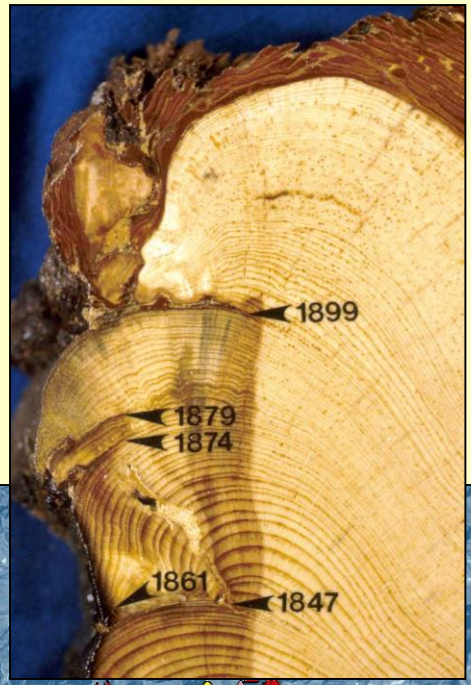
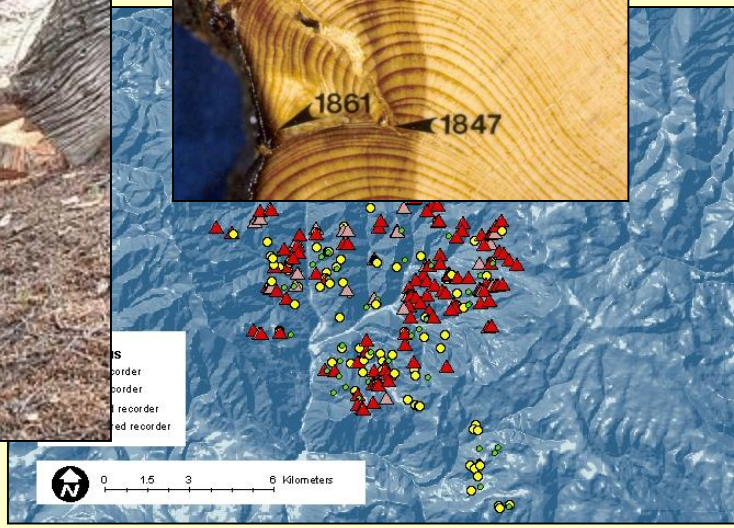
Reconstructing fire as a multi-scale spatial process

Dendroecology Summer Course

Laboratory of Tree-Ring Research

University of Arizona, May 2014





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Forest fires and the structure of the universe

Kan Chen*, Per Bak[1]

Department of Computational Science, National University of Singapore, Singapore 117543, Singapore

Overview of topic:

- Reconstructing spatial properties of individual fires
- Fire as a multi-scale landscape spatial process
- Case studies:
  - Rincon Mountains, AZ
  - Jemez Mountains, NM
  - Pinaleño Mountains, AZ
  - Sierra Madre Orientale, Coahila, MX
- Development of multi-scale fire networks
  - Sampling designs
- New analytical approaches


Are some areas becoming converted to historically unprecedented regimes (esp. uncharacteristically large patches of high severity)?
Near-total overstory tree mortality at watershed scale, 2011 Las Conchas Fire, Jemez Mountains, NM

Fires alters microhabitats and microclimate at fine scales

- Spatial heterogeneity in fuel environment
- Leads to heterogeneity in fire behavior and effects
- Resulting mosaic of microhabitats can increase ecological diversity


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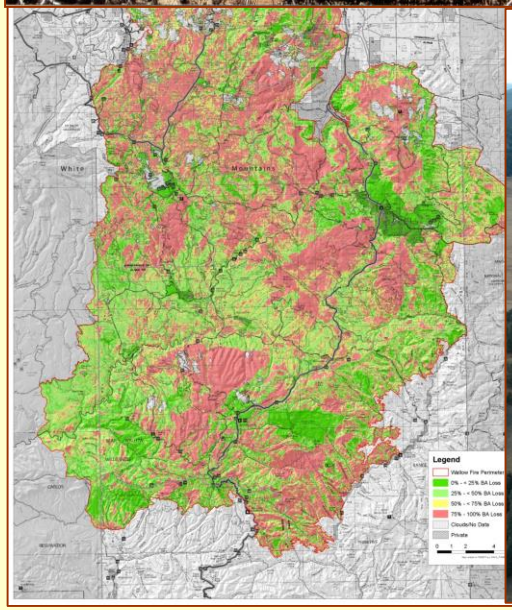
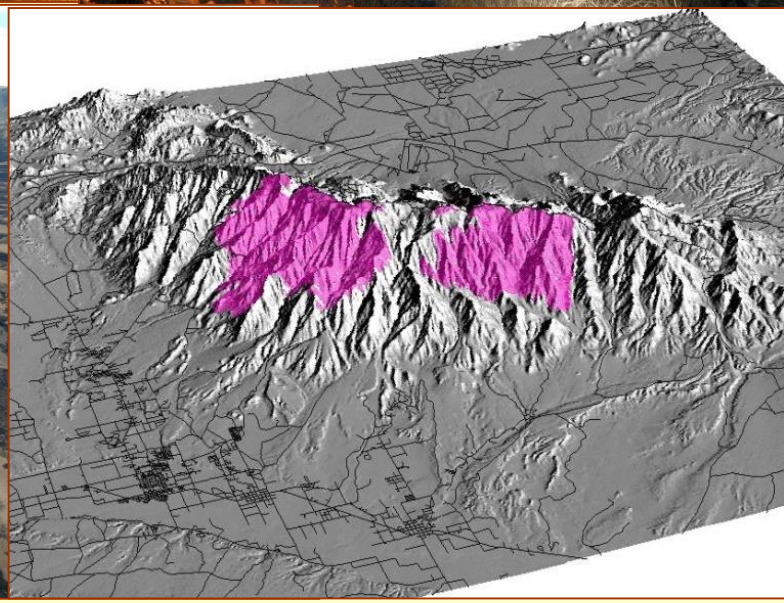
Image courtesy Cal Farris, NPS

Fire as a multi-scale landscape process





The fire record is fundamentally a **point (tree scale) process**…

…so how do we make inferences about **landscapes**?

Top-down and bottom-up regulation of fire regimes

- Top-down factors are those that affect large areas relatively similarly
- For example, spatial coherence in regional climate patterns (e.g. 1996) leads to synchronous fire patterns in space and time
- Humans can also play a top-down role (regional land use, management policy)

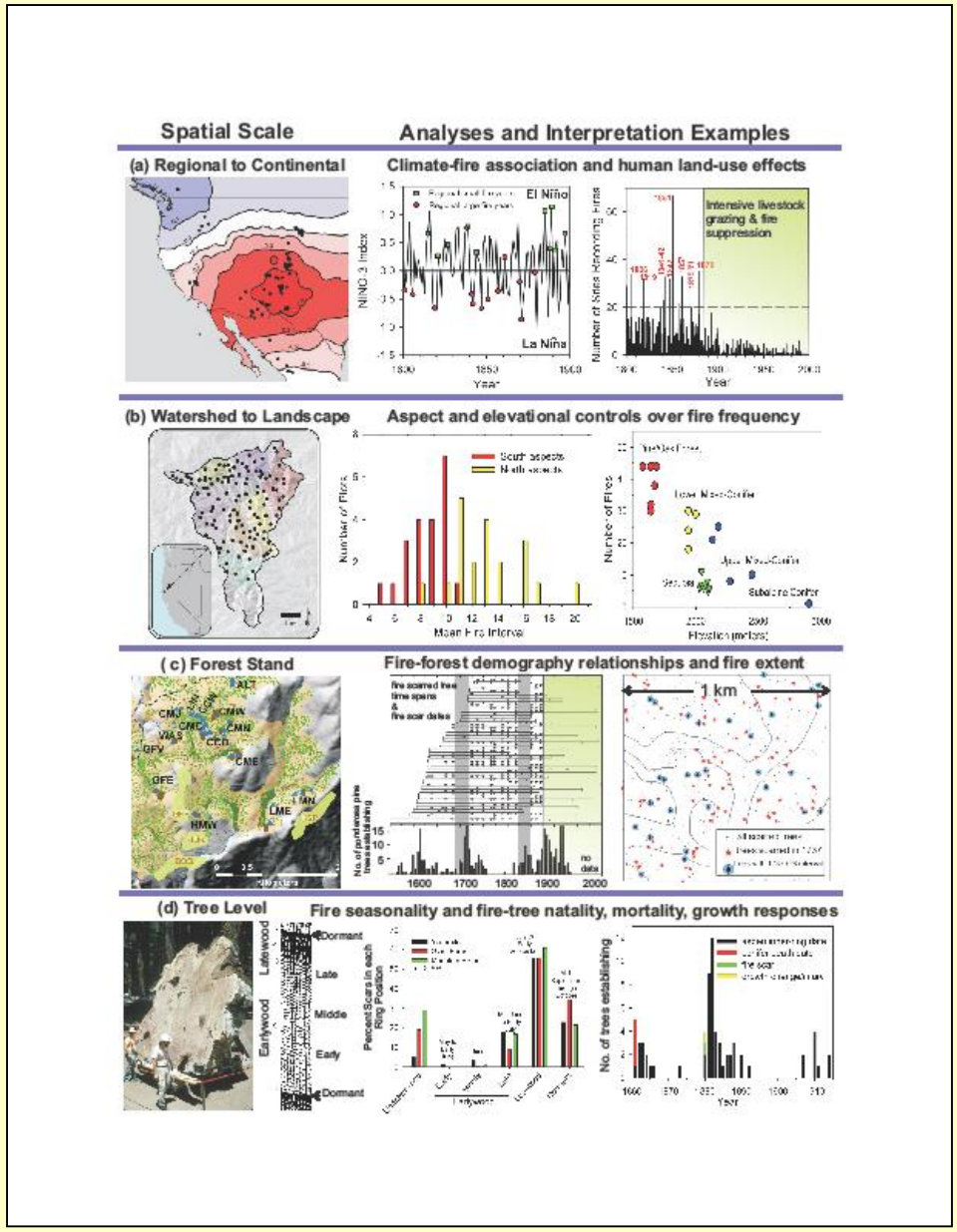
Falk et al. 2007; McKenzie et al. 2011

Bottom-up factors

- Bottom-up factors work on local processes, especially fire spread, and thus introduce heterogeneity into a fire regime
- For example, spatial variation in fuels, topography, and ignitions cause differences in fire between areas receiving similar climate
- Humans can also exert bottom-up influence (e.g. local ignitions, fuel modification)

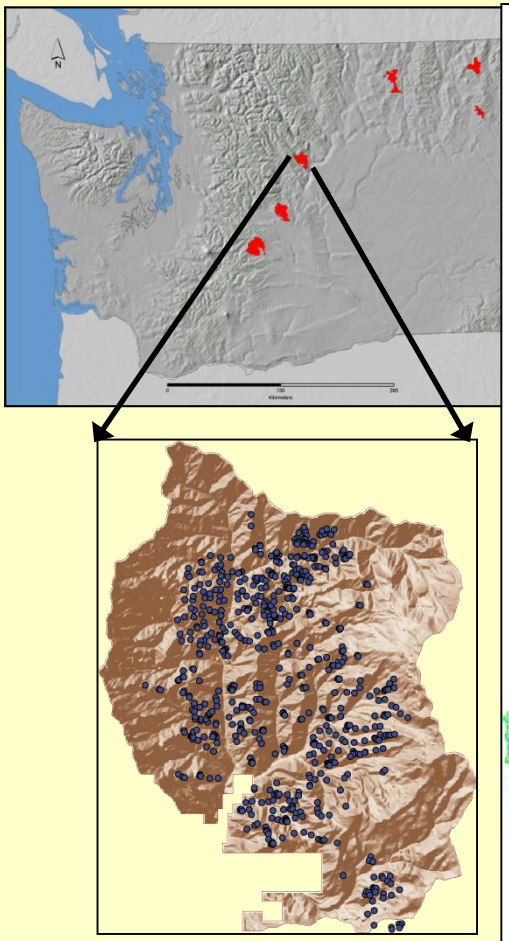
McKenzie et al. 2011; Kennedy and McKenzie 2011

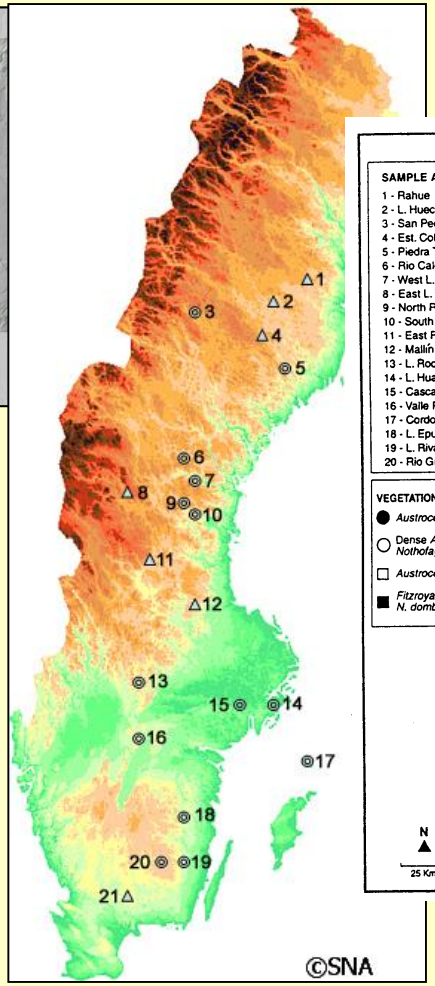
Can we use the tools of dendroecology to understand the interplay of top-down and bottom-up control at multiple spatial scales?

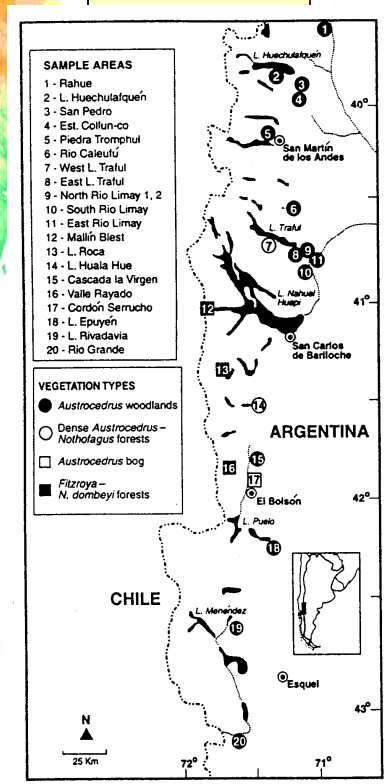


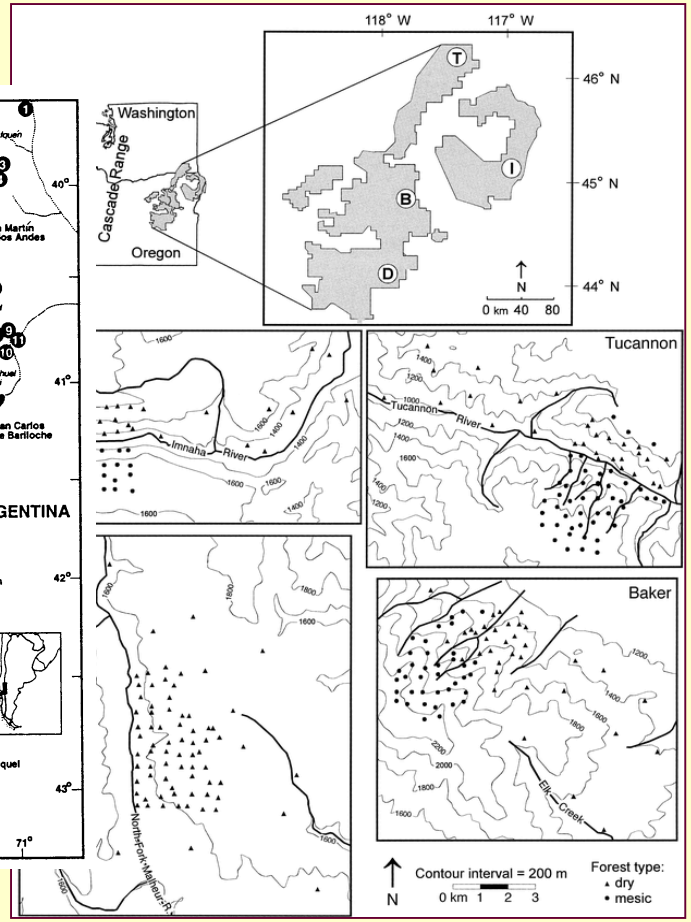
Falk *et al.* 2011

Multiscale fire history: Spatially distributed within and among sites



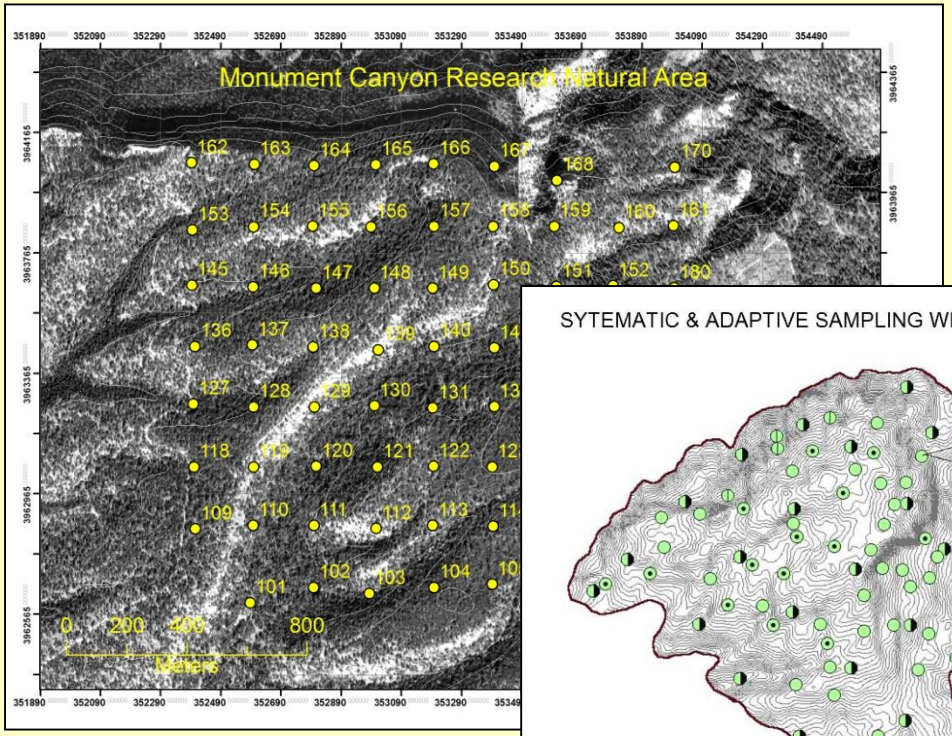


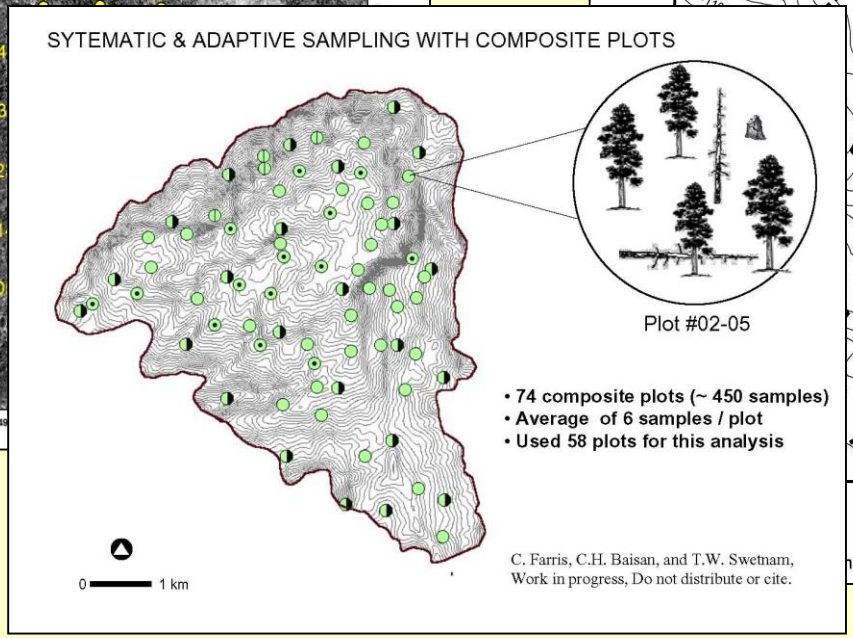


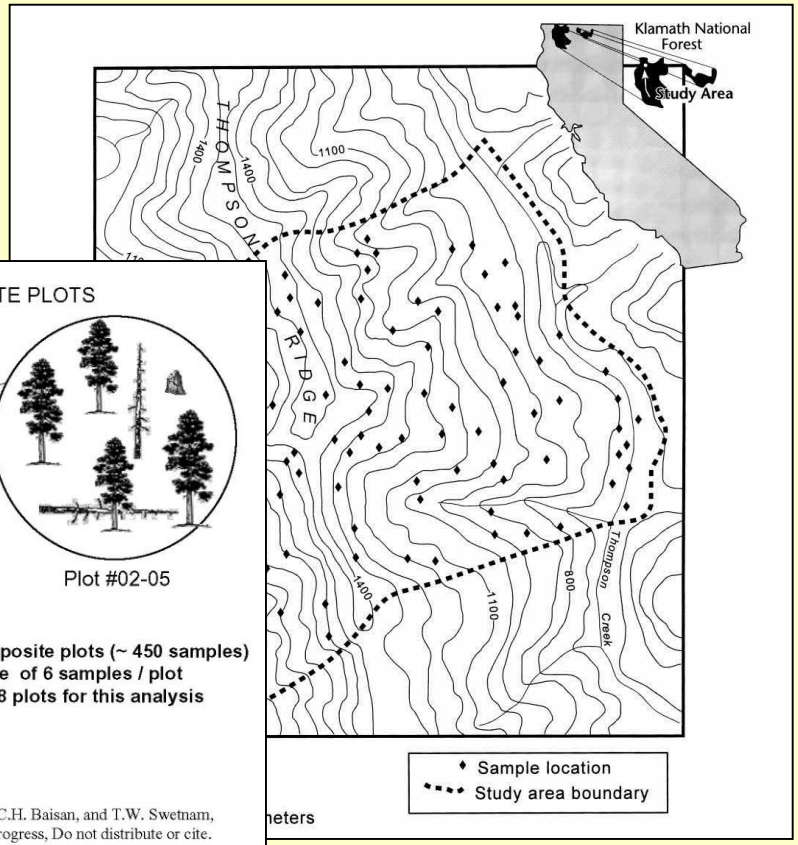


McKenzie et al. 2000; Multi-author (Sweden and Norway); Heyerdahl et al. 2001; Multi-author (Chile and Argentina); Falk et al. 2011

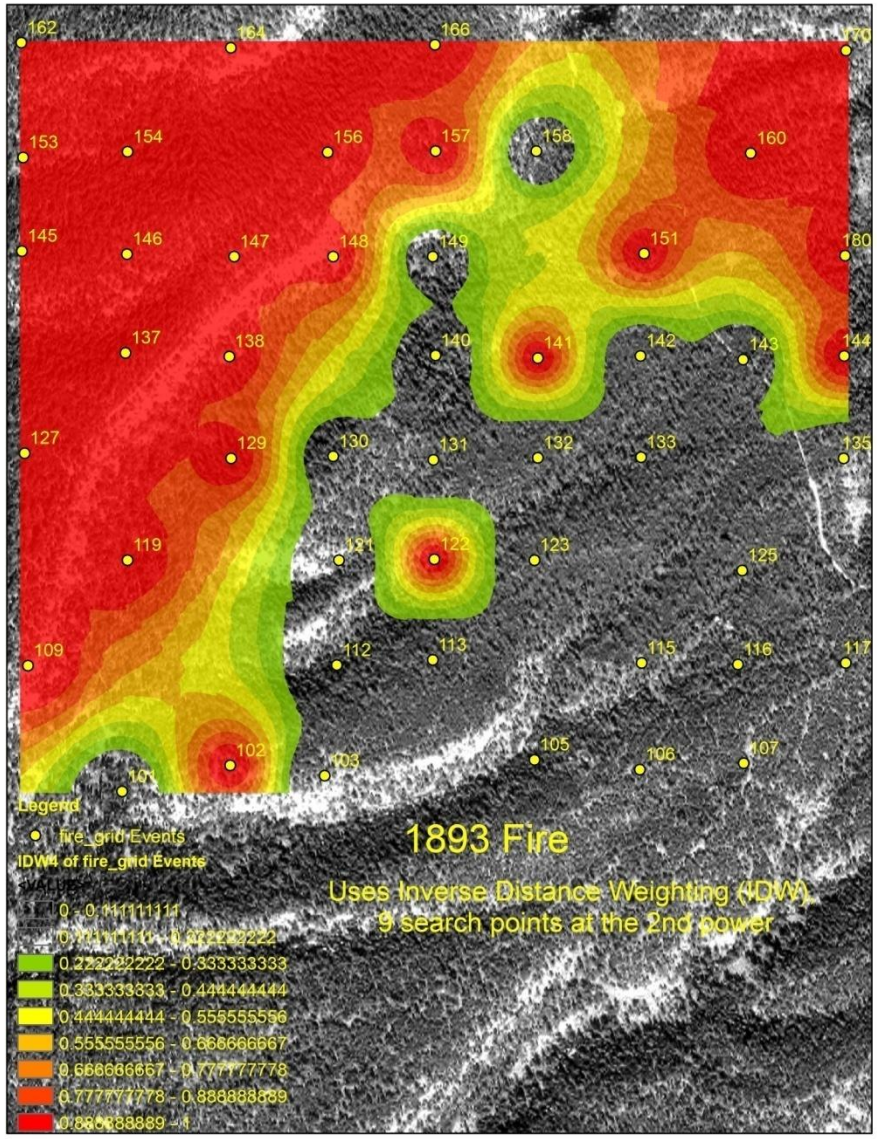
Spatially distributed sampling at the site scale (systematic or random plot spacing)



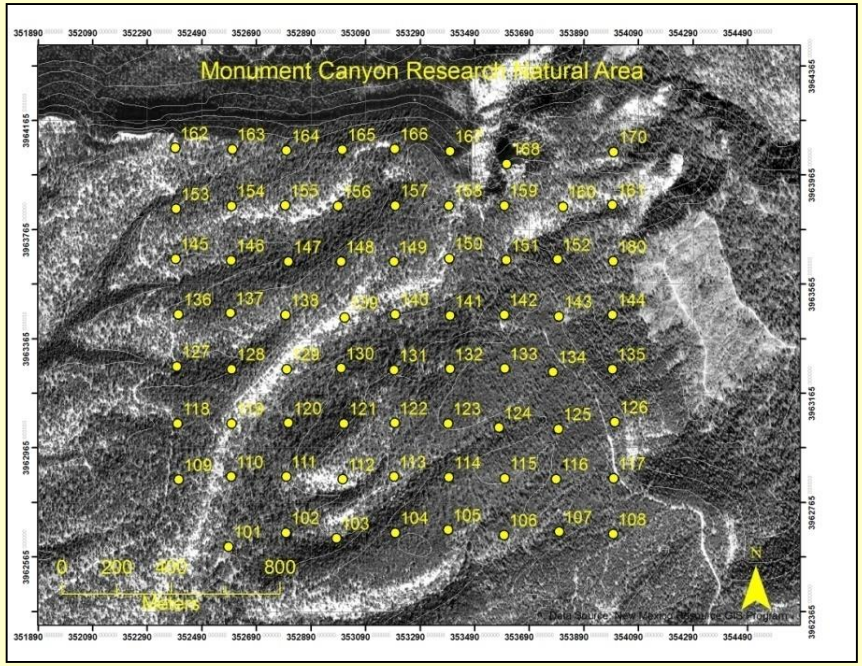




Falk 2004; Taylor & Skinner 2003; Farris 2010



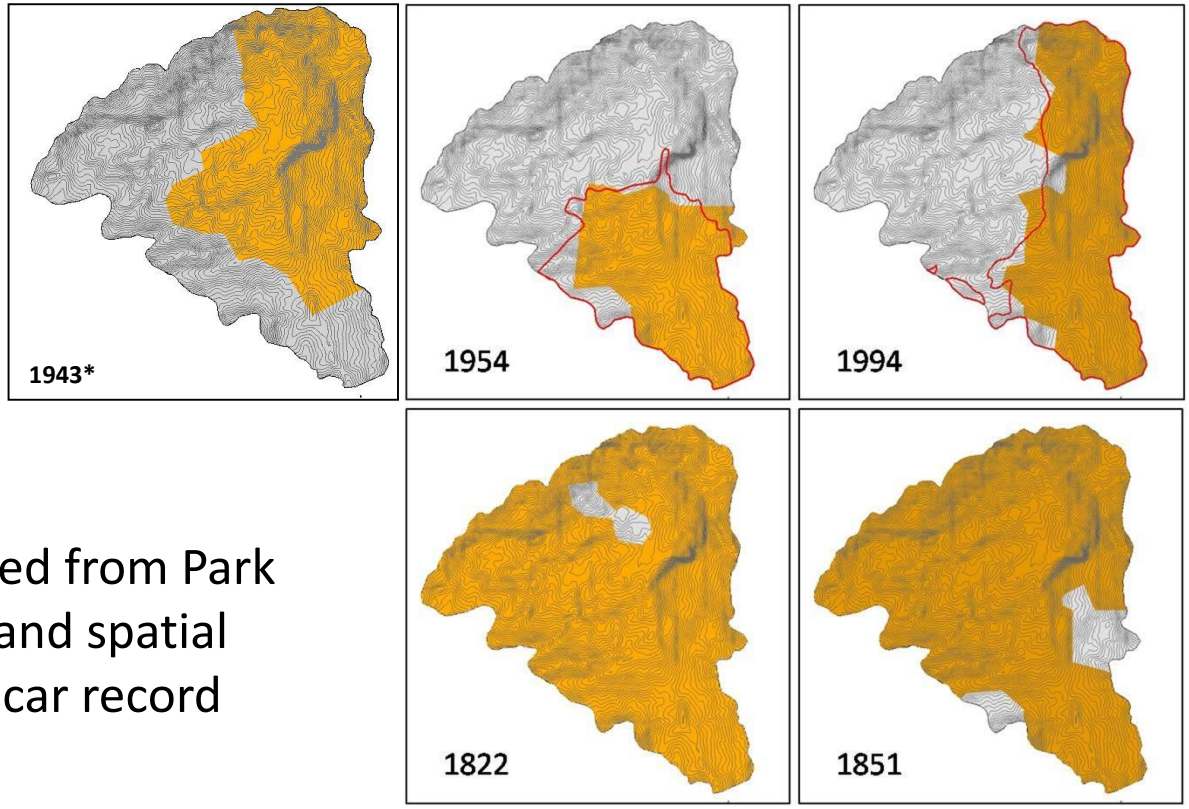
Reconstructing spatial properties of disturbance regimes using gridded sampling designs



Swetnam, Falk et al. 2011

Fire scar reconstruction accurately reflects landscape fire spatial pattern

*** 1943 was the largest 20th century fire year, but would have only been the EIGHTH largest fire during the 19th century.**



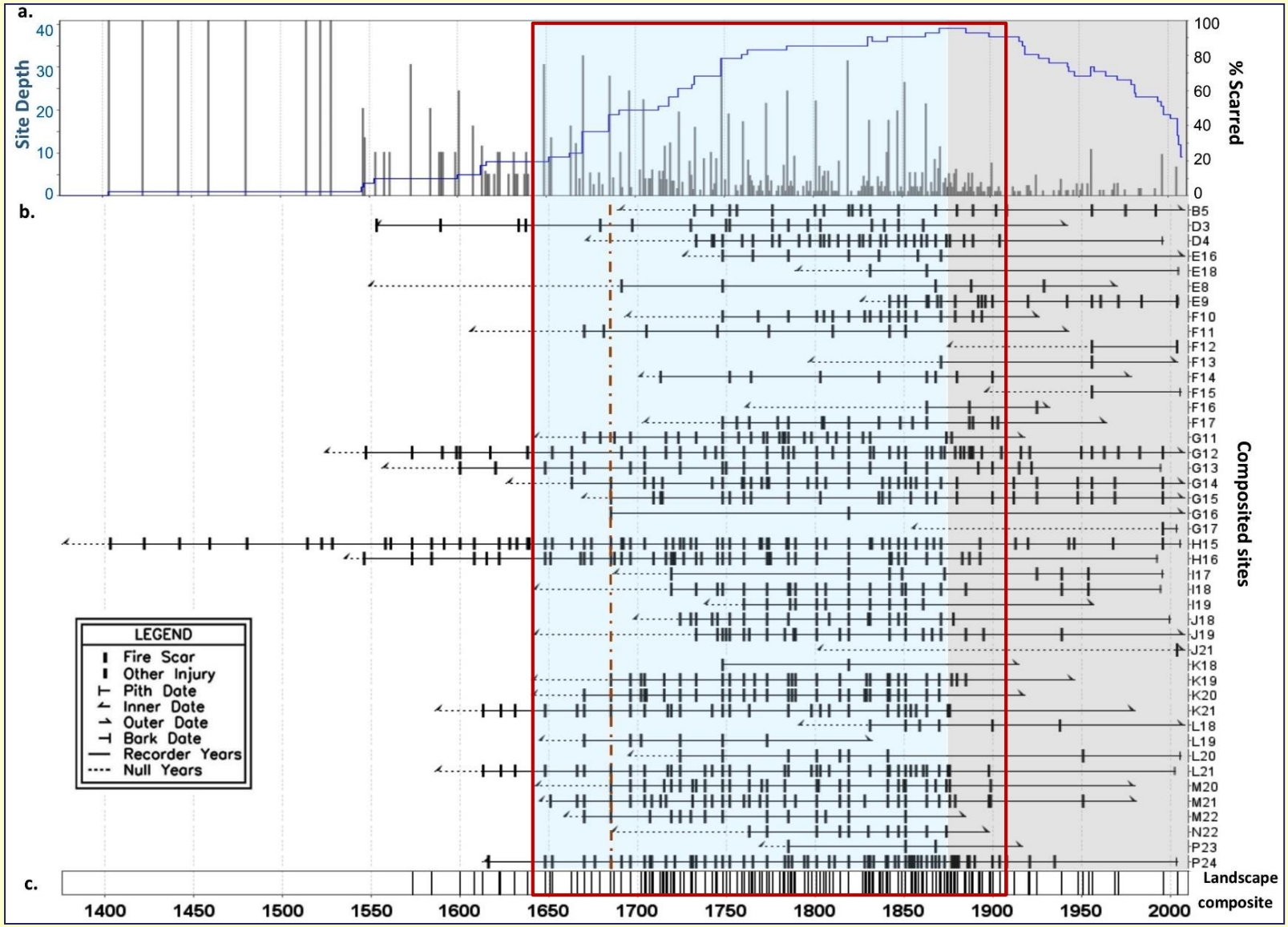
Fire perimeters derived from Park Service atlases (red) and spatial interpolation of fire scar record (shaded polygons)

Farris 2007 Farris et al. 2010

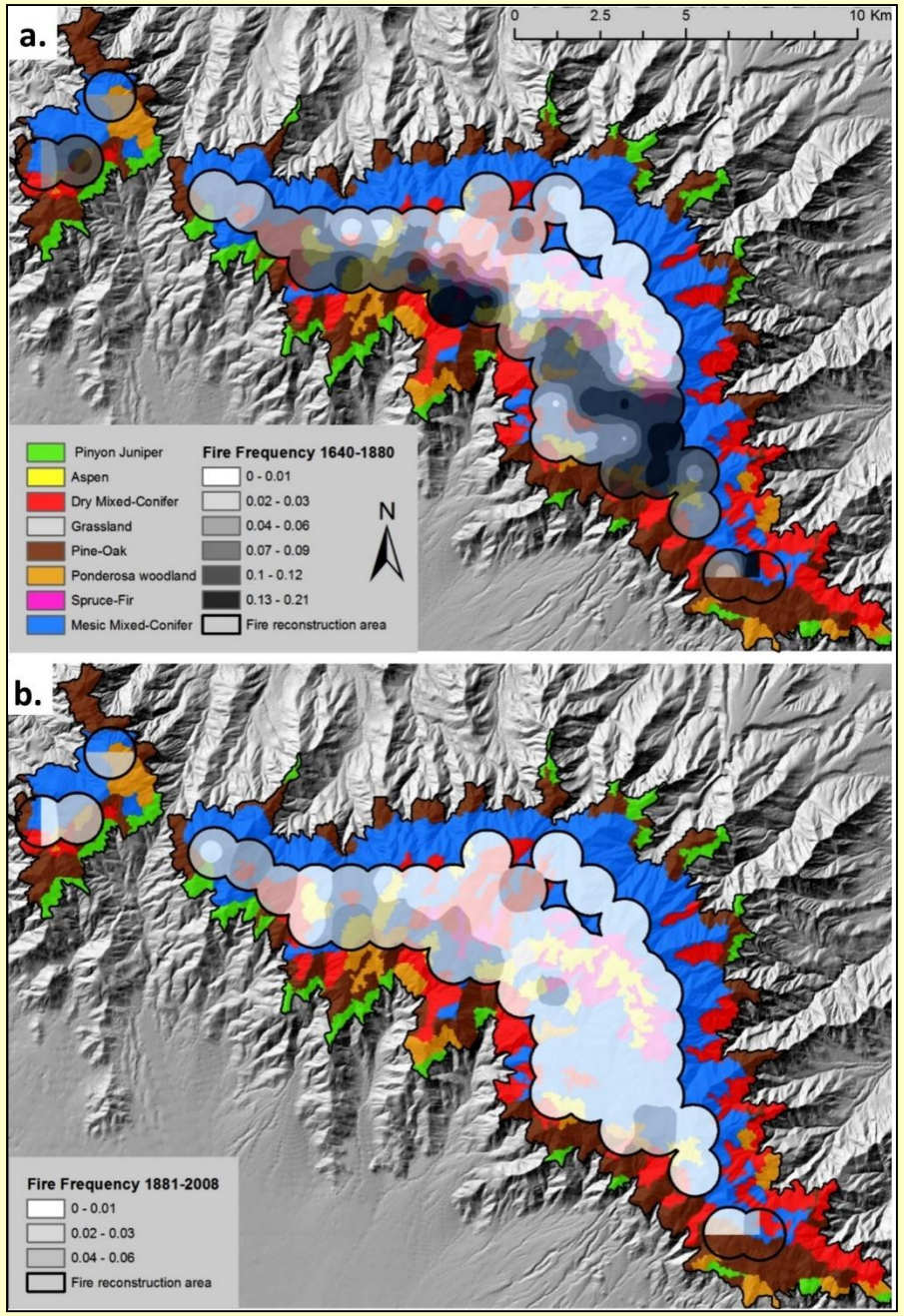
Grid-based fire history in the Pinaleño Mountains, the “tallest” Madrean Sky Island

C. O’Connor 2103 and in prep.

Fire chronology across vegetation types in the Pinaleño Mountains (O'Connor 2013)



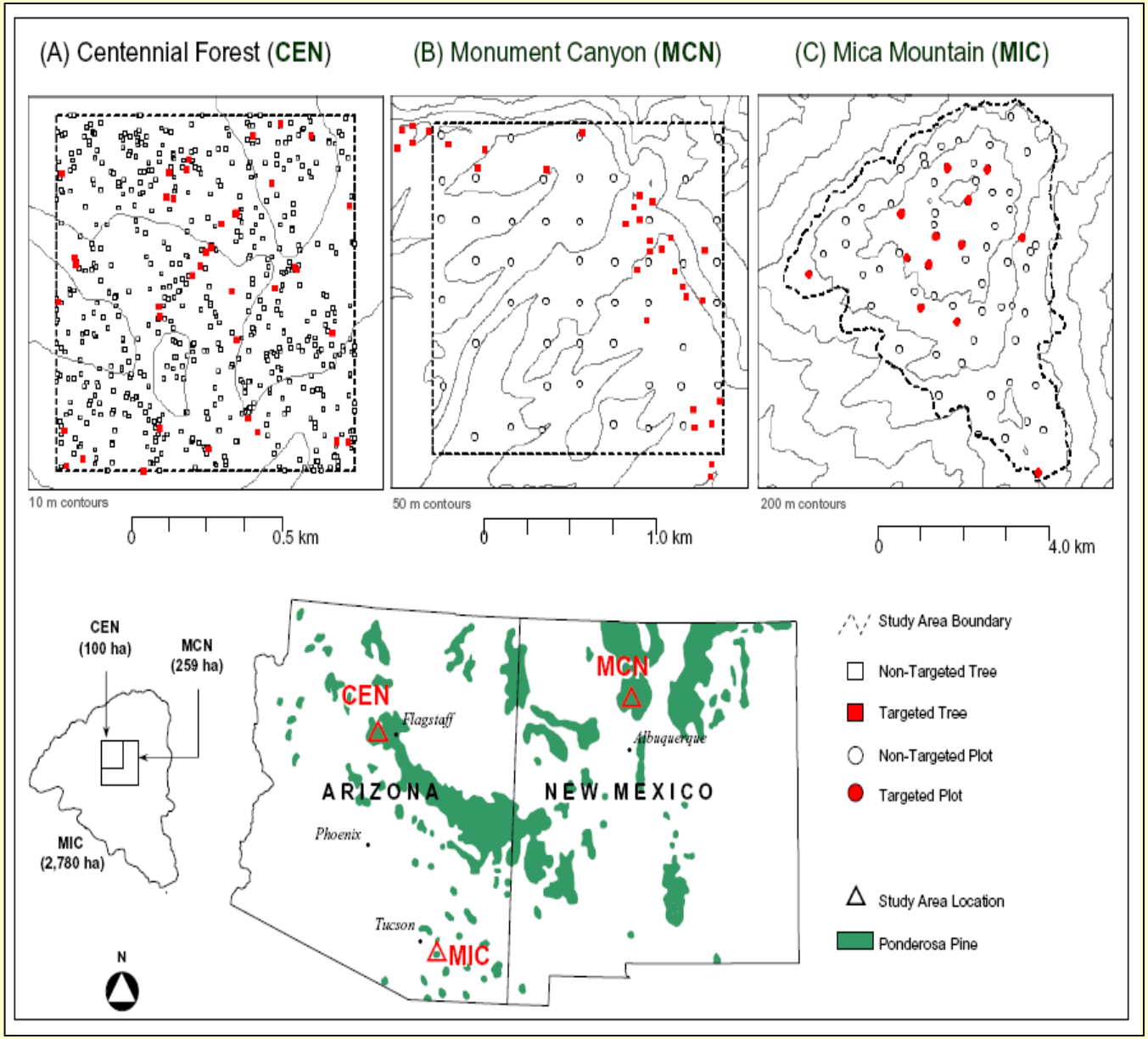
Spatial reconstruction of fire frequency 1640-1880 (a.) and 1881-2008 (b.). Fire frequency surface is based on inverse distance weighting of 53 composited fire-recording sites using four nearest neighbors with a power factor of two. Fire frequency is calculated from fires recorded in two or more sites from 1640-1880 (*n* = 104) and 1881-2008 (*n* = 27).



C. O'Connor et al., in prep.

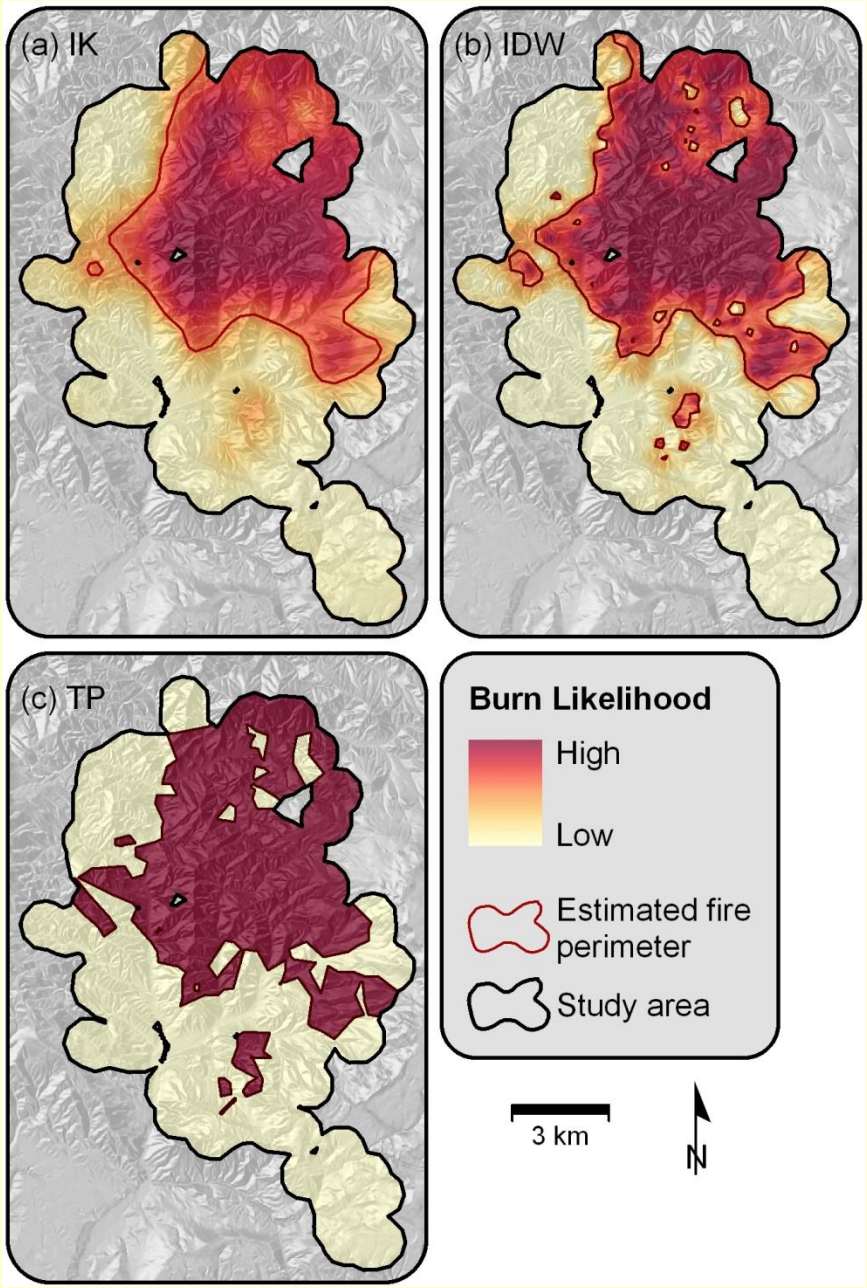
What about <u>non</u>-gridded sampling methods?

Does selecting scarred trees in the field bias the resulting fire record?



Farris et al. 2103, IJWF

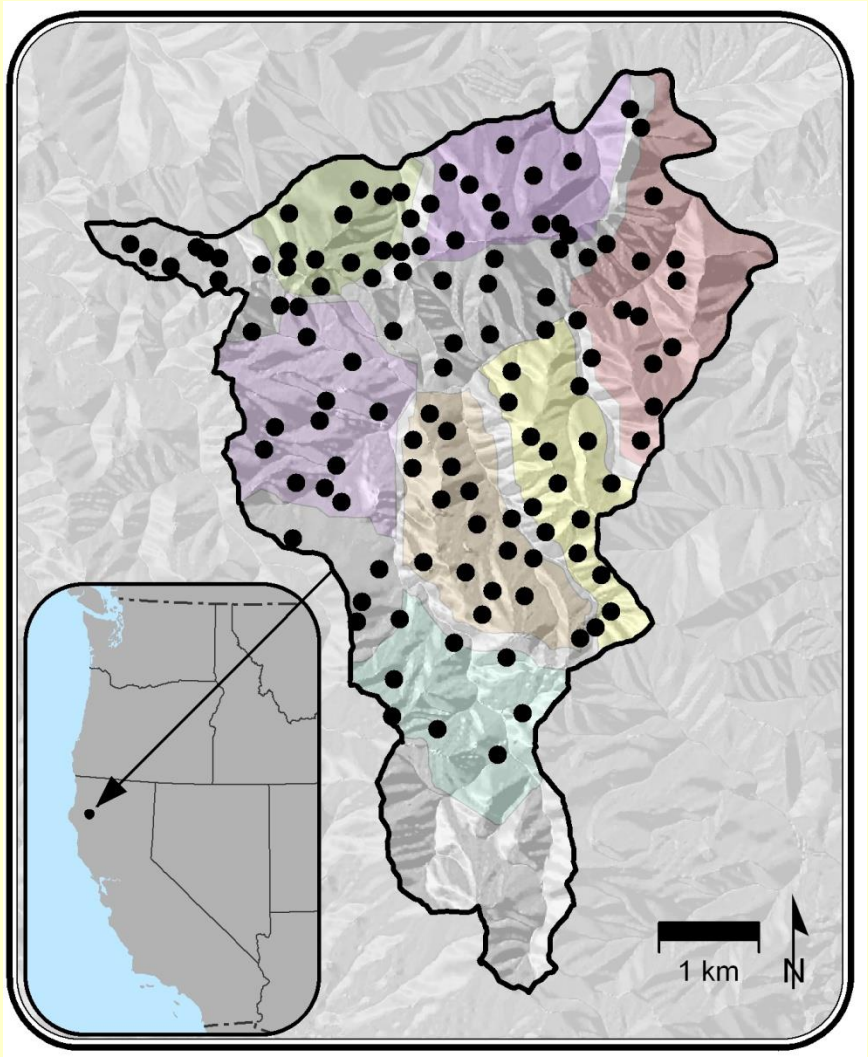
Slide TW Swetnam



Spatial patterns of fire can be reconstructed across large watersheds using extensive searches

Fire spatial patterns for 1874, Swauk Watershed, eastern WA reconstructed from a network of 200+ individual trees (Hessl et al. 2007)

Spatial networks can reveal bottom-up regulation

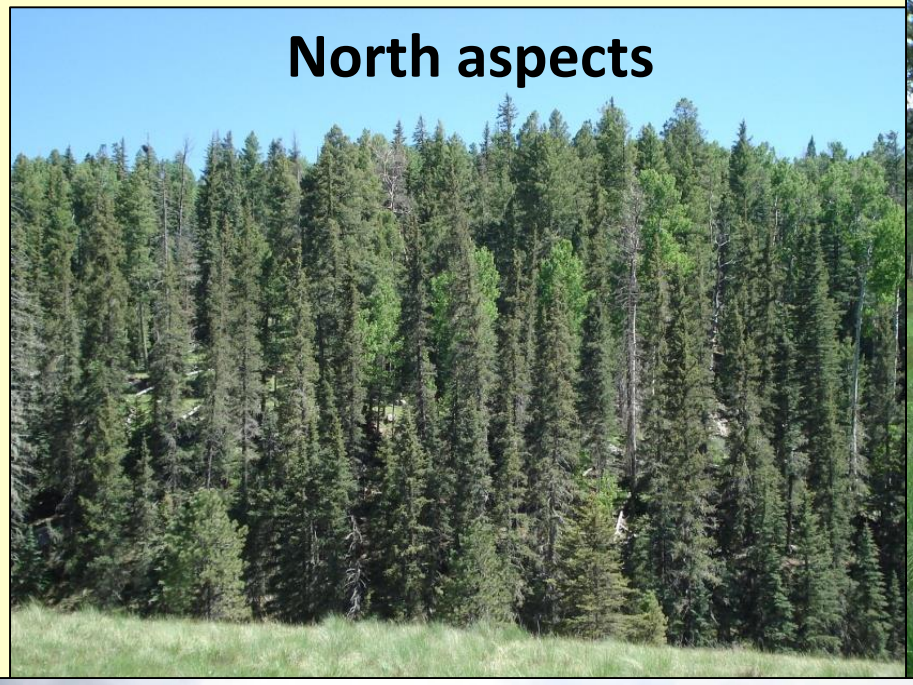


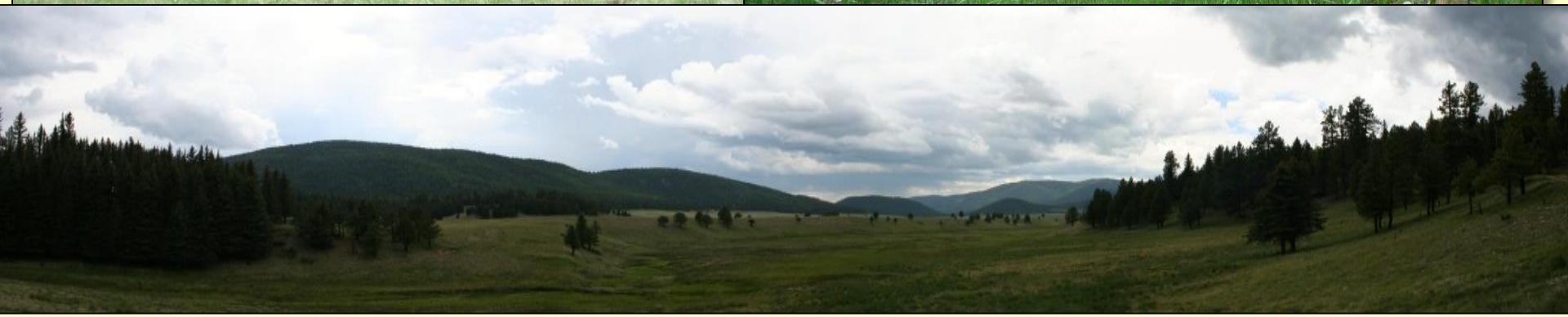
Taylor and Skinner (2003) sampled stumps and dead trees across the landscape of a N California watershed

- In moderate climate years, fire was contained by watershed boundaries
- Under more severe climate conditions, fire spread over-rode those filters

Top-down and bottom-up control of fire regimes in montane grasslands of the Valles Caldera, New Mexico

(Dewar, Falk et al., in prep.)



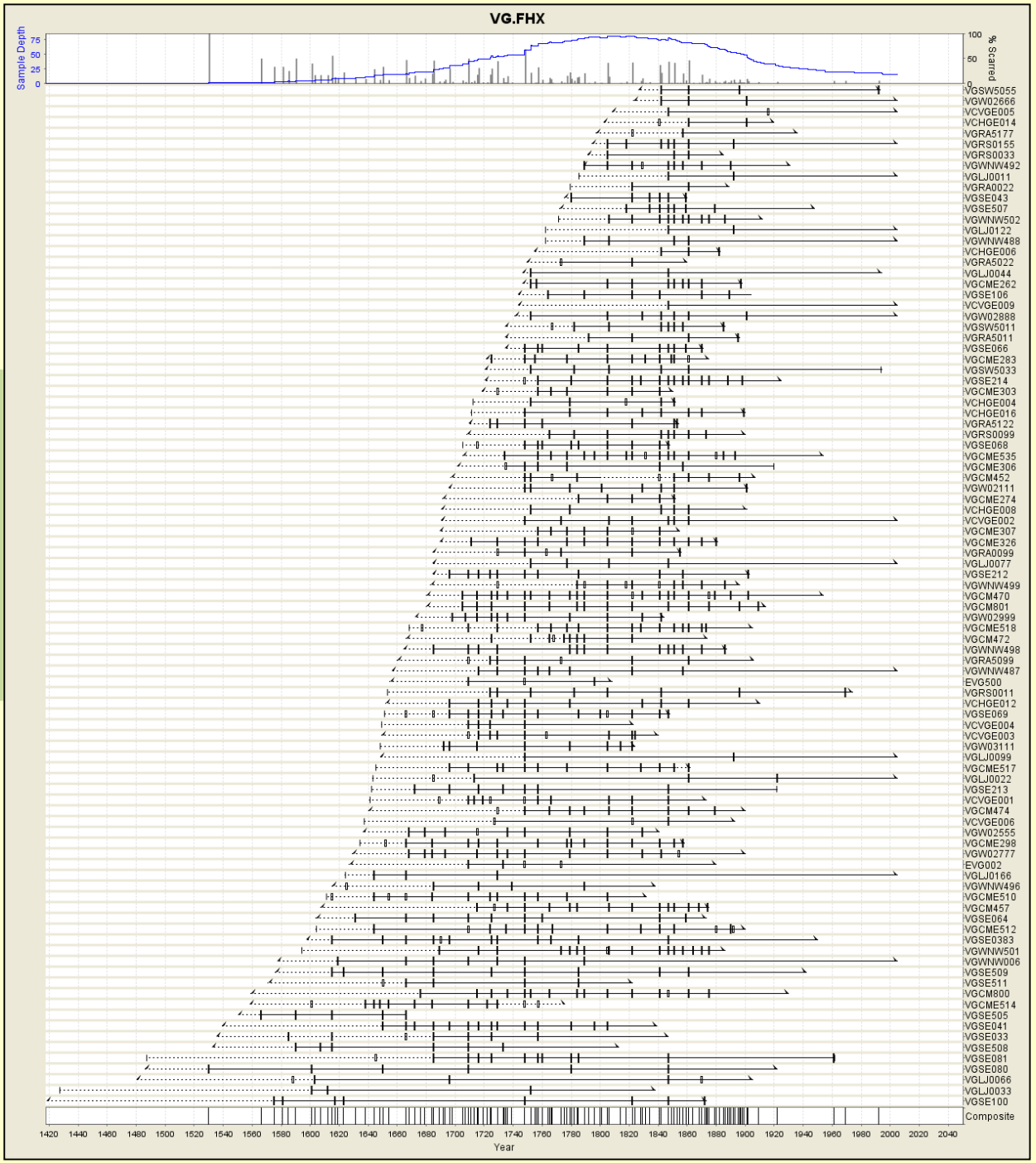


The Valles Caldera, heart of northern New Mexico's Jemez Mountains

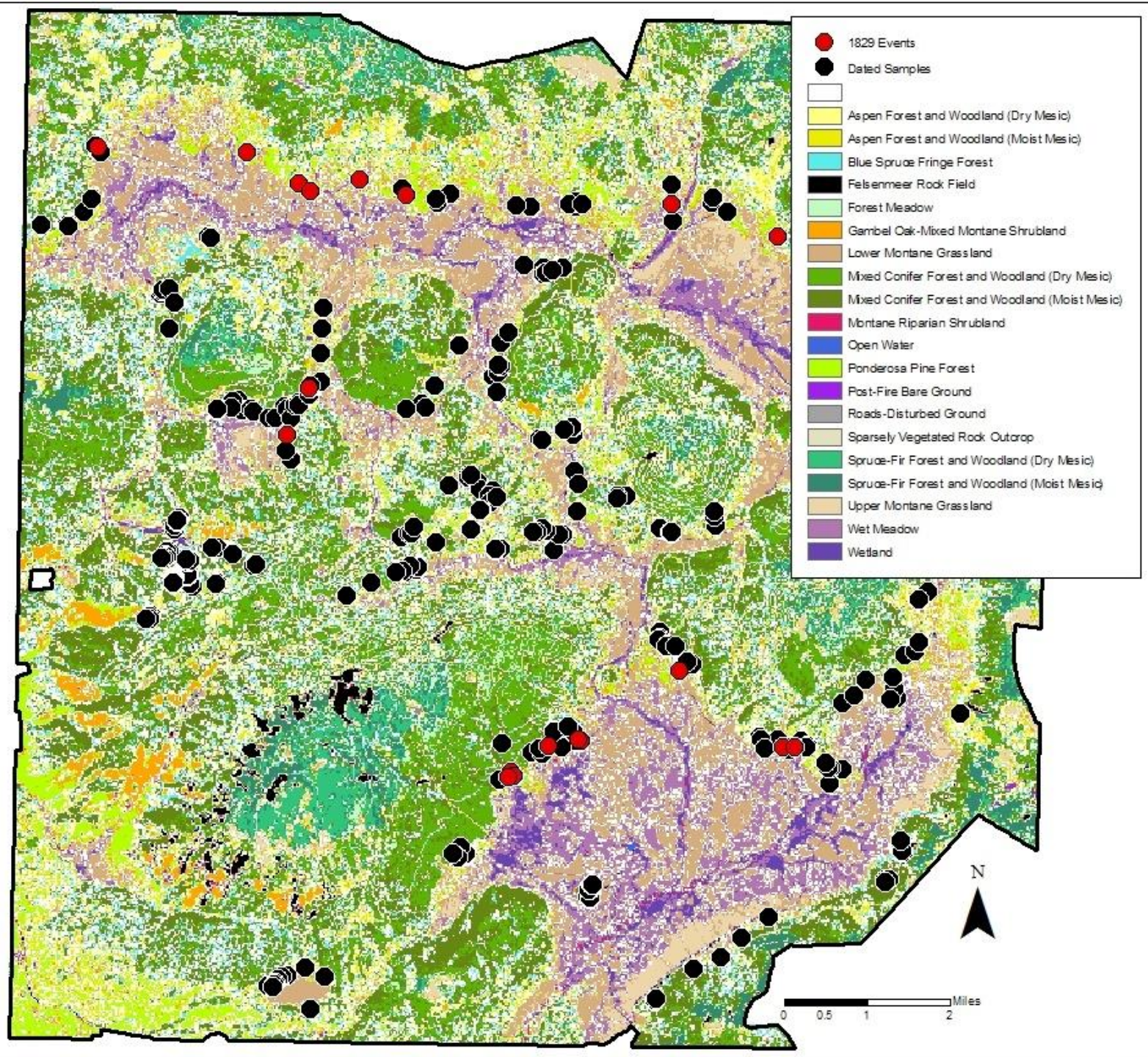
Fire in the forest-grassland ecotone

Valles Caldera National Preserve, NM

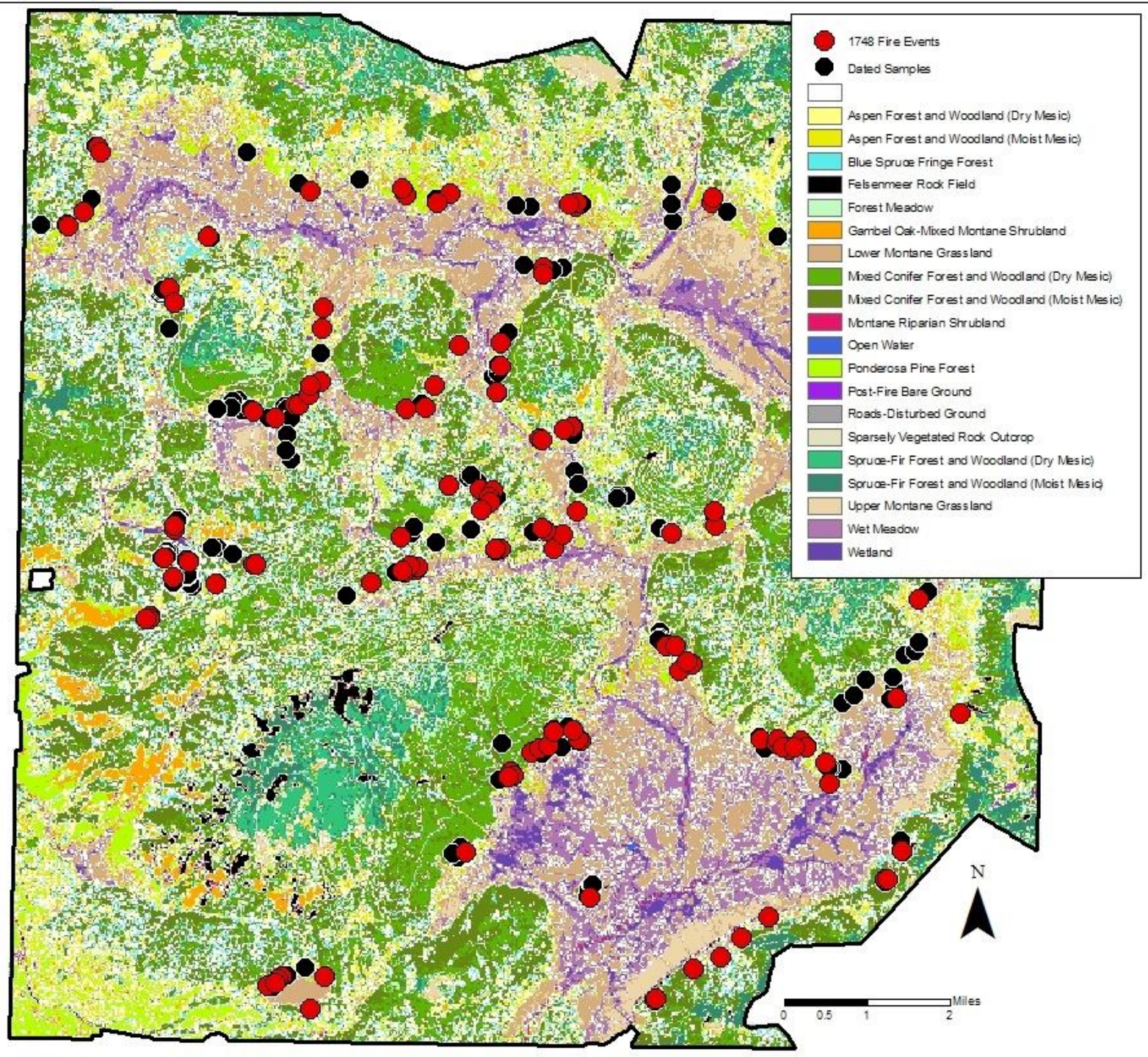
Valle Grande



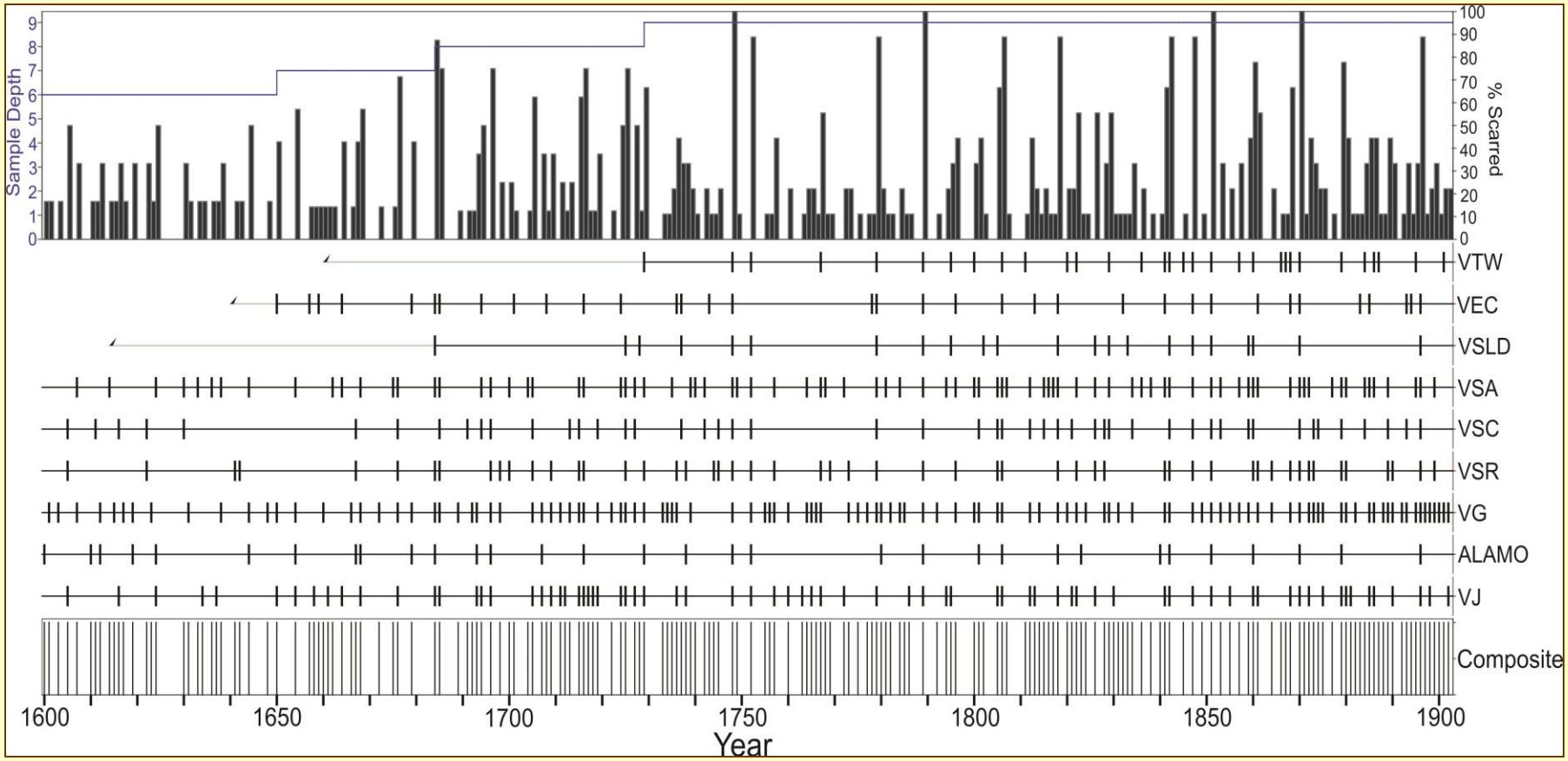
1829 FIRE YEAR



1748 FIRE YEAR

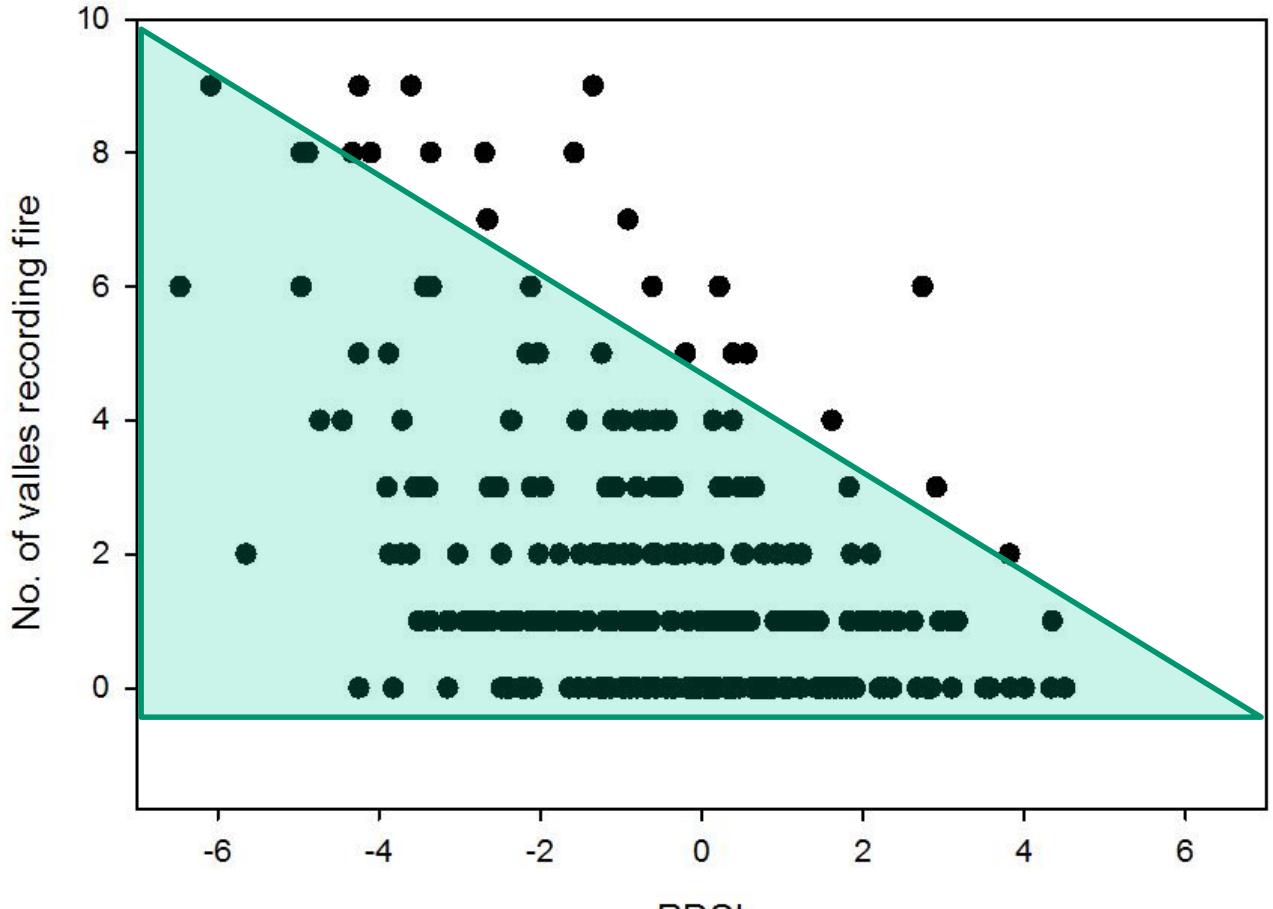


Landscape structure (multiple *valles*) leads naturally to a multi-scale approach



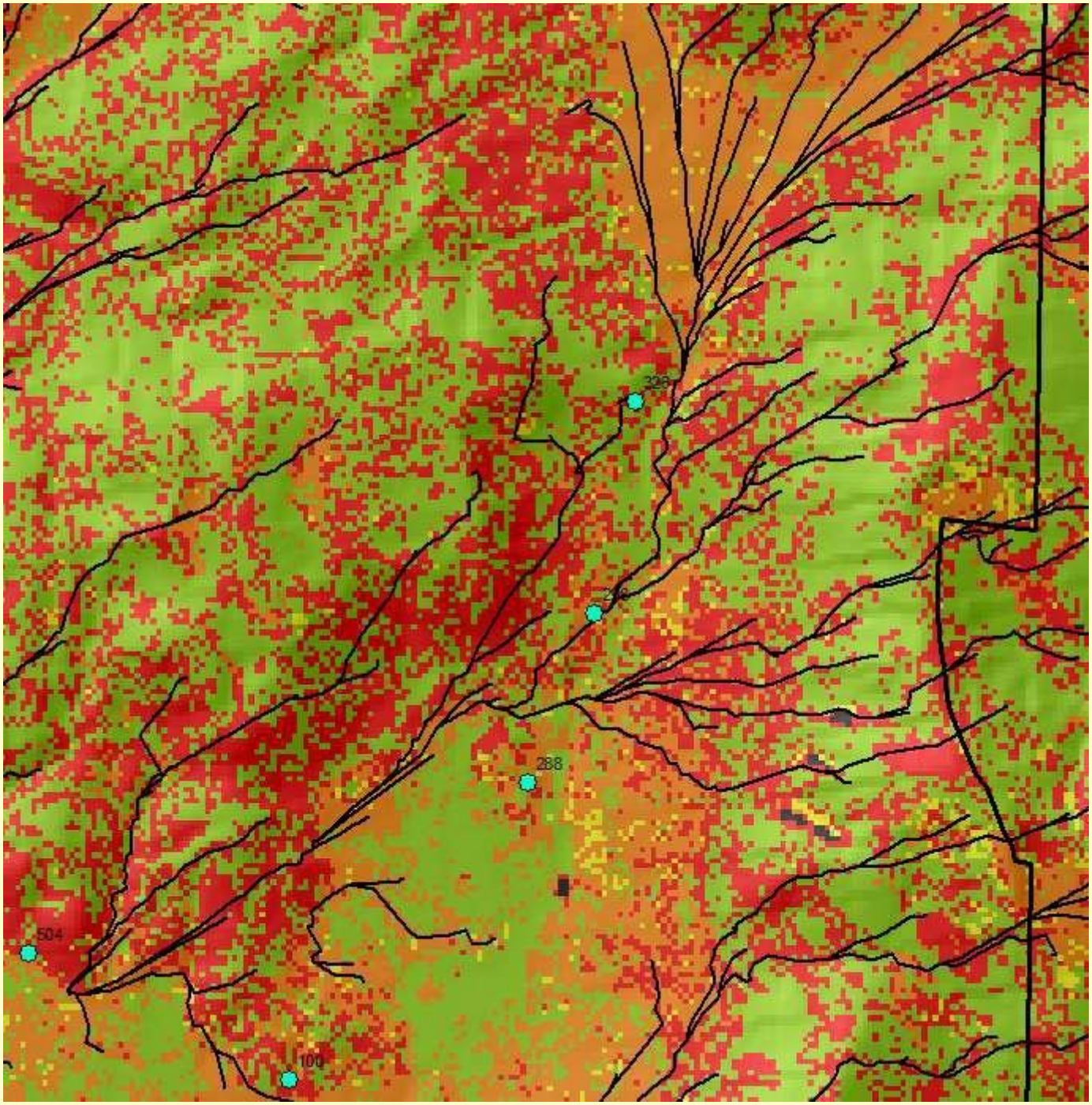
Dewar, Falk et al., in prep.

Fire is a contingent process (*viz*., drought conditions are NBNS for widespread fire)

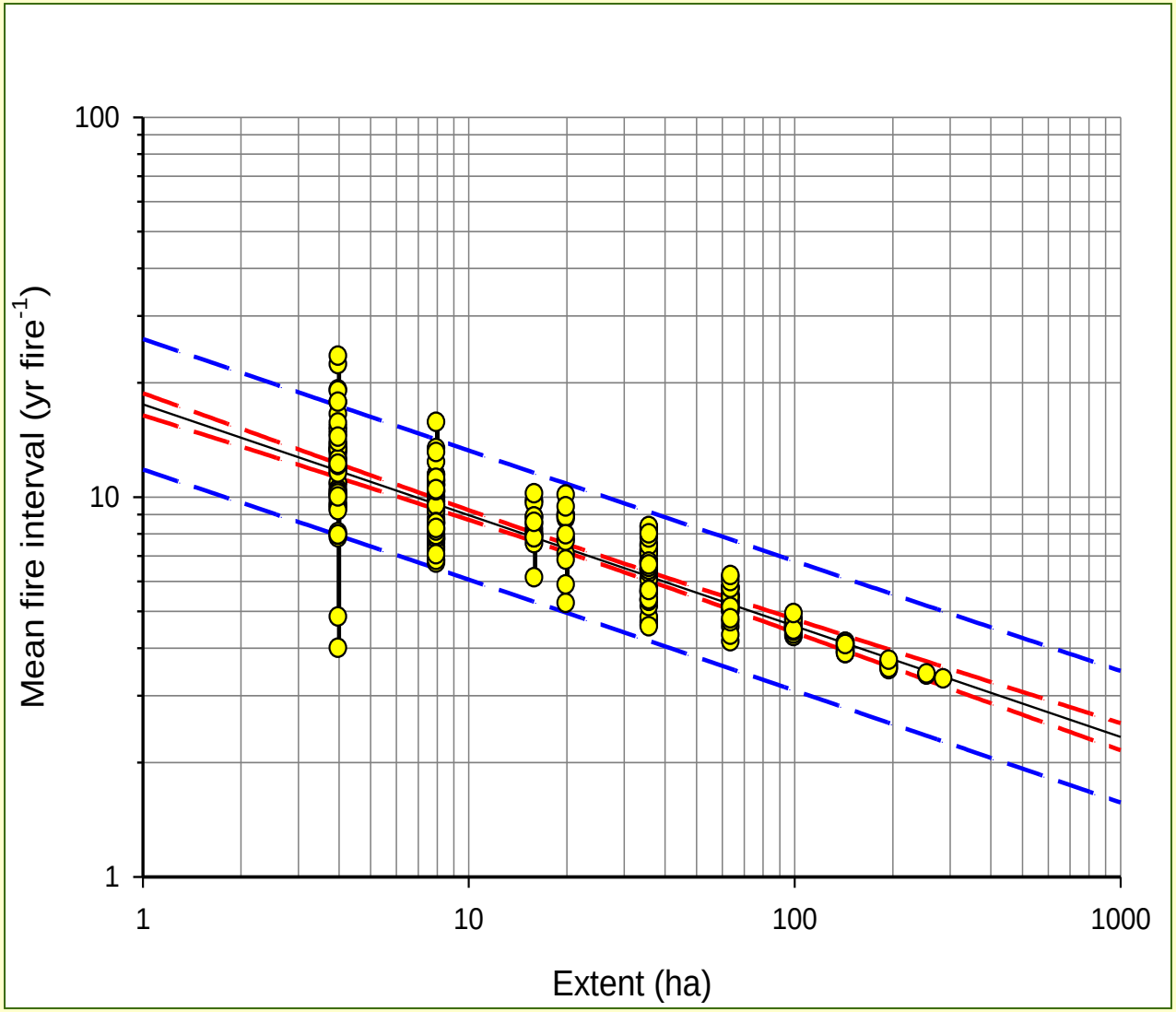


Fire spread modeling shows how fire spreads across landscapes, and confirms the findings from fire scar analysis

J. Conver, 2103 and in rev.

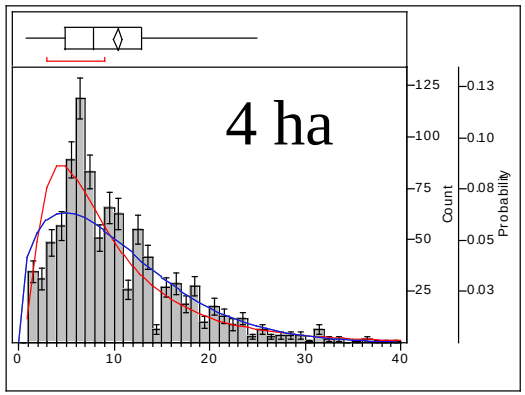


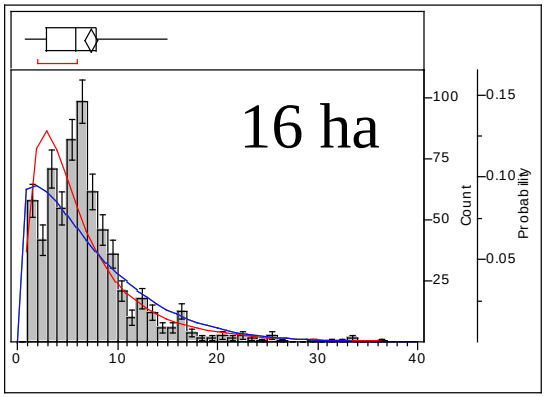
Multiscale reconstruction shows scale dependence in fire intervals

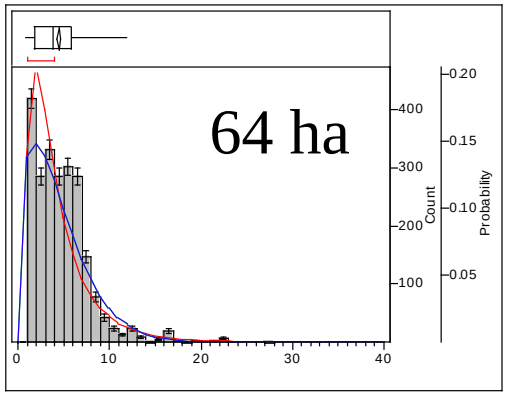


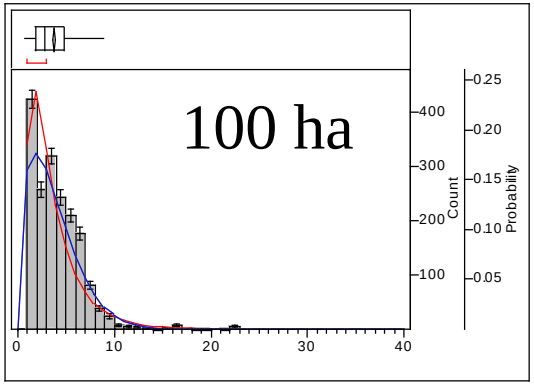
Scale dependence in mean fire interval (Falk et al. 2007)

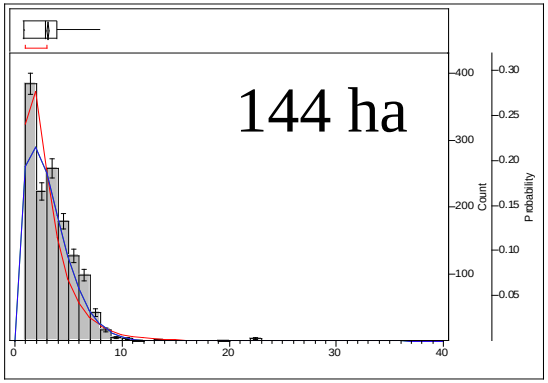
Scale dependence of fire intervals

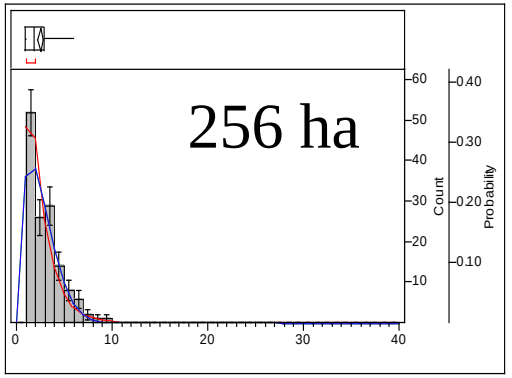








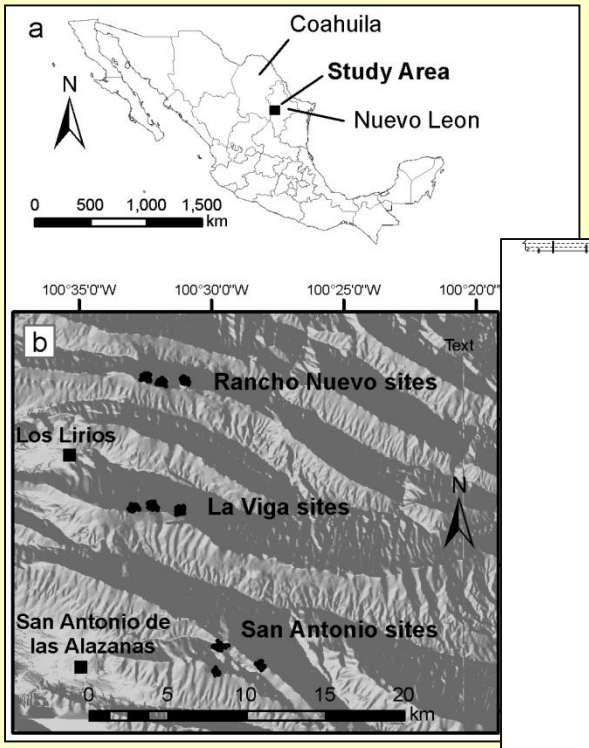


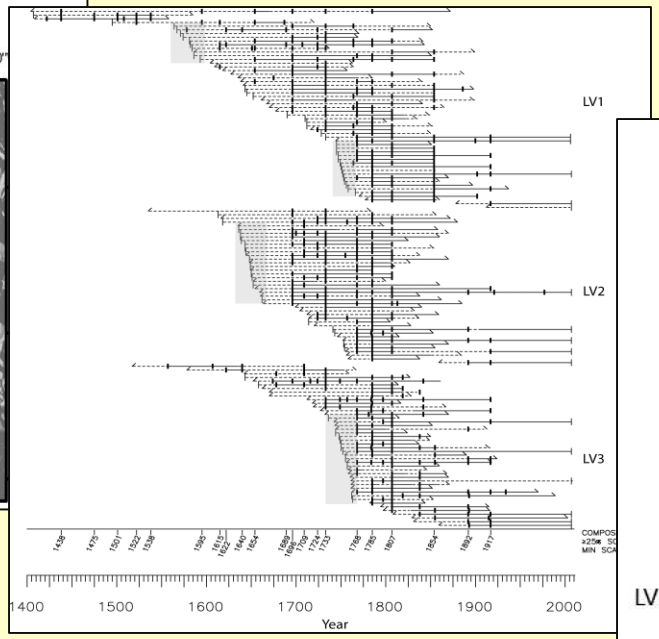


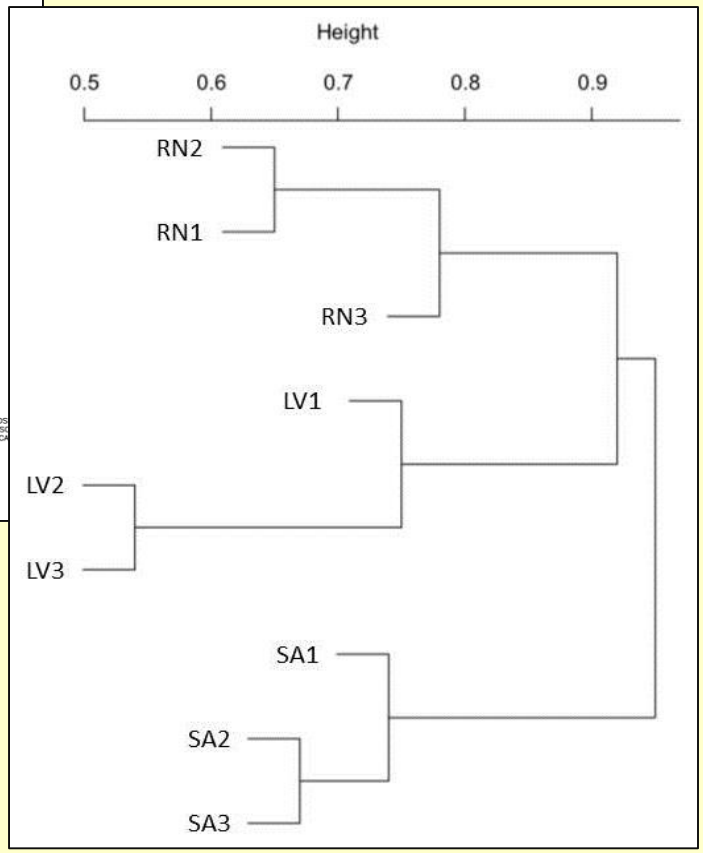
Fitted lognormal and Weibull probability-time density functions

Falk 2004, Falk et al. 2007

Using similarity analysis in fire history







Yocom et al. in press (2014), *IJWF*

What about other possible multi-scale dendroecology networks?

- Insect outbreaks
- Forest stand age
- What else…?