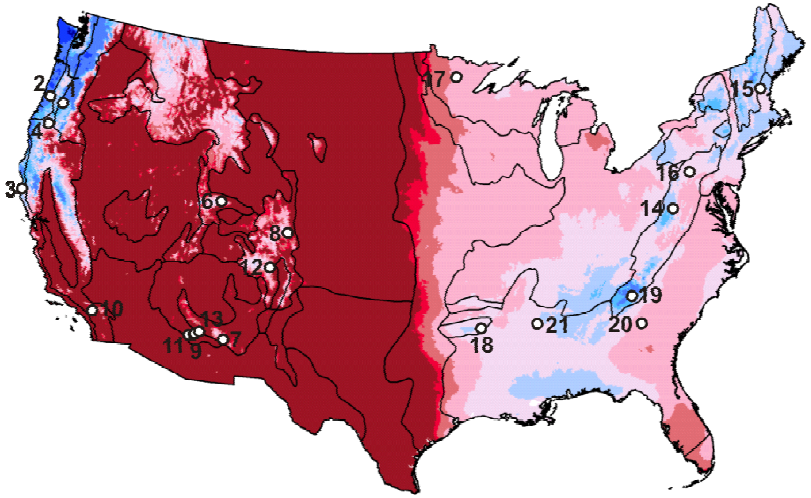


John Wesley Powell
1834-1902

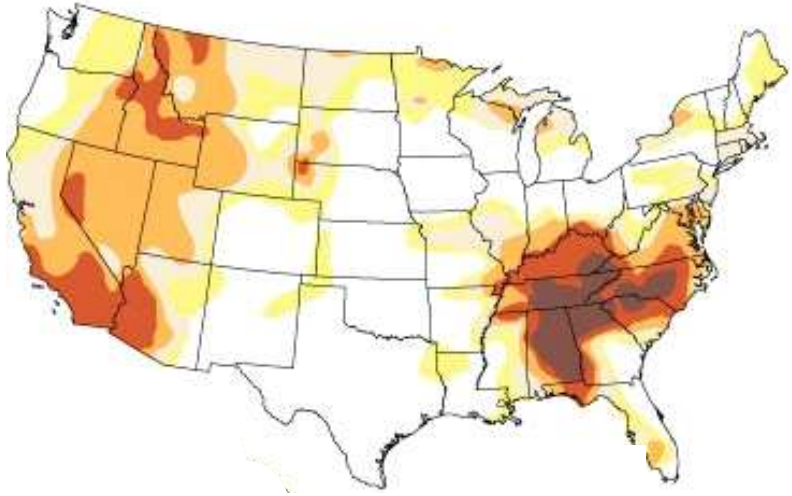
A Report on the Arid Regions of the United States (1876)

- 2% arable land
- Homestead Act allotments (65 hectares) not viable

Mean Annual Water Yield

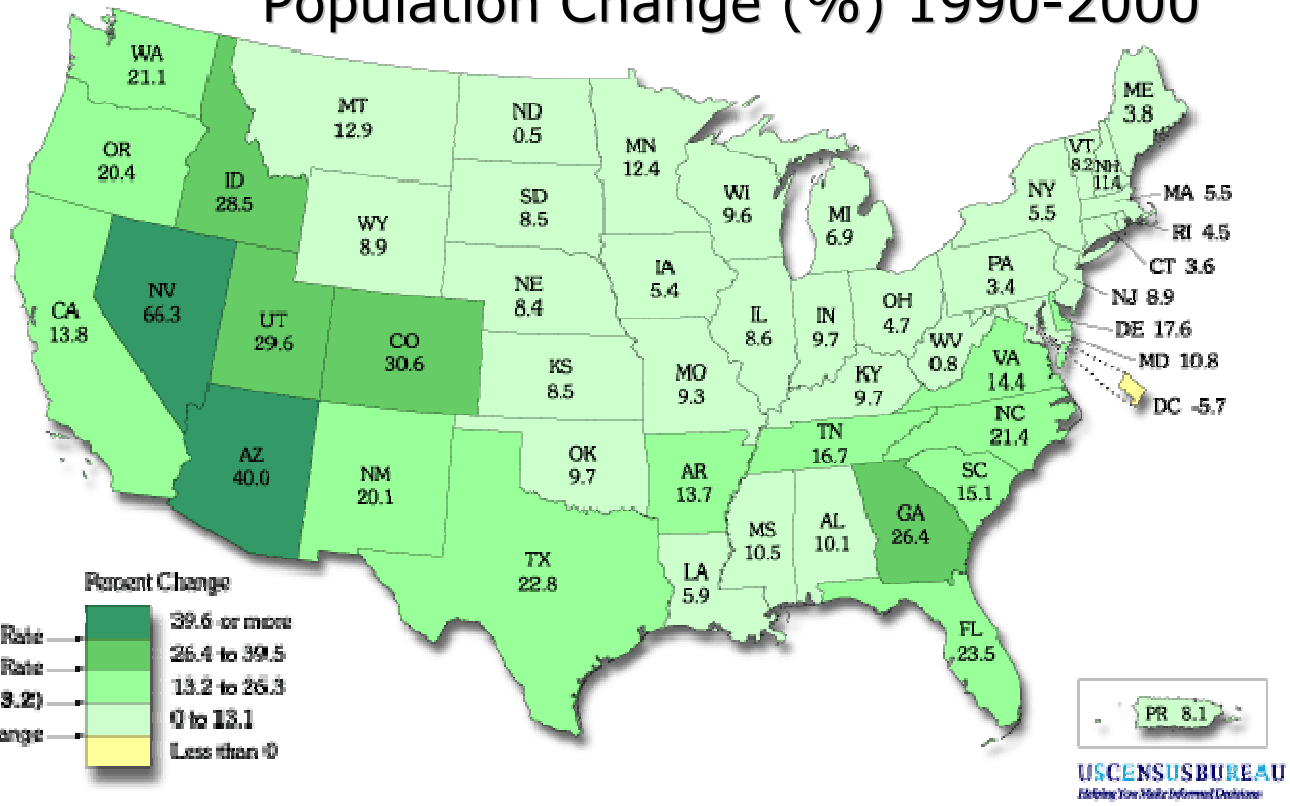


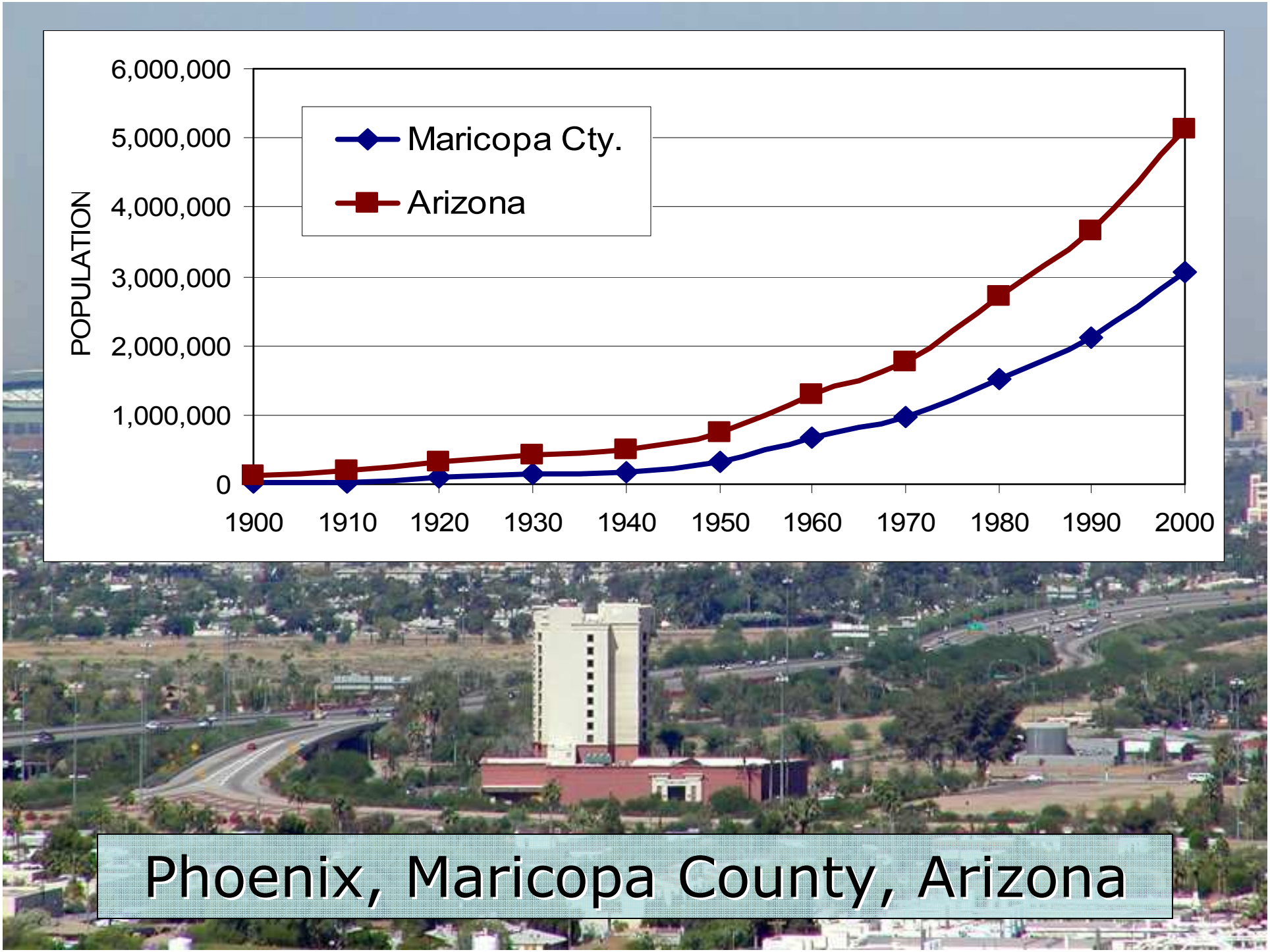
2007 Test of Safe Yield



Hey! ...I *think* I see the problem.

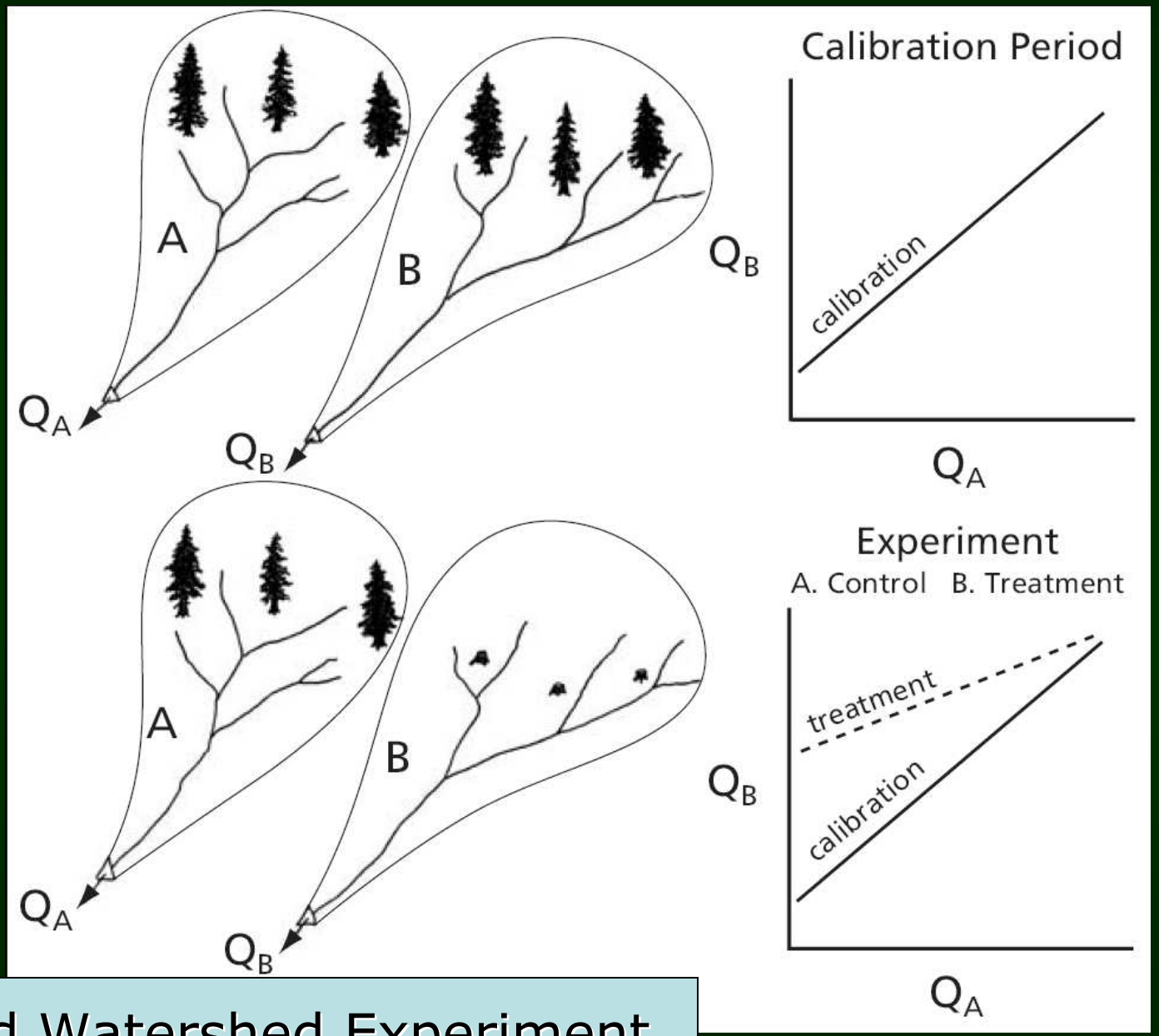
Population Change (%) 1990-2000





Phoenix, Maricopa County, Arizona

Managing Forests to Increase Water Yield



Paired Watershed Experiment

(Brooks et al., 2002)

herbicides
3 years

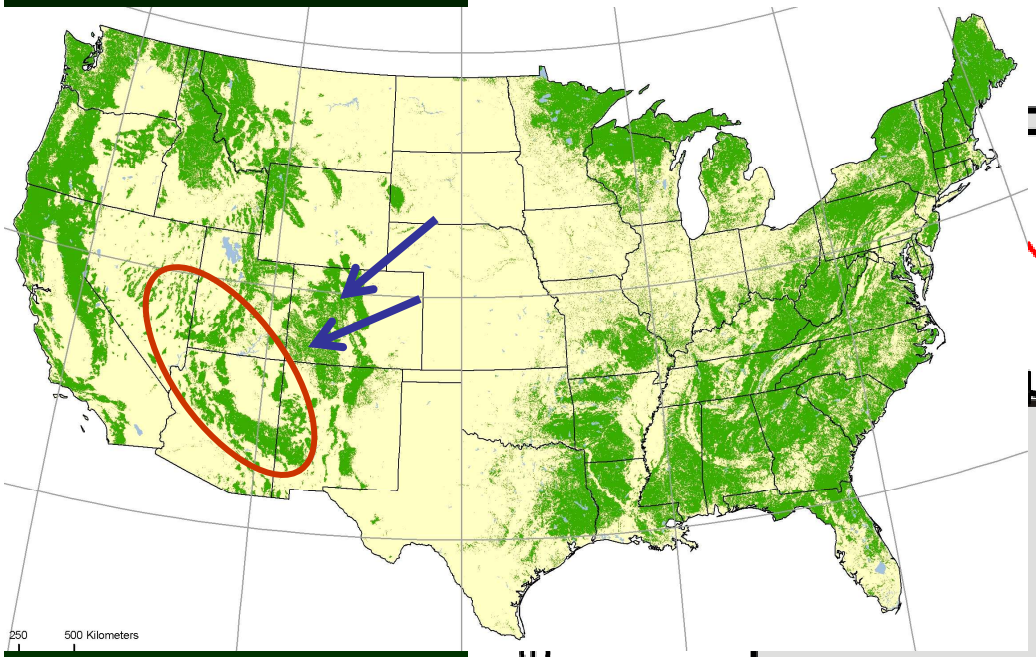
15
14
1996
15
14
17

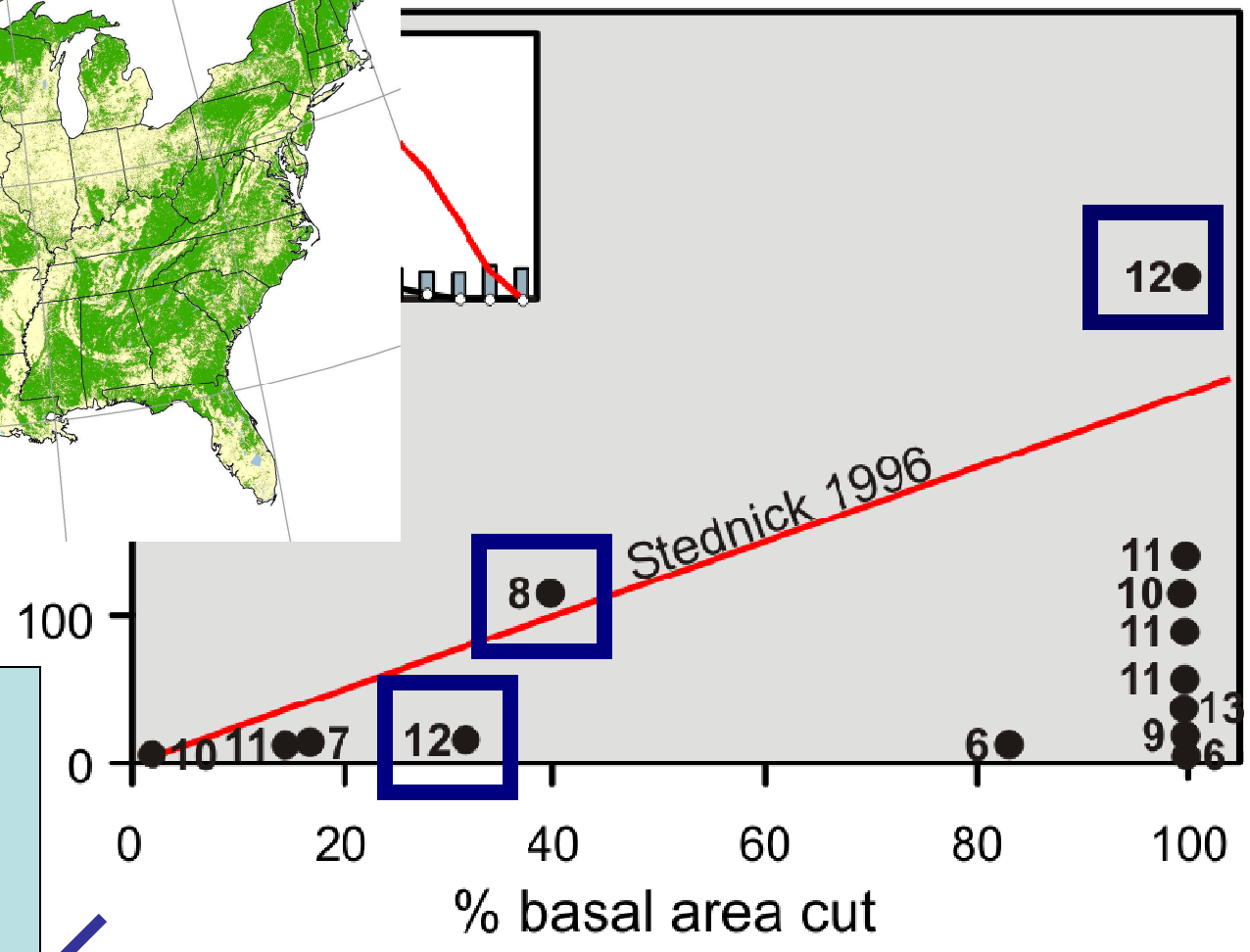
80
100

% basal area cut **3-5 years**

15. Hubbard Brook, NH
16. Leading Ridge, PA
17. Marcell, MN

(NRC 2008, Figure 3-2)

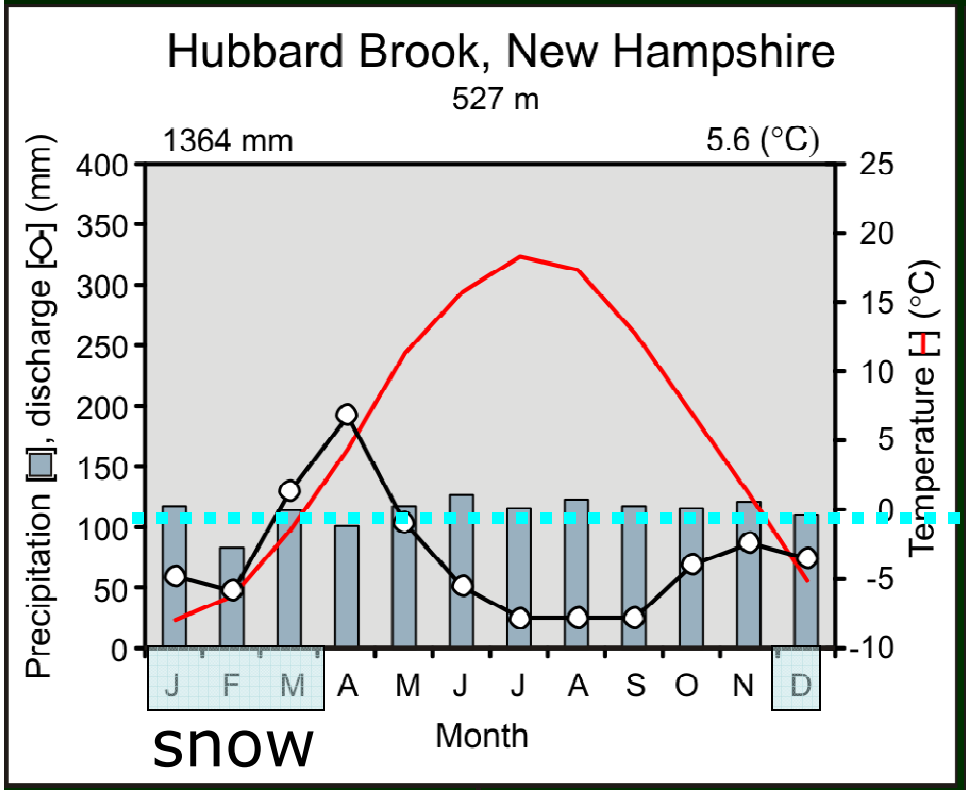


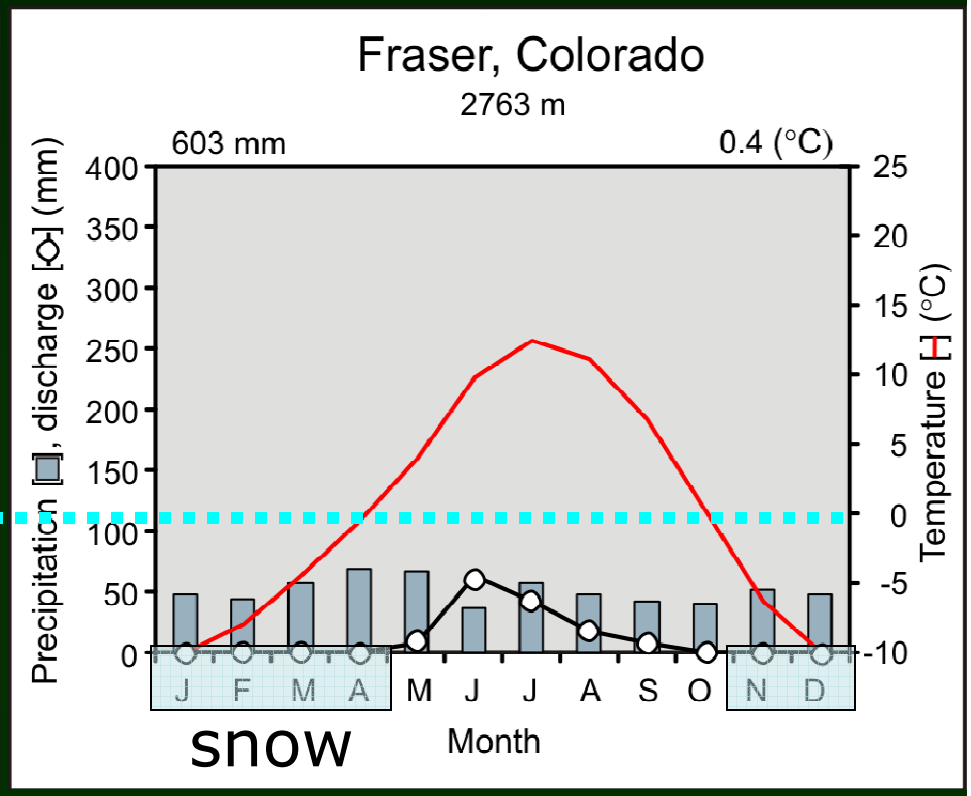


Southwest

6. Beaver Creek, UT
7. Castle Creek, UZ
8. Fraser, CO
9. Natural Drainage, AZ
10. San Dimas, CA
11. Three Bar, AZ
12. Wagon Wheel Gap, CO
13. Workman Creek, AZ

(NRC 2008, Figure 3-2)


Hubbard Brook, New Hampshire
527 m
1364 mm
5.6 (°C)
Precipitation [□], discharge [◇] (mm)
Temperature [┤] (°C)
400
350
300
250
200
150
100
50
0
25
20
15
10
5
0
-5
-10
J F M A M J J A S O N D
snow
Month


Fraser, Colorado
2763 m
603 mm
0.4 (°C)
Precipitation [□], discharge [◇] (mm)
Temperature [┤] (°C)
400
350
300
250
200
150
100
50
0
25
20
15
10
5
0
-5
-10
J F M A M J J A S O N D
snow
Month

E/L Ranch, Greenough, Montana

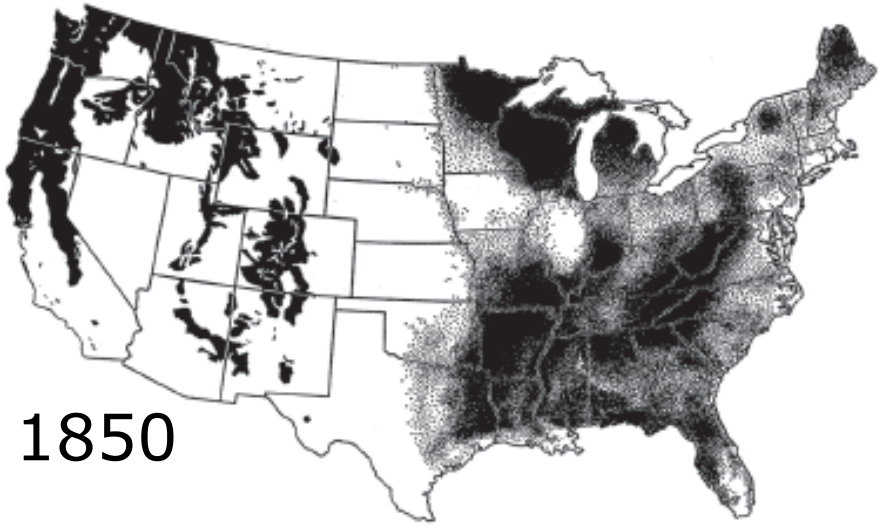
Water yield (Q) increases from harvesting linked to:

1. proportion of biomass removed or area treated
2. post-harvest treatment (burning, herbicides, etc.)
3. Δ species composition (deciduous $\rightarrow$ evergreen)
4. climate and inter-annual variation ($Q \approx P - ET$)
5. seasonal timing of precip. (Growing? ...Dormant?)
6. time since harvest (re-growth rate ...leaf area)
7. soil thickness (carry-over storage …or deficit)
8. *net* effect of all of the above

"Water yield augmentation is, at best, impractical."

Quantity, timing, and quality are inextricably linked.

Photo: US Forest Service



(Greeley 1925)

Each dot ~ 10,000 hectares of virgin forest

"The treatment of the forest wealth of the United States is one long example of prodigal waste."

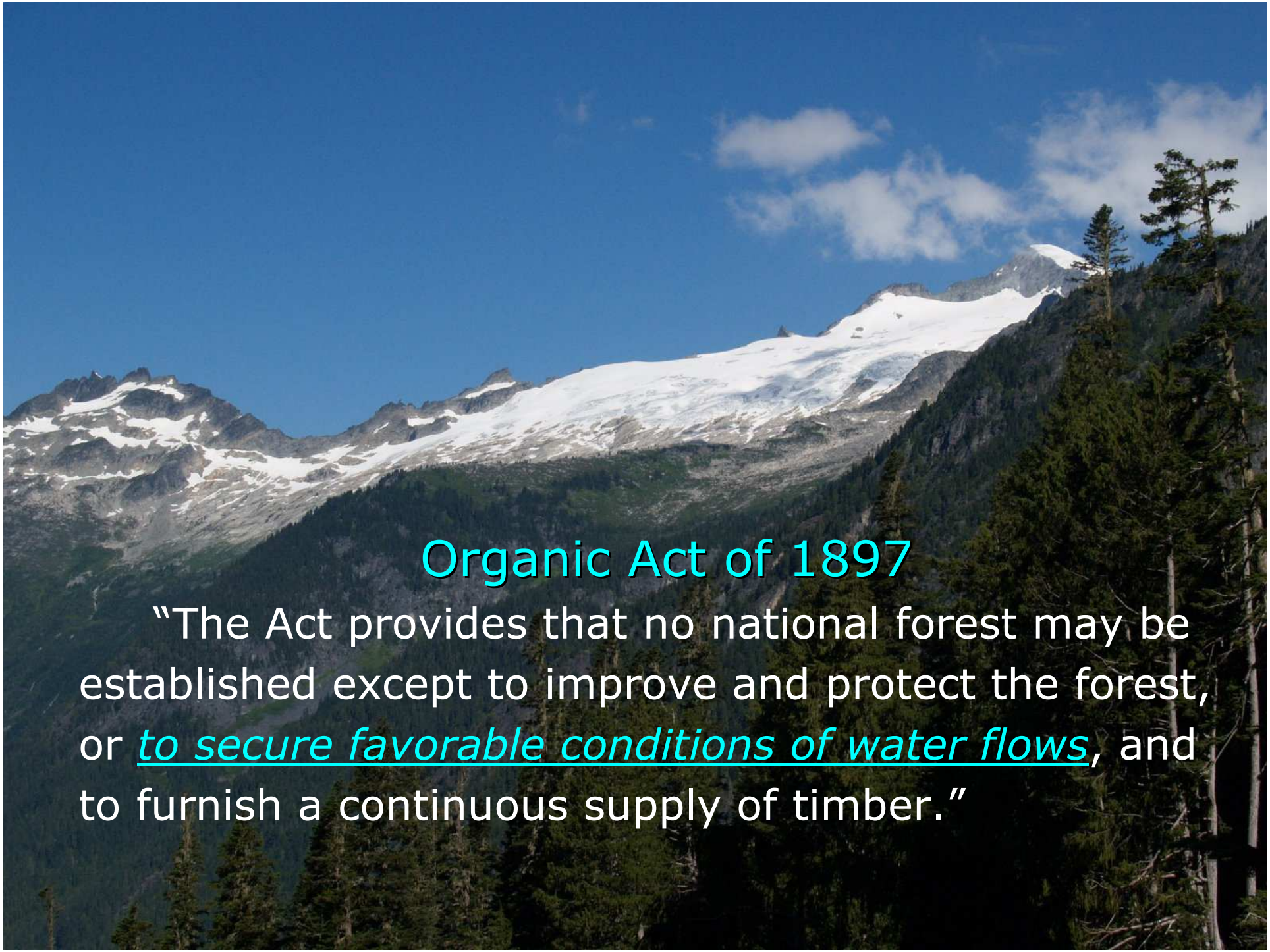
William Bullock, 1915

Photo: US Forest Service

Circa 1900

Society for the Protection of New Hampshire Forests

Androscoggin River
Maine



Organic Act of 1897

"The Act provides that no national forest may be established except to improve and protect the forest, or *to secure favorable conditions of water flows*, and to furnish a continuous supply of timber."

the Eastern National Forests ...and State Forests

...purchase such forested, cut-over, or denuded lands within the watersheds of navigable streams as in his judgment may be *necessary to the regulation of the flow of navigable streams* or for the production of timber."

Map: US Forest Service

"Water yield augmentation is, at best, impractical."
(quantity, timing, and quality are inextricably linked)

- **$Q \approx P - ET$**
  - PET varies little
  - $\therefore Q \propto P$
  - possibility of increased Q is lowest in dry years.

- **>>**Annual Allowable Cut (1-3%) ...and markets?

- *What* about multiple use? ...ecosystem-based mgt.?

- ROADS! (sediment, mass erosion, fragmentation)

Other concerns and constraints:

- timing of yield increases relative to need
  (invariably the growing season)

- timing of yield increases relative to available storage

Watershed Forest Management Alternatives

- multimedia education and outreach

- risk-based zoning
  (let-burn and controlled burning then possible)

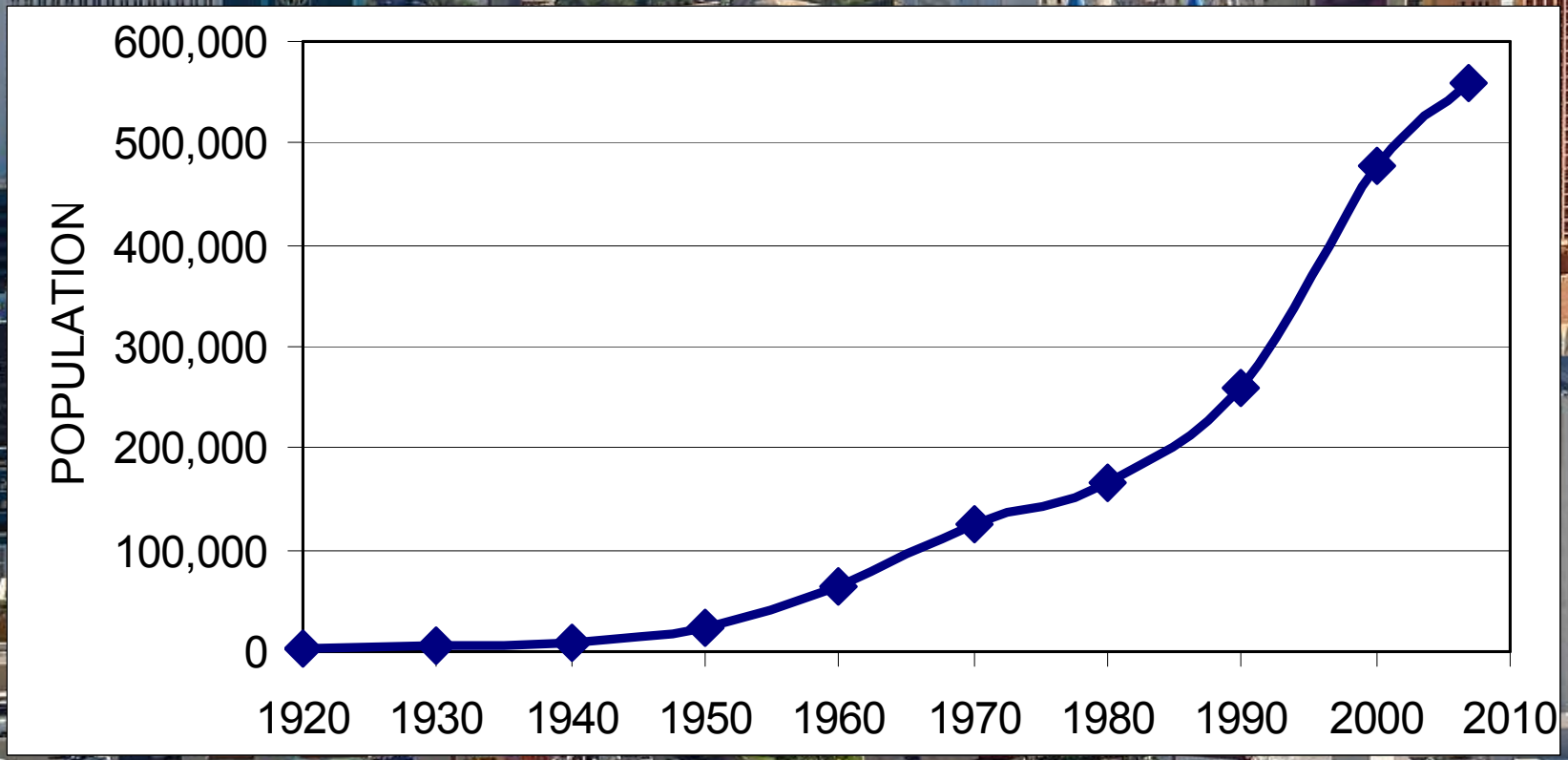
- silviculture/fuel load reduction, **reduce high severity fire risk**, use wood for biomass energy
  (*e.g.*, Vermont schools …~carbon neutral and local)
  (< snow interception, desynchronize snowmelt)

- change irrigation methods and requirements
  - Reclamation Act of 1902
  - Municipal, Industrial, Hydropower, Irrigation
  - In-stream flow and ecosystem restoration(?)

Watershed Forest Management Alternatives

- multimedia education and outreach
- risk-based zoning
  (let-burn and controlled burning then possible)
- silviculture/fuel load reduction, **reduce high severity fire risk**, use wood for biomass energy
  (*e.g.*, Vermont schools …~carbon neutral and local)
  (< snow interception, desynchronize snowmelt)
- change irrigation methods and requirements
- "cap and trade" …"pay-to-waste" (demand mgt.)

Las Vegas, Nevada




PET ~ 30 meters/year
BELLAGIO

Watershed Forest Management Alternatives

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- risk-based zoning
  (let-burn and controlled burning then possible)
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  (*e.g.,* Vermont schools …~carbon neutral and local)
  (< snow interception, desynchronize snowmelt)
- change irrigation methods and requirements
- "cap and trade" …"pay-to-waste" (demand mgt.)
- place- and community-based watershed mgt.

James F. Dubuar Forest from Cathedral Rock — New York State Ranger School — Wanakena

Wangum Brook, Great Mountain Forest, Falls Village, Conn.

for Scientists

Current Understanding

Effects (±)can be predicted in relation to changes in: (a) forest area and structure, (b) water balance components, (c) flow paths, and (d) erosion, nutrient cycling, and soil chemistry.

Information Gaps and Research Needs

...reliable ways to scale up experimental watershed results.

Recommended Actions

1. Maintain monitoring on experimental watersheds
2. Engage in adaptive management experiments with managers and community groups

for Managers

Current Understanding

US forests are altered by: (a) timber harvesting, (b) road systems, (c) wildfires, *and* (d) sprawl [etc.]; In sum, they alter the influence of forests on water.

Information Gaps and Research Needs

Assessment of BMP effectiveness *and* a compilation of principles and practices of adaptive management.

Recommended Actions

BMP development *and* monitoring ...adaptive management support for scientists ...technical support of watershed councils

for Communities ...towns ...cities ...states ...regions

Current Understanding

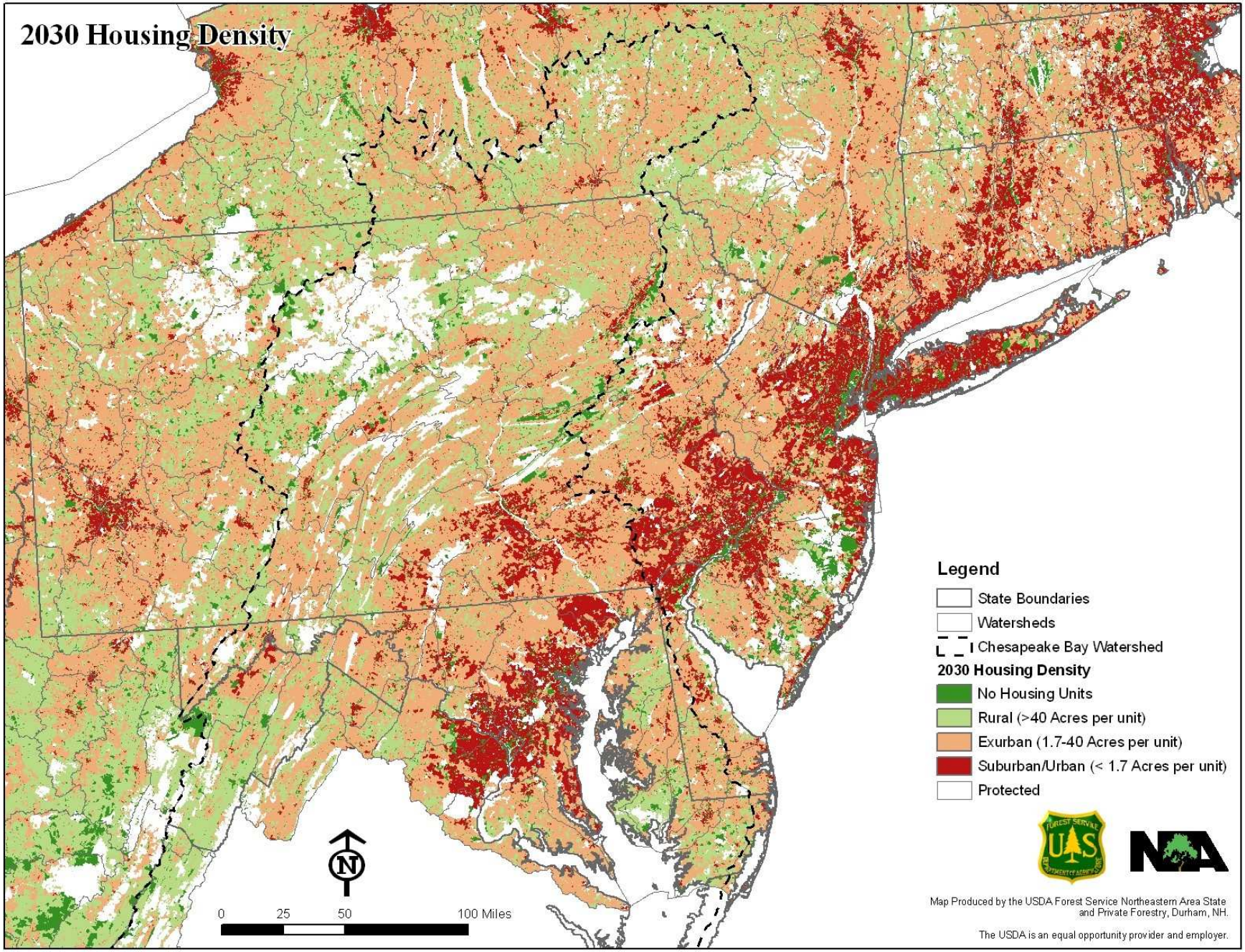
"Integrated watershed management is a viable vehicle for community groups and state and federal agencies to help manage water and forest resources at the community scale."

Information Gaps and Research Needs

How watershed councils and their stakeholders view and use hydrologic science and expertise from federal agencies and others [*or not*].

Recommended Actions

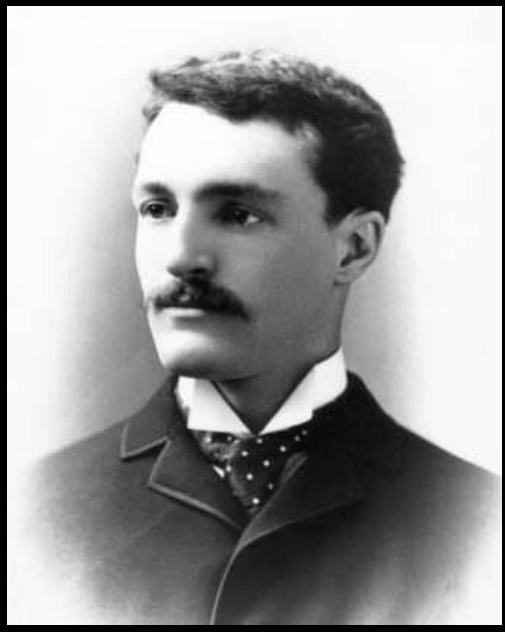
Expand the number and influence of watershed councils *and* undertake adaptive management with scientists and managers.


2030 Housing Density
Legend
State Boundaries
Watersheds
Chesapeake Bay Watershed
2030 Housing Density
No Housing Units
Rural (>40 Acres per unit)
Exurban (1.7-40 Acres per unit)
Suburban/Urban (< 1.7 Acres per unit)
Protected
N
0
25
50
100 Miles
Map Produced by the USDA Forest Service Northeastern Area State and Private Forestry, Durham, NH.
The USDA is an equal opportunity provider and employer.

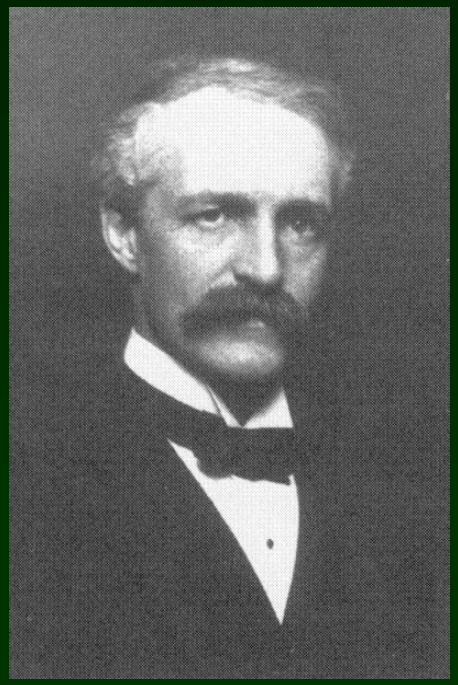
NATIONAL SCHOOL OF WATER AND FORESTS

Photo: Steve Dunsky, US Forest Service

Gifford Pinchot



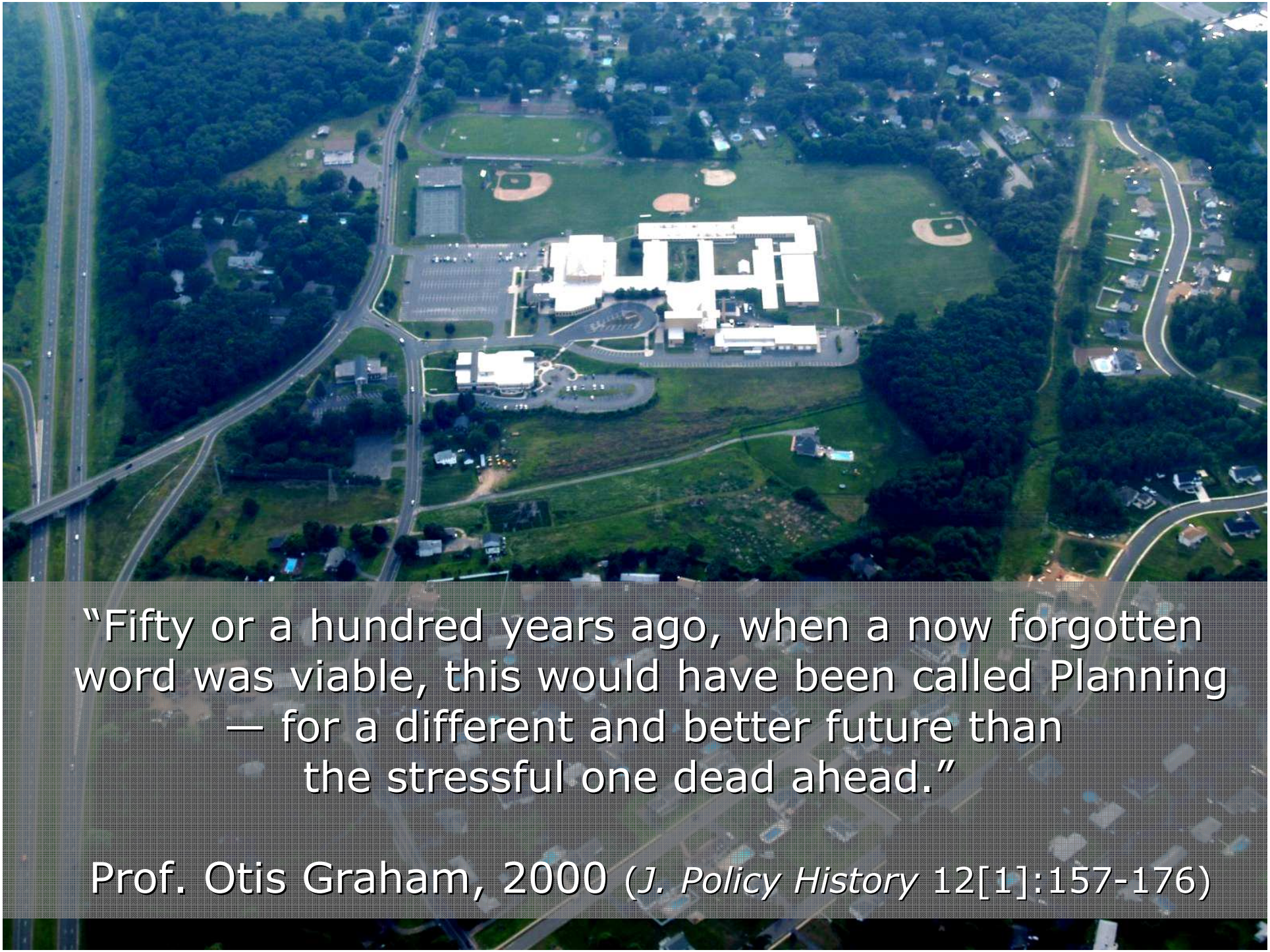
1889-1890
Nancy, France



1903 …Gifford Pinchot

A Primer of Forestry

"A forest, large or small, may render its service in many ways. It may reach its highest usefulness by standing as a safeguard against floods, winds, snow slides, moving sands, or especially against the dearth of water in streams."



"Fifty or a hundred years ago, when a now forgotten word was viable, this would have been called Planning — for a different and better future than the stressful one dead ahead."

Prof. Otis Graham, 2000 (*J. Policy History* 12[1]:157-176)