# Unlocking the FIA Database: applications to US forest health monitoring

*Master's Thesis Defense with Hunter Stanke*

# Acknowledgements






# Why are we here?



***Management & Policy***

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Management &
Policy

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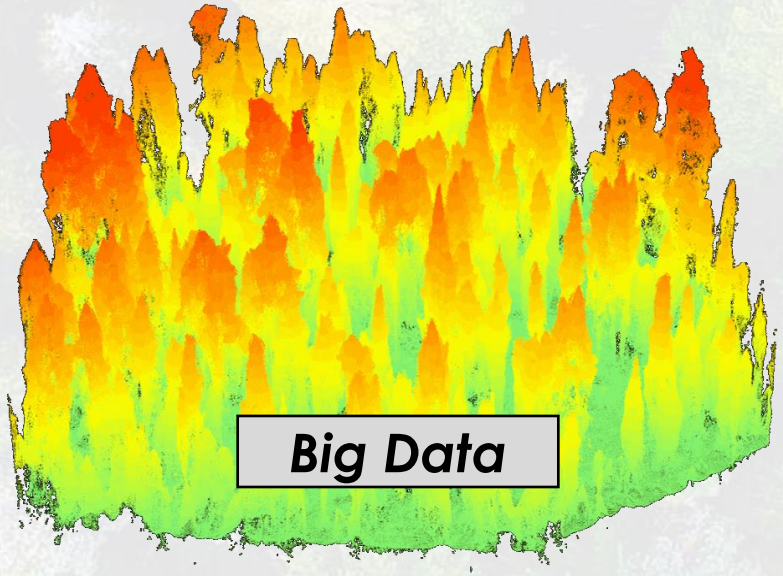



Management & Policy

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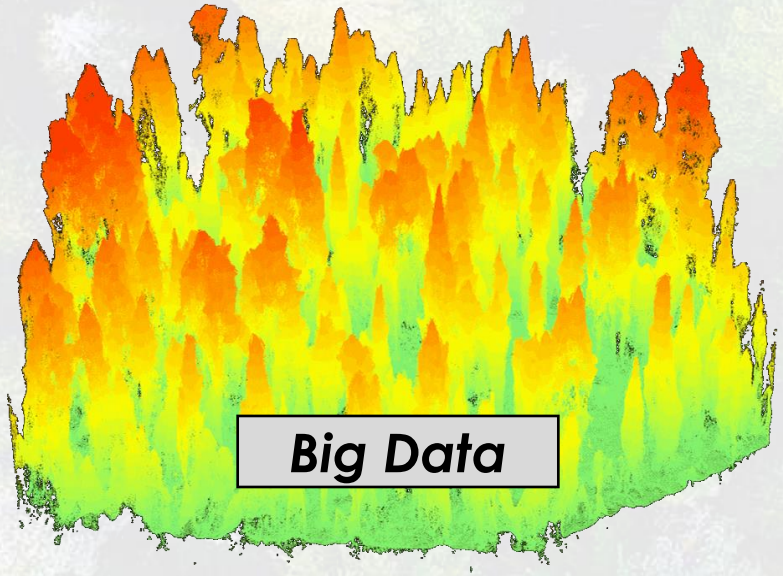



*Management & Policy*

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*Inference & Prediction*

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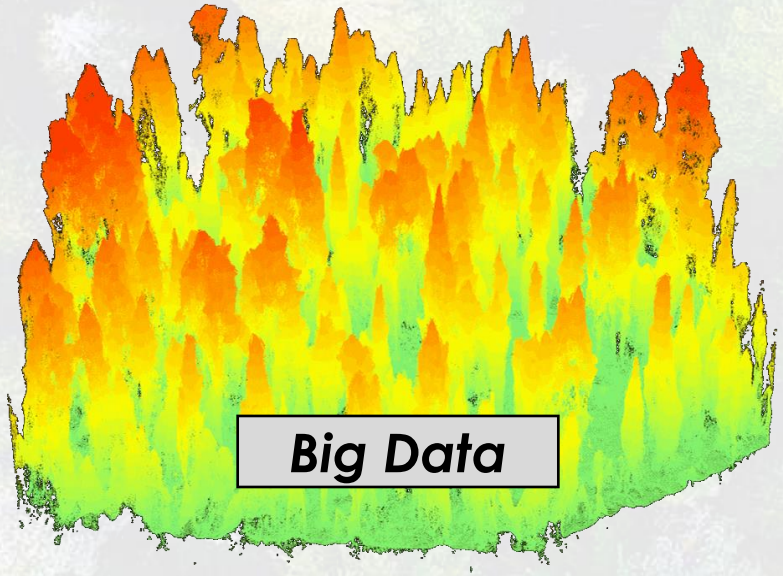


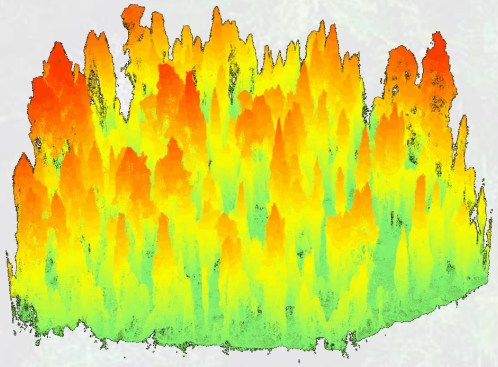


*Management & Policy*

# Objectives

***Use big data to solve big problems***

***Connect people to big data***



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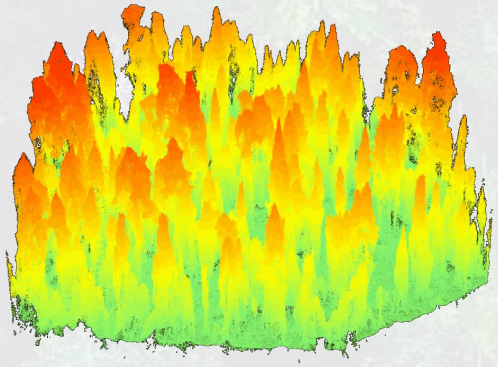
- *Unlocking the Forest Inventory and Analysis Database in R*



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- *Impact of disturbance and climate patterns*

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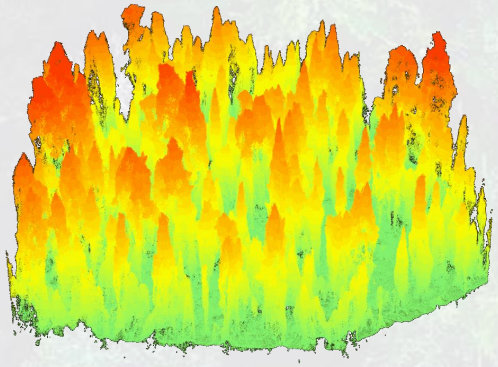

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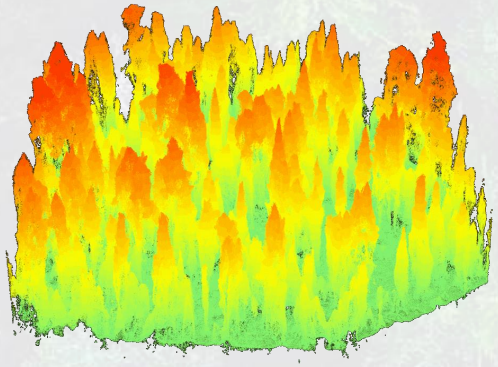

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*Connecting people to big data*

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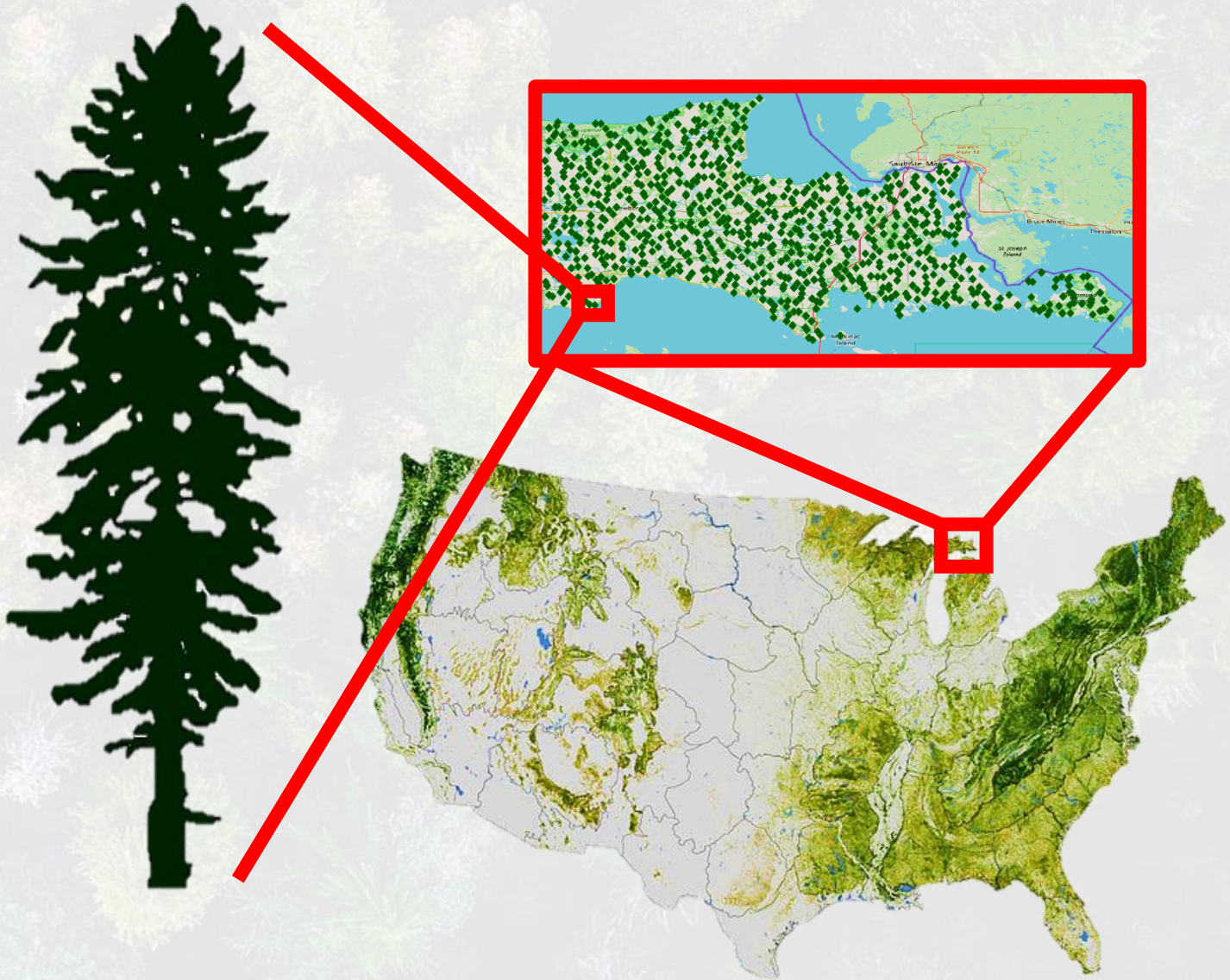

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# The FIA Database

*Connecting people to big data*

**The issue ..... *complexity*.**

# The FIA Database

*Connecting people to big data*

```
    end) non_zero_plots,
  grp_by_attrib
from (SELECT SUM((COALESCE(TREE.TPA_UNADJ * CASE
                WHEN TREE.DIA IS NULL THEN
                 POP_STRATUM.ADJ_FACTOR_SUBP
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                 CASE LEAST(TREE.DIA, 5 - 0.001)
                  WHEN TREE.DIA THEN
                   POP_STRATUM.ADJ_FACTOR_MICR
                  ELSE
                   CASE
                    LEAST(TREE.DIA,
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                     WHEN TREE.DIA THEN
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                      POP_STRATUM.ADJ_FACTOR_MACR
                   END
                 END
               END,
               0))) AS y_hid_adjusted, -- edit to ref_pop_attribute.sql_query
    peu.cn estn_unit_cn, -- addition to ref_pop_attribute.sql_query
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   &grp_by_attrib grp_by_attrib -- addition to ref_pop_attribute.sql_query
 FROM &FIADB_SCHEMA.POP_EVAL_GRP PEG
 JOIN &FIADB_SCHEMA.POP_EVAL_TYP PET
  ON (PET.EVAL_GRP_CN = PEG.CN)
 JOIN &FIADB_SCHEMA.POP_EVAL PEV
  ON (PEV.CN = PET.EVAL_CN)
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| | | | |
|---|---|---|---|
| 3.1.38 | VOLCFNET | Net cubic-foot volume | NUMBER(11,6) |
| 3.1.39 | VOLCFGRS | Gross cubic-foot volume | NUMBER(11,6) |
| 3.1.40 | VOLCSNET | Net cubic-foot volume in the sawlog portion of a sawtimber tree | NUMBER(11,6) |
| 3.1.41 | VOLCSGRS | Gross cubic-foot volume in the sawlog portion of a sawtimber tree | NUMBER(11,6) |
| 3.1.42 | VOLBFNET | Net board-foot volume in the sawlog portion of a sawtimber tree | NUMBER(11,6) |
| 3.1.43 | VOLBFGRS | Gross board-foot volume in the sawlog portion of a sawtimber tree | NUMBER(11,6) |
| 3.1.44 | VOLCFSND | Sound cubic-foot volume | NUMBER(11,6) |
| 3.1.45 | GROWCFGS | Net annual merchantable cubic-foot growth of a growing-stock tree on timberland | NUMBER(11,6) |
| 3.1.46 | GROWBFSL | Net annual merchantable board-foot growth of a sawtimber tree on timberland | NUMBER(11,6) |
| 3.1.47 | GROWCFAL | Net annual sound cubic-foot growth of a live tree on timberland | NUMBER(11,6) |

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| [illegible].1 | VOLCSGRS | C[illegible] cubic-foot volum[illegible]he s[illegible]g portion of a sa[illegible]er tree | NUMBER(11,6) |
| [illegible].2 | VOLBFNET | N[illegible]ard-foot volume[illegible] sawlog | NUMBER(11,6) |
| | VOLBFGRS | [illegible]ee | NUMBER(11,6) |
| | VOLCFSND | | NUMBER(11,6) |
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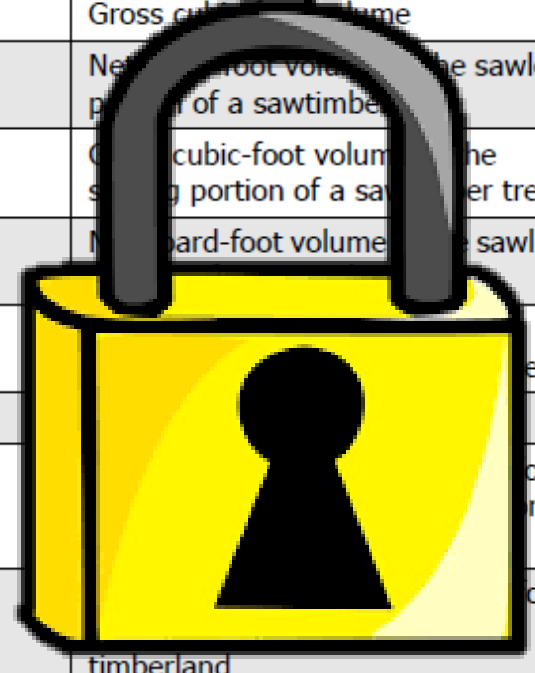

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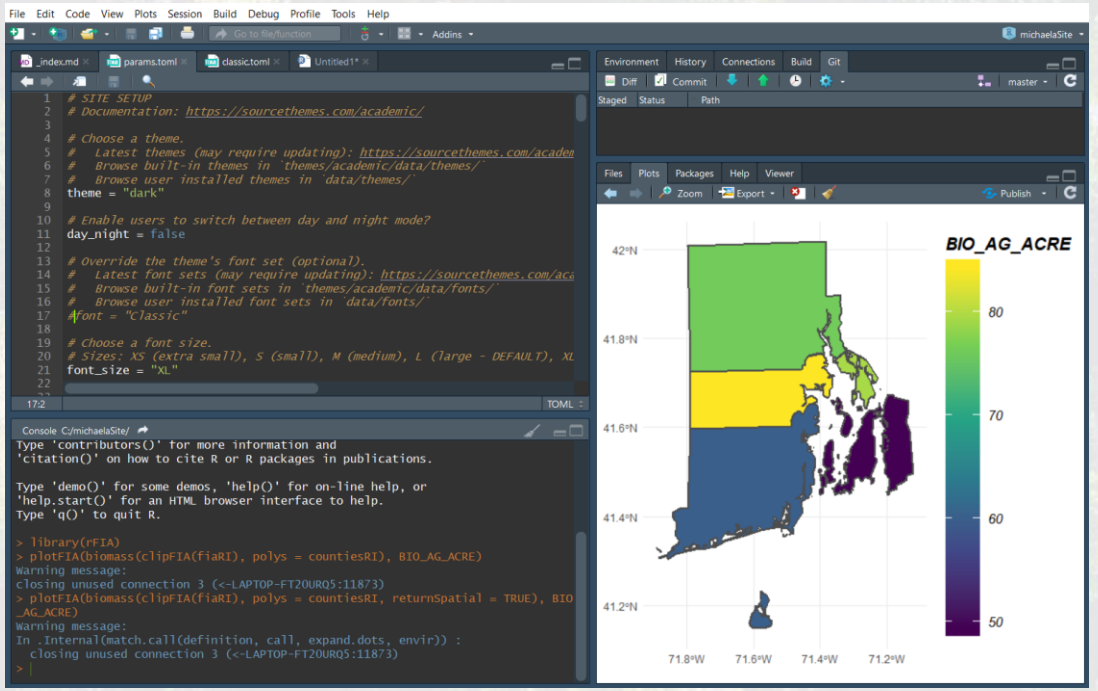
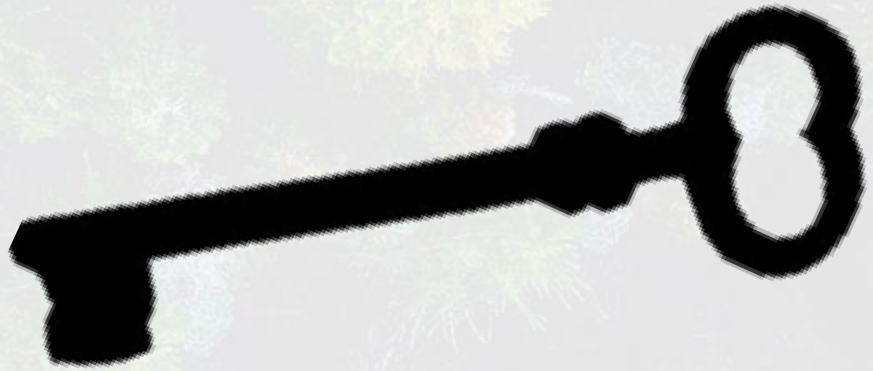
*Connecting people to big data*

- Open source package for **R**



# Enter, `rFIA`

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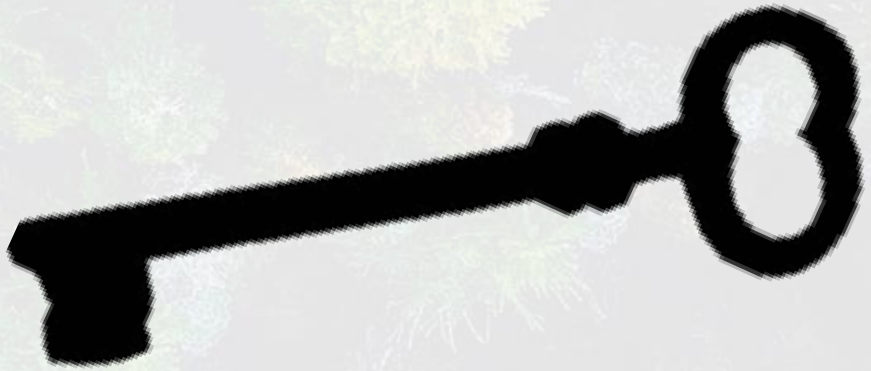
- Open source package for **R**
- Easy to use, but powerful
- Space-time estimation made easy



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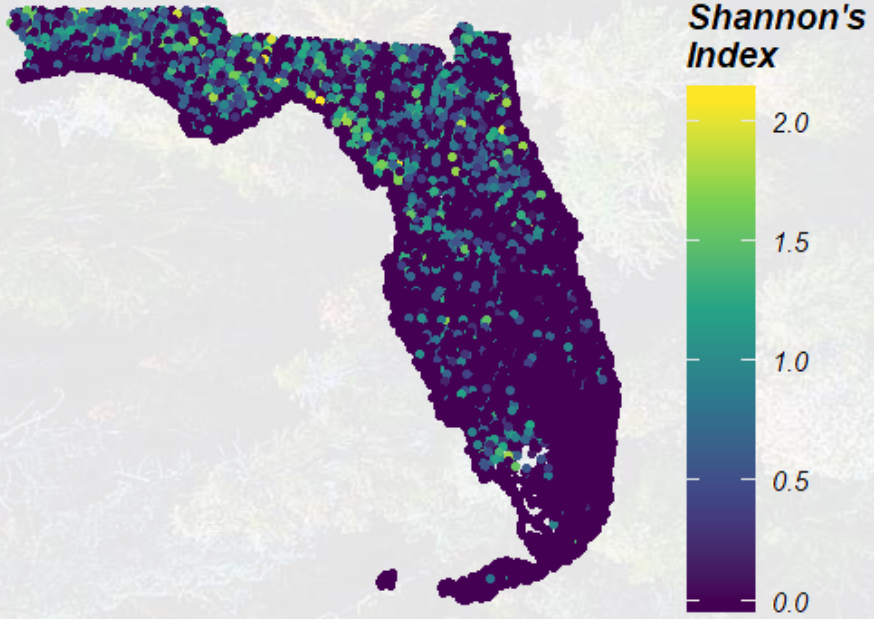


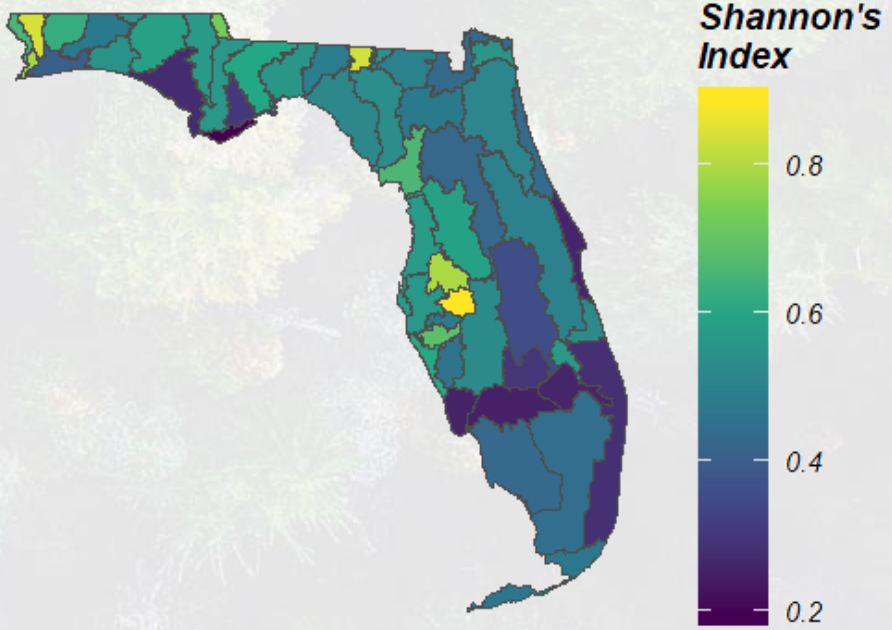

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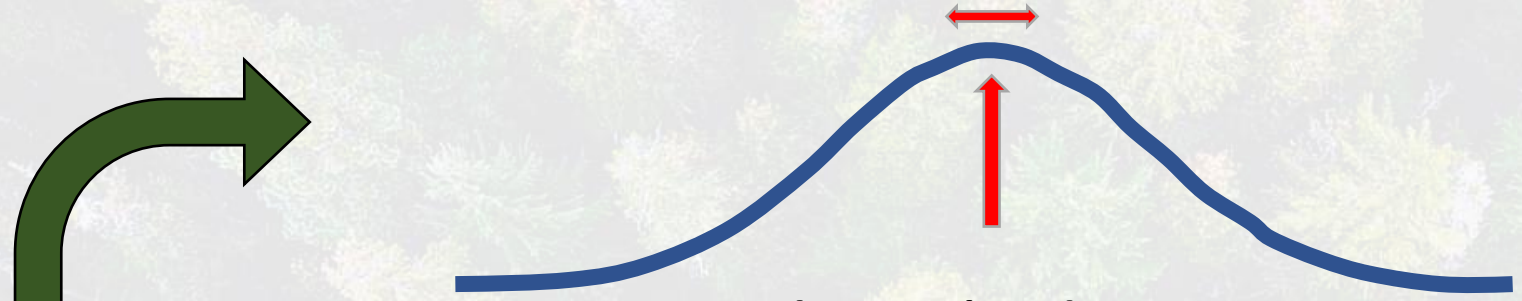


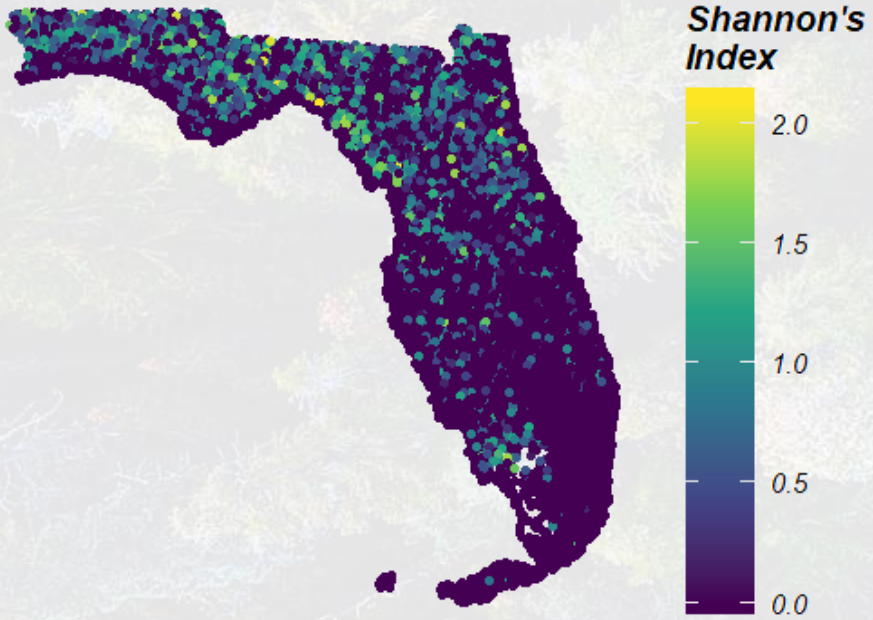


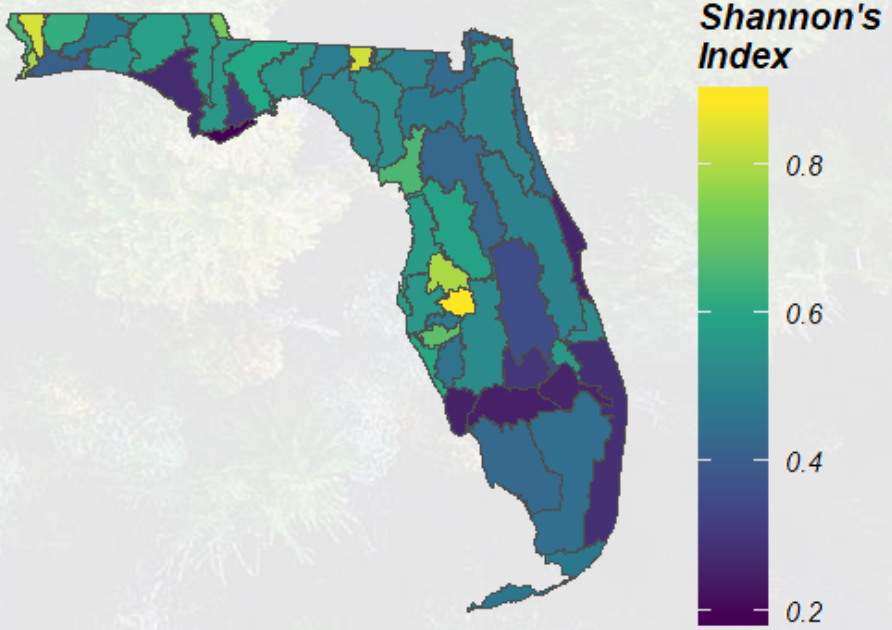

# What can rFIA do?

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$$y_{hid} = \frac{\sum_j^4 \sum_t y_{hijt} \delta_{hijtd}}{a_o \bar{p}_{oh}} + \frac{\sum_j^4 \sum_t y'_{hijt} \delta'_{hijtd}}{a'_o \bar{p}'_{oh}}$$

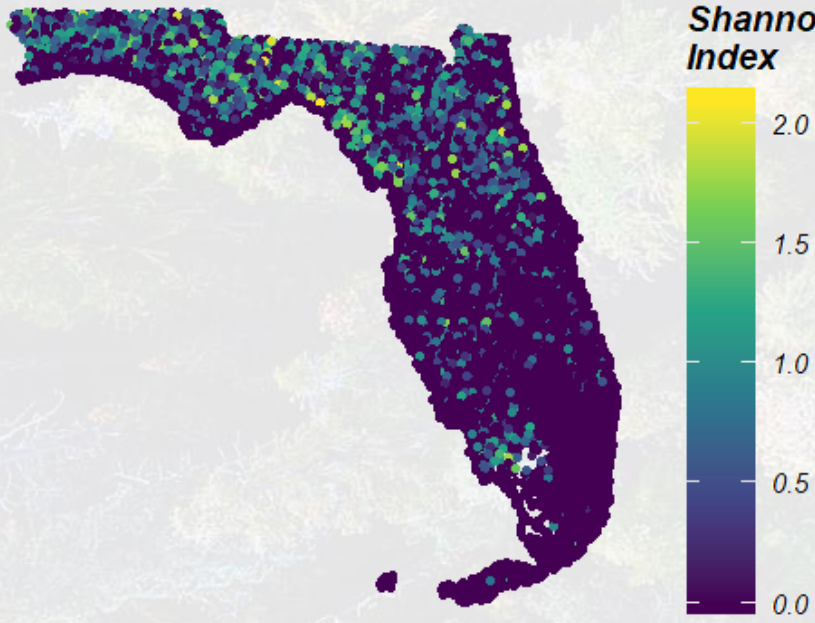
$$v(\hat{R}_{dd'}) = \frac{1}{\hat{X}_{d'}^2}\left[v(\hat{Y}_d) + \hat{R}_{dd'}^2 v(\hat{X}_{d'}) - 2\hat{R}_{dd'}\text{cov}(\hat{Y}_d, \hat{X}_{d'})\right] \quad v(\hat{Y}_d) = \frac{A_T^2}{n}\left[\sum_h^H W_h n_h v(\overline{Y_{hd}}) + \sum_h^H (1 - W_h)\frac{n_h}{n} v(\overline{Y_{hd}})\right]$$

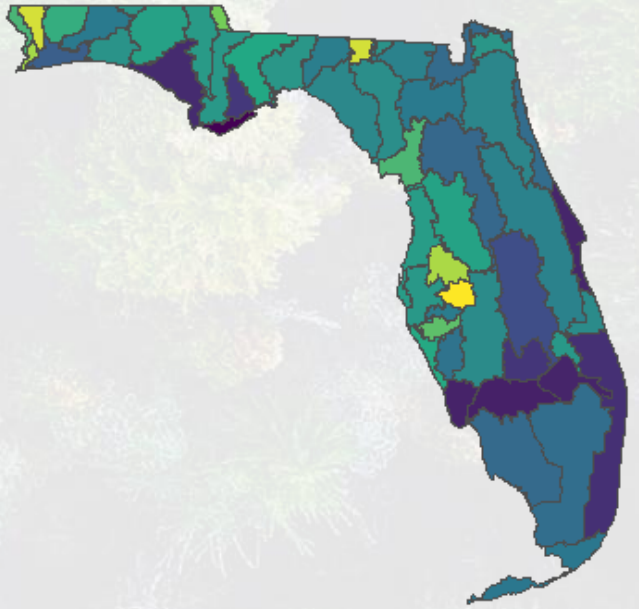
$$\text{cov}(\hat{Y}_d, \hat{X}_{d'}) = \frac{A_T^2}{n}\left[\sum_h^H W_h n_h \text{cov}(\overline{Y_{hd}}, \overline{X_{hd'}}) + \sum_h^H (1 - W_h)\frac{n_h}{n}\text{cov}(\overline{Y_{hd}}, \overline{X_{hd'}})\right]$$

$$\overline{Y_{hd}} = \frac{\sum_i^{n_h} y_{hid}}{n_h} \qquad \hat{R}_{dd'} = \frac{\hat{Y}_d}{\hat{X}_{d'}} = \frac{\sum_h^H W_h \overline{Y_{hd}}}{\sum_h^H W_h \overline{X_{hd'}}}$$

$$v(\overline{Y_{hd}}) = \frac{\sum_i^{n_h} y_{hid}^2 - n_h \overline{Y_{hd}}^2}{n_h(n_h - 1)} \qquad \hat{Y}_d = A_T \sum_h^H W_h \overline{Y_{hd}} = A_T \overline{Y_d}$$

$$v(\overline{P_{hd}}) = \frac{\sum_i^{n_h} P_{hid}^2 - n_h \overline{P_{hd}}^2}{n_h(n_h - 1)}$$

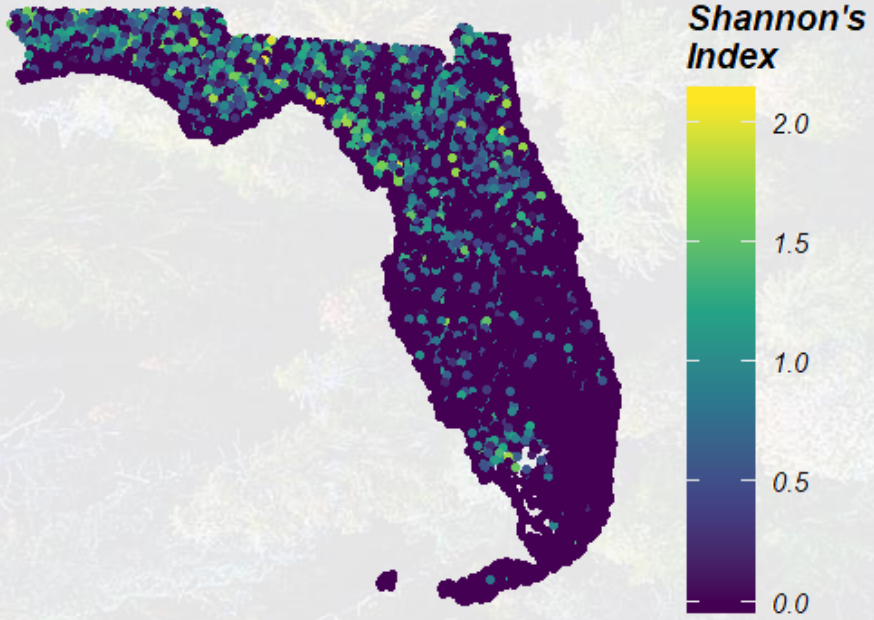


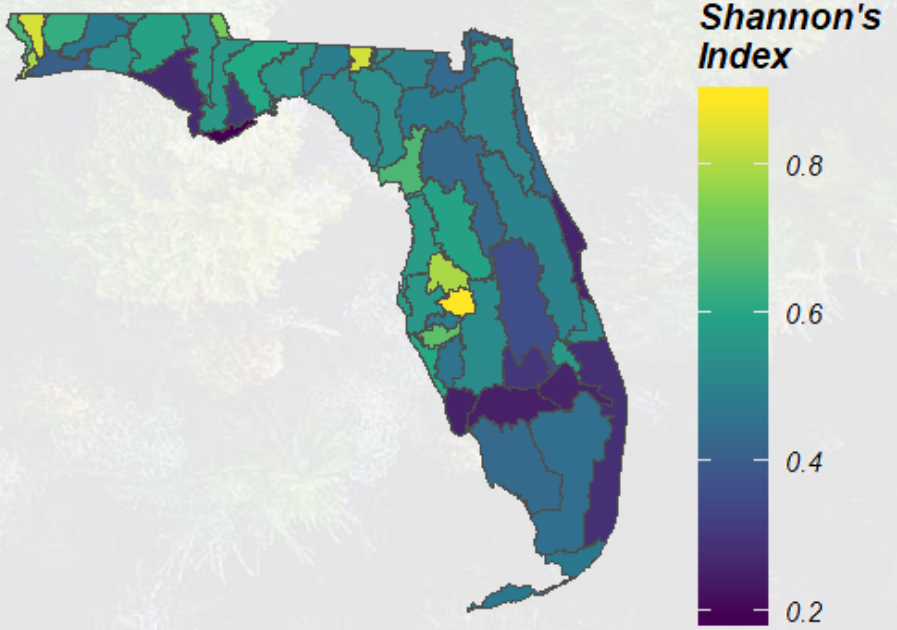



# What can rFIA do?

*Connecting people to big data*

```
fl <- getFIA("FL")
```



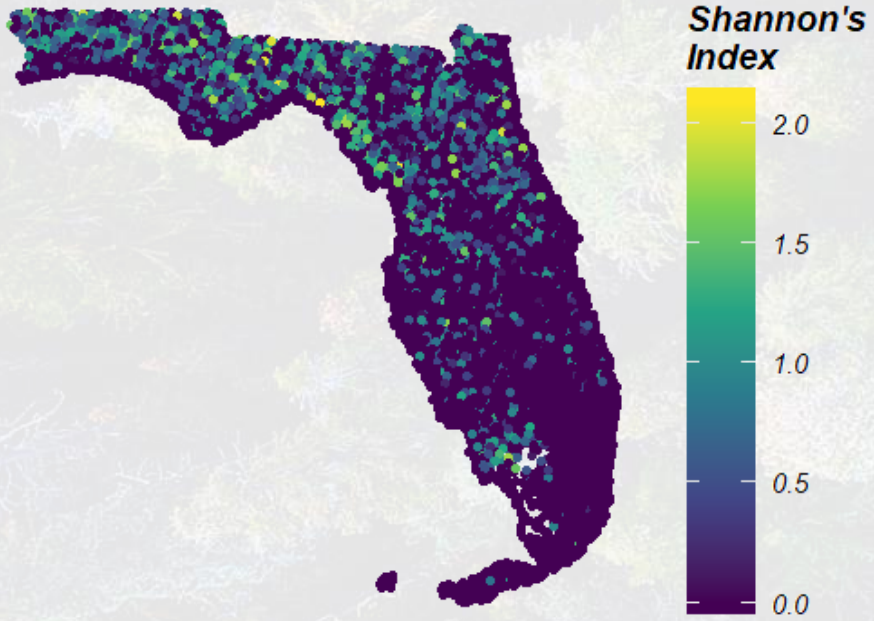



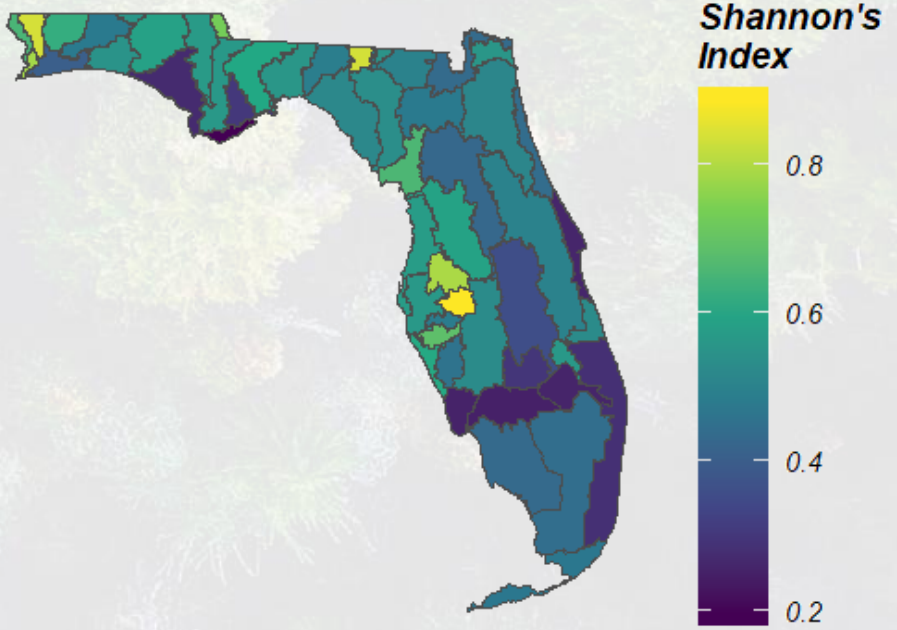
# What can rFIA do?

*Connecting people to big data*

```
fl <- getFIA("FL")

diversity(fl)
```



# What can rFIA do?

*Connecting people to big data*

***vs.***

Tree abundance

Tree biomass

Species diversity

# What can rFIA do?

*Connecting people to big data*

*Tree abundance*

*Tree biomass*

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Demographic rates

# What can rFIA do?

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*Demographic rates*

Down woody material

Invasive plant coverage

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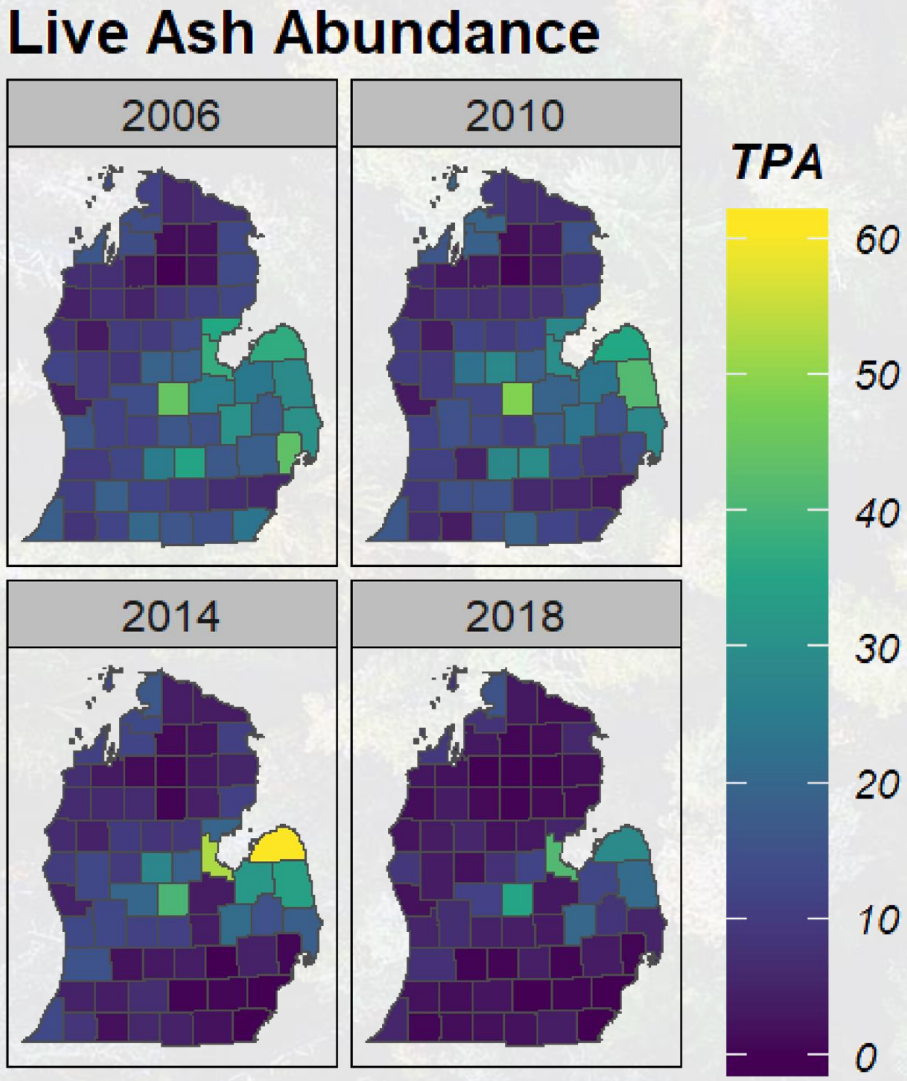
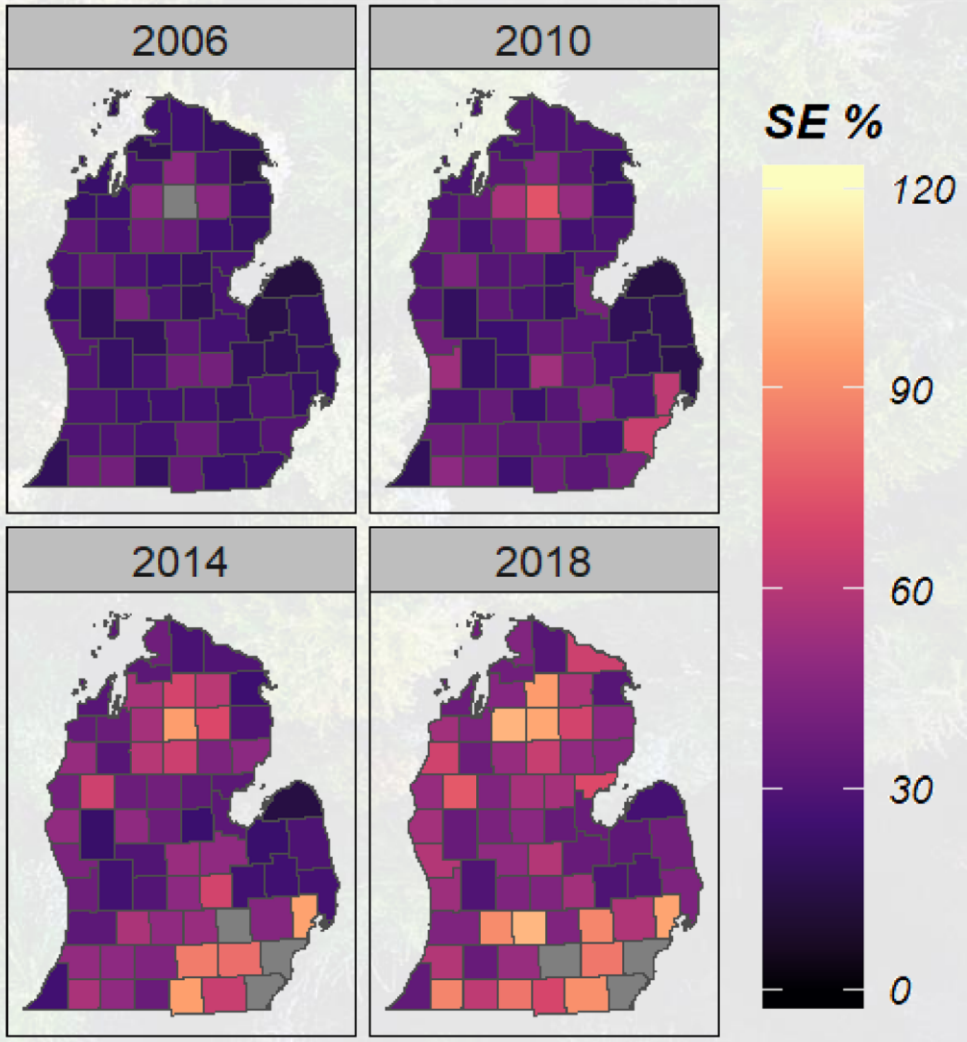


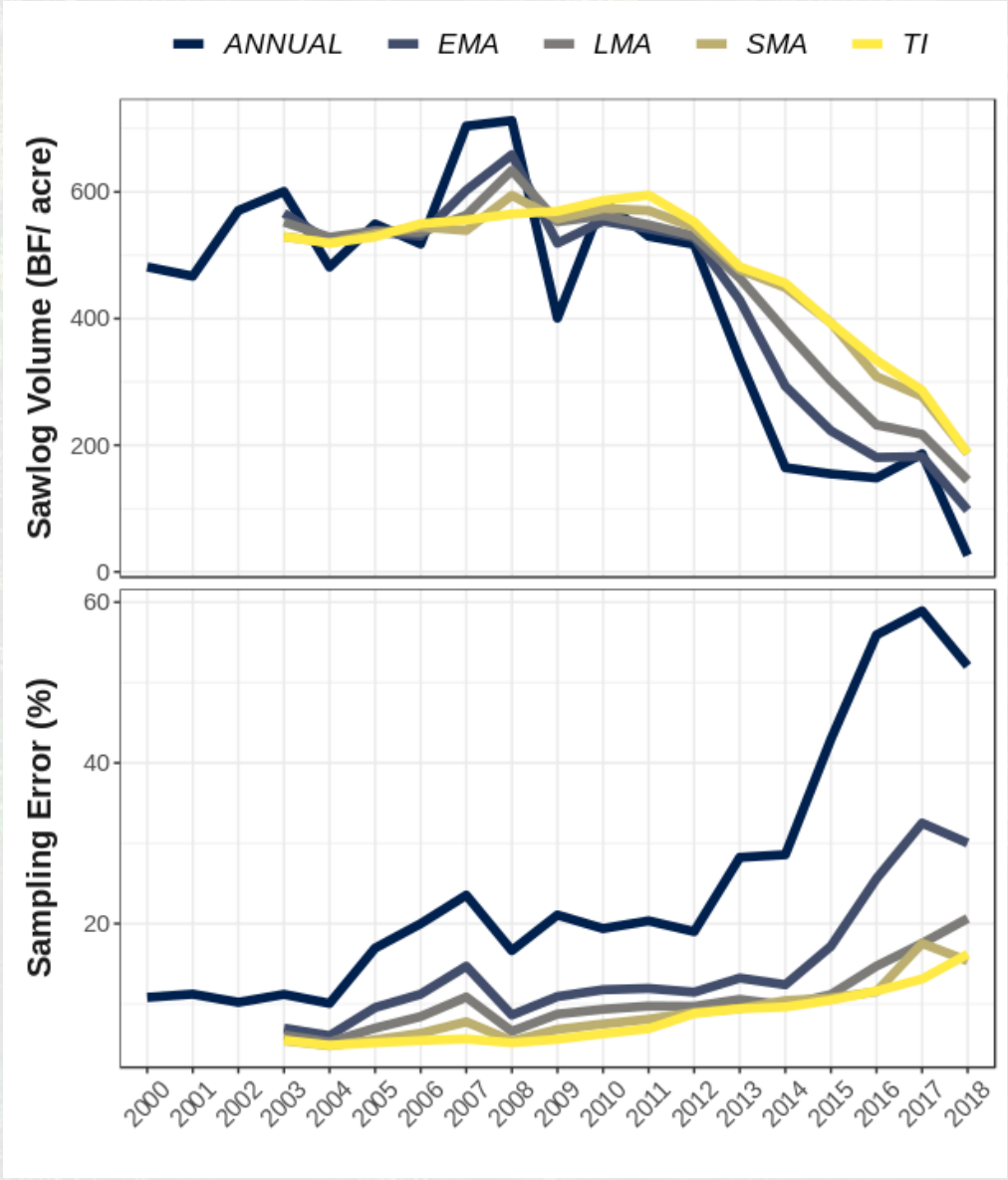



# What can rFIA do?

*Connecting people to big data*

*Large time-lag:*

$$\frac{2016 + 2017 + 2018}{3} = 2018_{est}$$



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*Connecting people to big data*

*Large time-lag:*

$$\frac{2016 + 2017 + 2018}{3} = 2018_{est}$$

*Reduced time-lag:*

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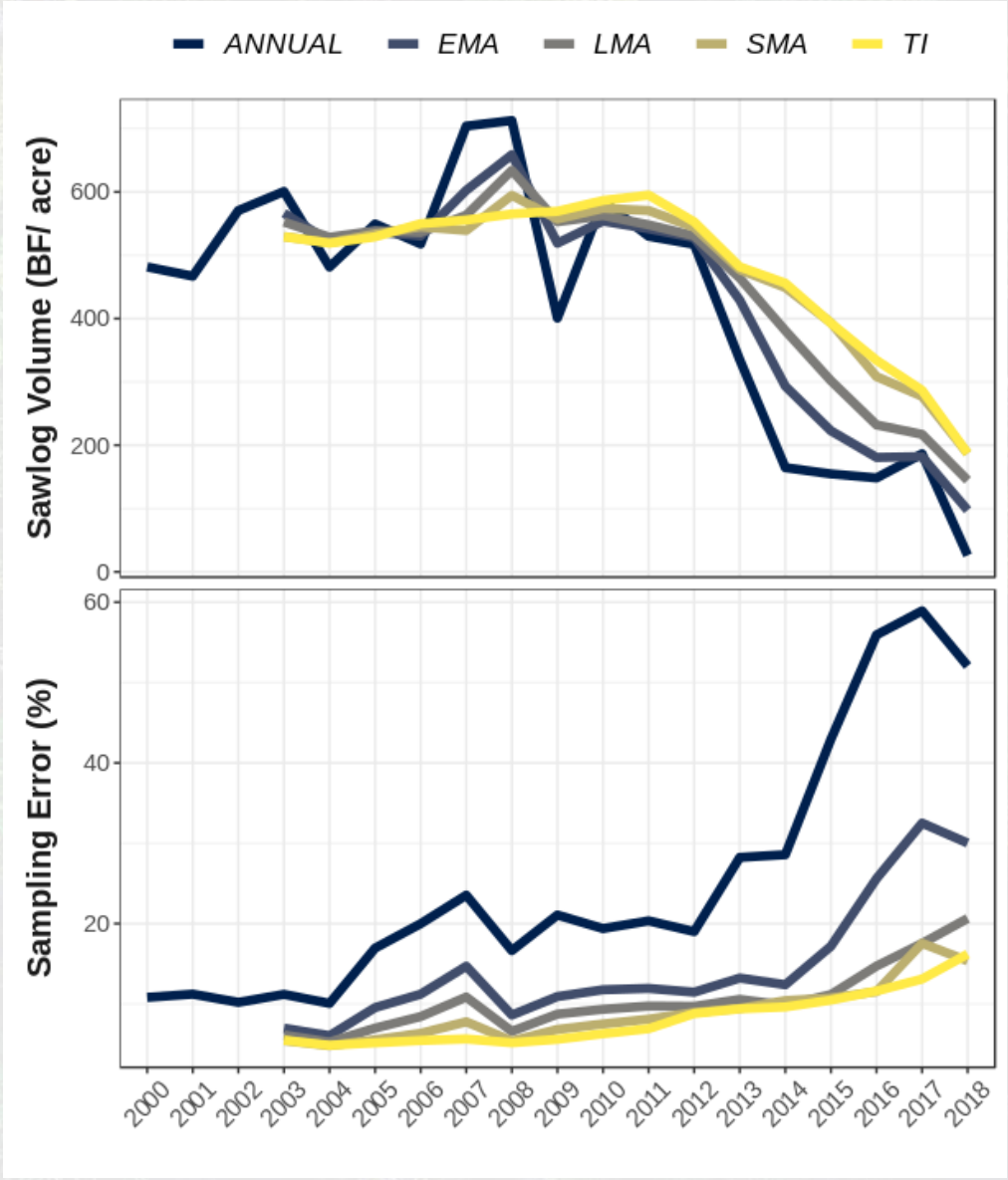
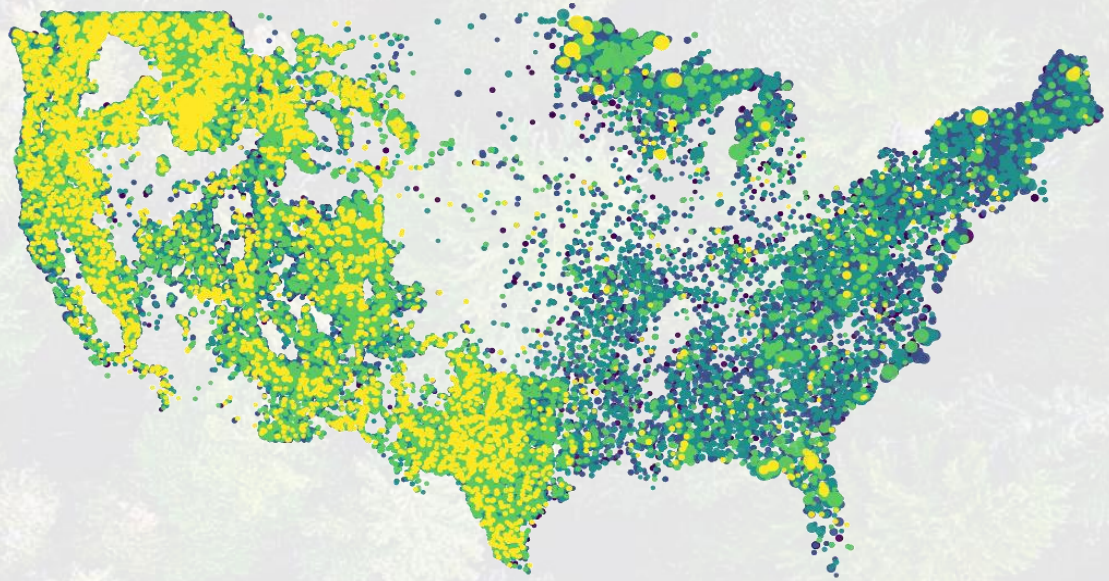


# Why rFIA?

*Connecting people to big data*

- More forest variables than any other FIA tool
- Only public tool to implement alternative estimators
- Flexible, fast, and powerful
- Graphics capabilities



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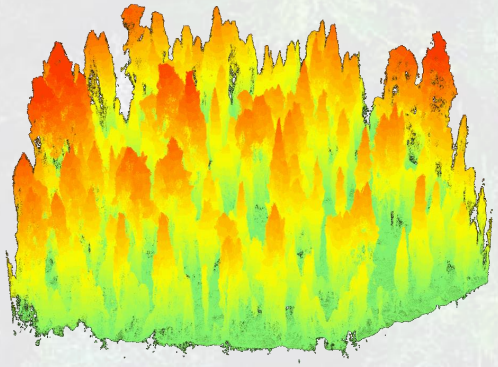

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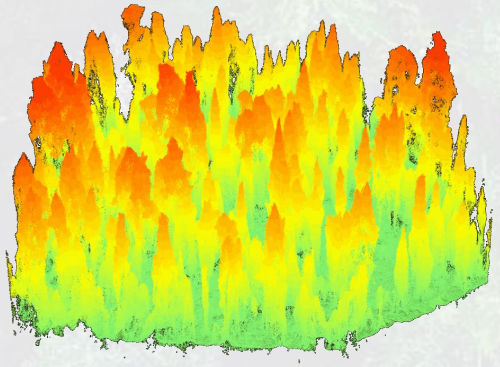
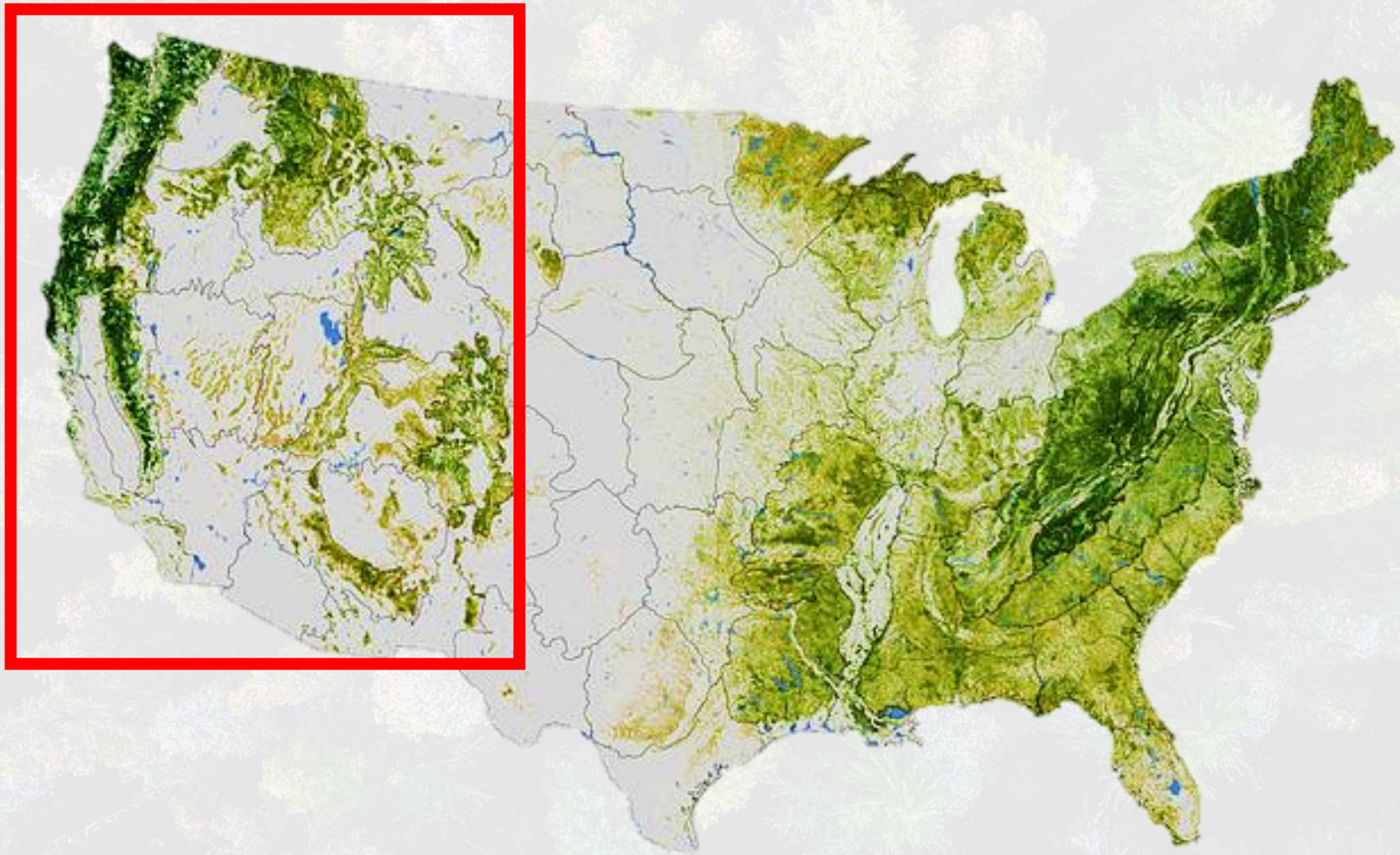


# Western Forests in Flux

*Using big data to solve big problems*




The common thread…

# Western Forests in Flux

*Using big data to solve big problems*

- Shifting *disturbance regimes* and *environmental drivers*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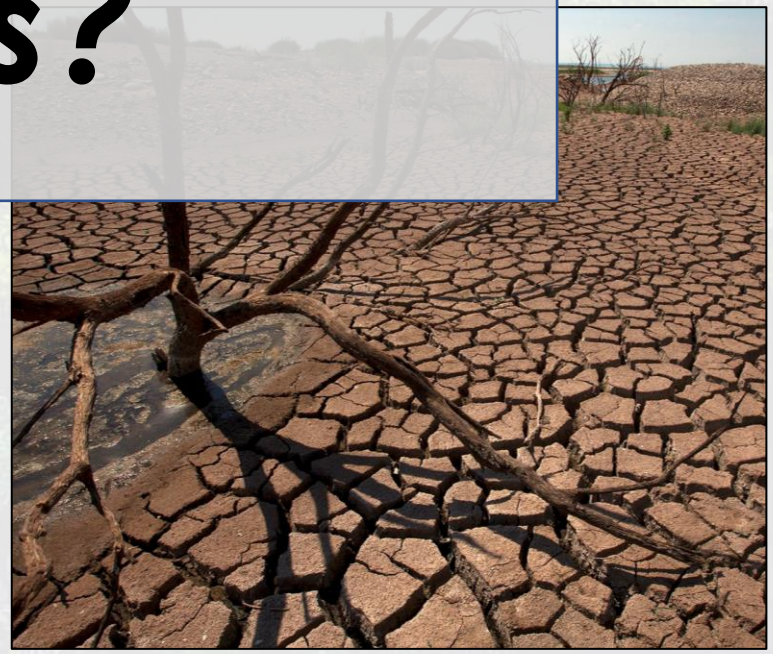
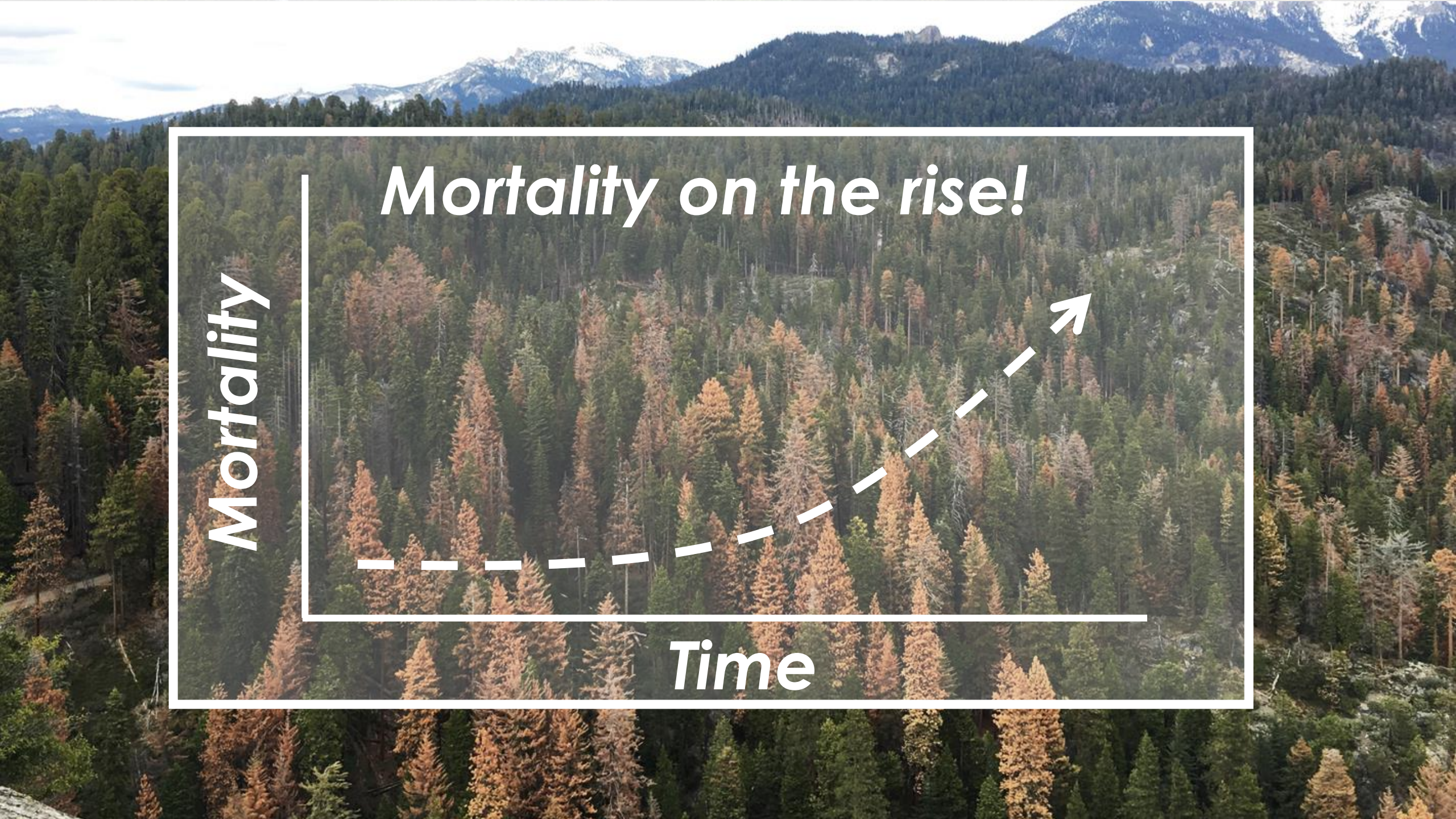
## ***What does this mean for western forests?***

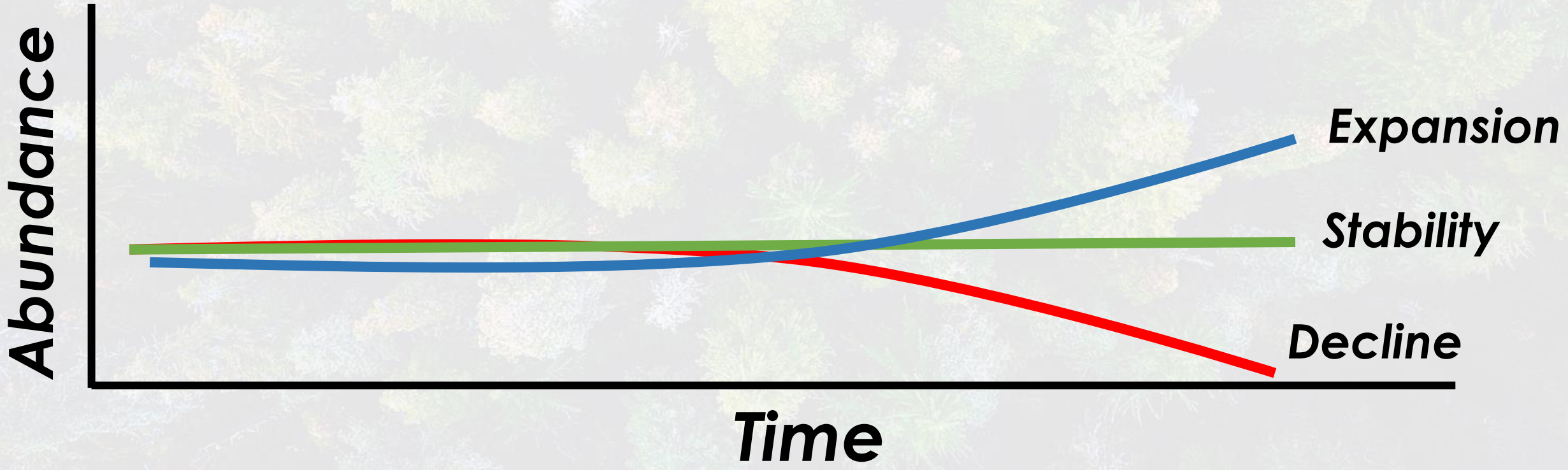




Mortality on the rise!
Mortality
Time

# Mortality ≠ Decline

*Using big data to solve big problems*

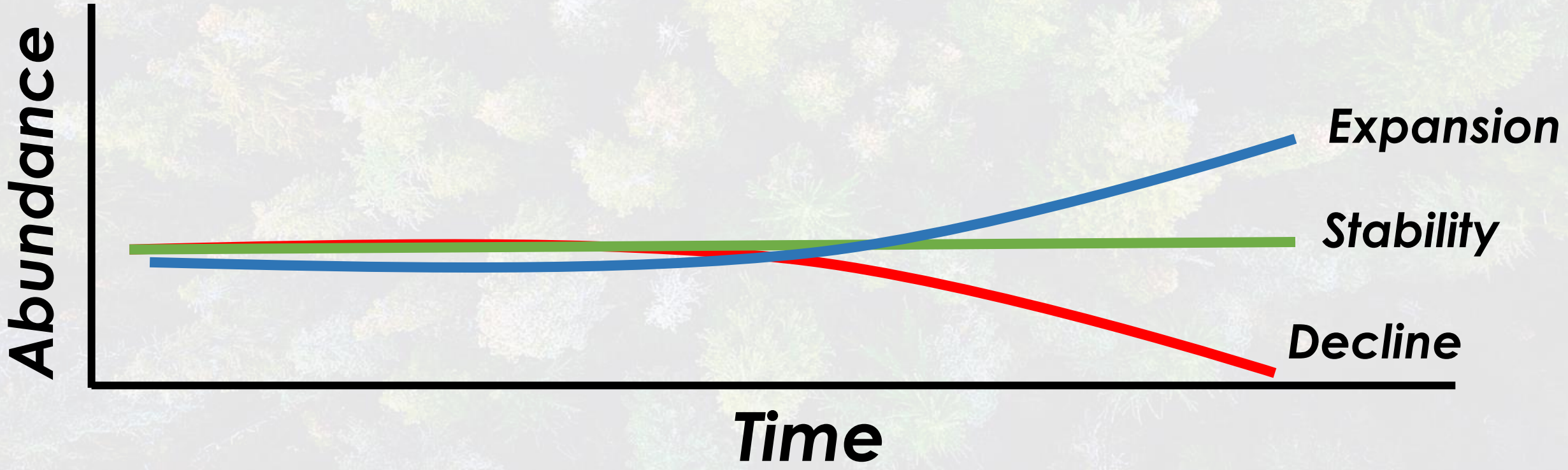
Increased **tree mortality** does NOT indicate **population decline**



# Mortality ≠ Decline

*Using big data to solve big problems*

**Population Performance** = **Growth** + **Recruitment** − **Mortality**

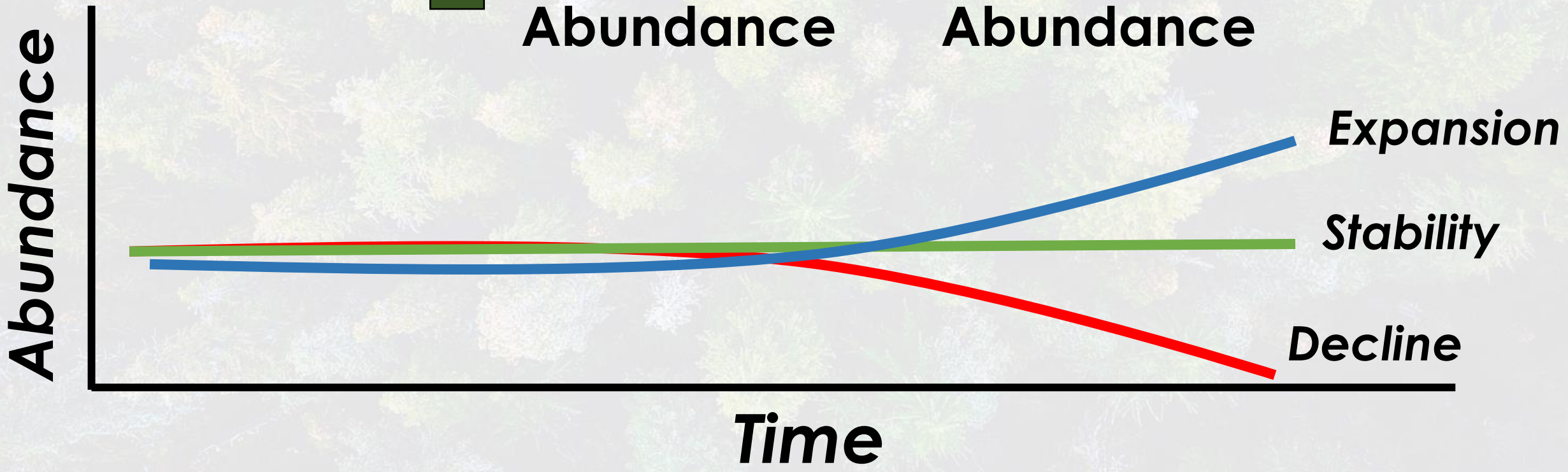


# Mortality ≠ Decline

*Using big data to solve big problems*

**Population Performance** = Growth + Recruitment − Mortality

= **Current Abundance** − **Previous Abundance**



# Mortality ≠ Decline

*Using big data to solve big problems*

***Despite elevated mortality…***

***the status of western tree populations remains unclear.***

# Objectives

*Using big data to solve big problems*

1) **Develop an index of forest population stability that is independent of species traits, stand age, and ecological setting**

# Objectives

*Using big data to solve big problems*

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2) Assess the relative population performance of the 10 most abundant western tree species using FIA

   - ❖ Winners and losers?
   - ❖ Evidence of range shifts?
   - ❖ Climate and disturbance drivers?

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# Forest Stability Index

*Using big data to solve big problems*

***BAA Change***

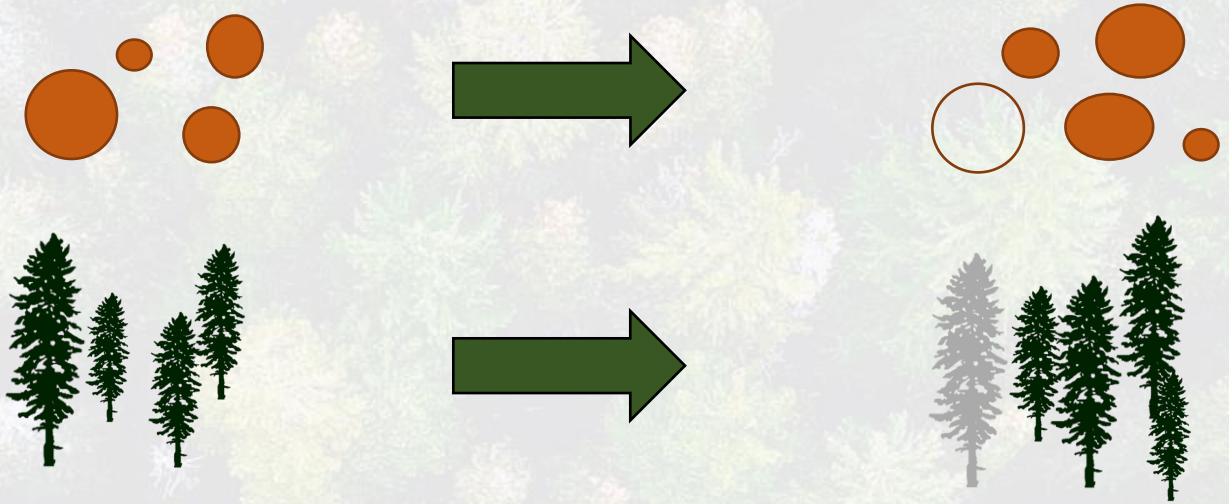
***TPA Change***

# Forest Stability Index

*Using big data to solve big problems*

***BAA Change***

***TPA Change***

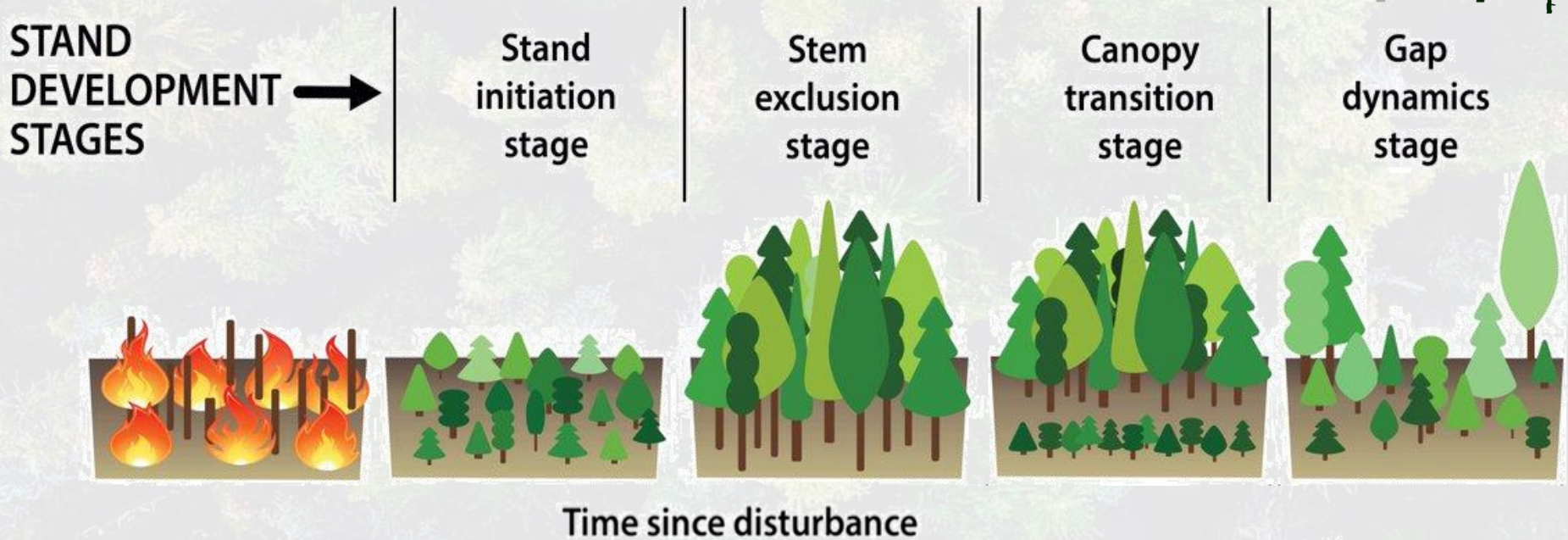


# Forest Stability Index

*Using big data to solve big problems*

***BAA Change***

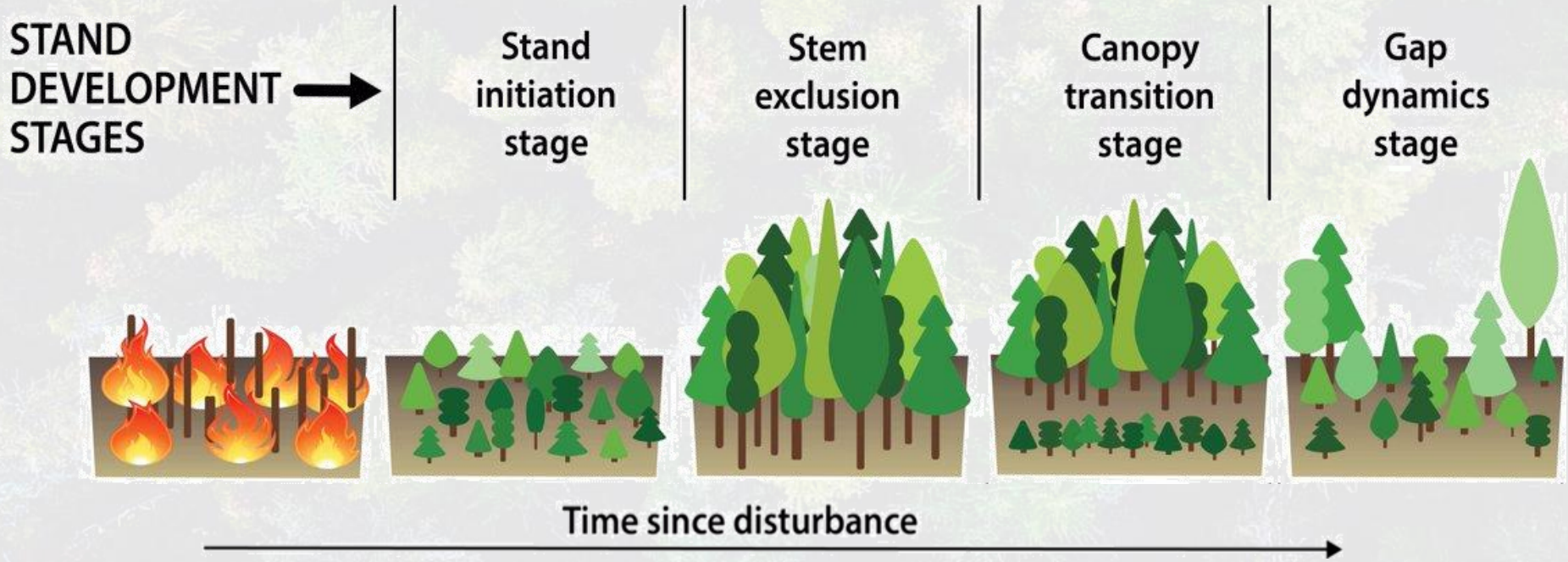
***TPA Change***



# Forest Stability Index

*Using big data to solve big problems*

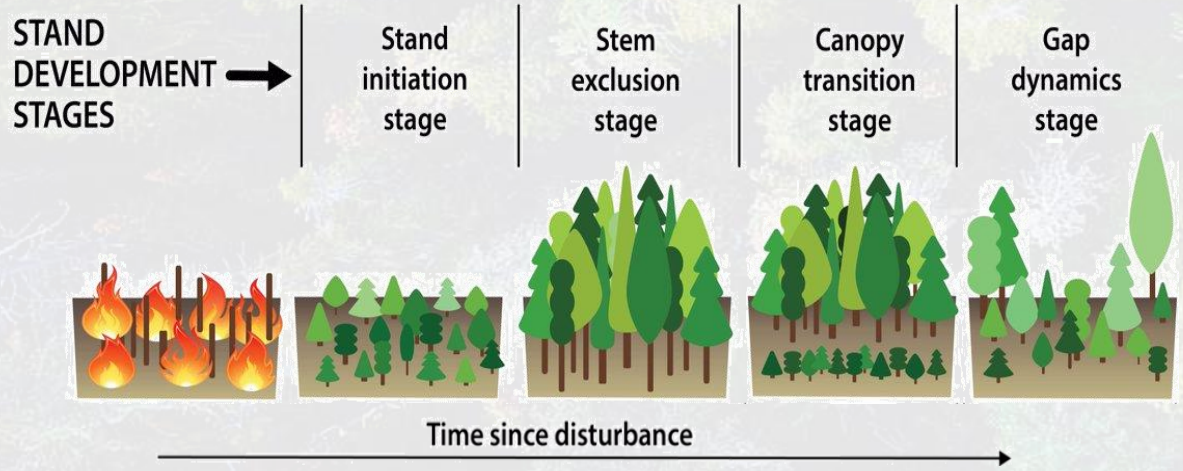
*Responses are offsetting*

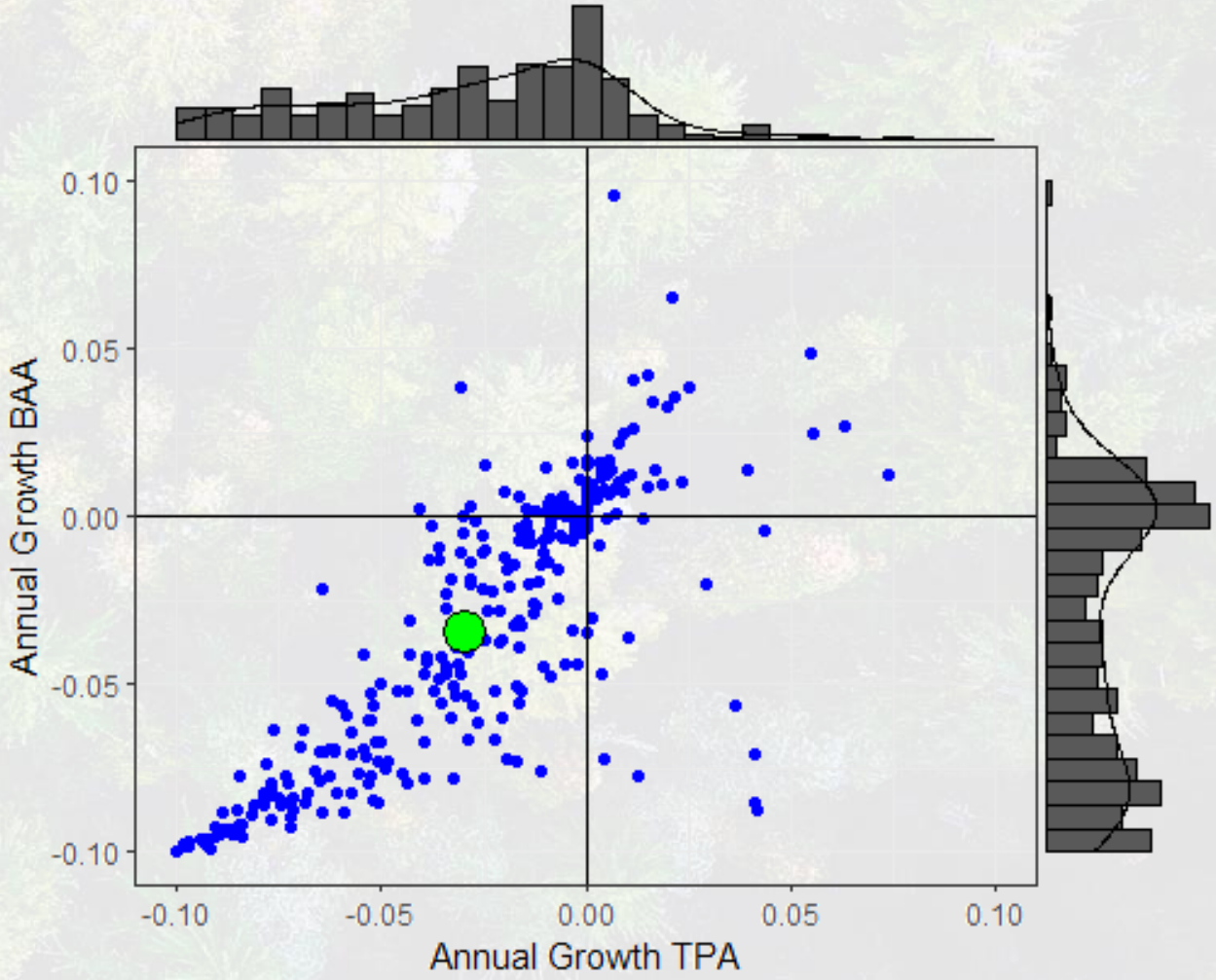



# Forest Stability Index

*Using big data to solve big problems*

- Colorado lodgepole pine
- Each point represents one remeasured plot



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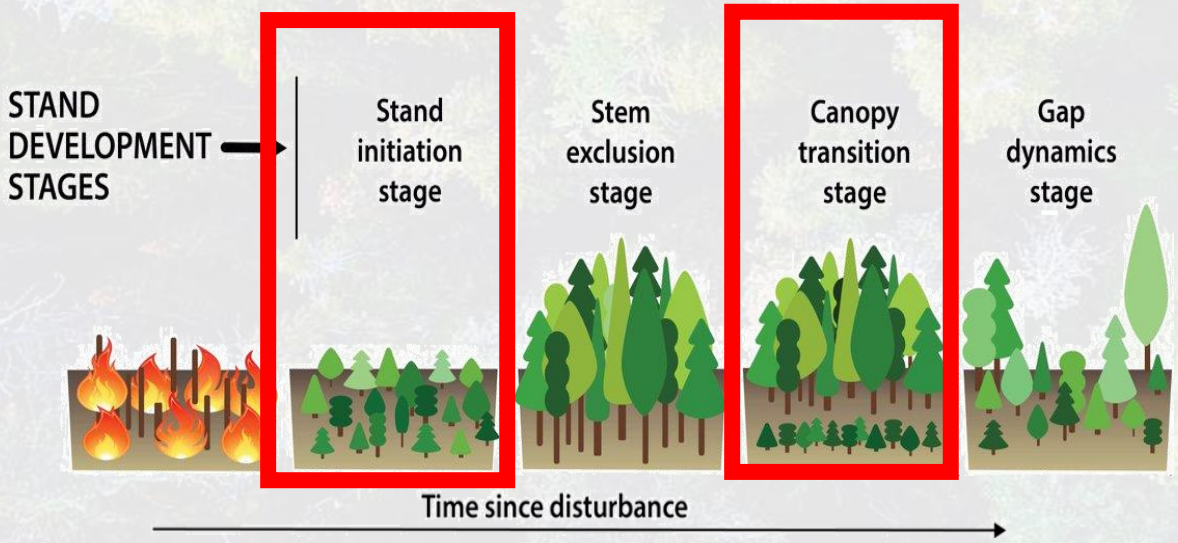


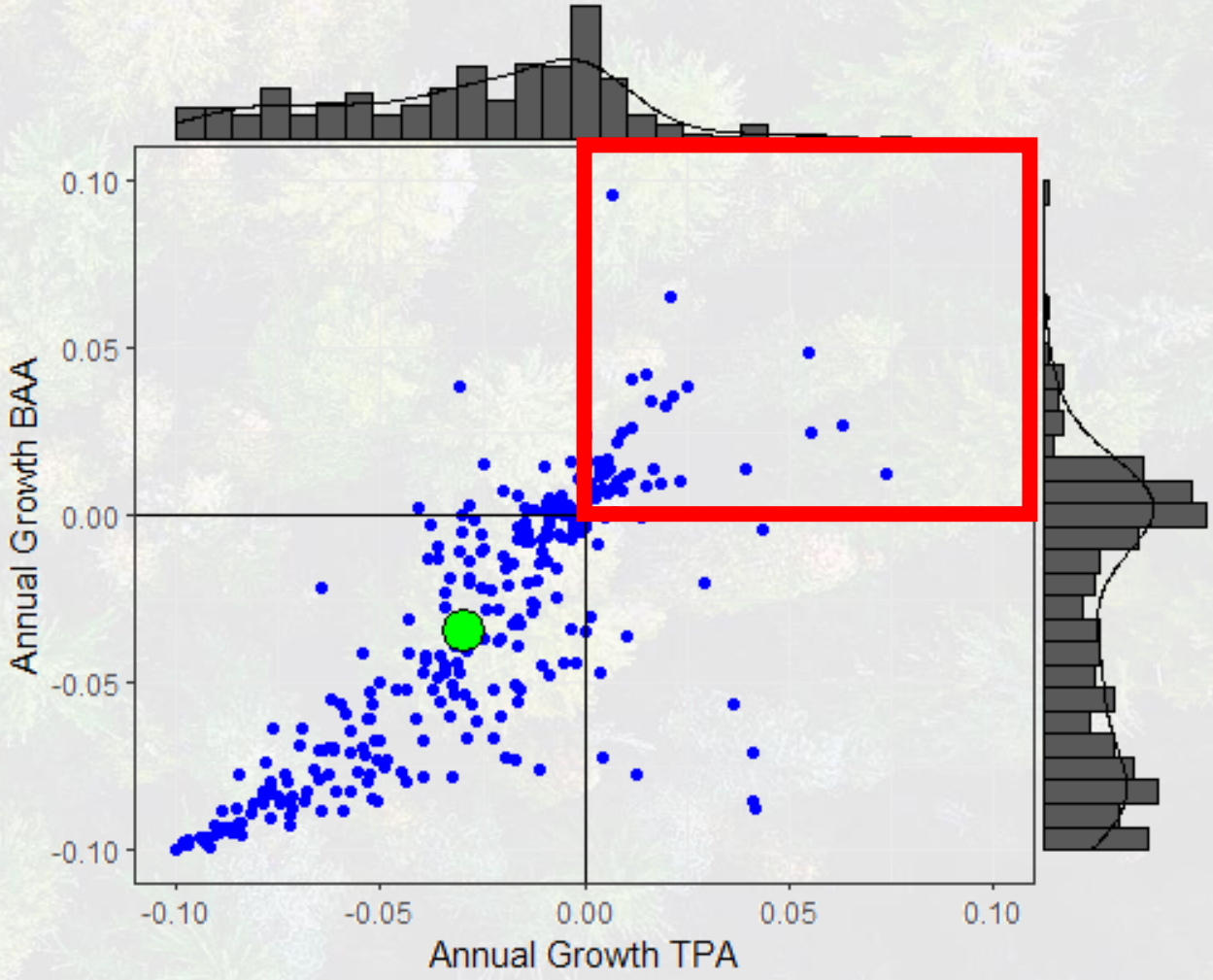

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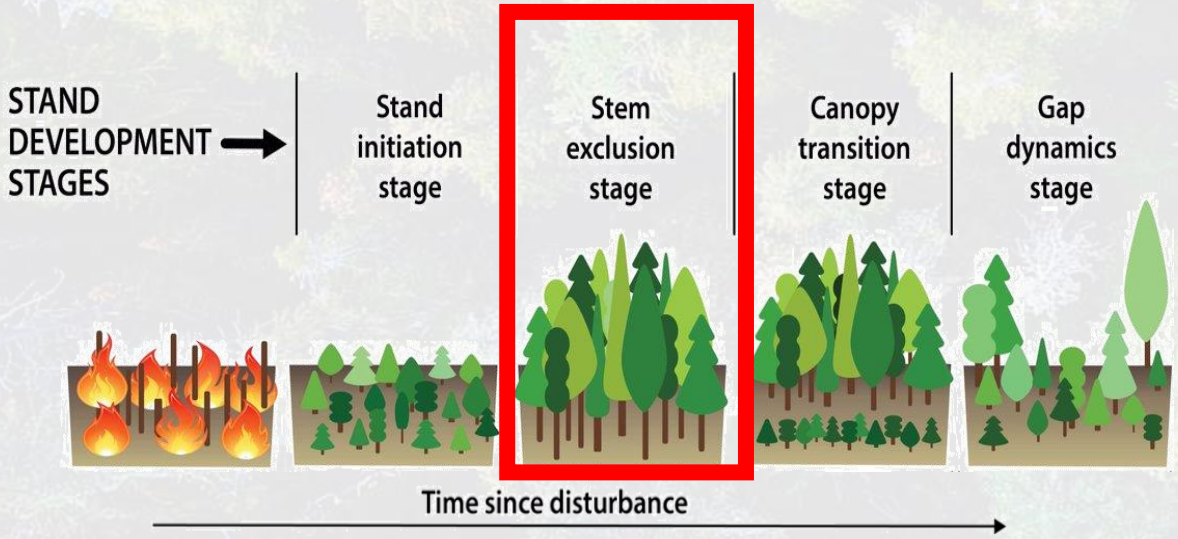


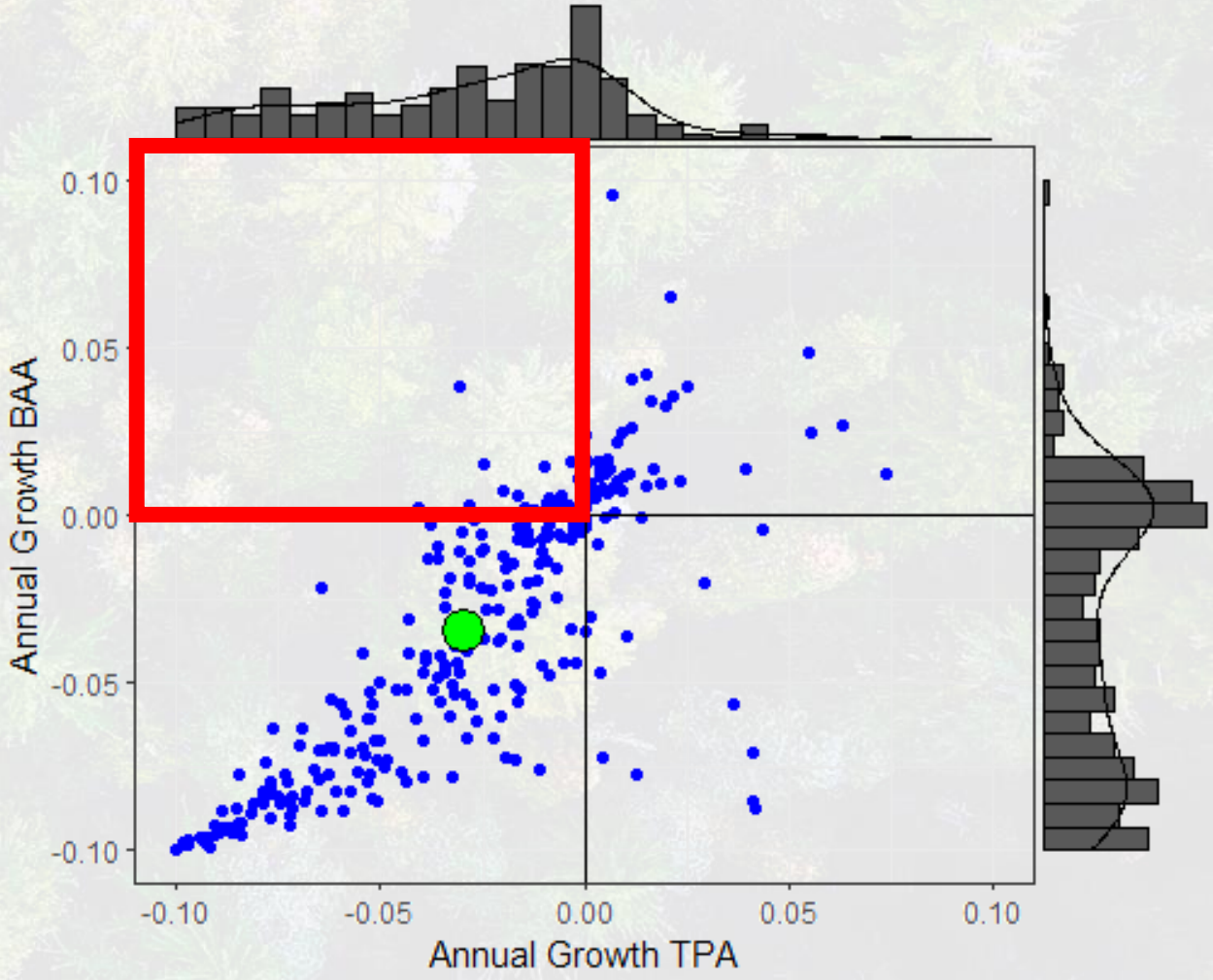

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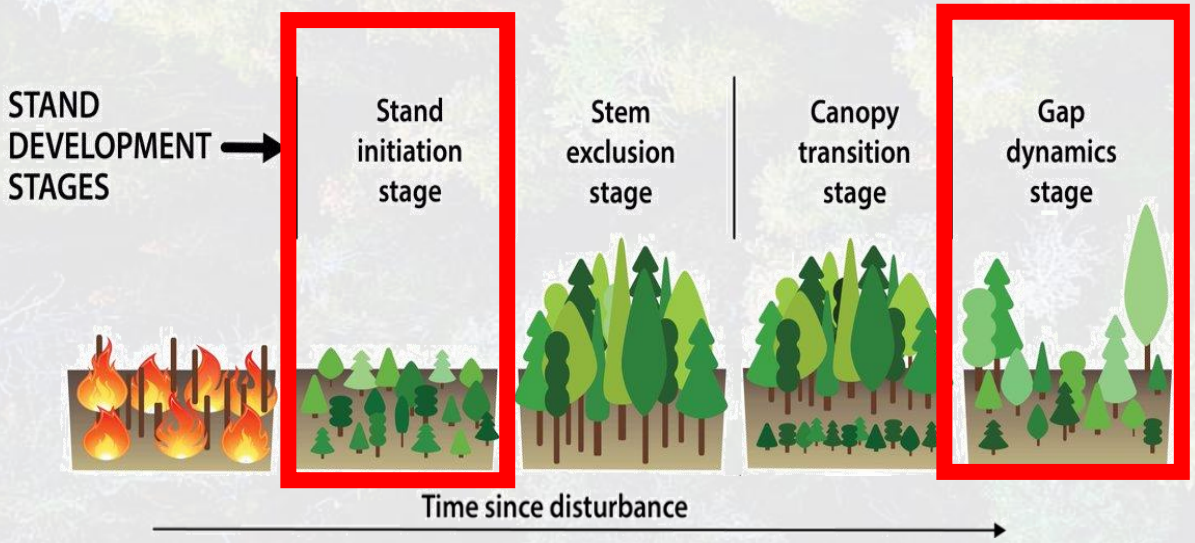


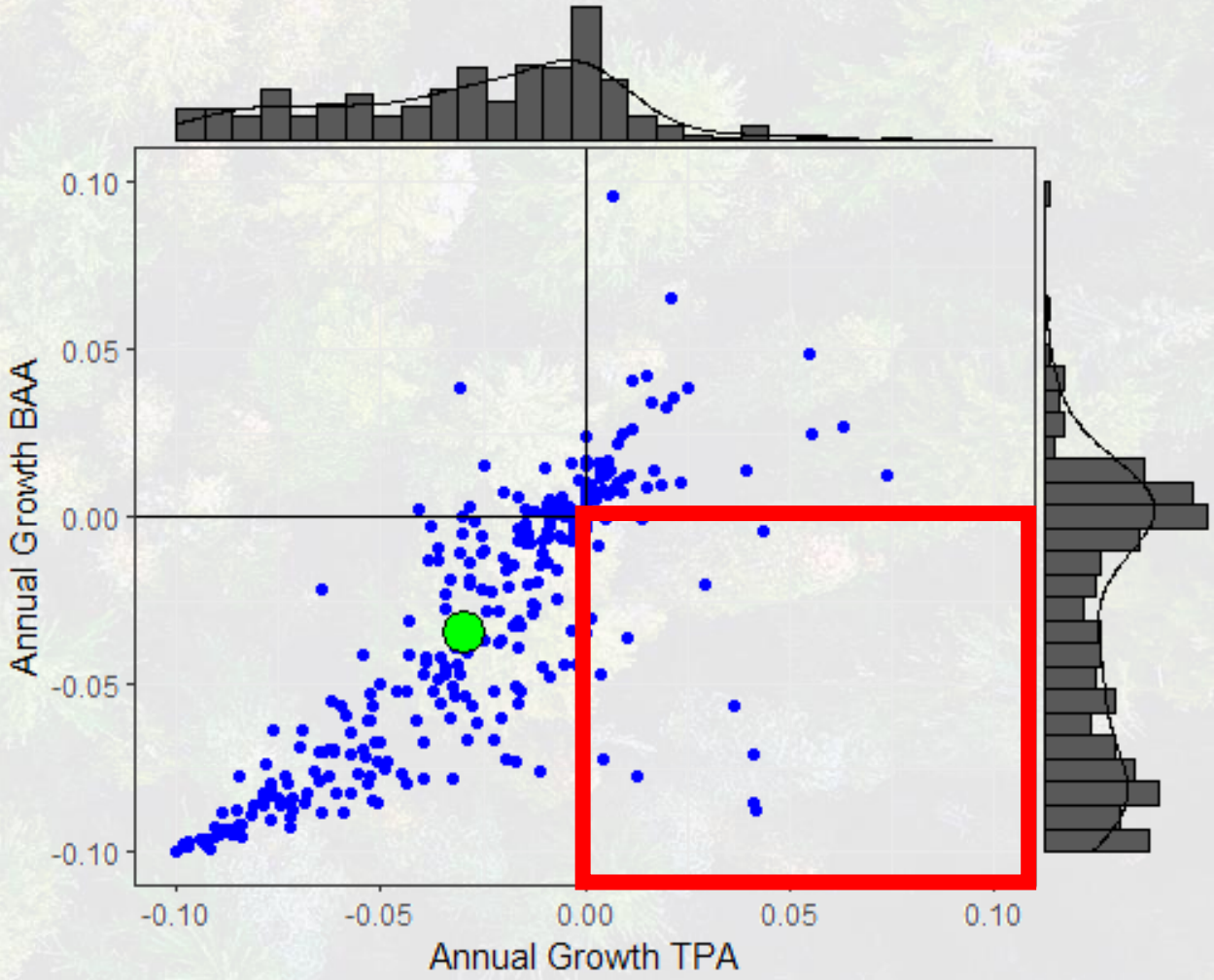

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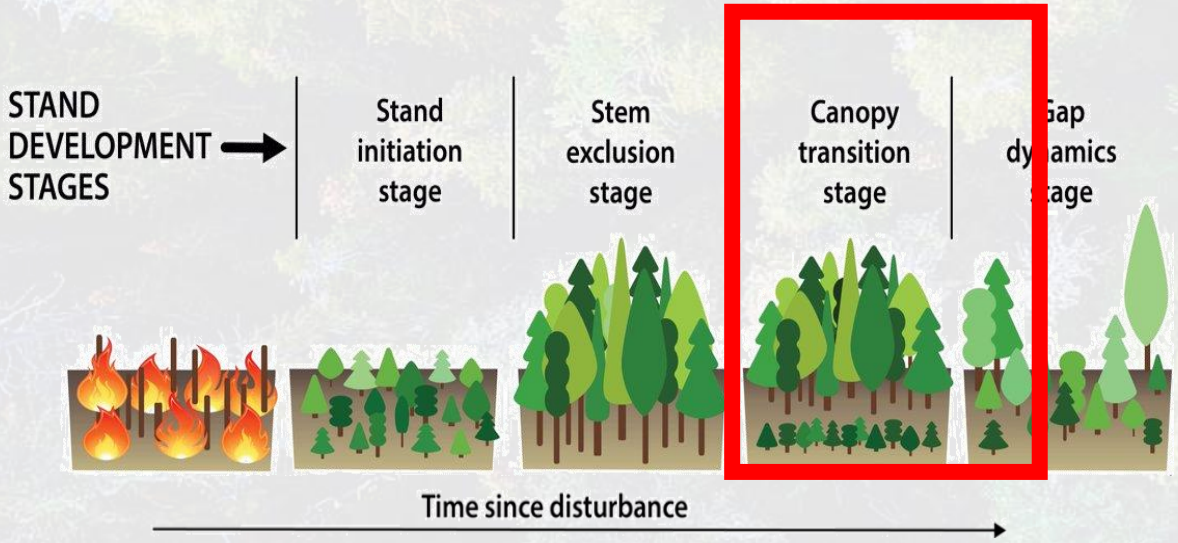


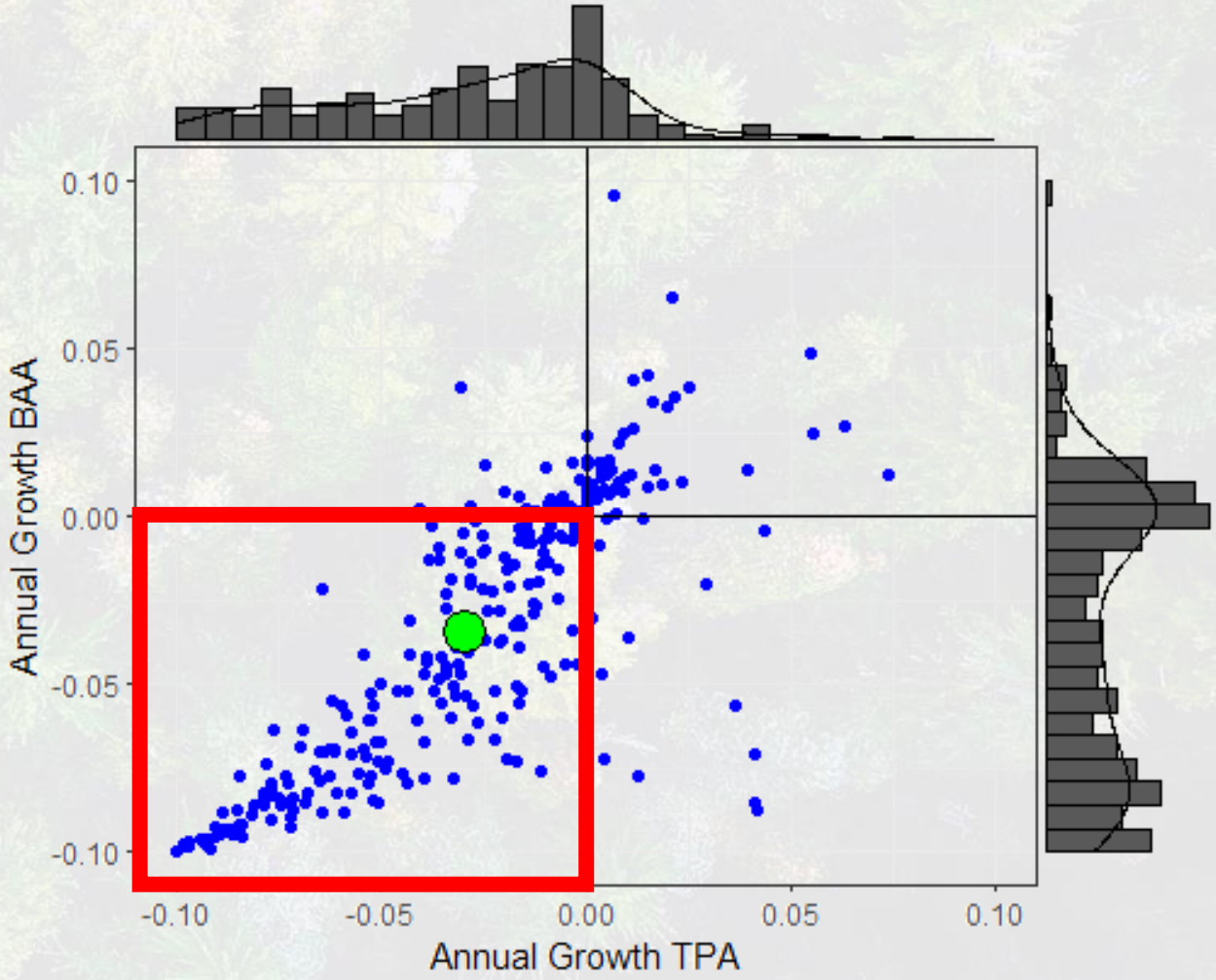

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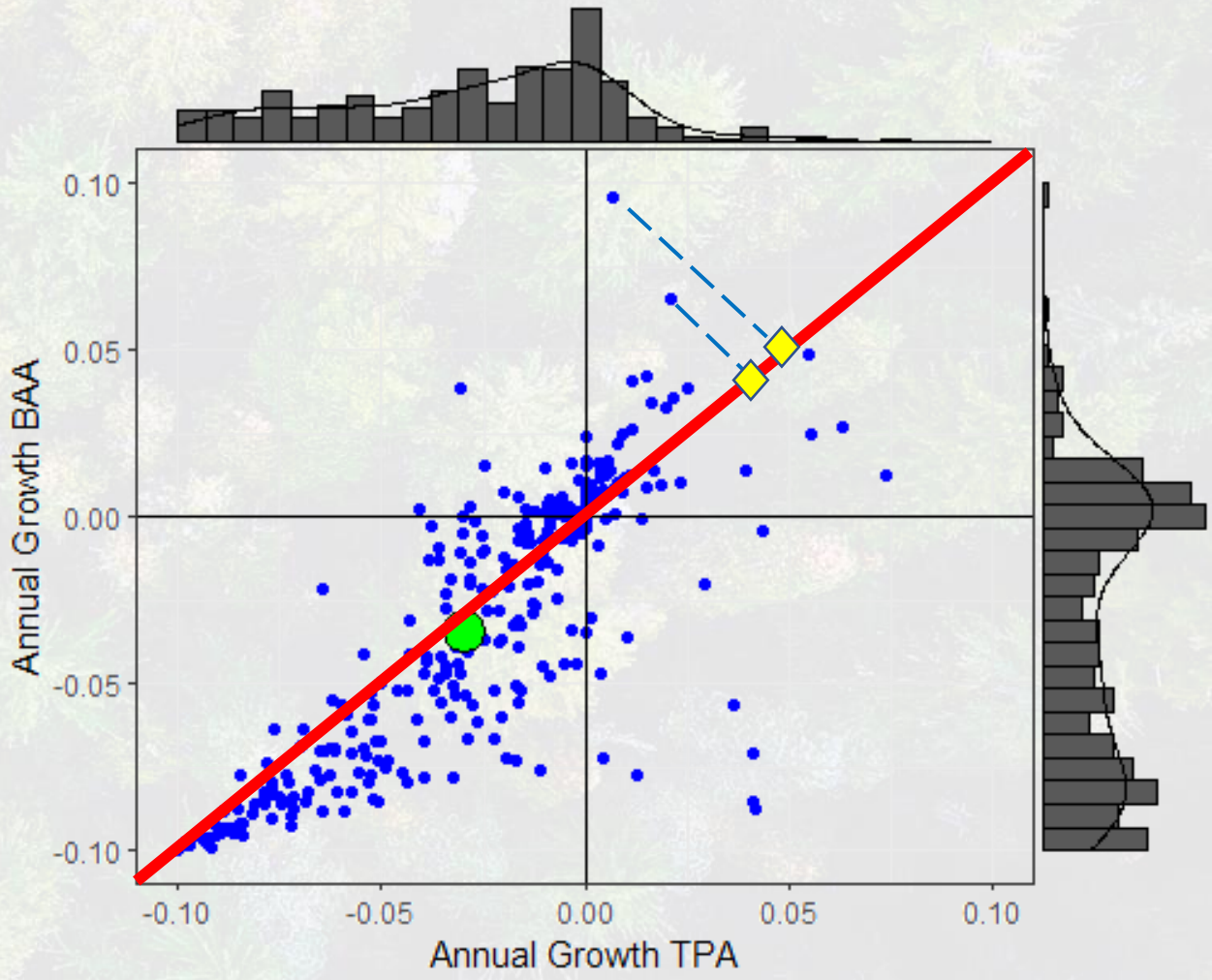

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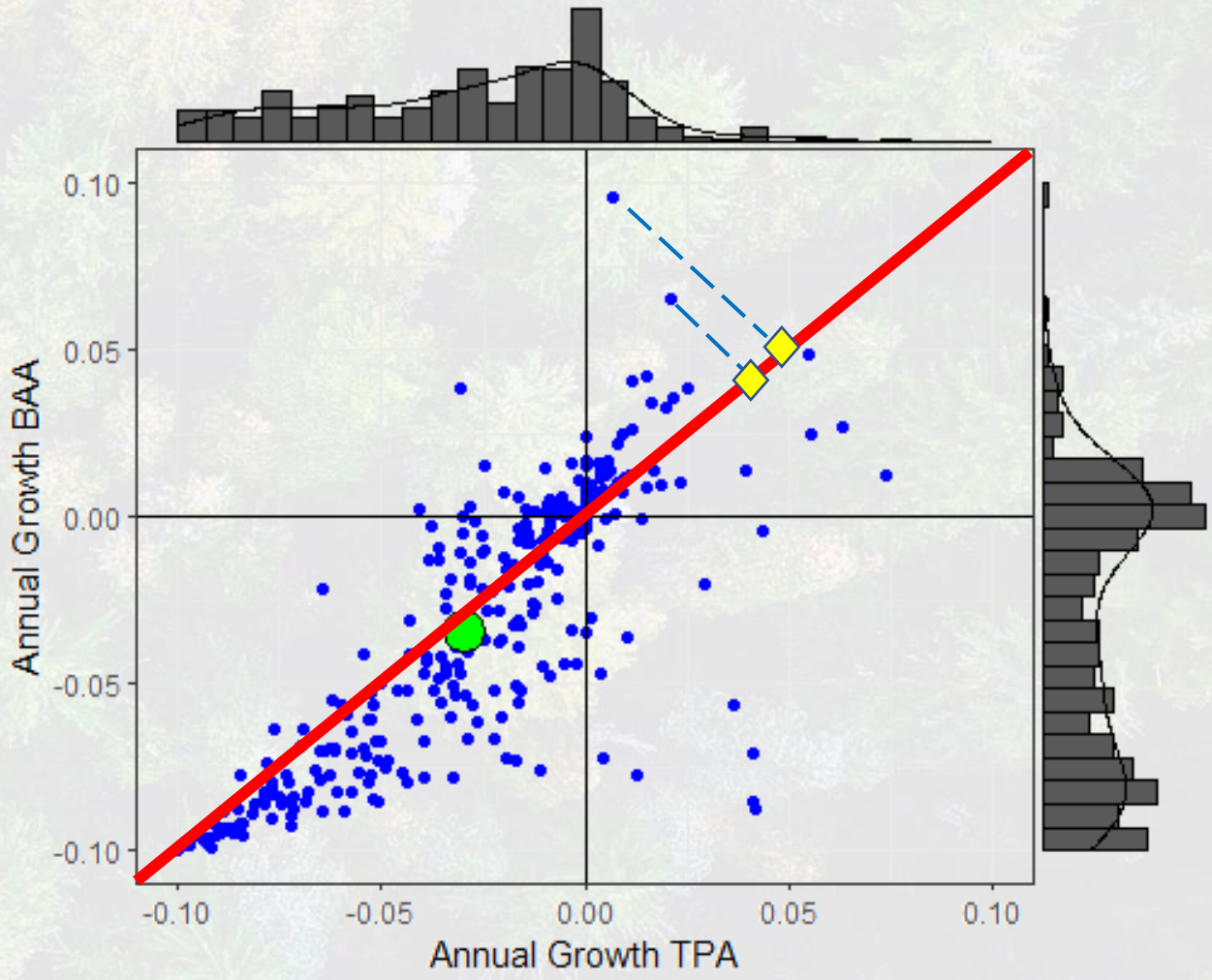
- **Mean indicates regional population decline**



# Forest Stability Index

*Using big data to solve big problems*

***Offsetting TPA & BAA →***
*independence of stand age*

***Mortality-productivity tradeoff →***
*independence of species, site class*

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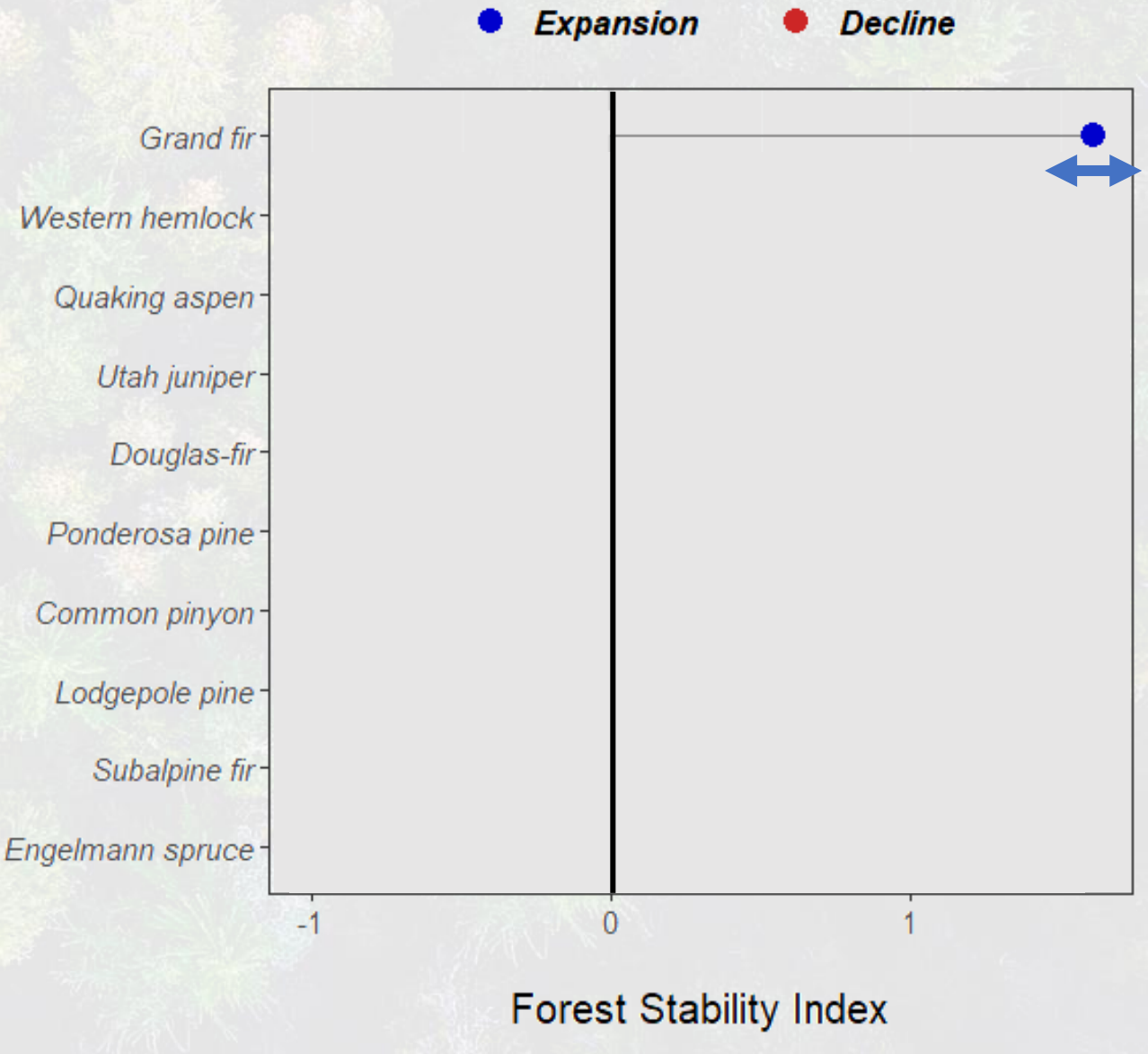
# Applying the FSI

*Using big data to solve big problems*

- ~ 25,000 FIA plots
- **Range-wide** index of population performance



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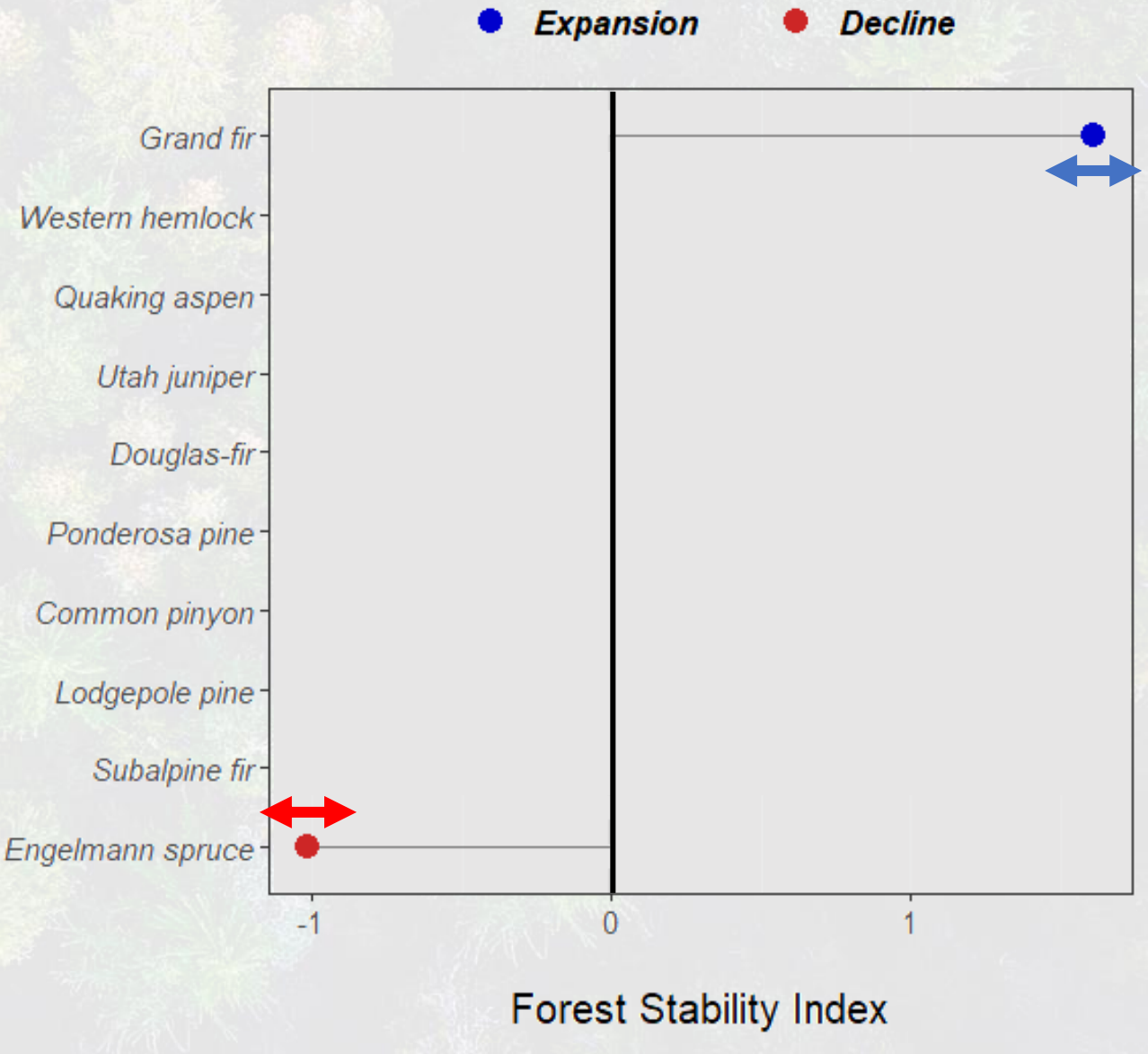

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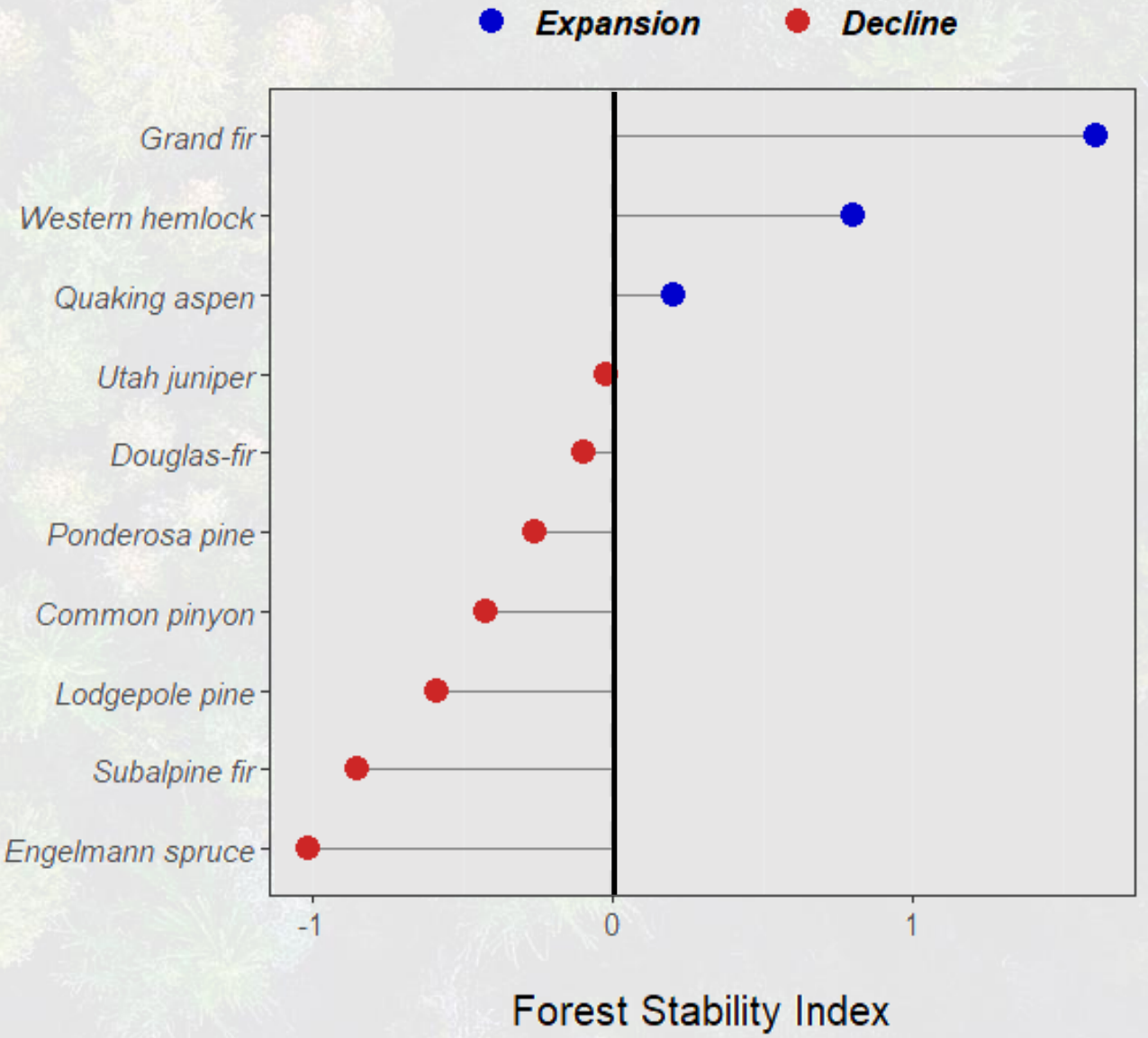

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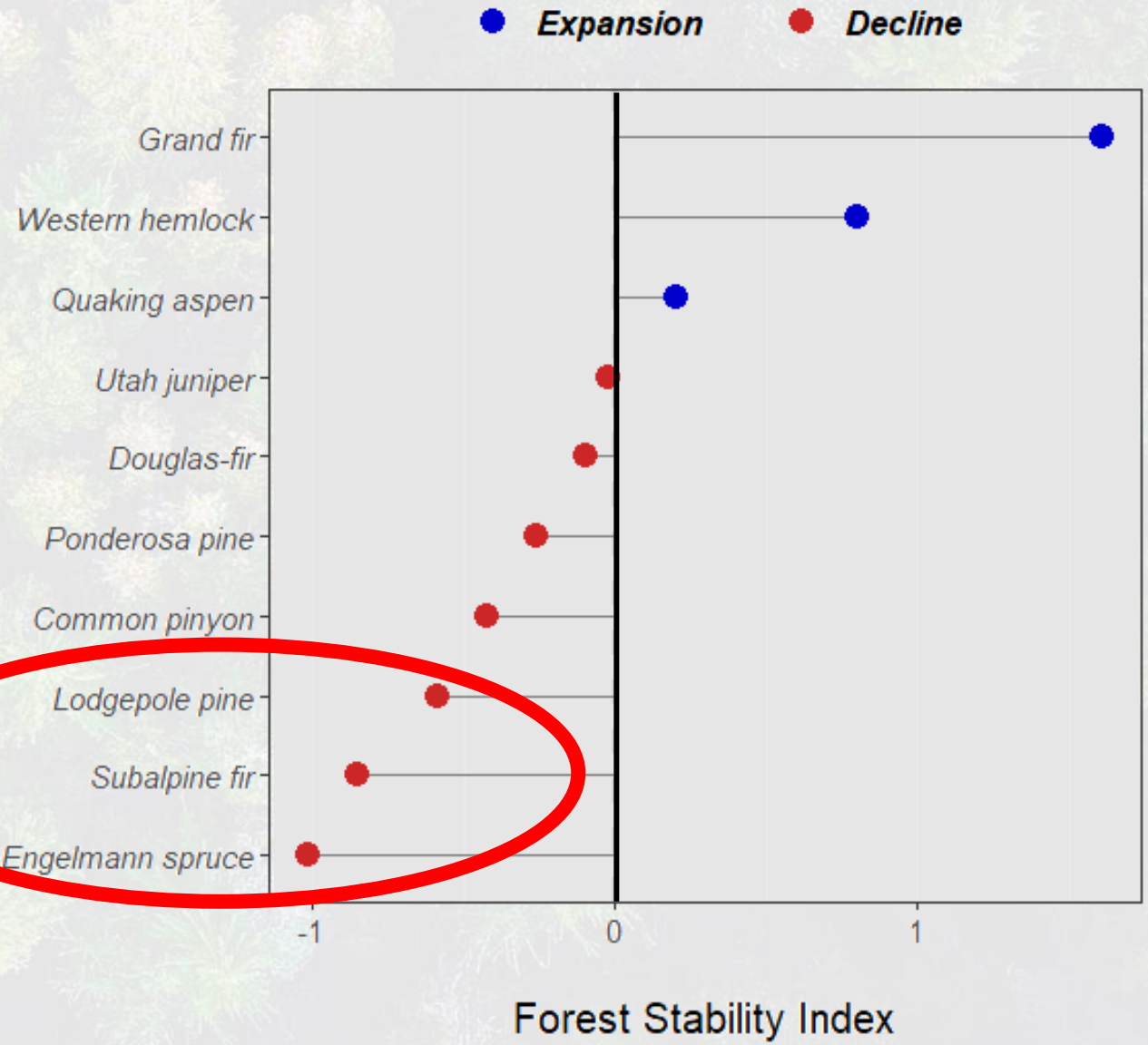

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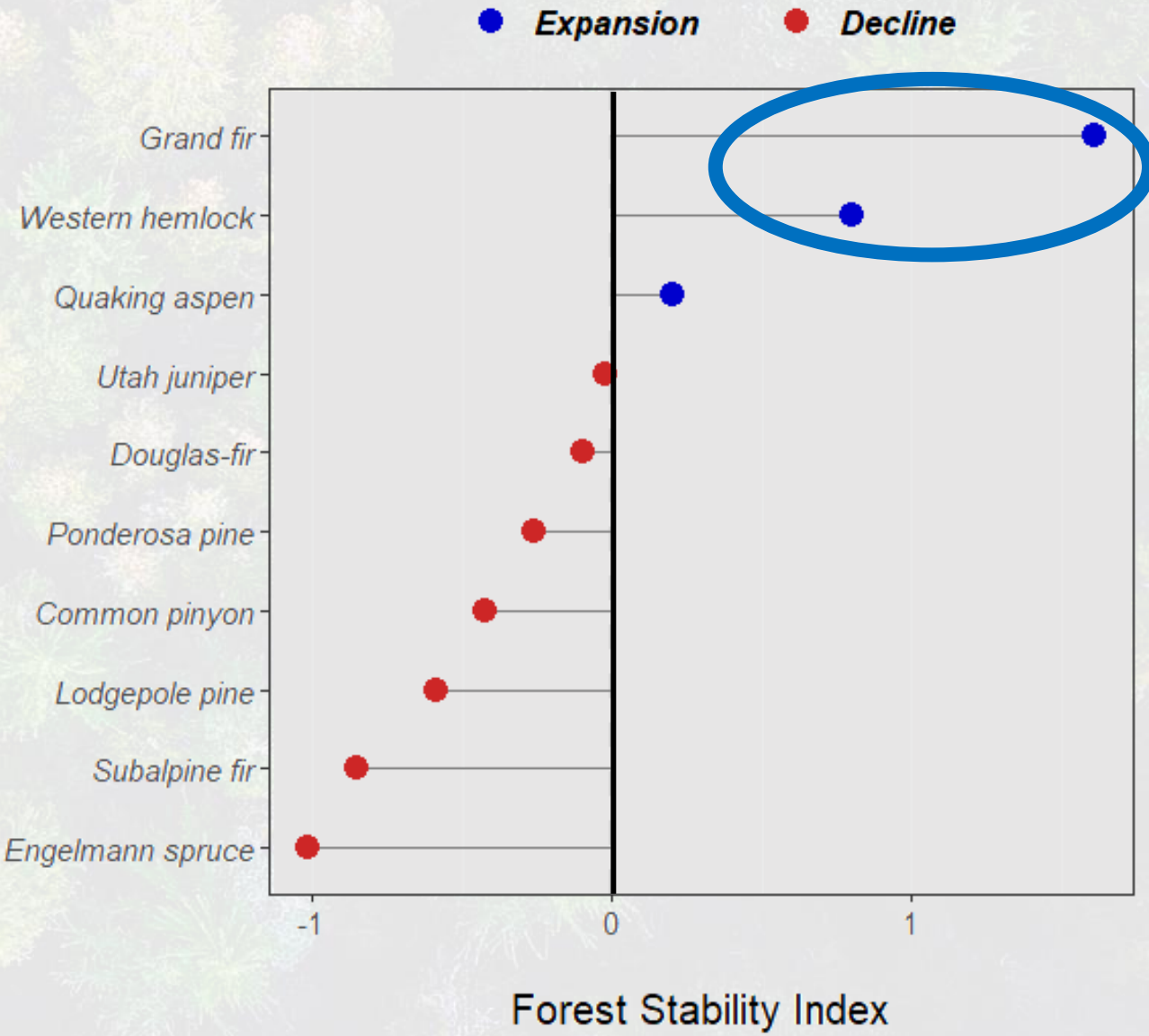

# Applying the FSI

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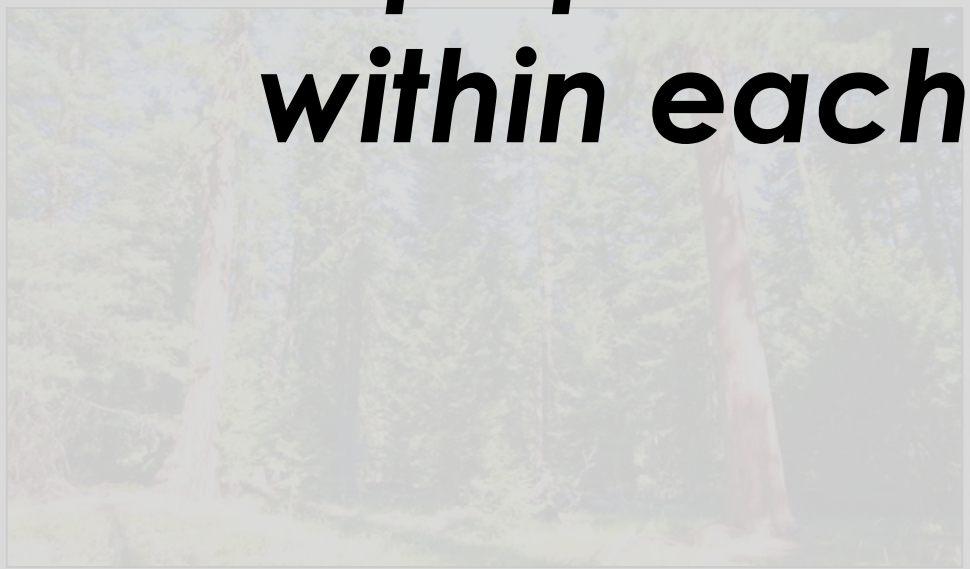
- **Range-wide** index of population performance
- % of species in decline

***Does population performance vary within each species' range?***



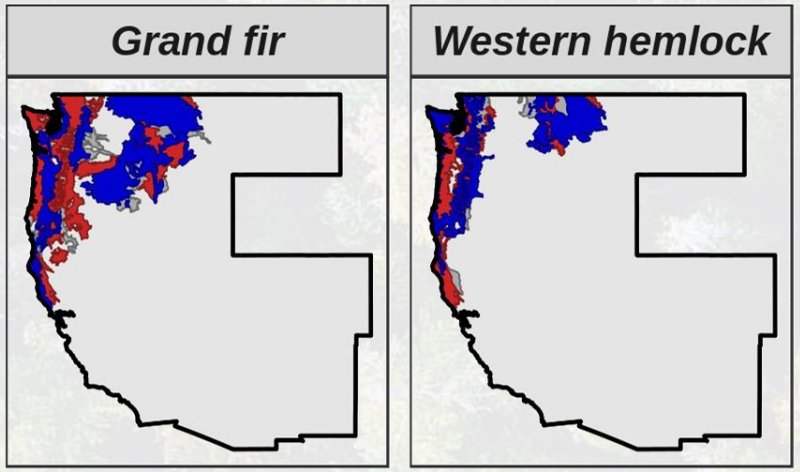
# Species on the move?

*Using big data to solve big problems*

Expansion

Stabilty

Decline



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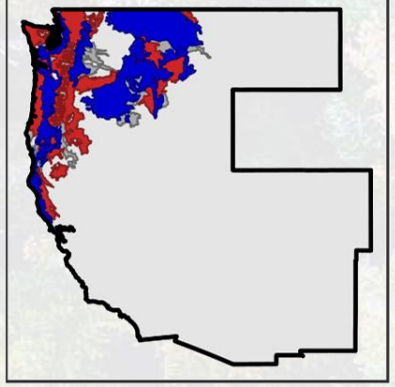
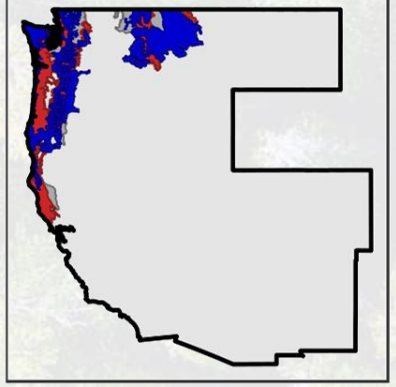
Stabilty

Decline

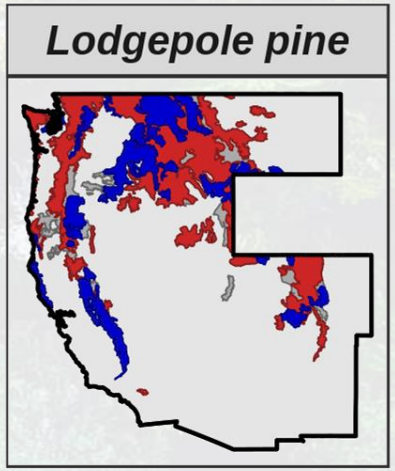
*Grand fir*



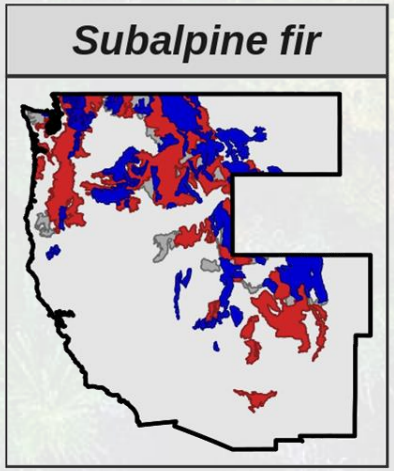
*Western hemlock*



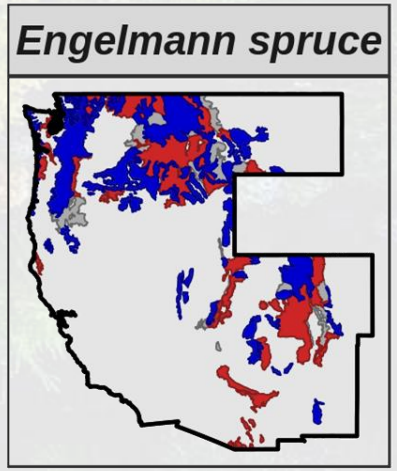
*Lodgepole pine*



*Subalpine fir*



*Engelmann spruce*



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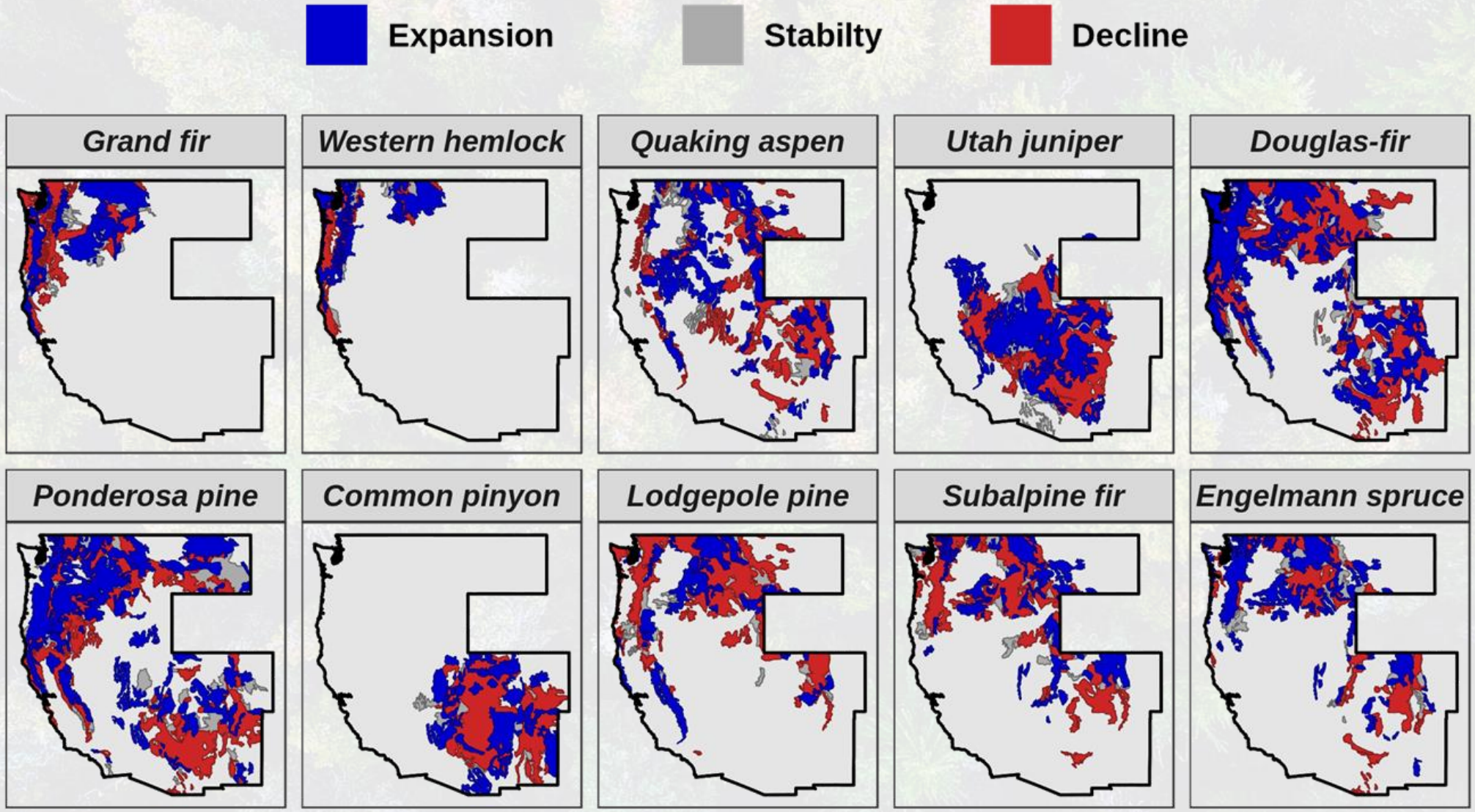
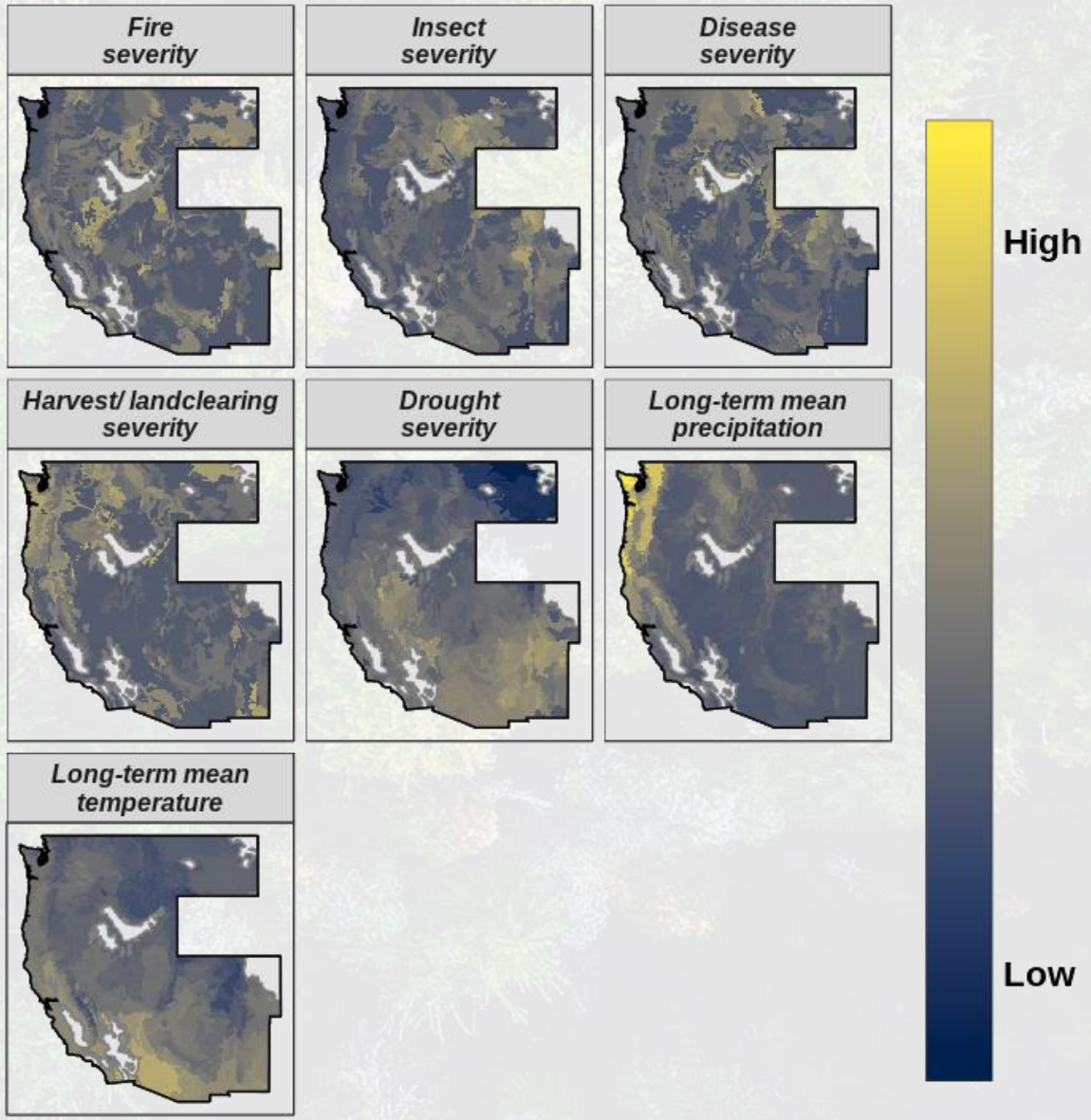


# Drivers of performance

*Using big data to solve big problems*

- How important are patterns in *long-term climate* and *disturbance severity*?



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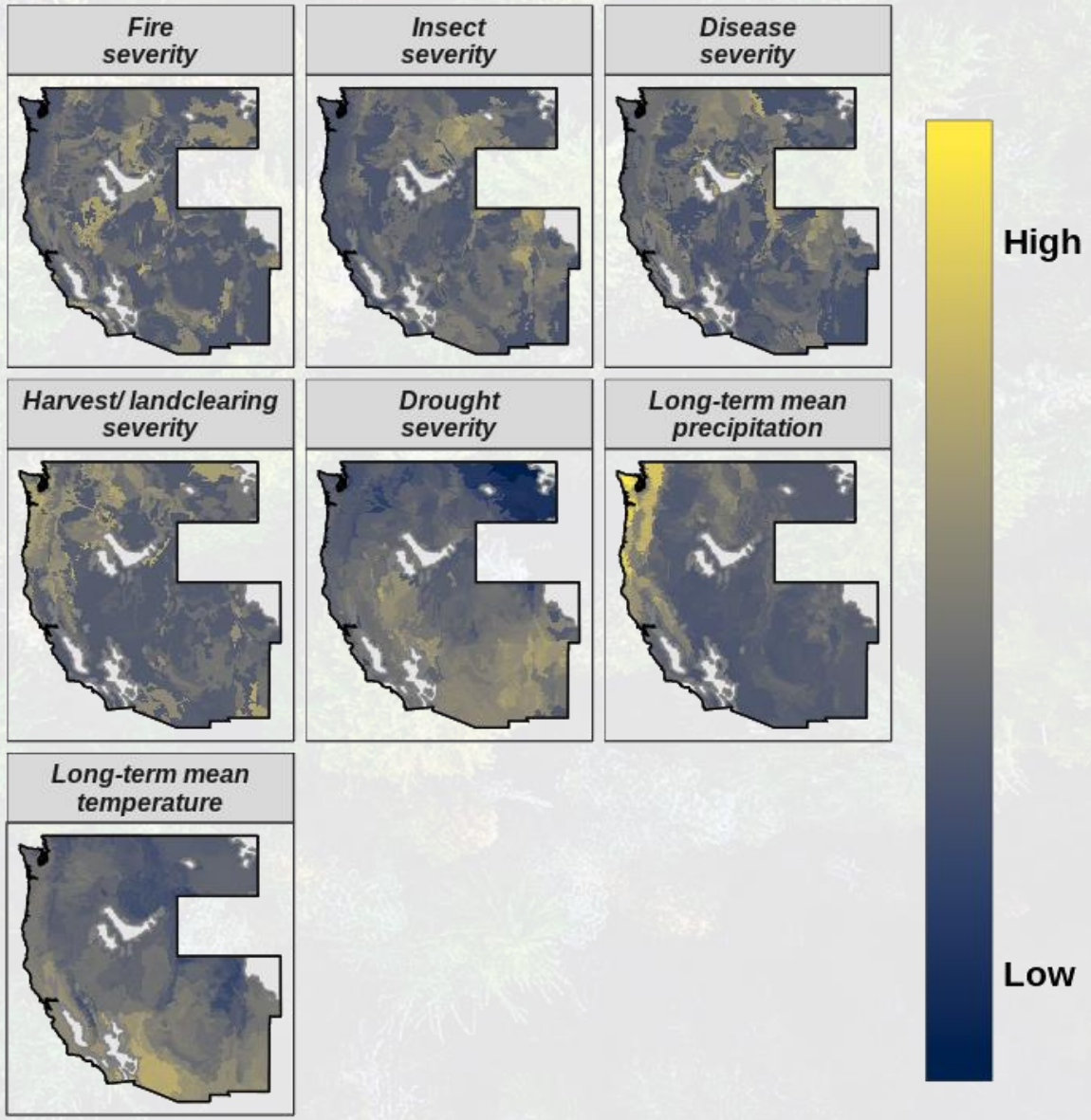
*Using big data to solve big problems*

- How important are patterns in *long-term climate* and *disturbance severity*?
- Linear mixed model w/ standardized coefficients
- Predicting plot-level FSI



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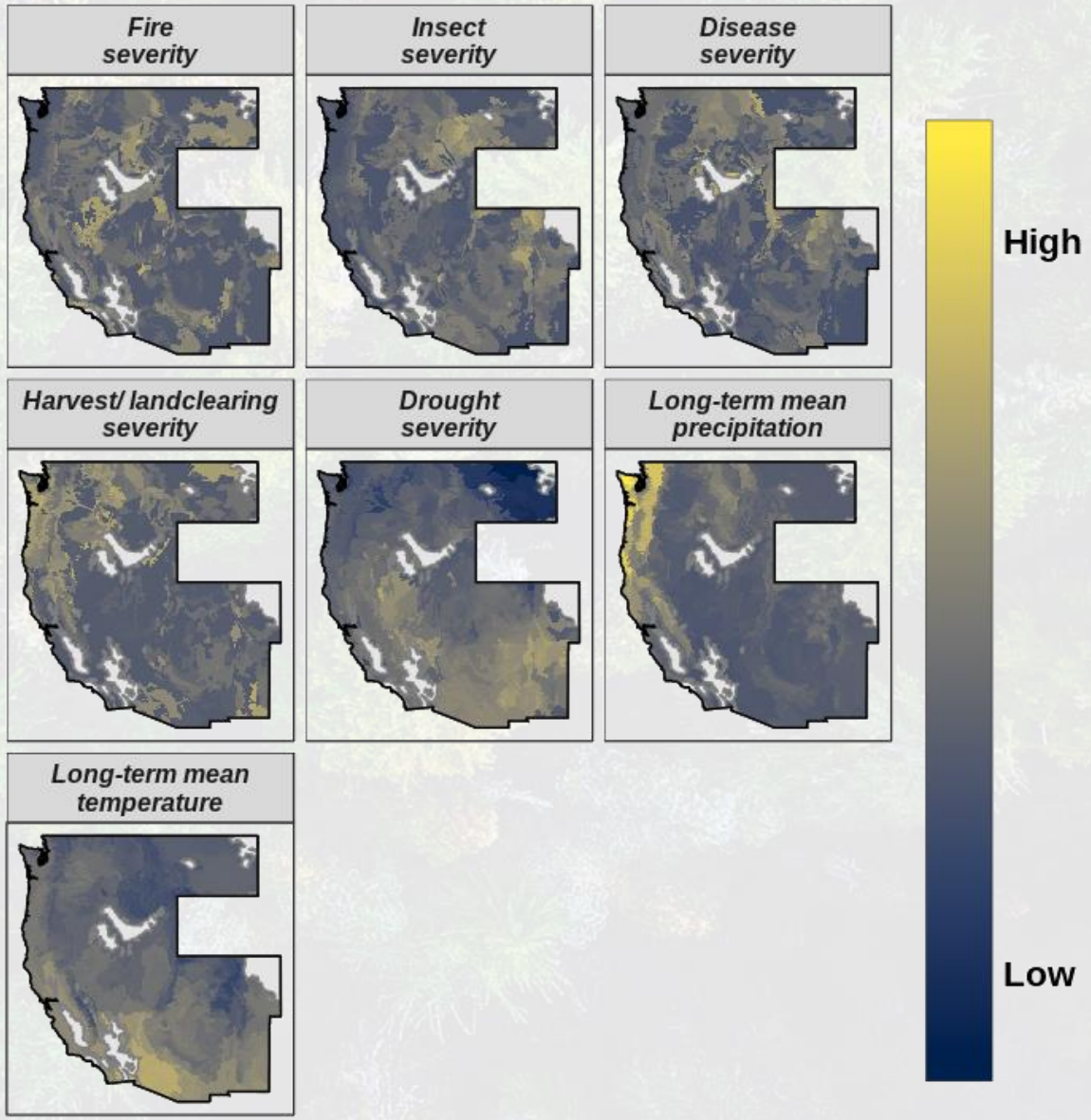
- Species and size-class as random effects



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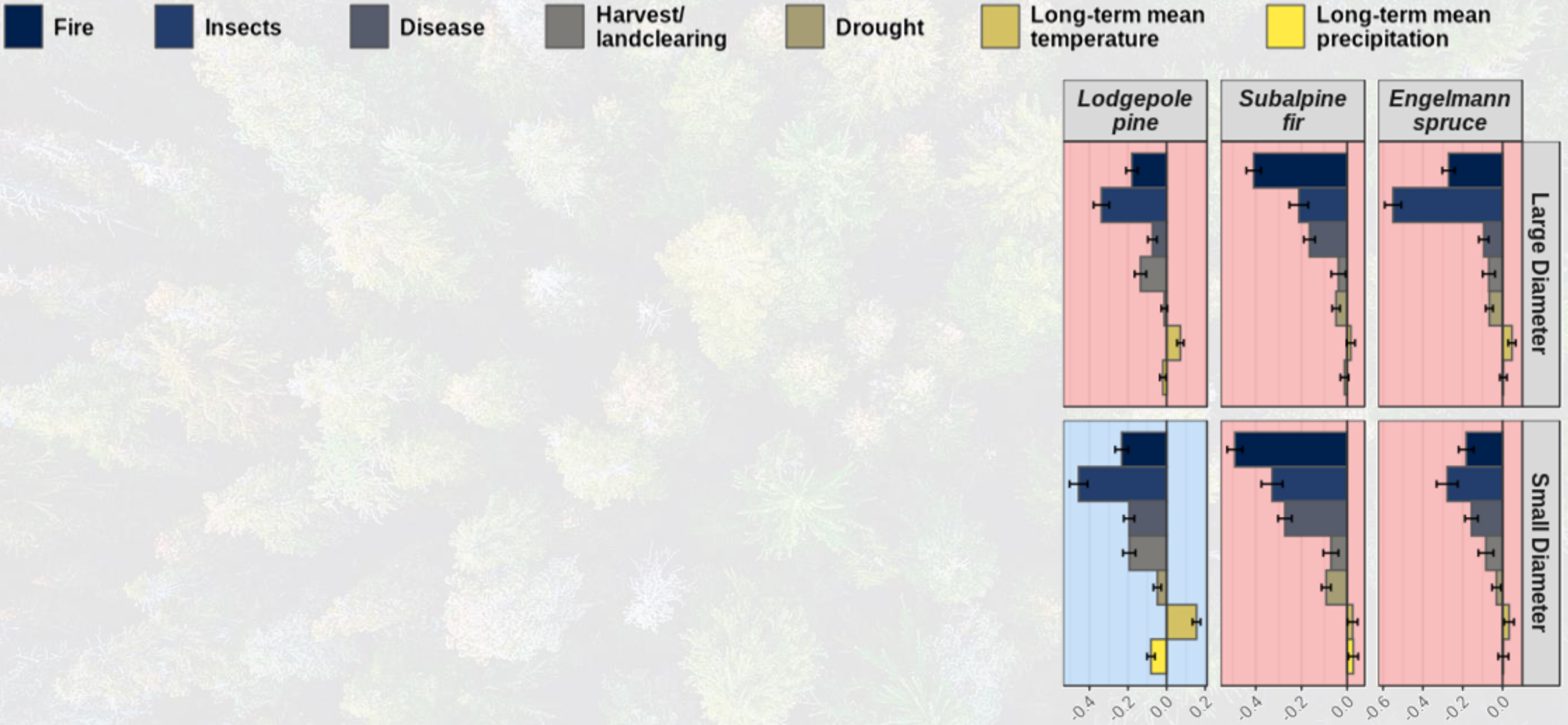

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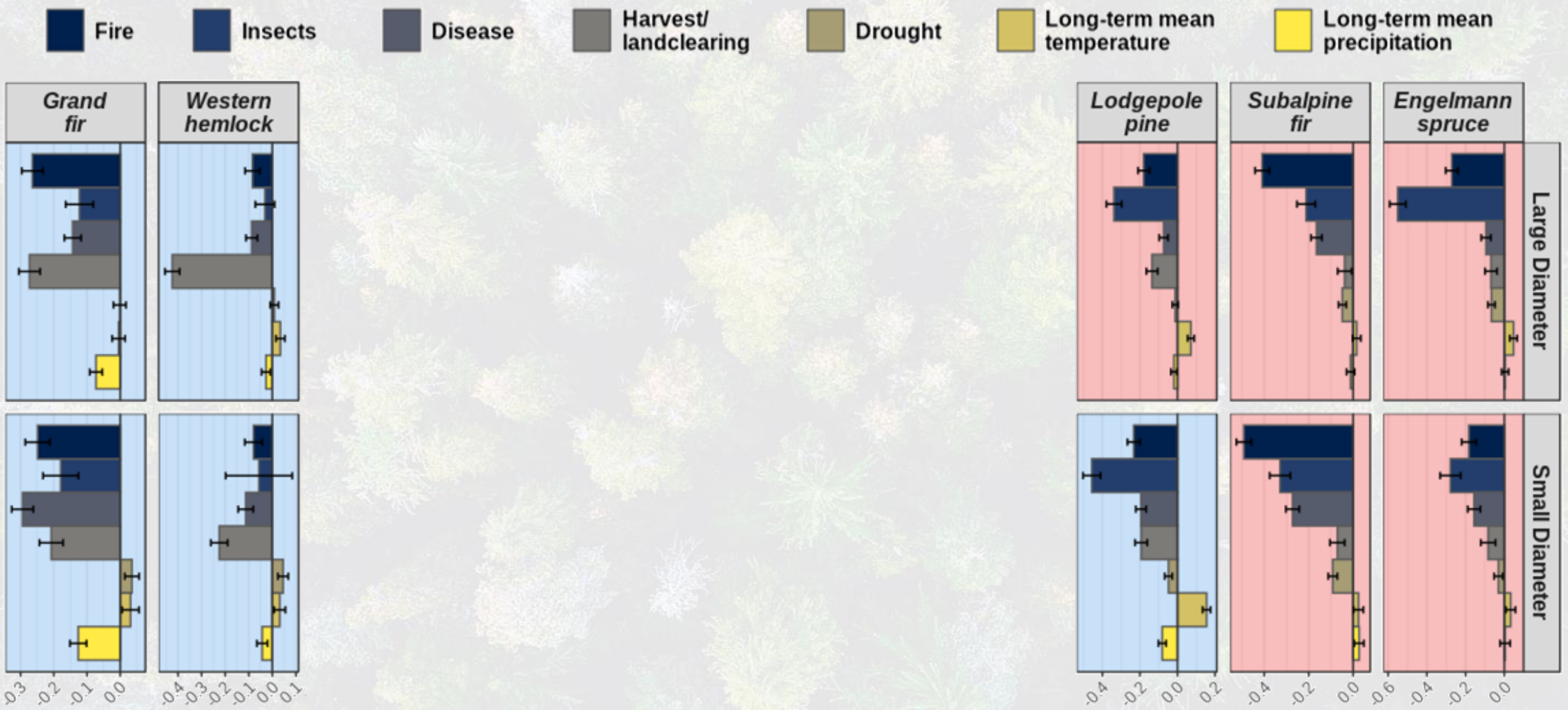

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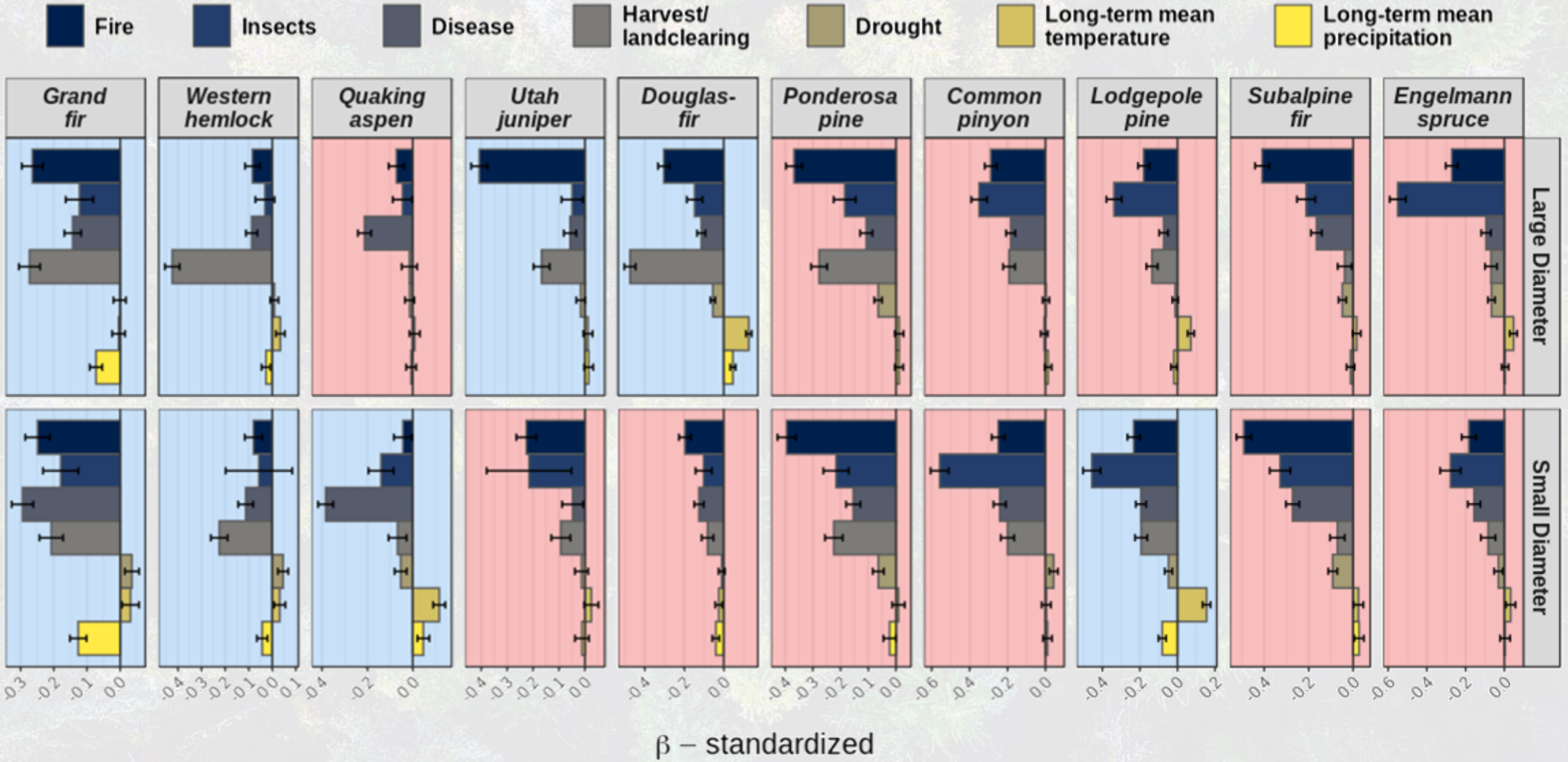

# State of Western Forests

*Using big data to solve big problems*

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# State of Western Forests

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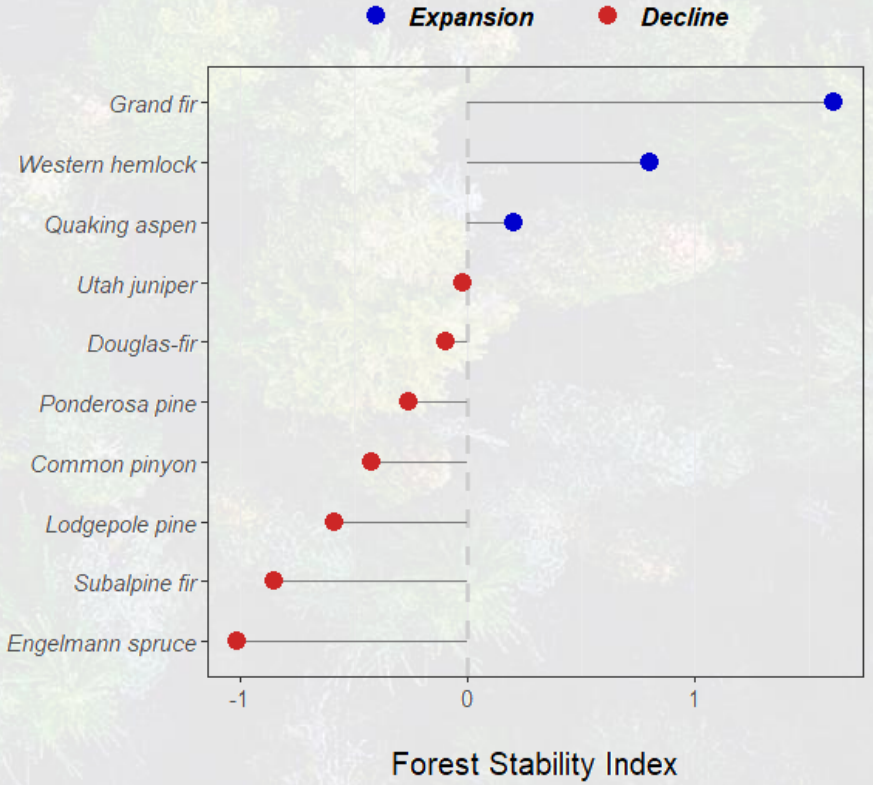
- ***Over half of top species in decline***



# State of Western Forests

*Using big data to solve big problems*

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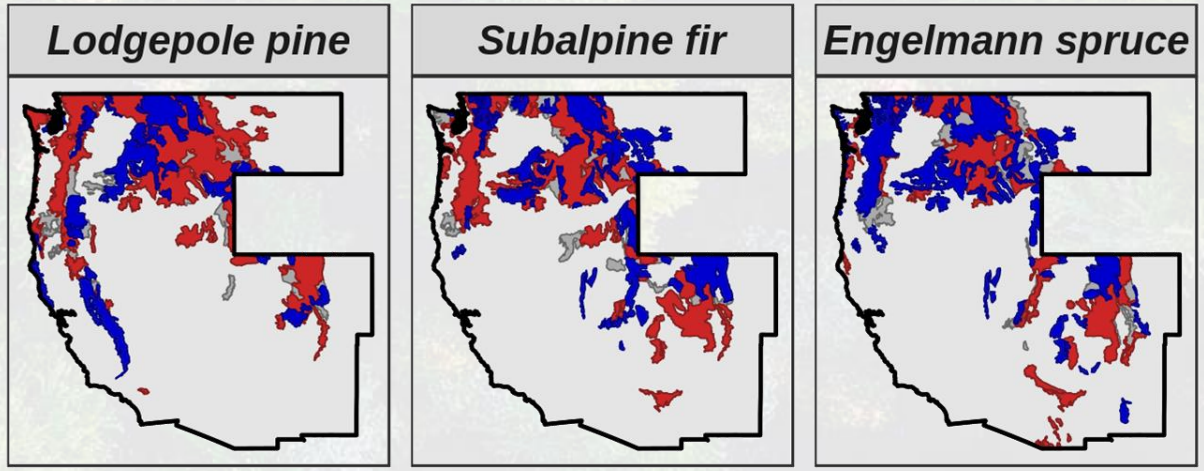
- ***Over half of top species in decline***
- ***Spatial shifts in species distribution are evident***



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*Using big data to solve big problems*

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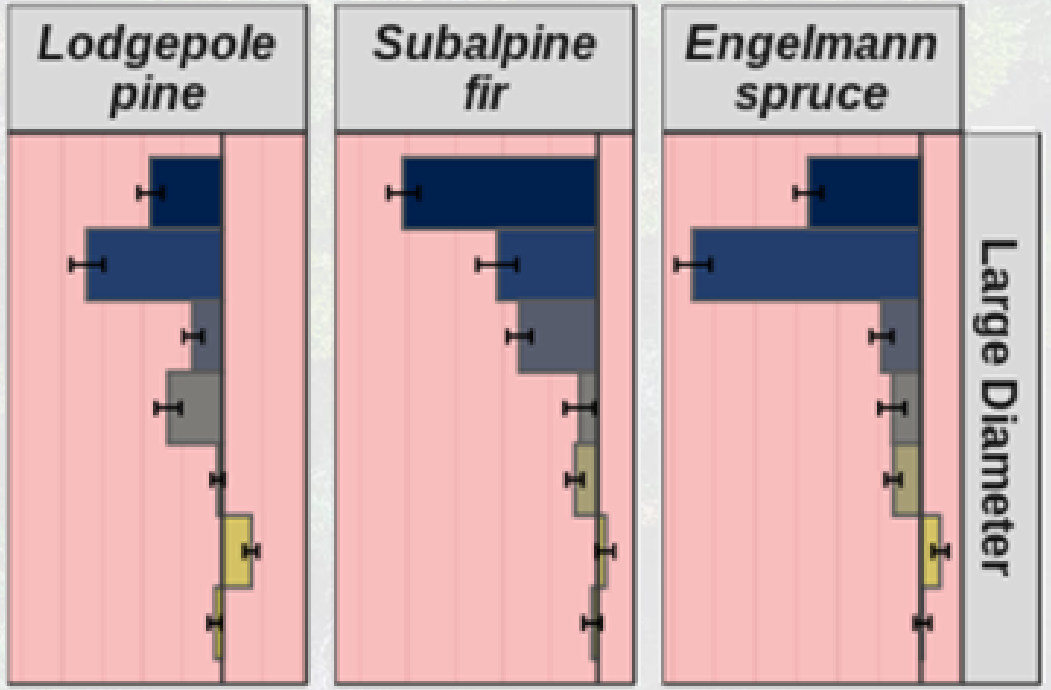
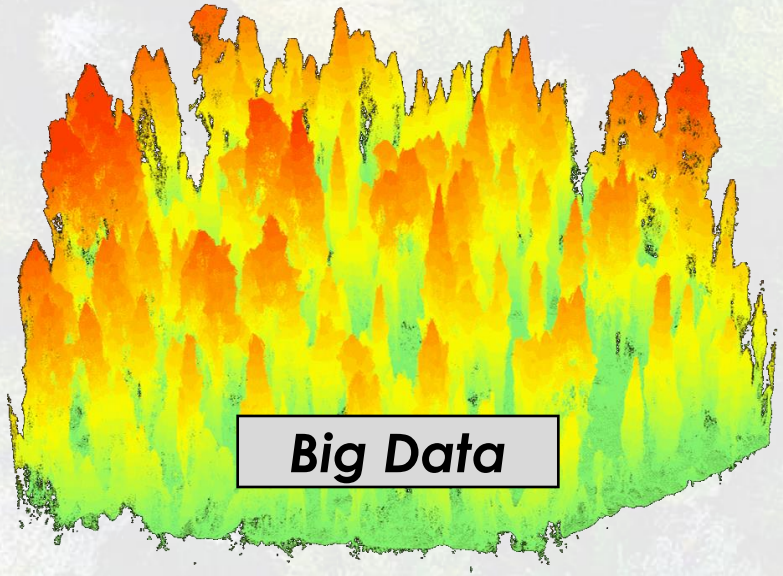
- ***Over half of top species in decline***
- ***Spatial shifts in species distribution are evident***
- ***Fire and insect outbreaks are prominent drivers of species performance***



# Why are we here?

*Inference & Prediction*

*Software & data access*



*Management & Policy*

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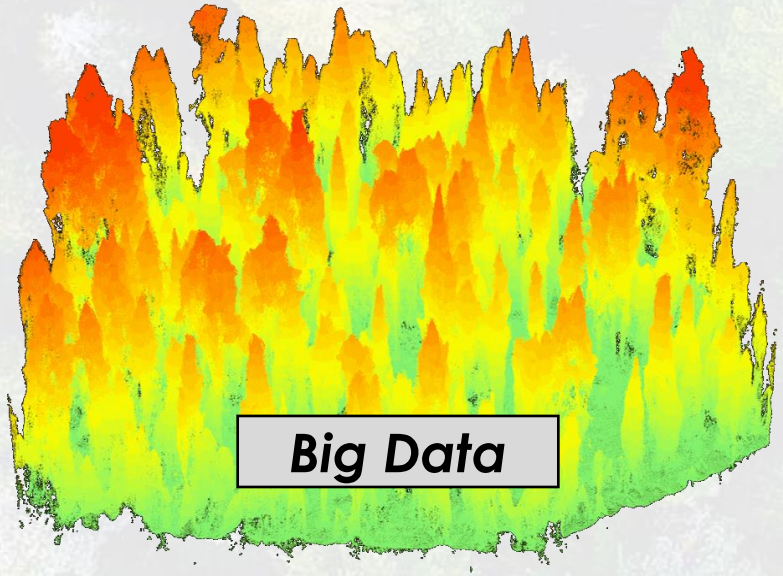



*Management & Policy*

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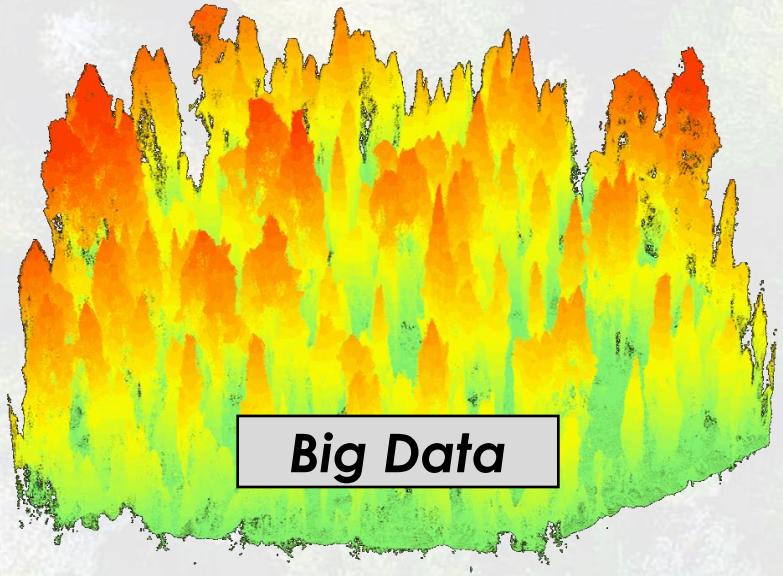



*Management & Policy*


# Questions?

## For more on rFIA …

rFIA.netlify.com

https://doi.org/10.1016/j.envsoft.2020.104664