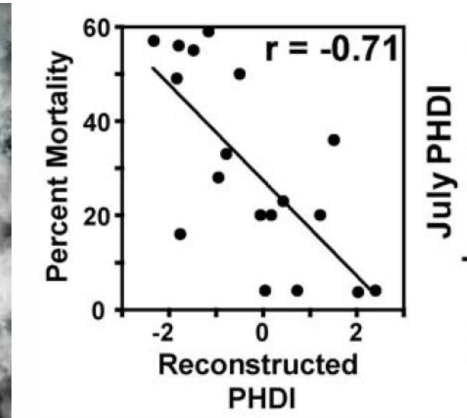
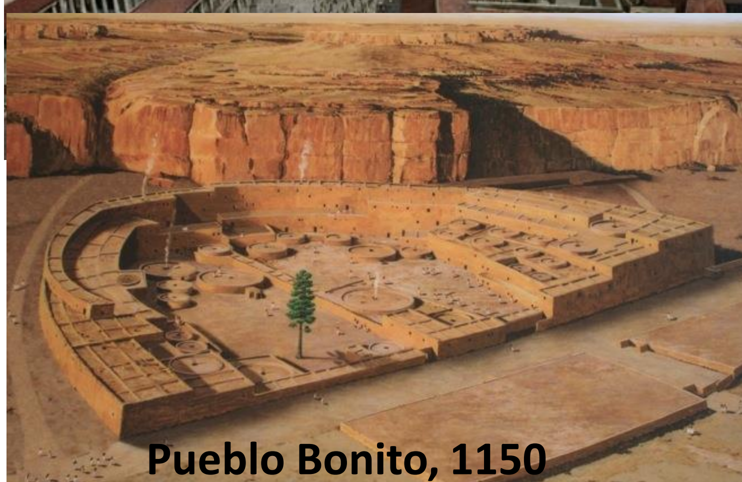
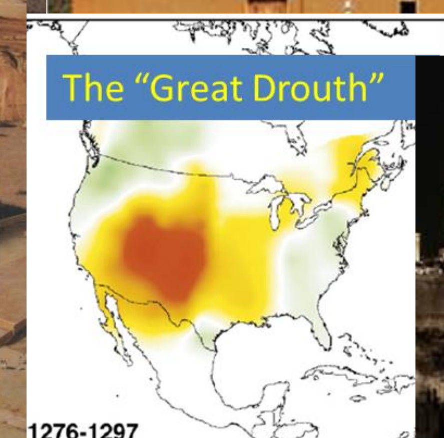
Dendroecology as Multi-Disciplinary Dendrochronology

Tom Swetnam, Laboratory of Tree-Ring Research, University of Arizona







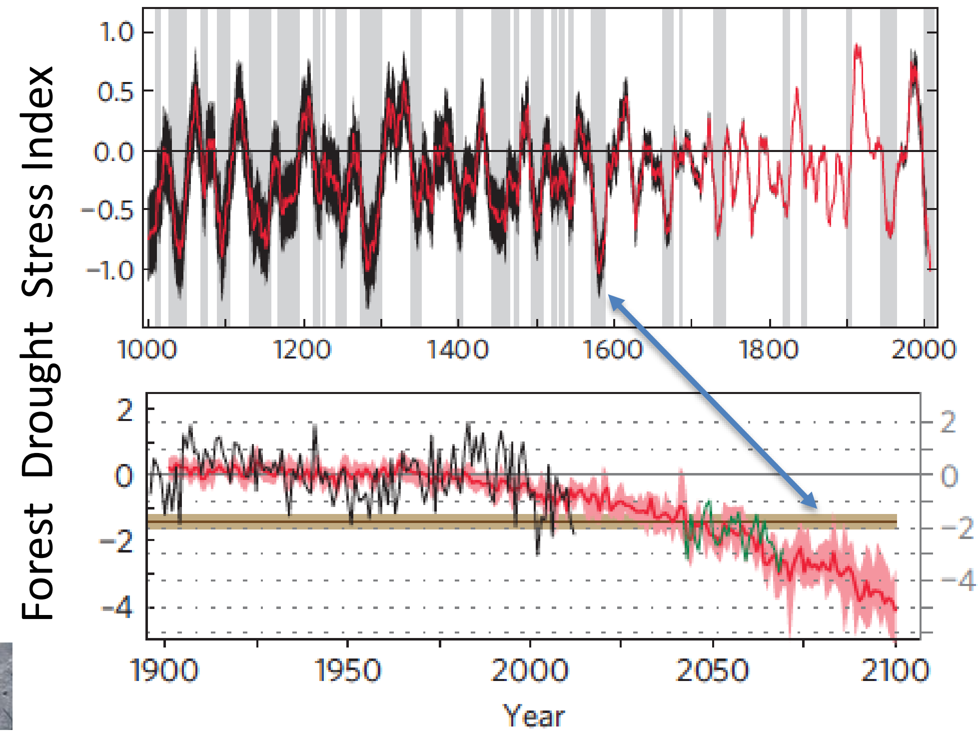

Wildfire, Tasmania, January 2013


Wildfire, San Diego, CA 2005


“Haboob” dust storm, Phoenix, AZ, June 2012


Tsunami, Indonesia, 2004

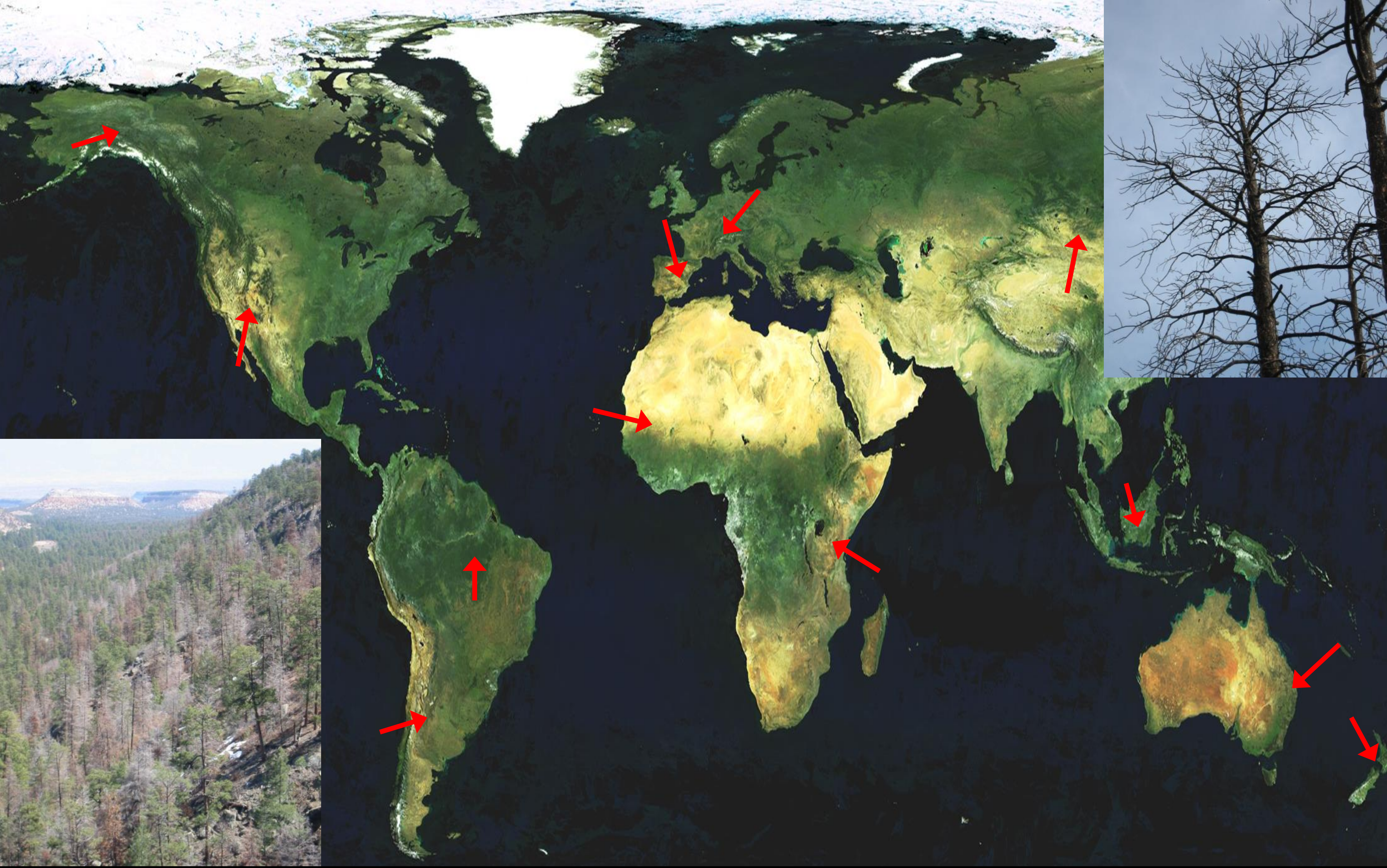
Increasing Tree & Forest Die-offs as a Consequence of Warming are Expected



Temperature as a potent driver of regional forest drought stress and tree mortality

A. Park Williams[1]*, Craig D. Allen[2], Alison K. Macalady[3,4], Daniel Griffin[3,4], Connie A. Woodhouse[3,4], David M. Meko[4], Thomas W. Swetnam[4], Sara A. Rauscher[5], Richard Seager[6], Henri D. Grissino-Mayer[7], Jeffrey S. Dean[4], Edward R. Cook[6], Chandana Gangodagamage[1], Michael Cai[8] and Nate G. McDowell[1]

Fire-killed trees in Las Conchas Fire, New Mexico 2011



Forest stress and dieback are now becoming apparent in many parts of the world. Examples from all forested continents, including Australia, Europe, Asia, Africa, South America, and North America.

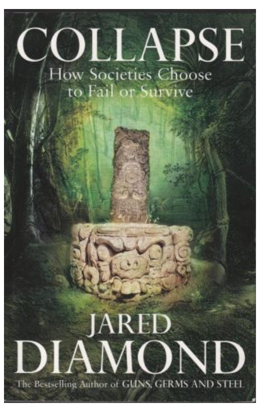
Allen et al.2009. Forest Ecology & Management

Courtesy of Craig Allen, USGS

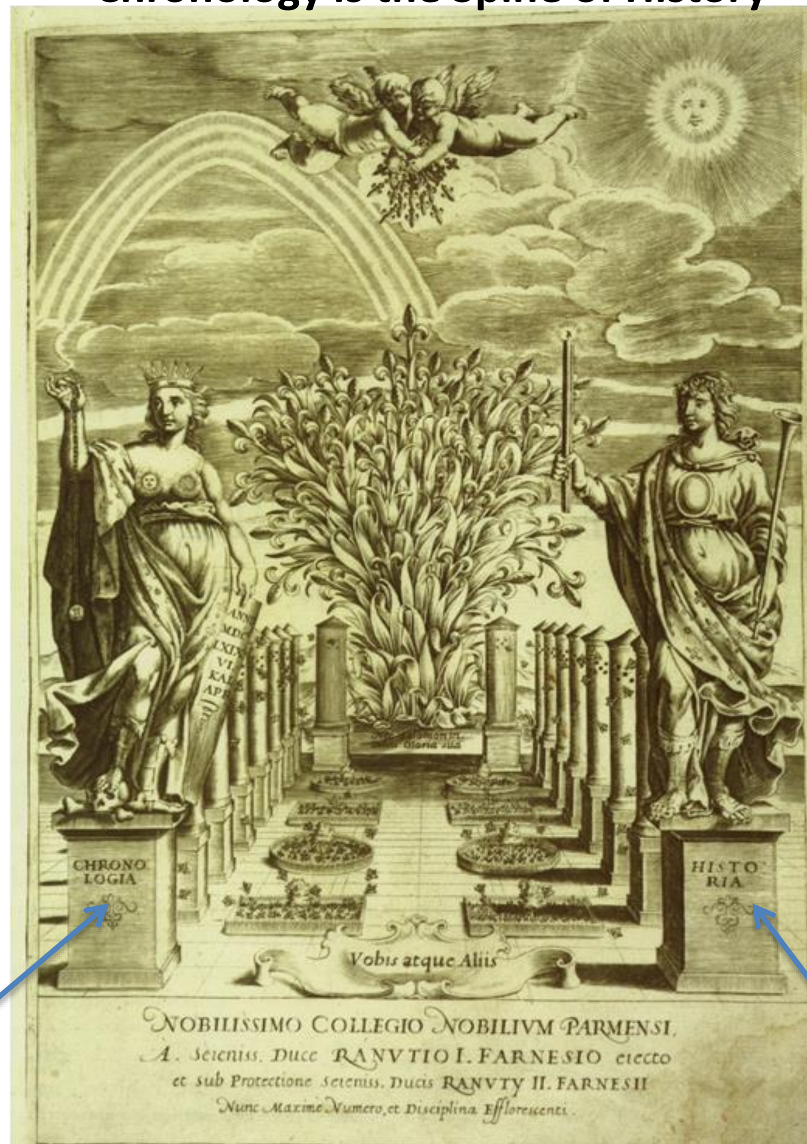
What are the “Grand Challenges” in Dendrochronology?

How have human societies responded in the past to extreme, climatic, ecological, and geological events?

How did past societies increase their vulnerability or resilience to environmental change?



“Chronology is the Spine of History”



Chronologia

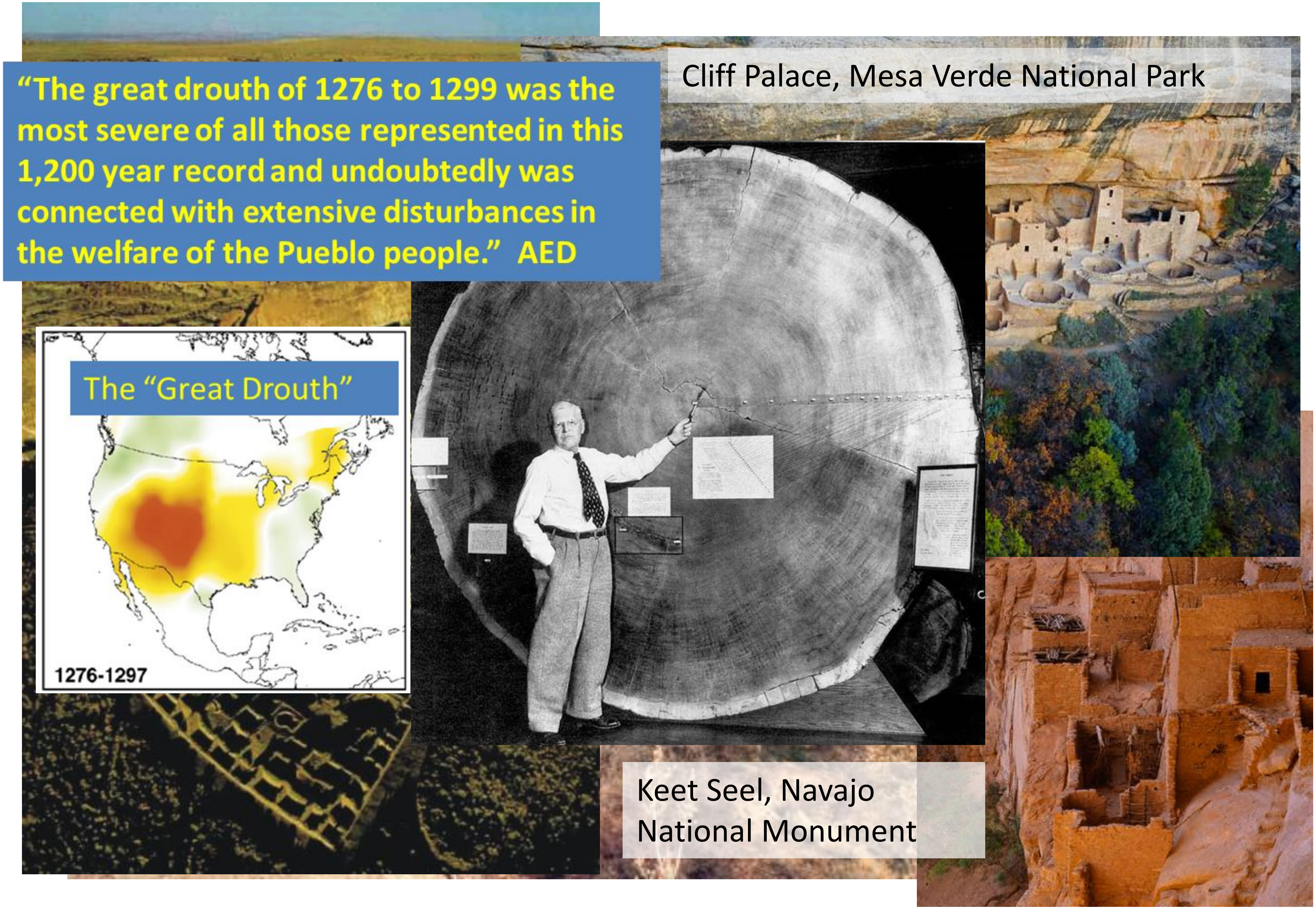
Historia

What can chronological and historical perspectives from tree-ring data and analyses provide to address these questions?

What hypotheses and theory about human-environment dynamics can be developed or tested with dendrochronology?

16th Century plate, reproduced in “Cartographies of Time: A History of the Timeline”, Rosenberg & Grafton, 2012

What happened to the Cliff Dwellers? Why did they leave and where did they go?



Bruno Huber
(1899 – 1969)

Reconstruction of a pile house at the Pfahlbau Museum Unteruhldingen on Lake Constance in Germany, Wikipedia

HUMAN BEHAVIOR, DEMOGRAPHY, AND PALEOENVIRONMENT ON THE COLORADO PLATEAUS

Jeffrey S. Dean, Robert C. Euler, George J. Gumerman, Fred Plog,
Richard H. Hevly, and Thor N. V. Karlstrom

American Antiquity, 50(3), 1985, pp. 537–554.

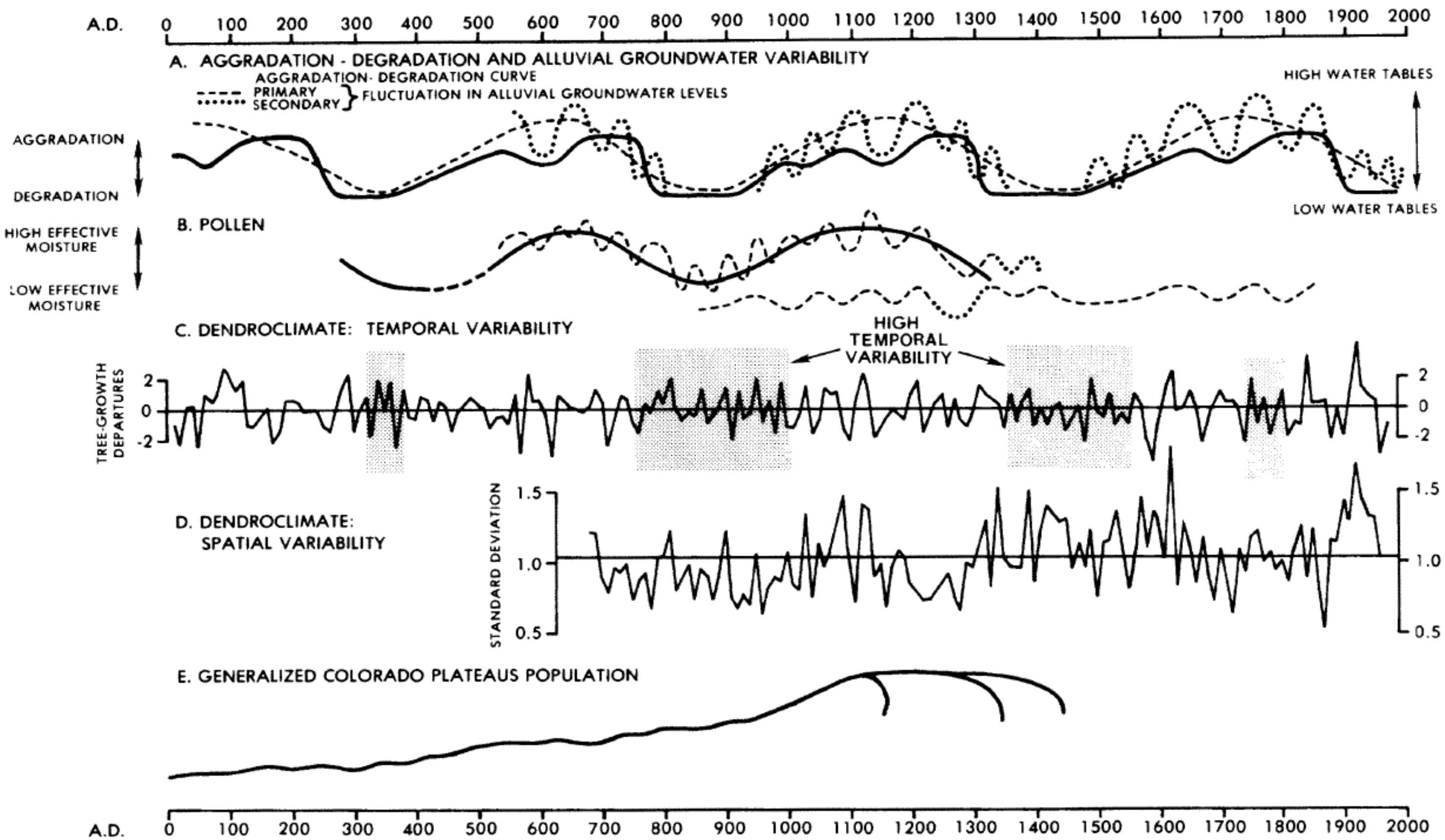
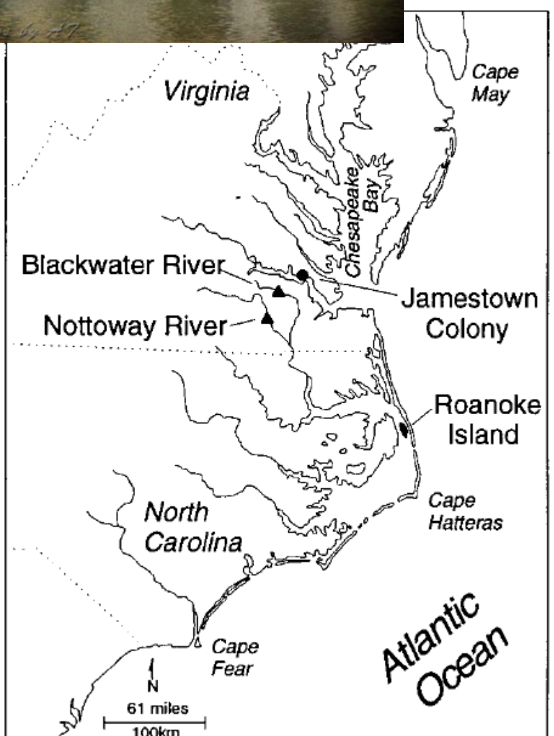


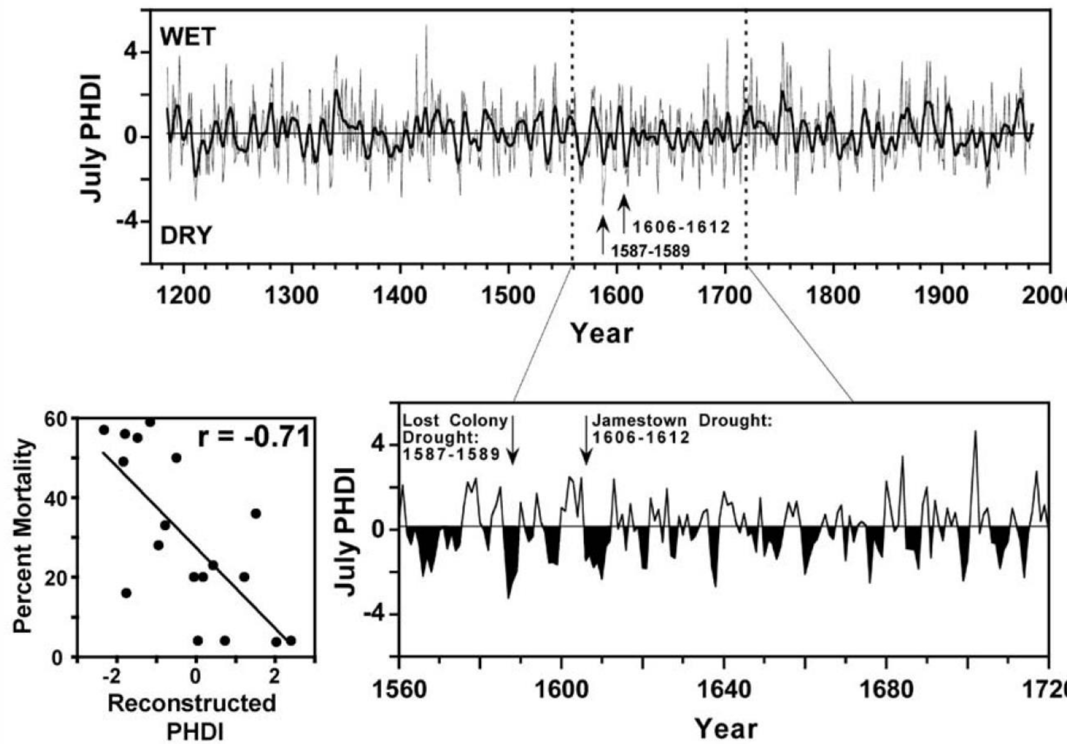
Figure 1. Environmental and demographic variability on the southern Colorado Plateaus, A.D. 1-1970. A, hydrologic fluctuations and floodplain aggradation-degradation. B, primary (solid) and secondary (dashed) fluctuations in effective moisture as indicated by pollen data. C, decadal tree growth departures in standard deviation units. D, spatial variability in dendroclimate. E, relative population trends, A.D. 1-1450.

The Lost Colony and Jamestown Droughts

David W. Stahle,* Malcolm K. Cleaveland, Dennis B. Blanton, Matthew D. Therrell, David A. Gay

SCIENCE • VOL. 280 • 24 APRIL 1998

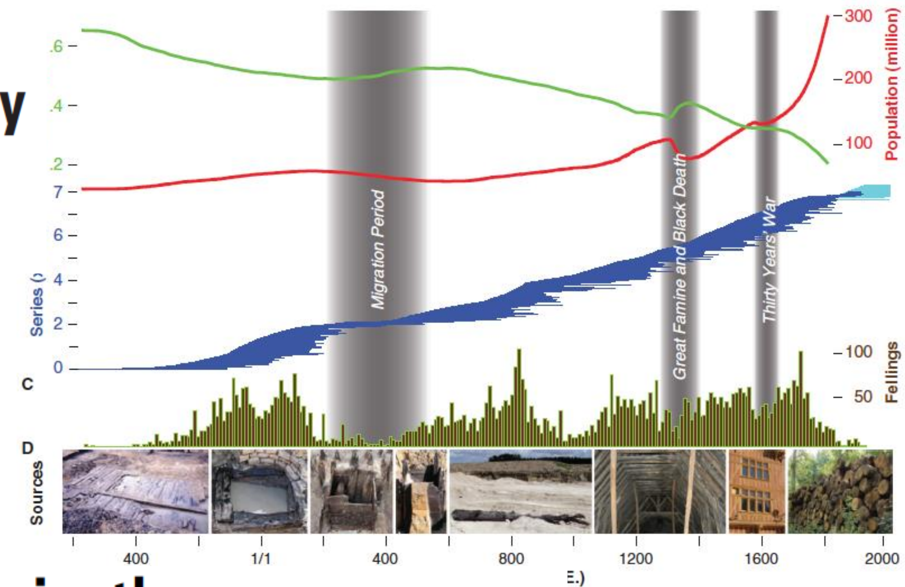




2500 Years of European Climate Variability and Human Susceptibility

Ulf Büntgen,[1,2]* Willy Tegel,[3] Kurt Nicolussi,[4] Michael McCormick,[5] David Frank,[1,2] Valerie Trouet,[1,6] Jed O. Kaplan,[7] Franz Herzig,[8] Karl-Uwe Heussner,[9] Heinz Wanner,[2] Jürg Luterbacher,[10] Jan Esper[11]

Science **331**, 578 (2011)



Climate as a contributing factor in the demise of Angkor, Cambodia

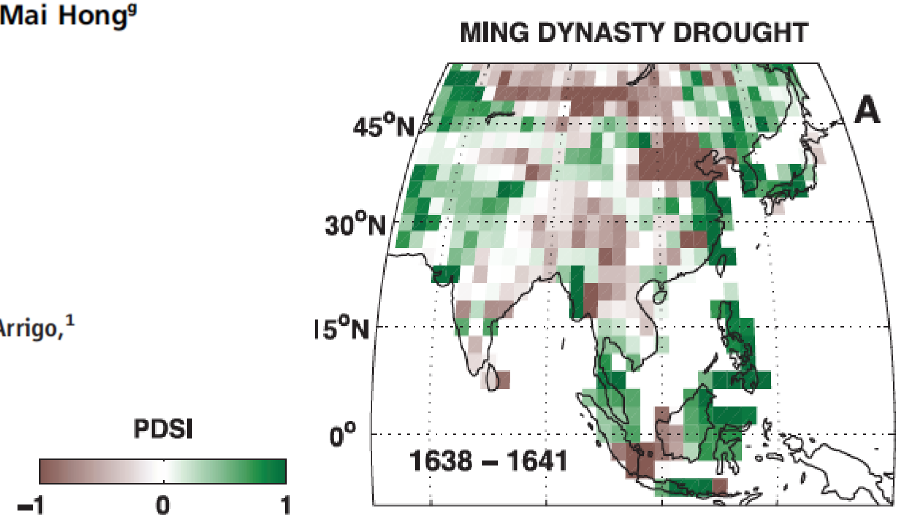
6748–6752 | PNAS | April 13, 2010 | vol. 107 | no. 15

Brendan M. Buckley[a,1], Kevin J. Anchukaitis[a], Daniel Penny[b], Roland Fletcher[c], Edward R. Cook[a], Masaki Sano[d], Le Canh Nam[e], Aroonrut Wichienkeeo[f], Ton That Minh[e], and Truong Mai Hong[g]

Asian Monsoon Failure and Megadrought During the Last Millennium

Edward R. Cook,[1]* Kevin J. Anchukaitis,[1] Brendan M. Buckley,[1] Rosanne D. D'Arrigo,[1] Gordon C. Jacoby,[1] William E. Wright[1,2]

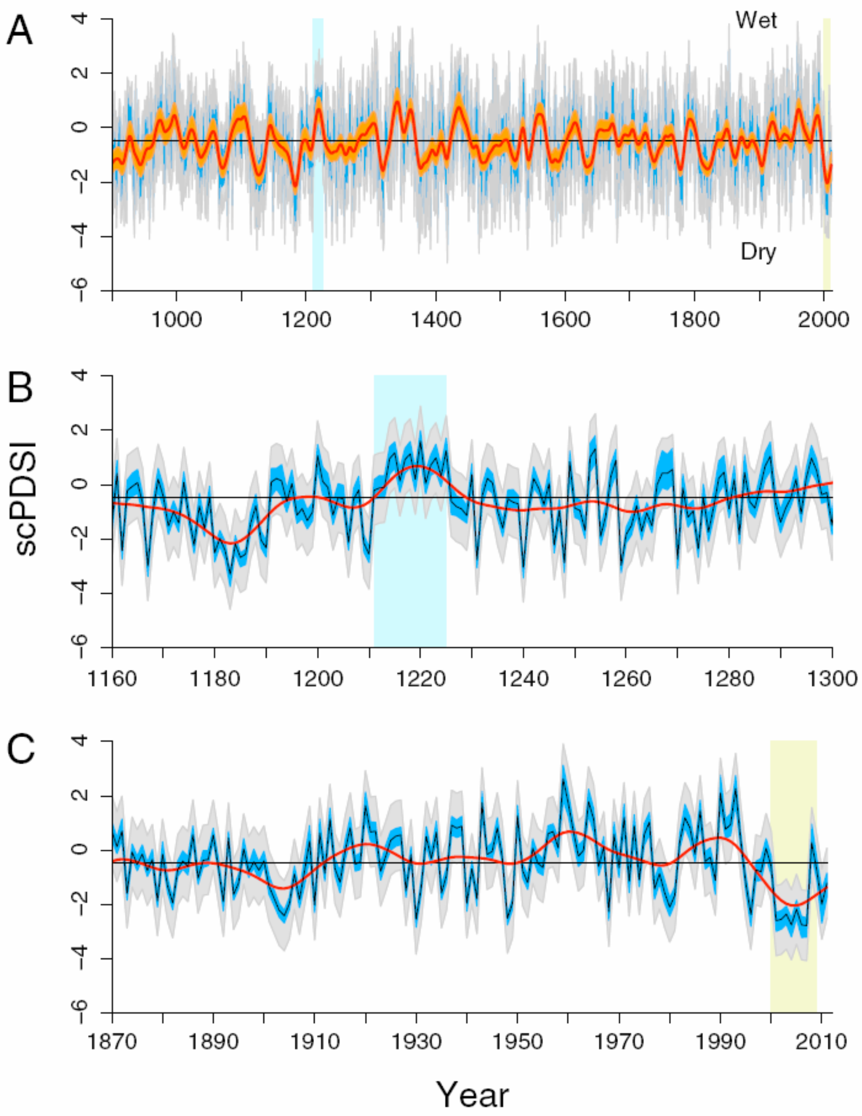
Science **328**, 486 (2010)

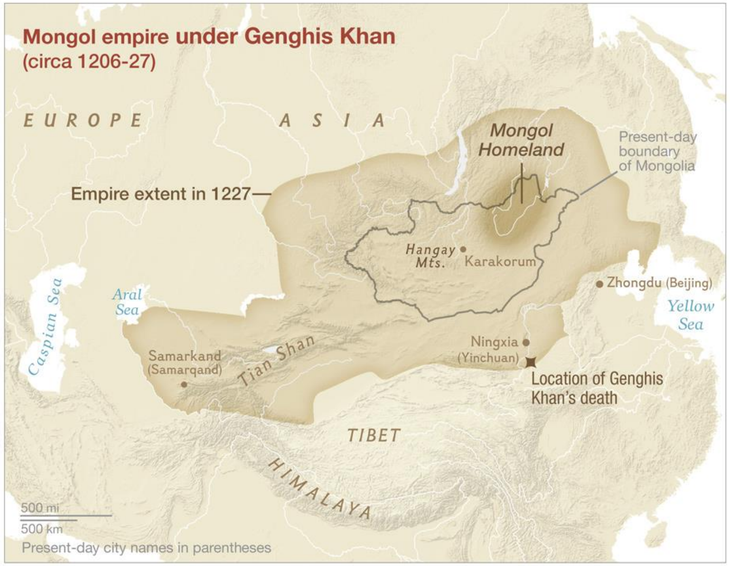


Pluvials, droughts, the Mongol Empire, and modern Mongolia

Neil Pederson[a,1,2], Amy E. Hessl[b,1,2], Nachin Baatarbileg[c], Kevin J. Anchukaitis[d], and Nicola Di Cosmo[e]

PNAS | March 25, 2014 | vol. 111 | no. 12 | 4375–4379





Funding
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A-Z Index of Funding Opportunities
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Crosscutting

Dynamics of Coupled Natural and Human Systems (CNH) C

CONTACTS

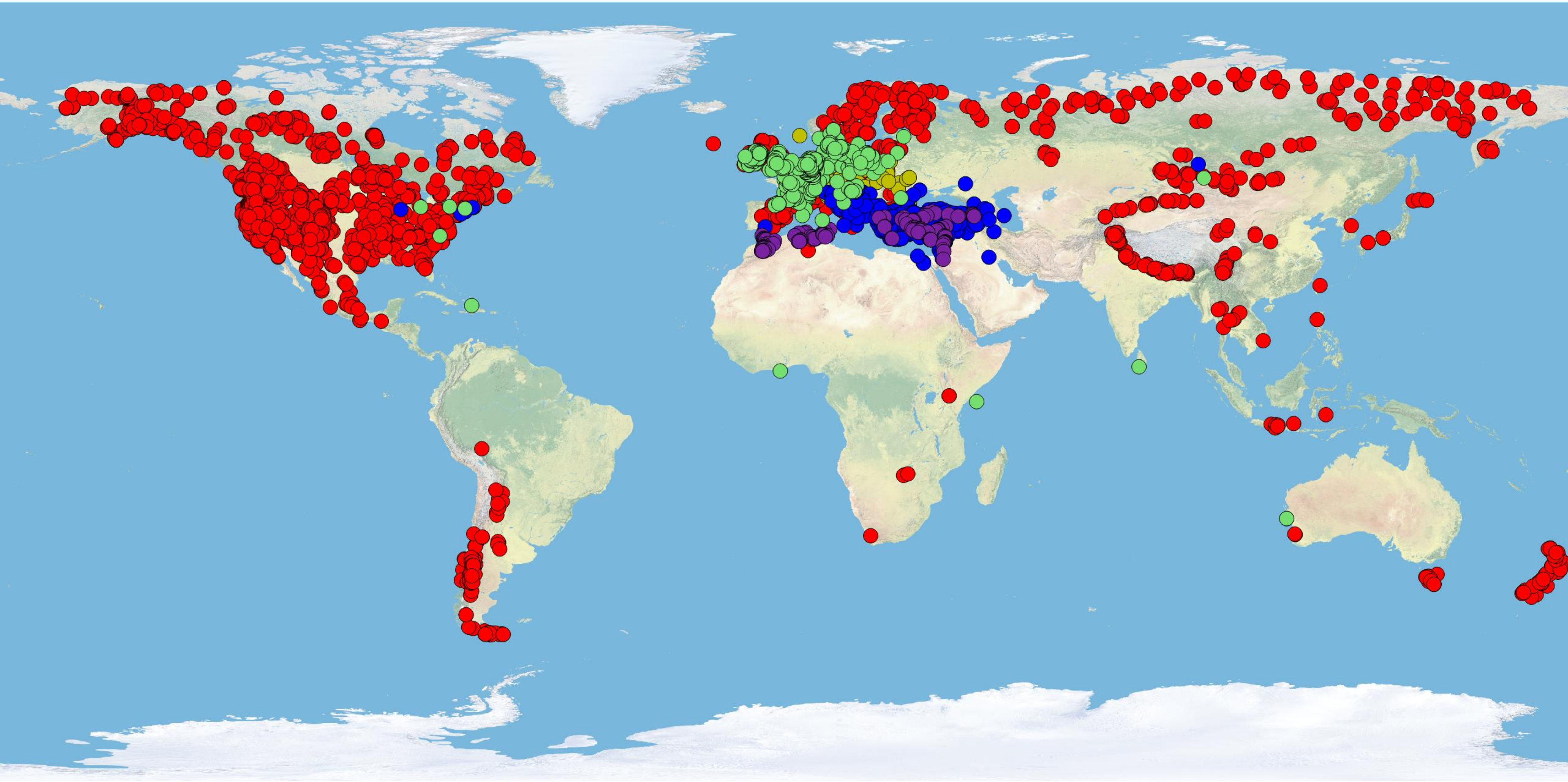
Tree-Ring Based Human-Environment Projects funded by NSF CNH Program: A major source of Tree-Ring Funding now in the United States

Paleoclimatic Shocks: Environmental Variability, Human Vulnerability, and Societal Adaptation During the Last Millennium in the Greater Mekong Basin; Principal Investigator: Brendan Buckley; Co-Principal Investigator: Edward Cook, Upmanu Lall, Tanya Heikkila, Kevin Anchukaitis; Organization: Columbia University; NSF Organization: GEO Award Date 10/01/2009, Award Amount: $1,401,351.

Long-Term Vulnerability and resilience of Coupled Human-Natural Ecosystems to Fire Regime and Climate Changes at an Ancient Wildland-Urban Interface; Principal Investigator: Thomas Swetnam; Co-Principal Investigator: Robert Keane, TJ Ferguson, Matthew Liebmann, Christopher Roos; Organization: University of Arizona; NSF Organization: GEO Award Date:09/01/2011; Award Amount:$1,498,027.

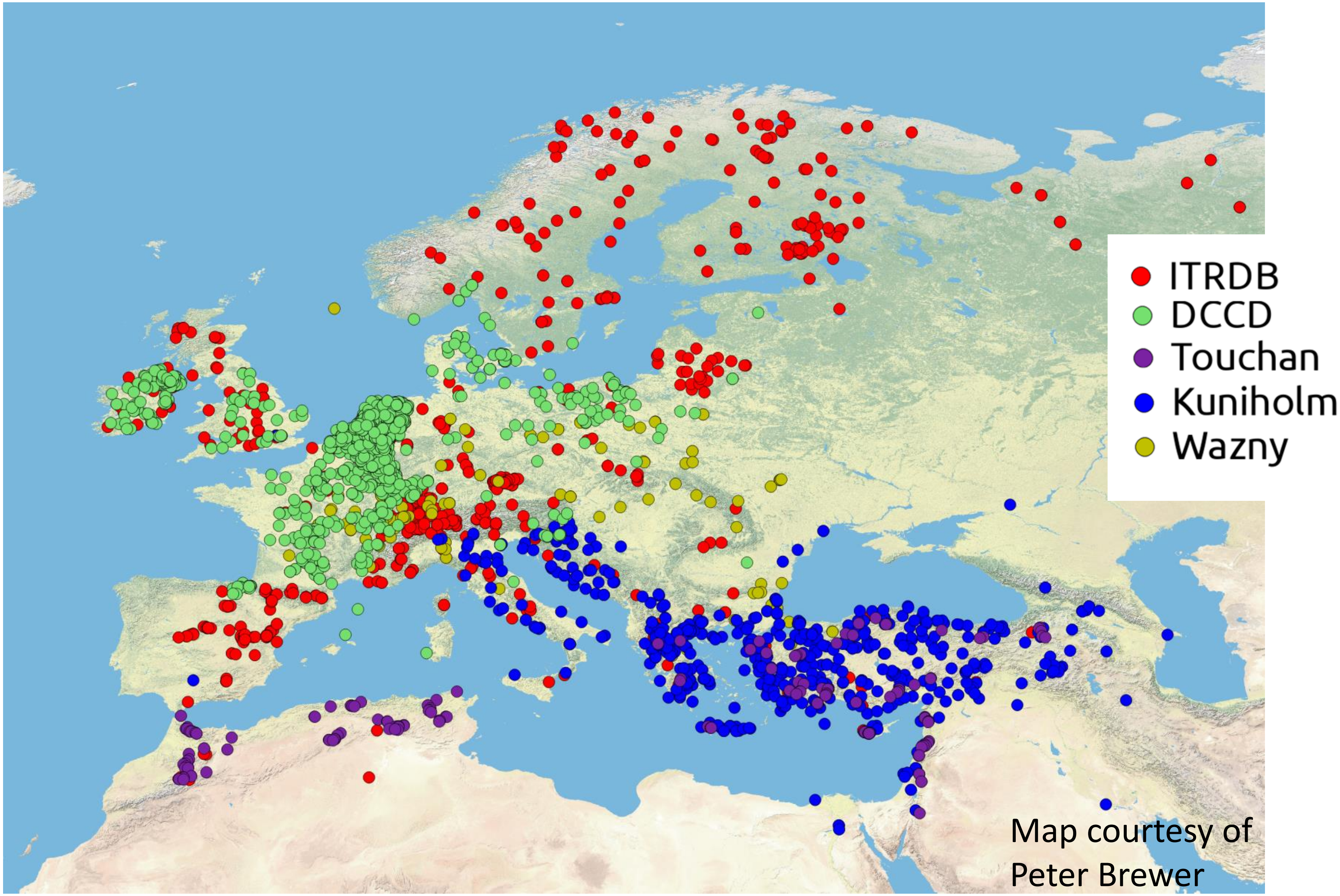
Pluvials, Droughts, Energetics, and the Mongol Empire; Principal Investigator: Amy Hessl; Co-Principal Investigator: Hanqin Tian, Neil Pederson, Nicola Di Cosmo; Organization: West Virginia University Research Corporation; NSF Organization: BCS Award Date:09/01/2012; Award Amount:$1,394,398.

Regional to global-scale networks of tree-ring chronologies provide the means to evaluate human-environment interactions across a range of temporal and spatial scales.

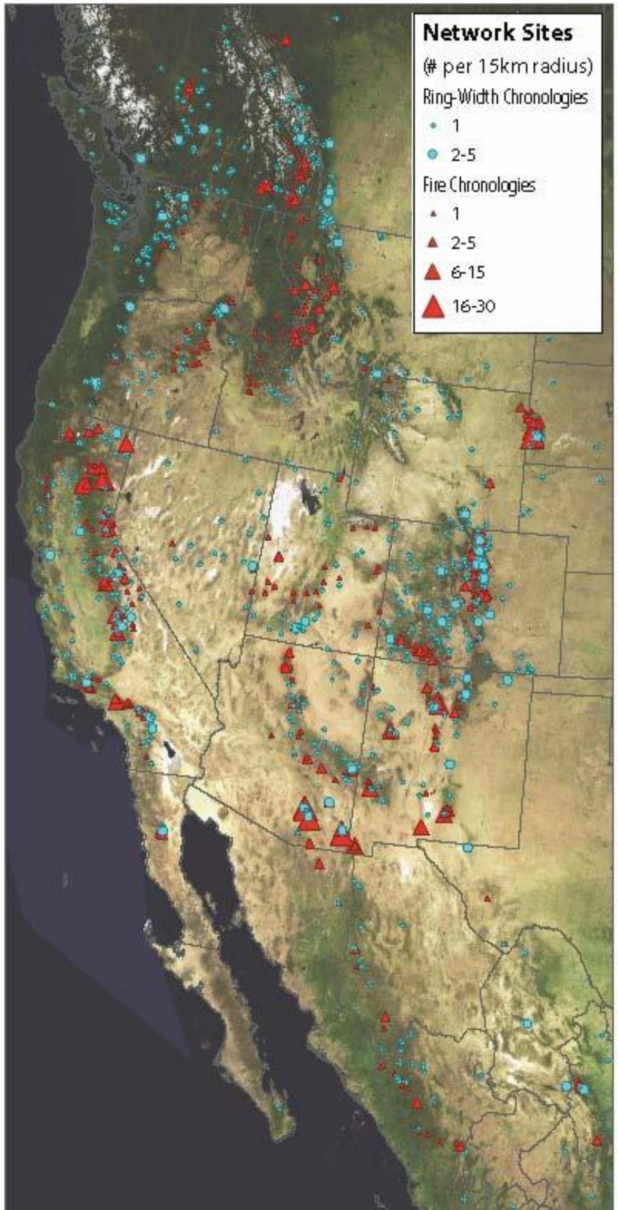


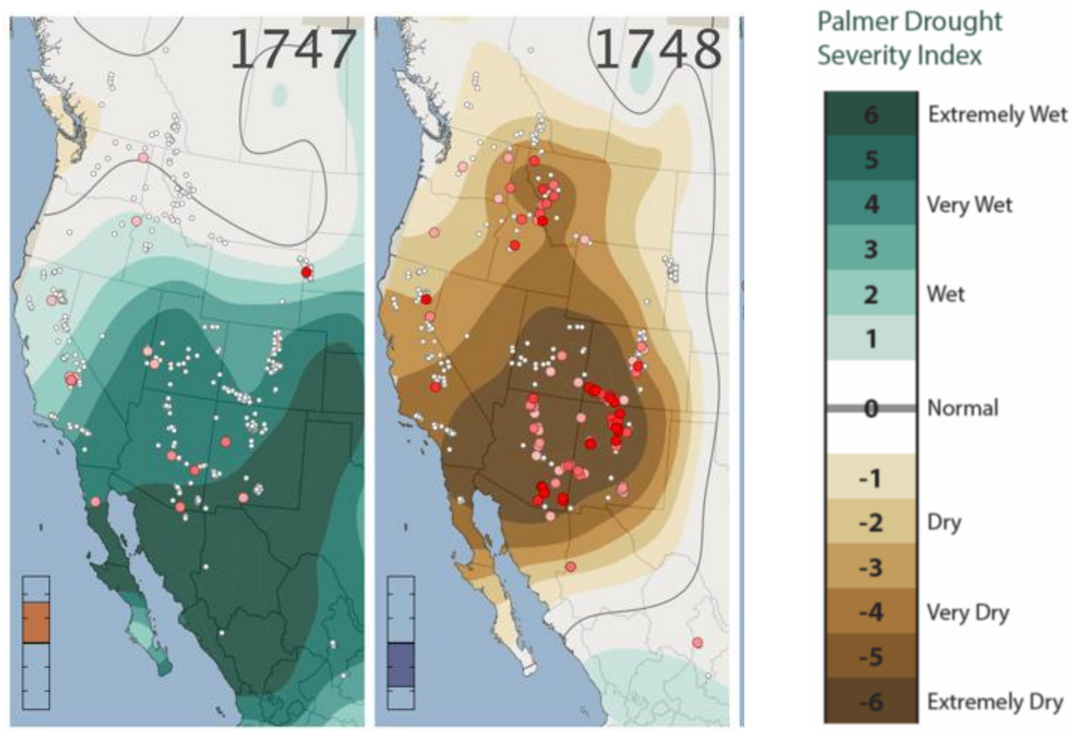
Map courtesy of
Peter Brewer

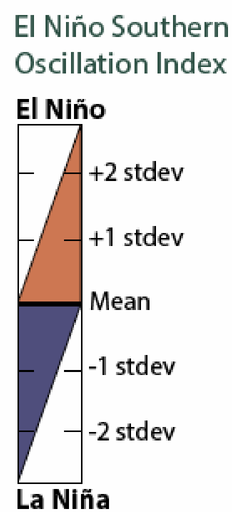
Combinations of climatic, ecological and archaeological/historic tree-ring networks provide an unparalleled opportunity for broad syntheses, aimed at evaluating synchrony/asynchrony, pattern and process.

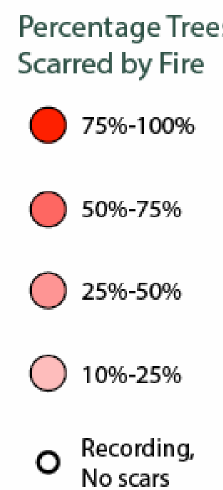


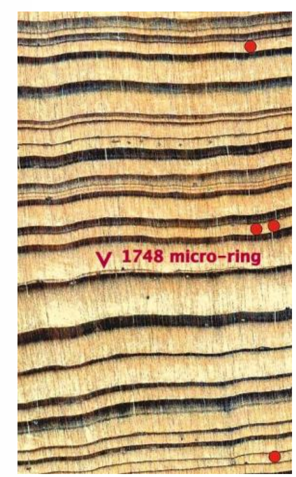
Four Centuries of Fire & Drought History in Western North America Using Regional Networks in Dendroclimatology & Dendroecology





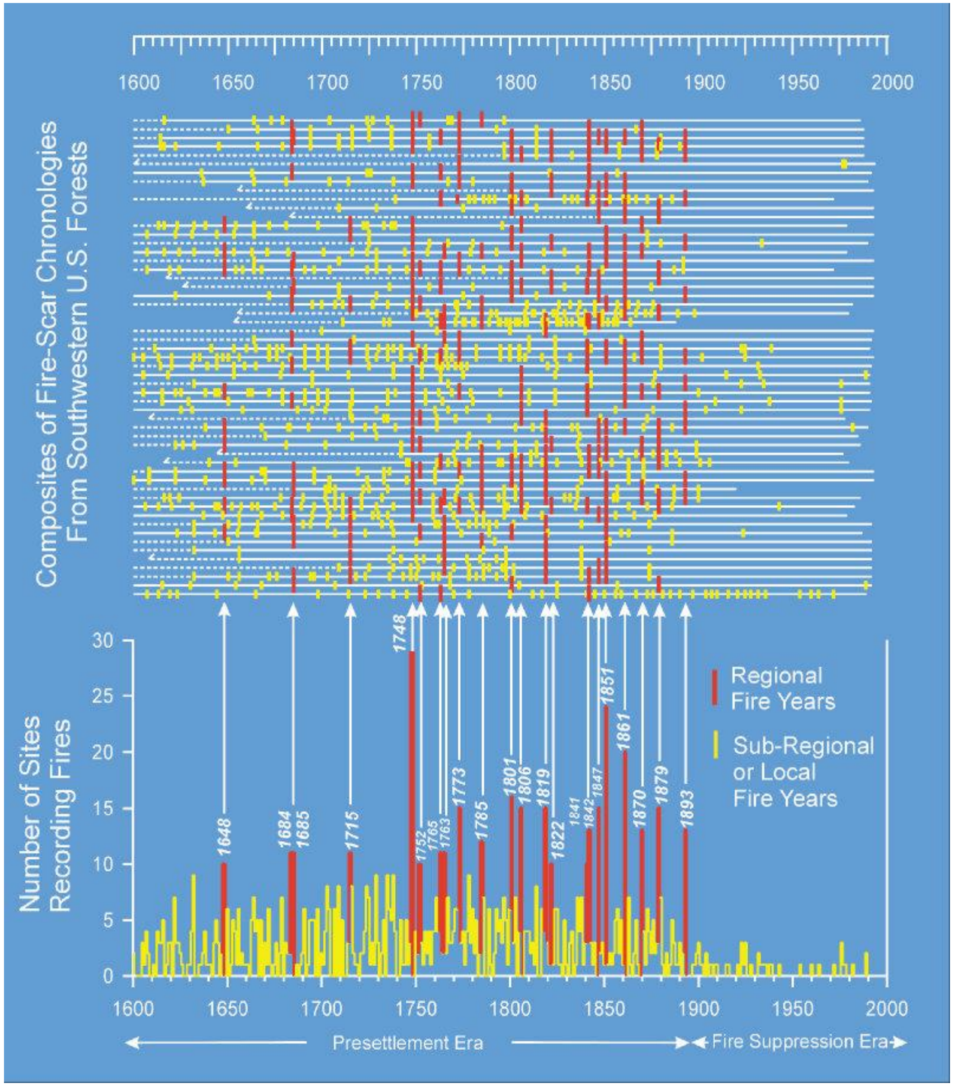






Falk, Swetnam, Brown, Sutherland, et al. in prep.

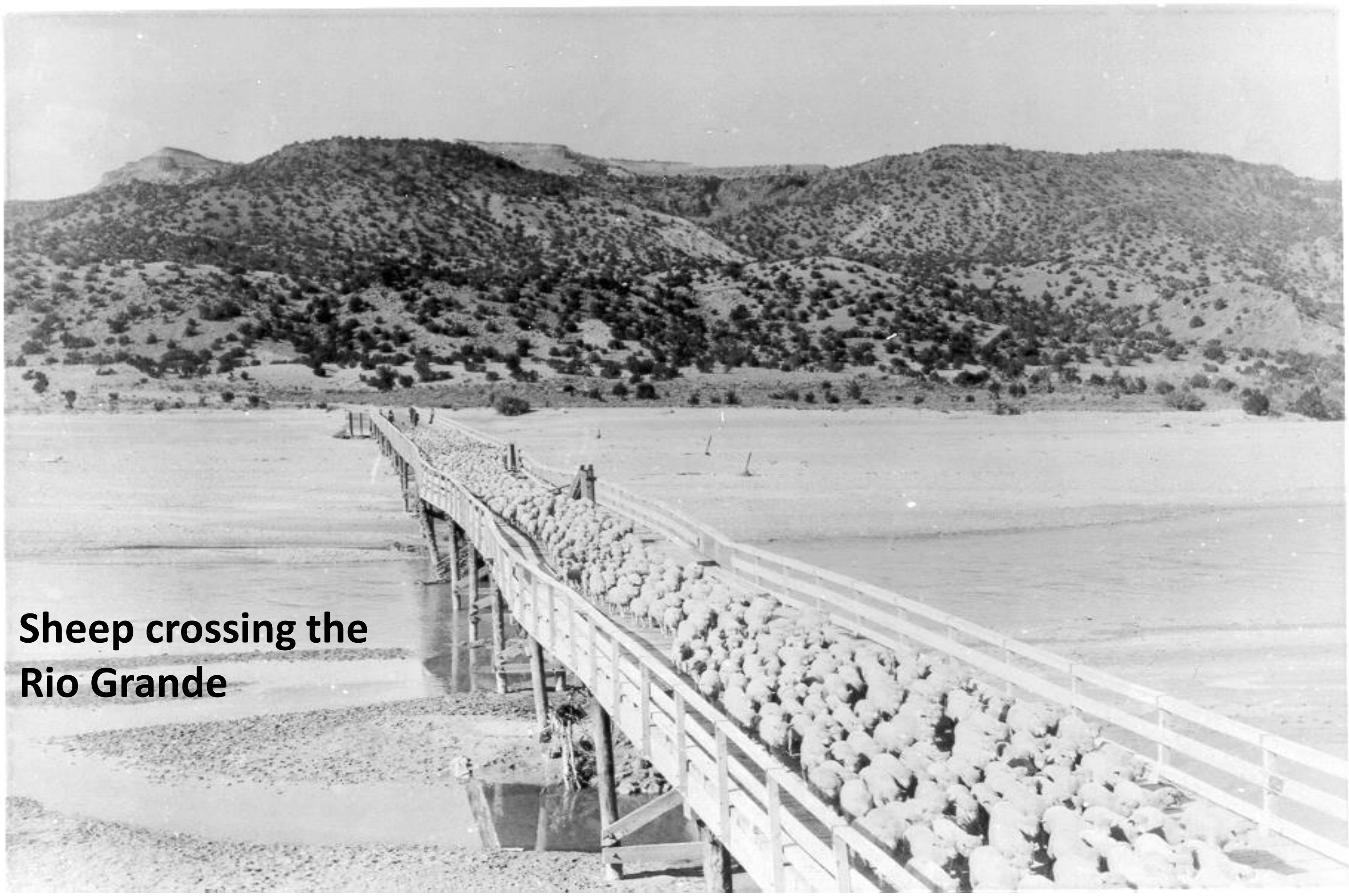
The largest effect that humans have had on wildfire regimes in the Jemez, and the Southwest overall, has been the elimination of extensive, frequent, low severity surface fires at about 1890-1910.



Swetnam, Allen & Betancourt Ecological Applications, 1999

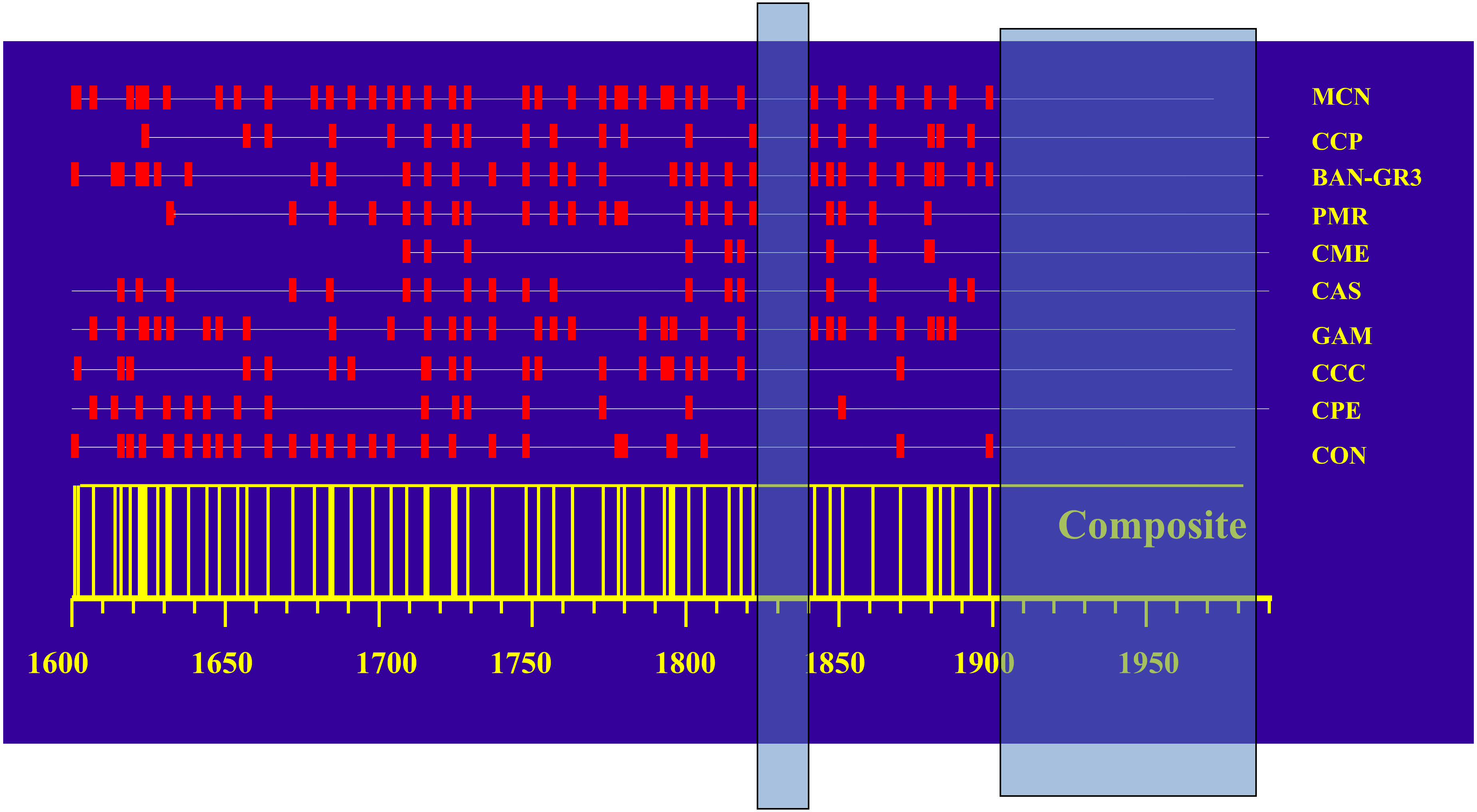
Very clearly, the first reason for reduction of widespread surface fires was the introduction very large numbers of sheep, cows and horses. After the markets for wool collapsed around 1920, organized suppression by the Forest Service and other agencies became the primary reason for continued absence of extensive surface fires.

<u>RAILROADS</u> led to > 5 million sheep and 1.5 million cattle in New Mexico by 1890

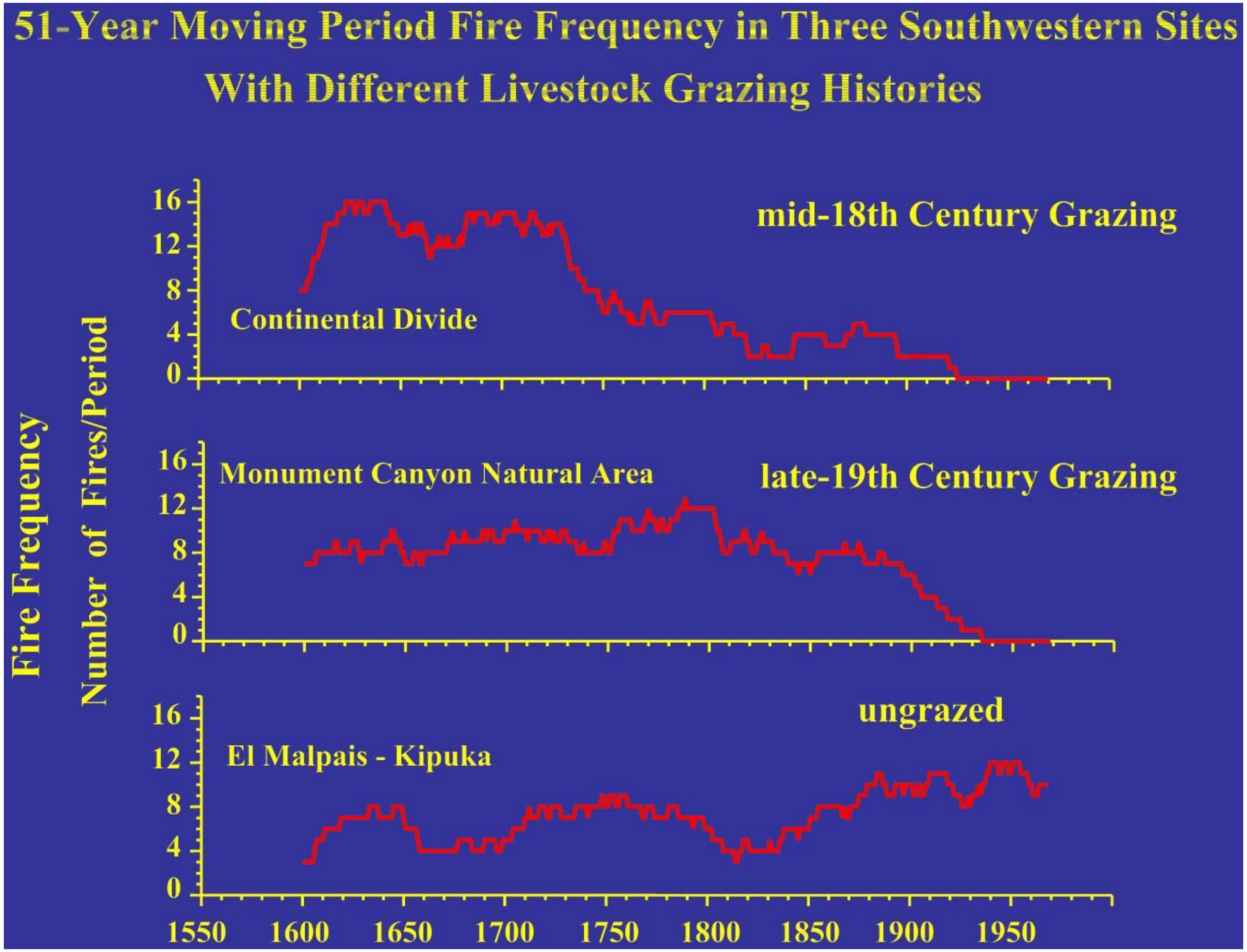


Sheep crossing the Rio Grande

Composite fire scar chronologies from 10 forest stands in the Jemez show the usual pattern of drastically reduced surface fires circa 1900. Some sites on the peripheries of the Jemez (and some within the range) show EARLY reductions of burning, and there is documentary evidence suggesting these early fire regime disruptions were likely due to earlier livestock grazing, e.g., seasonal sheep grazing into certain areas, before the peak grazing era of 1880s-1920.



The influence of livestock grazing (i.e., removing the grass fuels and disrupting fuel continuity by trails and “driveways”) is further demonstrated across the Southwest by the special cases where fire regime changes occurred at different timings, depending on when intensive grazing began. An unusual example is in El Malpais National Monument which has never had intensive grazing, and very limited fire suppression, and consequently more-or-less continuous surface fires have continued there.



The many examples of extensive surface fire regime disruption, depending on TIMING of intensive grazing, points to the VERY IMPORTANT EFFECT OF CONTINUOUS FUELS, AND THAT EXTENSIVE SPREADING FIRES IN THE PRE-1900 ERA WAS HIGHLY DEPENDENT ON FINE FUELS.

Long-Term Vulnerability and Resilience of Coupled Human-Natural Ecosystems to Fire Regime and Climate Changes at an Ancient Wildland Urban Interface

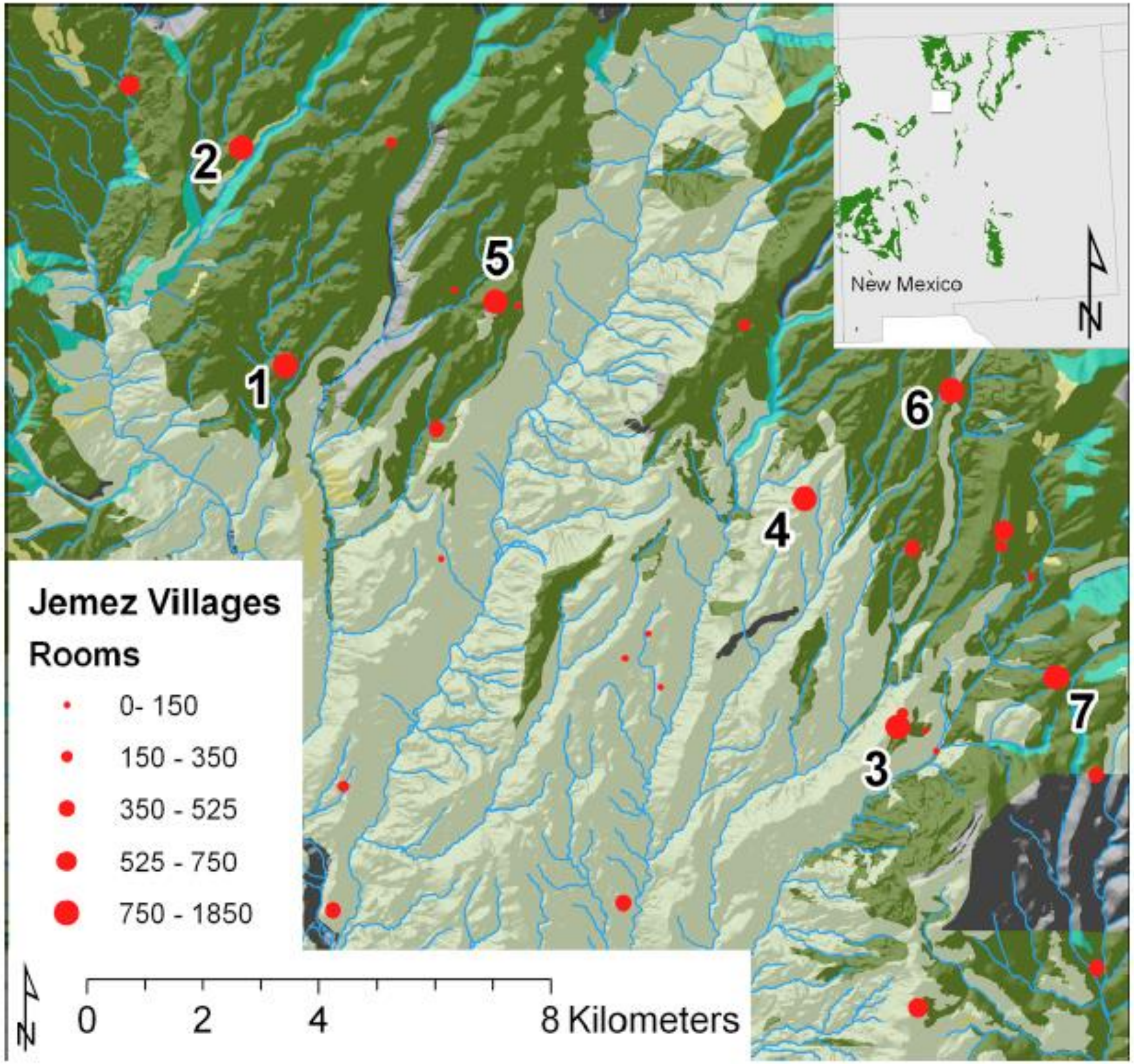
A fundamental goal of our proposed project is to understand the dynamic interactions of climate, human activities, and fire regimes over a variety of temporal, spatial, and demographic scales in an ancient Wildland Urban Interface.

How did Puebloan people live within drought and fire-prone forests and woodlands of the Southwest for multiple centuries?

What insights might integrated ethnographic studies, paleoecological and archaeological reconstructions, and dynamic fire and vegetation models provide to understanding long term human-environment interactions in these landscapes?

"Kwastiyukwa" in Jemez Mountains

At least 6 very large Jemez Villages (>700 rooms, 2 to 4 story townhouses) were occupied when the Spaniards arrived in the late 1500s. Many other smaller villages were also occupied.



These rough estimates of Jemez populations (which are conservative estimates) indicate that the density of humans/area was at least equivalent to the threshold definition of the "Wildland Urban Interface" - WUI

~7,000 people lived in as many as nine villages within or adjacent to ponderosa pine forests

~7 pueblos with > 1,000 rooms, and 15 other pueblos with >500 rooms

-hundreds of "field houses"

<u>~28 people/km2 population density</u>

~Modern WUI = minimum population density of 25 people/ km2

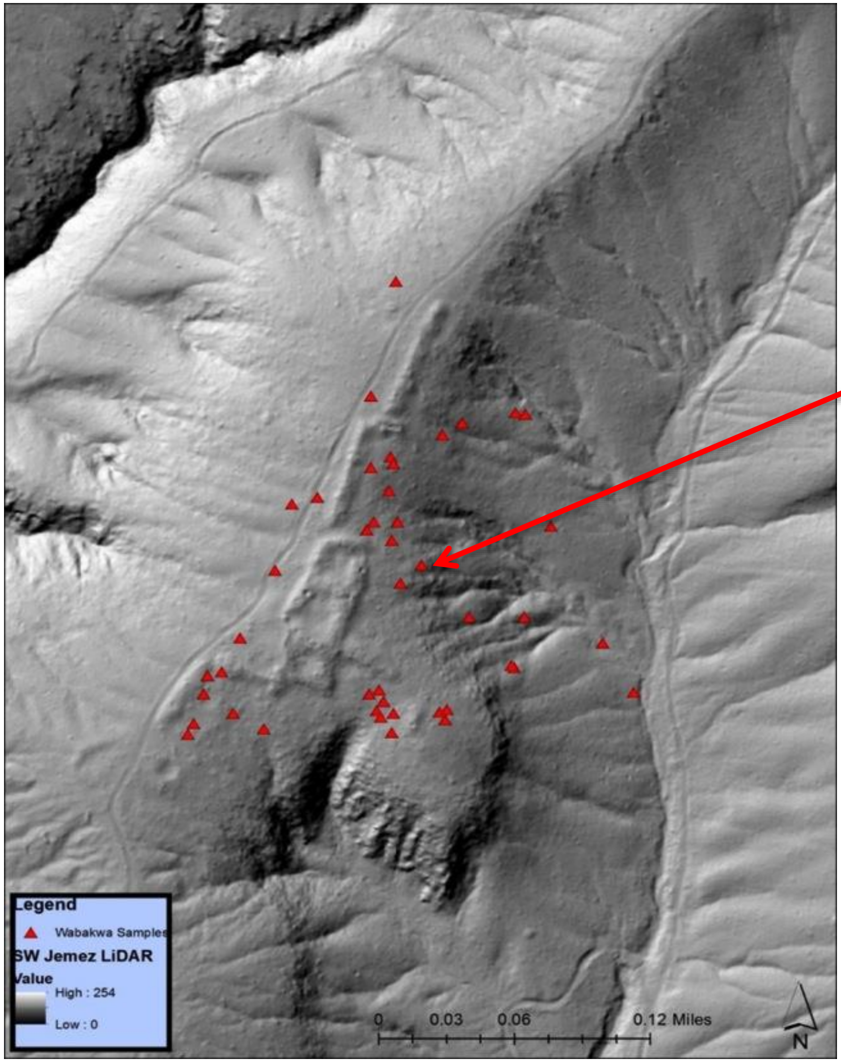
Name	Rooms	LA_Num	FS_Num
Tovokwa	1,850	0	576
Boletsakwa	1,400	136	2
Wabakwa	1,400	478	400
Pejunkwa	1,300	130	571
Kwastiyukwa	1,250	483	11
Amoxiumqua	1,200	481	530
Seshukwa	1,100	303	12
Wahajhamka	750	0	573
Kiatsukwa	625	132	31
Kiashita	600	484	1
Patokwa	525	96	5
	525	5918	30
	475	5920	18
	450	0	8
Nanishagi	450	541	320
	400	0	3
Guacamayo	400	189	572
	350	135	199
Kiatsukwa	325	133	504
	300	96	7
Unshagi	300	123	337
Totaskwinu	300	479	579
Astialakwa	250	1825	360
	150	386	554
	125	0	575
	125	128	647
	125	0	688
	100	137	580
Hot Springs Pueblo	75	0	505
	75	385	535
	75	0	574
Hanakwah	75	0	578
	75	403	689

TOTAL No. of Rooms: 17,525
No. of Sites >1,000 Rooms 7

Beginning in the early 1600s Spanish soldiers and missionaries forcibly "congregated" Jemez people in one to a few locations. The mission church, now in ruins in Jemez Springs was constructed in the first decades of the 1600s. (photo from 1880s)

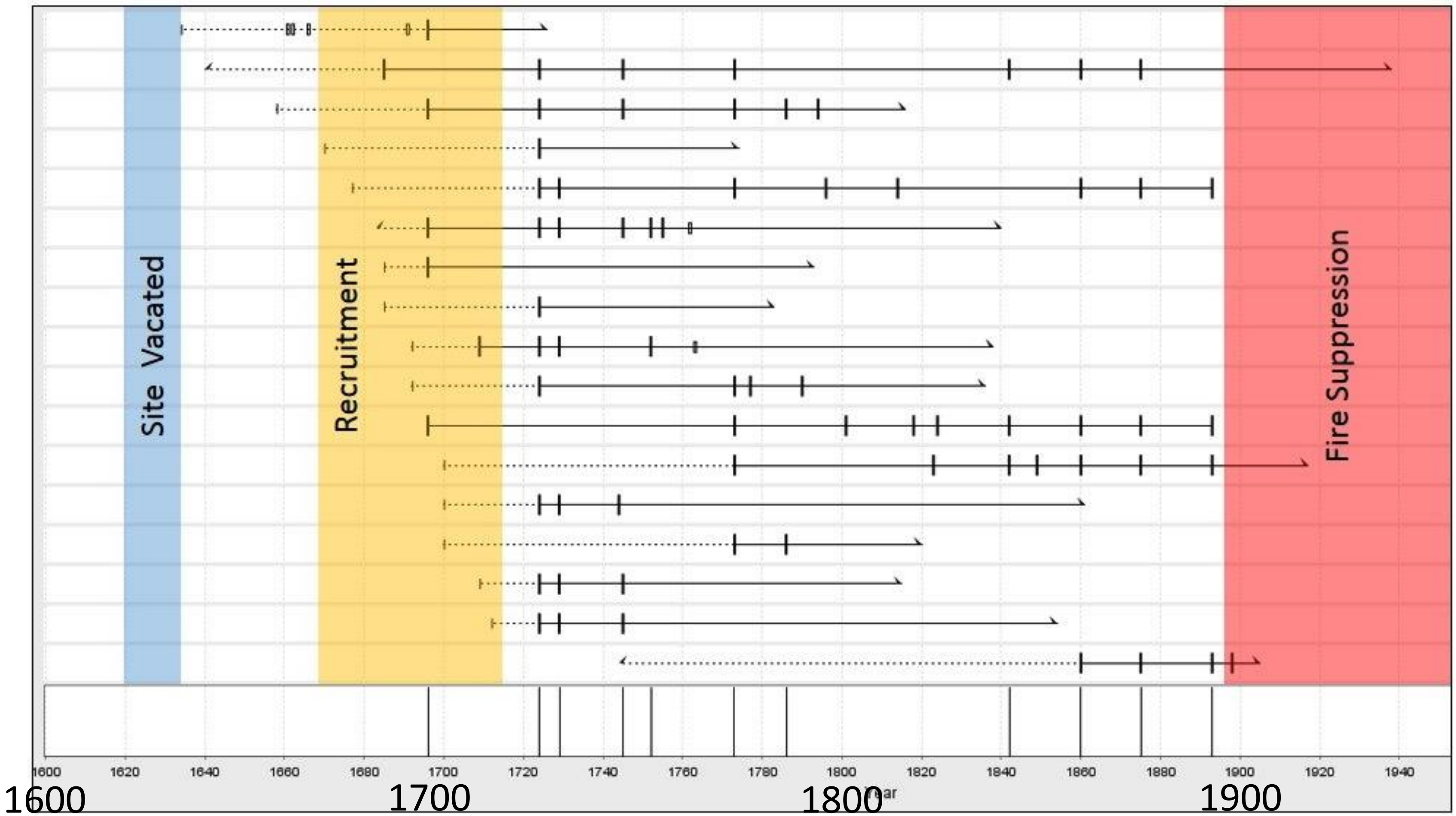
We are reconstructing the detailed fire history within, and in the vicinity of Jemez ancestral villages and in likely farming and summer residence locations (i.e., "field houses"). Josh Farella (grad student) and Tom Swetnam are obtaining fire scarred sections and samples from dead and living trees in these areas to reconstruct fire history.

Tree Rings



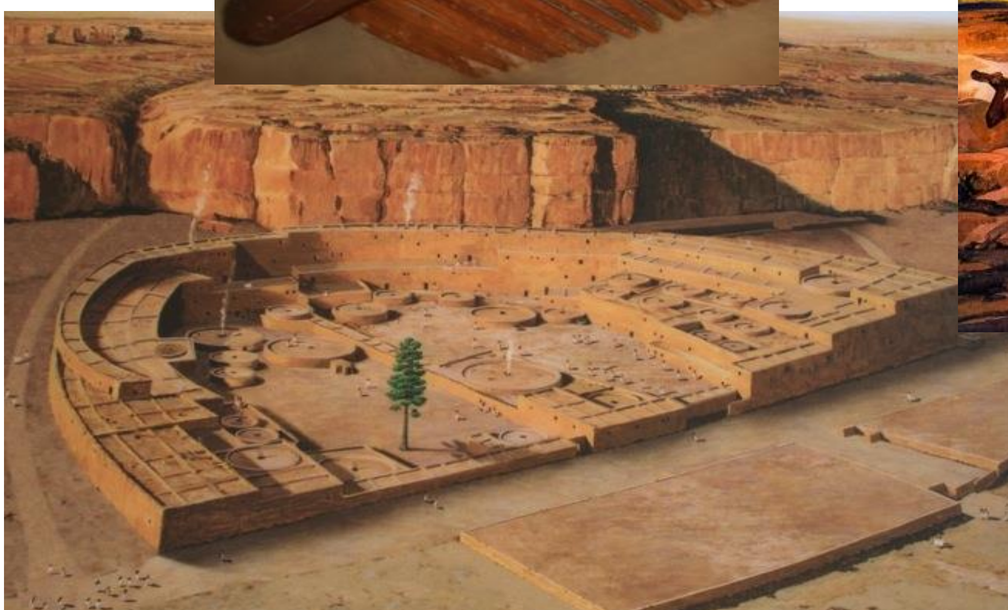
Fire scarred trees (stumps, logs, snags) sampled within and near the village of "Wabakwa"

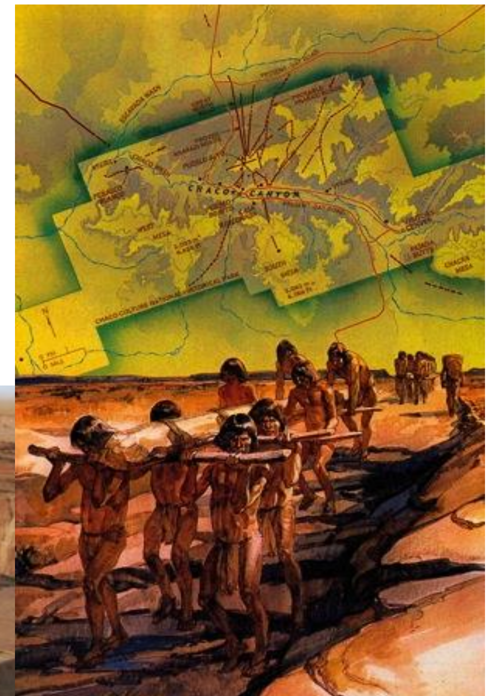
This chart shows fire scar dates (vertical bars) on individual trees (horizontal lines) sampled within and around the ancestral village known as "Wabakwa" on San Juan Mesa. From pottery types it is thought that this village was unoccupied after 1400, but nearby field houses suggest usage of the area into the early 1600s. After the "congregation" of the Jemez people near Spanish missions (after circa 1620) the site began to burn with surface fires, until the livestock grazing and fire suppression era around 1900.



Consider how much fuel wood Jemez ancestral people would use over 200-300+ year periods of time when they were living primarily on the mesa tops, at 6,000-7,000+ feet elevations and with cold winters. Also, consider how many timbers and other wood products were required for many large villages, and all of the various uses of wood.

How did such wood utilization (forest management?) affect fire regimes?





More than 200,000 beams were cut and hauled 50 miles or more for construction of the “Great Houses” at Chaco Canyon

Ethnographic Research

TJ Ferguson, University of Arizona
John Welch, Simon Fraser University

Barnabe Romero

Persingula Toya

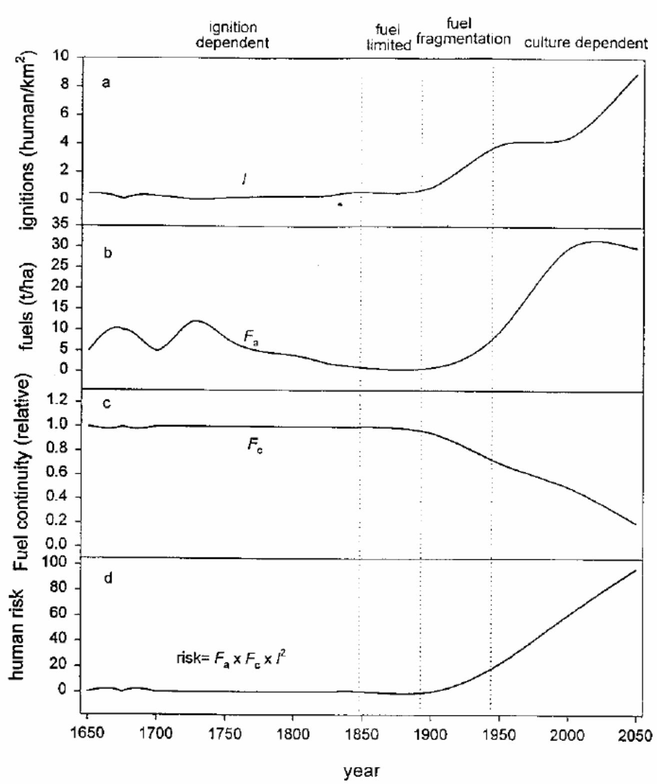
- Use of fire in agriculture
- Use of fire in grazing
- Use of fire in cultural practices
- Concepts of good forest structure
- Cultural values and beliefs regarding fire
- Personal experience with forest fires

Developing and Testing Forest, Wildfire and Human Dynamics Theory

Ecosystems (2002) 5: 472–486
DOI: 10.1007/s10021-002-0115-7
ECOSYSTEMS

Dynamics of an Anthropogenic Fire Regime

R. P. Guyette,[1]* R. M. Muzika,[1] and D. C. Dey[2]



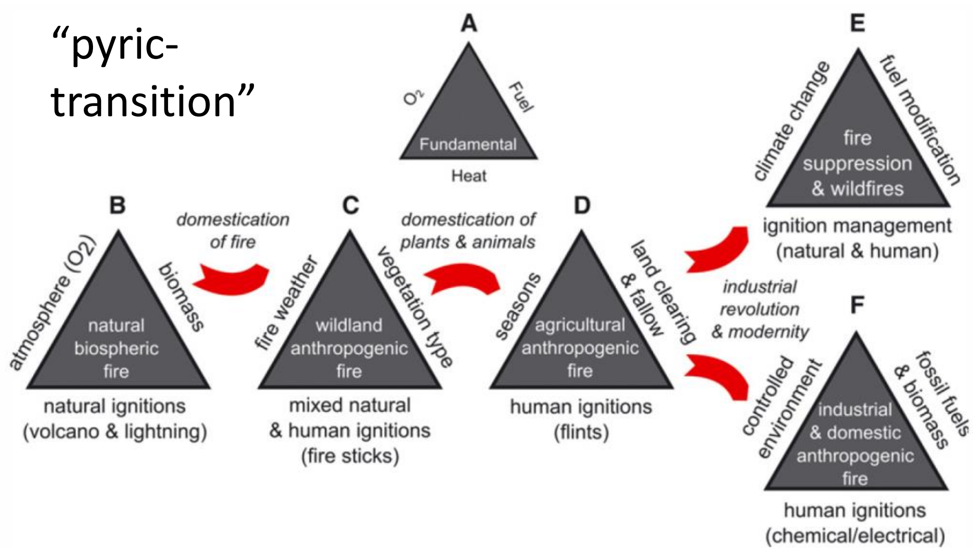
Journal of Biogeography (*J. Biogeogr.*) (2011)

SYNTHESIS

The human dimension of fire regimes on Earth

David M. J. S. Bowman[1]*, Jennifer Balch[2], Paulo Artaxo[3], William J. Bond[4], Mark A. Cochrane[5], Carla M. D'Antonio[6], Ruth DeFries[7], Fay H. Johnston[8], Jon E. Keeley[9,10], Meg A. Krawchuk[11], Christian A. Kull[12], Michelle Mack[13], Max A. Moritz[14], Stephen Pyne[15], Christopher I. Roos[16], Andrew C. Scott[17], Navjot S. Sodhi[18†] and Thomas W. Swetnam[19]

"pyric-transition"



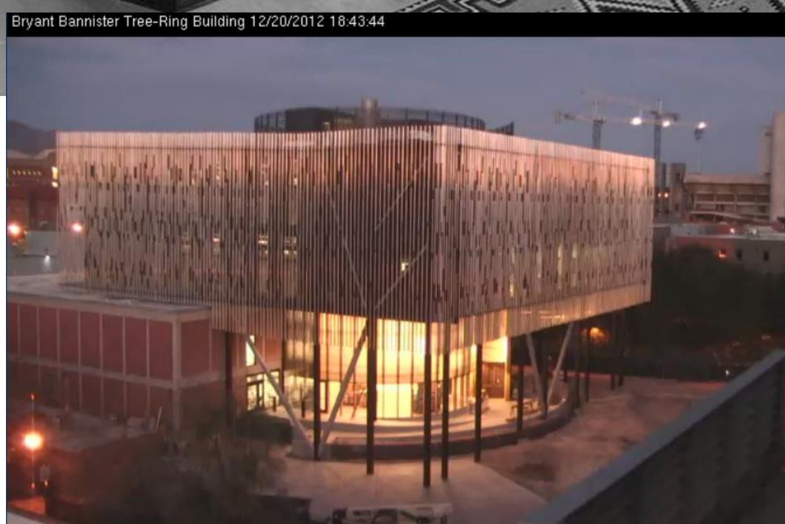
Main Points

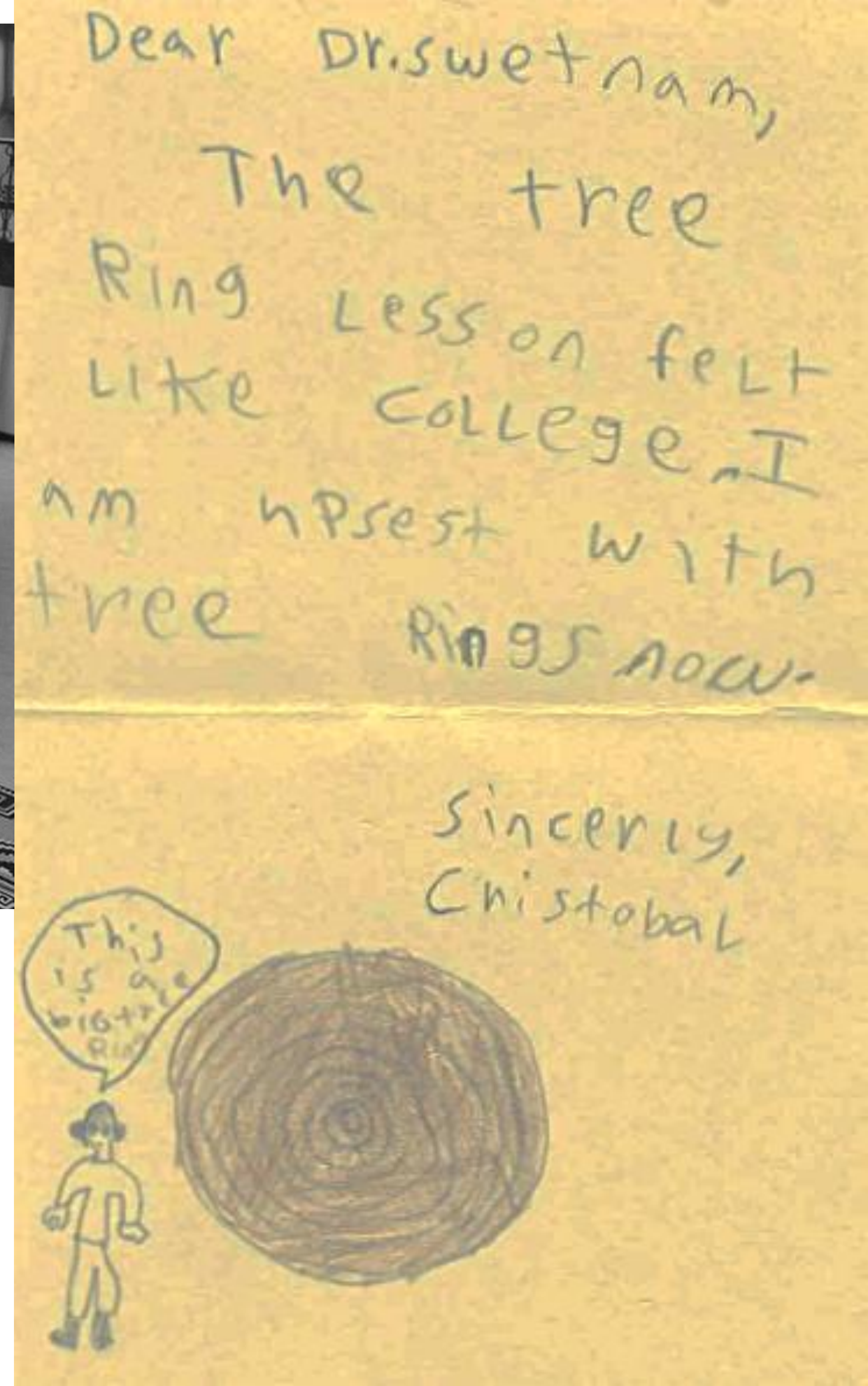
- The multi-disciplinary nature of dendrochronology goes back to the beginning of the field in the early 20th century, with both Douglass and Huber, for example, connecting their tree-ring work with climate, solar astronomy, biology, and archaeology.

- We are entering a new era of multi-disciplinary dendrochronology focused on "dynamics of coupled human-environmental systems", with a number of exemplary studies recently published and underway; support is increasing for these endeavors from funding agencies in the U.S. and elsewhere.

- Several elements are needed for progress in meeting grand challenges in human-environment studies, including: (1) effective collaborations between physical, biological/ecological, and social scientists (not so easy to achieve!), and multi-scale approaches, ranging from cells to regions and the planet (also, not so easy to achieve!)


MASTER KEY
TO SOUTHWESTERN ARCHAEOLOGY


Bryant Bannister Tree-Ring Building 12/20/2012 18:43:44

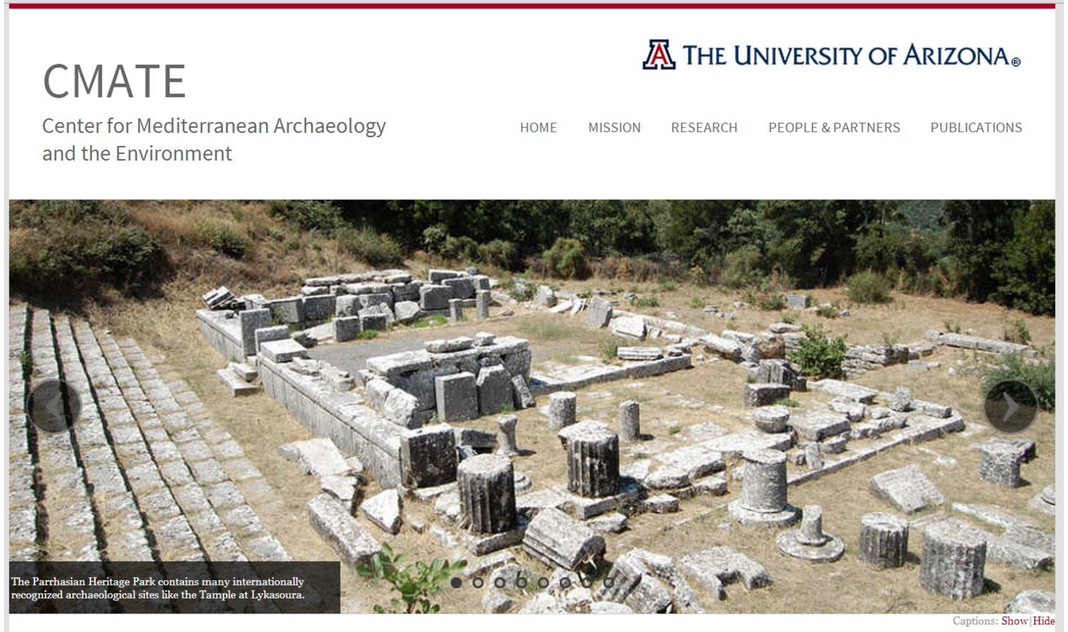

Dear Dr. Swetnam,
The tree Ring Less on felt Like college. I am upsest with tree Rings now.
Sincerly,
Cristobal
This is a bigtre


THANKS, FOLKS
ONLY YOU CAN PREVENT FOREST FIRES!

The Center for Mediterranean Archeology and the Environment (CMATE)
is a collaboration of faculty and the School of Anthropology and the School of Earth and Environmental Sciences -- in particular the Laboratory of Tree-Ring Research, Geosciences and the Accelerator Mass Spectrometry Laboratory.

Goals:

- Gain a deeper and more highly resolved understanding of human and environmental interactions over time in the greater Mediterranean region.
- Gain new insights into the driving forces behind key turning points in civilization.
- Support interdisciplinary research between faculty and students of the School of Anthropology and the School of Earth and Environmental Sciences to create a fully integrated understanding of past human-environmental interactions in Mediterranean Basin.



Main Points:

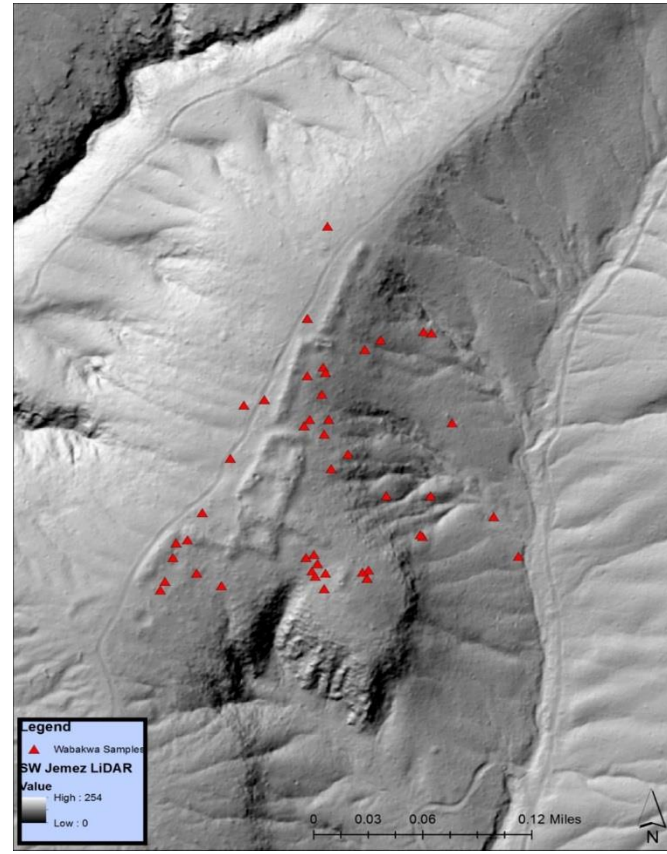
1. Humans have interacted with forests, fuels and fire for a very long time in the Jemez mountains. Understanding of the specific histories in this landscape can inform us about circumstances that we now find ourselves in, and potentially also point the way forward.

1. A multi-disciplinary research project funded by the National Science Foundation (FHiRE: Fire & Humans in Resilient Ecosystems), is working to improve our understanding of how ancestral Jemez people interacted with forests, fuels, fire and climate on these landscapes, with a goal of learning lessons that may be applicable, at least in part, to todays landscapes AND to provide historical and cultural context and perspectives to for future management

What lessons can we learn from the "traditional knowledge", cultural-environmental histories of Native American people and landscapes – and how they lived within drought and fire-prone forests and woodlands?

Architectural rendition of "Kwastiyukwa" in Jemez Mountains

The Jemez landscape offers a unique learning opportunity because of its long-term cultural history and ecological context.



The Jemez ancestral villages contain some of the largest Native American “townhouse” villages known to have existed anywhere in western North America within pine-dominated, surface fire regime forests.

The ancestral Jemez people found ways to live as dryland agriculturalists within these fire prone (and smoky) landscapes for centuries, through irregular pluvial and drought periods of varying magnitudes.

The villages and the surrounding forest areas were intensively occupied for generations prior to the 1600s when the Spaniards arrived, when populations relocated to new low elevation villages in the region and, in the case of some mesa top villages in forests, were reoccupied briefly *during the historic period following the Pueblo Revolt of 1680.*

The large village sites tend to be located at the current "ecotone" of ponderosa pine and pinyon-juniper woodlands. However, many sites are entirely within the ponderosa pine type.

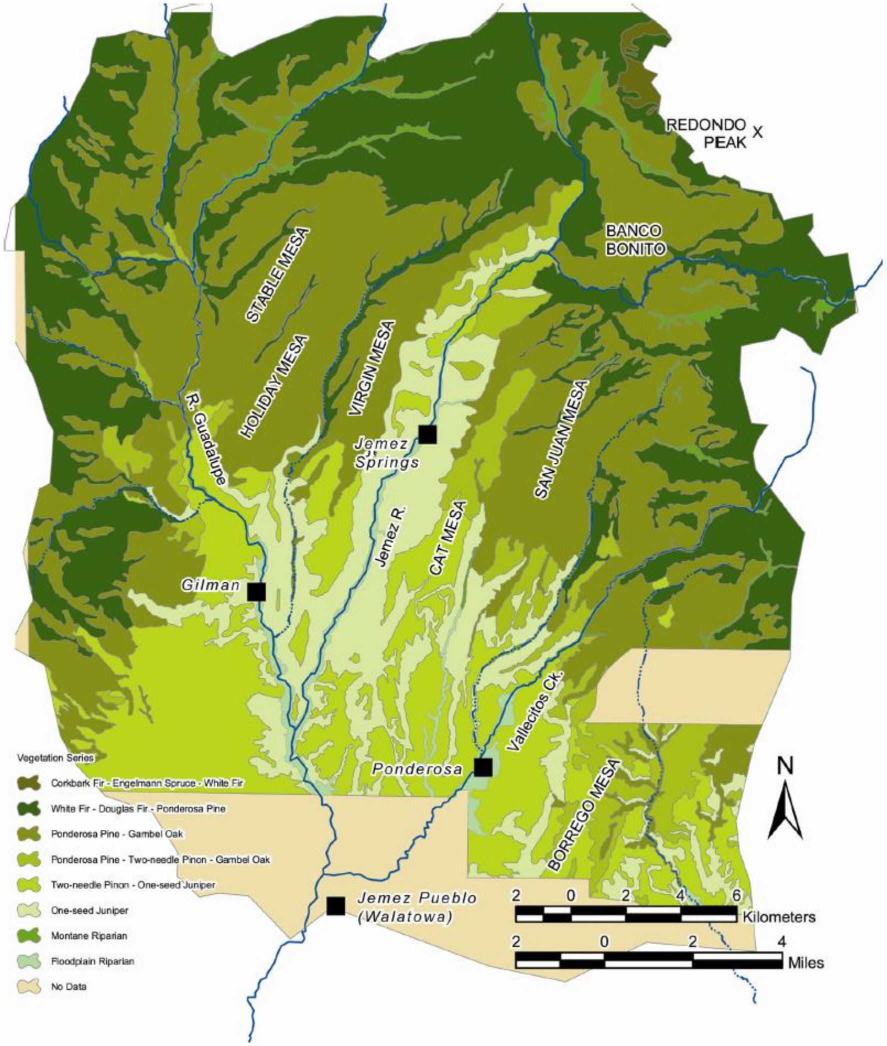


Figure 6.4. Major vegetation series present on the Jemez Plateau. Data adapted from Miller and others (1993). Series categories from Dick-Peddie (1993). Data available only for lands managed by the Forest Service. Vegetation data courtesy of the USDA Forest Service, Santa Fe National Forest.

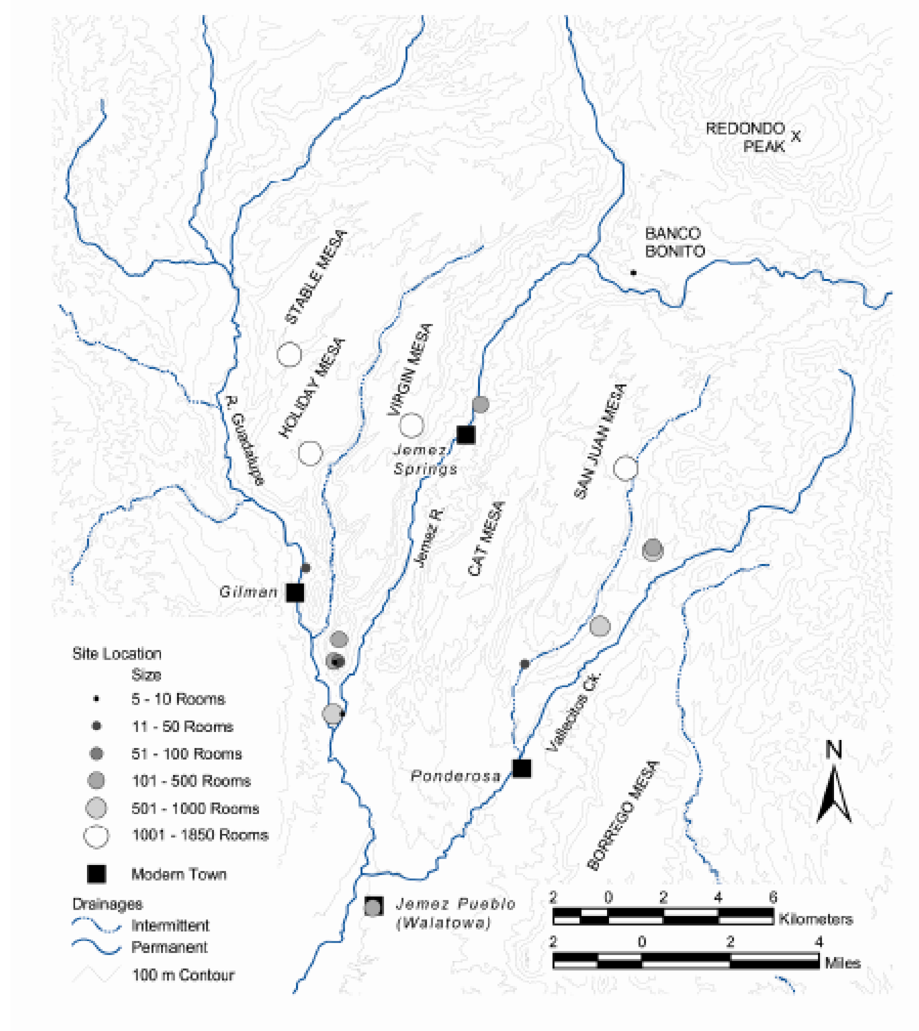
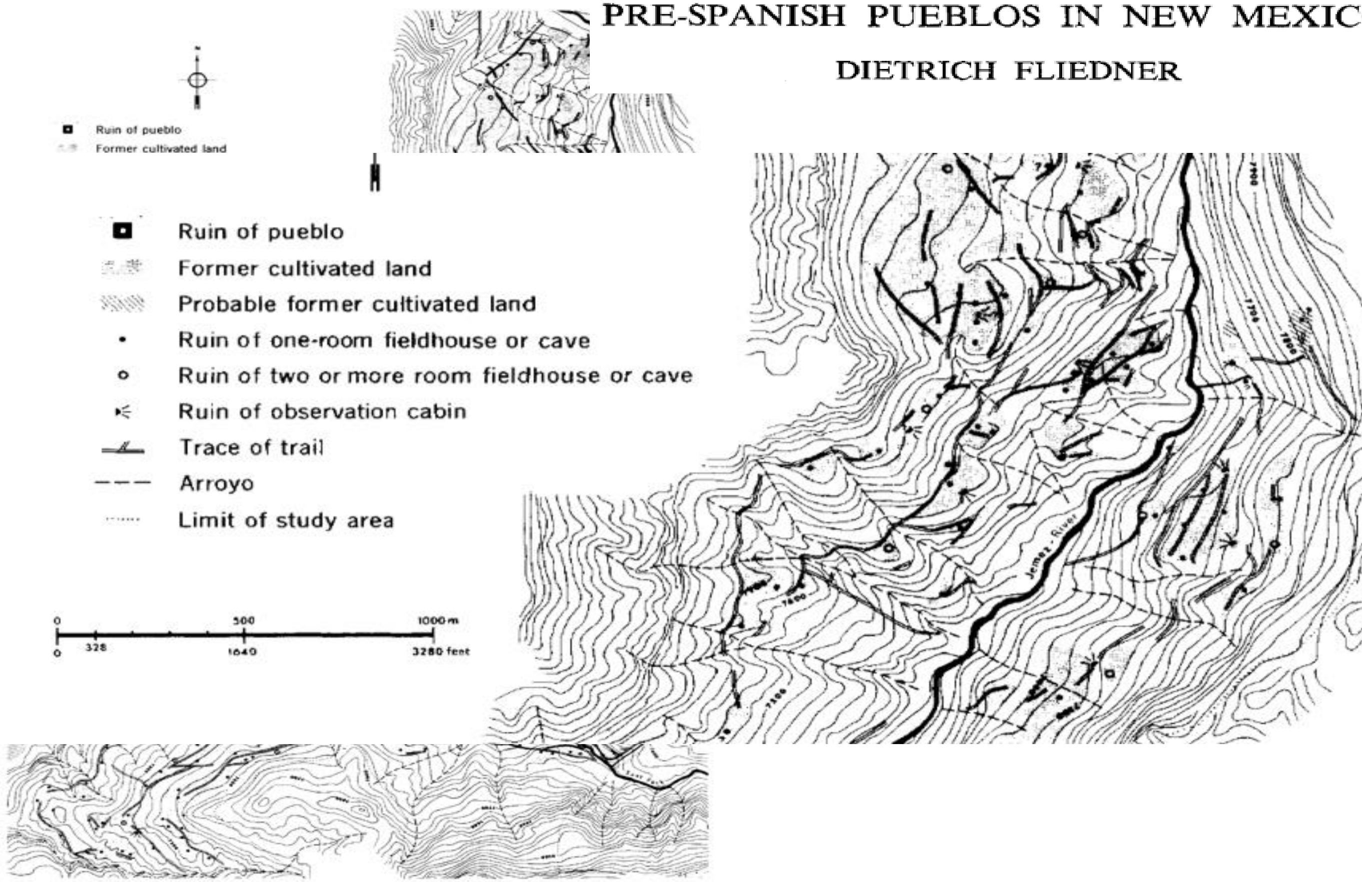


Figure 6.10. The locations of sites with five or more rooms dating to the Guadalupe Phase (A.D. 1600/1625 to 1700). Site data from Archeological Records Management Section files at the Laboratory of Anthropology, Museum of Indian Arts and Culture, Museum of New Mexico.

Fliedner's very interesting study (conducted in the 1970s) suggests that land utilization was VERY extensive and intensive by the Jemez people. Although his interpretations of various land-use features has not been tested yet (to our knowledge), even if only a fraction of the features he identifies were indeed contemporaneous cultural features, then we MUST consider: **<u>What effects did this level of use have on forests, fuels and fire regimes?</u>**

PRE-SPANISH PUEBLOS IN NEW MEXICO*

DIETRICH FLIEDNER



His study area was in Sand Diego Canyon, just downstream from Battleship Rock and near the 16th/17th century occupied villages of Unshagi and Nanishagi.

FIG. 1. General map of pre-Spanish relics in upper Jemez Canyon.

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Keep in mind that lightning strikes and ignitions of fire by lightning are very common during certain times of the year. In a fully human-occupied Jemez landscape, people would have advertently or inadvertently added more ignitions, especially in the low lightning occurrence seasons.

Overall, ignition sources were MUCH LESS LIMITING IN THESE LANDSCAPES THAN FUELS.

Automated Lightning Detection System – Jemez Mountains, northern New Mexico:

- 165,117 cloud-to-ground lightning strikes over a 775,554 ha area, 1984-1994
- 16,500 strikes per year on average
- Minimum annual 9,410 strikes
- Maximum annual , 23,317 strikes
- Average 21 strikes/1000 ha/year
- Minimum 12 strikes/1000 ha/year
- Maximum 30 strikes/1000 ha/year

- See Craig Allen's classic paper: "Lots of Lightning, Plenty of People"

LOTS OF LIGHTNING AND PLENTY OF PEOPLE 147

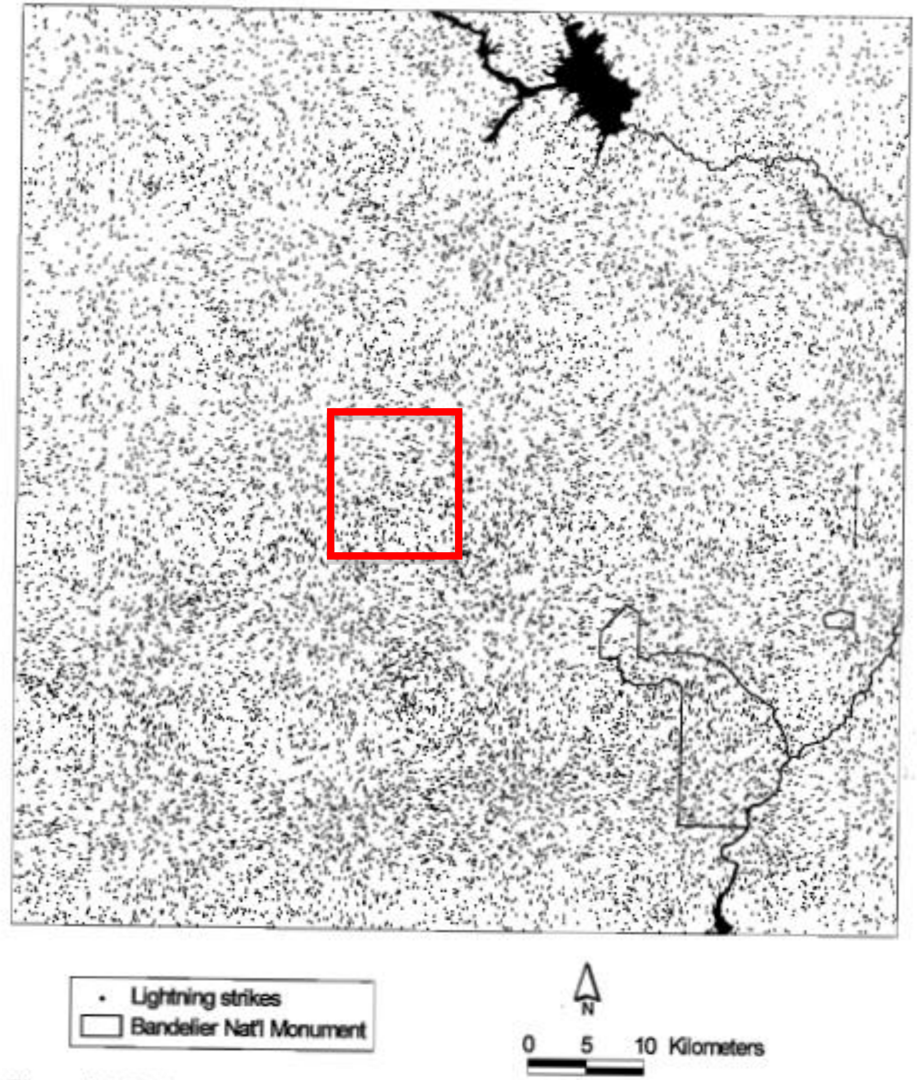


Figure 5.2. Lightning strikes in the Jemez Mountains, 1986. Map of 23,317 lightning strikes recorded across 775,554 ha in the Jemez Mountains area during 1986 by the national automated lightning detection system. The nominal resolution of the locational data is approximately 2 km. Surprisingly little difference in lightning strike frequencies is evident across the 1,800-meter elevational gradient present in this field of view, which is also the same in Figures 5.4 and 5.5.

Long-Term Vulnerability and Resilience of Coupled Human-Natural Ecosystems to Fire Regime and Climate Changes at an Ancient Wildland Urban Interface

A fundamental goal of our proposed project is to understand the dynamic interactions of climate, human activities, and fire regimes over a variety of temporal, spatial, and demographic scales in an ancient Wildland Urban Interface.

FHiRE: Fire & Humans in Resilient Ecosystems

Investigators:

Tom Swetnam, UA – fire history, climate, tree rings
Sara Chavarria, UA – education and outreach
Josh Farella, UA – fire history, archaeology, tree rings
TJ Ferguson, UA – ethnography, oral traditions
Chris Roos, SMU – geomorphology, archaeology, fire hisory
Matt Liebmann, Harvard U, archaeology, ceramic analyses
John Welch, Simon Fraser U – archaeological resource management
Bob Keane, USFS Fire Lab – fire and ecological modeling
Rachel Loehman, USFS Fire Lab – fire and ecological modeling

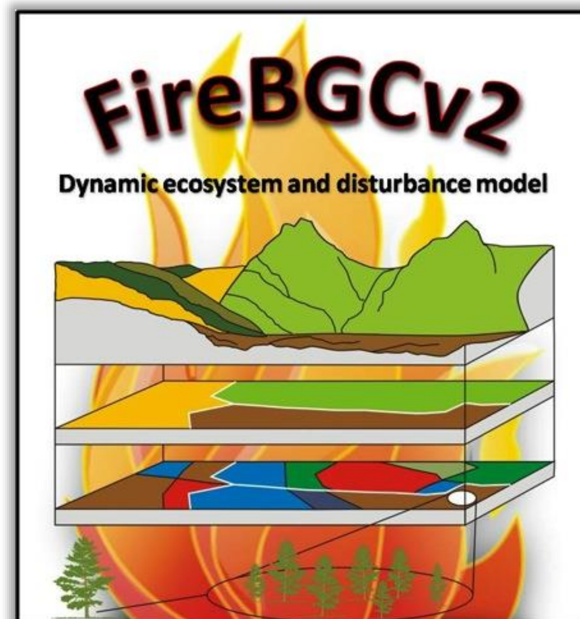
Funded by the National Science Foundation

Dynamics of Coupled-Natural Human Systems Program

In addition to developing chronologies of fire dates (annual), we can identify the intra-annual position of about 2/3rds of all fire scars, enabling us to estimate the relative seasonal timing of past fires: i.e., prior to, during, and after the growing season. The scar below (right side, is an “earlywood” scar, occurring during the summer, probably in May or June.

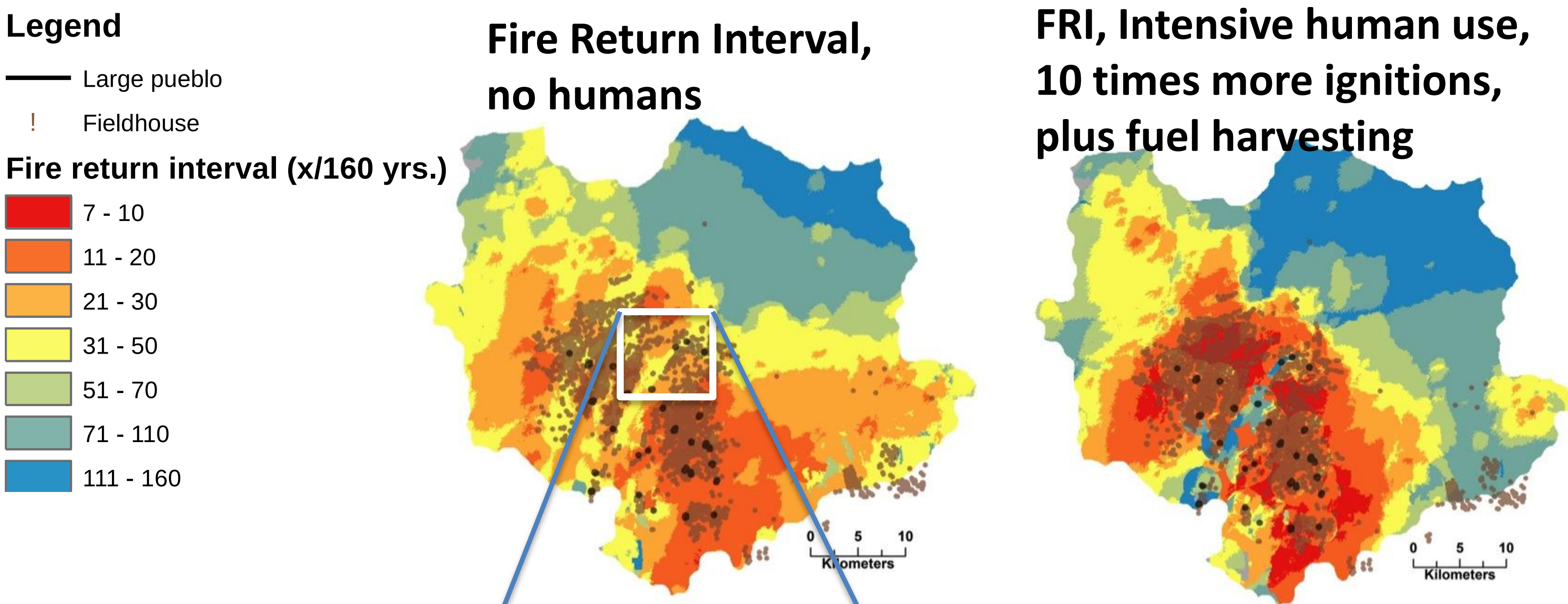
FireBGCv2 modeling platform

- Mechanistic ecosystem process model
- Includes fire behavior, effects
- Scaled from individual tree to landscape processes
- Incorporate range of future conditions
- Test strategies for mitigation and adaptation

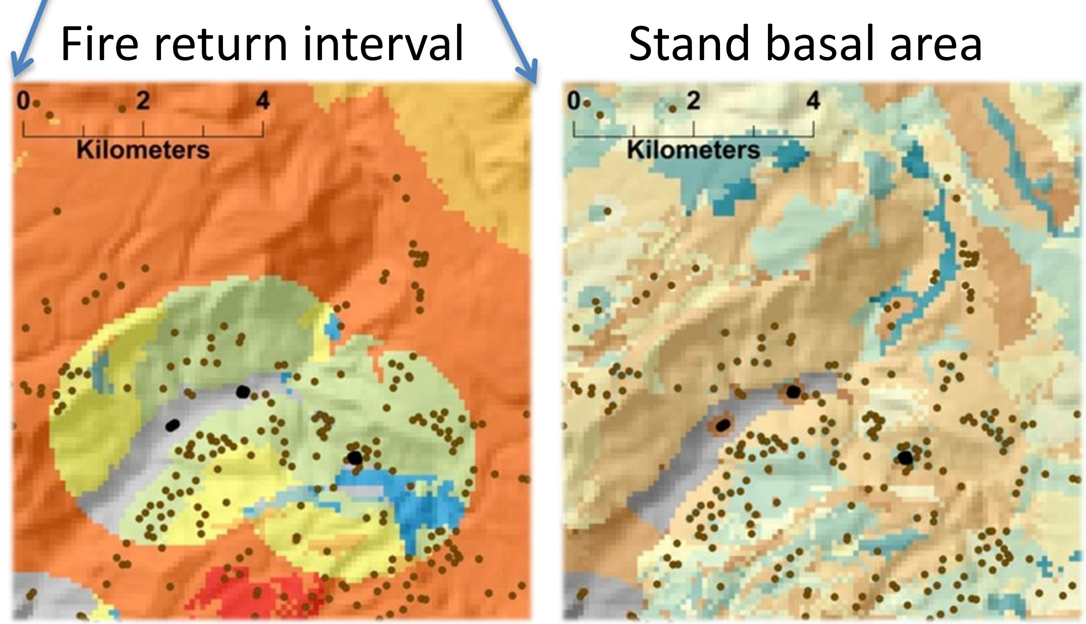


Keane, Loehman, Holsinger 2011

http://www.firelab.org/research-projects/fire-ecology/139-firebgc



Moderate human use, **2 times more ignitions (outside of use zone), plus fuel harvesting**



Terminus ante quem Dating of Wabakwa and the Return of Fire to an ancient WUI, Jemez Mountains, New Mexico.

Joshua Farella and Thomas Swetnam
University of Arizona Laboratory of Tree Ring Research