Using Remote Sensing to Investigate the Overlap of Swiss Needle Cast and Bark Beetle Infections

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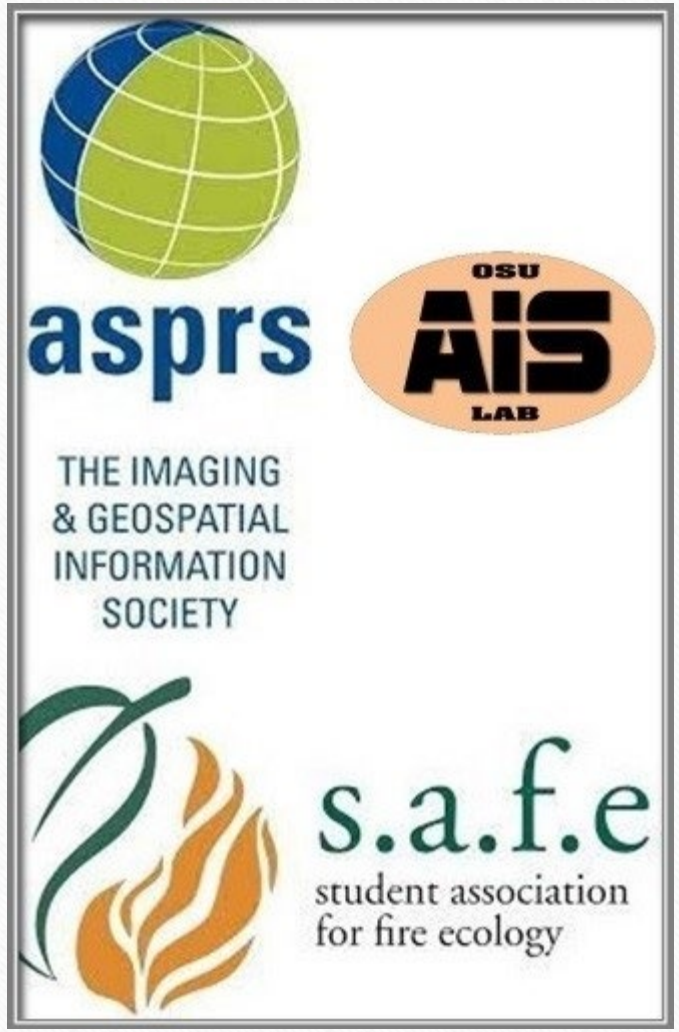
Introduction

- This will be a "big picture" talk, with data visualization rather than data analysis.
- Aerial Information Systems Lab in the Forest Engineering, Resources, and Management Department.
- We use remote sensing, geographic information systems, and machine learning to measure, classify, and make predictions about forested ecosystems, including the impact of disturbances.



Overall Research Question

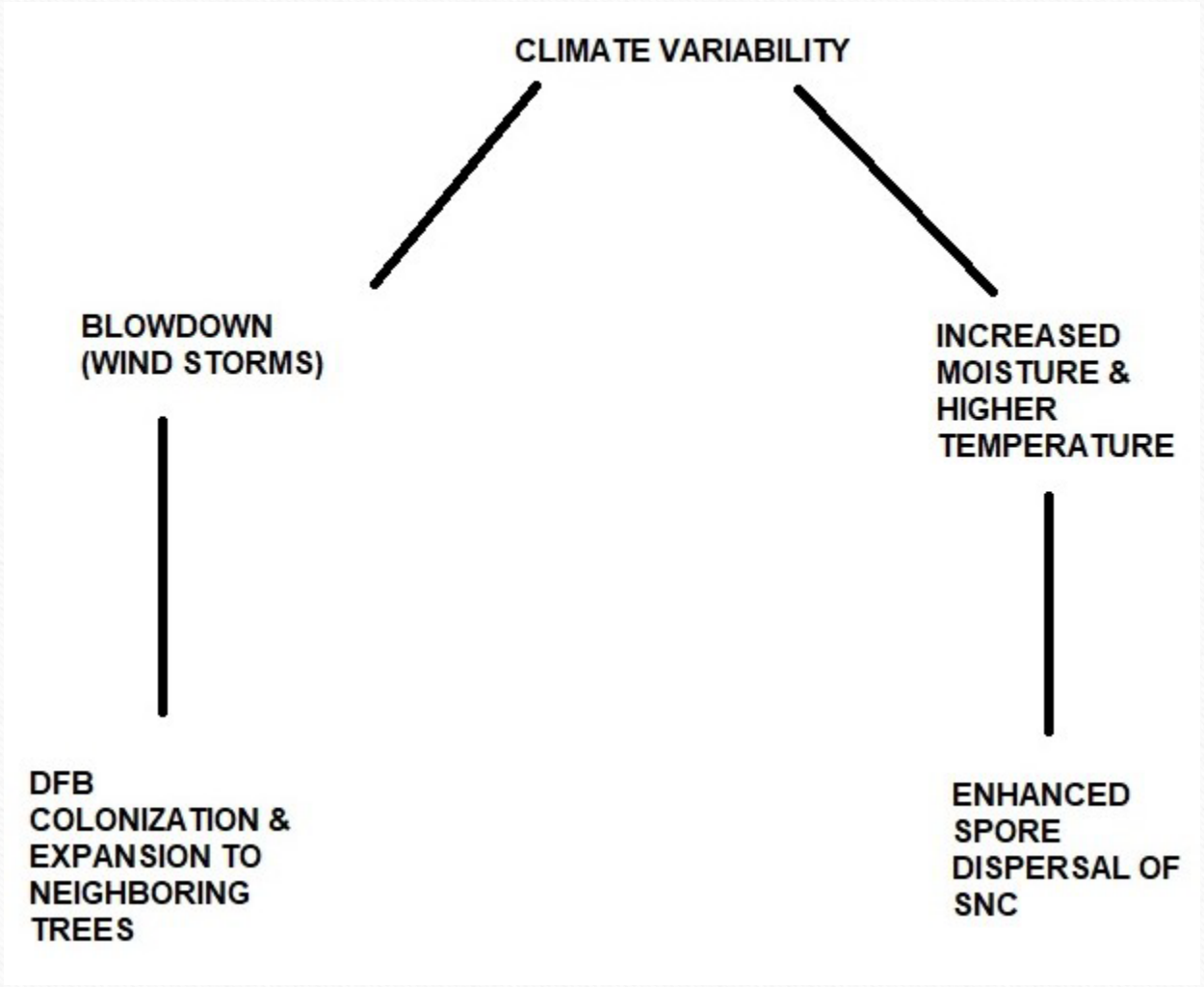
- "How do Swiss Needle Cast and Douglas-fir bark beetle infestation influence each other in coastal Pacific Northwest forests?"
- **Why does this matter to forest managers and ecologists?** First, the phenomenon is understudied and if there is an interaction, both managers and scientists should be informed. Second, as climate change increases the magnitude of coastal storms and the resulting blowdown, as well as the chance of drought, the corridor of overlapping disturbance and its related quantity of downed wood could move (e.g., SNC moving to the east, Douglas-fir bark-beetle moving west, and the combined distribution moving north). Both long-term monitoring and implementing treatments would therefore be of value, given the potential impact on timber resources and the increased risk of stand-replacing wildfires.

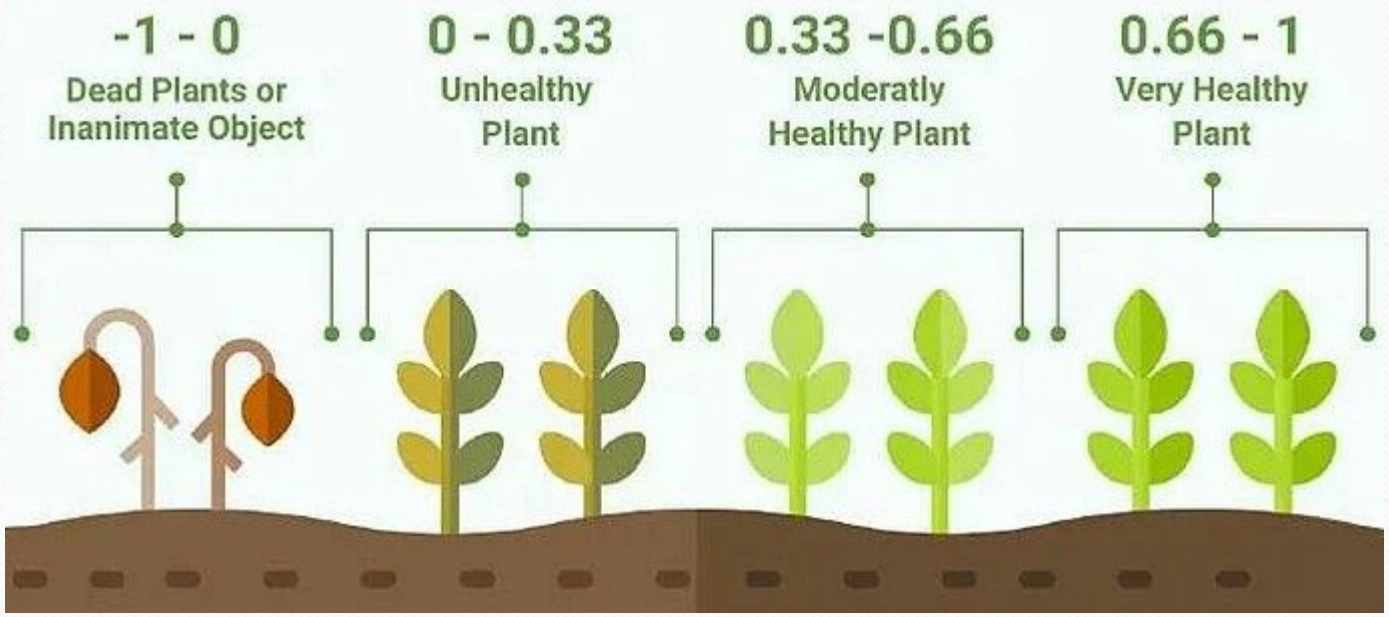
Why do Swiss Needle Cast and Douglas-Fir Bark Beetle Overlap?

- Swiss Needle cast (*Phaeocryptopus gaeumannii*) ("SNC") is a foliage disease that afflicts Douglas-fir forests (Agne, et al. 2018). It causes defoliation and loss of basal area and top height growth, which is a threat to coastal plantations where Douglas-fir productivity is paramount (Maguire, et al. 2002). Its visible attributes (e.g., thin crowns and loss of foliage) are typically detected via aerial survey (Ritóková, et al. 2021), but researchers also use foliage sampling methods in situ (Shaw, et al. 2021). The severity of Swiss Needle cast ("SNC") has been shown to vary with climate (e.g., seasonal temperature, moisture, drought, distance from the coast/fog, etc.) on a site-specific basis (Ritóková, et al. 2021).

Why do Swiss Needle Cast and Douglas-Fir Bark Beetle Overlap?

- Douglas-fir bark beetles ("DFB") are bark beetles native to the Pacific Northwest (Agne, et al. 2018). They almost exclusively target Douglas-fir (*Pseudotsuga menziesi*) in the Pacific Northwest, which is a threat to coastal plantations where Douglas-fir productivity is paramount. Douglas-fir bark beetles often colonize dead and/or fallen trees in the aftermath of windstorms that cause windthrow. From there, outbreaks spread to healthy trees nearby in the following year. Douglas-fir bark beetles interfere with the photosynthetic process and can cause landscape-wide tree mortality.
- ***The variability in climate that increases Swiss Needle cast severity is also associated with storm-caused windthrow that leads to bark beetle colonization.***


CLIMATE VARIABILITY
BLOWDOWN
(WIND STORMS)
INCREASED
MOISTURE &
HIGHER
TEMPERATURE
DFB
COLONIZATION &
EXPANSION TO
NEIGHBORING
TREES
ENHANCED
SPORE
DISPERSAL OF
SNC



Hypothesis & Expected Results

- **Hypothesis:** Douglas-fir subjected to overlapping disturbances register greater stress in their remaining foliage than Douglas-fir subjected to one or no disturbances.
- To identify *stress*, I will use satellite imagery and conduct drone surveys to capture RGB and NIR imagery, and then use vegetation indexes (NDVI, RENDVI, red-edge NDVI, NDVI705, etc.) to identify red edge stress. I expect that dual disturbance site-types will register more stress.

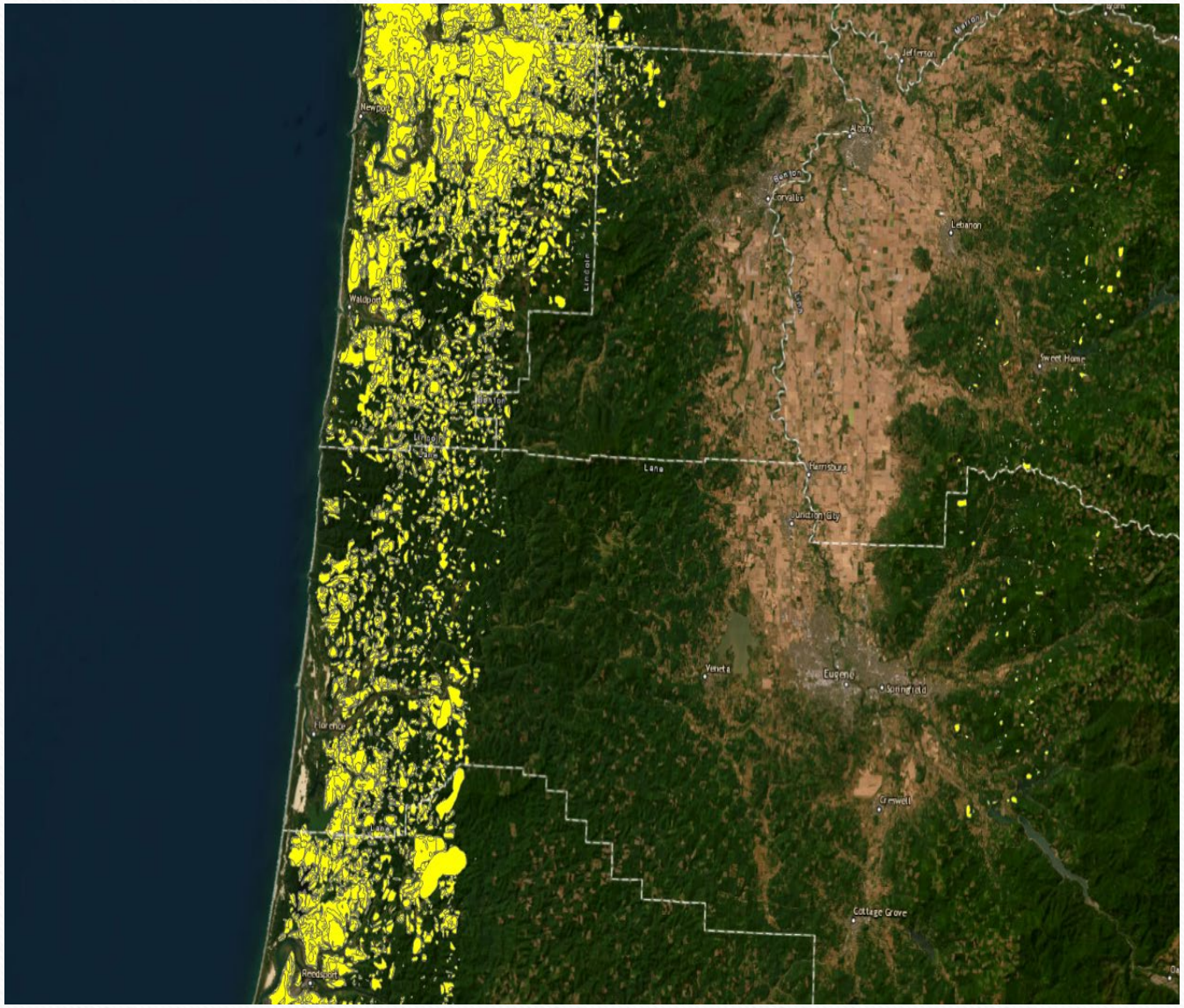
Data visualization

"Is there an overlap and is it large enough to justify this research?"

Swiss Needle Cast distribution

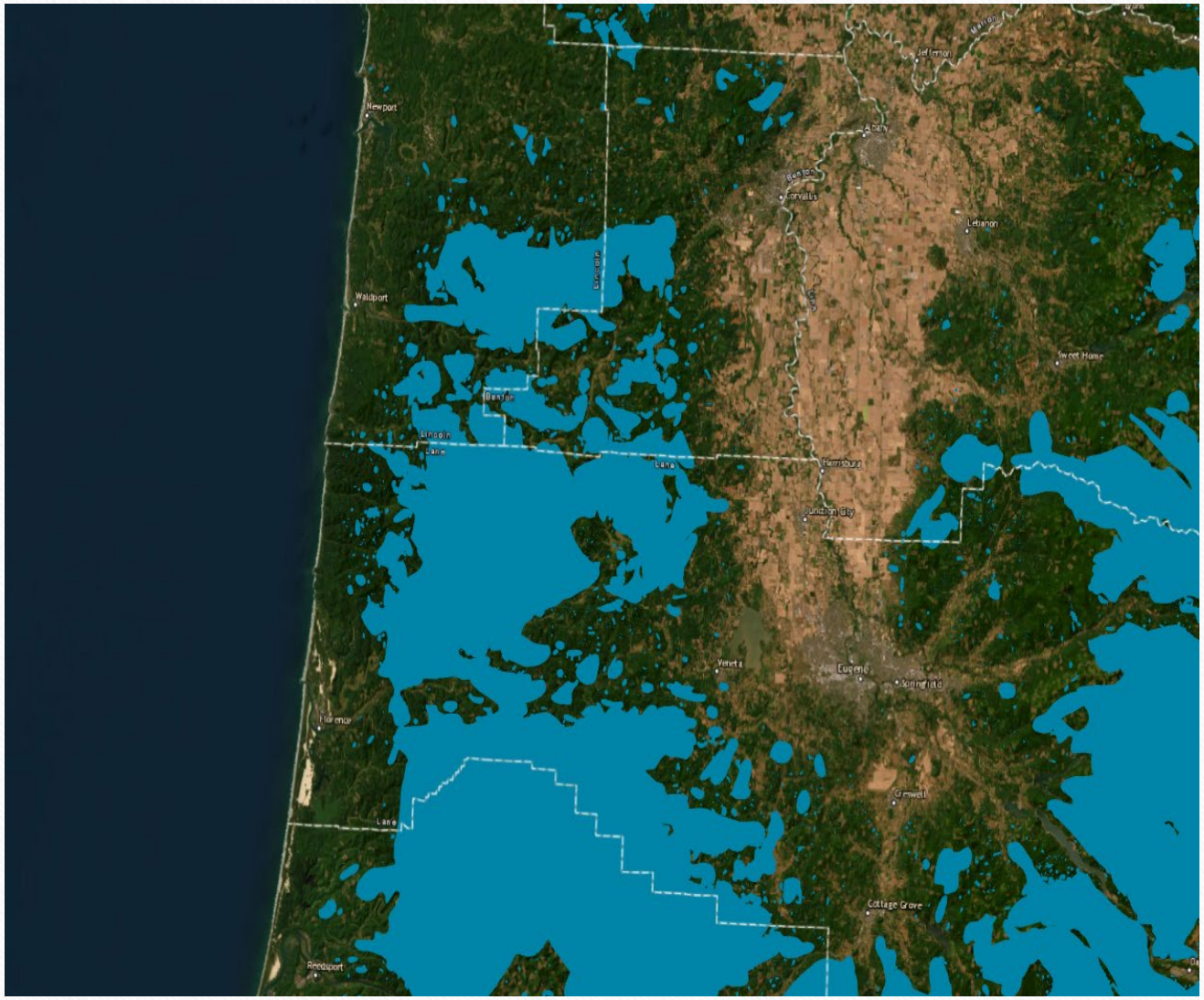
From 1947 to 2021.

Note: I combined two databases, the Aerial Insect and Disease Survey GIS Data for Oregon and Washington 1947-2021 and the Swiss Needle Cast Aerial Surveys flown by the Oregon Department of Forestry Forest Health and Air Operations sections from years 2006 to 2018, with years 2008 and 2017 excluded.



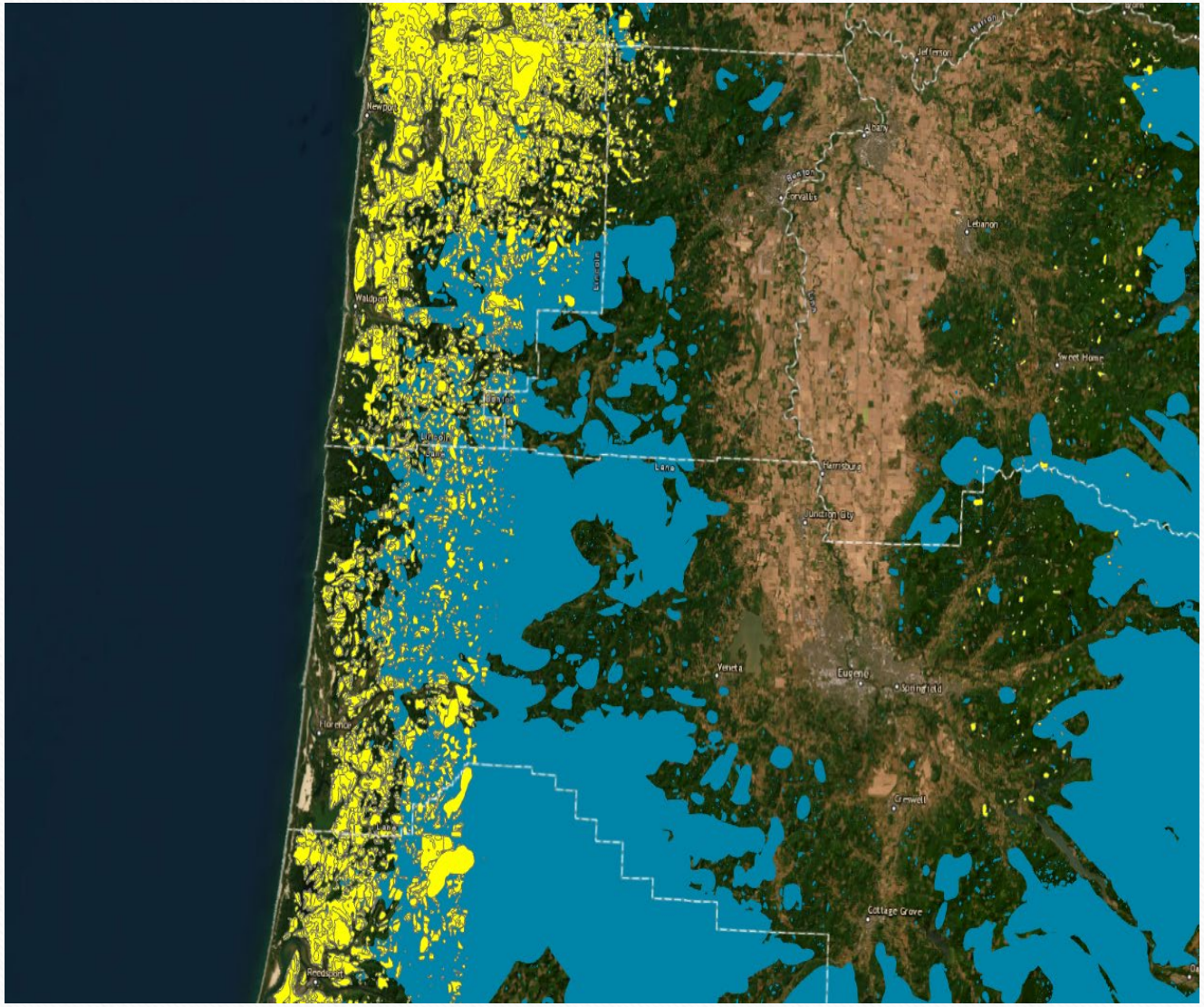
Douglas-Fir Bark Beetle Distribution

The blue polygon shapefiles here are from the from the Aerial Insect and Disease Survey GIS Data for Oregon and Washington 1947-2021. This database measures mortality in percentage of trees affected per acre (TPA).



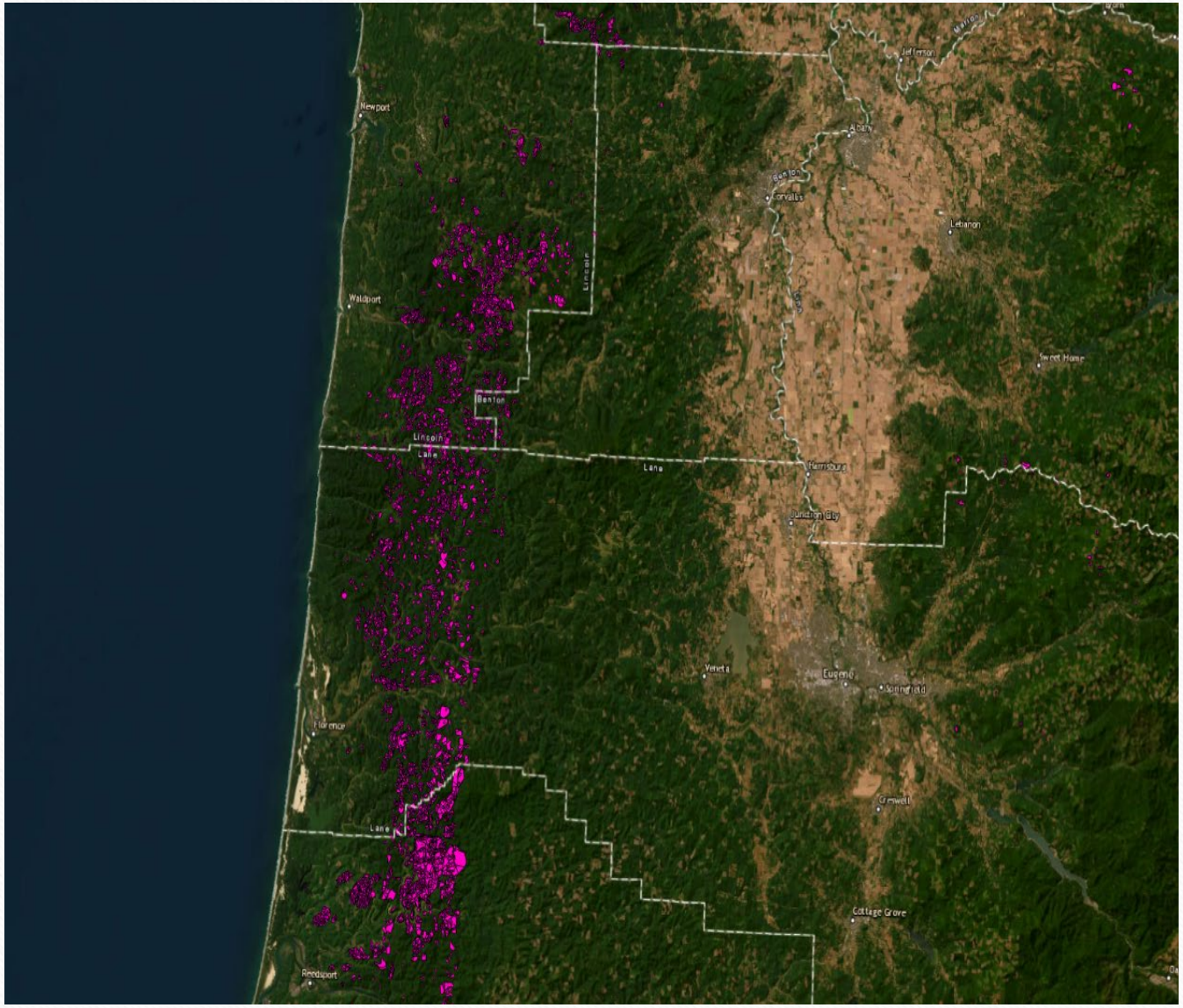
Overlapping Disturbances

The disturbances overlap.



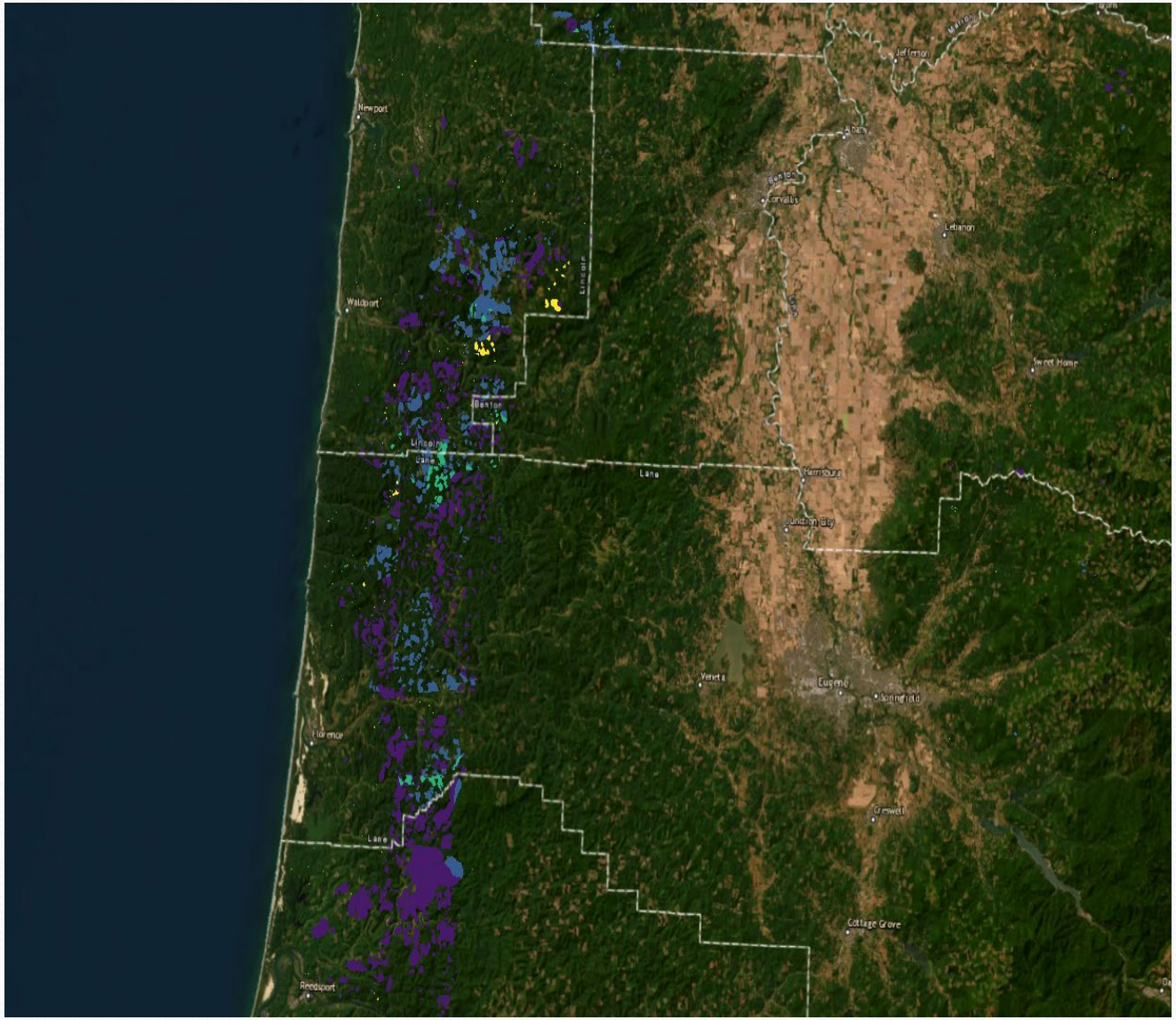
Intersection of both datasets

The corridor of intersection.



Intersecting corridor by DFB TPA

Here is the intersecting area in terms of DFB TPA. The mortality increases with lightness of color (the least mortality is purple, the greatest mortality is yellow).



Why does this matter to forest managers and ecologists?

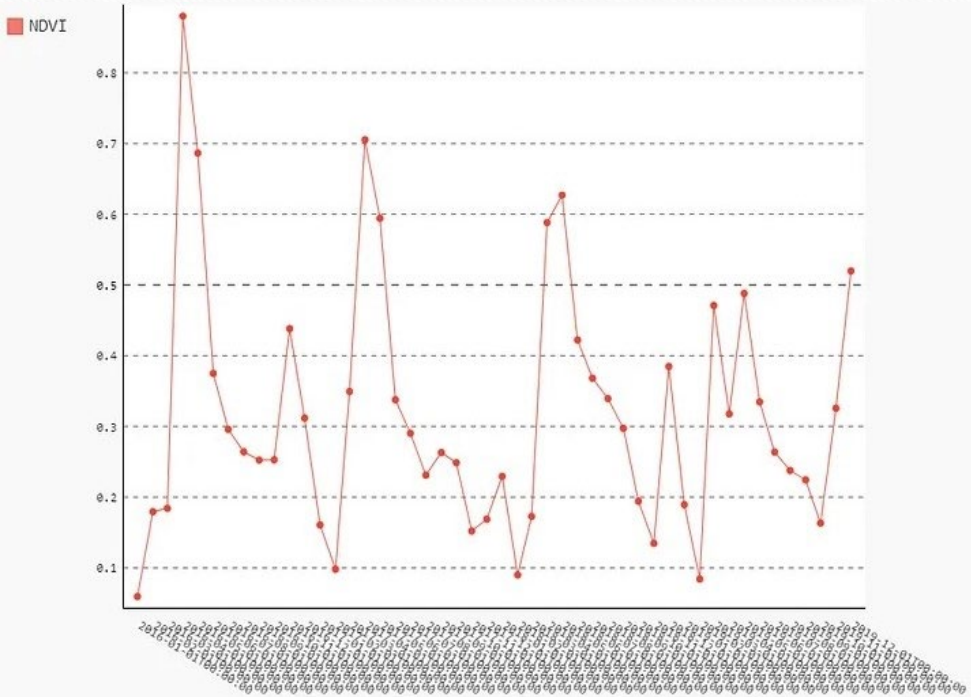
- As you can see, there is overlap and what's going on in there is understudied.
  - For that reason, I'm actively seeking funding options to study it, using remote sensing and machine learning.

How does remote sensing come into play?

(Also, machine learning.)

Remote Sensing, I

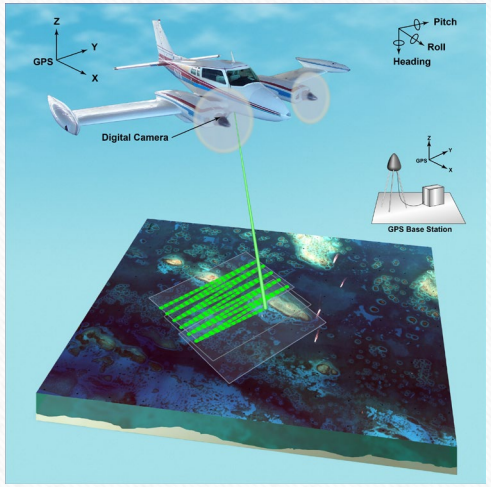
- Satellite imagery
  - Spatial resolution not limited to 30m, 10m - 3 to .5 m available
  - Spatial coverage for a large N and larger scale variables (e.g., slope, aspect, lat/long)
  - Harmonic (time series) NDVI
    - Using harmonic NDVI, I would be able to identify inflection points in the time series; these declines in the NDVI signal should correspond to needle retention loss. The expected pattern where SNC is present would be low declines and then flatlining. The trend should be more severe where there is an overlapping disturbance.
    - The 5-year mean/median NDVI for each site-type could be compared, which should correspond to area around the crown and/or central tendency of spectral information. ***It is expected that reduced crown content should be worst with an overlapping disturbance, second worst with SNC alone, and best in the absence of either disturbance.***



(Source: Joao Otavio Nascimento Firigato)

Remote Sensing, II

- Lidar
  - High accuracy in measuring tree characteristics (e.g., height)
  - Free (DOGAMI covers Oregon)
  - Used for tree characteristics (height, diameter, etc.).



(Source: Betsy Boynton, public domain.)

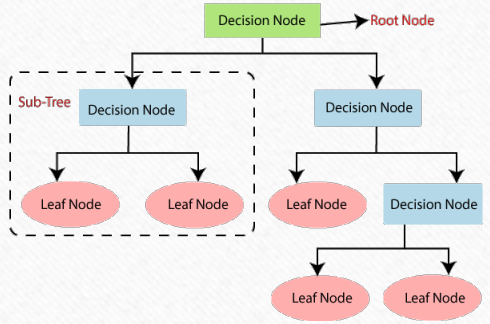
Remote Sensing, III

- Drone surveying
  - Higher spatial resolution (e.g., 3 cm) to capture within plot variation
  - See next slide for use of collected data.

(Source: Todd Hoefen, public domain.)

Machine Learning

- Binary classification, not multi-class
  - If SNC+DFB > SNC, then multiple predictor variables can explain the difference between classifications at the level of individual trees, using drone survey data.
  - (Some trees will bear marks of two disturbances; some will have one.)
- Prediction of SNC prior to chlorosis
  - Response variable of later survey is Y/N (yellow-not yellow).
  - Predictors from earlier survey include tree characteristics and NDVI.



(Source: https://www.javatpoint.com/machine-learning-decision-tree-classification-algorithm)

Citations

- Agne, Michelle C., et al. "Interactions of predominant insects and diseases with climate change in Douglas-fir forests of western Oregon and Washington, USA." Forest Ecology and Management 409 (2018): 317-332.
- Maguire, Douglas A., et al. "Growth of young Douglas-fir plantations across a gradient in Swiss needle cast severity." Western Journal of Applied Forestry 17.2 (2002): 86-95.
- Ritóková, Gabriela, et al. "Douglas-fir foliage retention dynamics across a gradient of Swiss needle cast in coastal Oregon and Washington." Canadian Journal of Forest Research 51.4 (2021): 573-582.
- Shaw, David C., et al. "Persistence of the Swiss needle cast outbreak in Oregon Coastal Douglas-fir and new insights from research and monitoring." Journal of forestry 119.4 (2021): 407-421.

Q & A

- Questions? Feedback?