Site and tree selection in dendroecology

Don Falk, University of Arizona

What is the most important criterion for site and tree selection?

What is the most important criterion for site and tree selection?

YOUR QUESTION!

In other words:

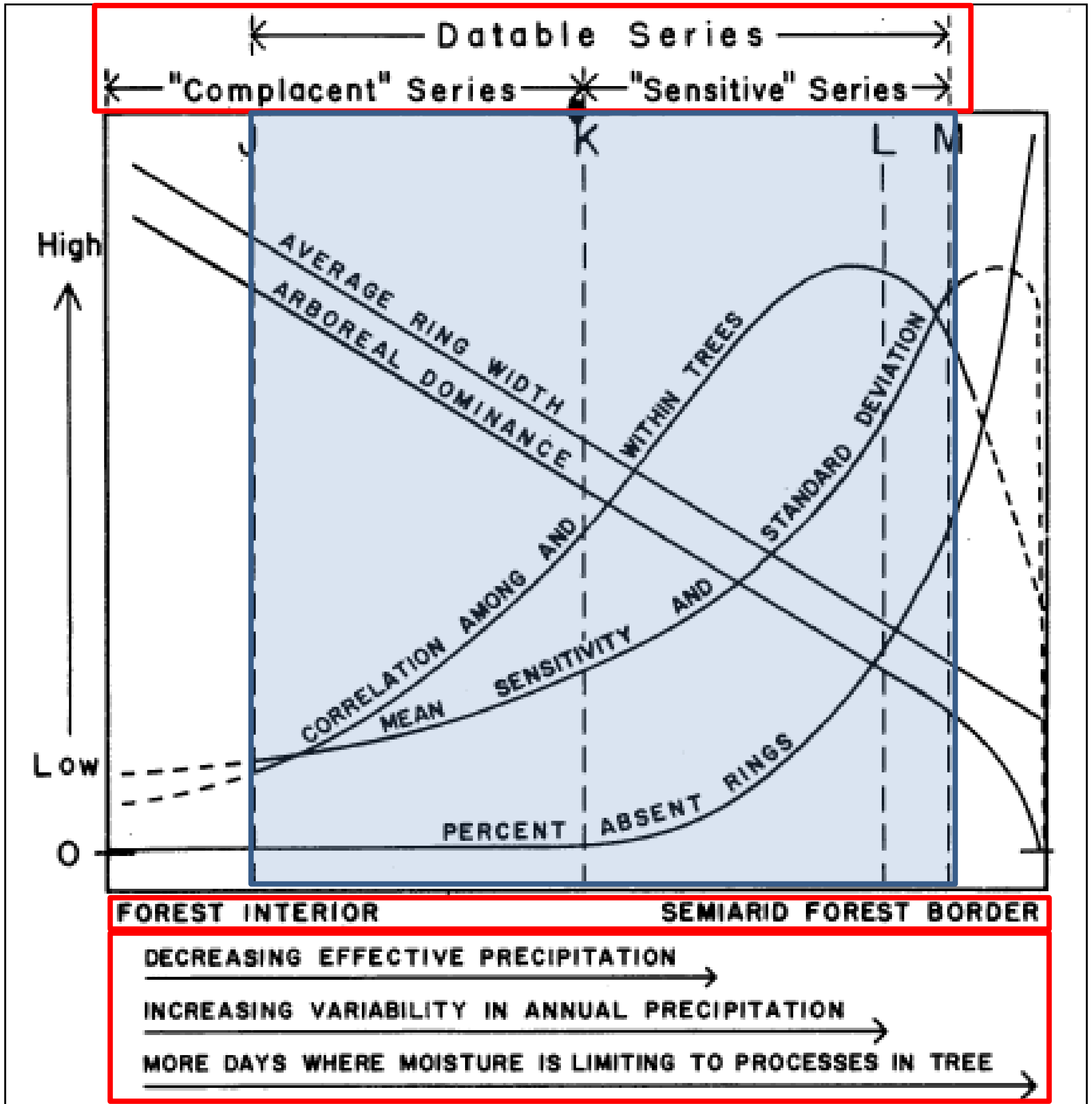
- There is **no** universal guide to site or tree selection
  - Like everything else in research*, it should be guided completely by your study design, which in turn should be guided completely by the question(s) you hope to answer

* resources permitting

That said, to do dendrochronology of any kind we require:

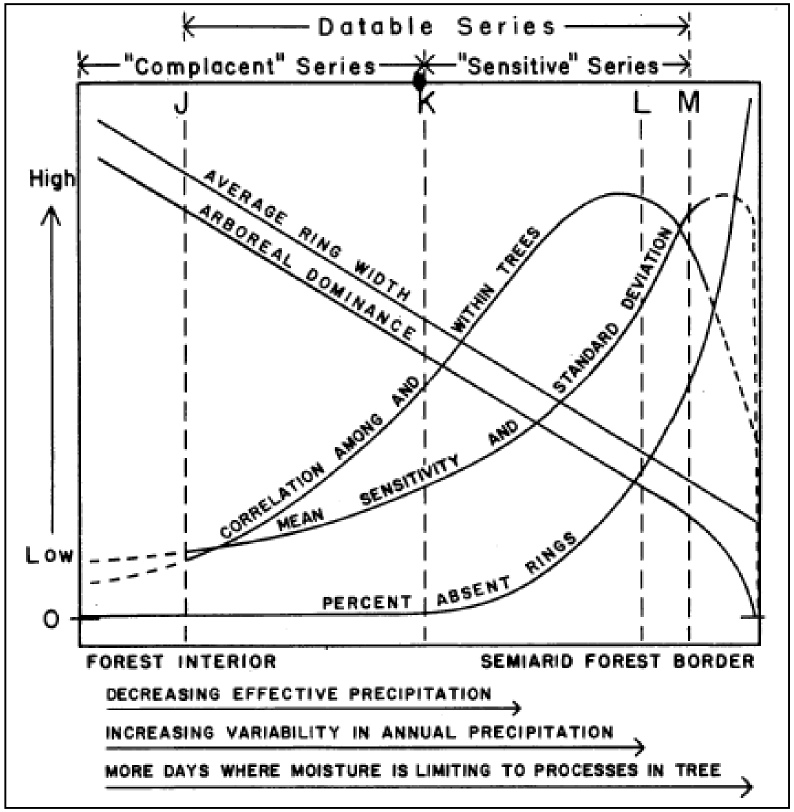
1. Growth increment (e.g. “rings”) **distinct and detectable** (by some method)
2. Reliable **annual** ring formation
3. Ring formation **sensitive to time-varying environmental conditions** (growth-limiting environmental factors)
4. Sensitivity reflected in growth **variability among years**
5. Strong **common patterns** of measurable properties

The canonical view (Fritts 1965):



A few notes about the canon:

1. Series that are either too complacent or overly sensitive are generally **problematic**
2. **Gradients are species specific**; thus the x-axis really refers to the **middle and lower elevational range of a population of species X**
3. Note that the **upper elevational limit is not shown**; what might happen up there?
4. Elevation is really a **proxy for other variables**!



Species populations vary **uniquely** along environmental gradients

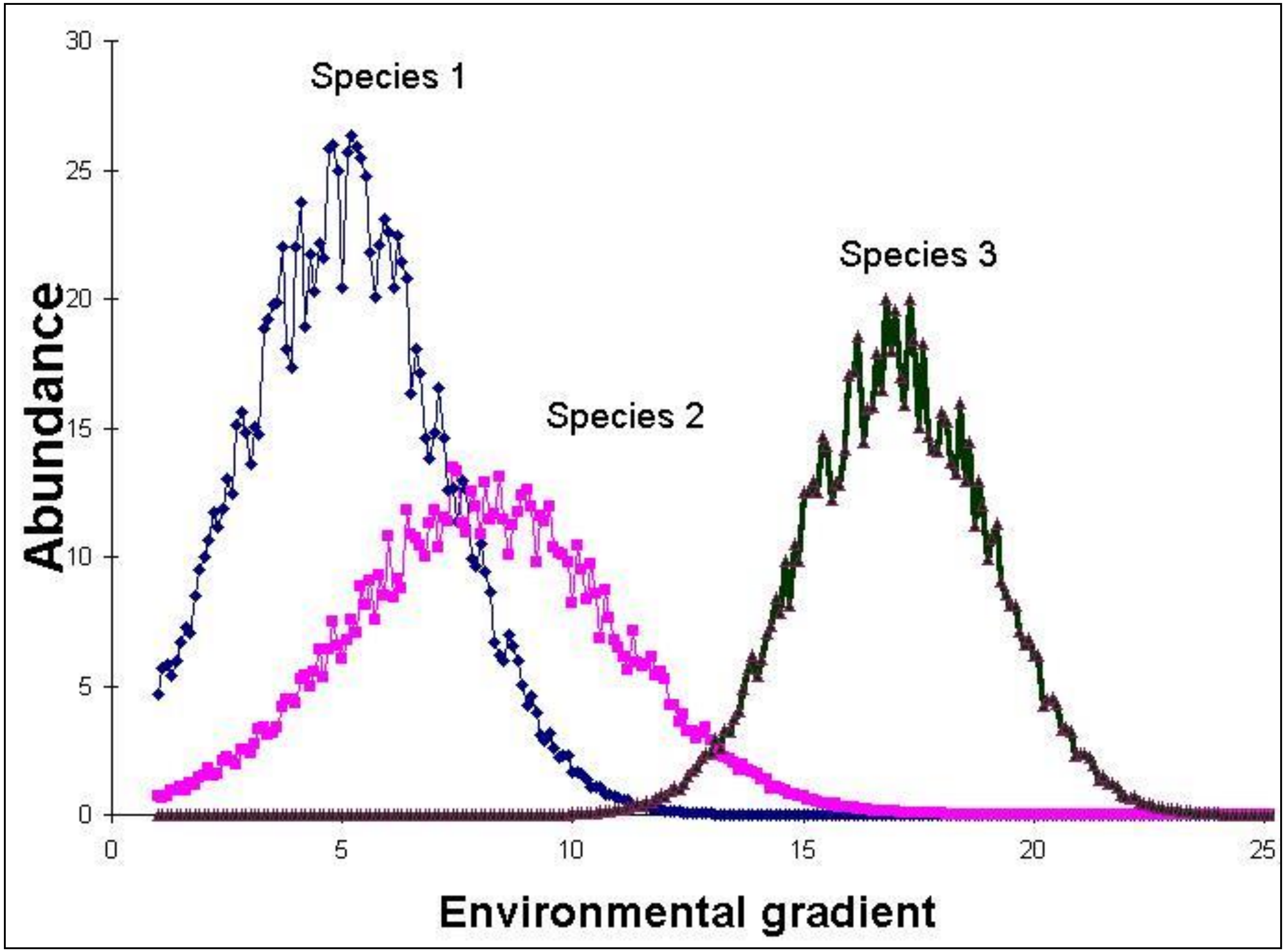
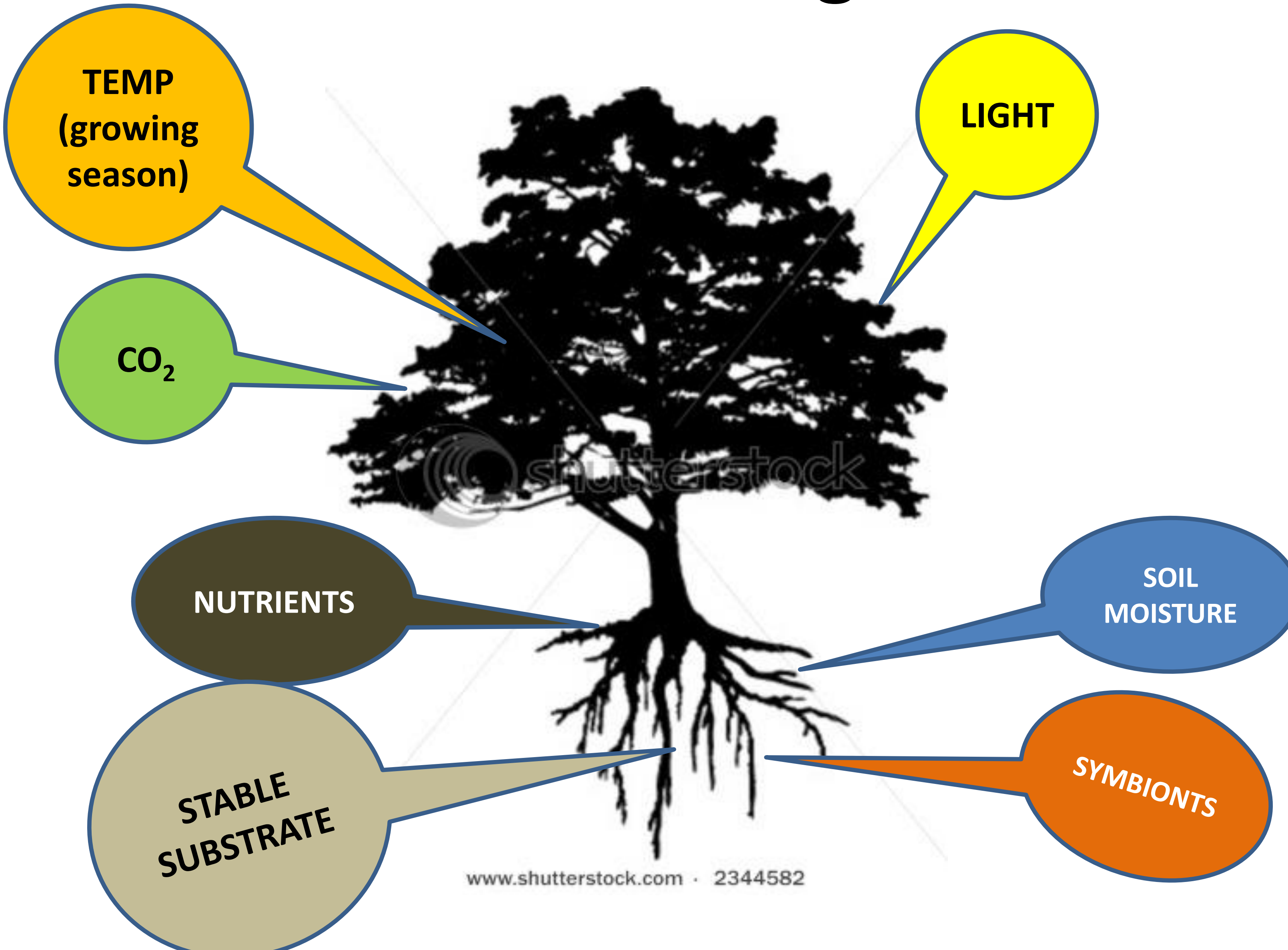
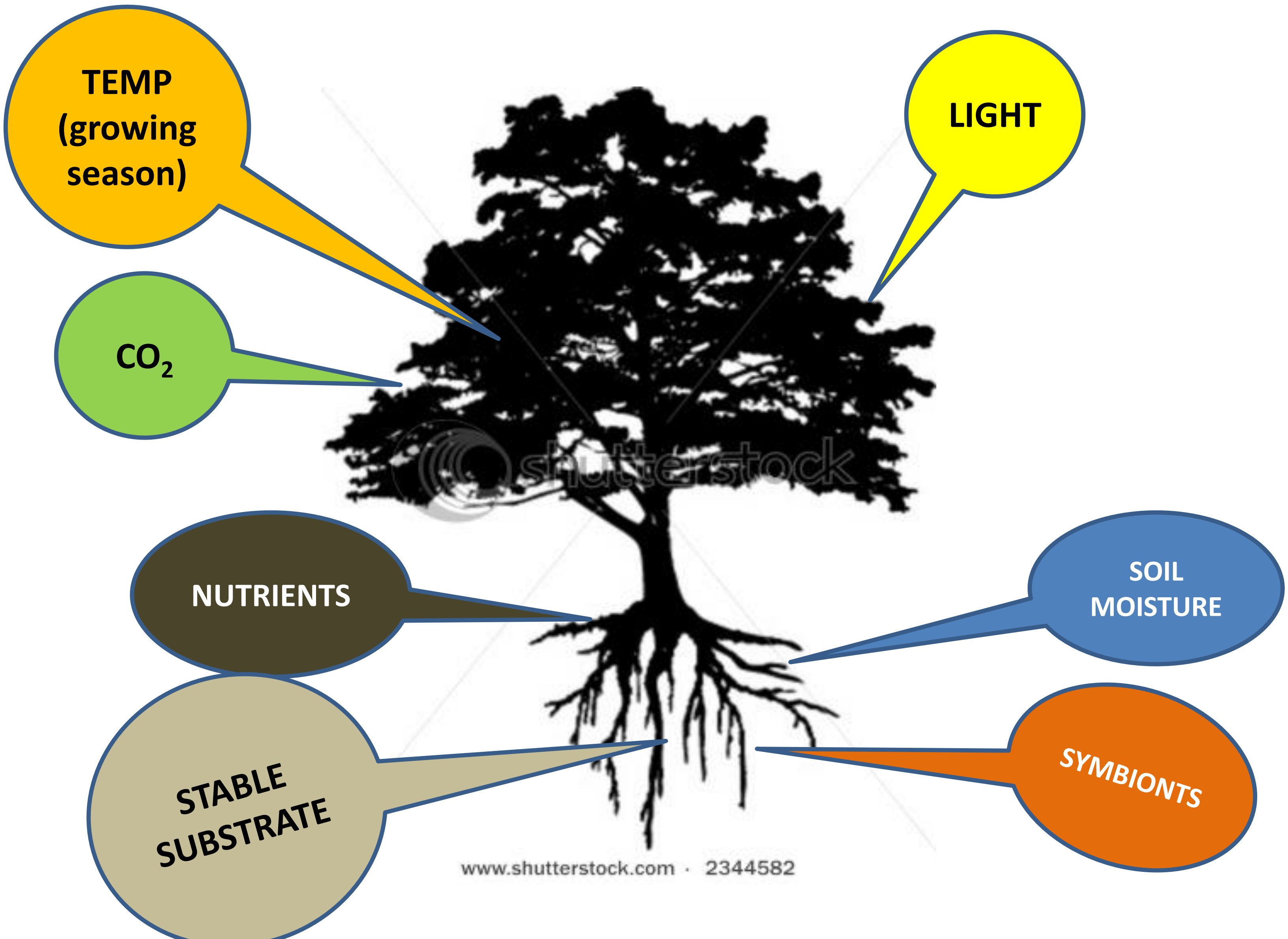


Figure: Dr Michael Palmer, University of Oklahoma

What does it take to grow a tree?



Which of these factors are time varying (meeting our dendro dating criteria)?



How do we apply our "fundamental sampling principle" to this ecological understanding of a tree?

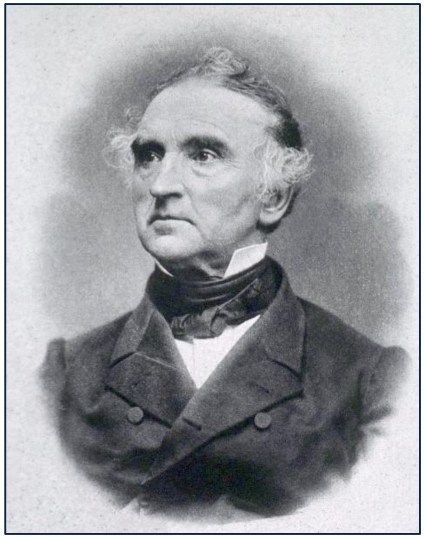
- Follow the principle of **limiting factors to growth**:
- If we are trying to reconstruct "climate" (sic) we want "climate-limited growth"
- If we are trying to answer an ecological question…
  - Not so obvious!

Liebig's "Law of the Minimum":

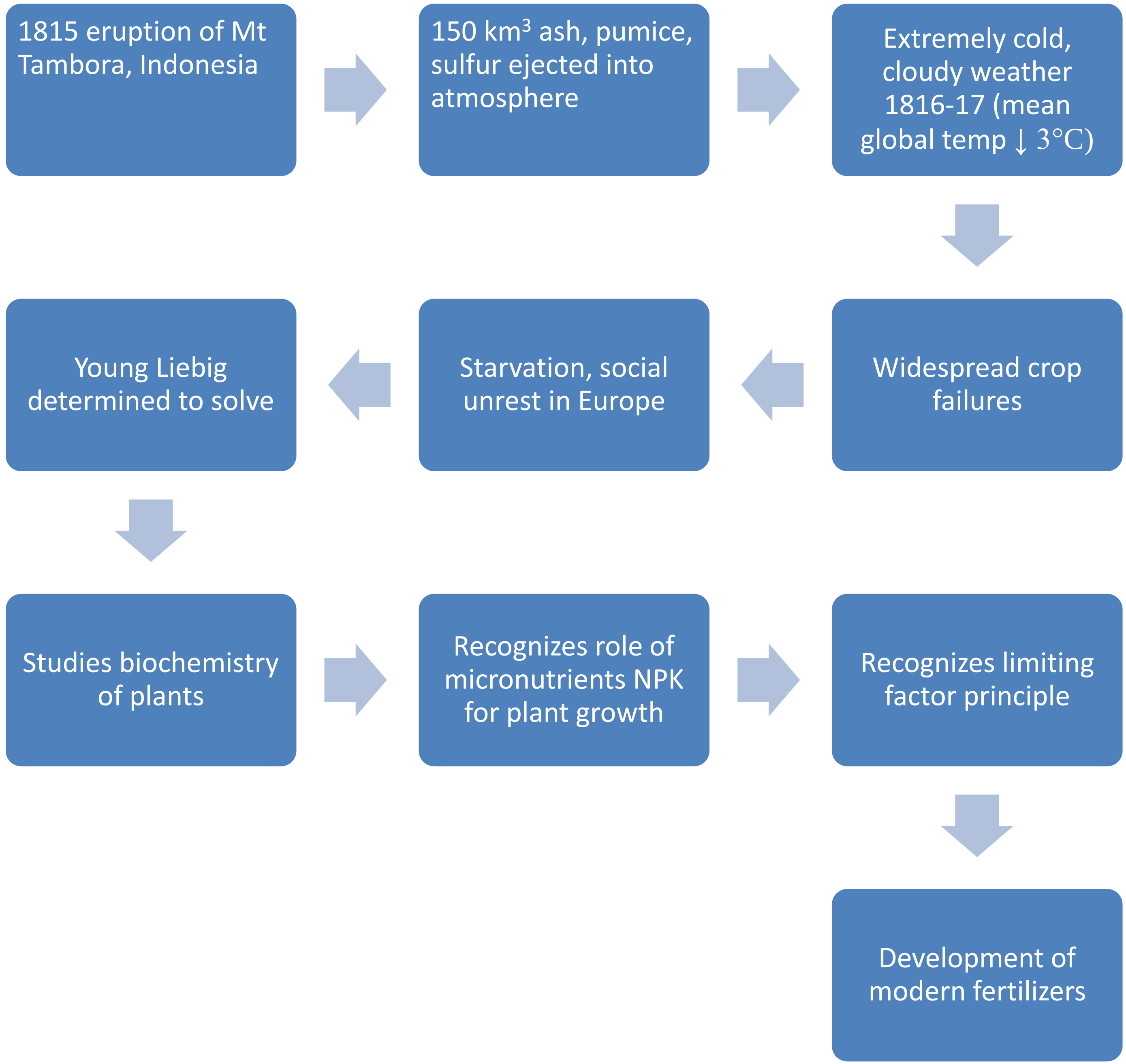
Growth is controlled by the essential factor in most limited supply, not by total resources

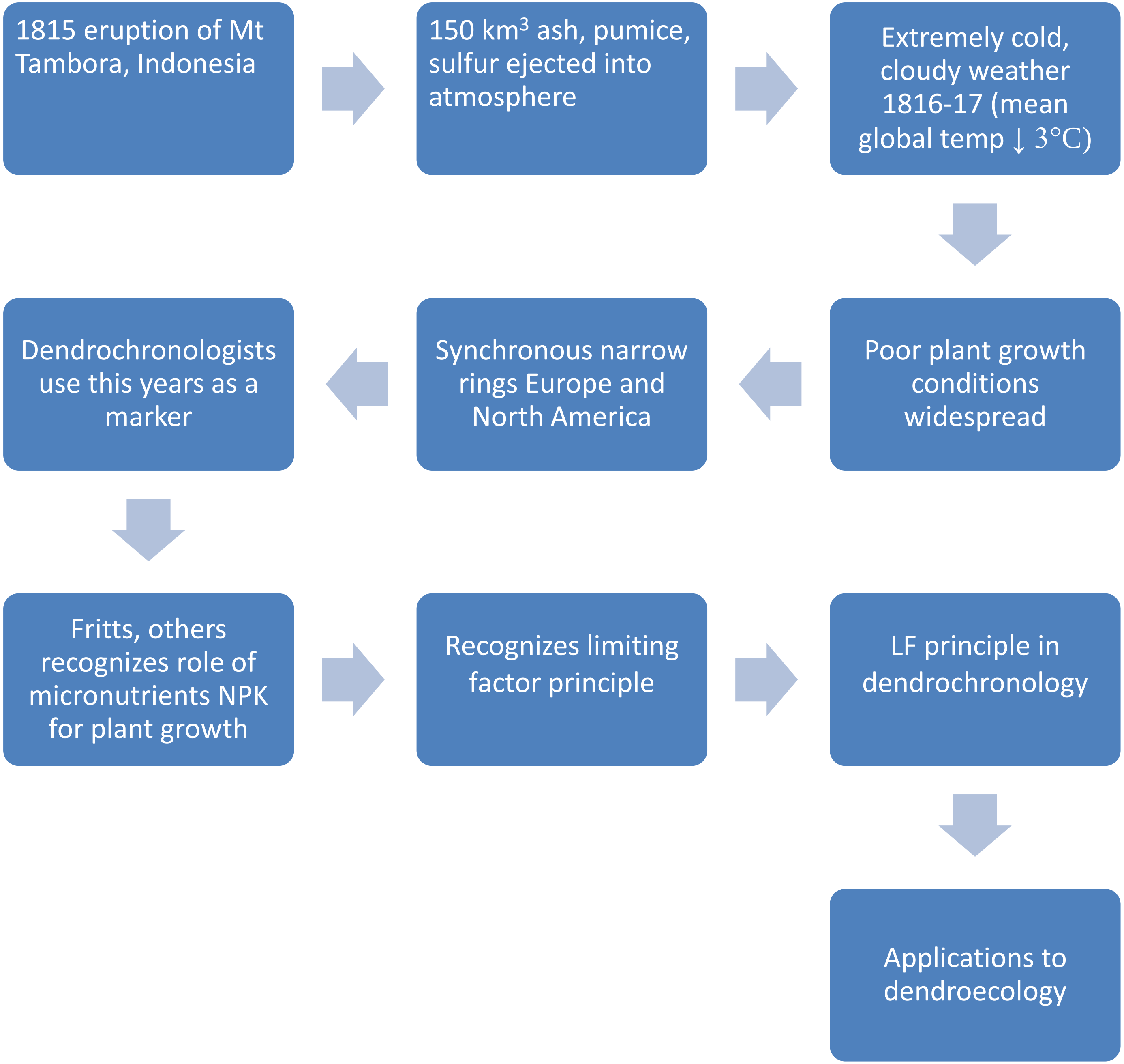
Liebig applied this principle to the development of plant fertilizers

Influenced by the "year without a summer" (1816) due to volcanic influence, which led to widespread famine in Europe – and clearly visible in the tree-ring record



Justus von Liebig, German chemist (1803 – 1873)


1815 eruption of Mt Tambora, Indonesia
150 km^3 ash, pumice, sulfur ejected into atmosphere
Extremely cold, cloudy weather 1816-17 (mean global temp ↓ 3°C)
Widespread crop failures
Starvation, social unrest in Europe
Young Liebig determined to solve
Studies biochemistry of plants
Recognizes role of micronutrients NPK for plant growth
Recognizes limiting factor principle
Development of modern fertilizers


1815 eruption of Mt Tambora, Indonesia
150 km^3 ash, pumice, sulfur ejected into atmosphere
Extremely cold, cloudy weather 1816-17 (mean global temp ↓ 3°C)
Poor plant growth conditions widespread
Synchronous narrow rings Europe and North America
Dendrochronologists use this years as a marker
Fritts, others recognizes role of micronutrients NPK for plant growth
Recognizes limiting factor principle
LF principle in dendrochronology
Applications to dendroecology

Limiting factors can influence site or tree selection in two ways

Constants (scalars or factorials)

- Growth factors affected by topography
- Major soil types
- Species
- Stand conditions, competition
- Geologic-scale climate
- Atmospheric pCO_2

Time-varying

- Temperature (growing season)
- Precipitation (proxy for soil moisture)
  - May also affect nutrient availability
- Light (photoperiod)

The same reasoning applies to selecting a <u>sampling site</u>

- In general, we assume that the “site” represents a mean environment for the trees that grow there:
  - Soil, hydrology
  - Air chemistry
  - Mean and daily climate
  - Ecological interactions (e.g., exposure to fire, insects, disease, other environmental factors)
  - Net overall productivity

Tree age: do we always want the oldest trees?

Yes, **IFF***:

- We are trying to build the longest possible chronology with the fewest number of trees
- We want to avoid modern era influences
- We want to know about long-ago environments

But **maybe not** if:

- We are trying to quantify a particular process (e.g. post-fire regeneration)
- Old trees are less sensitive to some environmental influence of interest
- We are interested in recent history (e.g. tree response to climate since 1950)

* In mathematical logic, **IFF** ≡ “if and only if”

Pinus flexilis near Red River, NM.
Photo by AM Lynch

Do we always want the most climate-sensitive sites or trees?

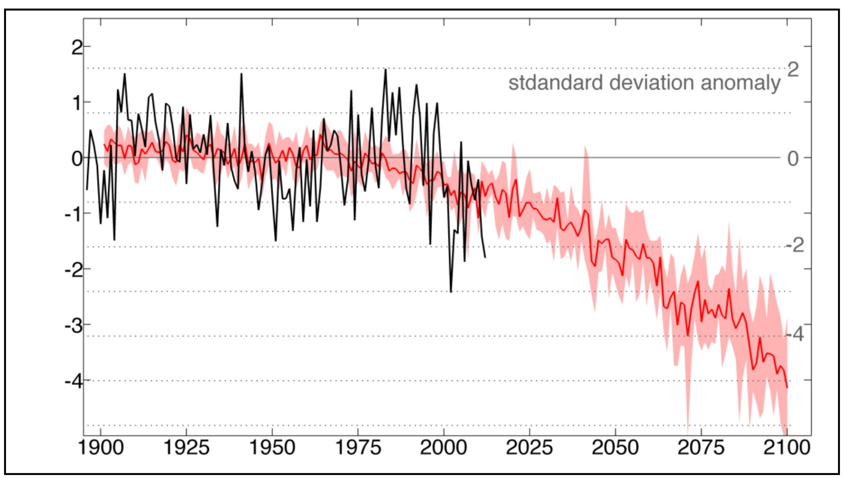
Yes, **IFF**:

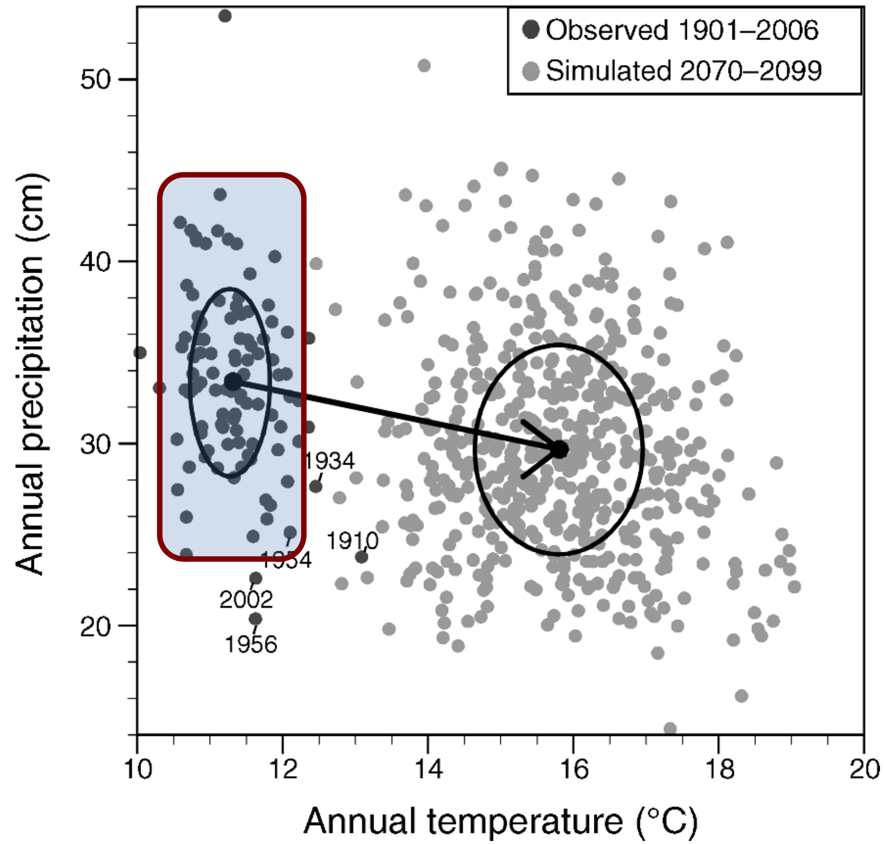
- We are trying to **build a climate chronology** with the strongest climate correlation

But **maybe not** if:

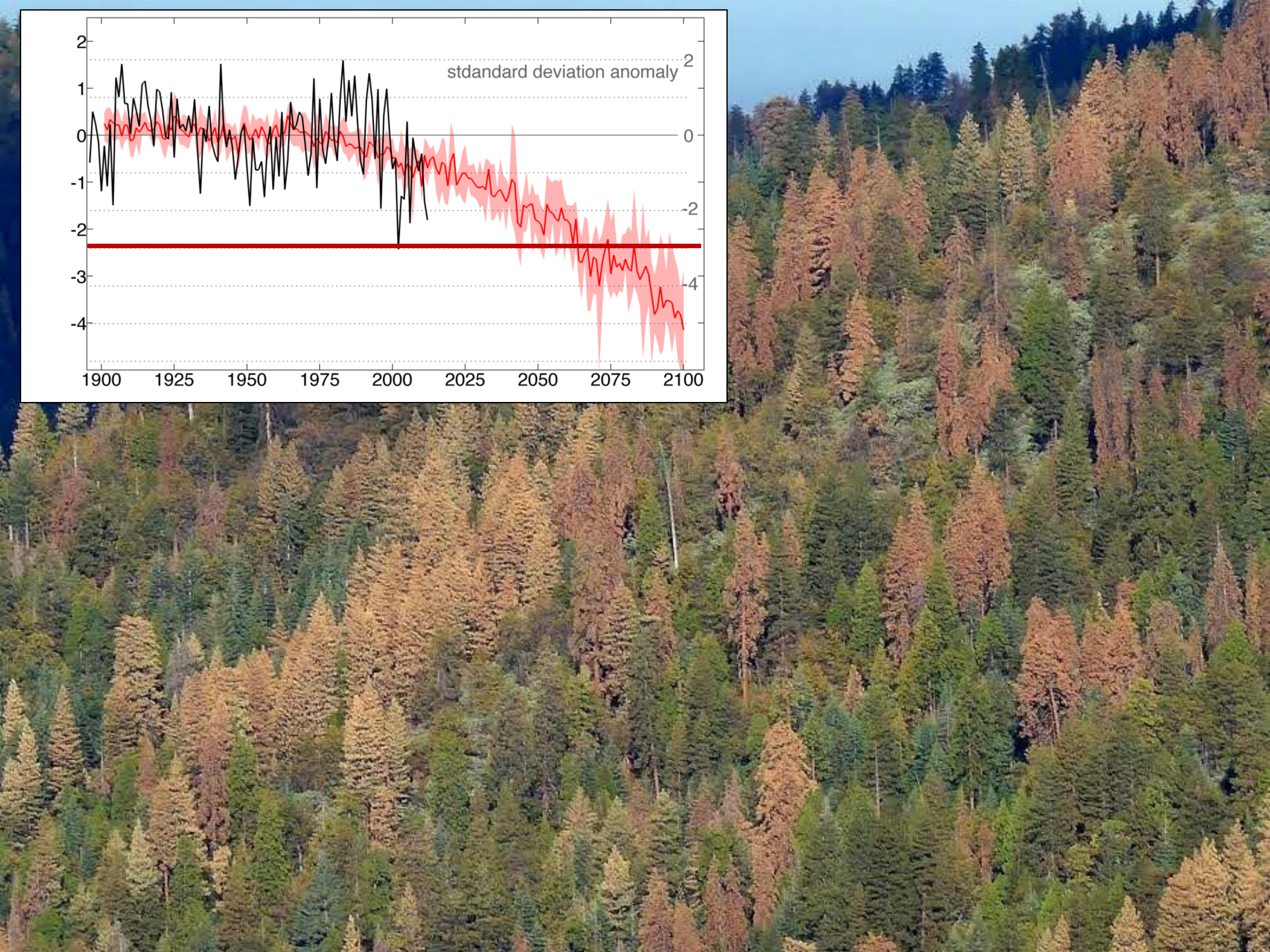
- We are trying to estimate the **ecological response** of tree populations over a **wider range of conditions**

Changes in regional expression of the global climate system are hypothesized to drive major changes in tree growth and survivorship

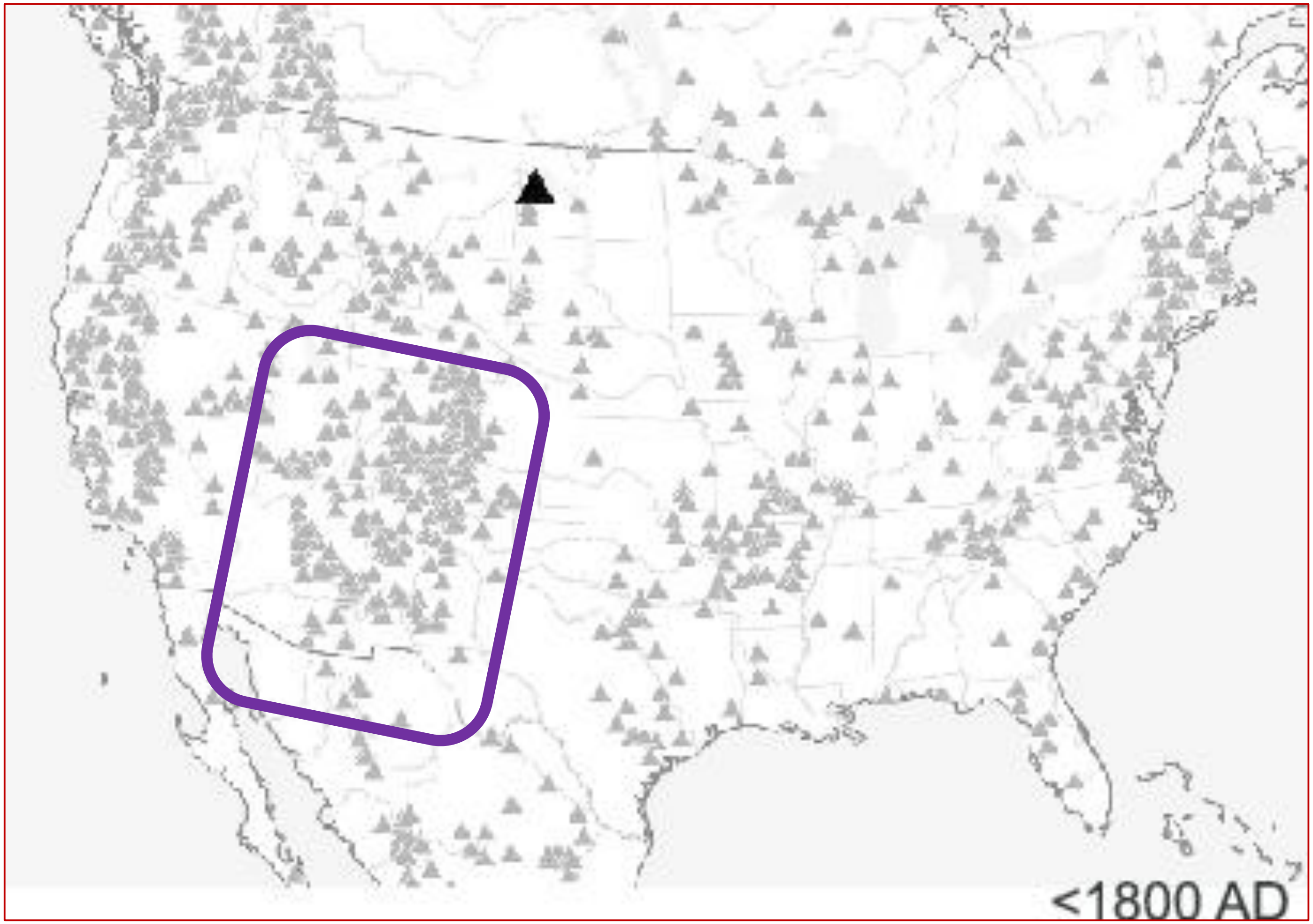




Left: Williams et al. 2012, *Nature Climate Change*. Right: Notaro et al. 2012, *Ecological Applications*

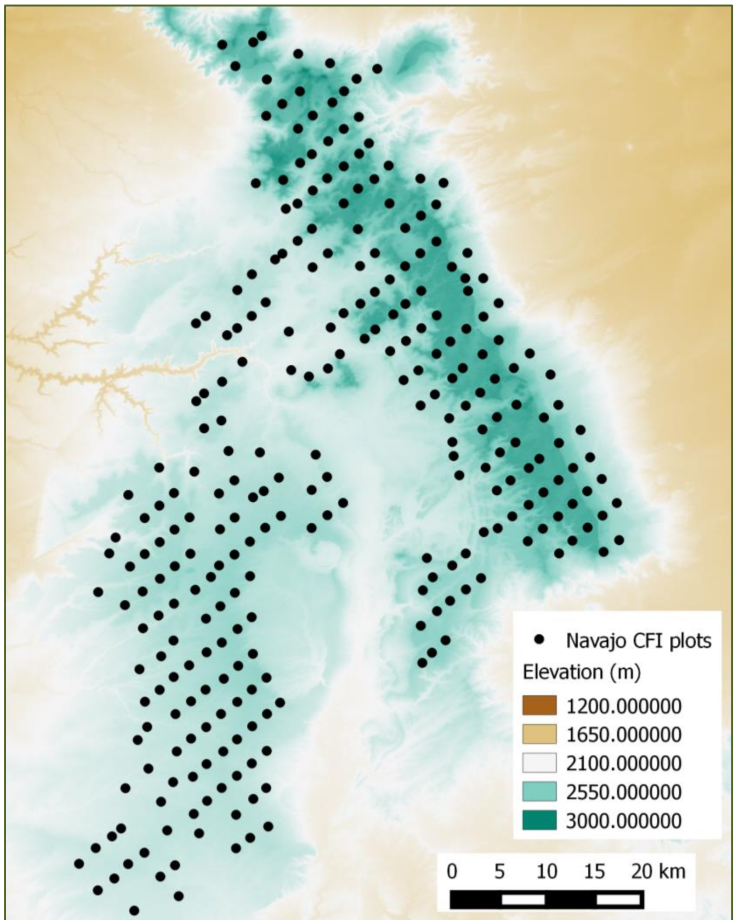

stdandard deviation anomaly
2
1
0
-1
-2
-3
-4
1900
1925
1950
1975
2000
2025
2050
2075
2100

But these projections were based on composites of the most climate-sensitive trees



Source: Edmondson et al. 2014, *TRR*.

We test this hypothesis by breaking the canonical climate-sensitive rule



- Ask whether tree growth and survivorship are well predicted by the FDSI or other strongly drought-driven indices over large landscapes
- Lower-elevation sites may fit FDSI prediction (recall that elevation is a proxy for environment)
- What about higher-elevation sites and other topoclimatic refugia?

CFI plot network, Chuska Mts, AZ; Guiterman 2016 and in prep.

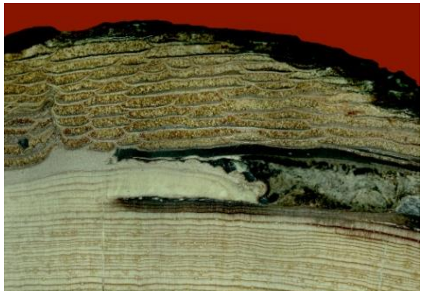
What about species?

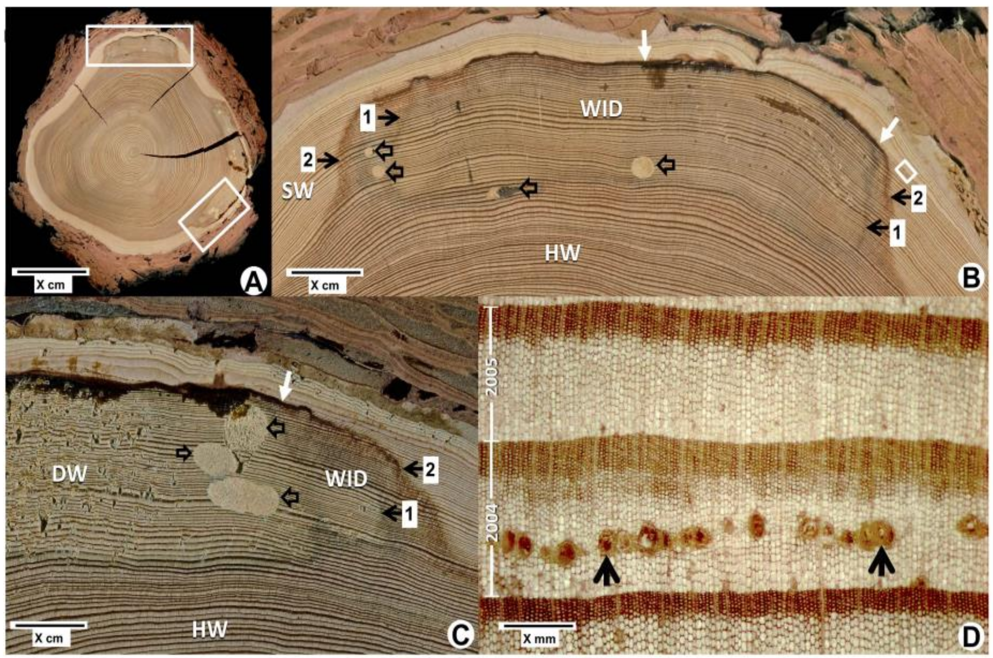
- In dendroclimatology trees are sensors of climate variation, so we want to maximize that signal
- In ecology, we may be interested in other questions

Important bark beetles of the American Southwest

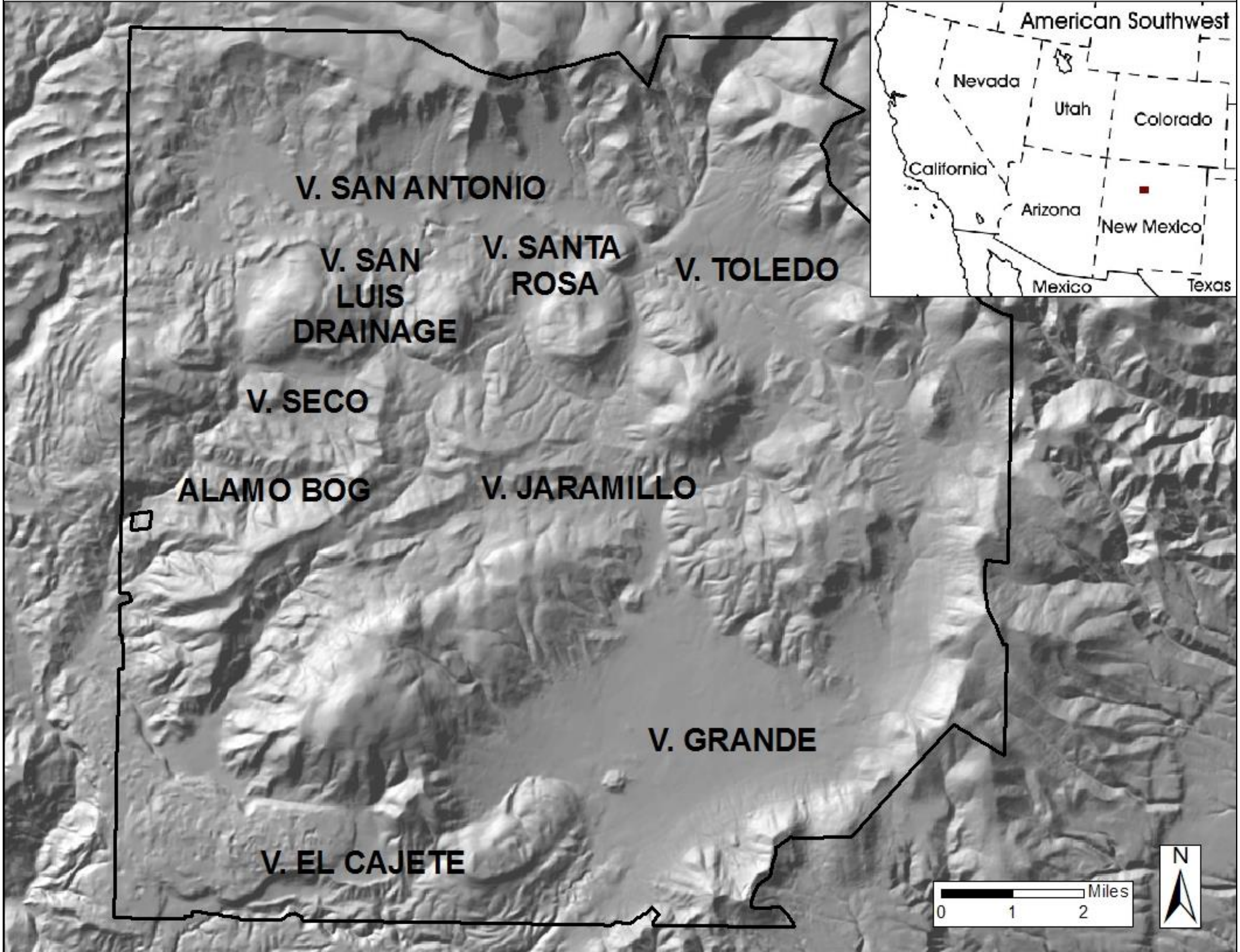
Insect	Main hosts	Voltinism	1st attack	Last
Western pine beetle	pines	1-3	Late spring	Cold weather
Mountain PB	PIPO PICO	1	Early July	September
Roundheaded PB	PIPO PIST	1	October	November
Southern PB, Mex PB	pines	Multi	Possible 12 m/yr	
Spruce beetle	PIEN	≤ 1	May	July
DF beetle	PSME	1	Late spring	Early summer
W balsam bark beetle	ABLA	Semi to 1	early June	Mid-September
Fir engraver	Abies	Semi to 1+	July	August
Pinyon ips	piñons	Multi (3-4)	April	October

Exposure to disturbance (here, fire)



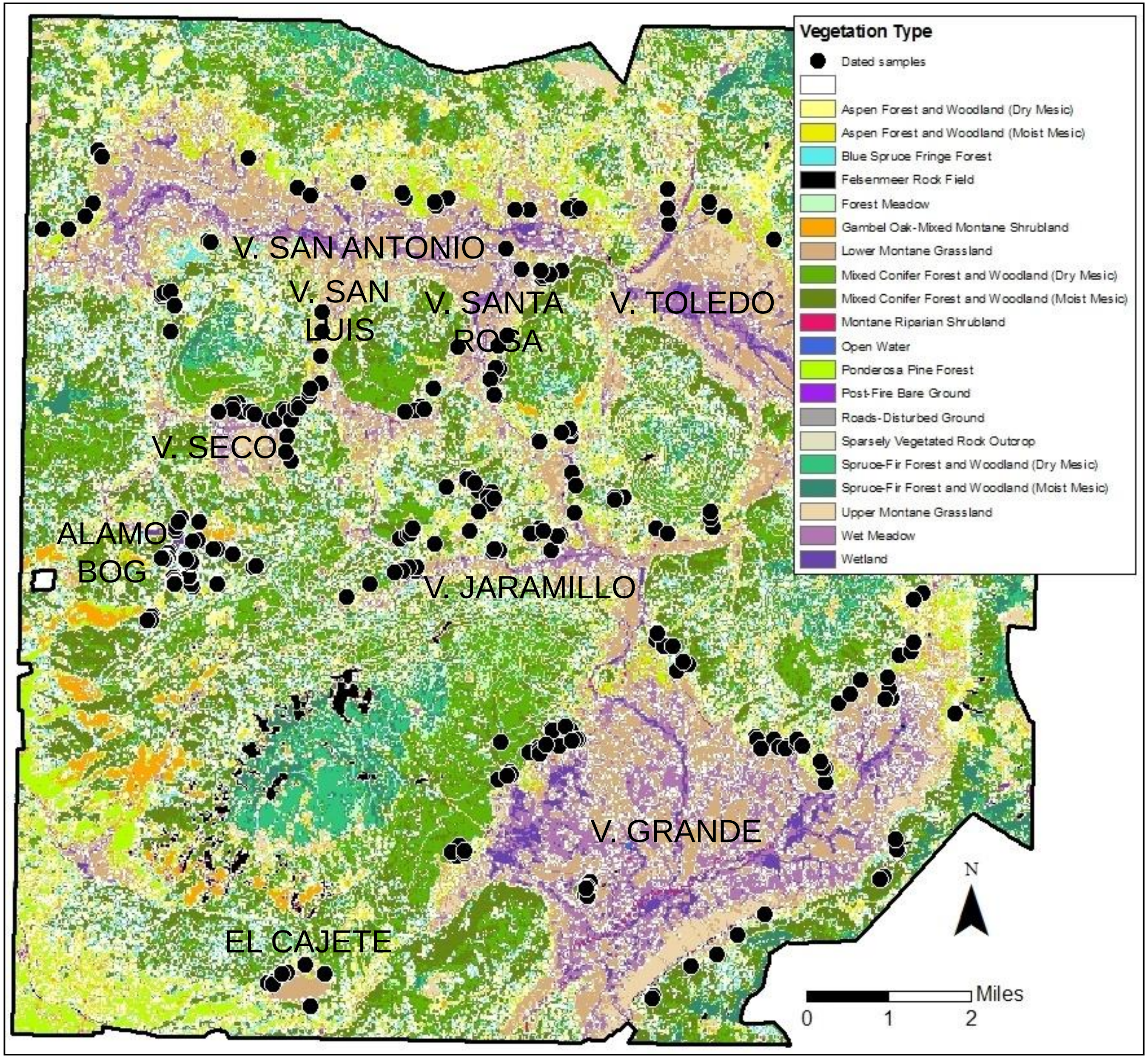


Arbellay et al. 2014a, b (*Annals of Botany*); Smith et al. 2016 (*CJFR*)

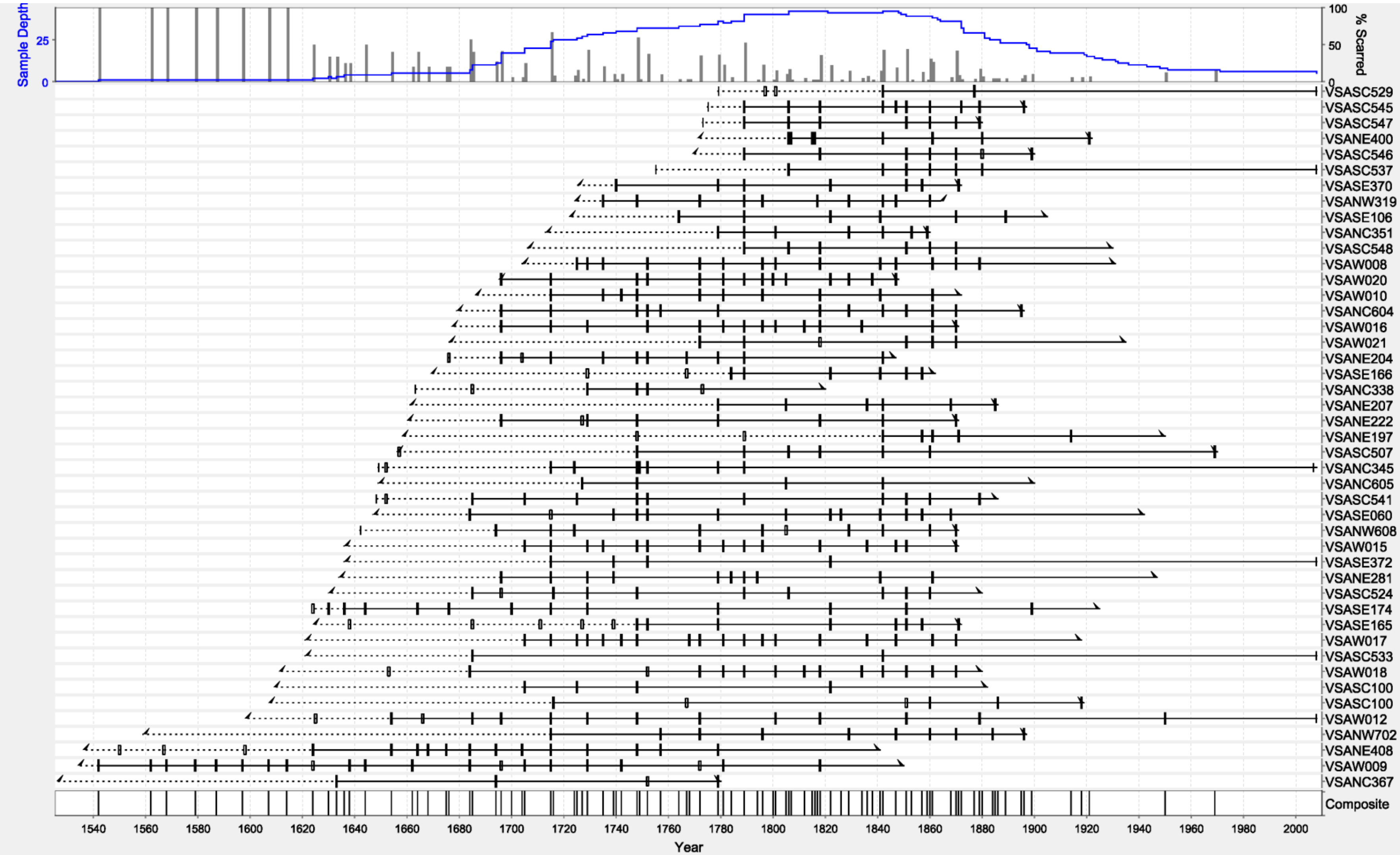

American Southwest
Nevada
Utah
Colorado
California
Arizona
New Mexico
Mexico
Texas
V. SAN ANTONIO
V. SAN LUIS DRAINAGE
V. SANTA ROSA
V. TOLEDO
V. SECO
ALAMO BOG
V. JARAMILLO
V. GRANDE
V. EL CAJETE
Miles
0
1
2
N

Forest-grassland ecotones

Sample Distribution

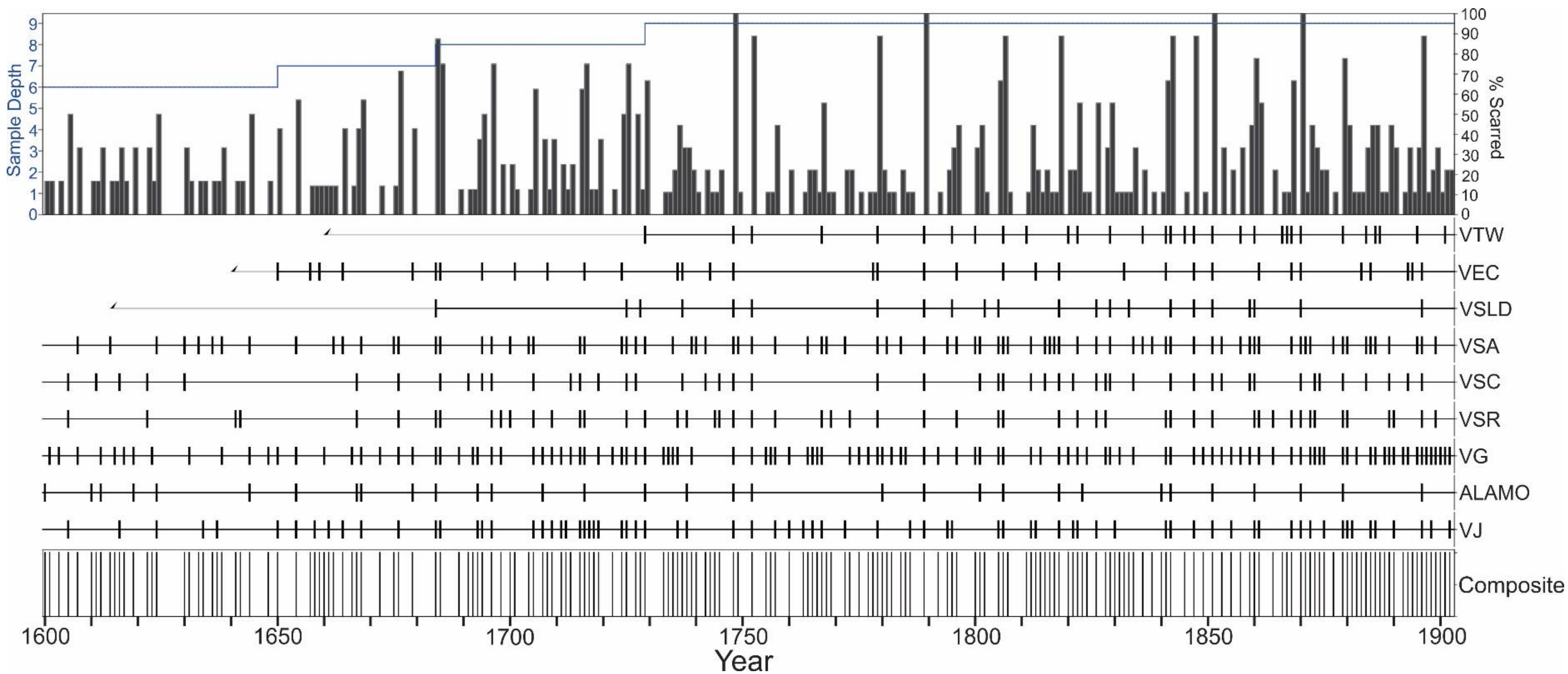


Fire history reconstruction (tree precision, valle scale) for Valle San Antonio, Valles Caldera National Preserve, Jemez Mts, NM, USA



Dewar 2012 and in prep.

Fire history reconstruction (valle precision landscape scale) for Valles Caldera National Preserve, Jemez Mts, NM, USA



Dewar 2012 and in prep.

Figure 9

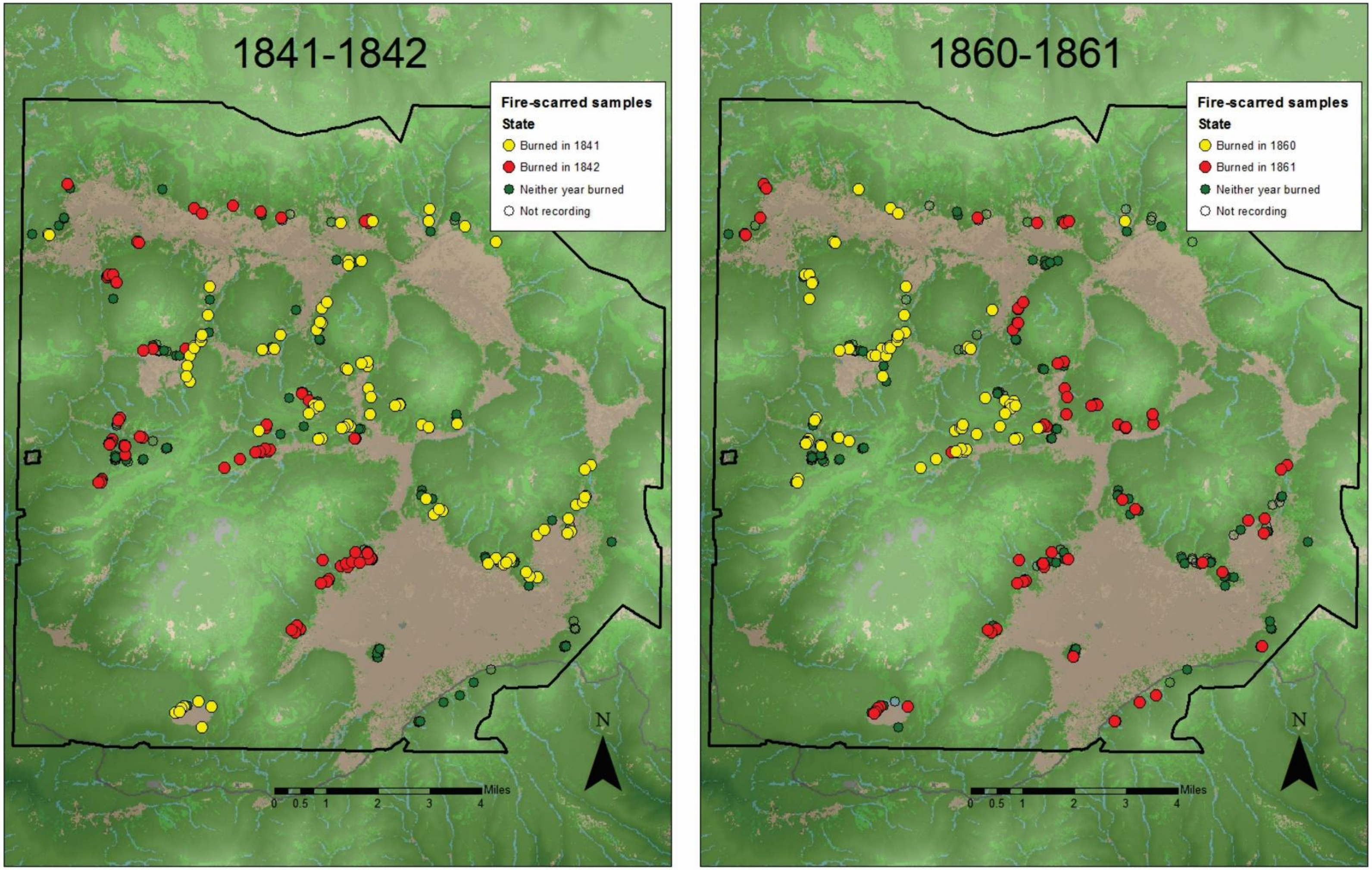

1841-1842
Fire-scarred samples
State
Burned in 1841
Burned in 1842
Neither year burned
Not recording
N
Miles
0 0.5 1 2 3 4
1860-1861
Fire-scarred samples
State
Burned in 1860
Burned in 1861
Neither year burned
Not recording
N
Miles
0 0.5 1 2 3 4

Photo courtesy Phil Van Mentgem, USGS

Another example:

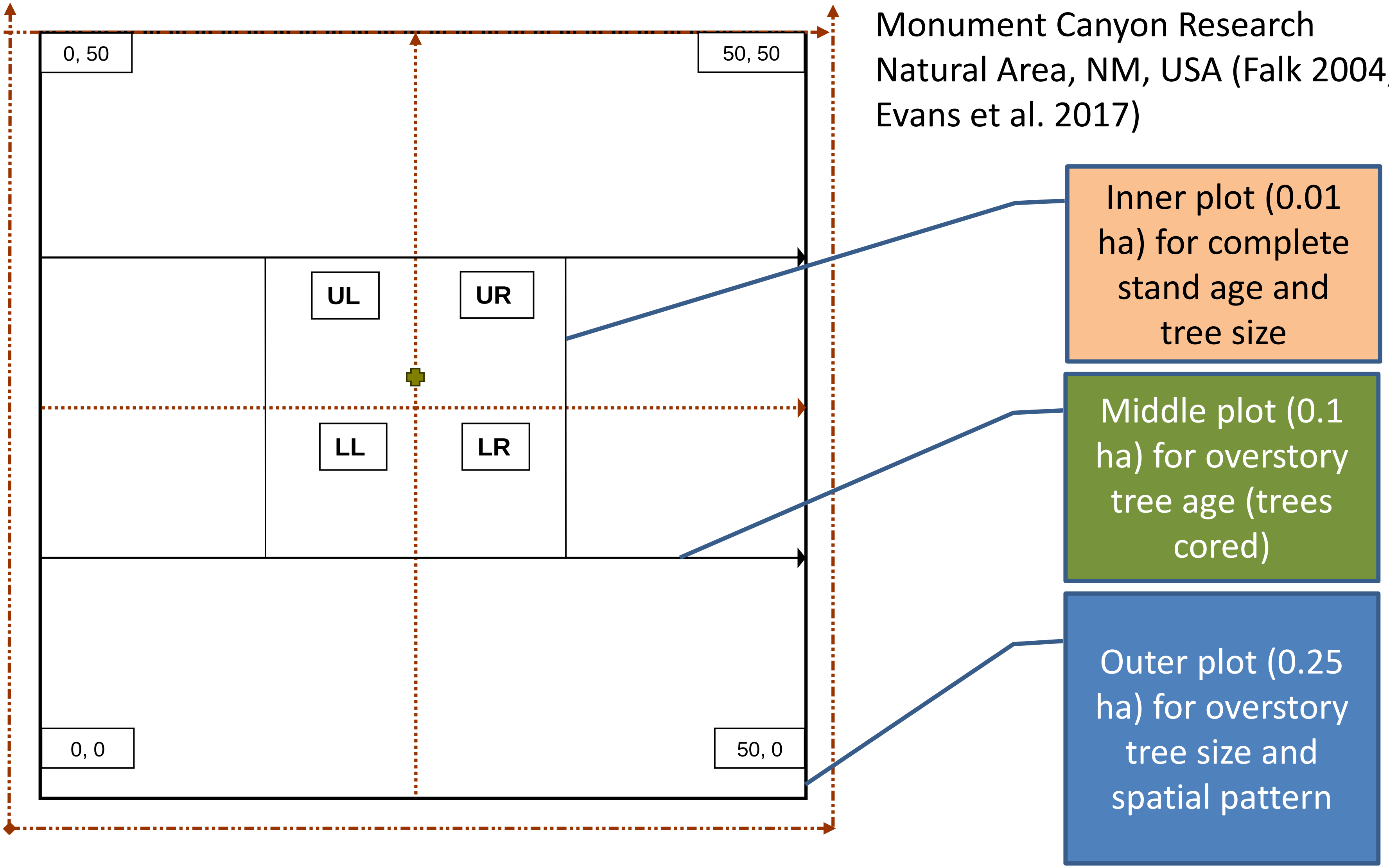
- If you want a “pure” climate signal, you would choose trees with minimal influence of competition or disturbance (LAM terms)
- But if you want to study competition, you would **sample along the relevant gradient** (e.g. stand density)
- This might then be part of an experimental treatment design


02/03/2007 18:36


01/03/2007 20:54

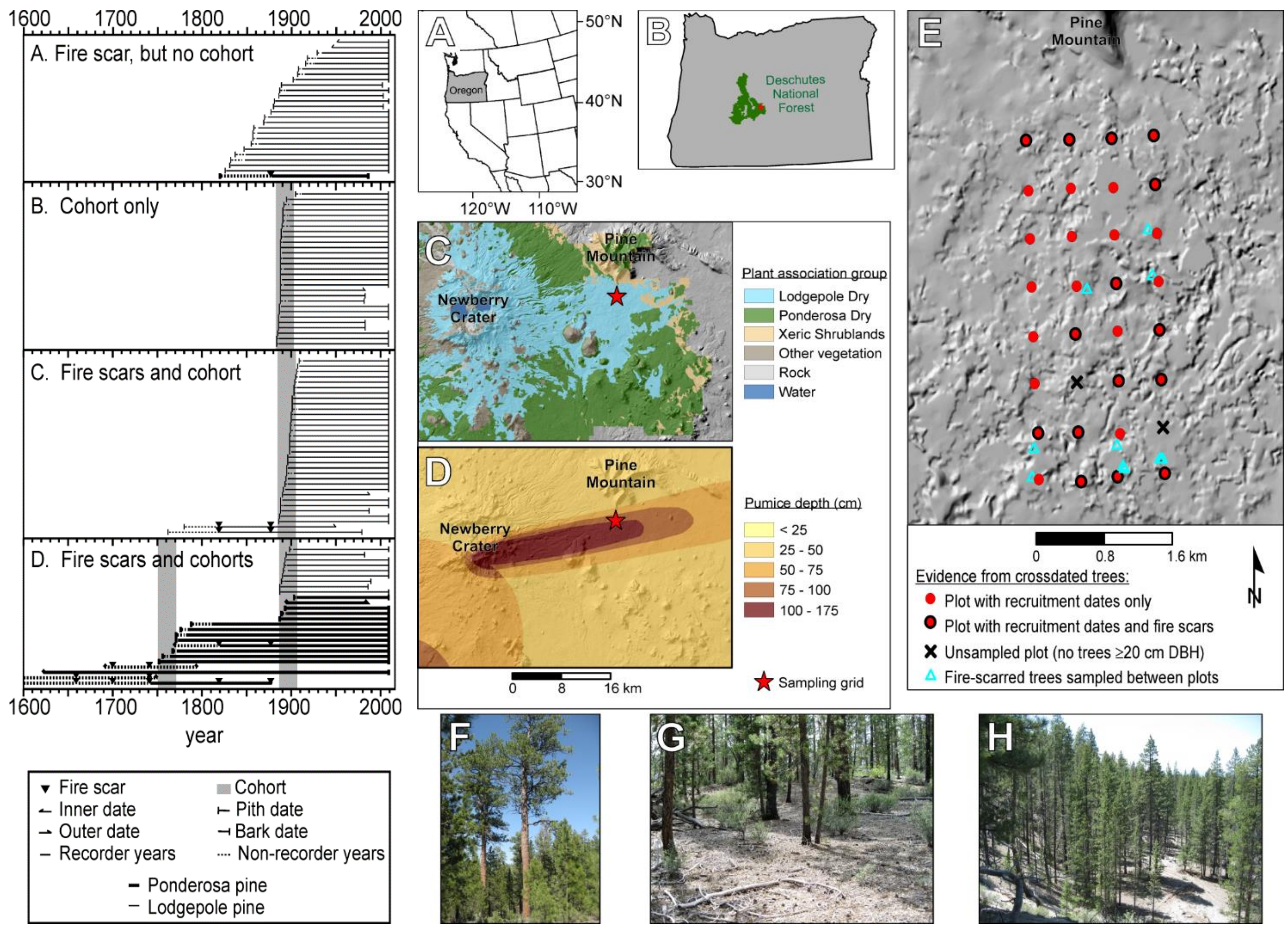
Nested plot designs work well for stratified sampling

Sampling design for tree demography, size and spatial structure, and fire history, Monument Canyon Research Natural Area, NM, USA (Falk 2004, Evans et al. 2017)



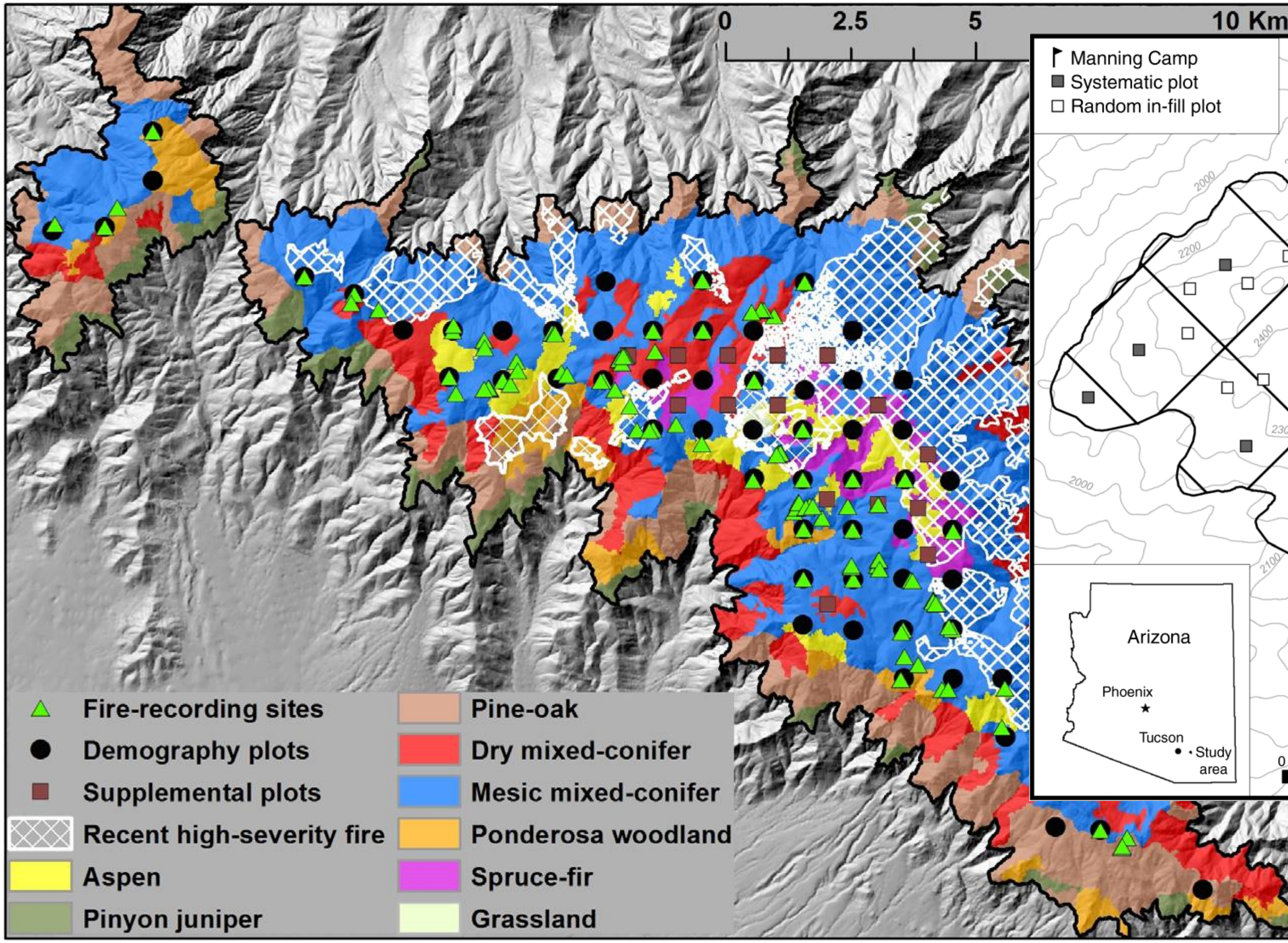
Randomized tree selection for demography (*n*-tree sampling)

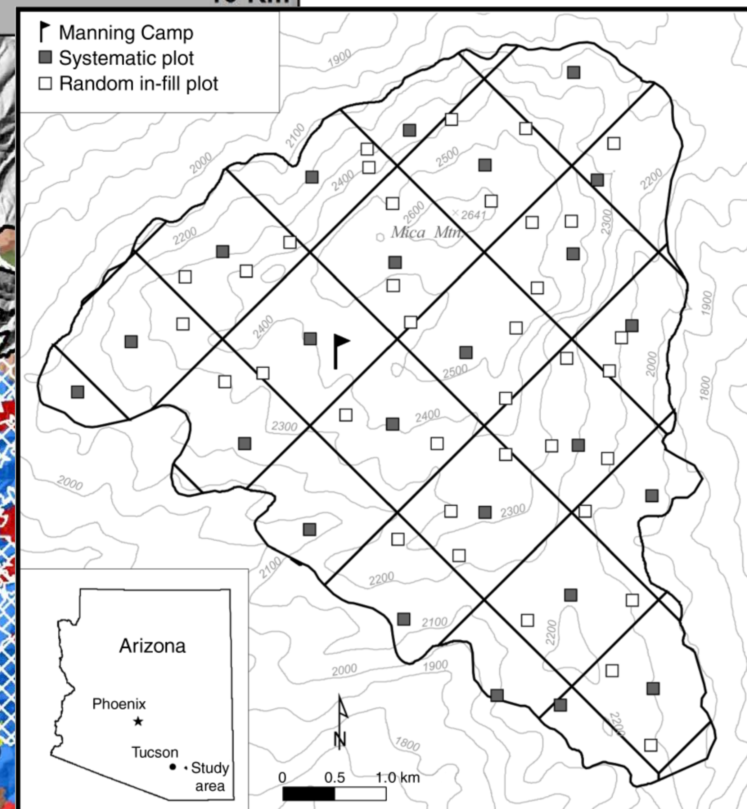
- Sample point center, no plot established
- Sampled trees by distance from center until reach *n*
- *n* typically = 20-30



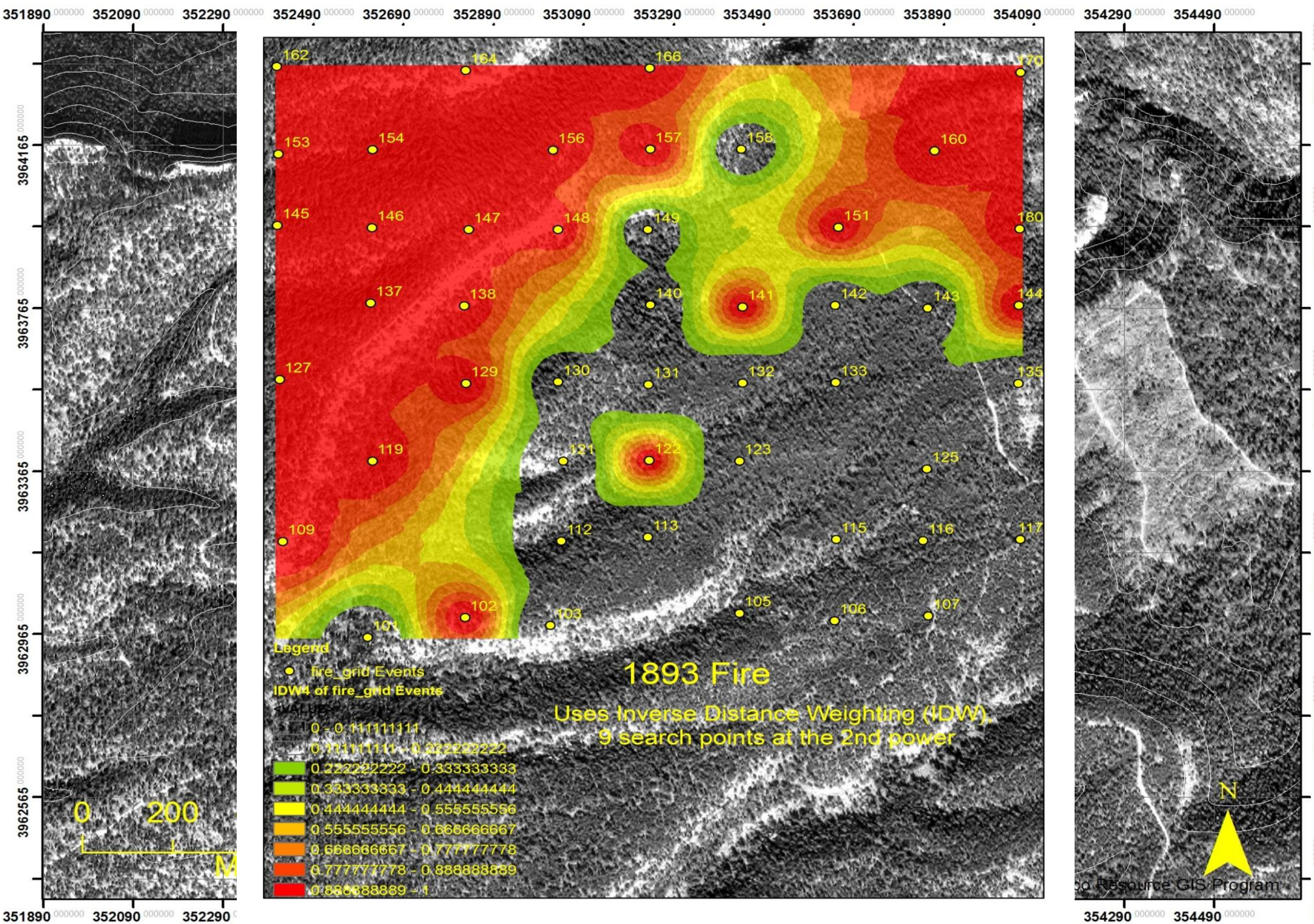
Heyerdahl, Falk, Loehman (2014), *CJFR*

Many studies require the use of systematic sampling





Left: O'Connor et al. 2014, *Forest Ecology & Management* 329: 264–278.
Right: Farris et al. 2010, *Ecol. Apps.* 20(6): 1598-1614.



1893 Fire
Uses Inverse Distance Weighting (IDW),
9 search points at the 2nd power
Legend
fire_grid Events
IDW4 of fire_grid Events
0 - 0.111111111
0.111111111 - 0.222222222
0.222222222 - 0.333333333
0.333333333 - 0.444444444
0.444444444 - 0.555555556
0.555555556 - 0.666666667
0.666666667 - 0.777777778
0.777777778 - 0.888888889
0.888888889 - 1
0
200
N
Resource GIS Program
351890
352090
352290
352490
352690
352890
353090
353290
353490
353690
353890
354090
354290
354490
3964365
3964165
3963965
3963765
3963565
3963365
3963165
3962965
3962765
3962565
3962365

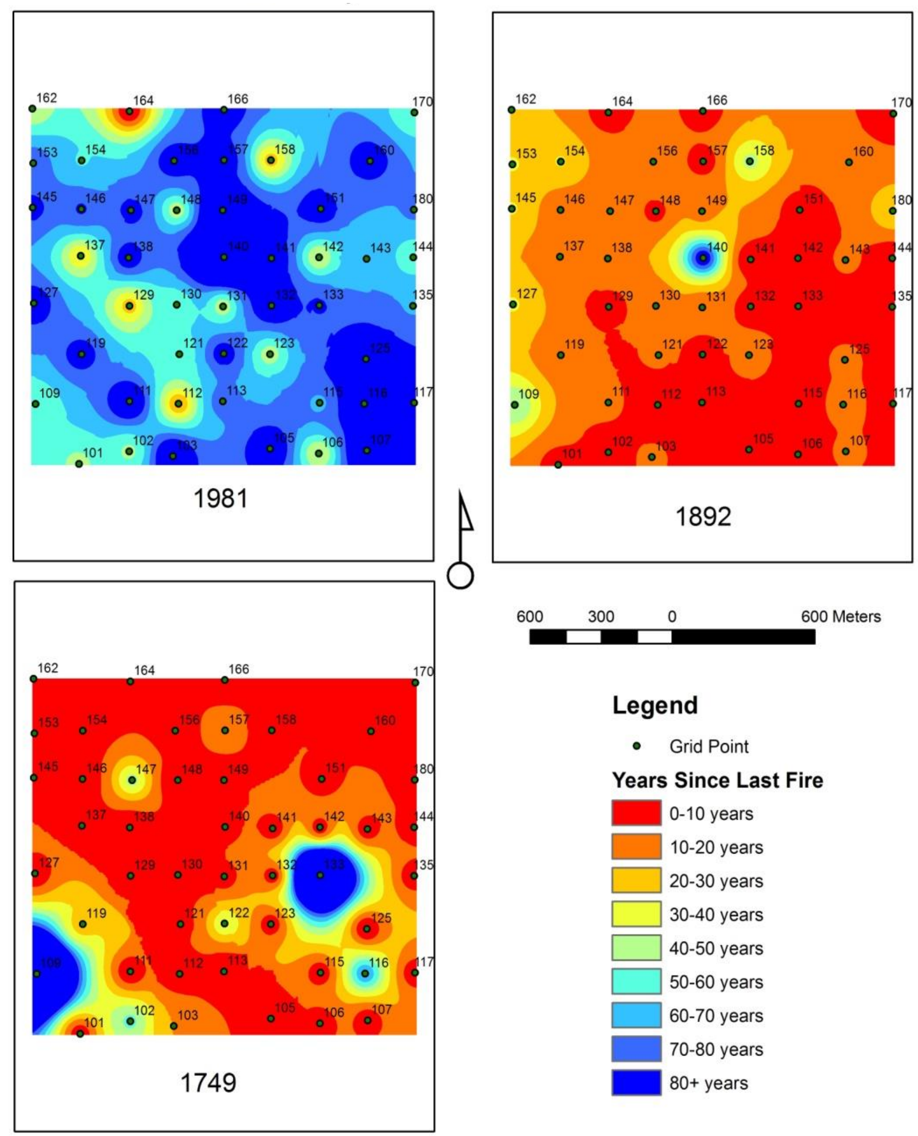
Fire History Mapping

1. Numbers of years since last fire
2. 20th century fire frequency

Fine scale spatial reconstruction of fire in MCRNA (Swetnam and Falk)

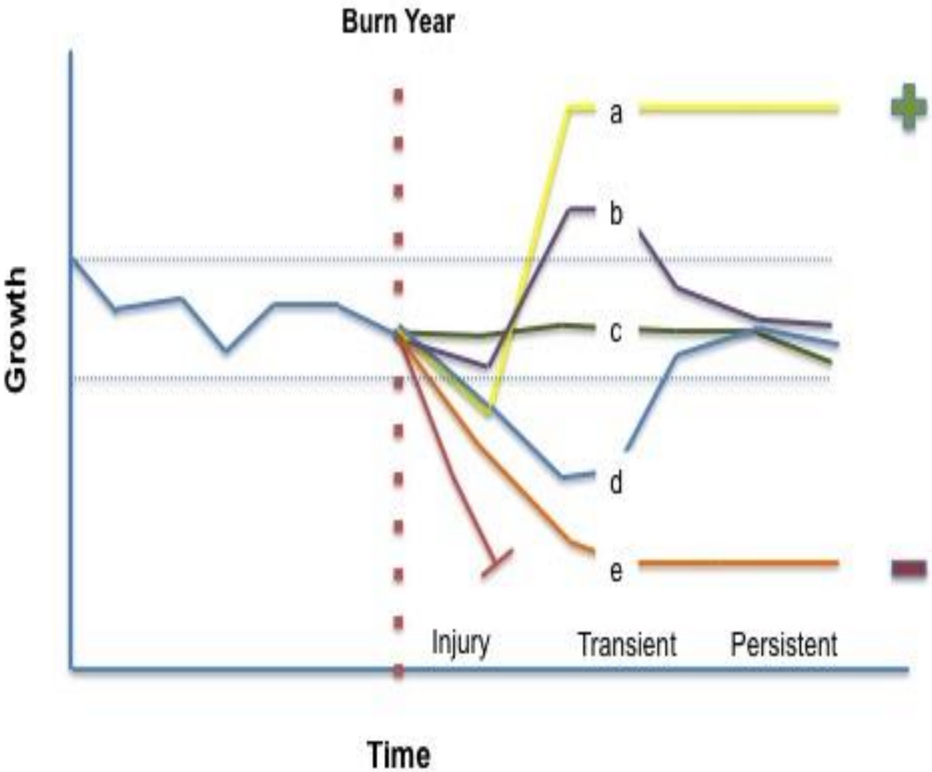
Absence of fire is fairly even across MCRNA in the modern period.

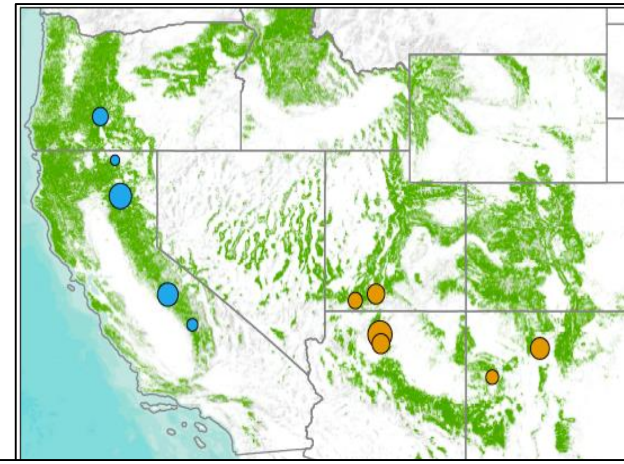
Years Since Last Fire

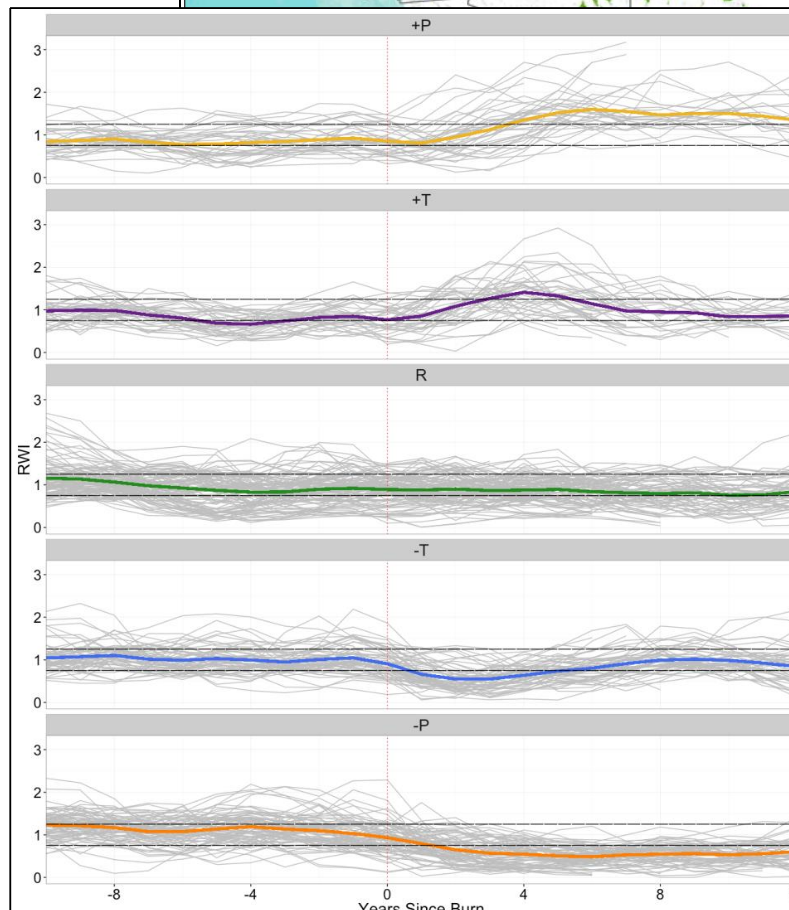


Fire year maps by Tyson Swetnam

Tree growth response to fire exposure







Tree responses can be positive (a,b), negative (d,e), transient (b,d), persistent (a,e), or netural.

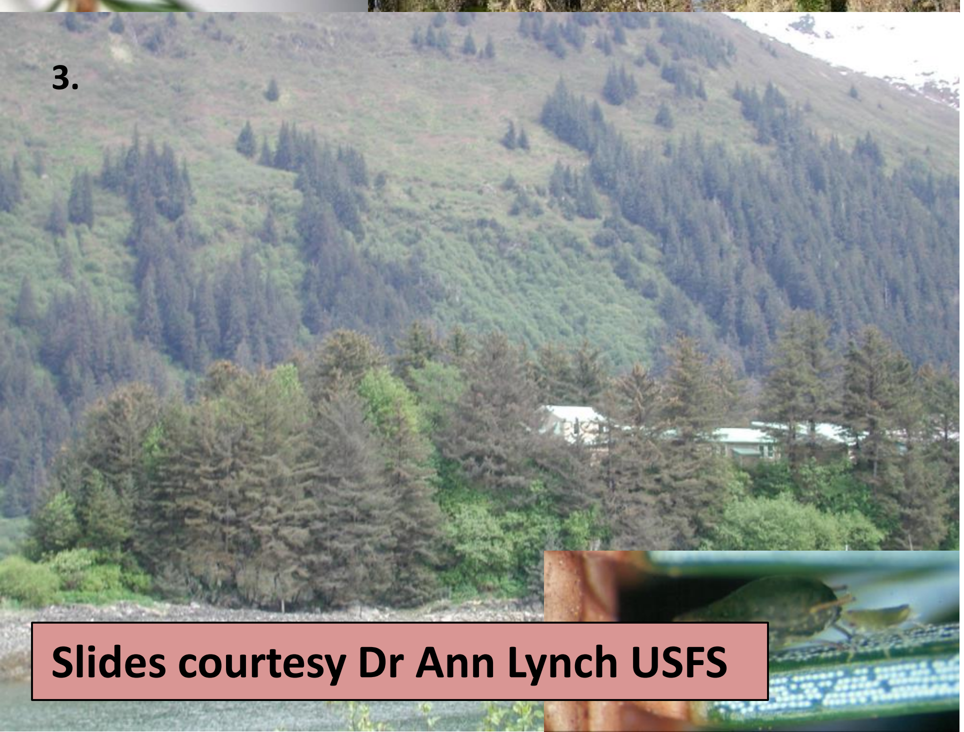
Williams EC et al. 2016 and in prep.

One more example: say you were interested in continental-scale latitudinal variation in tree growth in western North America

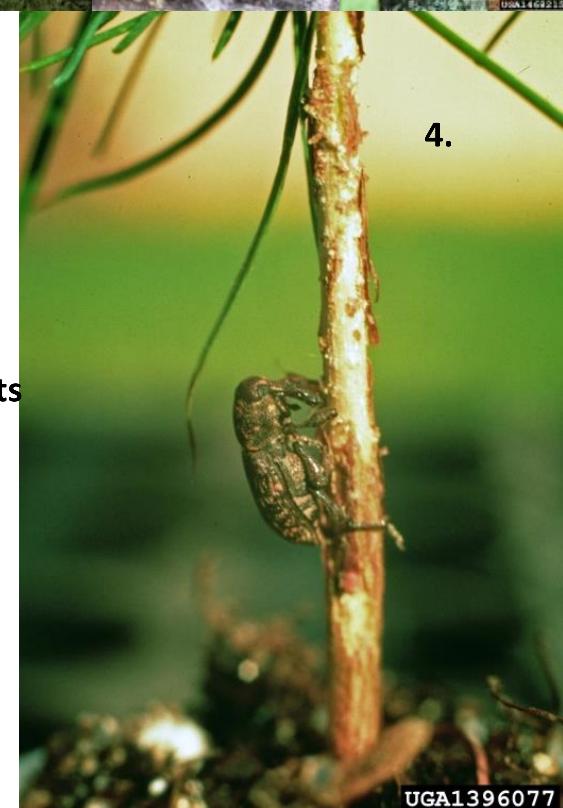
Falk and McKenzie, in progress

So: the central criterion in site and tree selection should always be:

What is <u>your</u> question?



1. **Defoliators**
2. **Bark beetles**
3. **Sap suckers**
4. **Regeneration pests**
5. **Wood-borers**
6. **Many more…**



Slides courtesy Dr Ann Lynch USFS