Bioregional Inventory Originated Simulation Under Management: a framework for evaluating forest restoration alternatives and their outcomes, over time, to inform monitoring

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Backstory: Biomass Summarization

FVS as treatment implementation engine for FIA data

- 2002: Framework to assess woody biomass supply available from fuels management
  - Effectiveness based on pre vs post treatment
  - Applied in OR, CA, AZ and NM
  - Components bolted together; complex workflow
- 2007: BioSum workflow management software
  - Effectiveness tied to torching/crowning indices
- 2011: Mixed-conifer fuel synthesis BioSum version
  - Flexible effectiveness metrics, multi-dimensional criteria for treatment optimization

Bioregional Inventory-Originated Simulation Under Management (BioSum 5)

- 2016: Multi-decade, multi-purpose system; 1st released
- Relied on by several projects now nearing completion
  - California Energy Commission: Biofuels feedstock
  - JFSP: Fuel Treatment Cost Effectiveness
  - ODF: Blue Mountains Fuels Mgt Pace and Scale Acceleration
  - OSU: Upper Klamath Biochar supply study
- Potential to be more universal than fuels treatment
  - Analysis of C dynamics with management and disturbance
  - Forest objectives other than fire resilience (e.g., habitat)
  - Wood supply (spatially explicit)

The BioSum Planning & Monitoring Vision

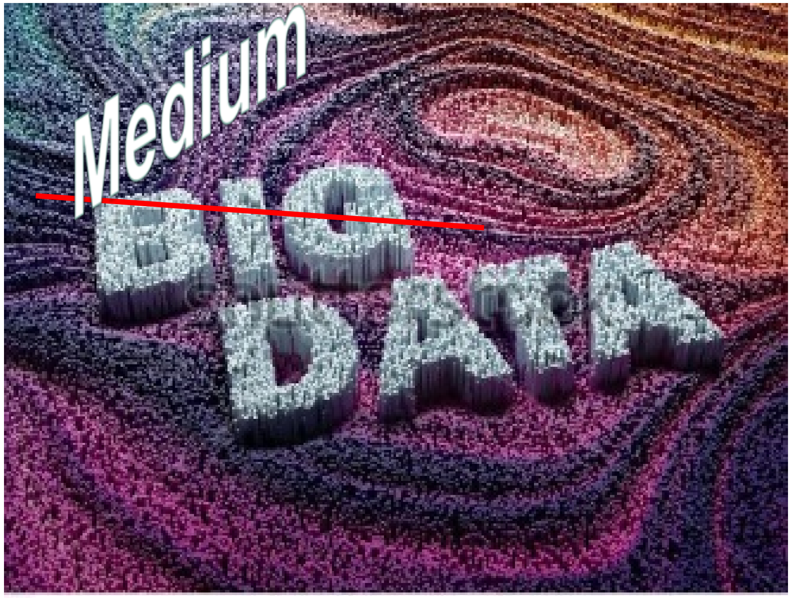
- FIA plots = representative sample of all forest
- FVS role:
  - Compute relevant stand metrics on today's forest
  - Apply multiple silvicultural sequences to each plot
  - Generate alternative stand trajectories
- BioSum role:
  - Manage work & data flow
  - Merchandise harvested wood, by spp & size, to facilities
  - Estimate prescription cost (via OpCost)
  - Support sifting through effects & costs of alternatives

Summarize & Compare

- Area for which each sequence is successful wrt
  - Multiple stand attributes, e.g., resilience to fire
  - Treatment longevity
  - Treatment affordability
  - Carbon outcomes
- Wood, energy and net revenue (or cost) produced
- Wood delivery to each processing facility, by decade
- Effect of policy constraints such as diameter caps, subsidies, limits on slash burning

Concept: Extend FIA sample data to simulate management

- Builds on FIA strengths
  - Broad, comprehensive, consistent sample of forest
  - Precisely observed/recorded vegetation attributes
  - Quasi-spatial analysis potential at some scales
    - For example, relative to wood markets
    - Not for prioritizing management locations or modeling spatial contagious processes
- Support scenario development and testing
  - What does management accomplish? At what cost?
  - Off-the-shelf, public, open, free, supported models integrate into a smooth workflow for rapid analysis



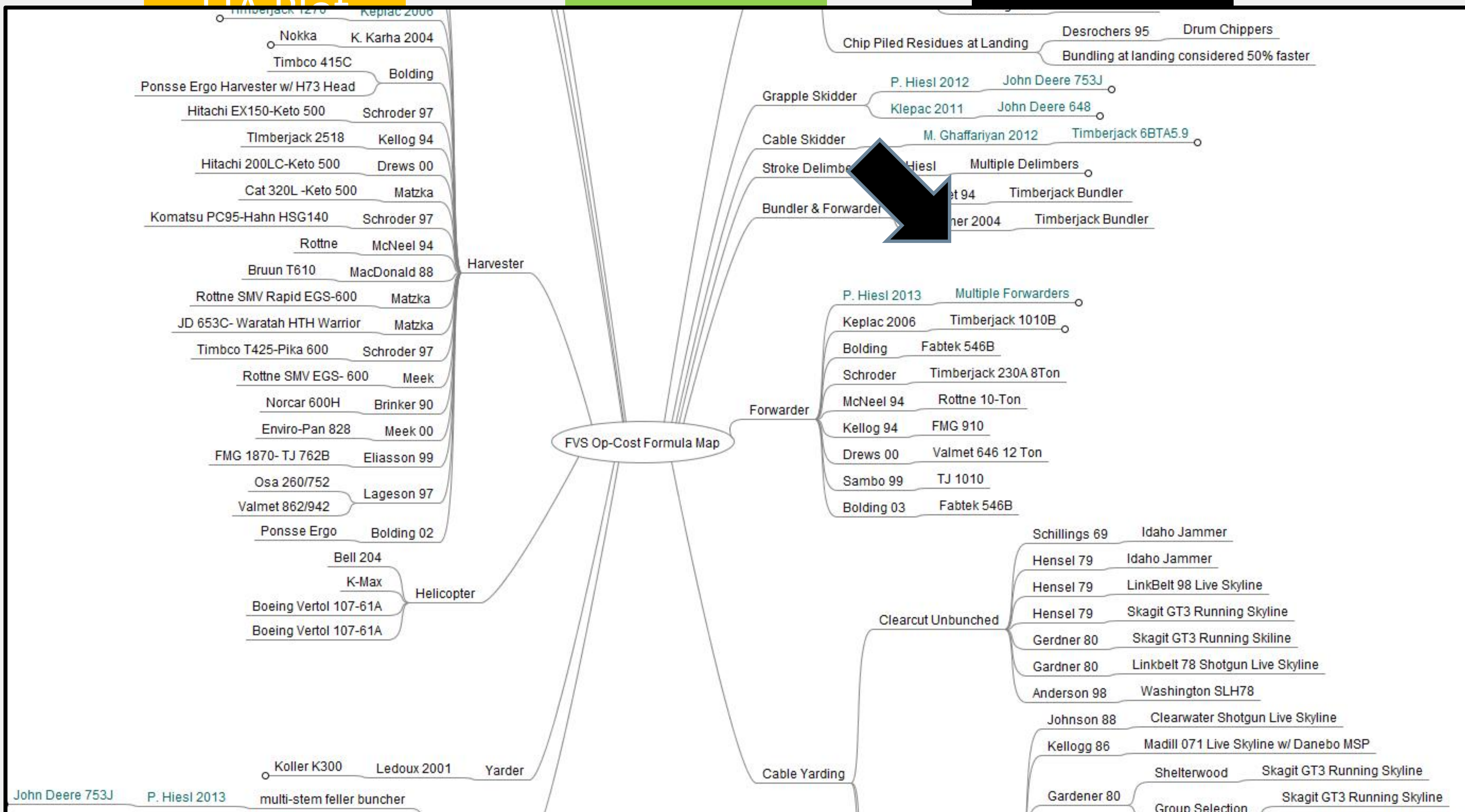
BioSum Metaphors

BioSum Model Framework

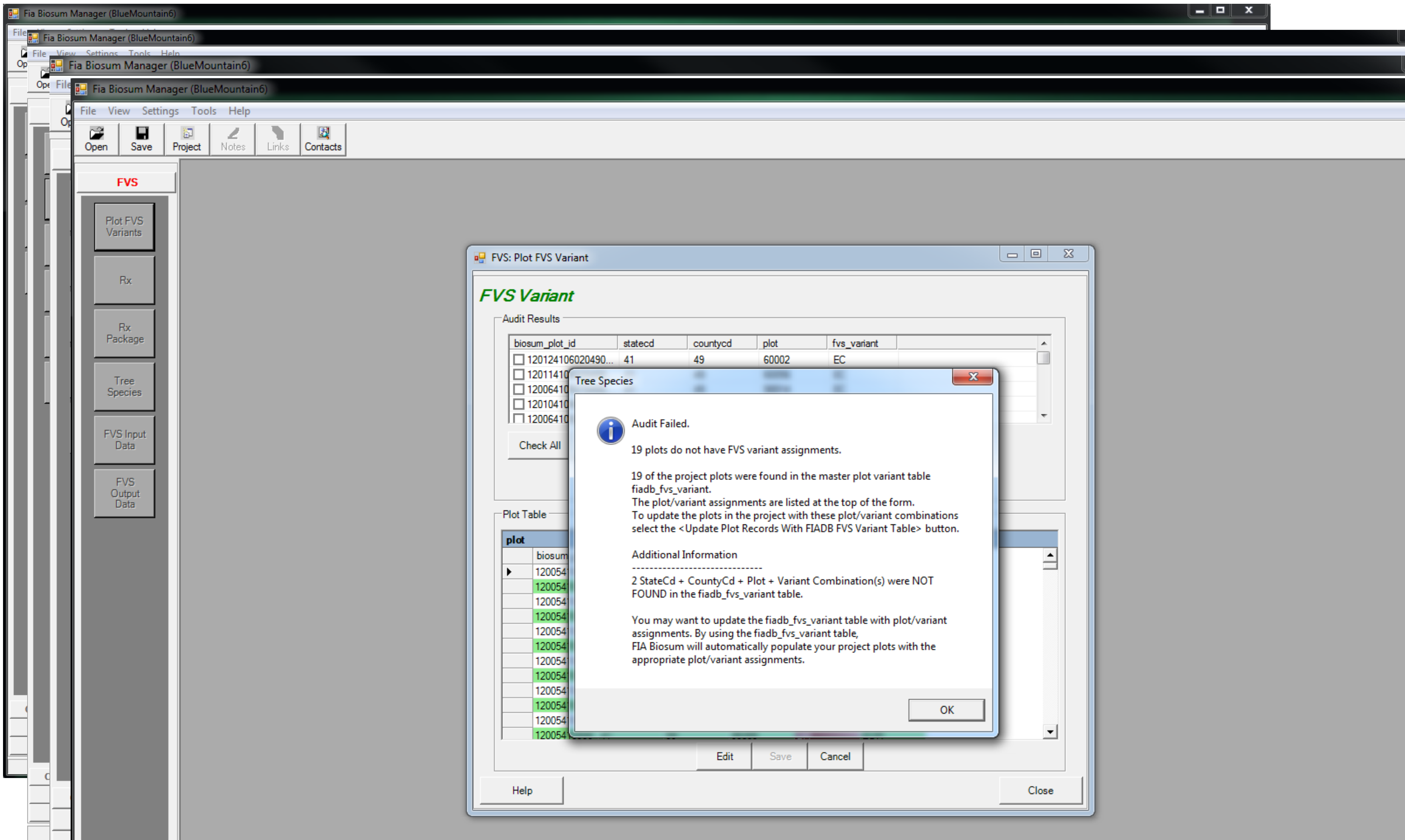
Subset for unreserved, dry mixed conifer forest

Simulate all silvicultural prescriptions; project

Simulate treatment costs



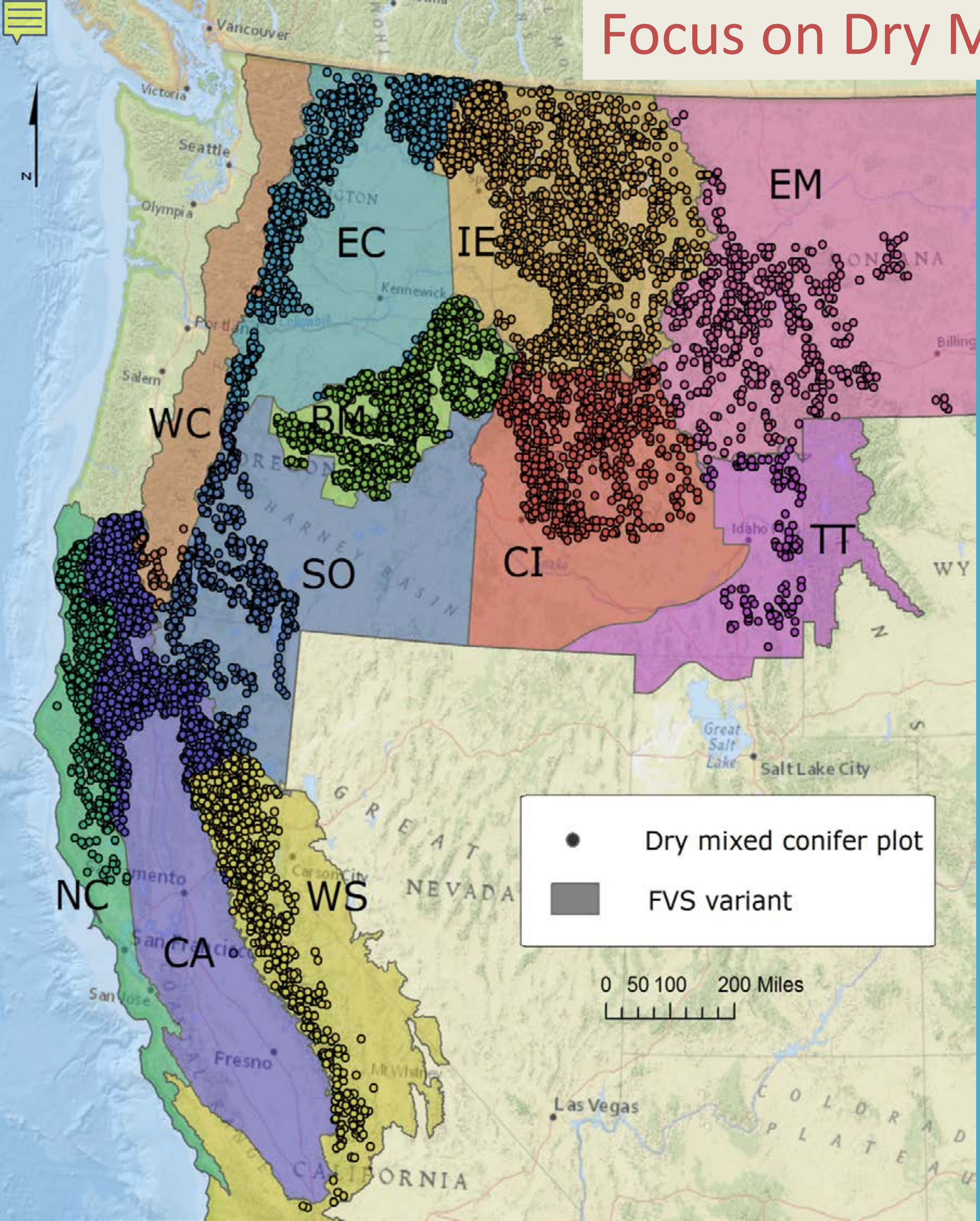
Bioregional Inventory Originated Simulation Under Management



Uses will vary by user: There is no one right way to use BioSum

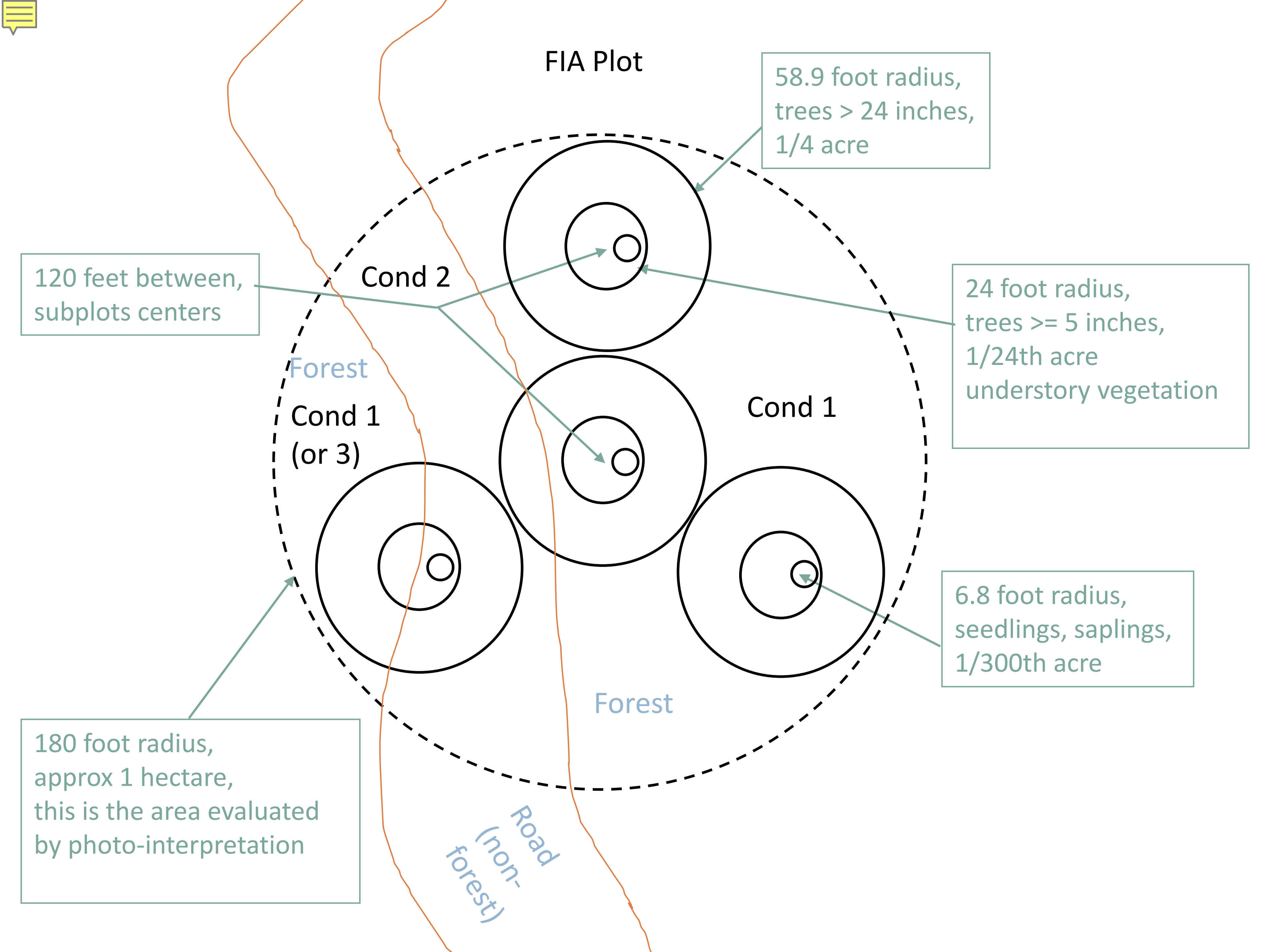
- Assess opportunities for today's forest
- Apply Rx today, monitor how effects play out over time
  - Via BioSum or via annual inventory sample
- Dynamic management over 4 projection cycles
- Evaluate outcomes of silvicultural alternatives on the full range of where you think they should work, to rate or rank them
- Predict what a forested landscape will produce under different policies, legal/economic restrictions and incentives, etc.
- Convert FIA data into FVS files to assess or experiment

Focus on Dry Mixed Conifer Forests



By the Numbers

- FIA sample contains
  - 7713 "conditions"
    - Full or partial plots
  - Represents 29 million ac.
  - Field visited
    - 2003-2013
- BioSum model
  - 11 FVS variants
  - 10 treatments
  - 283 sawmills, etc.
  - 58 Bioenergy sites


FIA Plot
58.9 foot radius, trees > 24 inches, 1/4 acre
120 feet between, subplots centers
Cond 2
24 foot radius, trees >= 5 inches, 1/24th acre understory vegetation
Forest
Cond 1 (or 3)
Cond 1
6.8 foot radius, seedlings, saplings, 1/300th acre
Forest
180 foot radius, approx 1 hectare, this is the area evaluated by photo-interpretation
Road (non-forest)

FIA plots sample operability

$< \frac{2}{3}$ of acres are on "easy" ground,on average, but varies

	Slope Class	
Variant	≤ 40 Percent	>40 Percent
SO	94%	6%
BM	80%	20%
WC	76%	24%
EC	73%	27%
EM	71%	29%
WS	69%	31%
TT	69%	31%
Variant Mean	63%	37%
IE	57%	43%
CA	49%	51%
NC	46%	54%
CI	44%	56%

Road access varies

	Yarding Distance		
Variant	< ¼ mile	¼ to ½ mile	> ½ mile
WC	93%	1%	5%
SO	93%	6%	2%
BM	90%	6%	3%
WS	84%	11%	5%
CA	84%	11%	5%
NC	79%	16%	5%
Variant Mean	78%	12%	10%
EC	78%	11%	10%
IE	74%	12%	14%
EM	63%	16%	21%
CI	60%	15%	24%
TT	55%	17%	28%

FVS STRATUM table defines forest structures

- **Multi-story**: Eligible for **I**mprovement **C**ut
- **Single-story**: Eligible for **C**ommercial **T**hin
- Young: Eligible for Pre-commerical Thin
- Fuel treatments from manager interviews

Treatment	Residual stand target	Max DBH (inches)	Min DBH (inches)	Understory Target TPA
6 IC Rx	80 to 100 ft^2	19-21, none	5-7	0 to 222
3 CT Rx	150 ft^2	None	7	50
	70-90 TPA	None or PP >=12	5-7	20
Grow Only	Grow Only			

Cut low vigor (LCR<40, Ht/DBH>80) and non-resistant species first

Whole tree harvesting, Pile & Burn, REPUTEd regeneration, project 2 decades

How do we know what's effective?

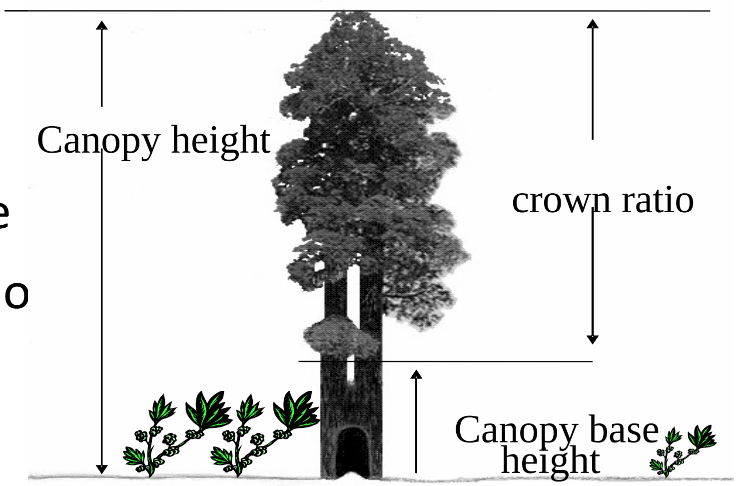
- Legacy: Pre/post FFE TI, CI, SFL, Ptorch, MortVol, **but**
  - All driven by *surface fuels*
  - FVS-FFE surface fuel choices depart from "reality"
    - Don't match FIA crew observations (collected since 2013)
    - SFL doesn't correspond to FIA-observed bole char
- Alternative: Base fire resistance on changes to trees
    - Less large tree mortality → economic, ecological, GHG mitigation & safety benefits & ↓post-fire restoration cost
    - Surface fuel *modeling* outside our scope
      - But surface fuels *accounted for* in treatment cost

To reduce hazard, increase resistance

- Score management accomplishment wrt:
  - **Elevating canopy base height (0-3 points)**
  - **Reducing canopy bulk density (0-3 points)**
  - **Increasing proportion of resistant species (0-3 points)**
  - **Increasing tree size (0-3 points)**
  - Reducing surface fuels, where necessary
- These strategies may have co-benefits wrt
  - Other forest health aspects (insects, disease)
  - Climate benefits of C sequestration and utilized wood
  - Sustainable production of economic benefits

Target Canopy Base Height

- Ran Scott and Burgan 40 fuel models through Behave+→fireline intensity for range of fuels, wind & slope
- Based on Van Wagner crown initiation equation, estimated minimum target canopy base height required to prevent crown fire ignition
- Results indicated some natural break-points for target canopy base height
- CBH from FVS STRUTURE
  - Weighted average height to crown base
  - If multi-stratum, distance between top o lower story and bottom of upper story



Greater CBH→ resistance for more surface fuel models & greater wind speed & slope

Scott & Burgan FM	≤ 7 feet	20 feet	30 feet
TL1 (0-60)	x	x	X
TL3 (0-60)		x	X
TL4 (0-60)		x	X
TL9 (0-10) (low)			X
TU1 (0-20)	x	x	X
TU1 (30-60)			X
TU1 (0-60) Low)			X
TU5 (0)			X

CBH Score	Canopy Base Height
0	< 7
1	7 to 20
2	20 to 30
3	> 30

Canopy Bulk Density

CBD Score	Canopy Bulk Density kg/m^3
0	> 0.15
1	0.1 to 0.15
2	0.05 to 0.1
3	< 0.05

Basal Area of Resistant Species

- Resistant species
  - Western larch
  - Ponderosa pine
  - Jeffrey pine
  - Sugar pine
  - Red fir
  - Douglas-fir
    - Except in IE, EM, BM

Resistant BA Score	Proportion of BA in Resistant Species > 5" DBH
0	< 0.25
1	0.25 – 0.50
2	0.50 – 0.75
3	> 0.75

Survival Volume Proportion as f(size, species)

- Resistance conferred by tree size depends also on species

Group trees by species, variant, and diameter class

Calculate FOFEM predicted survival by species, size at 6-8 ft flame lengths

Multiply volume of each species-diameter group by its FOFEM predicted survival rate, then sum

Survival Proportion = Predicted Survival Volume/Total Volume

Size Score	Survival Volume Proportion
0	< 0.02
1	0.02 to 0.30
2	0.30 to 0.60
3	> 0.60

Evaluating effectiveness

- Composite Resistance Score (CRS)= ∑(CBH, CBD, **Resist**ant Species BA, Size)
  - CRS Range: 0-12
  - Calculate CRS pre & post-treatment, and on decadal interval to assess treatment longevity
- Compare alternative treatments to Grow-only
  - At any post-treatment time, or
  - At an average of multiple post-treatment times

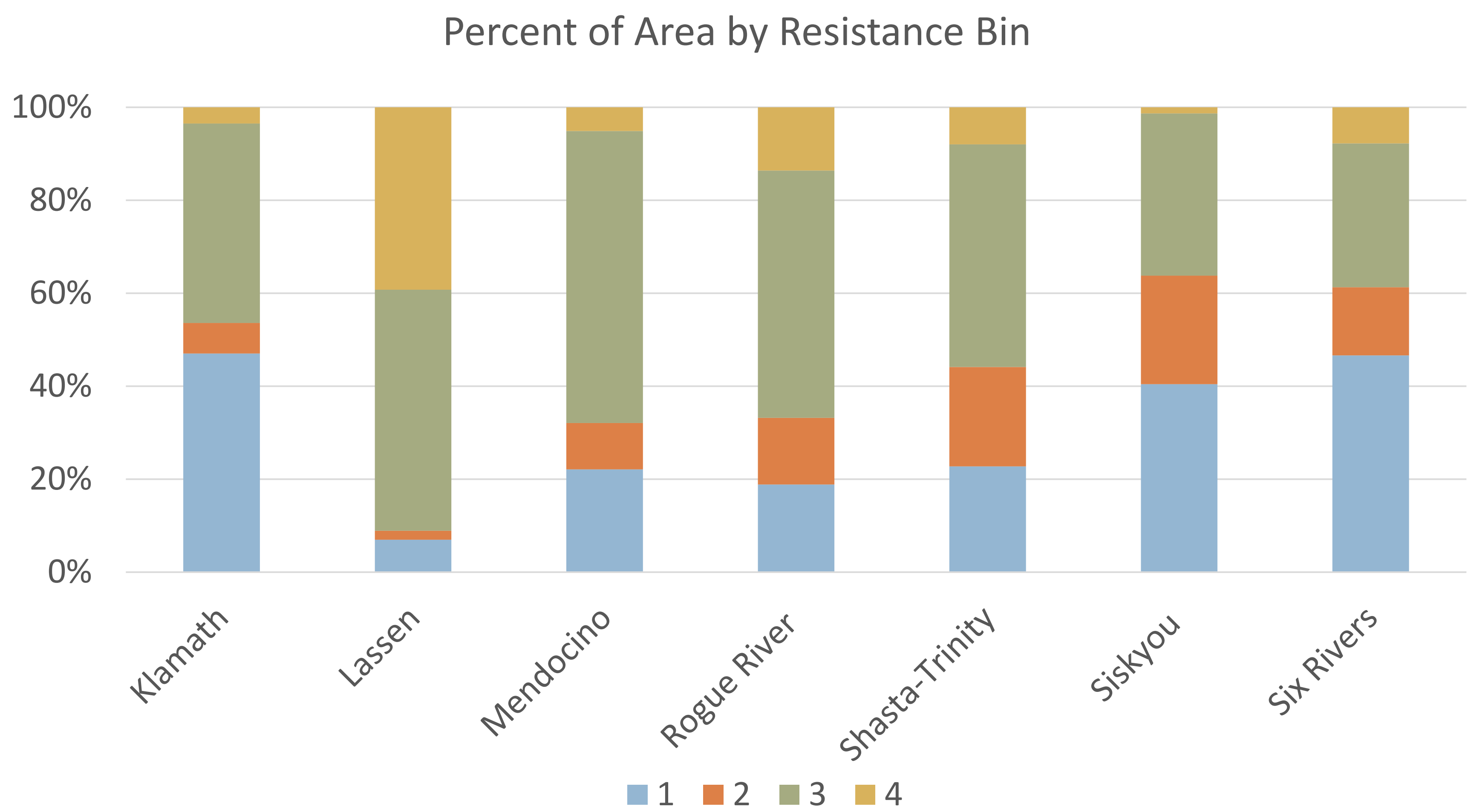
Classify Fire Resistance Prior to Treatments

Bin #	Bin Name	Resistant Species Score Description	Total Score
1	High resistance sp. + high total score	3 ≥75% fire resistant spp.	≥ 9
2	High resistant sp. + low total score	3 ≥75% fire resistant spp.	< 9
3	Mod. resistant sp.	1 or 2 25-75% fire resistant spp.	All values
4	Low resistant sp.	0 < 25% fire resistant spp.	All values

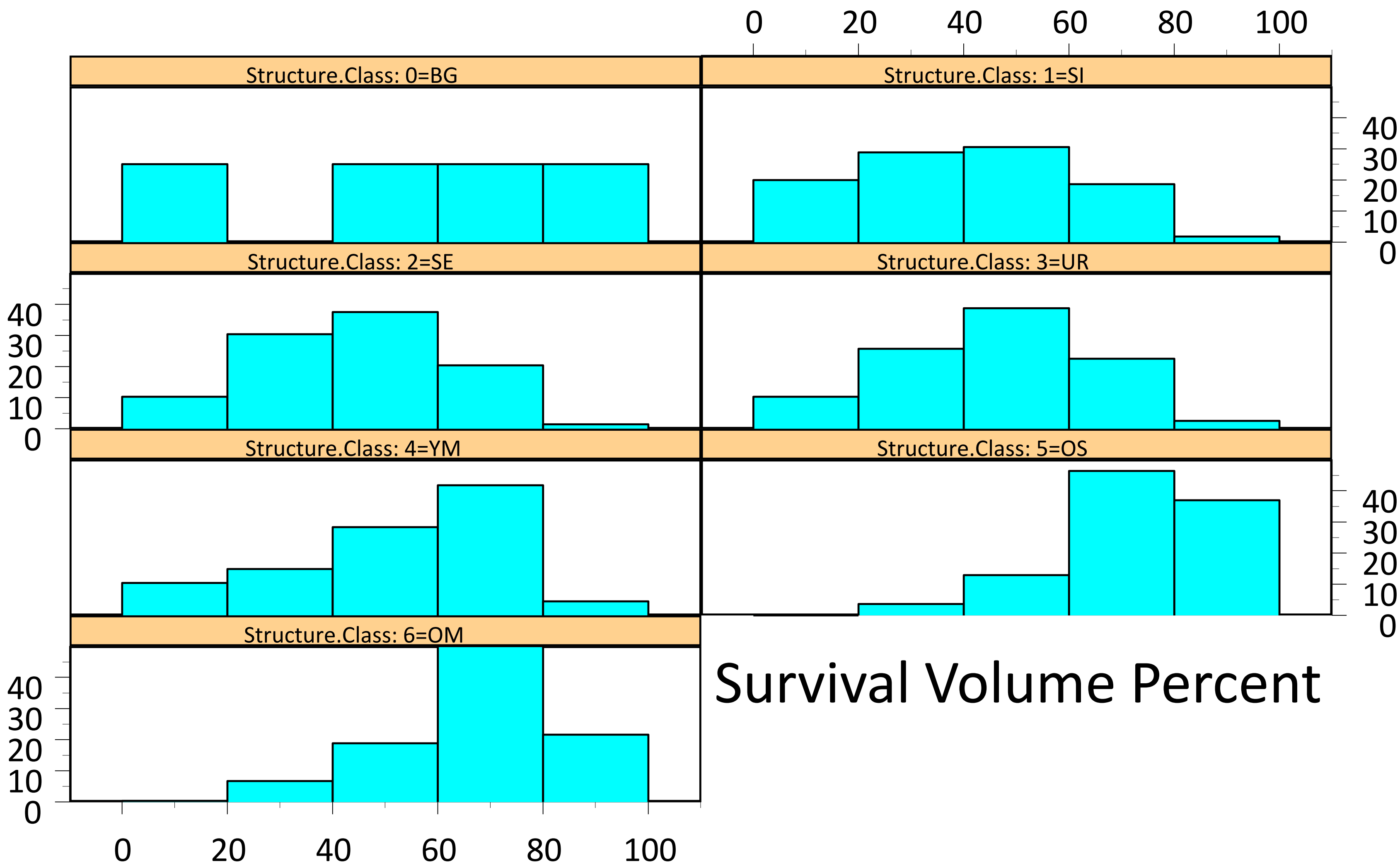
Bins distribution on 26 million acres of single & multi-storied stands

Fire Resistance Bin	Percent of Area	Mean Composite Resistance Score
1	19%	10.1
2	10%	7.3
3	33%	7.4
4	37%	5.1
All bins		7.5

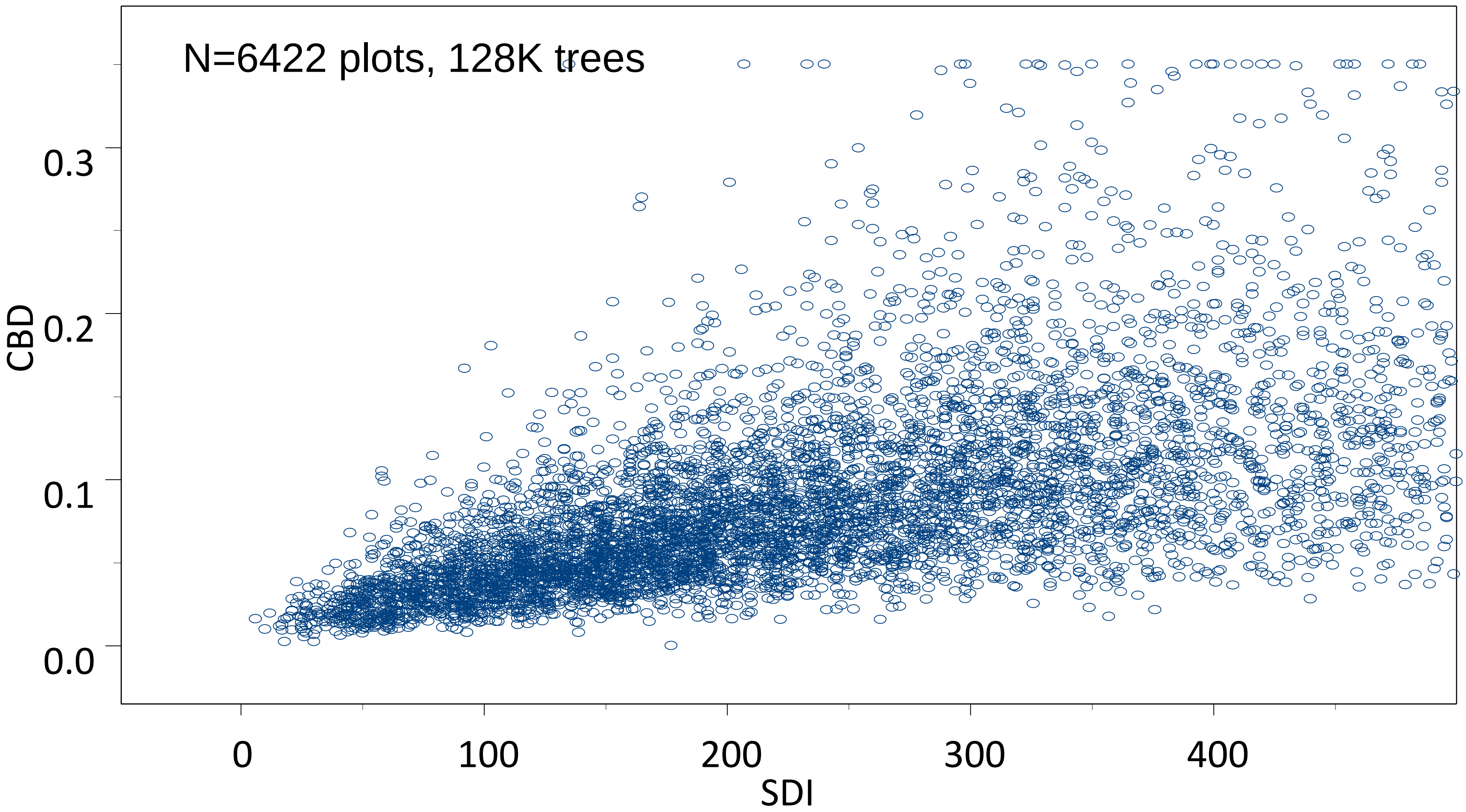
Assess fire resistance by National Forest



Survival volume proportion, by structure class for BM, EC, SO & WS variants



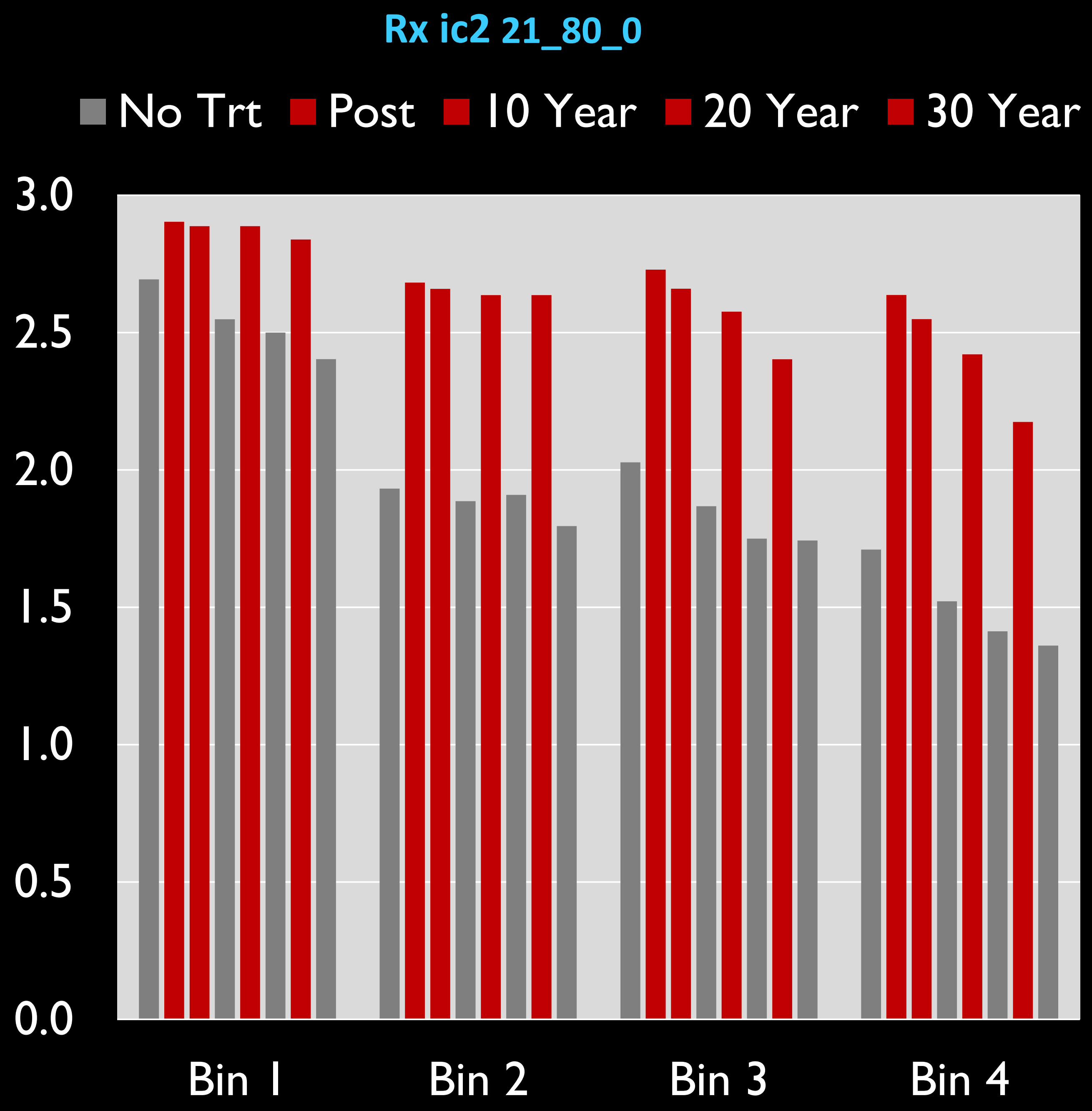
Explore relationships with “medium” data



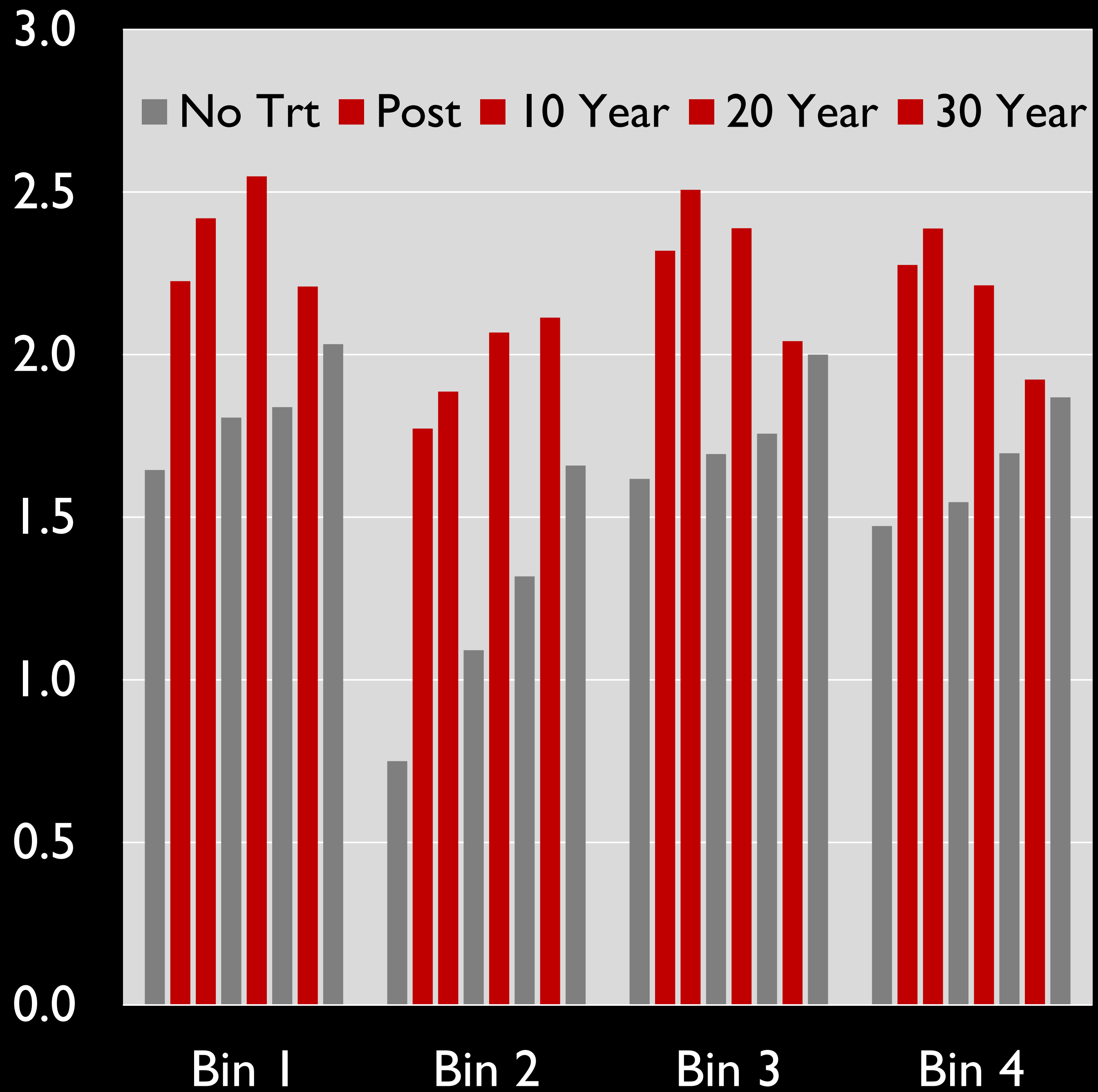
Year 1 resistance score most improved with lower residual over/understory

Sequence Dmax/BA or tpa/ UnderTPA	Average Net Revenue	Average Score Improvement	1000 Acres	Percent of Acres
ic1 21_100_150	-214	1.6	299,860	4%
ic2 21_80_0	-551	2.1	4,288,906	62% *
ic3 19_80_222	-552	1.2	509,543	7%
ic4 32_85_222	1,514	1.6	376,233	5%
ct5 xx_150_50	-431	1.0	3,243,277	24%
ct6 xx_90tpa_20	808	2.2	9,283,547	68% *
ct7 xx_194tpa_0	-1,039	1.7	1,207,809	9%
ic8 xx_100_150	3,808	2.2	118,040	2%
ic9 xx_80_0	5,027	2.4	1,347,126	19%

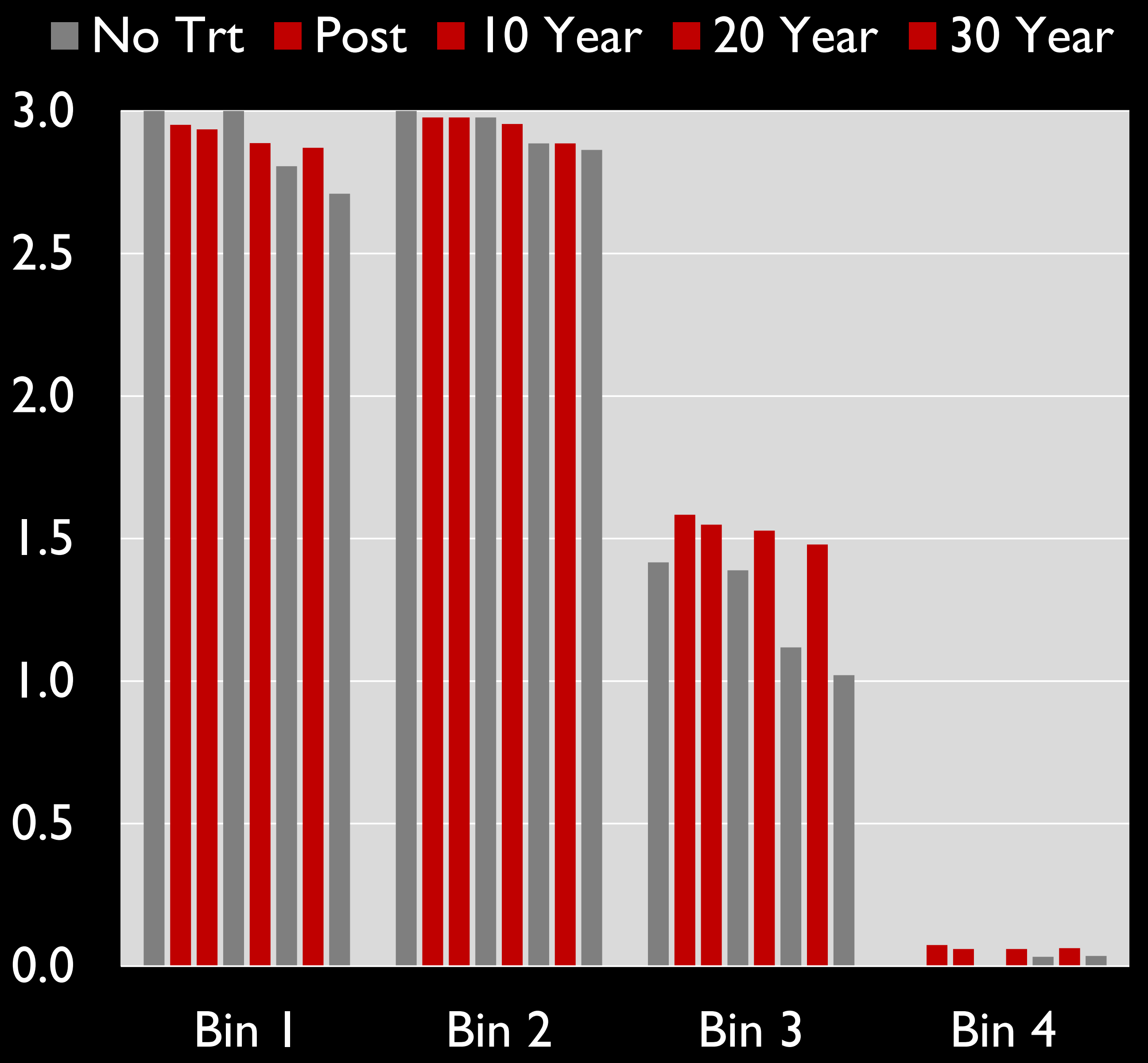
Score	Canopy bulk density
0	> 0.15
1	0.11-0.15
2	0.051-0.10
3	≤ 0.05



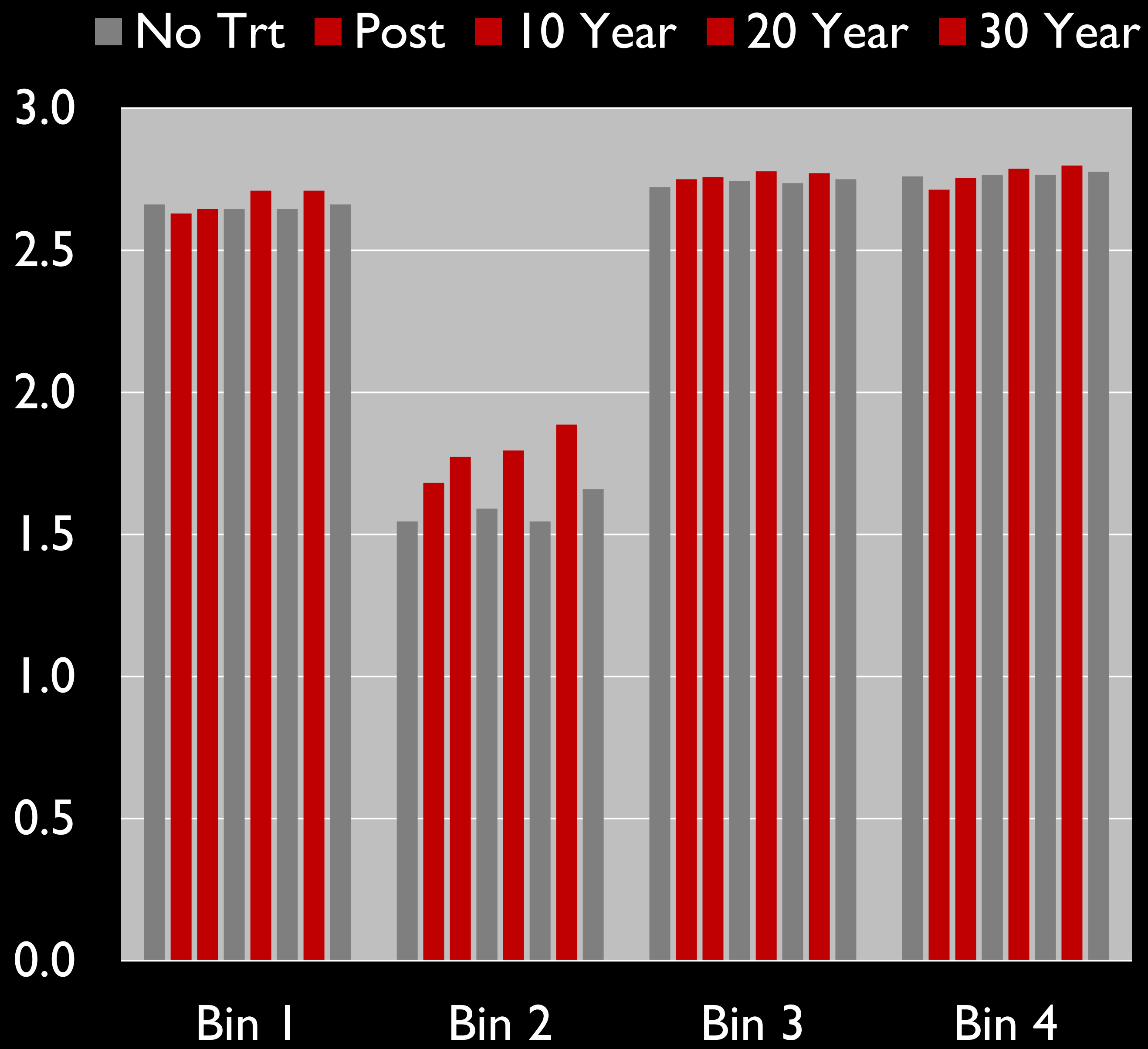
Score	Target canopy base height (feet)
0	≤ 7
1	7.1-20
2	20.1-30
3	> 30



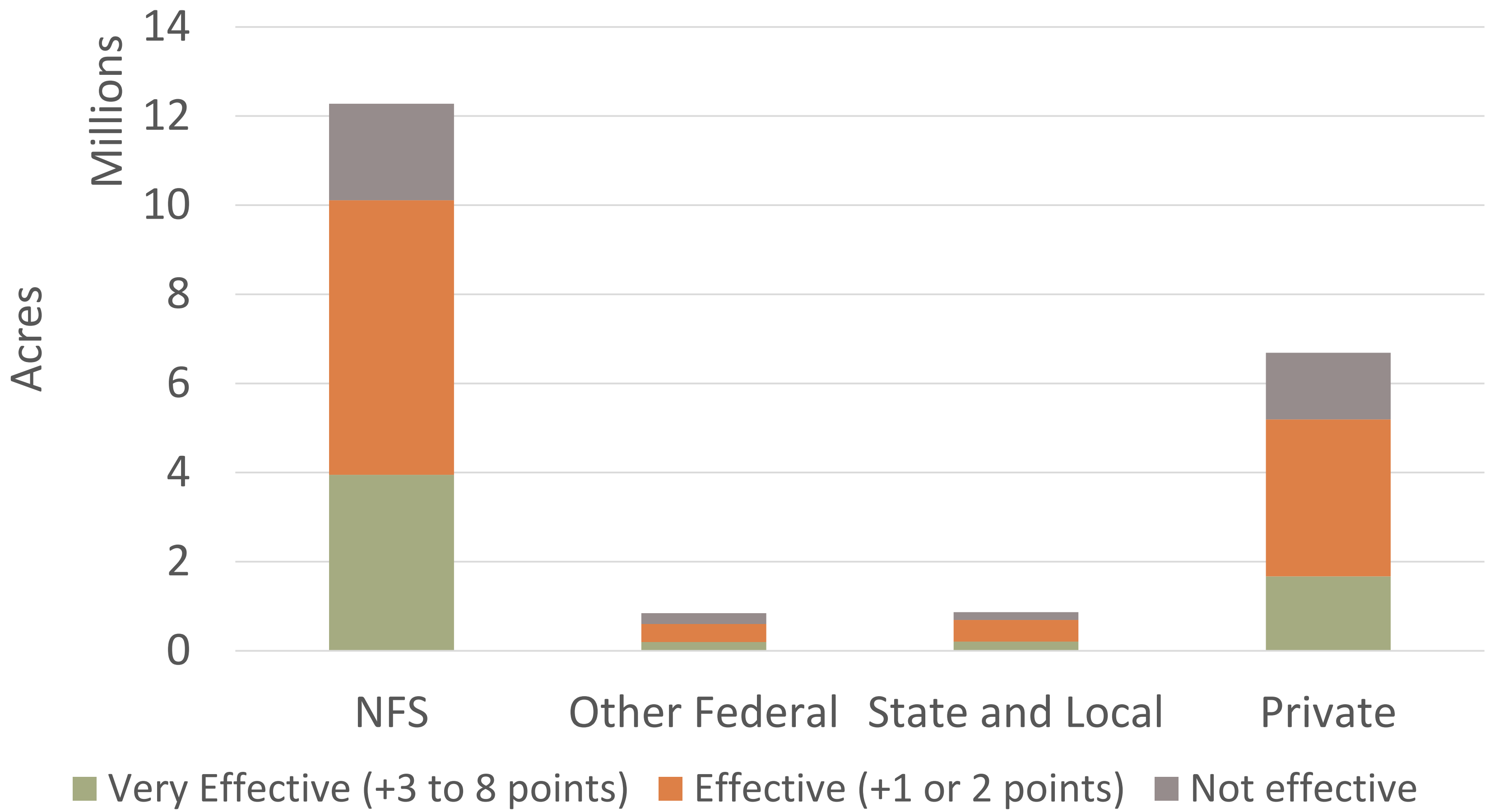
Score	Basal area of resistant species (%)
0	≤ 25
1	26.1-50
2	51.1-75
3	75.1-100



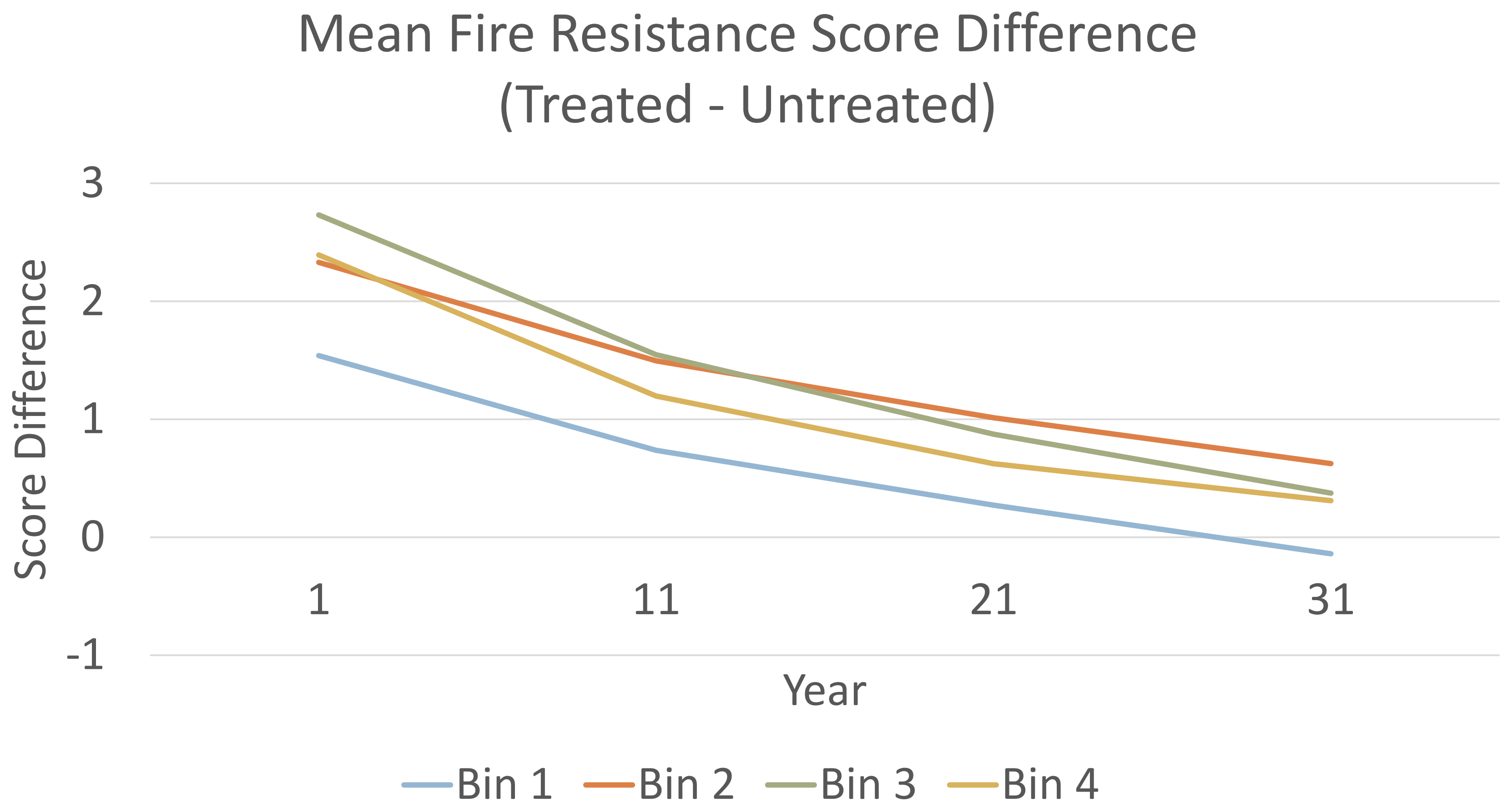
Score	volume left alive (%)
0	≤ 2
1	2.1-30
2	30.1- 60
3	> 60

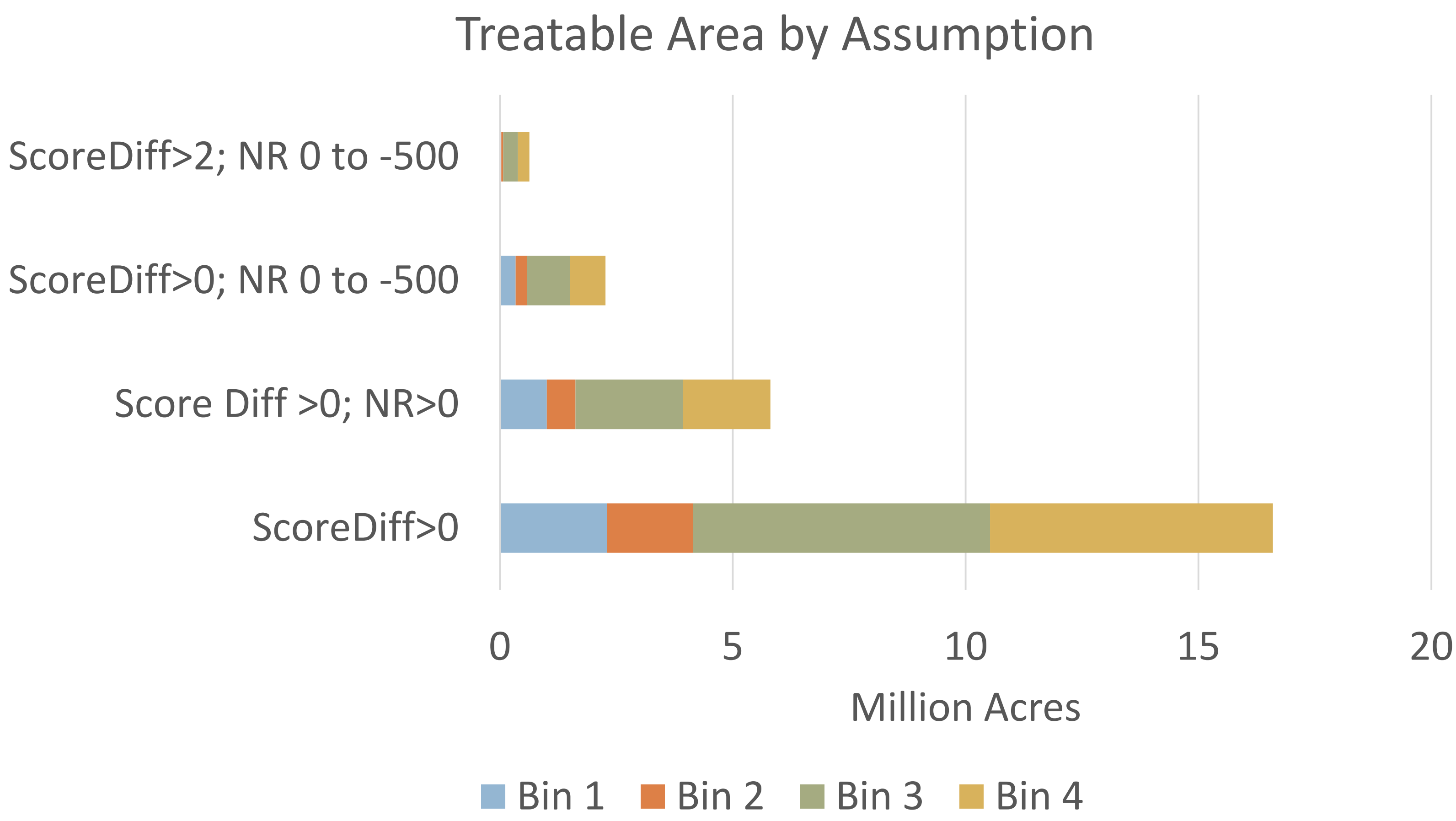


Most stands have ≥1 effective Rx



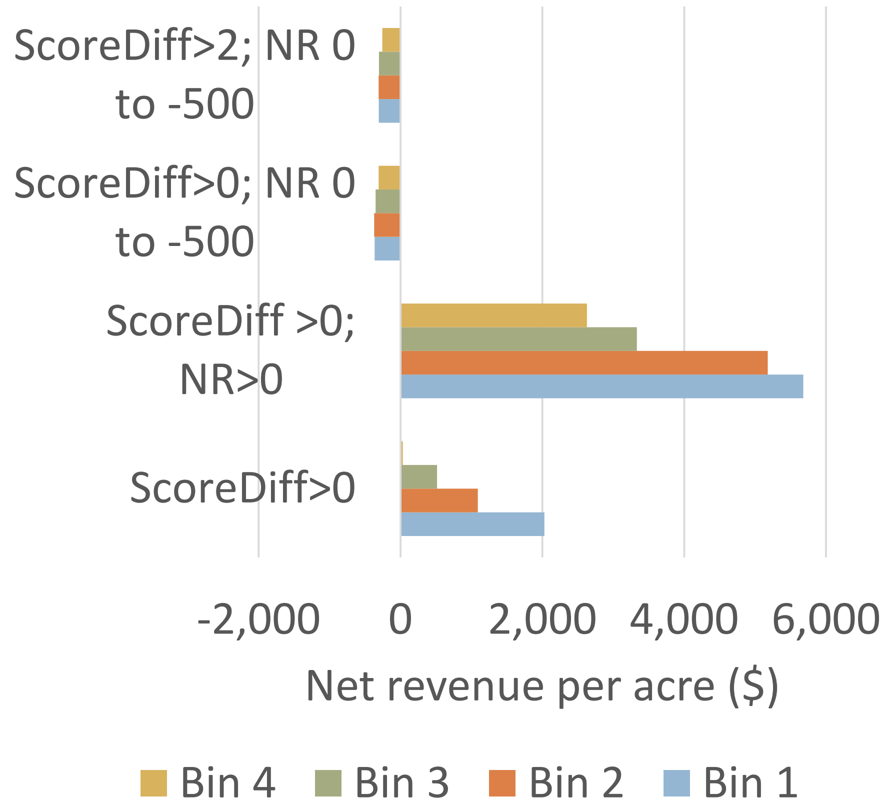
Resistance improvement degrades with time



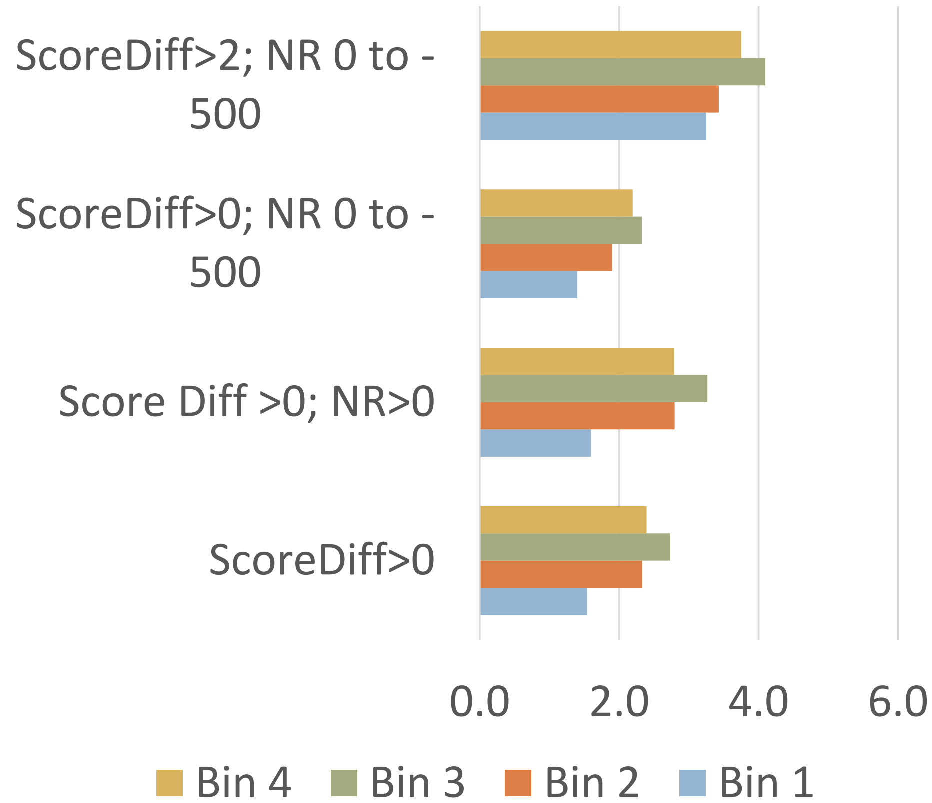


Treatable Area by Assumption
ScoreDiff>2; NR 0 to -500
ScoreDiff>0; NR 0 to -500
Score Diff >0; NR>0
ScoreDiff>0
0
5
10
15
20
Million Acres
Bin 1
Bin 2
Bin 3
Bin 4

Mean **Net Revenue** of Most Effective Treatment



Mean **Score Difference** of Most Effective Treatment



Monitoring prospects

- BioSum can inform about current choices and predict long-term success
- Continuous FIA annual inventory refresh can validate whether forested landscape is changing as desired
- Overlay of FIA plots on FACTS could produce high quality stand management information to link to plots
  - Provided that FACTS is correctly populated
  - FIA data could contribute to effectiveness monitoring, <u>IF</u> management is at sufficient scale to be detected

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QUESTIONS WELCOME

RESEARCH ARTICLE

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biomass, carbon & bioenergy

Inventory-Based Landscape-Scale Simulation of Management Effectiveness and Economic Feasibility with BioSum

Jeremy S. Fried, Larry D. Potts, Sara M. Loreno, Glenn A. Christensen, and R. Jamie Barbour

Thanks for your interest! More at **BioSum.info**

Who can use?

System Requirements

- MS Access 32-bit (2010 or above)
- Admin access (to install ORACLE Express)
- Arc/GIS (for travel times calculation)
- FVS with FFE extension
- OpCost (and R)
- Fast processor and ample disk space
- Downloaded FIADB formatted inventory data

Analytic Capacity Requirements

- Experienced with FVS-FFE and undaunted by need for creative data manipulation
- Facility with database queries in Microsoft Access
- Arc/GIS
- Silviculture/Fuels management
- Interpretive analysis
- Graphic communication