Modeling the Forest for the Trees: Calculating Annual Pathogen Dispersal of Sudden Oak Death

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GEOG 441

Background

California Oak Mortality Task Force

Stem canker on coast live oak trunk (*Quercus agrifolia*)

- Sudden Oak Death (SOD) caused by *Phytophthora ramorum* oomycete

- Established on the West Coast since mid 1990s and destructive in native oak forests (Rizzo et al., 2003, Cobb et al., 2012)

- There are no known effective management strategies for eradicating SOD from forests (Cunnife et al., 2016)

- Current estimates of impact are outdated and only consider data up to 2012 (Cobb et al., 2020)

Problem Statement

- The current extent of tree mortality from Sudden Oak Death is unknown

- Geospatial models are useful in estimating both current circumstances and future projections

- One facet of a bigger model is modeling infection pressure = Force of Infection (Meentenmeyer et al., 2008)
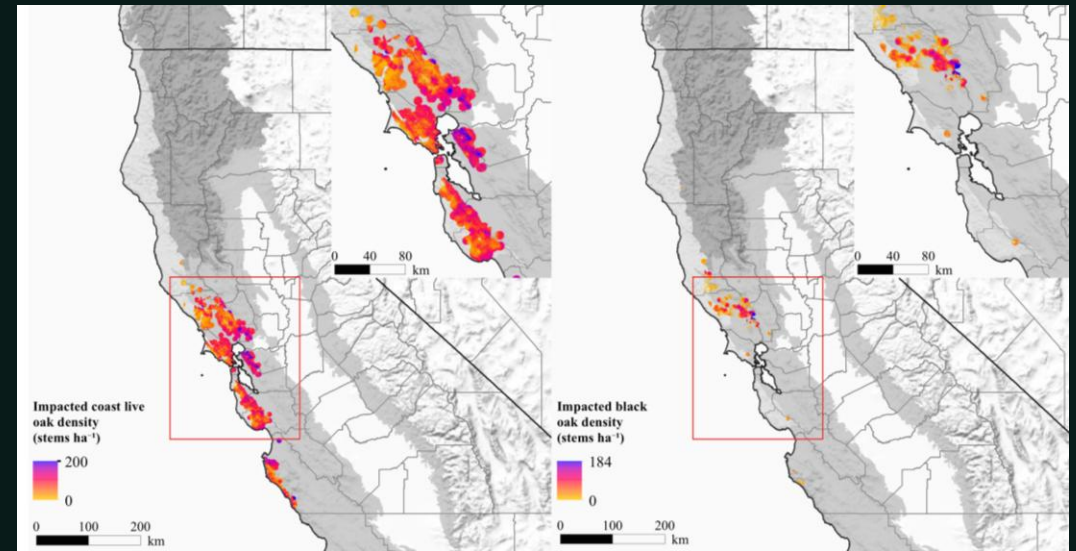
Cobb et al. 2020
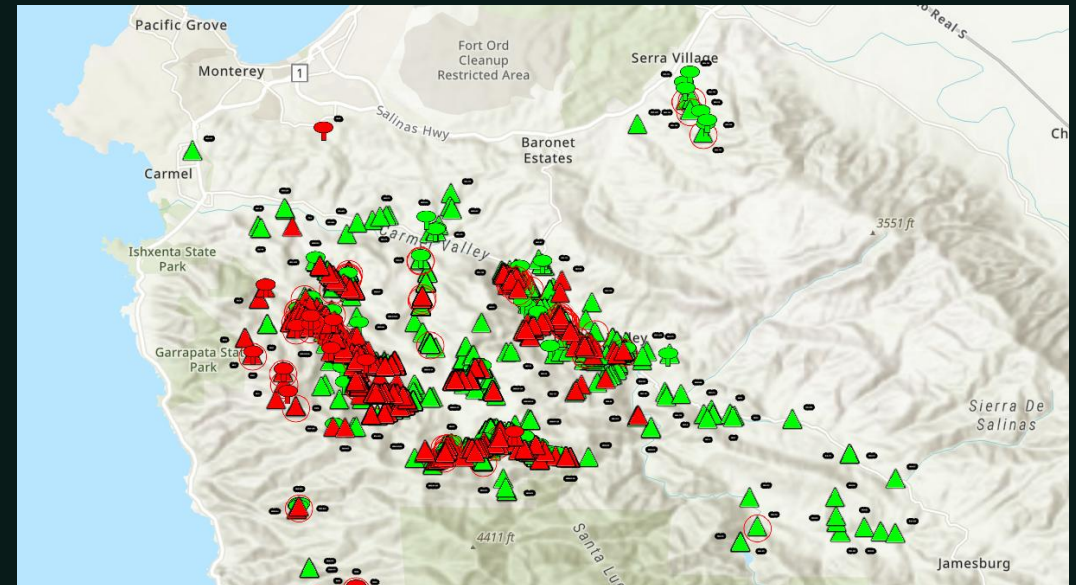
SOD Blitz 2023

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Force of Infection (FOI)

- Measures the probability of *P. ramorum* dispersal

- Probability decreases exponentially with distance from known infection
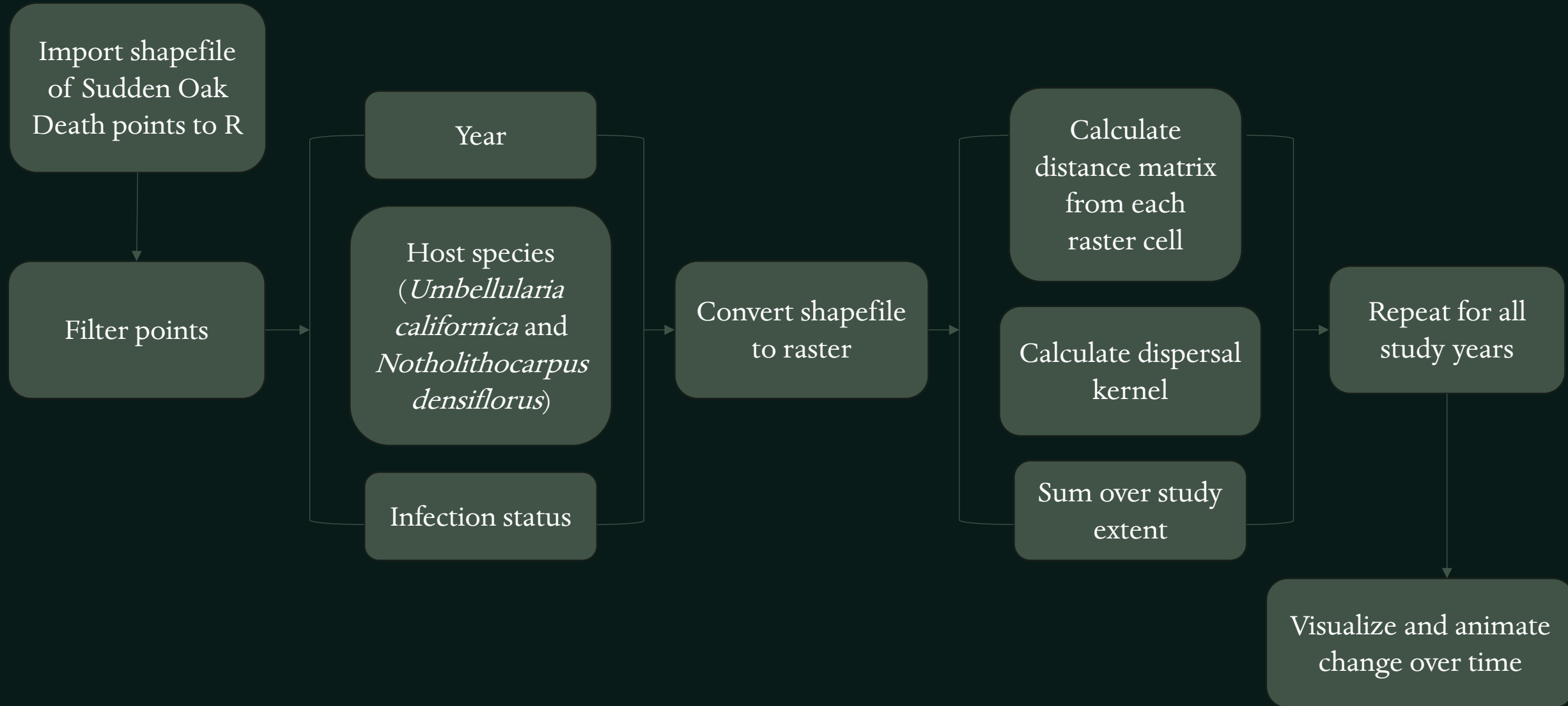
- "Heat map" of future infection

$$F_i = \sum_{k=1}^{N} \exp\left(\frac{-d_{ik}}{a.}\right)$$
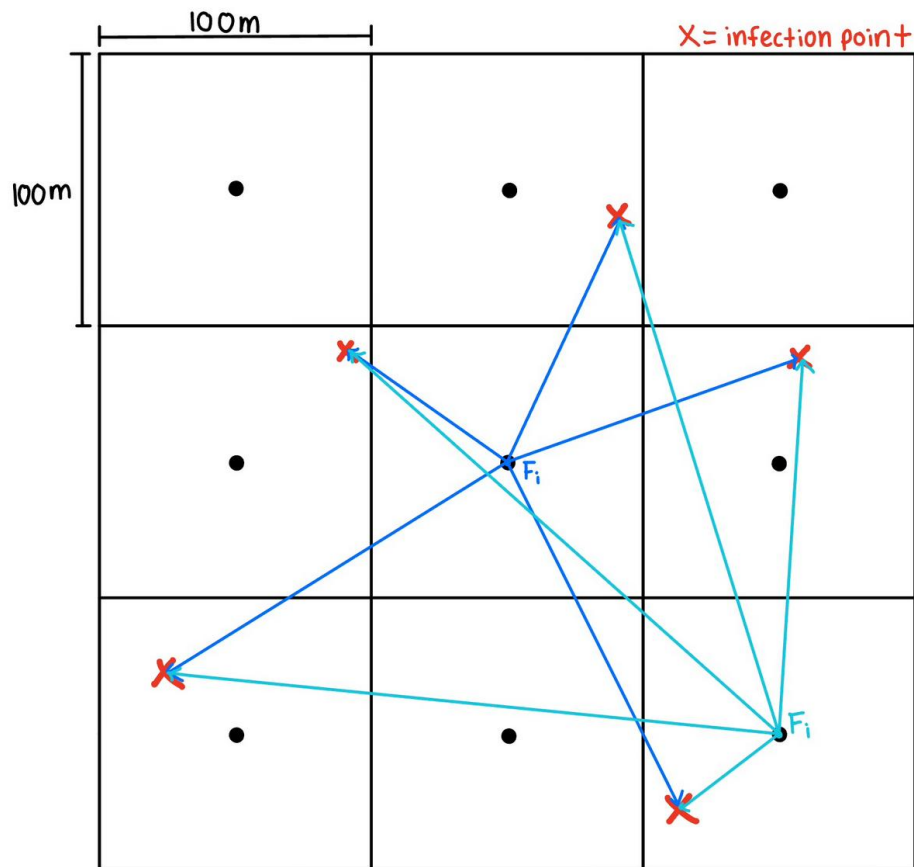
Meentenmeyer et al., 2008

- Obtain data from SOD Blitz citizen science project (Lanning et al., 2023)

- Calculate FOI over the host range (California and Southern Oregon) for study years 2007-2023

- Animate a time series map to display increase in infection pressure

Methods

Import shapefile of Sudden Oak Death points to R

Filter points

Year

Host species (*Umbellularia californica* and *Notholithocarpus densiflorus*)

Infection status

Convert shapefile to raster

Calculate distance matrix from each raster cell

Calculate dispersal kernel

Sum over study extent

Repeat for all study years

Visualize and animate change over time

Methods


```r
# Accumulate FOI
alpha      <- 25  # for testing we're using 5 km; later can change to 25 m
foi_rast <- r_template
for (i in seq_len(nrow(pts_vect))) { # loop over each point index
  # a) Extract the i-th point as a single-feature SpatVector:
  this_pt <- pts_vect[i, ]

  # b) Compute a distance-raster: for every cell in foi_rast, how far is its cen
  #     from this single point? Resulting d_rast has same dimensions as foi_rast,
  #     with values in meters.
  d_rast <- distance(foi_rast, this_pt)

  # c) Apply the negative-exponential kernel to those distances:
  #     exp(-d/alpha) yields a weight between 0 (far away) and 1 (zero distance).
  kernel_rast <- exp(-d_rast / alpha)

  # d) Add this point's kernel to the running total FOI raster:
  #     cell-wise addition accumulates contributions from each infection point.
  foi_rast <- foi_rast + kernel_rast

  # e) Optional progress bar to monitor status of for loop
  progress <- progress(i, 7764)
    Sys.sleep(0.02)
    if (i == 7764) message("Done!")
}
```
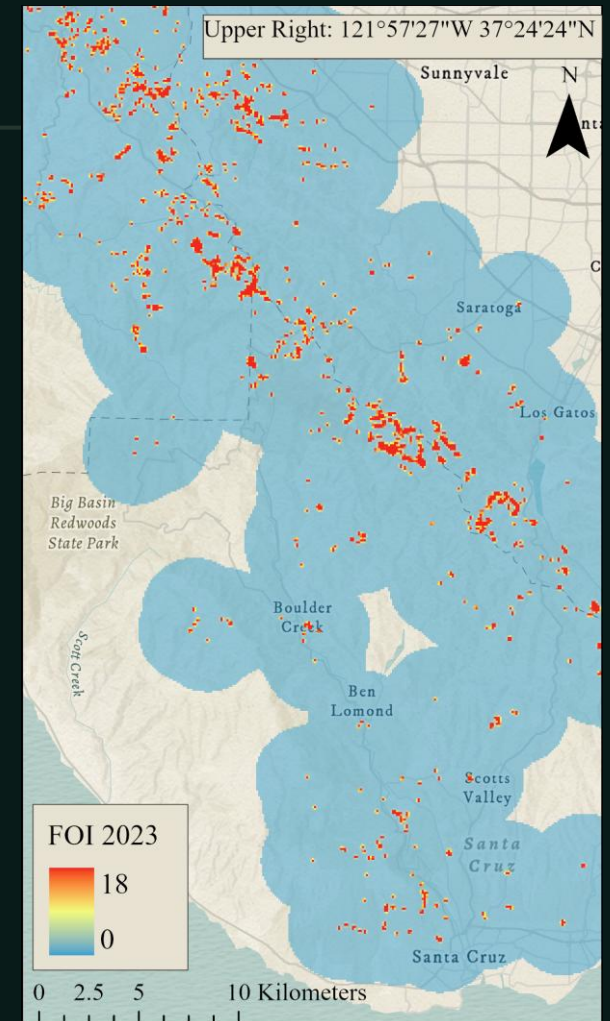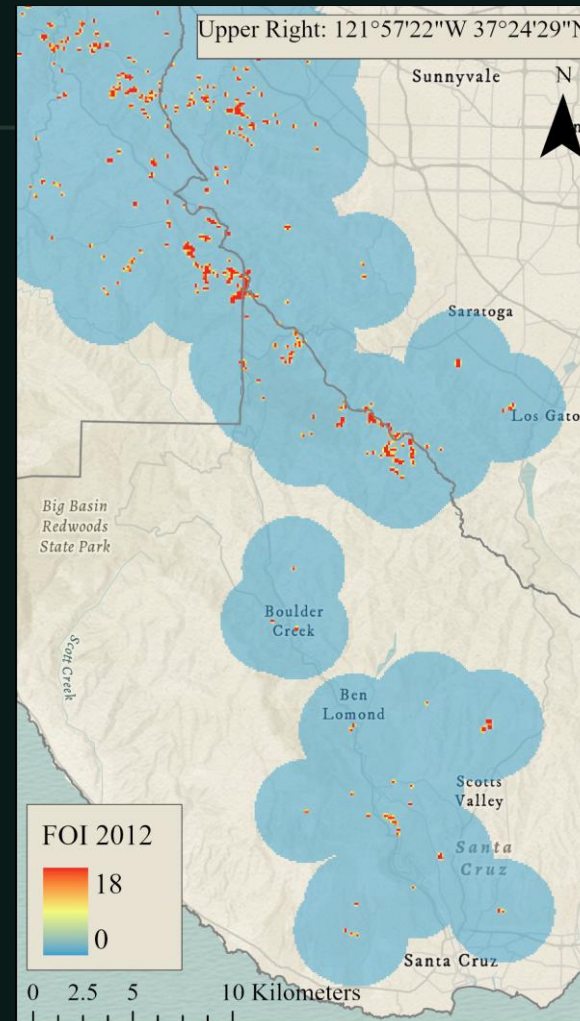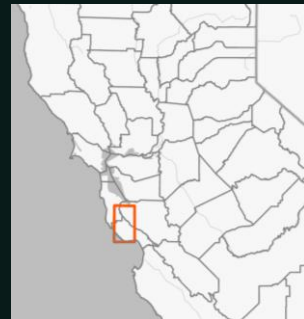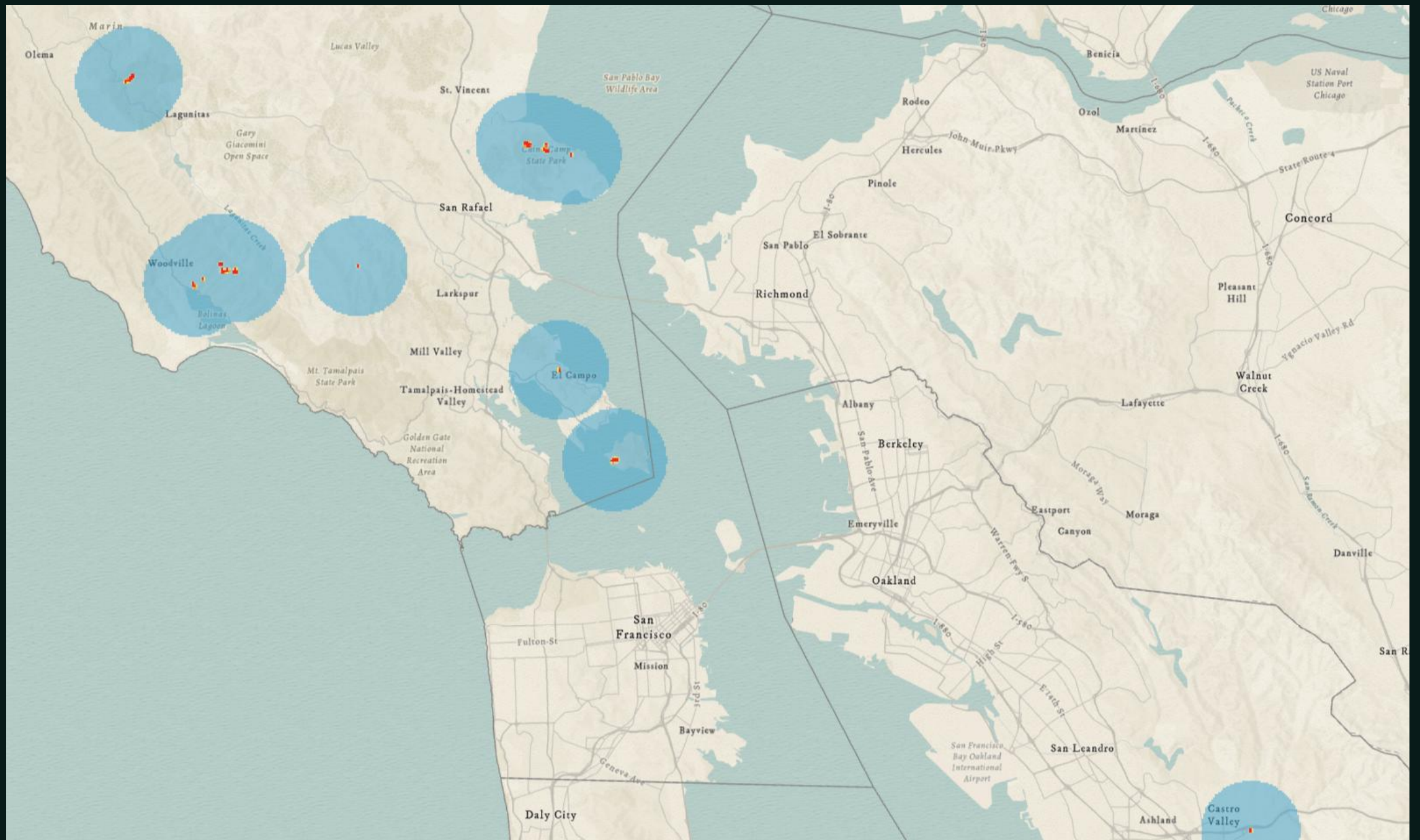
R programming help from Cal Poly statistics consulting department
Required packages: sf and terra

Results

- FOI increased across the entire study extent

- Expected because *U. californica* does not suffer mortality from SOD

- Animation was a success

Reflections

ACCOMPLISHMENTS

- Successfully calculated FOI over the study extent

- Animated a metric that is typically hard to visualize

- Calculated a metric that is useful as part of a larger model

NOTABLE CHANGES

- Calculations on R were very time consuming (1-2 hours per study year)

NEXT STEPS

- Calculate plot level tree dynamics (basal area, stem density, species distribution)

- Perform 2012 model on all study years

- Identify models that can be created with a temporal component

Thank you!

References

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3. Cobb, R. C., Filipe, J. A. N., Meentemeyer, R. K., Gilligan, C. A., & Rizzo, D. M. (2012). Ecosystem transformation by emerging infectious disease: Loss of large tanoak from California forests. *Journal of Ecology*, *100*(3), 712–722.

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5. Lanning, K. K., Kline, N., Elliott, M., Stamm, E., Warnick, T., LeBoldus, J. M., Garbelotto, M., Chastagner, G., & Hulbert, J. M. (2023). Citizen science can add value to Phytophthora monitoring: Five case studies from western North America. *Frontiers in Environmental Science*, *11*.

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7. Meentemeyer, R. K., B. L. Anacker, W. Mark, and D. M. Rizzo. 2008. Early Detection of Emerging Forest Disease Using Dispersal Estimation and Ecological Niche Modeling.