Modeling riparian forest dynamics and structure on alluvial rivers

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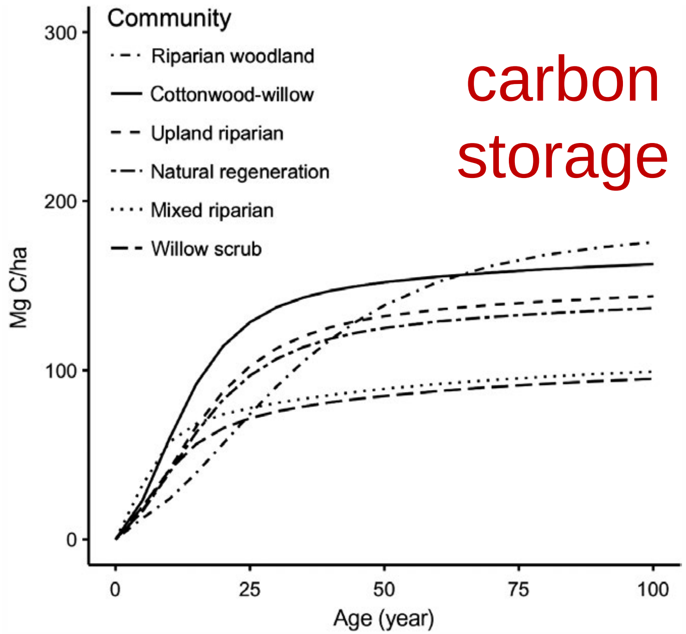
Many ecosystem benefits of riparian forests



carbon storage

large wood inputs

instream habitat

RESEARCH ARTICLE

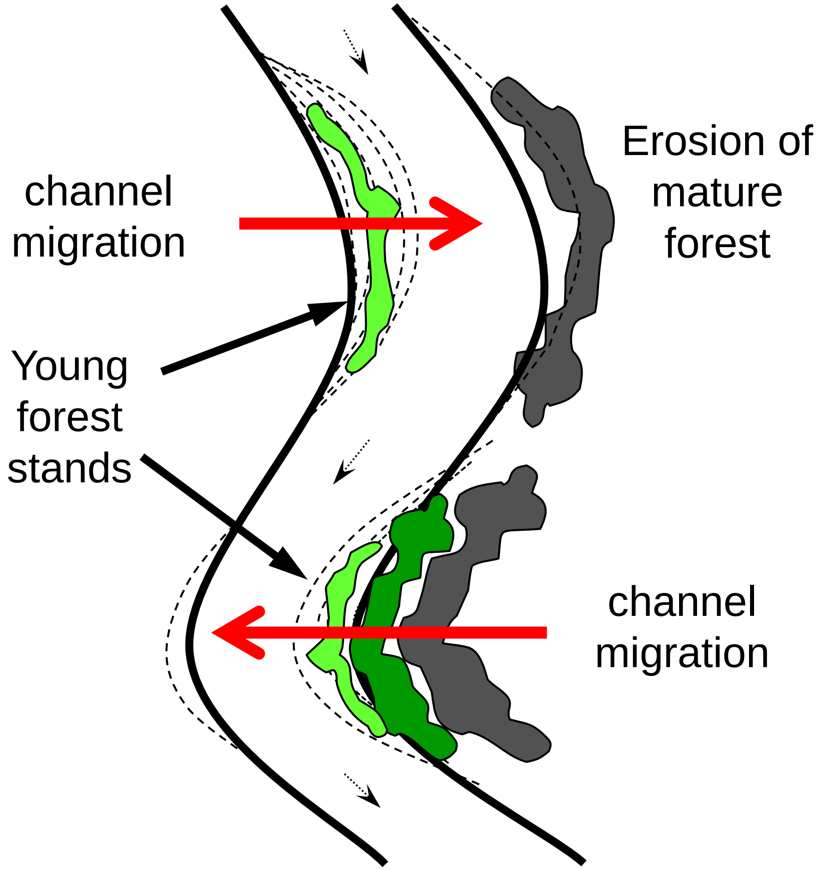
Applied Vegetation Science IAVS

Development of a carbon calculator tool for riparian forest restoration

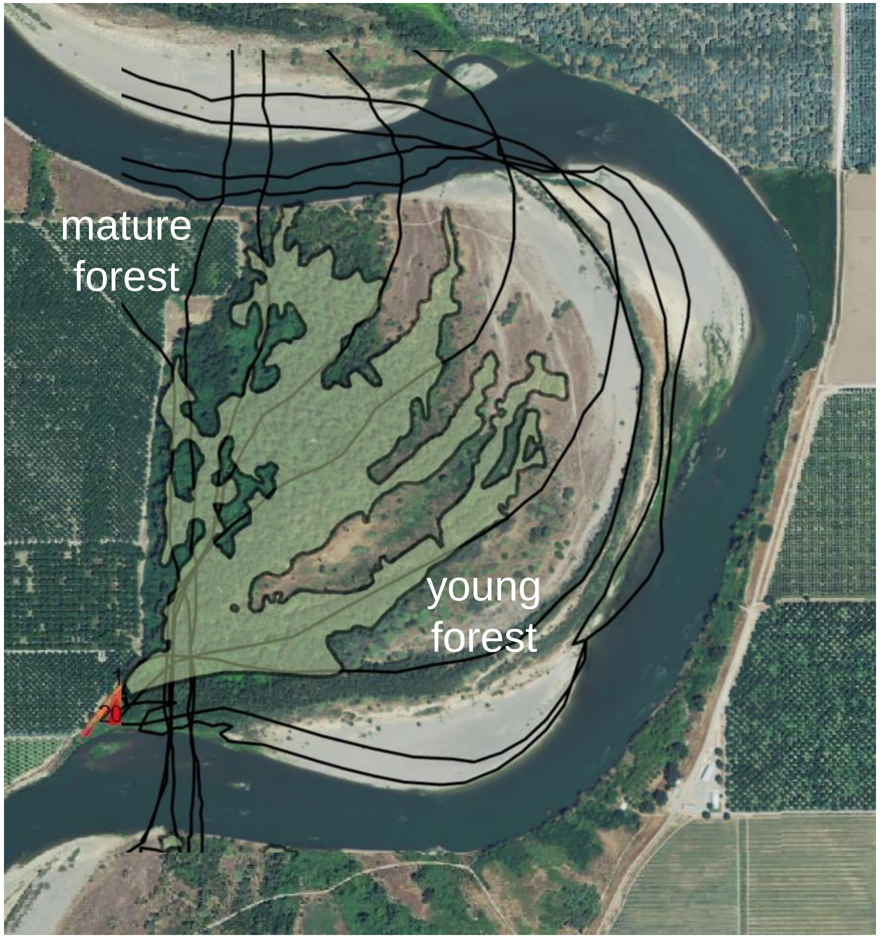
Virginia Matzek[1] | John Stella[2] | Pearce Ropion[3]

Bank erosion drives large wood inputs along alluvial rivers

Channel erosion and migration



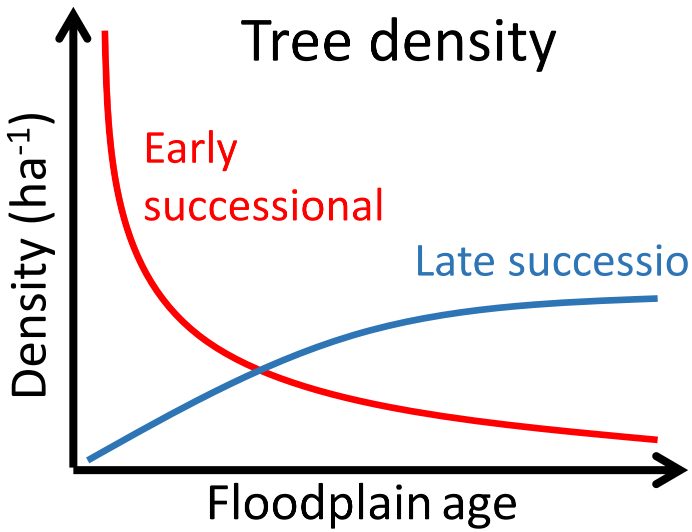
Floodplain and riparian forest development

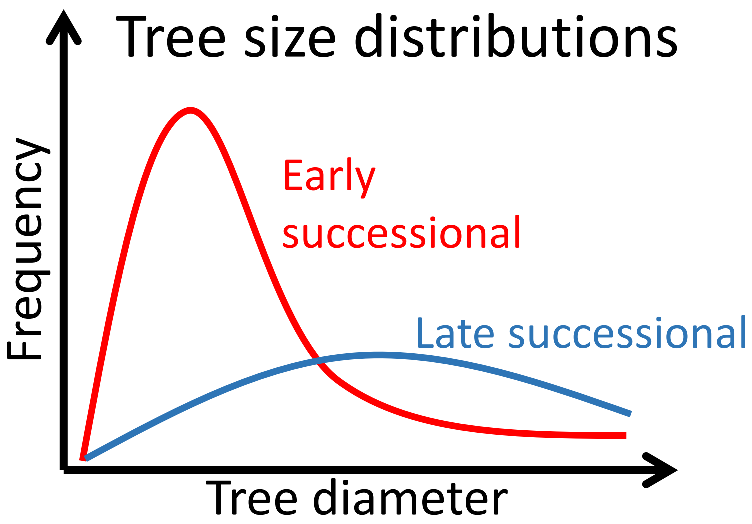


Forest stands shift over time in tree density, size and composition

How can we model riparian forest dynamics along alluvial rivers to predict stand structure over time?

- Floodplain development drives many forest processes:
  - Tree density
  - Tree size (diameter)
  - Species composition changes (forest succession)
- Develop quantitative relationships and predict tree diameter distributions for large wood (LW) inputs





Modeling approach

- Model forest structure development from field inventory data
- Predict tree density and diameter distributions with floodplain age
- Account for tree species and size shifts during riparian forest succession

Model structure

Field and spatial data inputs

- Stand density
- Floodplain age (FPA)
- Tree diameter distributions

Stand density ~ FPA

$$\text{Density}_{\text{all}} = r * \text{FPA}^{m}$$

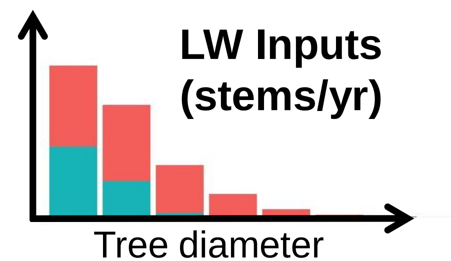
Tree diameter CDF ~ FPA

$$\text{Weibull CDF} = 1 - \exp\left(\left(\frac{10}{a}\right)^{b} - \left(\frac{\text{DBH}}{a}\right)^{b}\right)$$

$$\text{Time varying parameters: } a, b = t * \text{FPA}^{k}$$

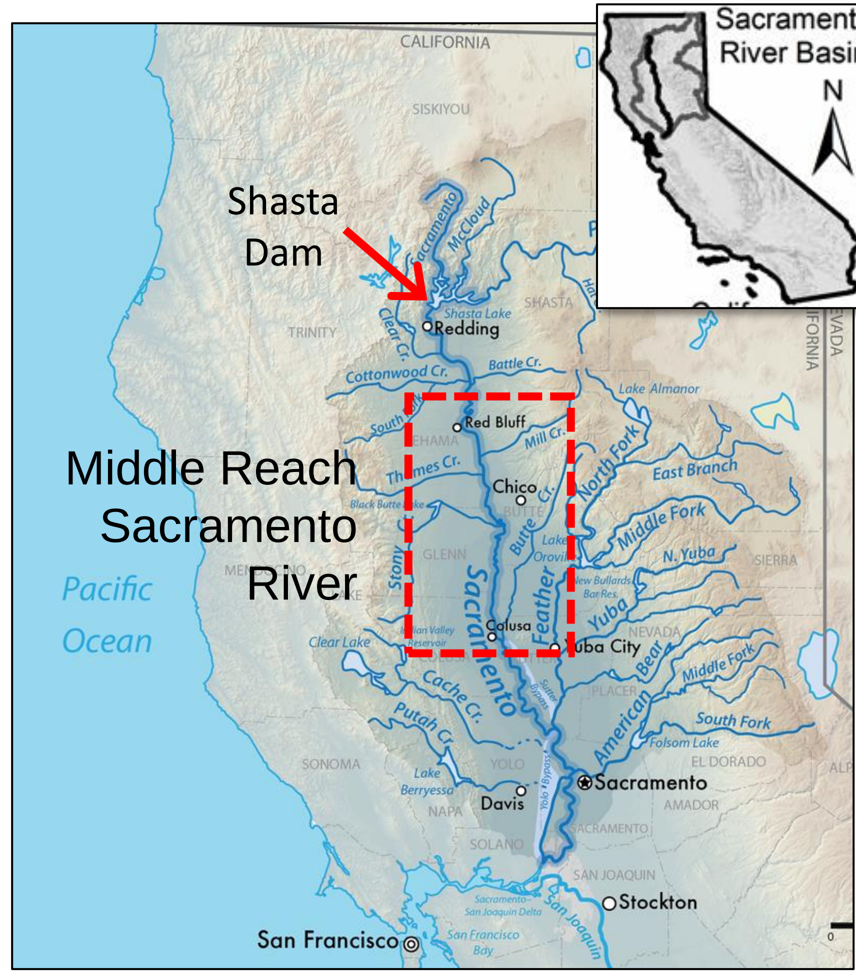
Final diameter distributions

$$\text{Density}_{\text{DBH}} = \text{Density}_{\text{all}} \times \text{CDF}_{\text{DBH}}$$

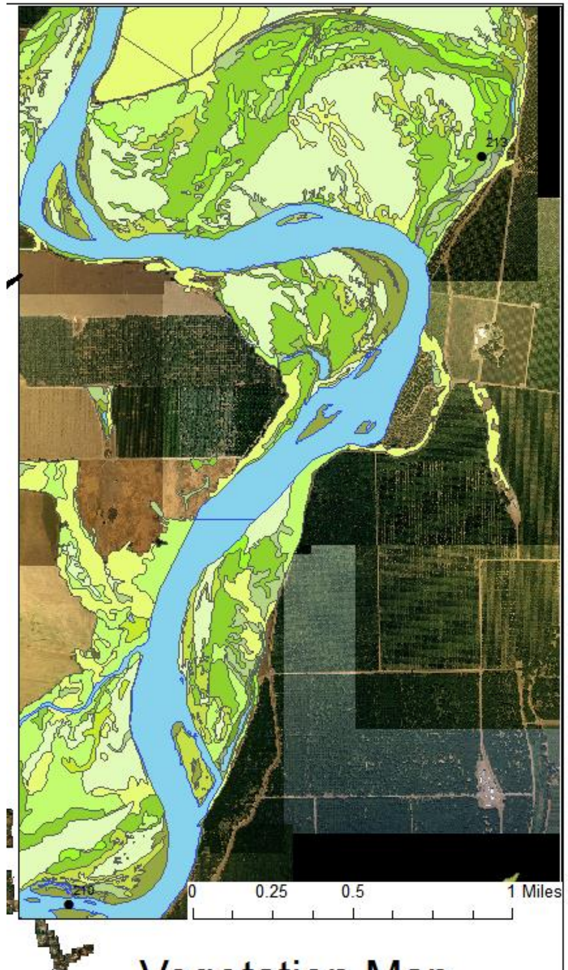


Middle Reach Sacramento River (CA)

- Reduced channel migration since Shasta Dam (1942)
- Still active channel migration for 160 km downstream of dam
- Large remnant patches of mature riparian forest



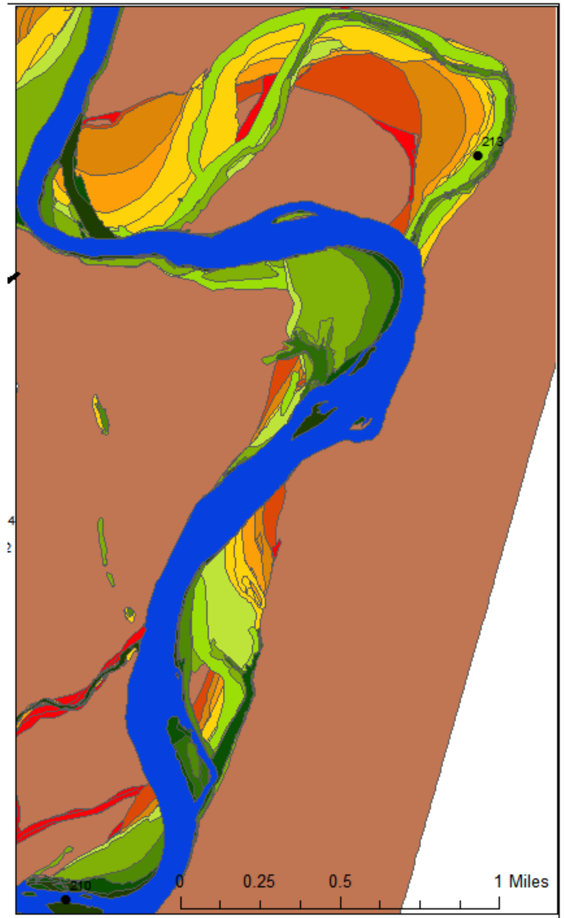
Existing vegetation and floodplain age maps



Vegetation Map, Sacramento River

Sacramento River Monitoring Project, Geographical Information Center, CSU Chico. 2008.

Viers, JH, AK Fremier, and RA Hutchinson, 2010.



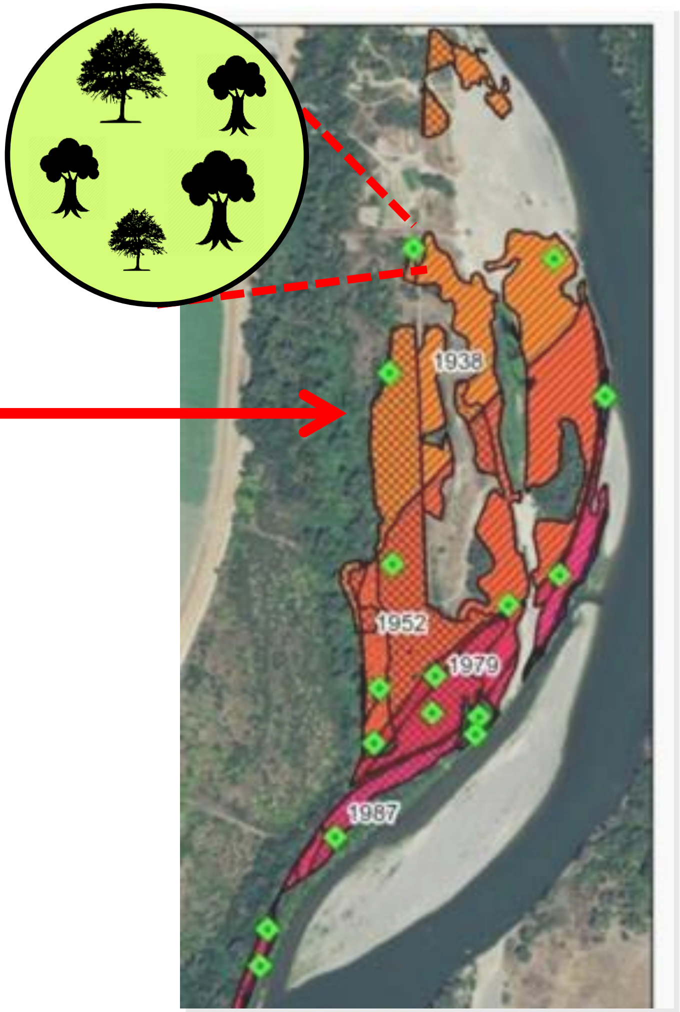
Floodplain Age Map, Sacramento River

Greco, S.E., A.K. Fremier, E.W. Larsen, and R.E. Plant, 2007.

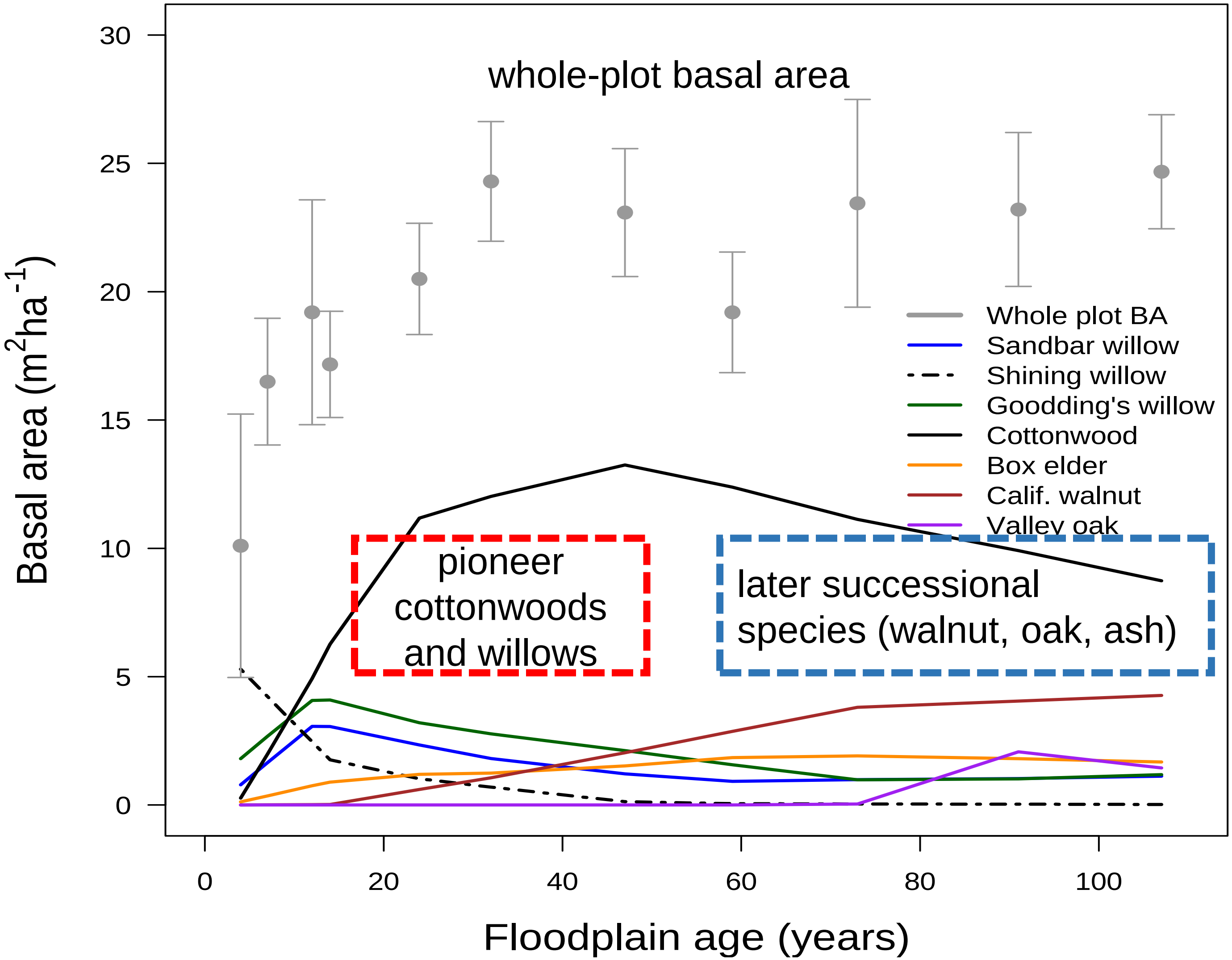
Greco, S.E., E.H. Girvetz, E.W. Larsen, J.P. Mann, J.L. Tuil, and C. Lowney, 2008.

Sacramento riparian forest inventory (2010 – 2012)

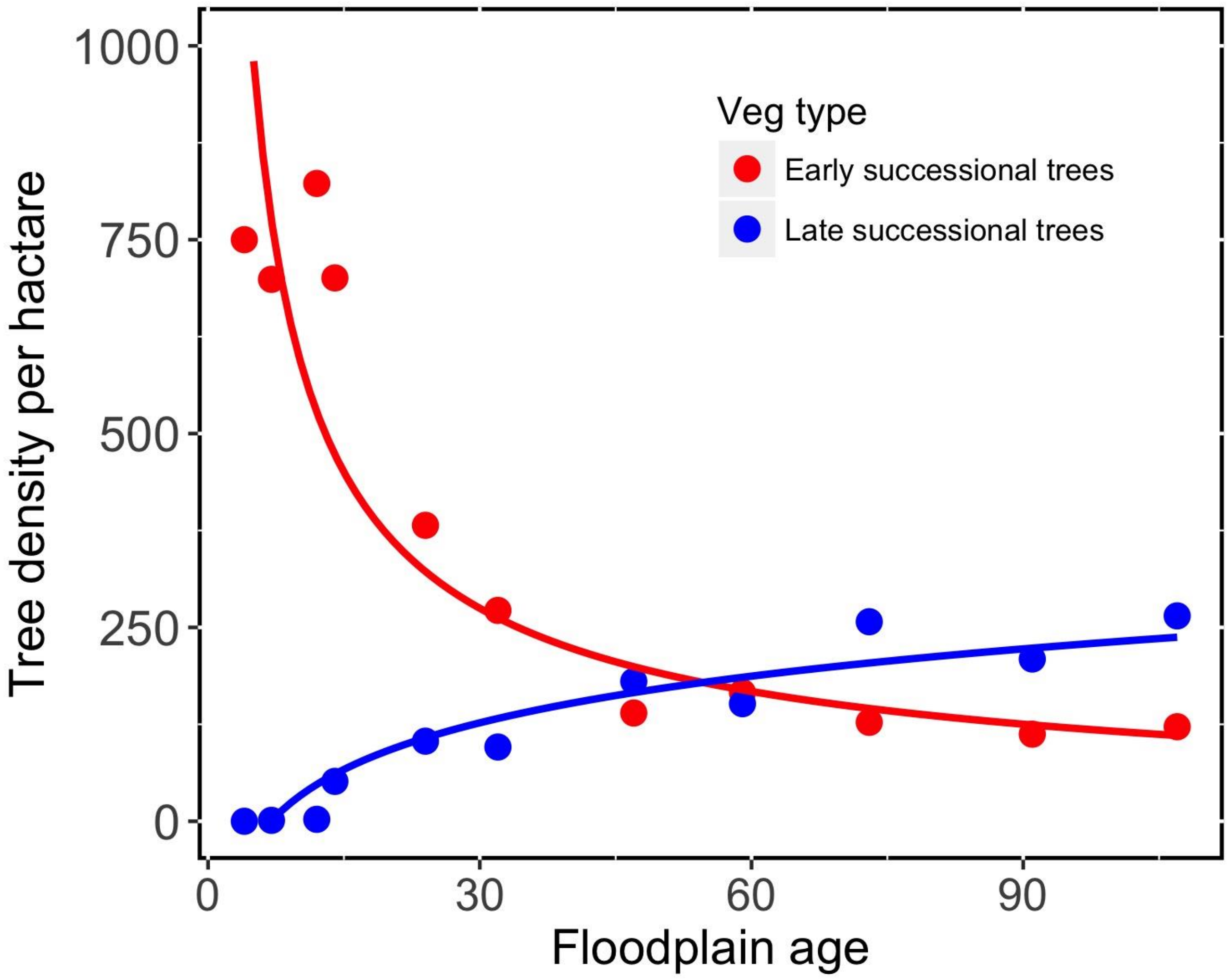
- 431 fixed-area plots on 19 large meander bends
- Stratified by floodplain age; 7–104 years old
- Tree species, diameter, basal area



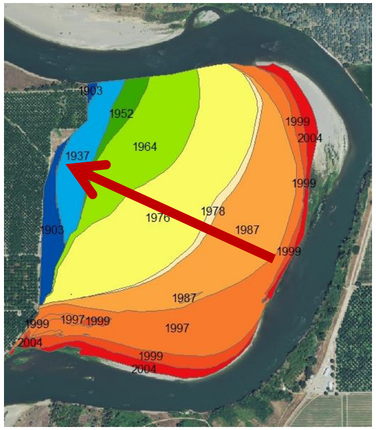
Shifting species with forest age

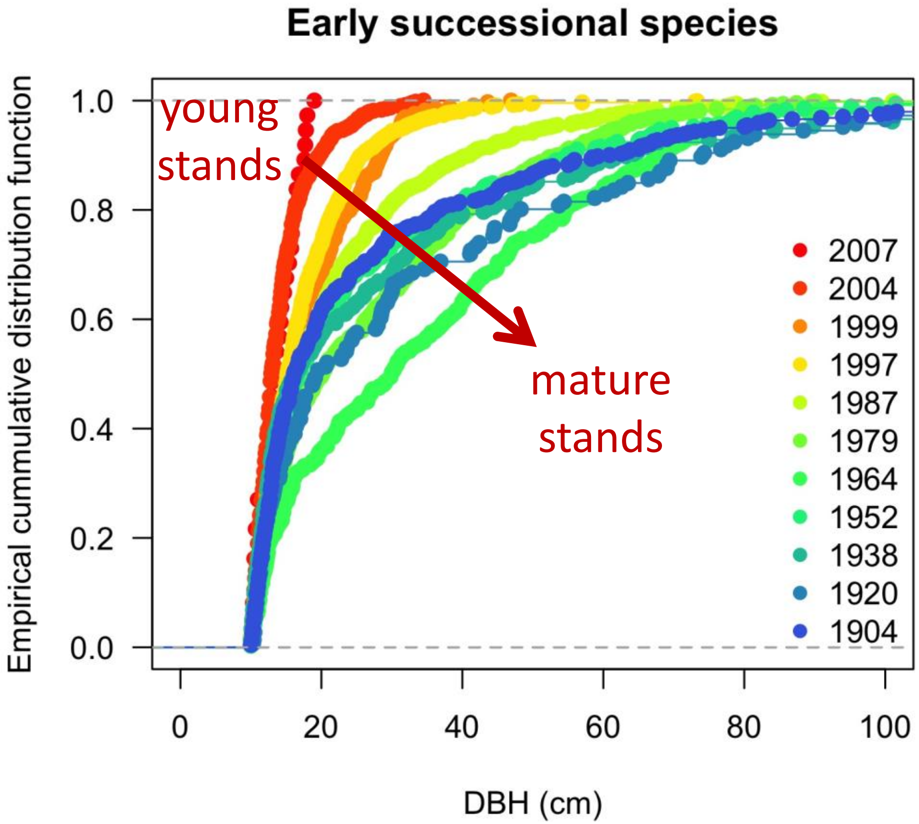


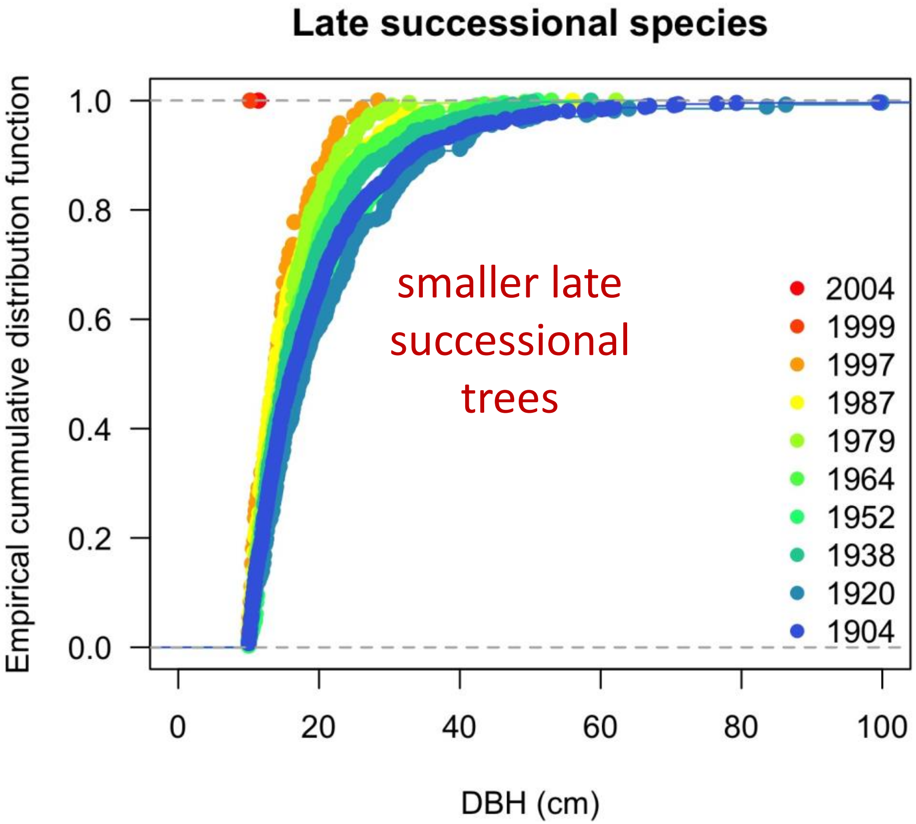
Stand density changes with forest age



Empirical diameter distributions shifted with floodplain age





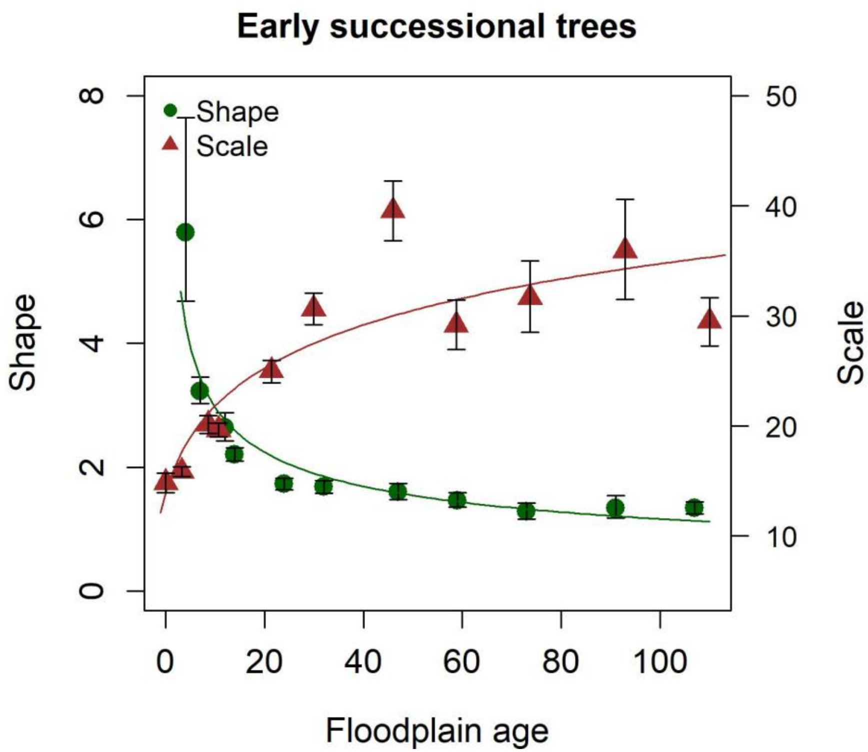


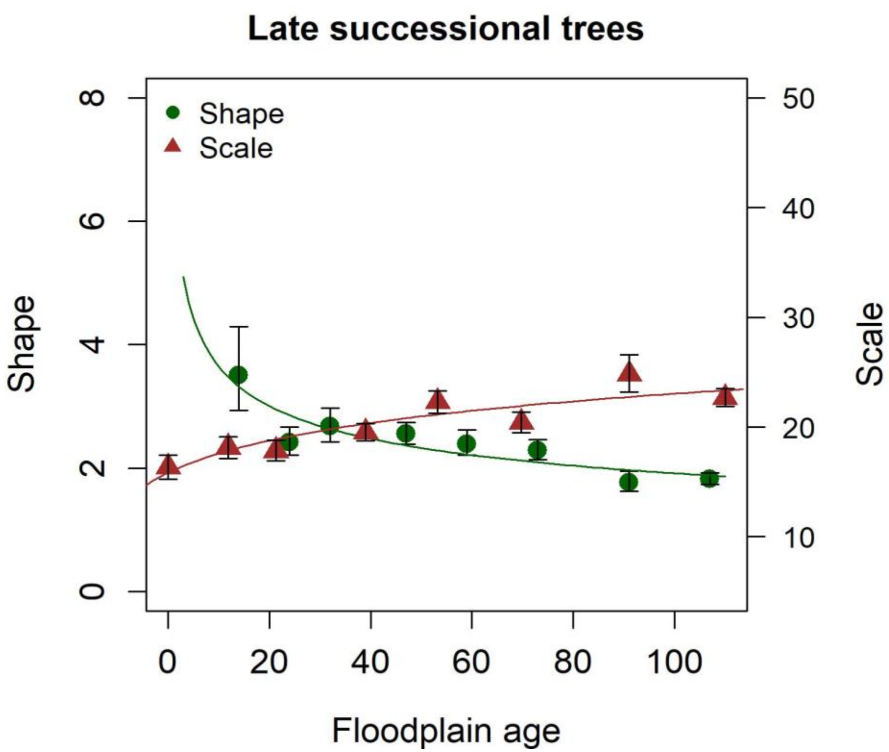
Weibull functions optimized with time-varying parameters

Tree diameter CDF ~ FPA

$$\text{Weibull CDF} = 1 - \exp^{\left(\left(\frac{10}{a}\right)^{b} - \left(\frac{DBH}{a}\right)^{b}\right)}$$

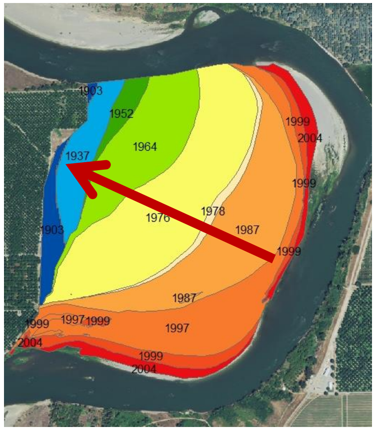
$$\text{Time varying a, b} \sim \text{FPA}$$





- Early successional trees: large parameter shifts
- Later successional: little change

Predicted diameter distributions based on Weibull functions



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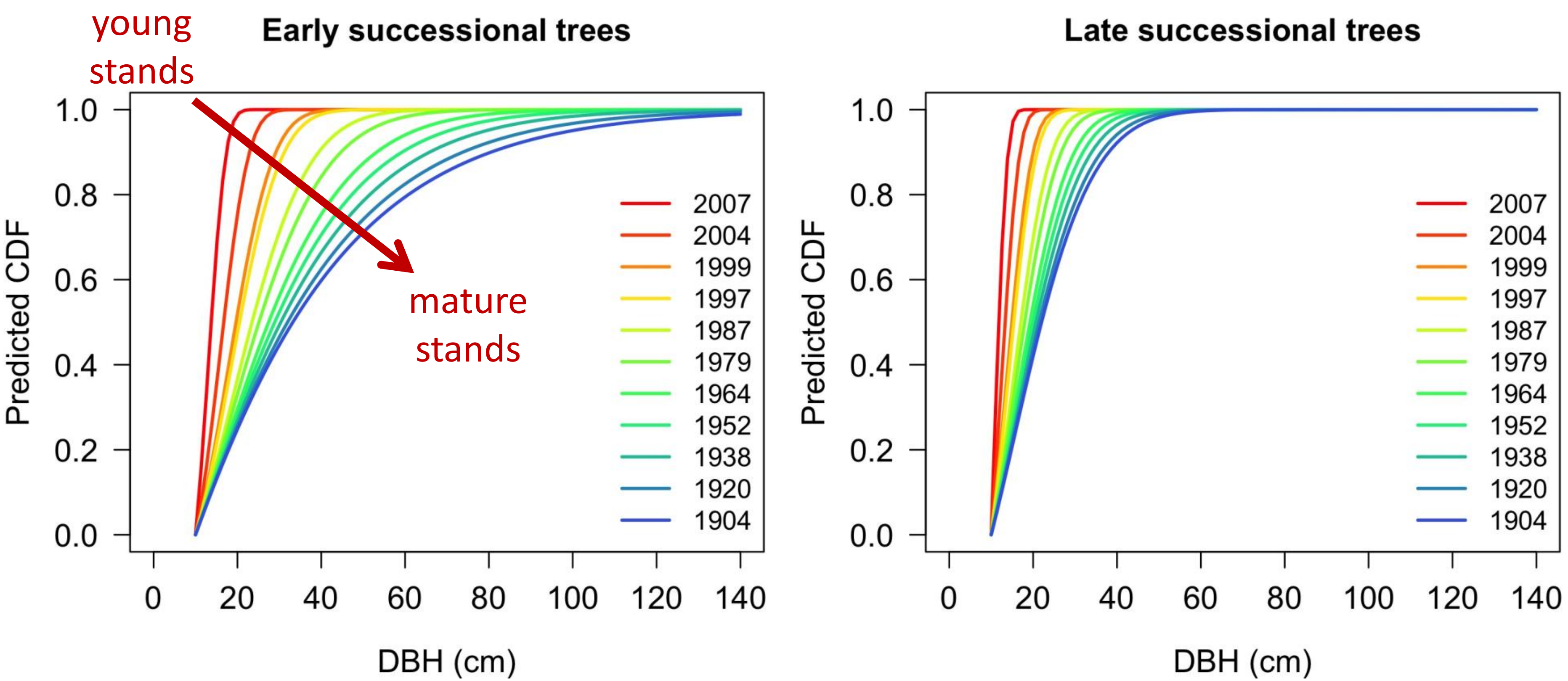
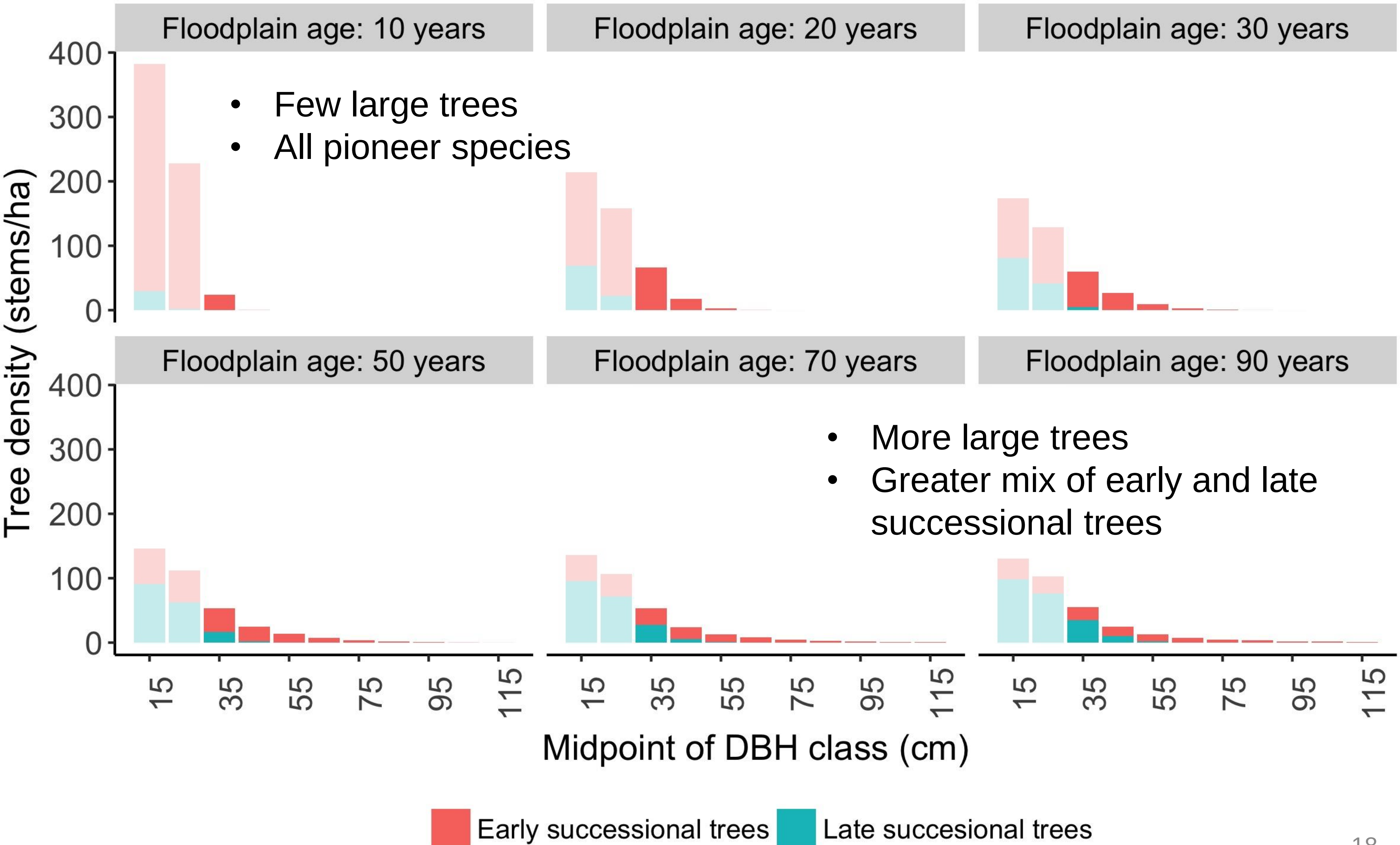
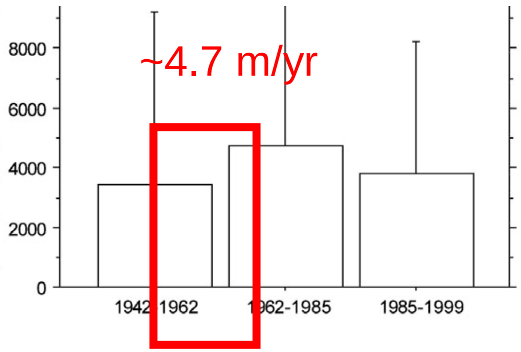


Predicting fractions of large wood (>30 cm dbh)

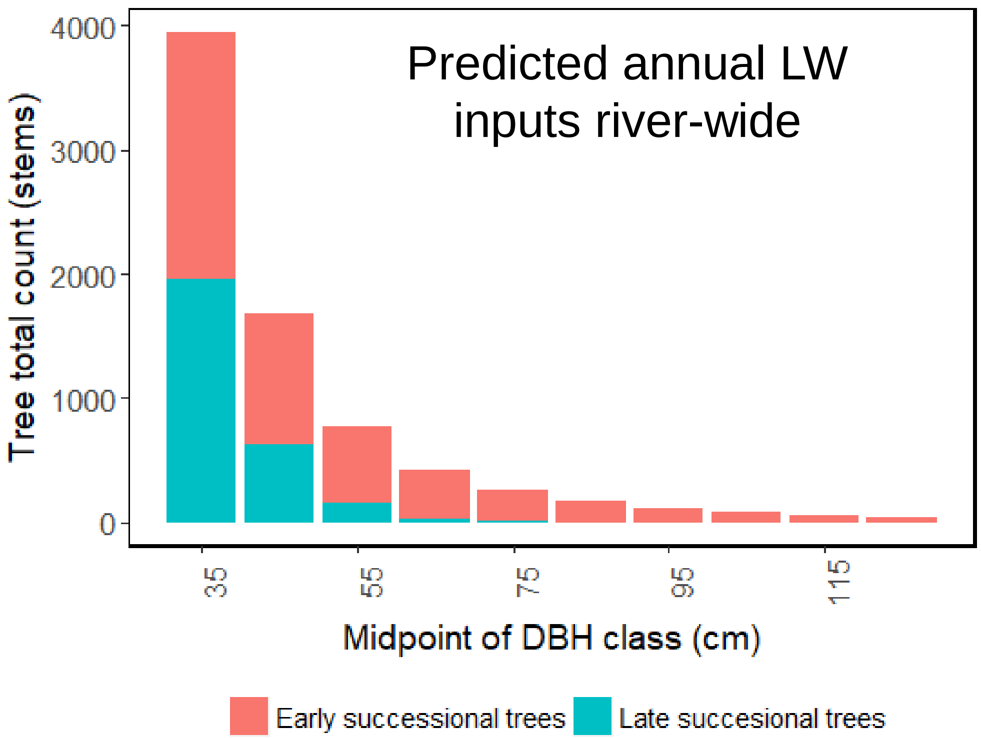


Large wood inputs for river management scenarios

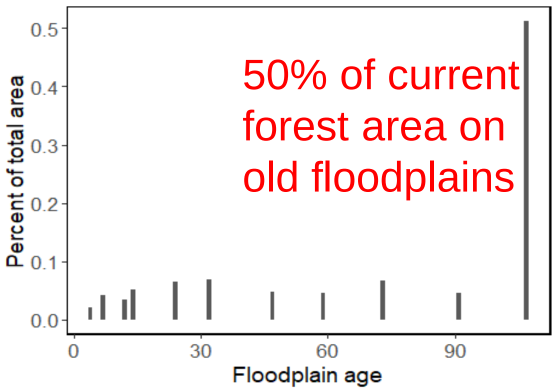
Current bank erosion rates



Micheli & Larsen (2010) RRA: 10.1002/rra.1360



Floodplain age distribution



- 7500 trees/yr based on current and historical erosion rates
- Largest trees are early successional (old cottonwood)
- Need to adjust rates for bank revetment, infrastructure, and patchy distribution of floodplain ages

Conclusions and applications

- Predict riparian forest dynamics using a simple probabilistic model
- Accounts for shifts in species composition and size structure over time
- Can be parameterized to other rivers using local inventory data
- Scenario development and quantitative targets for wildlife habitat
- Compare river management strategies, e.g., removing bank revetment, environmental flows

Thanks for your attention

Field work: J. Riddle, C. Swider, T. Hall, E. White (SUNY-ESF)

Statistical help: L. Zhang (SUNY-ESF)

Vegetation maps

- Nelson C., M. Carlson and R. Funes. 2008. Rapid Assessment Mapping in the Sacramento River Ecological Management Zone – Colusa to Red Bluff. Sacramento River Monitoring and Assessment Program. *Geographical Information Center, California State University, Chico.*
- Viers, J.H., A.K. Fremier, and R.A. Hutchinson. 2010. Predicting map error by modeling the Sacramento River floodplain. Proceedings from the 2010 *ESRI International User Conference*, San Diego, California. 21 pp.

Floodplain age map

- Greco, S.E., A.K. Fremier, E.W. Larsen, and R.E. Plant. 2007. A Tool for Tracking Floodplain Age Land Surface Patterns on a Large Meandering River with Applications for Ecological Planning and Restoration Design. *Landscape & Urban Planning* 81:354-373.

ESF UCSB The Nature Conservancy ESSA

RiversEdge West
RESTORE • CONNECT • INNOVATE

Defining Groundwater-Dependent Ecosystems and Assessing Critical Water Needs for their Foundational Plant Communities

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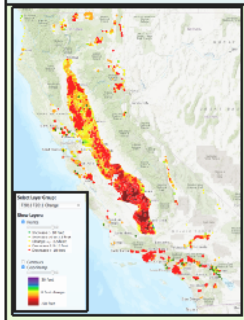
Department of Forest and Natural Resources Management, State University of New York, College of Environmental Science and Forestry, Syracuse, NY, USA

1. Threats to Groundwater-Dependent Ecosystems (GDEs)



In many water-limited regions, human water use in conjunction with increased climate variability threaten the sustainability of groundwater-

2. Which organi

Groundwater-dependent p classifications

- *Obligate* phreatophytes
  - Roots need constant contact water table and capillary fring
  - Poor drought tolerance
  - Springs, wetland and many ri communities
- *Facultative*, or proportional, user
  - Use a combination of ground and vadose zone water
  - Can switch water sources wh groundwater is not available
  - Physiological water-use adap

3. Identify key indic plant trait response

Groundwater Regime
- Depth to GW
- Flux and direction
- Seasonal variation
- QW quality

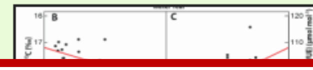
Pla Res
- Rooting
- Growth rate
- Morphologic adaptations
- Ecophysiology and stress tolerance
- Reproductive strategy

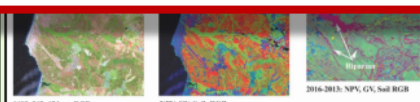
- Species composition and diversity
- Productivity and biomass
- Habitat structure
- New disturbance regimes
  - Fire freq. & severity
  - Wind and ice damage
  - Pest outbreaks

Guidelines for GW management

4. Approaches for quantifying groundwater change and plant water stress indicators (WSIs)

Groundwater well records
- Direct measure of GW dynamics
- Simple, inexpensive measures



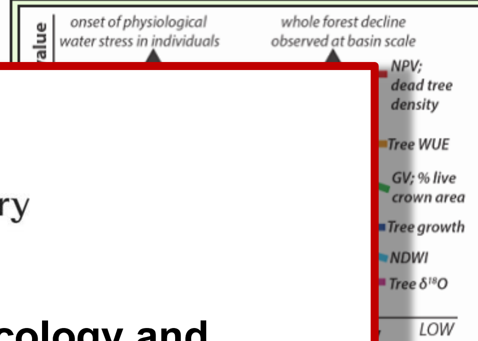


Negrón-Juárez et al., 2011.

Vegetation mortality in S. California, 2013 – 2016. D. Roberts et al., unpublished data, 2017

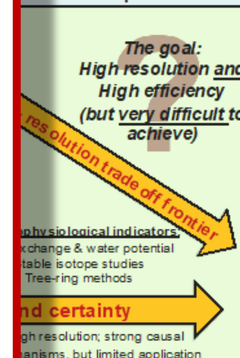
Remote sensing change detection
- Applied over large spatiotemporal scales
- Requires good correlation with groundwater change and veg response
- Common indices from long-term satellite data (e.g. NDVI and NDWI)
- Novel spectral mixing models from hyperspectral data (e.g., AVIRIS)
- Non-Photosynthetic Vegetation (NPV, proxy for dead plants)
- Greenness Vegetation Index (GV, proxy for photosynthetic activity)

5. Compare multiple WSIs: early warning signs ('canaries'), thresholds, and lagged responses



- Identify seasonal, annual and decadal signals
- Compare individual plants to forest stands to landscapes
- Evaluate interactions between water stress indicators

s between data data acquisition



eps forward

Emerging methodologies and increased data resolution are improving our ability to focus on individual plant species, including foundational and/or sensitive taxa that serve as early warning indicators of ecosystem impairment. Combining and cross-calibrating these approaches will provide insight into the full range of GDE response to environmental change, including increased climate variability and drought, human groundwater extraction, and flow regulation. In collaboration with project partners, we are analyzing GDE responses to water stress in semi-arid regions of the U.S. Southwest and southern Europe.

Project Partners and Funding Sources
- Michael Singer, Cardiff University
- Dar Roberts and Kelly Caylor, University of California at Santa Barbara
- The Nature Conservancy of California
- Funding: U.S. National Science Foundation and U.S. Strategic Environmental Research and Development Program (SERDP)

State University of New York
College of Environmental Science and Forestry

PhD Assistantship in Arid-land Riparian Ecology and Ecophysiology at SUNY-ESF

We are seeking a motivated graduate student with interests in riparian forest ecology, ecophysiology, dendroecology, and statistical analysis for a project investigating drought and its impact on riparian ecosystems in the Southwestern USA (Arizona and California). The position is at the State University of New York College of Environmental Science and Forestry (SUNY-ESF) in Syracuse, New York. The research project will assess the impacts of water limitation on riparian trees using tree-ring analysis, stable isotope methods, field surveys, and geospatial approaches. The position is part of an interdisciplinary collaboration with University of California at Santa Barbara and University of Cardiff, and is funded by the Strategic Environmental Research and Development Program (SERDP) of the US Department of Defense.

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