Dynamics of Coastal Forests: The UCSC Forest Ecology Research Plot

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http://ferp.ucsc.edu

https://ferp.ucsc.edu/research/ferp-data/ferp_publicr/

Goals

Why do long-term monitoring of forest dynamics?

How do we measure forest dynamics?

The UCSC Forest Ecology Research Plot (FERP)

a. How do we do it?
b. Spatial patterns in the forest and what they tell us
c. Size patterns in the forest and what they tell us
d. Change over time

Forest Phenology

Future of the FERP: fire and fungi

How to get and use FERP data

How do forests change? …and Why?

Composition
Composition
Diversity
Relative abundance

Structure
Biomass
Stature
Spatial pattern

Dynamics
Reproduction
Recruitment
Growth
Death

Ecosystem Services
Carbon storage
Hydrology
Recreation
Education

Species Interactions
Mammals
Birds
Herps
Fungi
Arthropods

Drivers of Change
Invasive plants
Emergent pests
Emergent pathogens
Fire
Climate change
Elevated CO_2
Recreation impact

How do we study forest dynamics?

Broad surveys with lots of small plots

- **USDA Forest Inventory & Analysis**
  - ⅛ acre plots (0.05 ha)
  - all US states and territories, 1 per 6,000 acres
  - trees ≥ 5 inches (12.7 cm) diameter
  - Subsampling of smaller vegetation

- **Continuous Forest Inventory**
  - ⅕ acre plots (0.08 ha)
  - global, often in managed forests
  - trees ≥ 5 inches (sometimes ≥ 1 in)
  - Subsampling of smaller vegetation

How do we study forest dynamics?

Detailed studies on fewer large plots

- **ForestGEO: Forest Global Earth Observatory**
  - Smithsonian Tropical Research Institute (coordinator)
  - 40 - 123 acre plots (16 - 50 ha)
  - global, fewer sites
  - trees ≥ 0.4 inches (1 cm) diameter
  - Subsampling of smaller vegetation

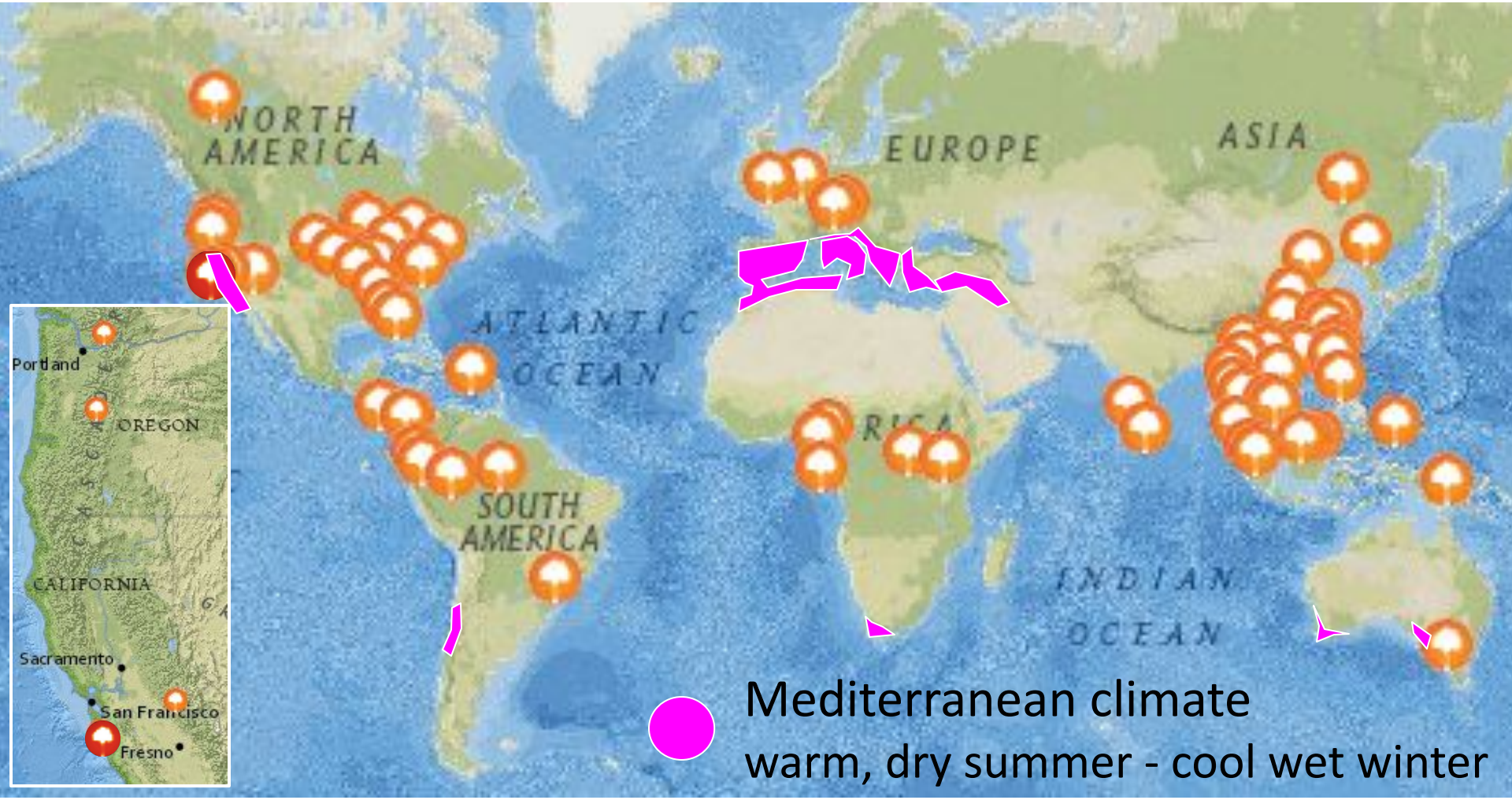
Trade-offs:

- Less extensive geographic coverage
- Much more information about dynamics (demographics)
- Much better understanding of spatial processes

ForestGEO

a worldwide network monitoring forests in an era of global change

78 Sites 29 Countries 7 Million Trees 12,000 Species



Davies, S.J. + many. 2021. ForestGEO: Understanding forest diversity and dynamics through a global observatory network. Biological Conservation 253: https://doi.org/10.1016/j.biocon.2020.108907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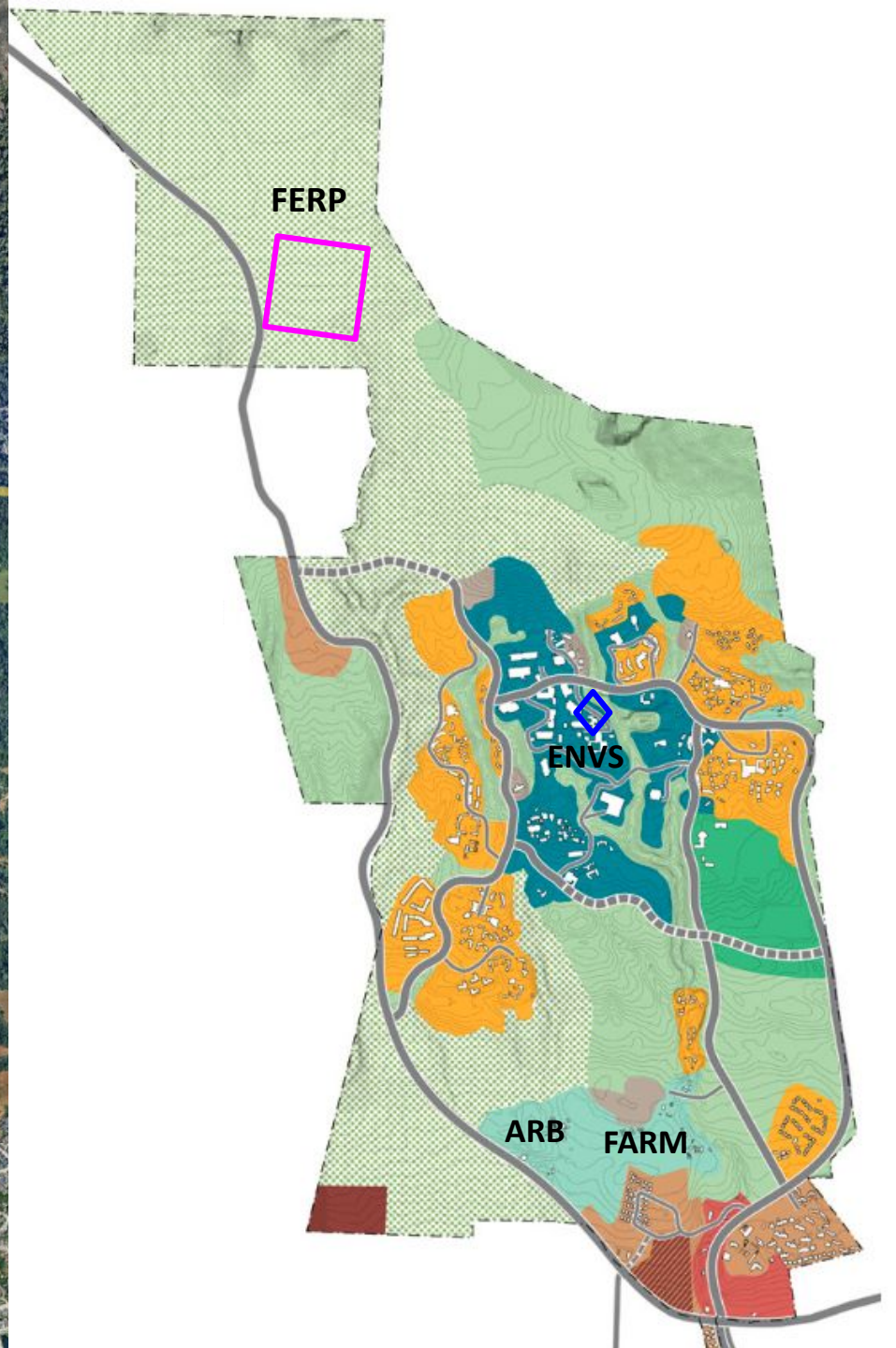
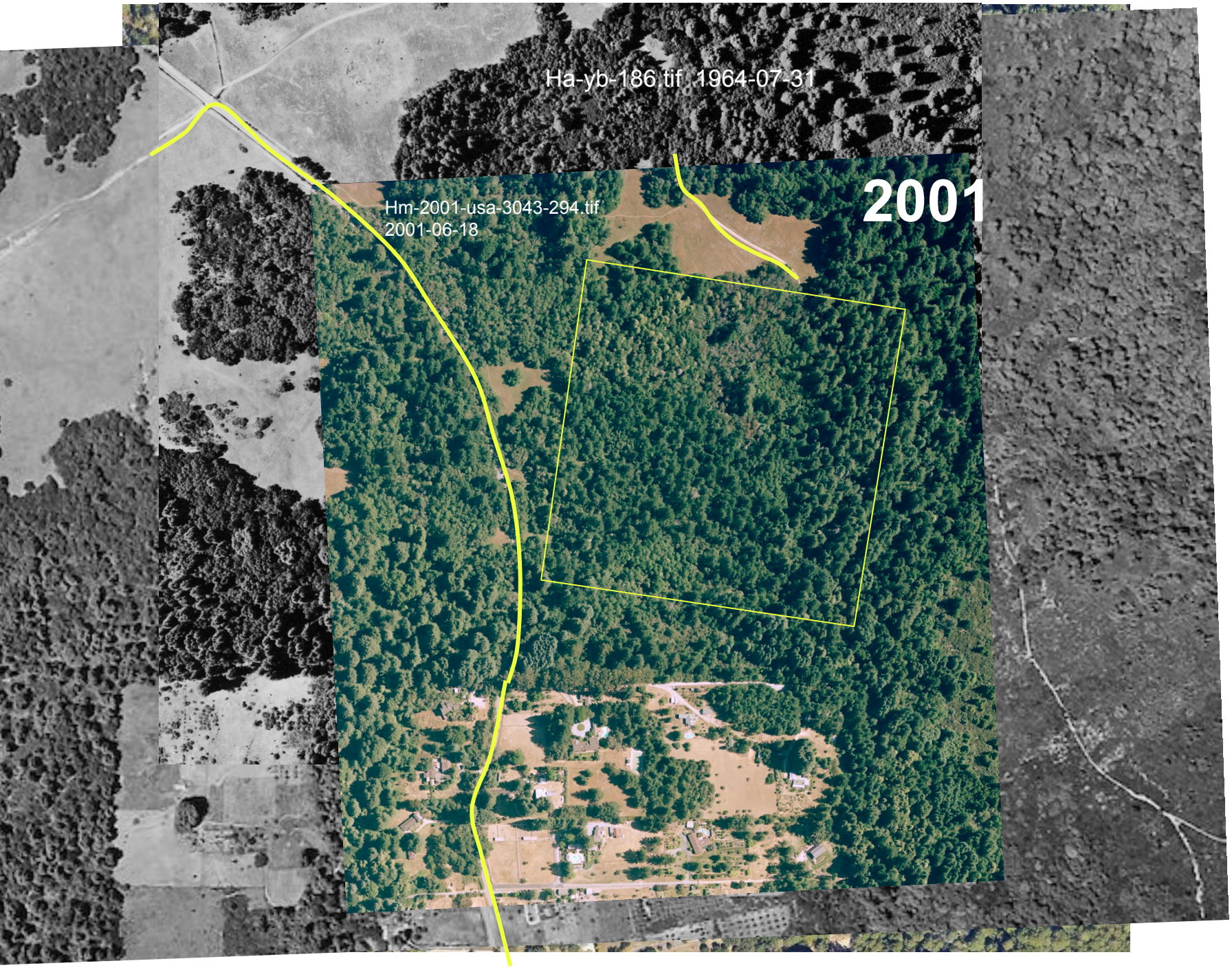



2022
FERP_NW
FERP_NE
FERP_SW
FERP_SE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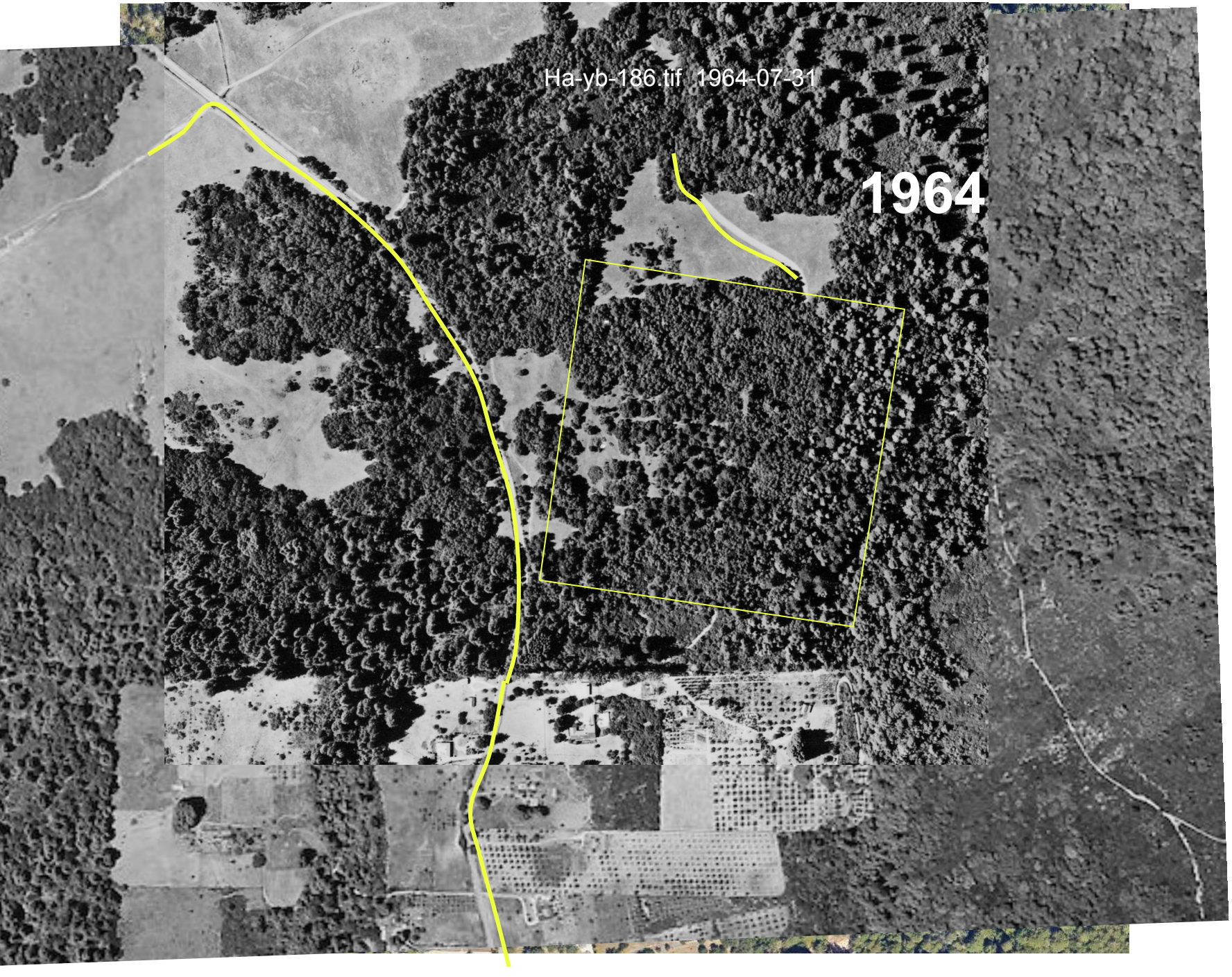
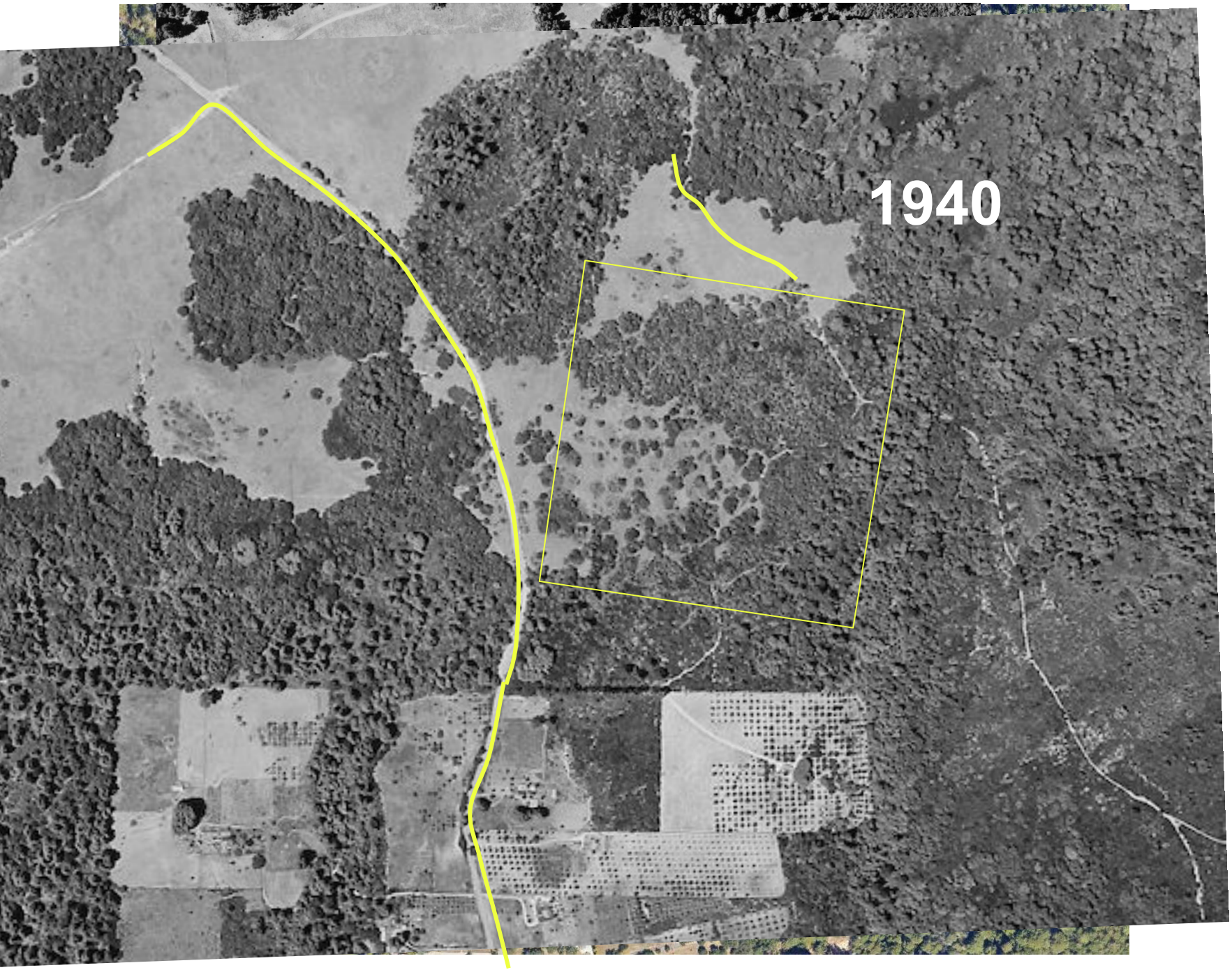
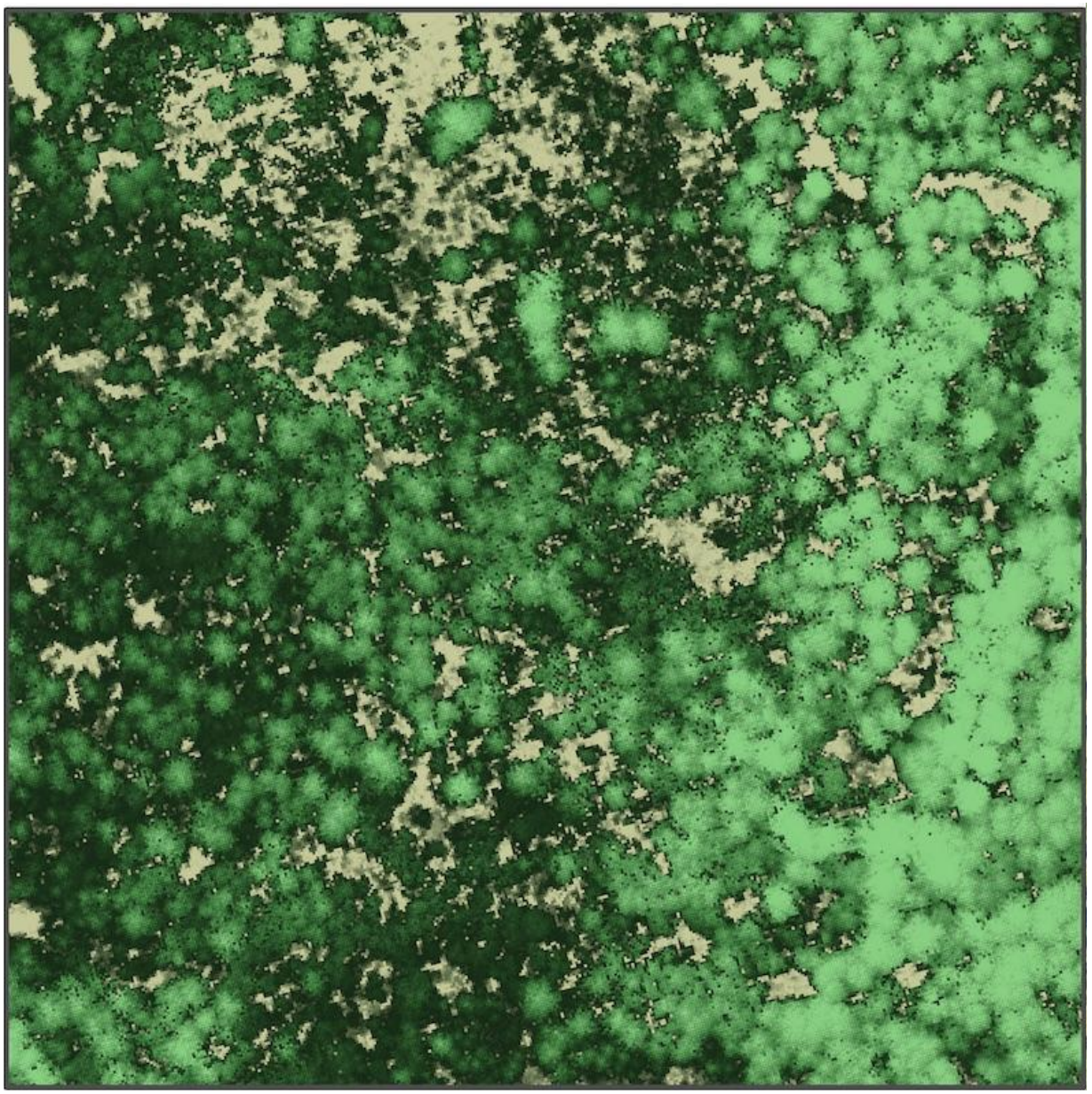
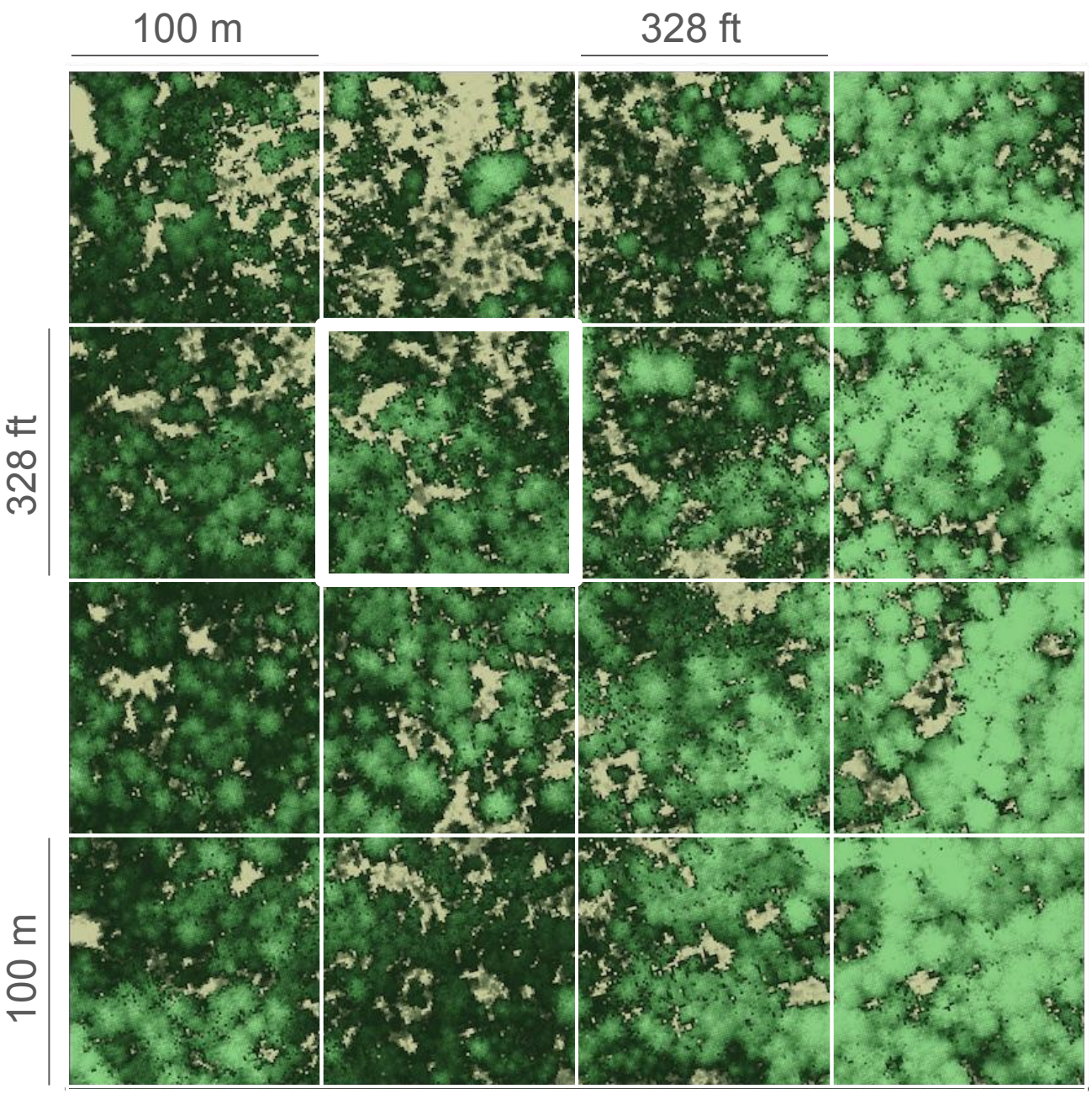
2001
Hm-2001-usa-3043-294.tif
2001-06-18


Ha-yb-186.tif 1964-07-31
1964


1940



LiDAR



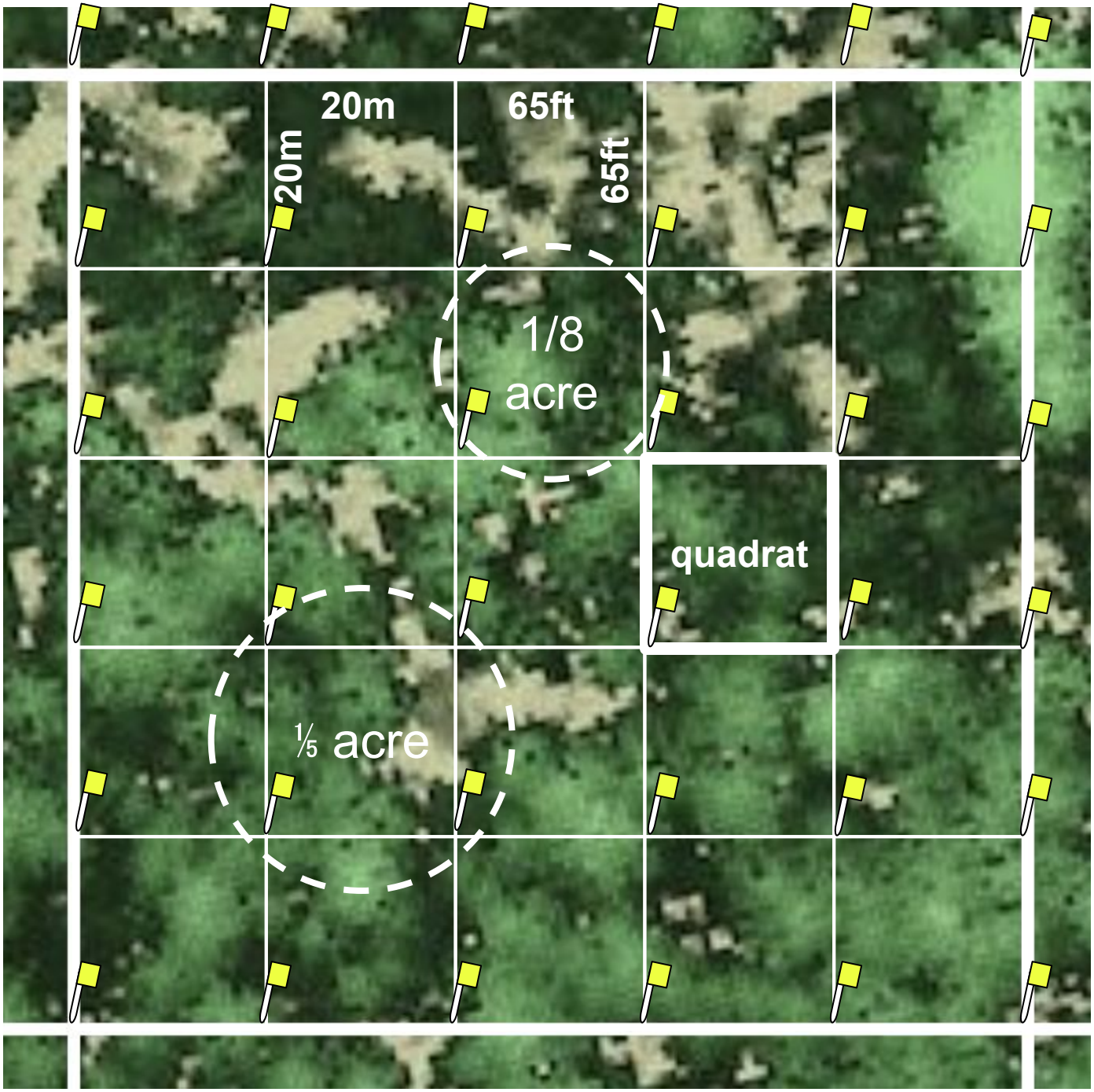
16 ha
39.5 acres

FIA =
⅛ acre

CFI =
⅕ acre

quadrat =
1/10 acre
= 0.04 ha

FERP =
400
20x20-m
quadrats
= 16 ha
= 39.5 ac




Redwood forest

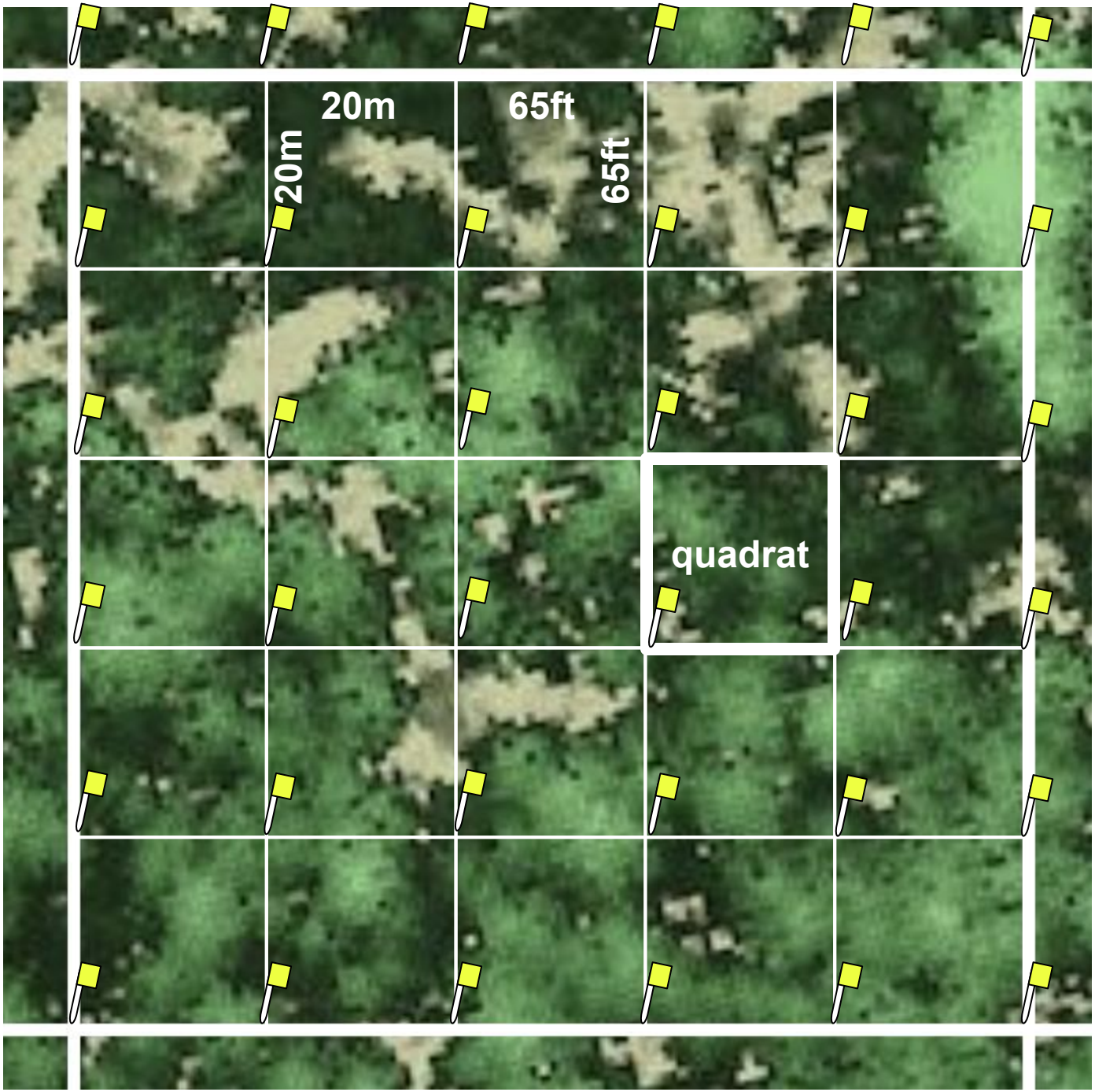

Douglas-fir dominant


Mixed-evergreen forest


Forest gap formation


Shrub-dominated gaps


Dense post-disturbance saplings


20m
65ft
20m
65ft
quadrat

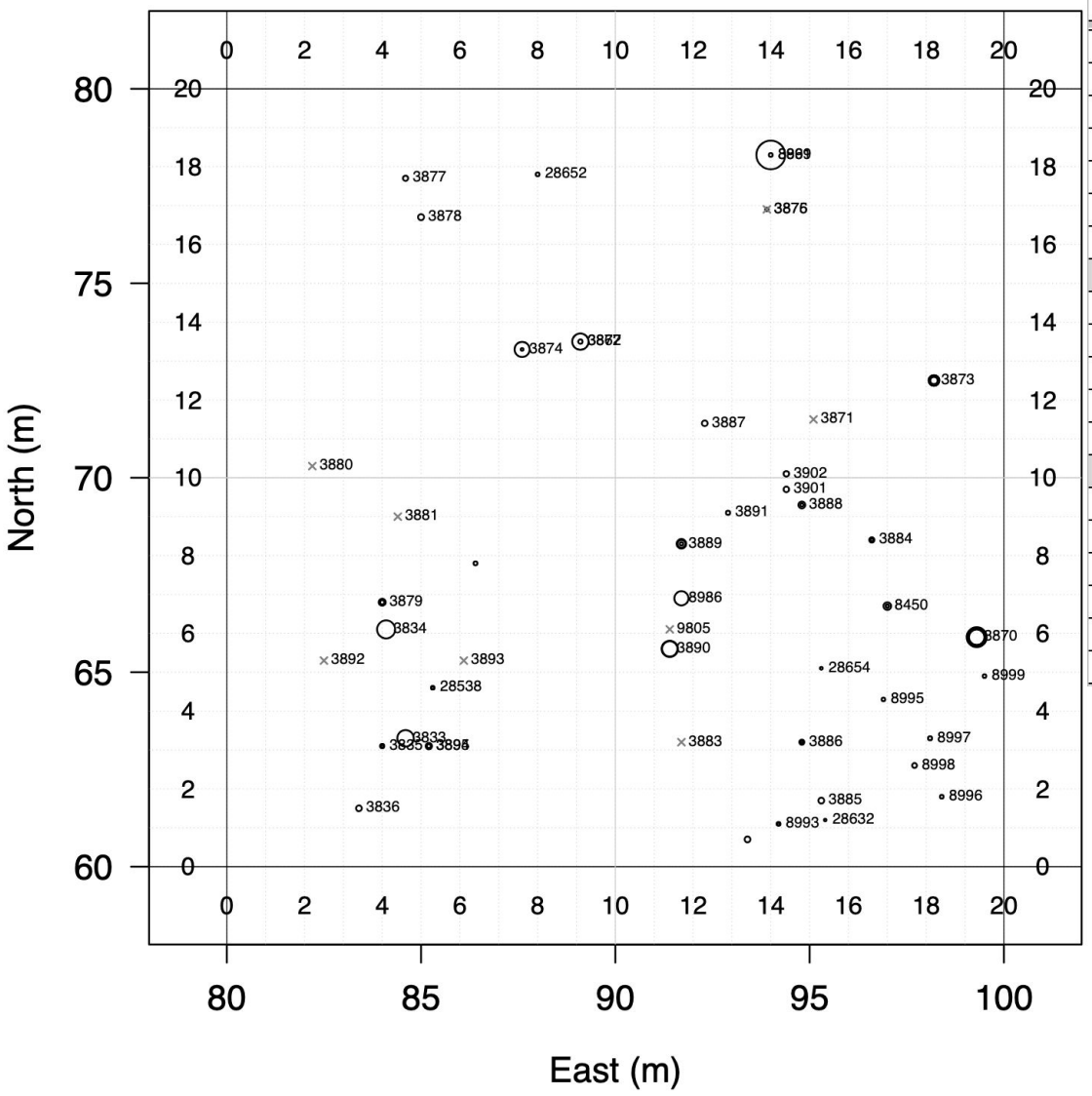
SUUNTO


GENERAL
mm
16 ths

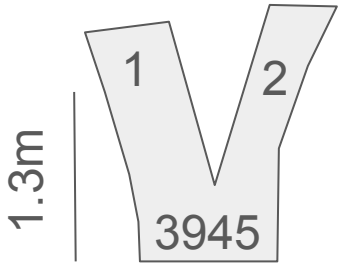

UCSC-ERP
13380


UCSC-ERP
13380

FERP4 E080_N060



quadrat	Em	Nm	tag	stem	code6	dbh4mm	status4	date4
E080_N060	3.4	1.5	3836	1	QUERPA	65	L	2022-02-12
E080_N060	9.1	13.5	3867	1	ARBUME		DS	2022-02-12
E080_N060	14	18.3	3869	1	PSEUME	1250	L	2022-02-12
E080_N060	19.3	5.9	3870	1	ARBUME	660	L	2022-02-12
E080_N060	19.3	5.9	3870	2	ARBUME	556	L	2022-02-12
E080_N060	19.3	5.9	3870	3	ARBUME	585	L	2022-02-12
E080_N060	19.3	5.9	3870	4	ARBUME	410	L	2022-02-12
E080_N060	15.1	11.5	3871	1	LITHDE		DF	
E080_N060	9.1	13.5	3872	1	TOXIDI		DF	2022-02-12
E080_N060	18.2	12.5	3873	1	QUERPA	191	L	2022-02-12
E080_N060	18.2	12.5	3873	2	QUERPA	108	L	2022-02-12
E080_N060	18.2	12.5	3873	3	QUERPA	185	L	2022-02-12
E080_N060	7.6	13.3	3874	1	ARBUME		DF	2022-02-12
E080_N060	13.9	16.9	3875	1	ARBUME			
E080_N060	13.9	16.9	3876	1	HEDEHE	21	L	2022-02-12
E080_N060	4.6	17.7	3877	1	QUERPA	74	L	2022-02-12
E080_N060	5	16.7	3878	1	QUERAG	79	L	2022-02-12
E080_N060	4	6.8	3879	1	QUERPA	88	L	2022-02-12
E080_N060	4	6.8	3879	2	QUERPA	80	L	2022-02-12
E080_N060	4	6.8	3879	3	QUERPA	37	L	2022-02-12



Map, measure, identify, and tag every stem ≥ 1cm DSH (diameter at standard height)

Student powered!

532 Interns

59 Student crew leaders

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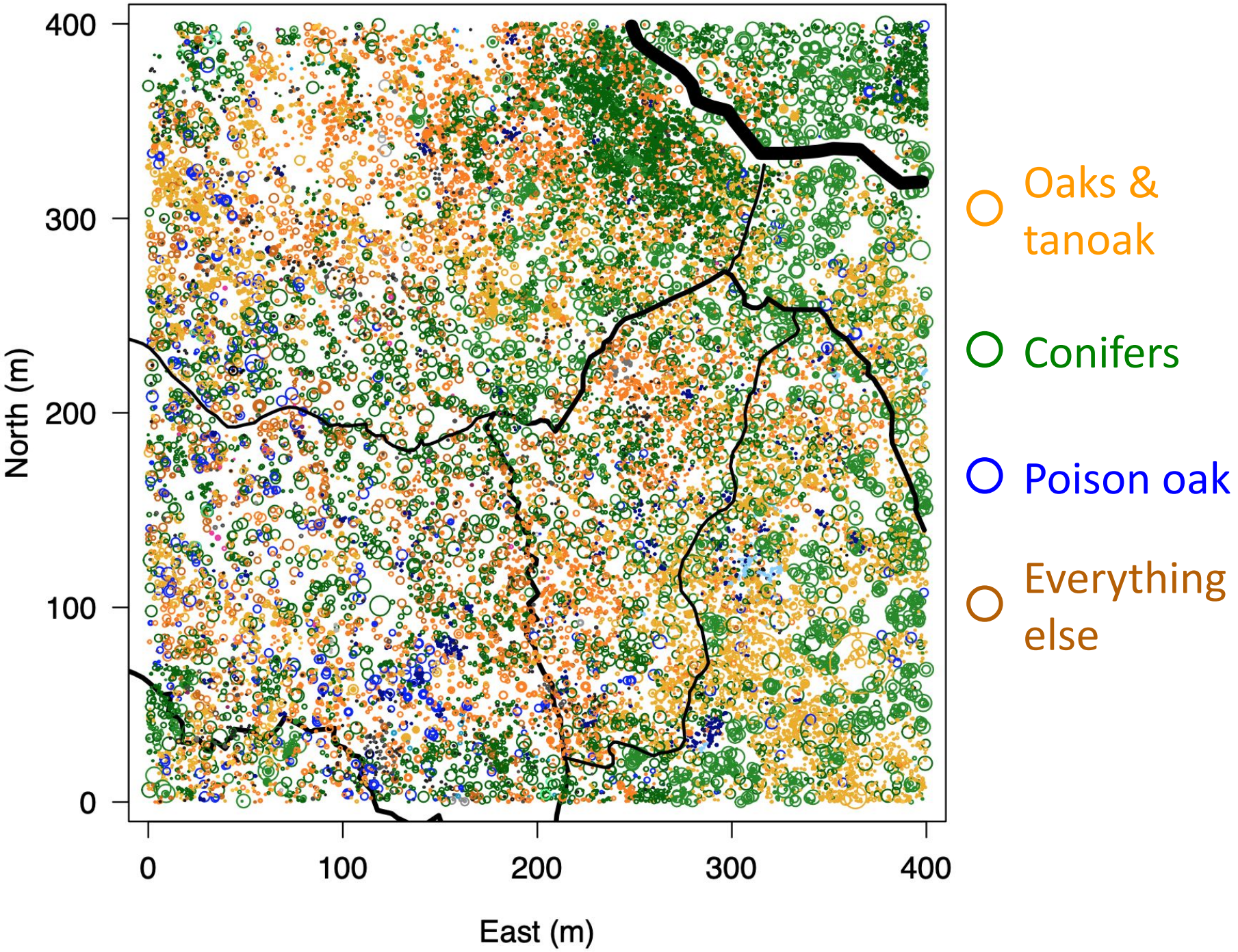
Alex Jones: Campus Natural Reserve Manager


400
300
200
100
0
North (m)
0
100
200
300
400
East (m)
Oaks & tanoak
Conifers
Poison oak
Everything else

UCSC Forest Ecology Research Plot

- Map, tag, identify, measure
- 16 ha (~40 acres)
- 31,210 trees, shrubs, lianas
- 51,022 stems (≥1 cm)
- 34 species, 18 families
- 2007, 2012,2013-2016,2017-20,2022-

Species	Individuals		Basal Area	
	#	%	m^2	%
Douglas-fir	7308	29.3	357.4	32.62
Tanoak	6314	25.3	36.9	3.36
Shreeve's oak	4747	19.0	35.7	3.25
Coast redwood	2015	8.1	565.8	51.65
Coast live oak	1242	4.6	32.6	2.97
Poison oak	732	2.9	0.2	0.01
Pacific madrone	415	1.7	57.9	5.28

<u>Seven species</u>

91% of individuals

99% of basal area

Trees of the UCSC FERP

Scientific Name	Family	Common Name	Origin	Code6
Ilex aquifolium	Aquifoliaceae	English holly	Introduced	ILEXAQ
Sequoia sempervirens	Cupressaceae	Coast redwood	Native	SEQUSE
Arbutus menziesii	Ericaceae	Pacific madrone	Native	ARBUME
Notholithocarpus densiflorus	Fagaceae	Tanoak	Native	LITHDE
Quercus agrifolia	Fagaceae	Coast live oak	Native	QUERAG
Quercus parvula var. *shrevei*	Fagaceae	Shreve's oak	Native	QUERPA
Umbellularia californica	Lauraceae	California bay	Native	UMBECA
Eucalyptus globulus	Myrtaceae	Blue gum	Introduced	EUCAGL
Pinus attenuata	Pinaceae	Knobcone pine	Native	PINUAT
Pinus ponderosa var. *pacifica*	Pinaceae	Pacific ponderosa pine	Native	PINUPO
Pseudotsuga menziesii	Pinaceae	Douglas fir	Native	PSEUME
Eriobotrya japonica	Rosaceae	Loquat	Introduced	ERIOJA
Acer macrophyllum	Sapindaceae	Bigleaf maple	Native	ACERMA

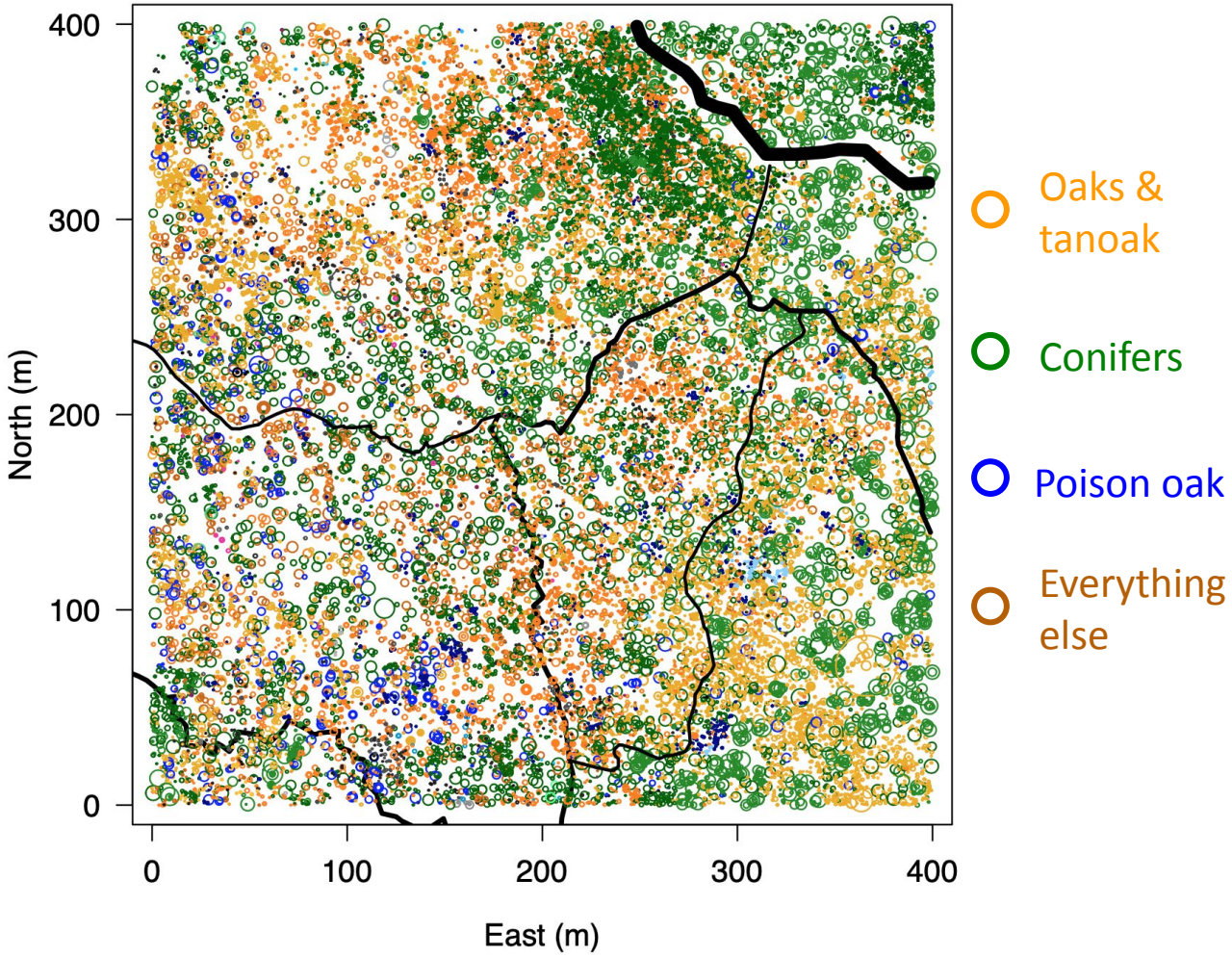
Shrubs of the UCSC FERP

Scientific Name	Family	Common Name	Origin	Code6
Baccharis pilularis	Asteraceae	Coyote brush	Native	BACCPI
Corylus cornuta subsp. *californica*	Betulaceae	Beaked hazelnut	Native	CORYCO
Arctostaphylos andersonii	Ericaceae	Santa Cruz manzanita	Native	ARCTAN
Arctostaphylos crustacea subsp. *crinita*	Ericaceae	Brittle leaf manzanita	Native	ARCTCR
Rhododendron occidentale	Ericaceae	Western azalea	Native	RHODOC
Vaccinium ovatum	Ericaceae	Evergreen huckleberry	Native	VACCOV
Ribes divaricatum	Grossulariaceae	Spreading gooseberry	Native	RIBEDI
Morella californica	Myricaceae	California wax myrtle	Native	MORECA
Ceanothus thyrsiflorus	Rhamnaceae	Blueblossom	Native	CEANTH
Frangula californica	Rhamnaceae	California coffeeberry	Native	RHAMCA
Adenostoma fasciculatum	Rosaceae	Chamise	Native	ADENFA
Cotoneaster franchetii	Rosaceae	Franchet cotoneaster	Introduced	COTOFR
Cotoneaster pannosus	Rosaceae	Woolly cotoneaster	Introduced	COTOPA
Crataegus monogyna	Rosaceae	One-seed hawthorn	Introduced	CRATMO
Heteromeles arbutifolia	Rosaceae	Toyon	Native	HETEAR
Pyracantha angustifolia	Rosaceae	Firethorn	Introduced	PYRAAN
Salix lasiandra	Salicaceae	Pacific willow	Native	SALILA
Sambucus caerulea	Vibernaceae	Blue elderberry	Native	SAMBNI

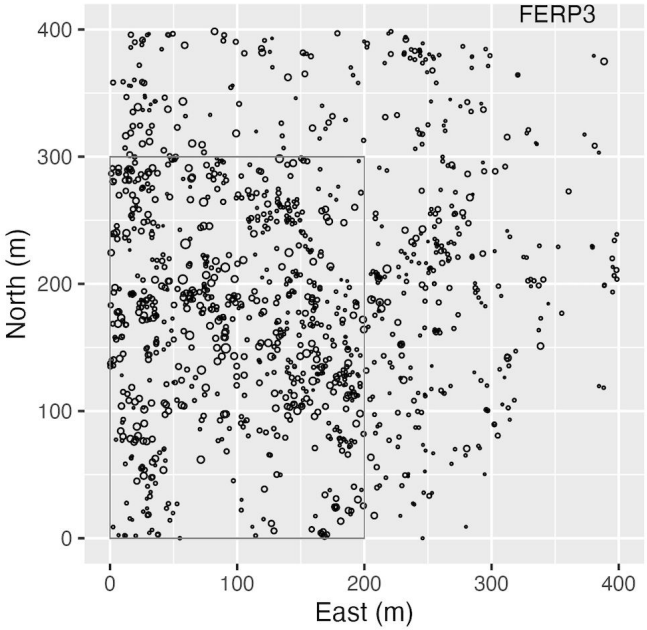
Lianas (woody vines) of the UCSC FERP

Scientific Name	Family	Common Name	Origin	Code6
Toxicodendron diversilobum	Anacardiaceae	Poison oak	Native	TOXIDI
Hedera helix	Araliaceae	English ivy	Introduced	HEDEHE
Lonicera hispidula	Caprifoliaceae	Pink honeysuckle	Native	LONIHI

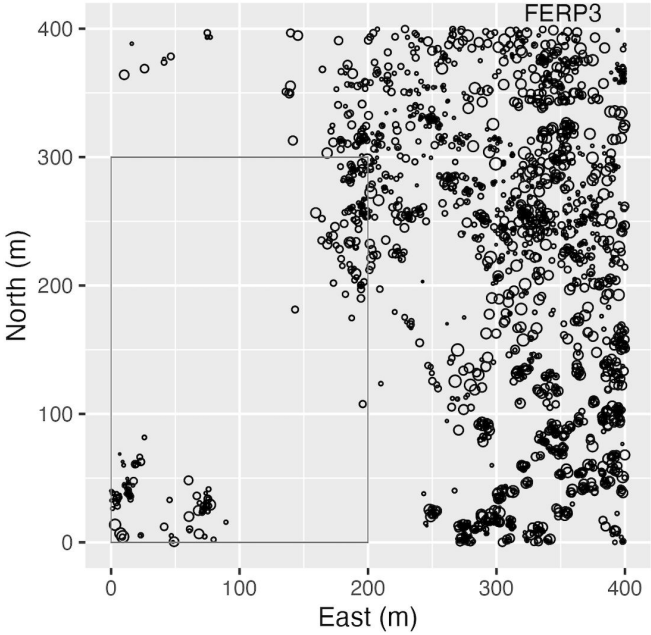
Forest composition across space



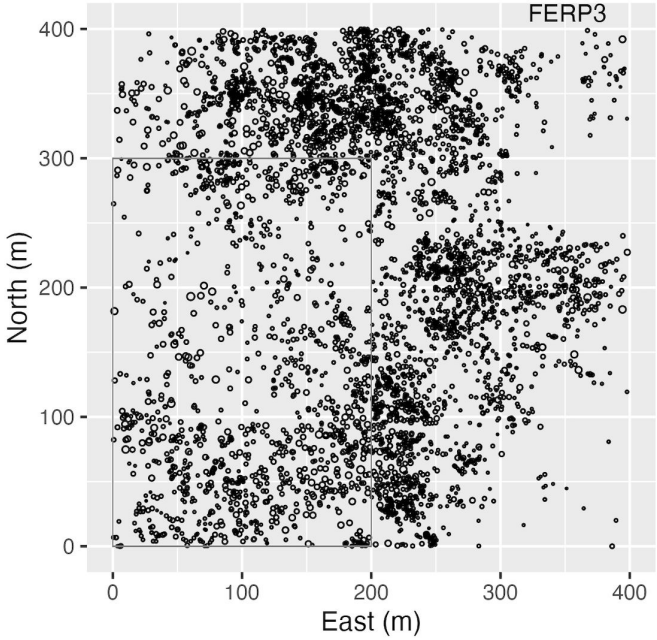
Coast live oak



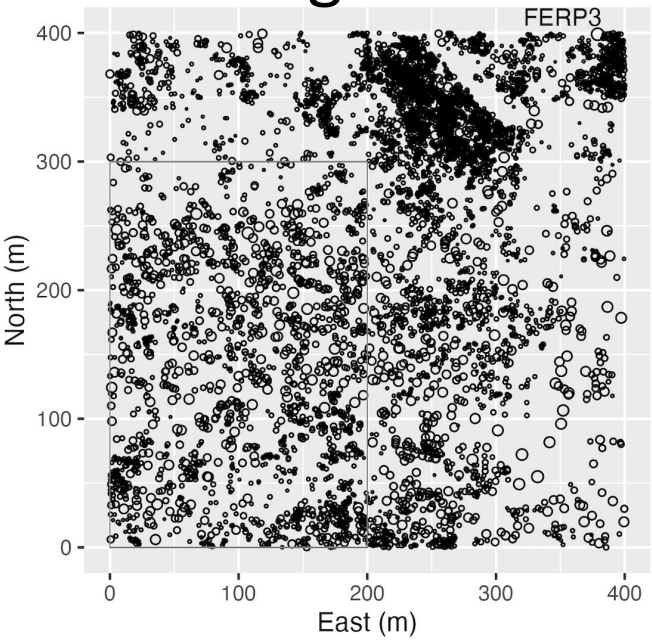
Coast Redwood



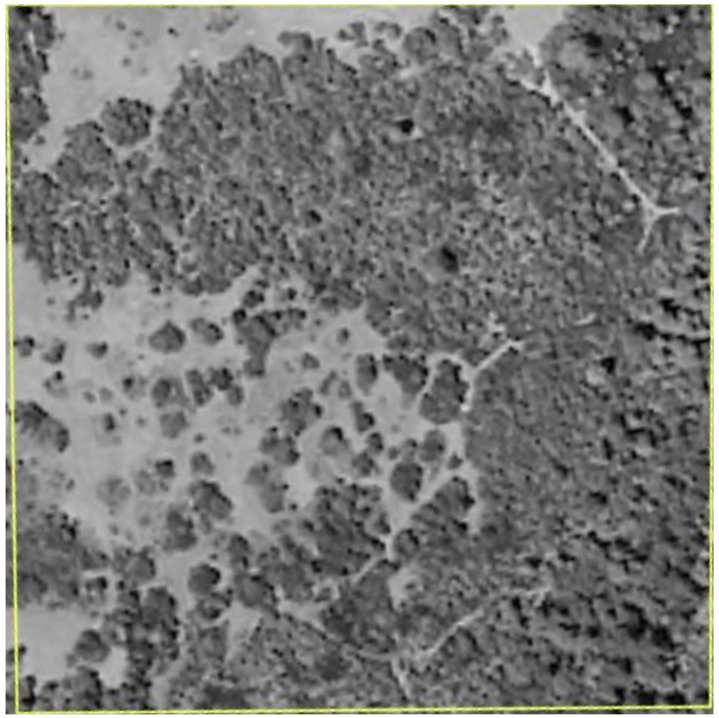
Shreve's oak



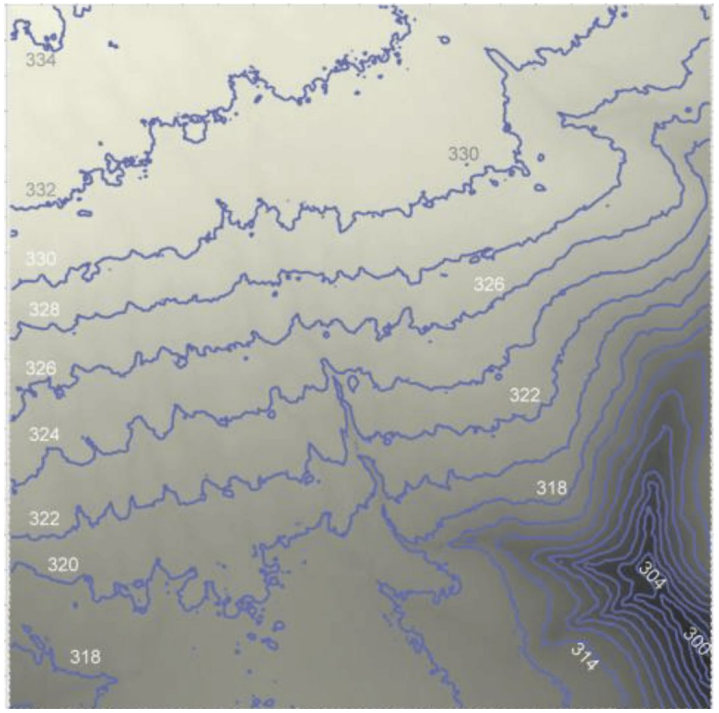
Douglas-fir



What drives broad spatial patterns?



History



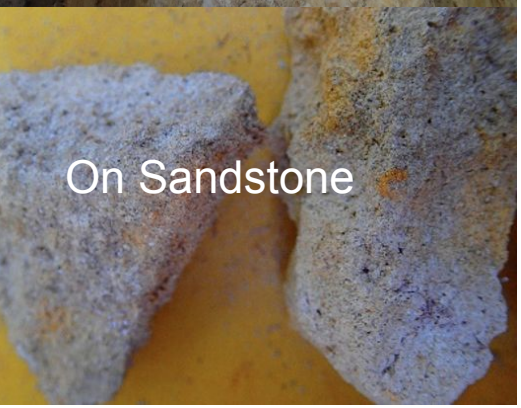
Environment

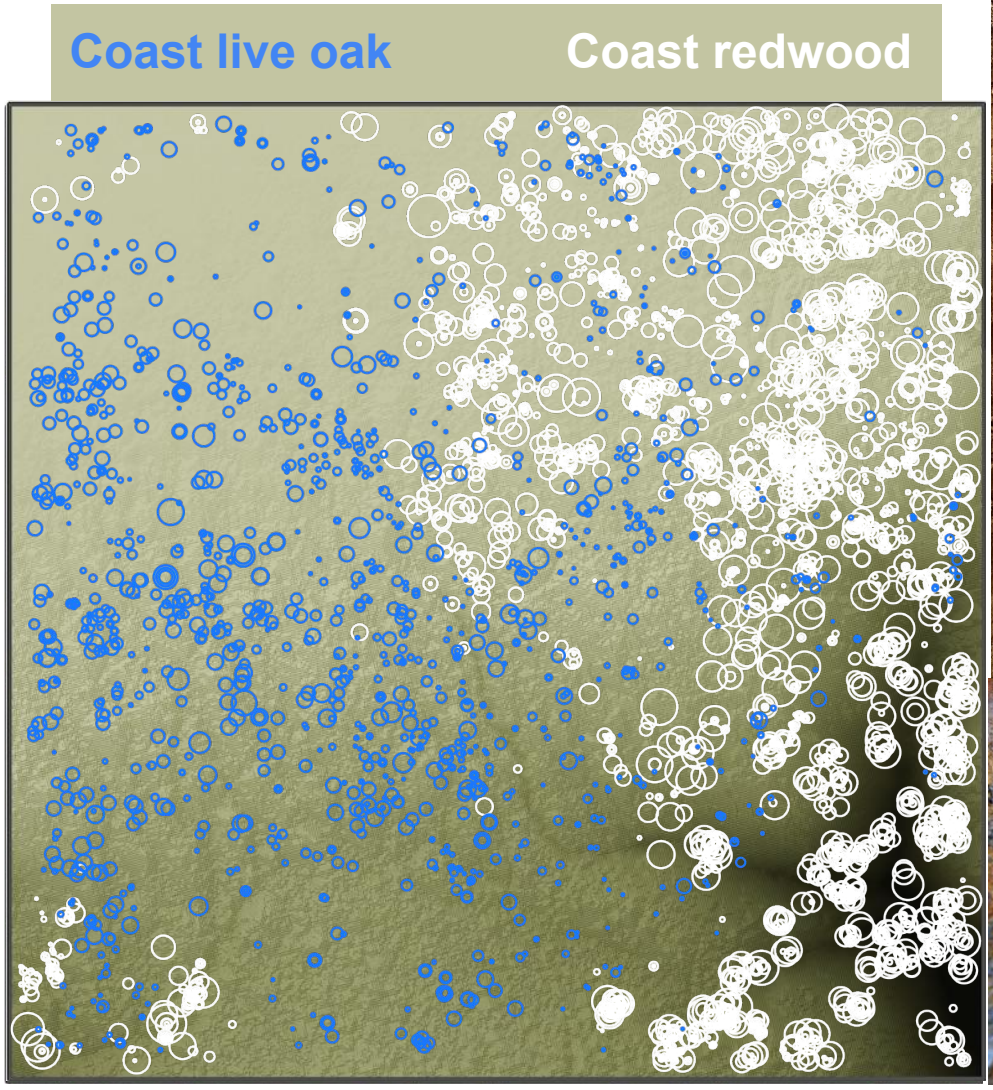
History of the FERP landscape

- Home of Awaswas-speaking Uypi Tribe for ~10,000 years.
- Land is on unceded territory; The Amah Mutsun Tribal Band, comprising the descendants of indigenous people taken to Missions Santa Cruz and San Juan Bautista during the Spanish colonization of the Central Coast, is today working hard to restore traditional stewardship practices on these lands and heal from historical trauma. (Amah Mutsun Land Trust)
- 1840s' Mexican land grant to Pedro Sainsevain called Rancho Cañada del Rincón en el Río San Lorenzo.
- Purchased by Henry Cowell in 1865 as part of the 2600-ha Cowell Ranch.
  - Marble quarries, lime kilns, cattle ranching, and logging.
  - Forest was clear-cut to fuel the kilns, which were in use until 1920.
  - Largely undisturbed since the 1930s; some trees date to early 20th century.
  - Active management of the ranch ceased in 1946.
  - Transferred to create UC Santa Cruz campus in 1961.
- Low-intensity wildfire on parts of the eastern extent of the FERP in 1964.

Soils

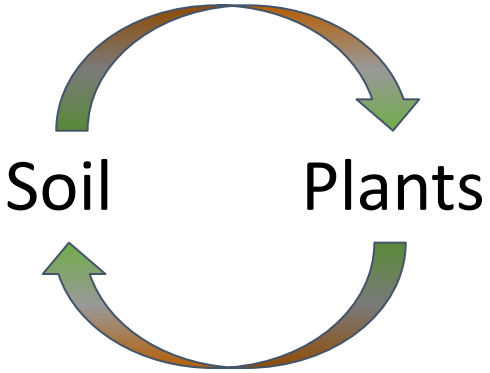

Sandy loam
70% sand
13% clay
Mollisol

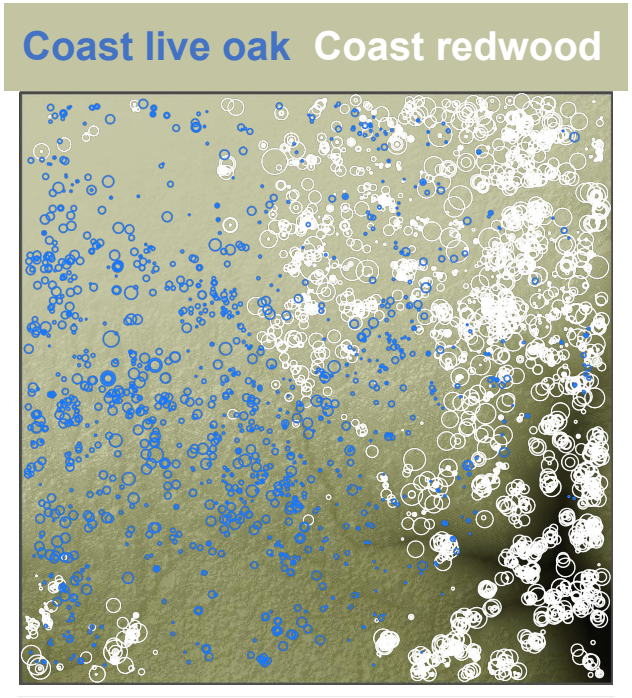

On Sandstone

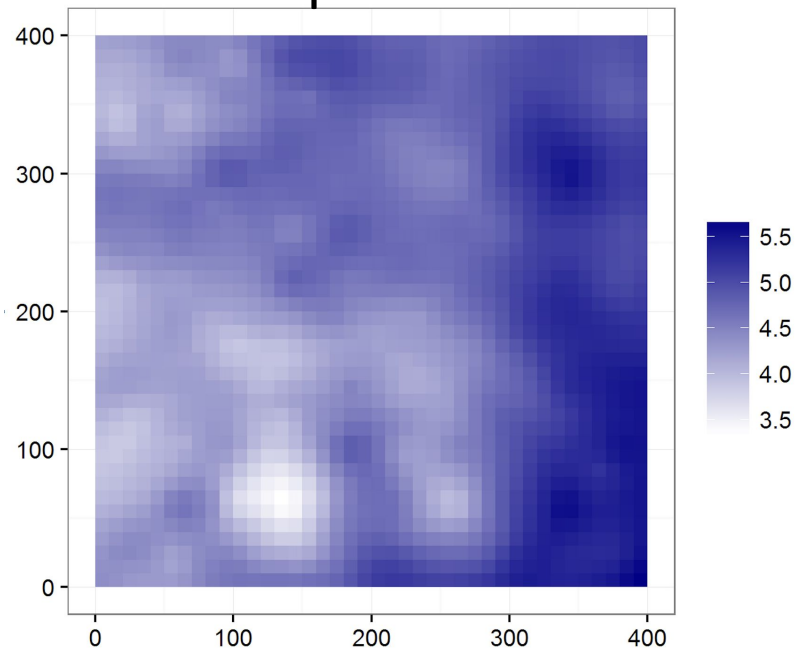

Coast live oak
Coast redwood

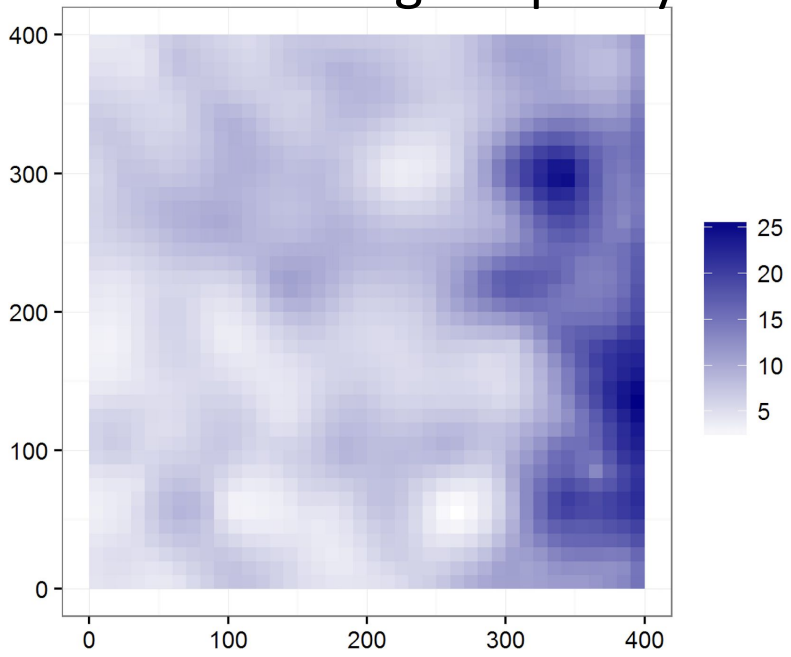

Sandy loam
65% sand
13% clay
Ultisol


On Schist

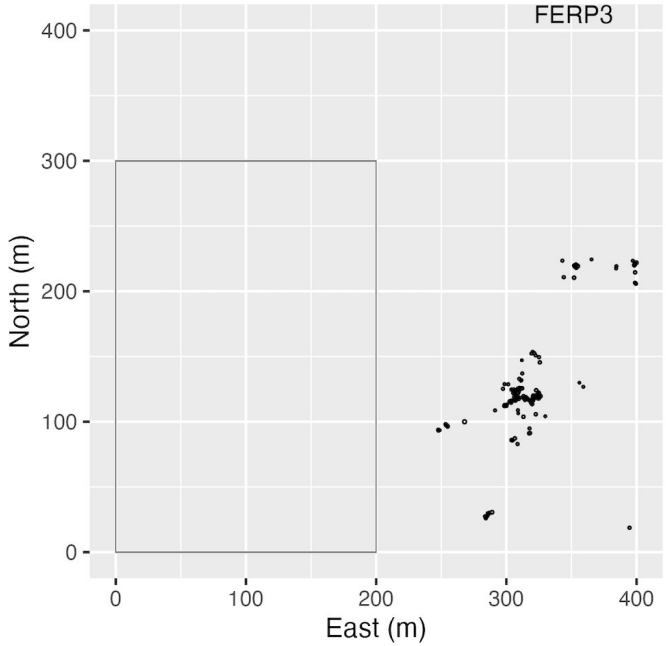

Soil
Plants


Coast live oak
Coast redwood

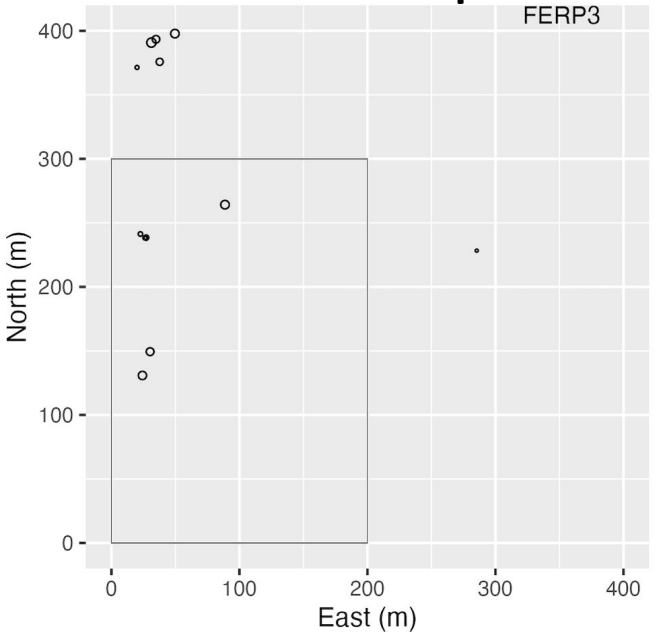

pH
400
300
200
100
0
0
100
200
300
400
5.5
5.0
4.5
4.0
3.5


Cation Exchange Capacity
400
300
200
100
0
0
100
200
300
400
25
20
15
10
5

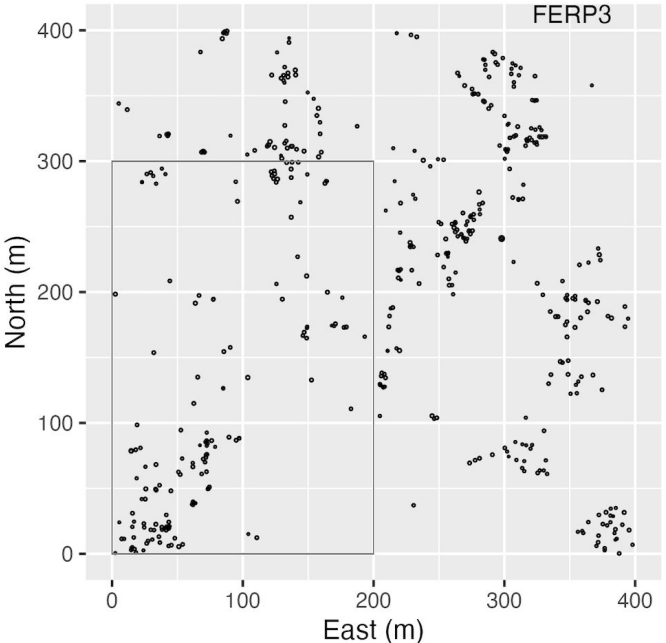
Western azalea



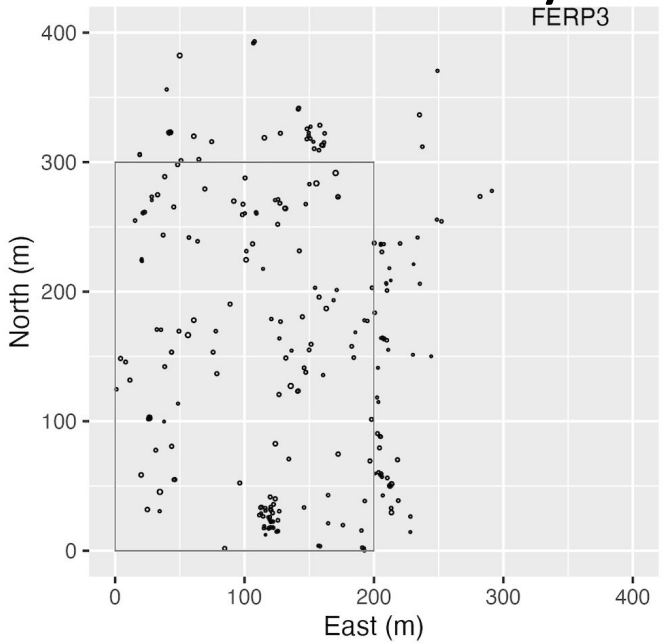
Ponderosa pine



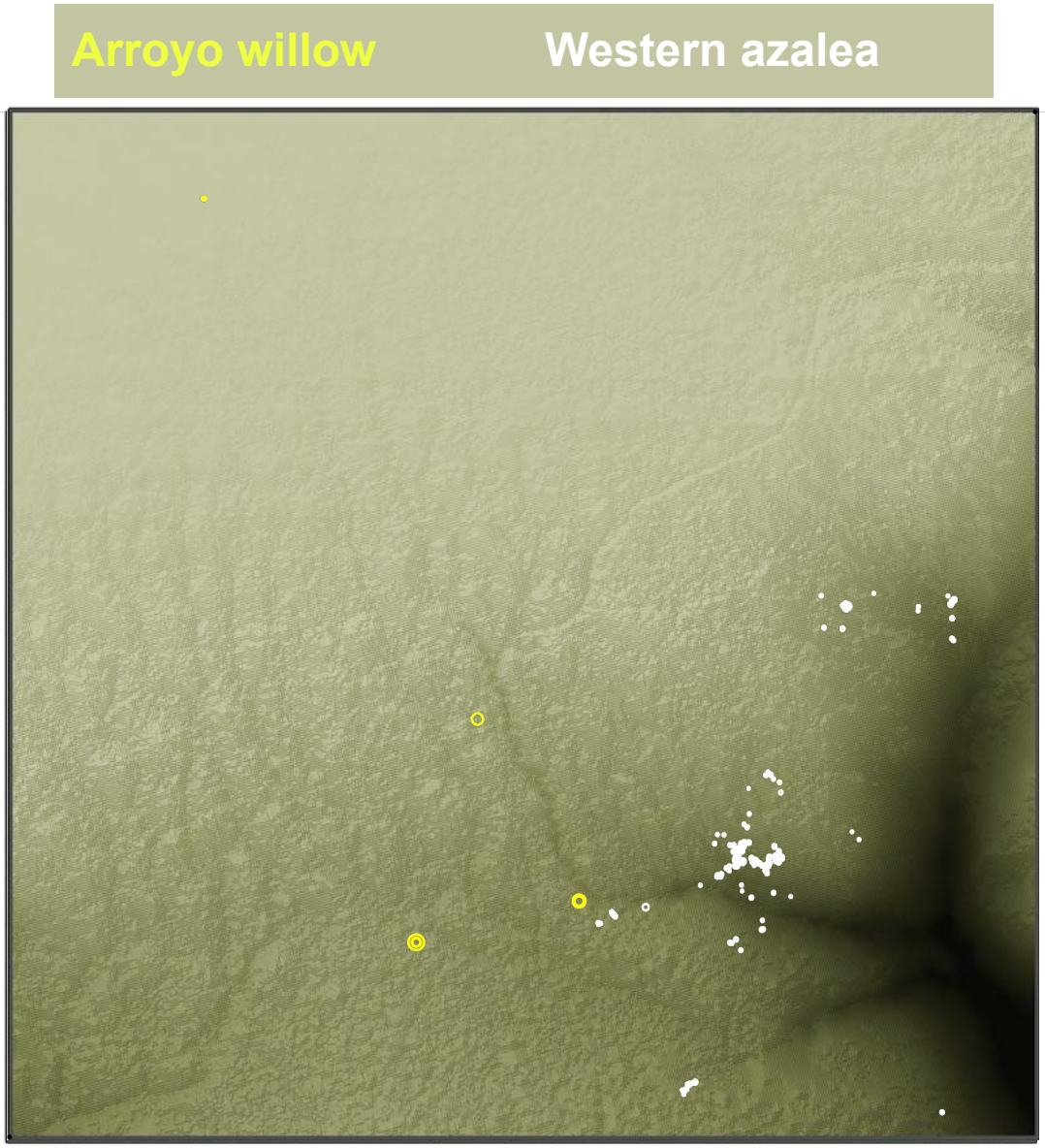
CA Hazelnut



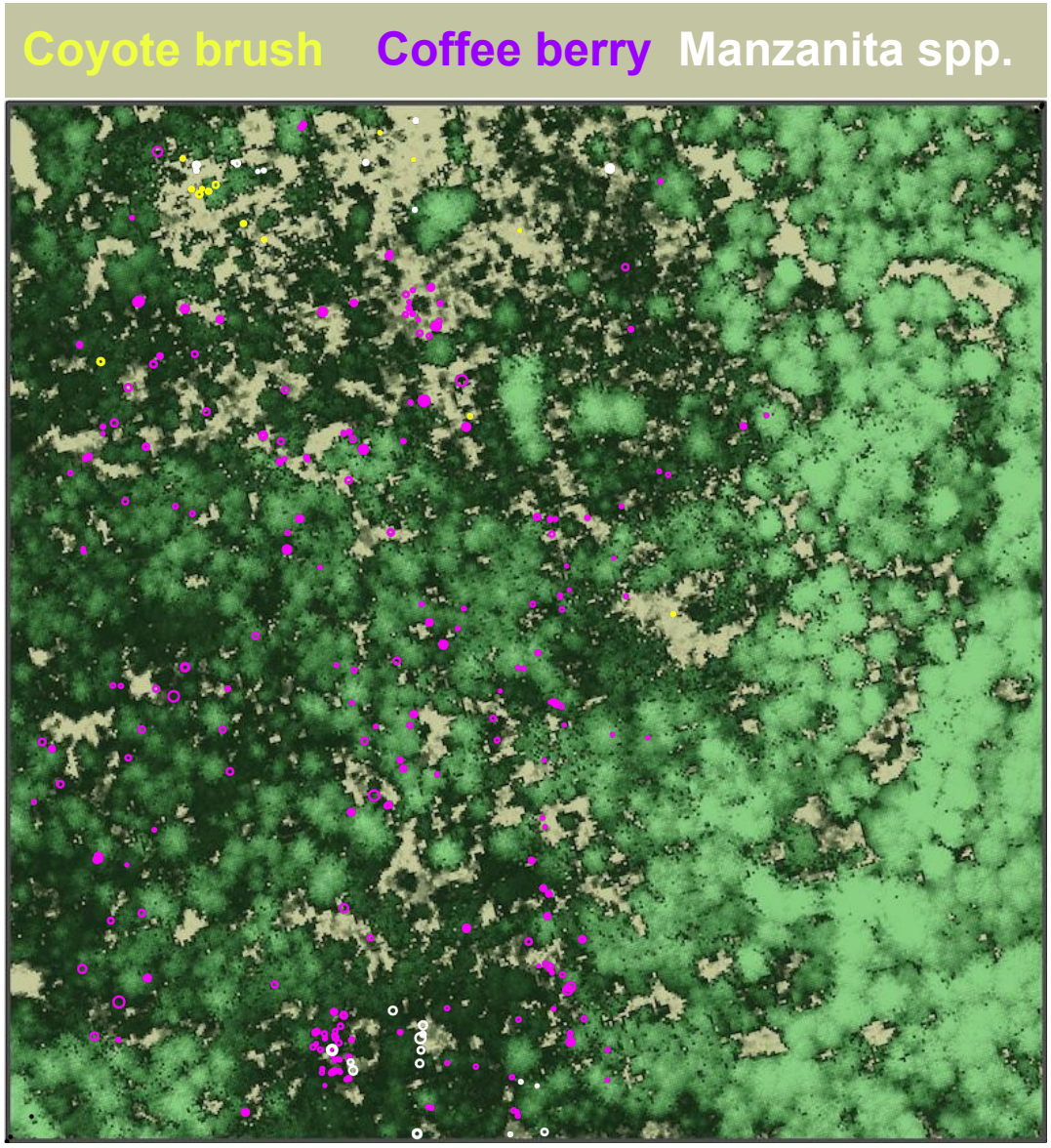
Coffee berry



Moisture



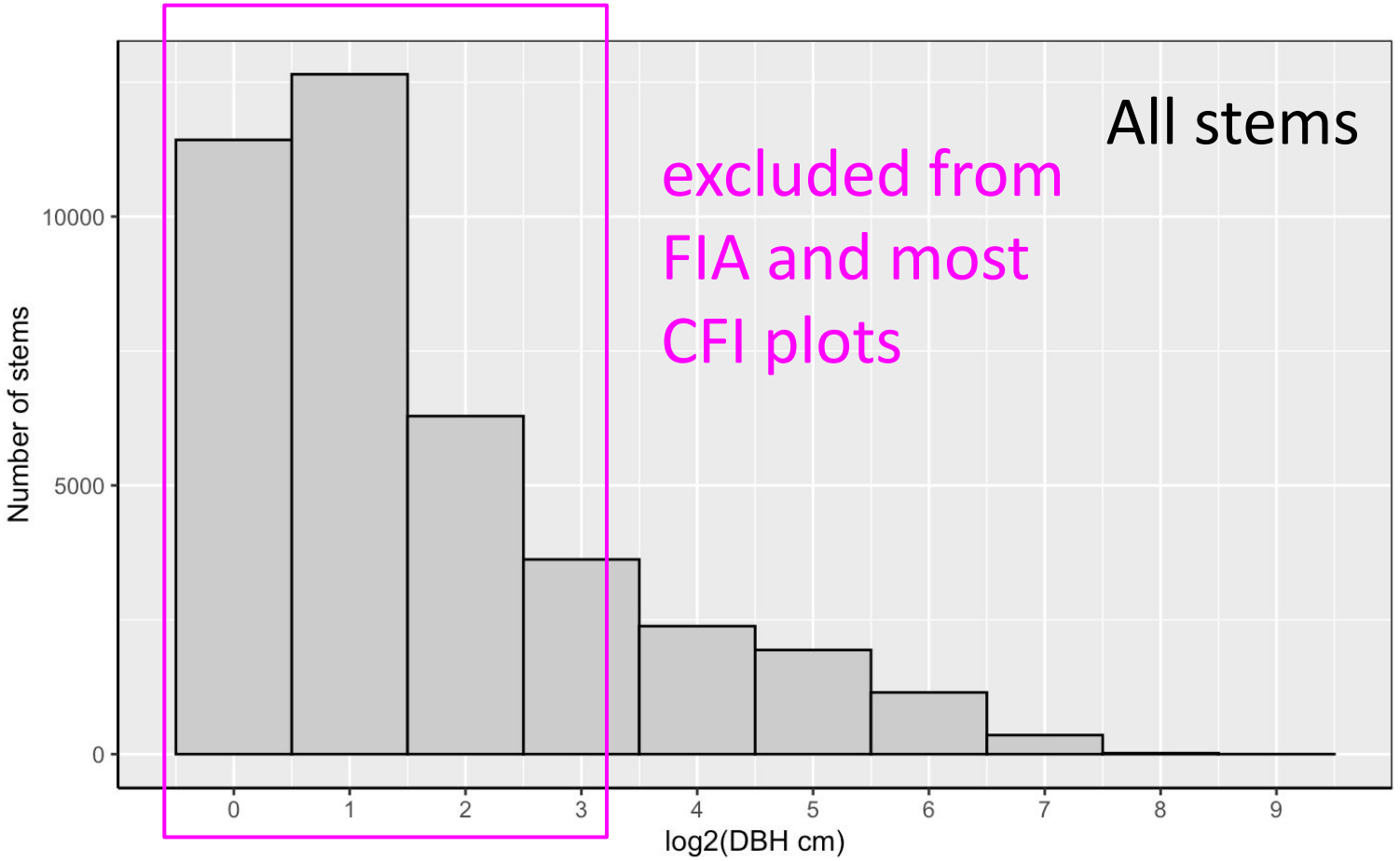
Light availability



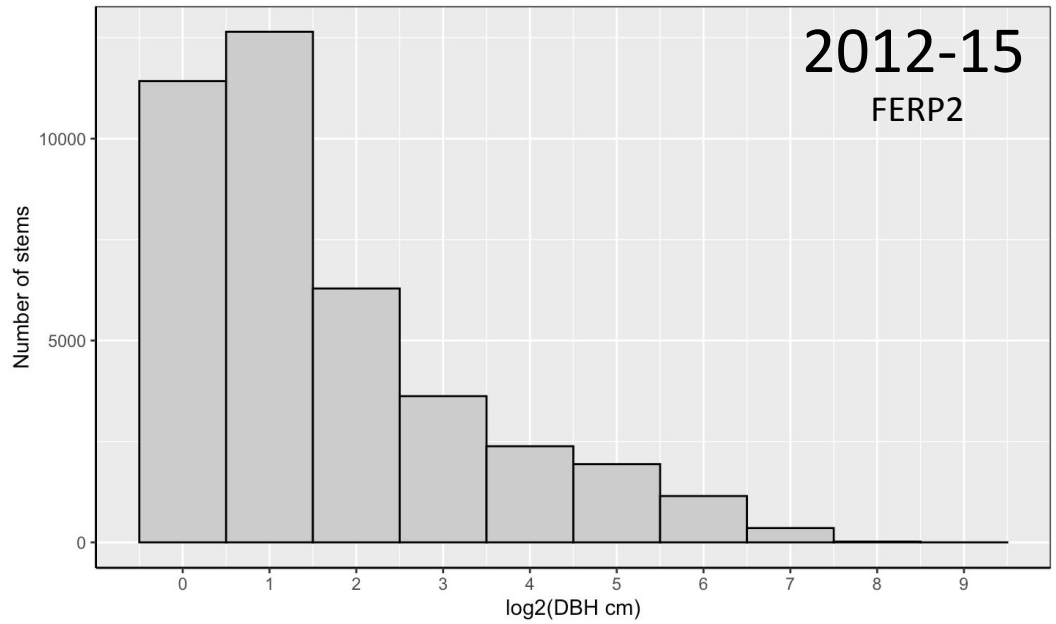
Tree demography: distribution and dynamics

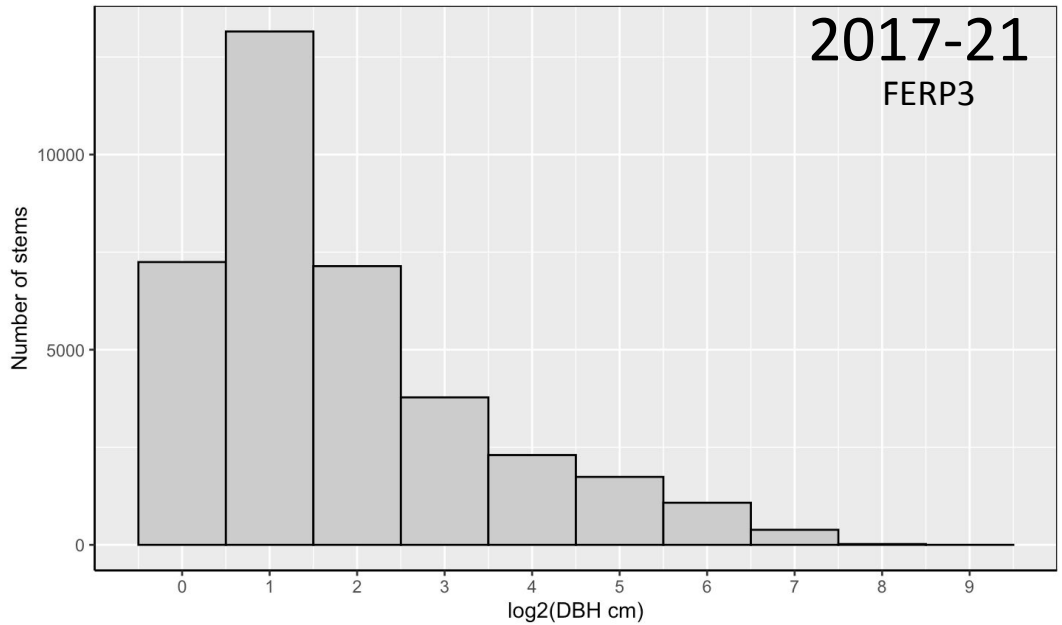
- Snapshots: tree size distribution
- Demography: change over time
  - Mortality
  - Growth
  - Recruitment

Tree size distributions



1	2	4	8	16	32	64	128	256	512	cm
0.5	0.8	1.6	3	6	12	24	50	100	201	inches





1 2 4 8 16 32 64 128 256 512 cm

0.5 0.8 1.6 3 6 12 24 50 100 201 inches

All stems of all species

Number of individuals

FERP2: 1636 ha^{-1}

FERP3: 1565 ha^{-1}

Total basal area

FERP2: 1073.0 m^2

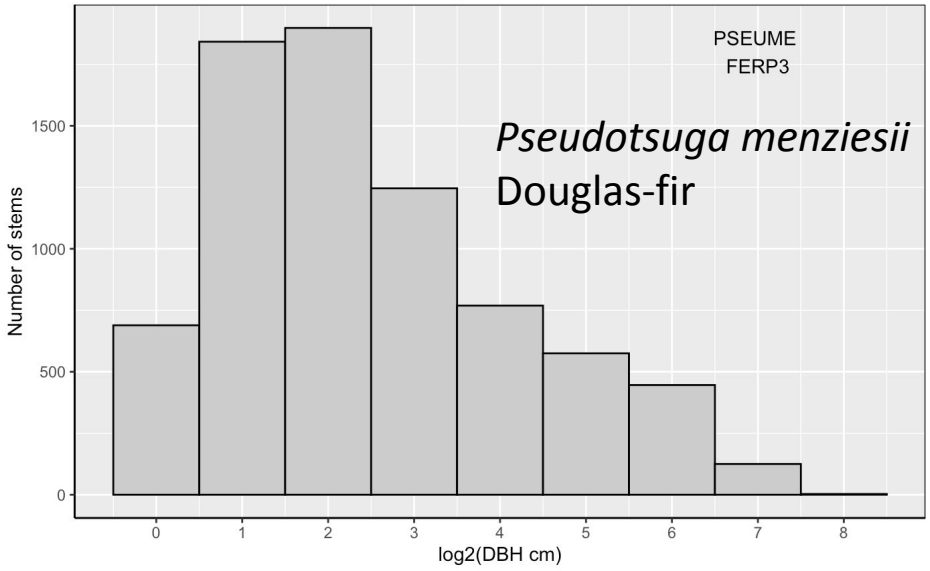
FERP3: 1095.5 m^2

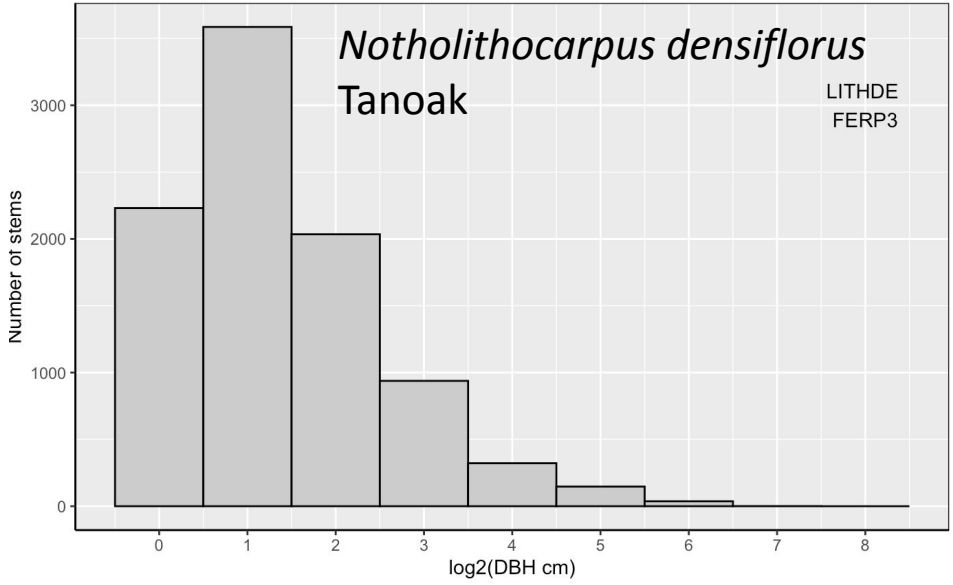
Basal area per ha

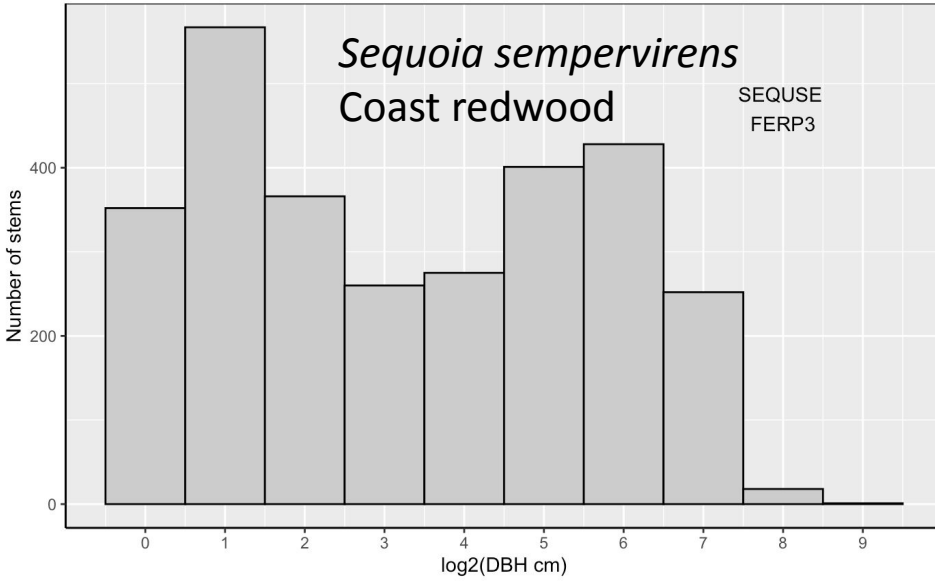
FERP2: 67.2 m^2 ha^{-1}

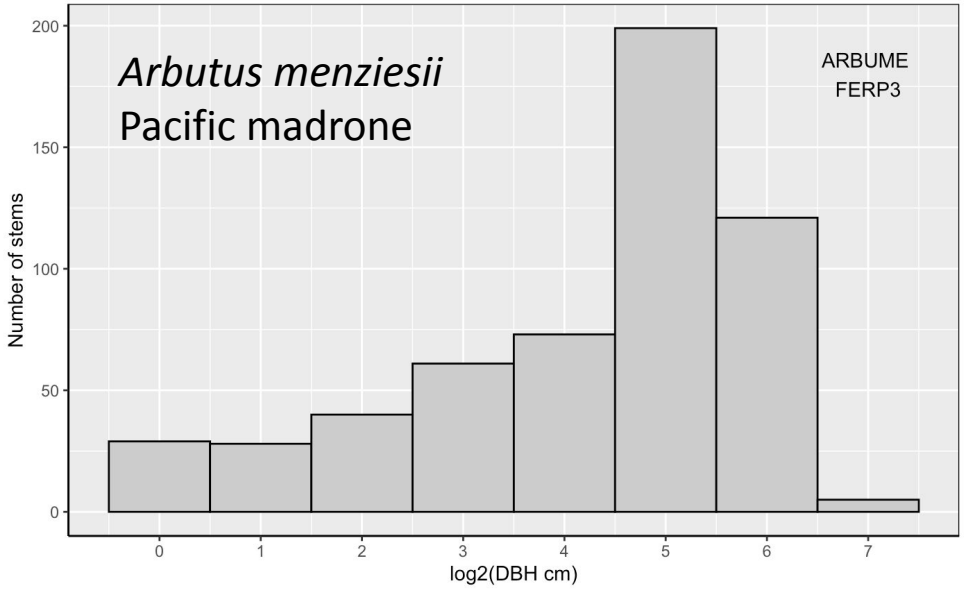
FERP3: 68.6 m^2 ha^{-1}

- Lots of trees dying
- Radial growth more than offsets mortality



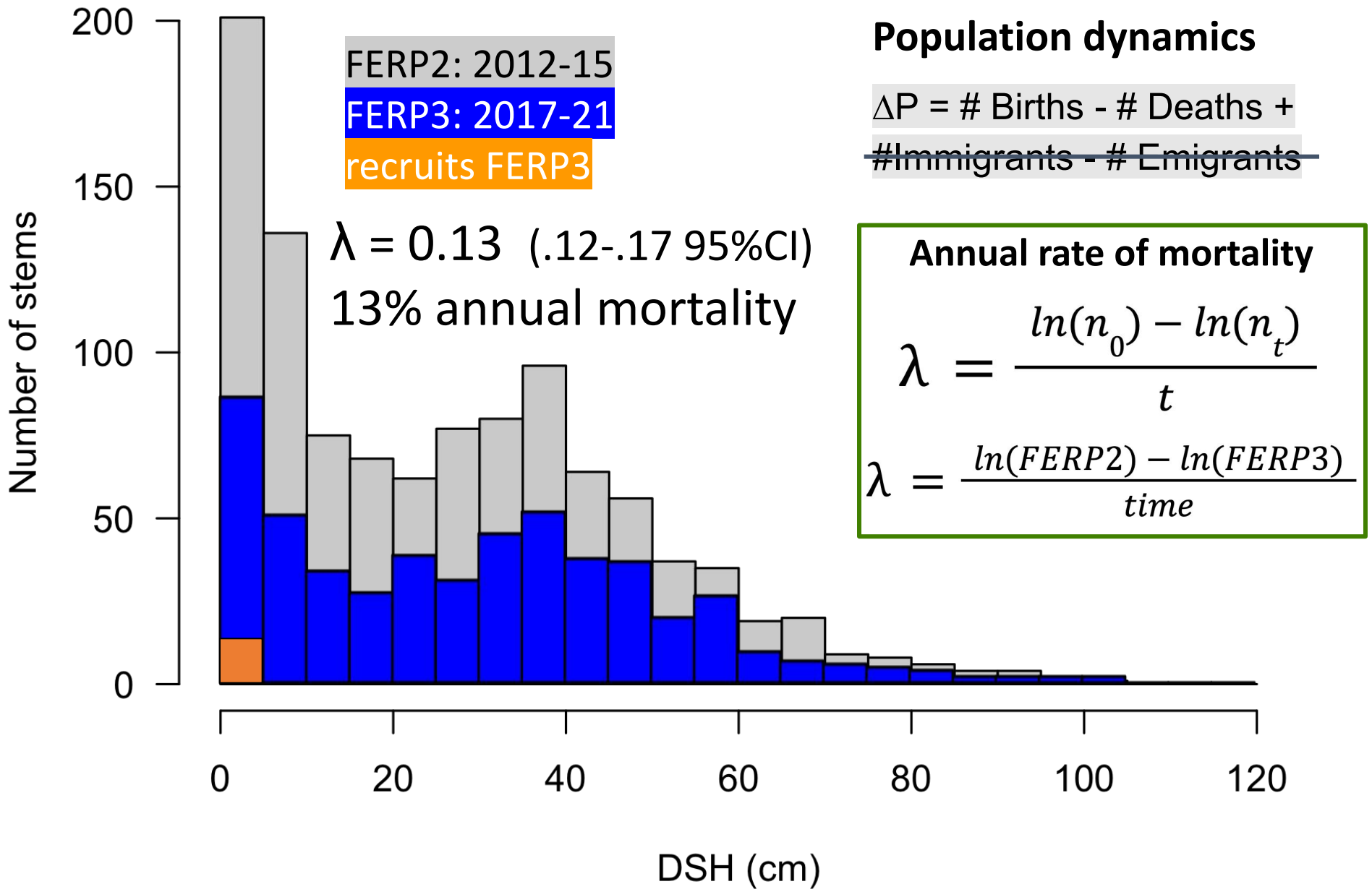






dbh (cm)	1	2	4	8	16	32	64	128	256	512	min dbh in class (cm)
$\log_2$(cm)	0	1	2	3	4	5	6	7	8	9	Preston octaves

Pacific madrone (*Arbutus menziesii*)



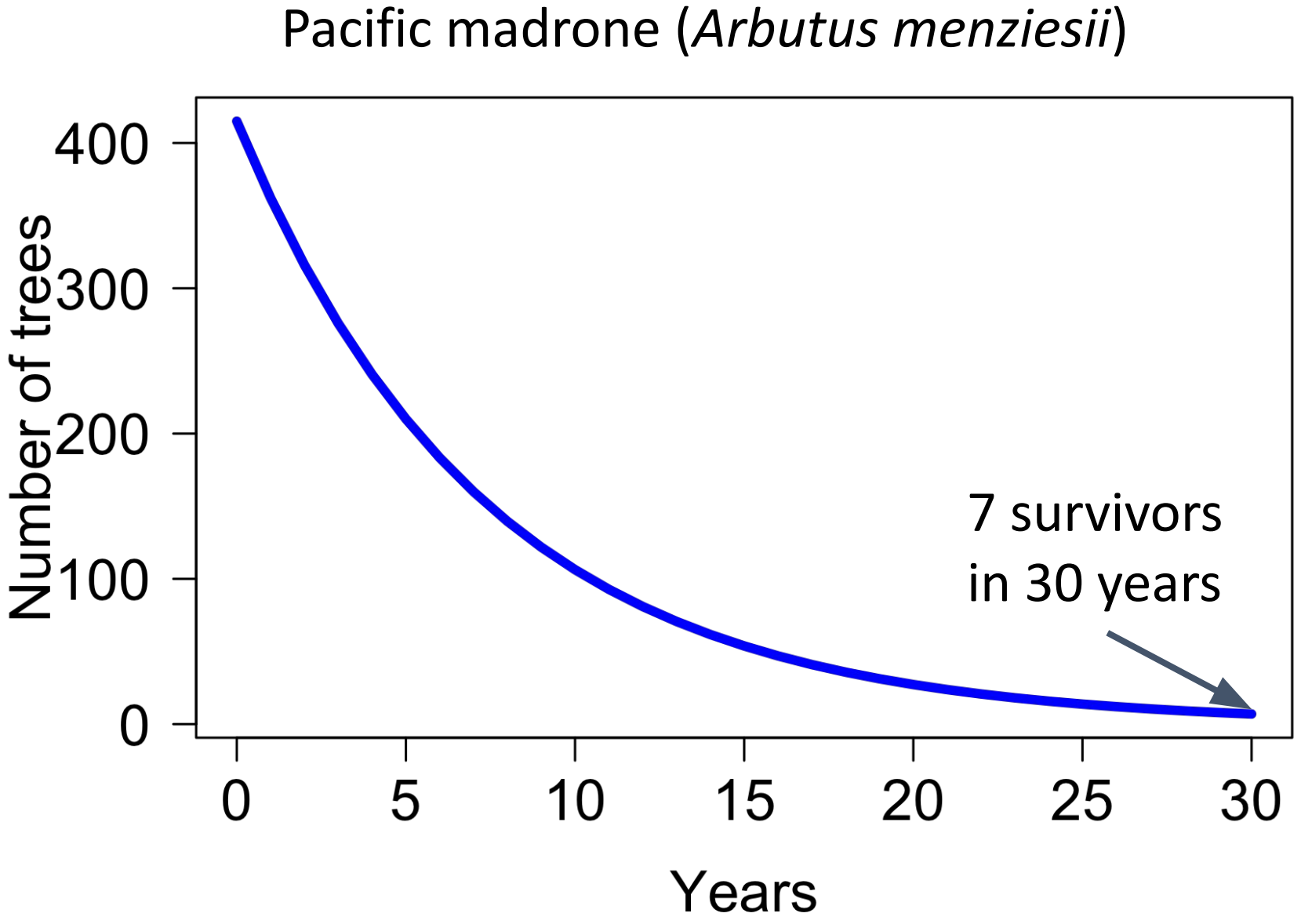
Population dynamics

ΔP = # Births - # Deaths + ~~#Immigrants - # Emigrants~~

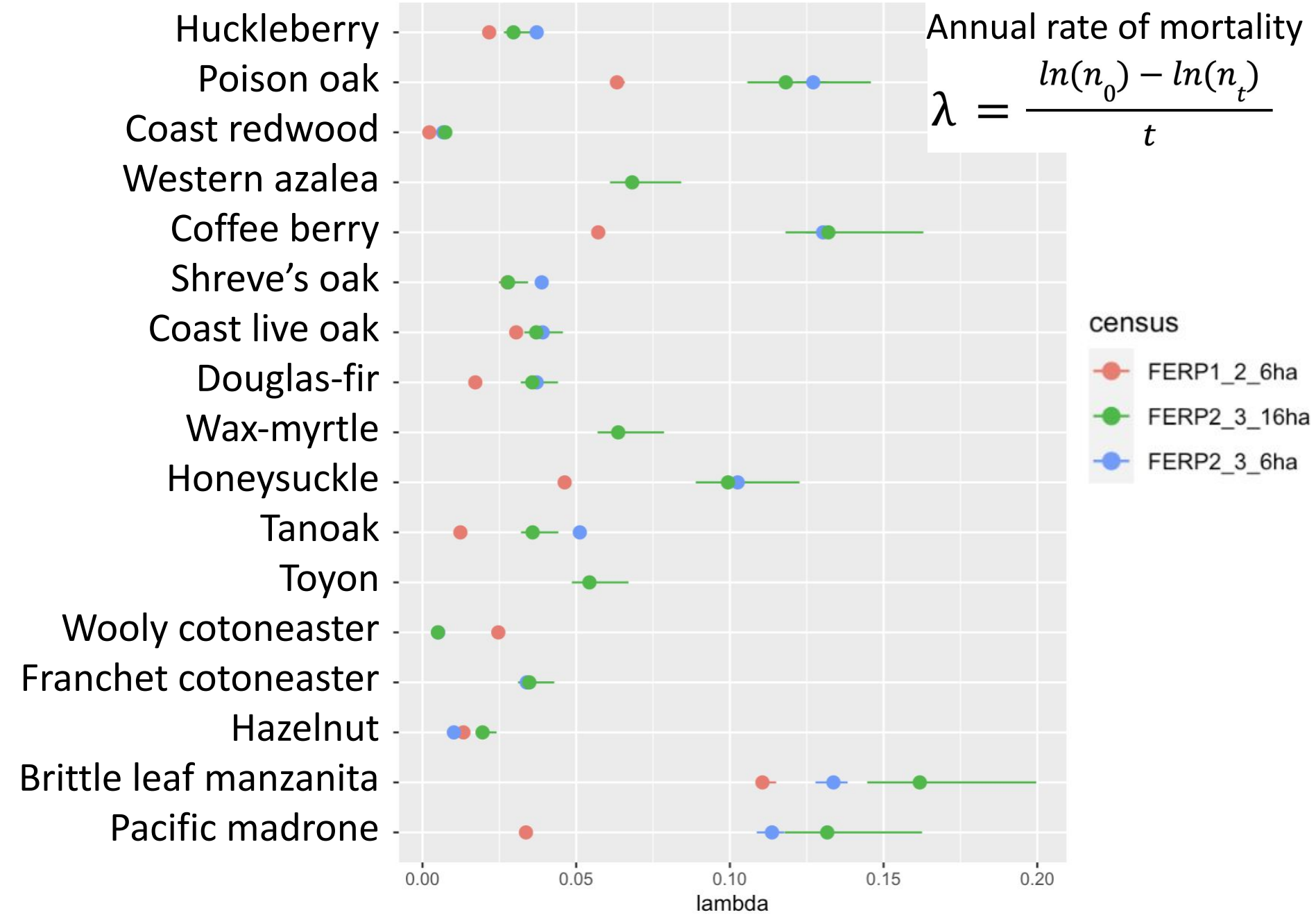
Annual rate of mortality

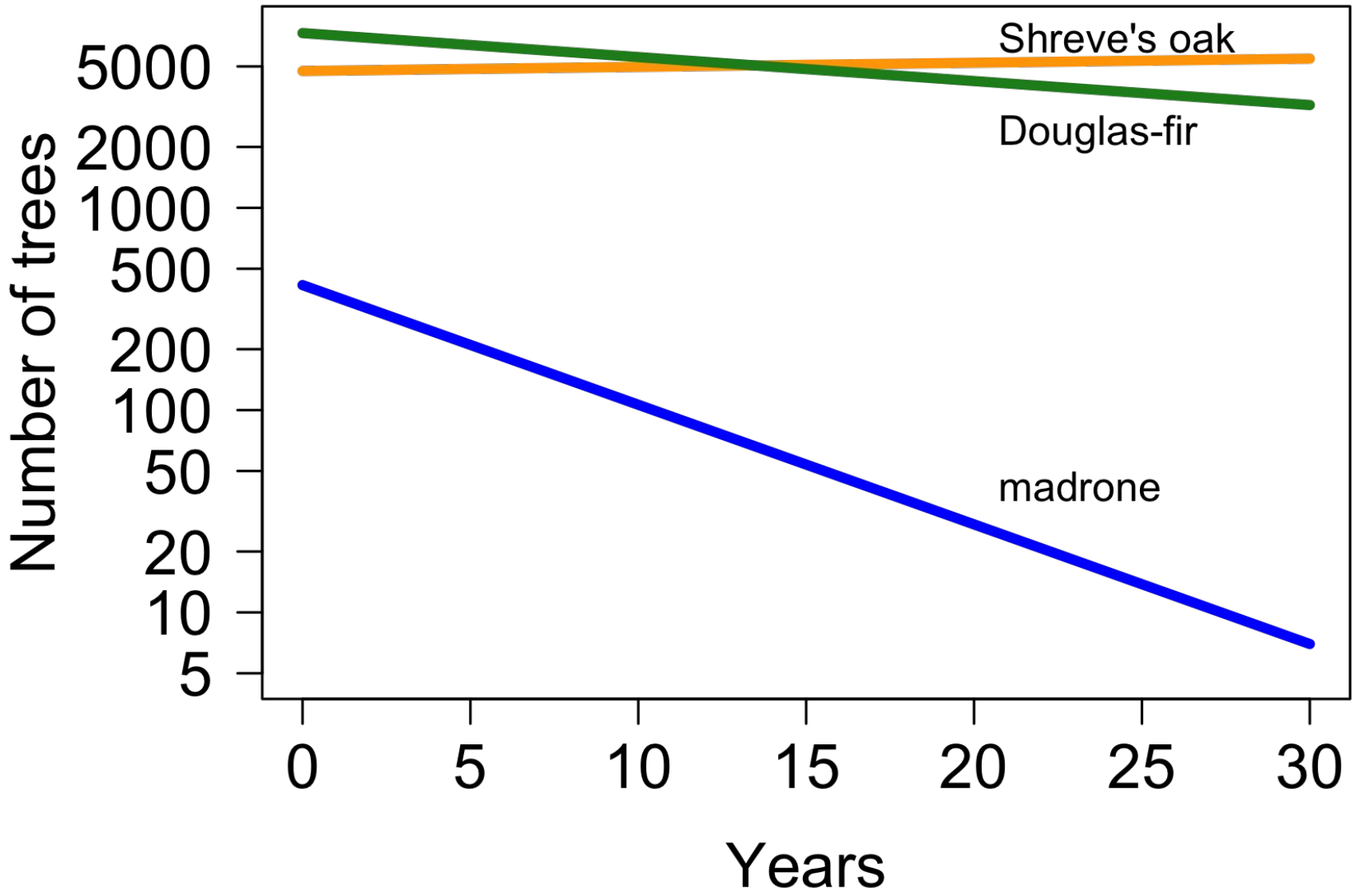
$$\lambda = \frac{ln(n_0) - ln(n_t)}{t}$$

$$\lambda = \frac{ln(FERP2) - ln(FERP3)}{time}$$



Population projection from 2017,
using mortality and recruitment from 2012-2017.


Huckleberry
Poison oak
Coast redwood
Western azalea
Coffee berry
Shreve's oak
Coast live oak
Douglas-fir
Wax-myrtle
Honeysuckle
Tanoak
Toyon
Wooly cotoneaster
Franchet cotoneaster
Hazelnut
Brittle leaf manzanita
Pacific madrone
0.00
0.05
0.10
0.15
0.20
lambda
census
FERP1_2_6ha
FERP2_3_16ha
FERP2_3_6ha
Annual rate of mortality
$\lambda = \frac{ln(n_0) - ln(n_t)}{t}$


Shreve's oak
Douglas-fir
madrone
Number of trees
5000
2000
1000
500
200
100
50
20
10
5
0
5
10
15
20
25
30
Years

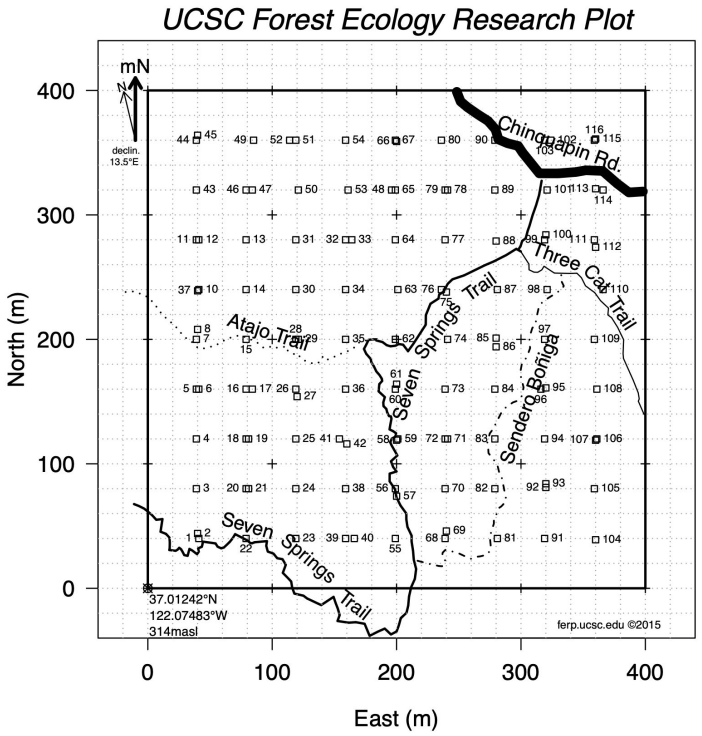
What we know about the coastal forest on the FERP

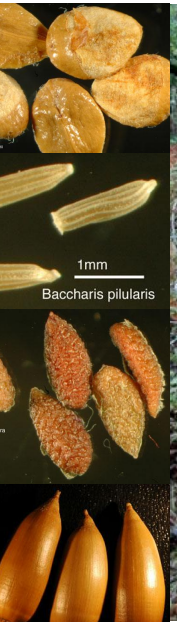
- FERP coastal forest is diverse
- Most individuals and biomass is from few species
- Forests are spatially heterogeneous
- History and environment shape forest structure
- Forest is dynamic: numbers going down, trees growing in stature.
- Some species are in rapid decline, some stable, none rapidly increasing

Forest Phenology

Timing of biological activity:

- Flowering
- Fruiting
- Seed dispersal
- Leaf fall
- Leaf production

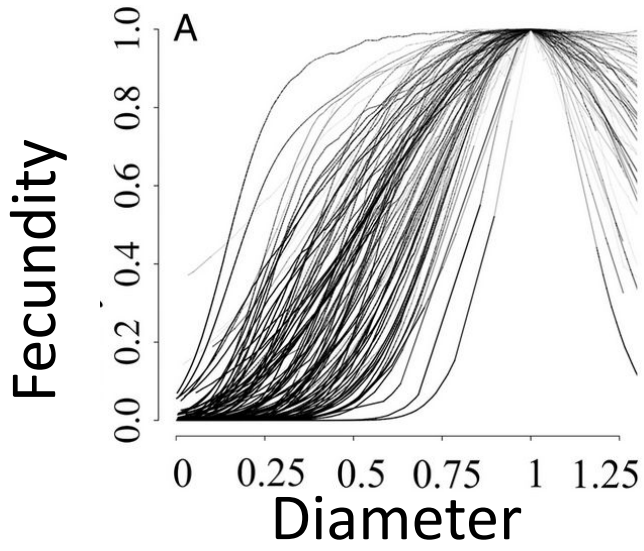




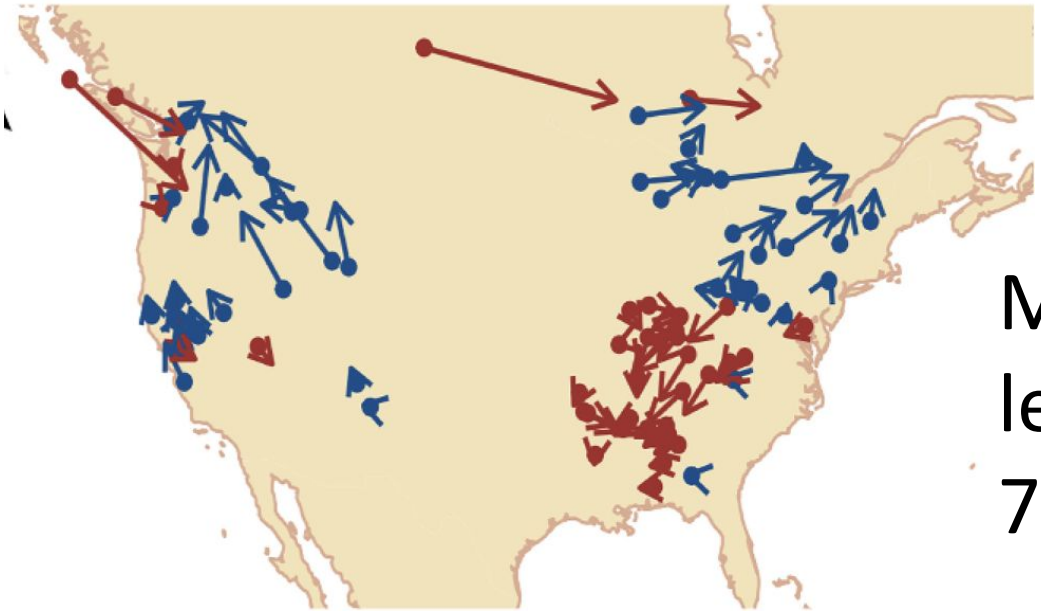
Phenology: timing of biological events

Dispersal ecology: how far do the seeds go?

Fecundity: how many seeds are being produced?



80% of 597 tree species show senescence at large size.
Qiu et al. 2021 PNAS

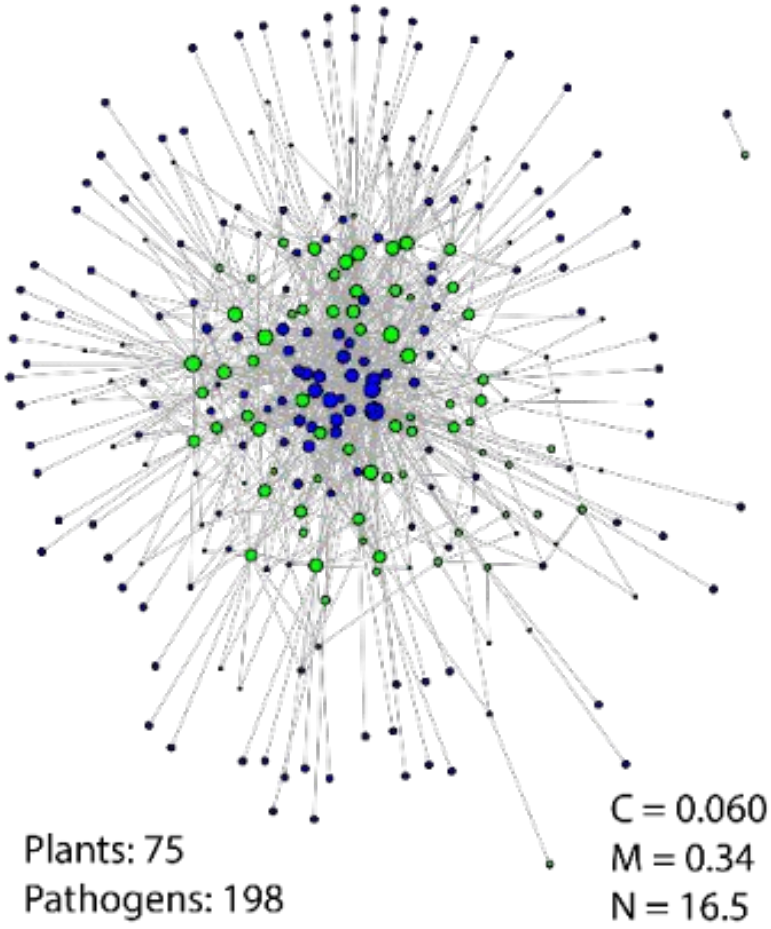


MASTIF network
led by Jim Clark, Duke U.
77 global sites

Fecundity of trees is migrating northward in west, but not in southeast. Sharma et al. 2022 PNAS

Forest fungi and tree diseases

Forest

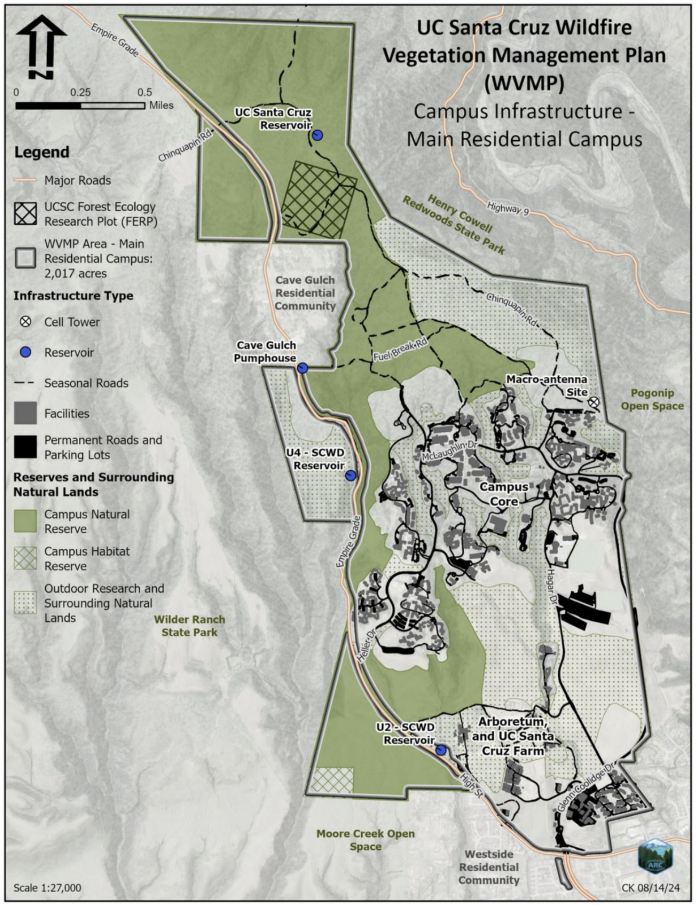


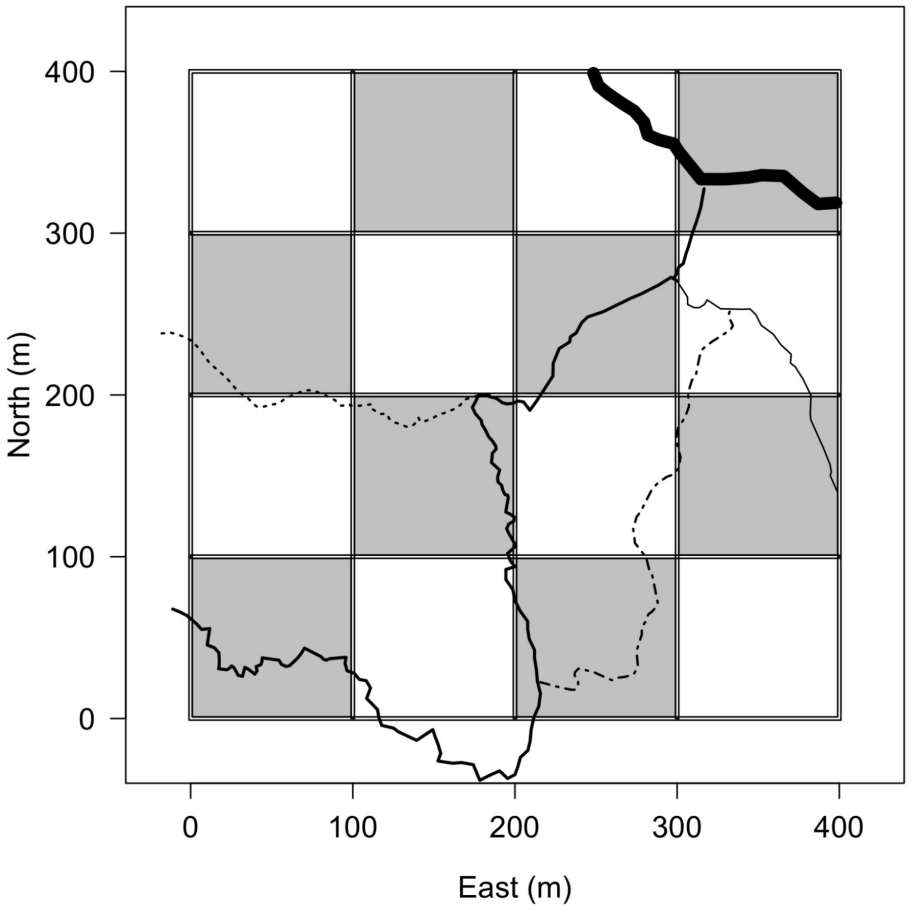
Metabarcoding (DNA sequence) of fungi in plant leaves

- 198 fungal pathogens
- 75 plant species
- ~40% of fungi on a 1 host
- Average plant species has about a dozen pathogens

FERP on fire (next phase)

Experimental prescribed burn coupled with long-term forest demographics, fire-disease interactions, Indigenous-led culturally inclusive monitoring, next-generation technology





Where to get the FERP data?

UC Santa Cruz Forest Ecology Research Plot

UCSC-FERP: Inquiry-based learning and ecological research for a changing planet

https://ferp.ucsc.edu

WELCOME INTERNSHIPS RESEARCH PLANTS PEOPLE

forests

https://doi.org/10.3390/f15010164

MDPI

Article

Three Censuses of a Mapped Plot in Coastal California Mixed-Evergreen and Redwood Forest

Gregory S. Gilbert [1,2,*], Sarah G. Carvill [1], Alexander R. Krohn [3] and Alexander S. Jones [3]

https://ferp.ucsc.edu/research/ferp-data/ferp_publicr/

Access to data, descriptions, and some basic R code here:

Metadata for the merged FERP123 data.

Full .csv data set for censuses 1, 2, 3: FERP123merged_20231029.csv

Google Sheet version of full data set for FERP censuses 1, 2, 3 (make a copy to be able to work with it)

List of species and codes: FERPspecies.csv

Coordinates of quadrats: quadrat_coords.csv

R Markdown file for basic data access, maps, and summaries.

HTML version of R Markdown file for basic data access, maps, and summaries.

Google slide presentation about the FERP (TreeSchool 2025-04-05).


http://ferp.ucsc.edu