Scoping cost-effective, multi-metric hazard reduction opportunities over a forested landscape: trade-offs among opportunity costs, treatment intensity, effectiveness and longevity

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JFSP: Fuel treatment cost-effectiveness

- A tool to help managers evaluate & prioritize fuel treatment "investment"
  - BioSum: Bioregional Inventory Originated Simulation Under Management
- Understand costs of different fuel treatment types
  - We developed 9 from manager interviews
- Scope a range of vegetation types
  - Drew from 23 FIA forest types in 5 states

Enhanced Biomass Summarization

FVS as treatment implementation engine for FIA data

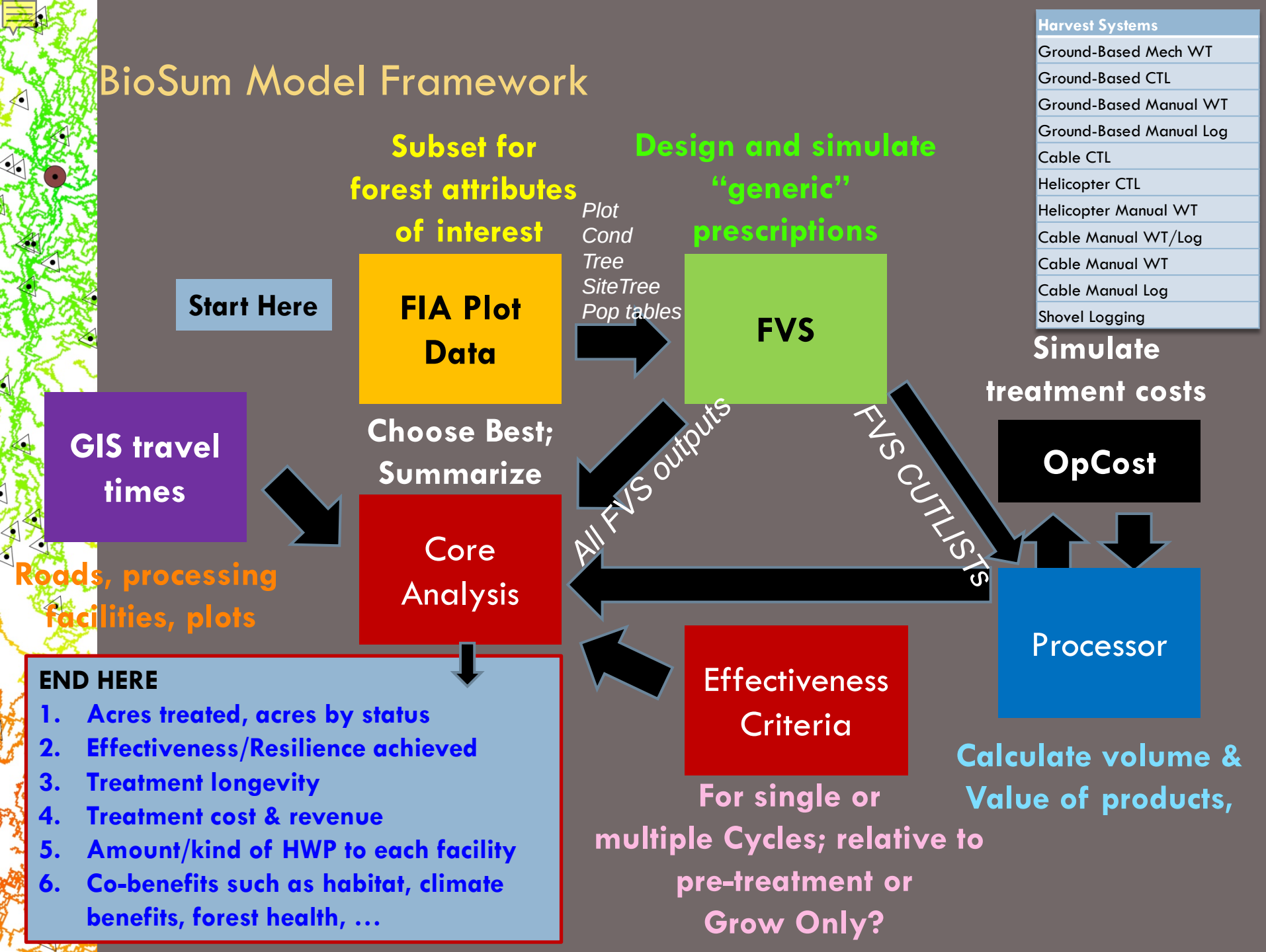
- 2002: Framework to assess biomass supply from fuels management in OR, CA, AZ and NM
- 2007: BioSum workflow management software (version 1)
  - Effectiveness tied to torching/crowning indices
- 2016: BioSum version 5 -- Multi-decade, multi-purpose system, multi-metric treatment selection criteria; Projects–
  - Sustainable biofuels feedstock (California)
  - Fuels Mgt Pace and Scale Acceleration Potential (Blue Mountains)
  - Biochar feedstock supply study (Upper Klamath)
  - **Fuel Treatment Cost Effectiveness (OR CA WA MT ID – JFSP)**

BioSum Analysis Framework:

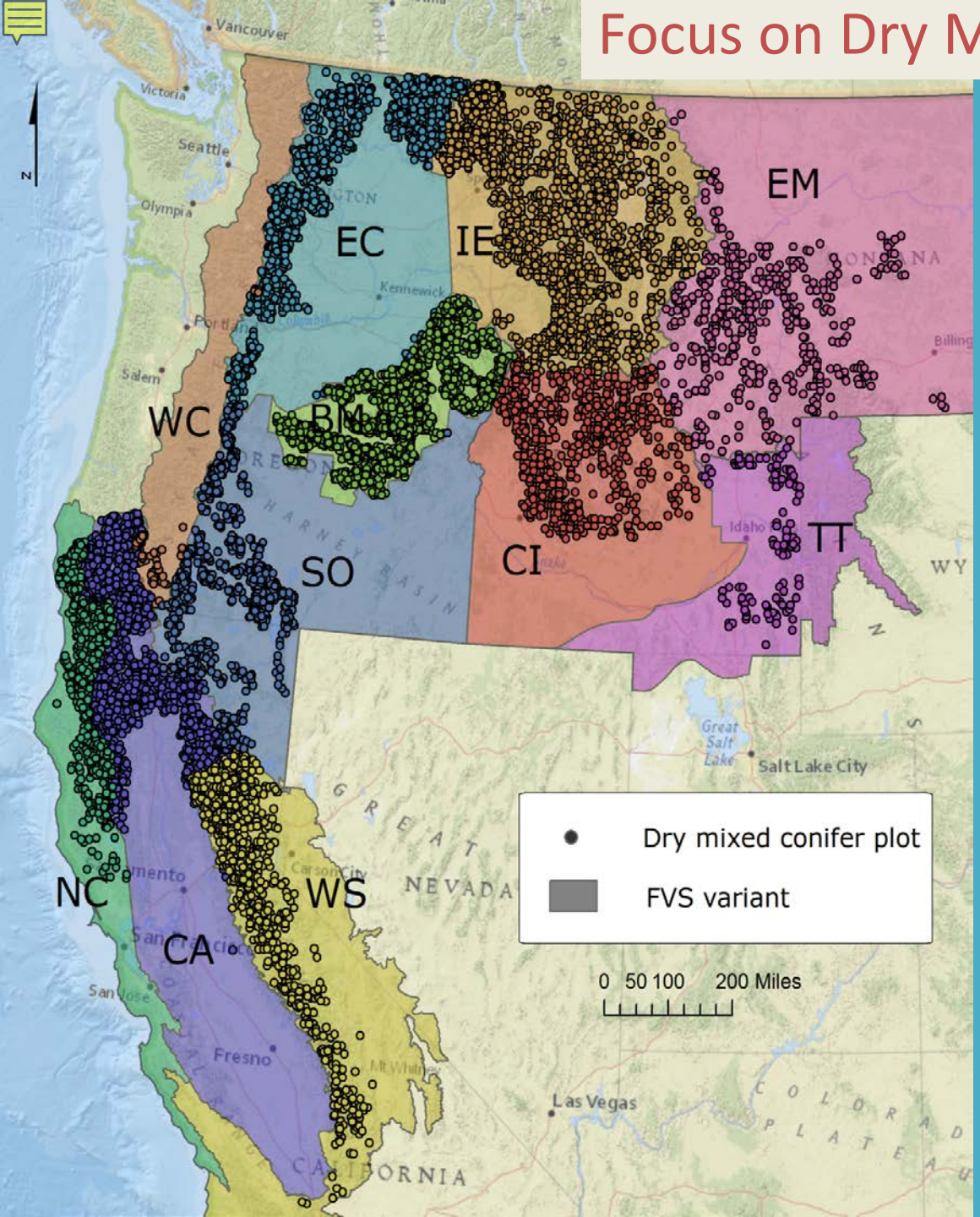
Builds on FIA's representative sample of all forest

- Inventory-originated, stand projection model-assisted, simulation and COMPARISON among outcomes of multiple, alternative, <u>multi-decade</u> forest management sequences *with respect to*
  1. Stand attributes (e.g., structure & composition)
  2. Resilience to stressors like fire,
  3. Climate benefits (sequestration, products storage, substitution),
  4. Feedstock delivered to existing/planned wood processing facilities,
  5. Revenues & costs associated with management, and
  6. Policy constraints (diameter caps, subsidies, Rx fire limits, …)
- Supports sifting through effects & costs of alternatives

BioSum Model Framework



Focus on Dry Mixed Conifer Forests



By the Numbers

- FIA sample contains
  - 6422 "conditions"
    - Full or partial plots
  - Represents 25 million ac.
  - Field visited
    - 2003-2013
- BioSum model
  - 11 FVS variants
  - 9 treatments
  - 283 sawmills, etc.
  - 58 Bioenergy sites

FVS STRATUM table defines forest structures

- **Multi-story**: Eligible for ***Improvement Cut***
- **Single-story**: Eligible for ***Commercial Thin***
- Prescriptions synthesized from manager interviews

Treatment	Residual stand target	Max DBH (inches)	Min DBH (inches)	Understory Target TPA
6 improvement cut Rx	80 to 100 ft^2	19-32, none	5-7	0 to 222
3 commercial thin Rx	150 ft^2	None	7	50
	70-90 TPA	None	5-7	20
Grow Only	Grow Only			

  - Cut low vigor and fire vulnerable species first
  - Whole tree harvest with slash piled & burned if > 15 t/ac
  - Regeneration via REPUTE

How do we know what's effective?

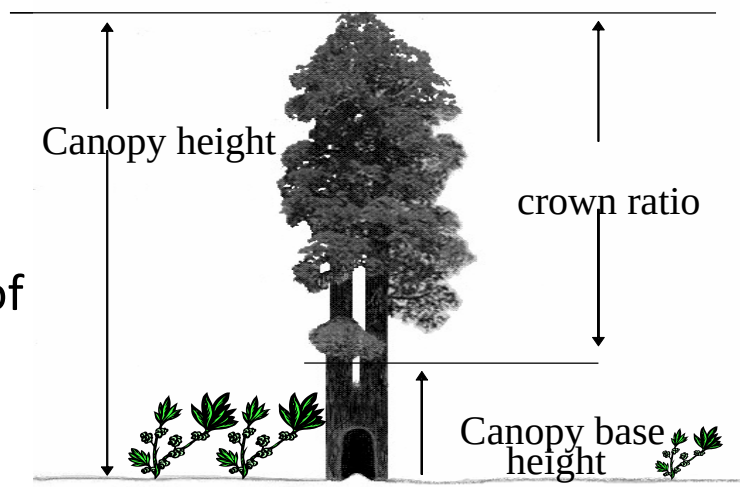
- Legacy: Pre/post FFE TI, CI, SFL, Ptorch, MortVol, **but**
  - All driven by *surface fuels*
  - FVS-FFE surface fuel choices depart from "reality"
    - Don't match FIA crew observations (collected since 2013)
    - SFL doesn't correspond to FIA-observed bole char
- New approach: Score resistance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

To reduce hazard, increase resistance

- Score management accomplishment with respect to
  - **Increased canopy base height (0-3 points)**
  - **Reduced canopy bulk density (0-3 points)**
  - **Increased share of resistant species (0-3 points)**
  - **Increased predicted tree volume survival (0-3 points)**
- These strategies may have co-benefits
  - Other forest health aspects (insects, disease)
  - Climate benefits of C sequestration and utilized wood
  - Sustainable production of economic benefits

Targeting 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 of 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

Literature sets Canopy Bulk Density targets

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

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

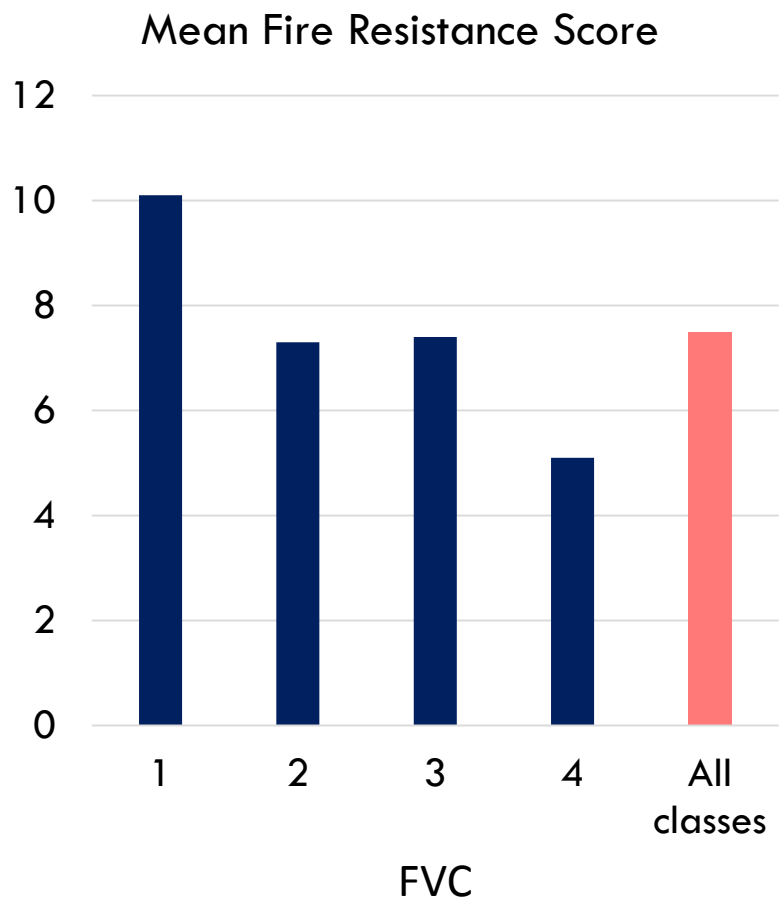
Evaluating effectiveness

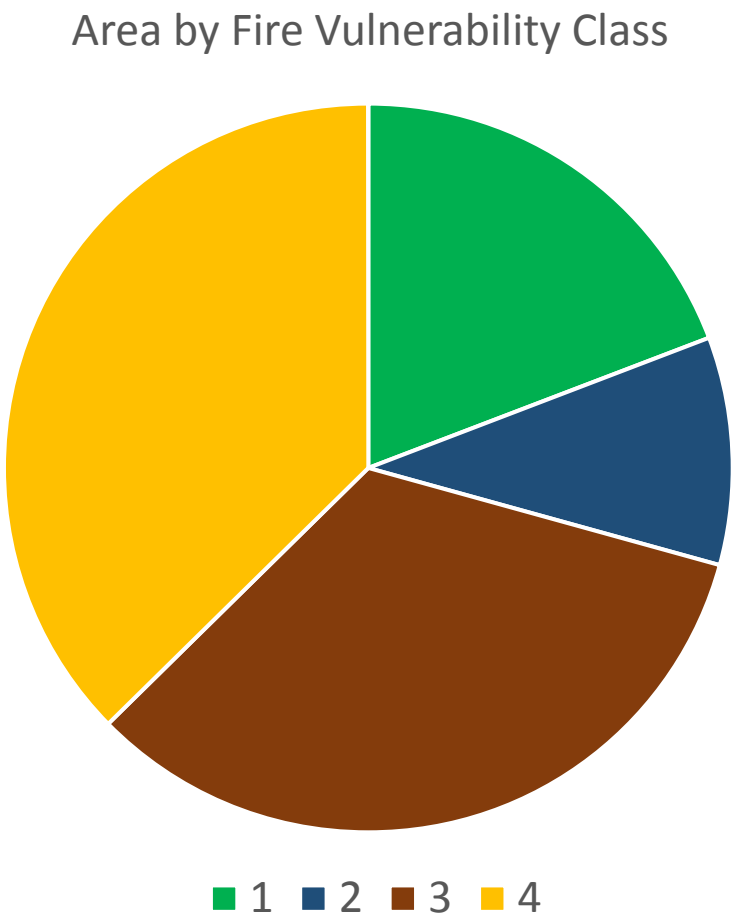
- Fire Resistance Score (FRS)= ∑ of 4 subscores (0-12)
  - Calculated before and after treatment at each FVS cycle
- Score difference = treated – grow-only outcome
  - Immediate: at year 1 (“Y1”)
  - Long-term: mean value over four cycles (“MS”)
- If score difference > 0, then effective
- Effective treatment with maximum score difference is “Best”

Fire Vulnerability Class (FVC) Before Management

FVC #	FVC Description	Resistant BA Score	FRS
1	High Resistant BA score & high FRS	3 ≥75% fire resistant spp.	≥ 9
2	High Resistant BA & low FRS	3 ≥75% fire resistant spp.	< 9
3	Mod. resistant BA score	1 or 2 25-75% fire resistant spp.	All values
4	Low resistant BA score	0 < 25% fire resistant spp.	All values

FVC distribution on 25 million acres of single & multi-storied stands

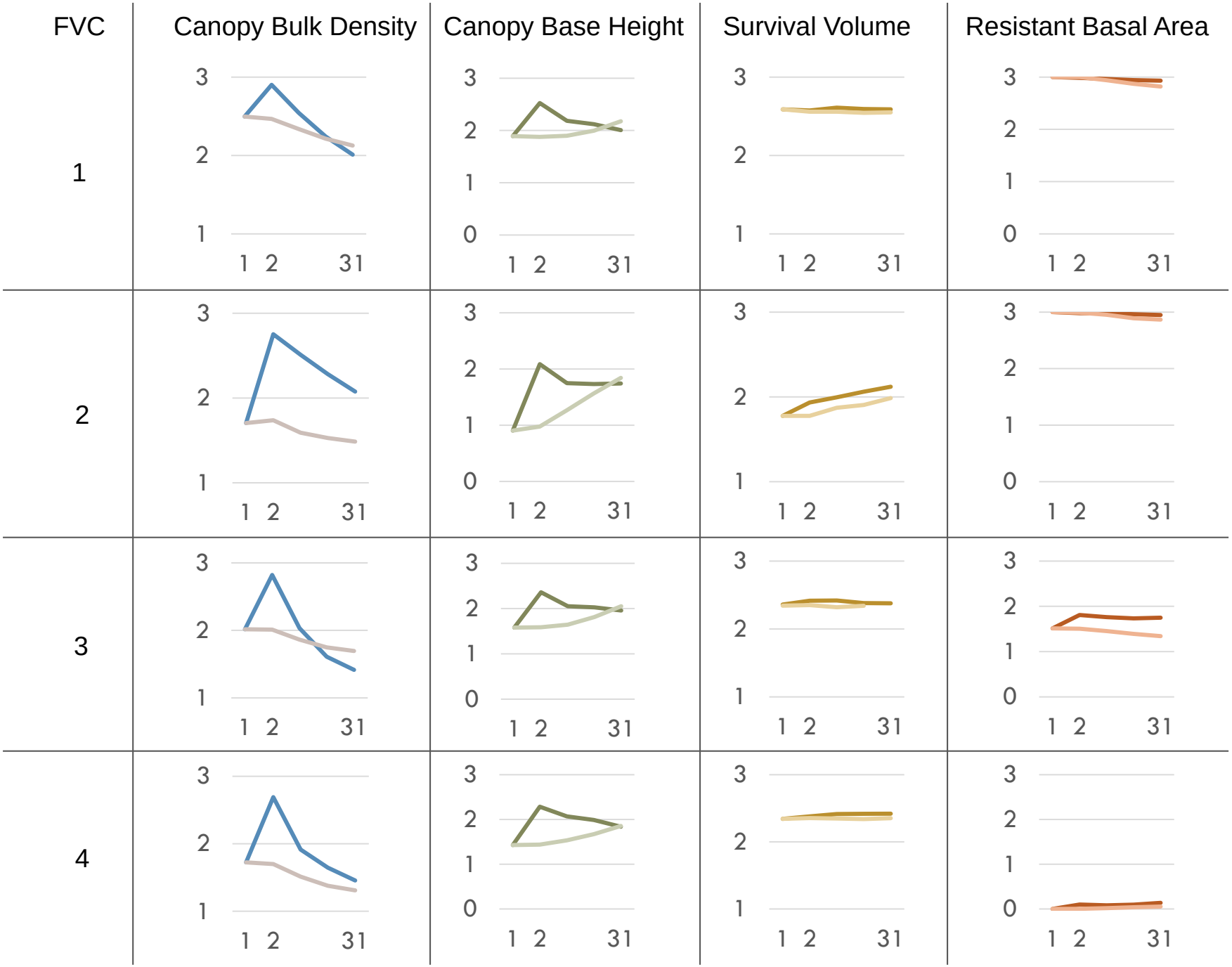




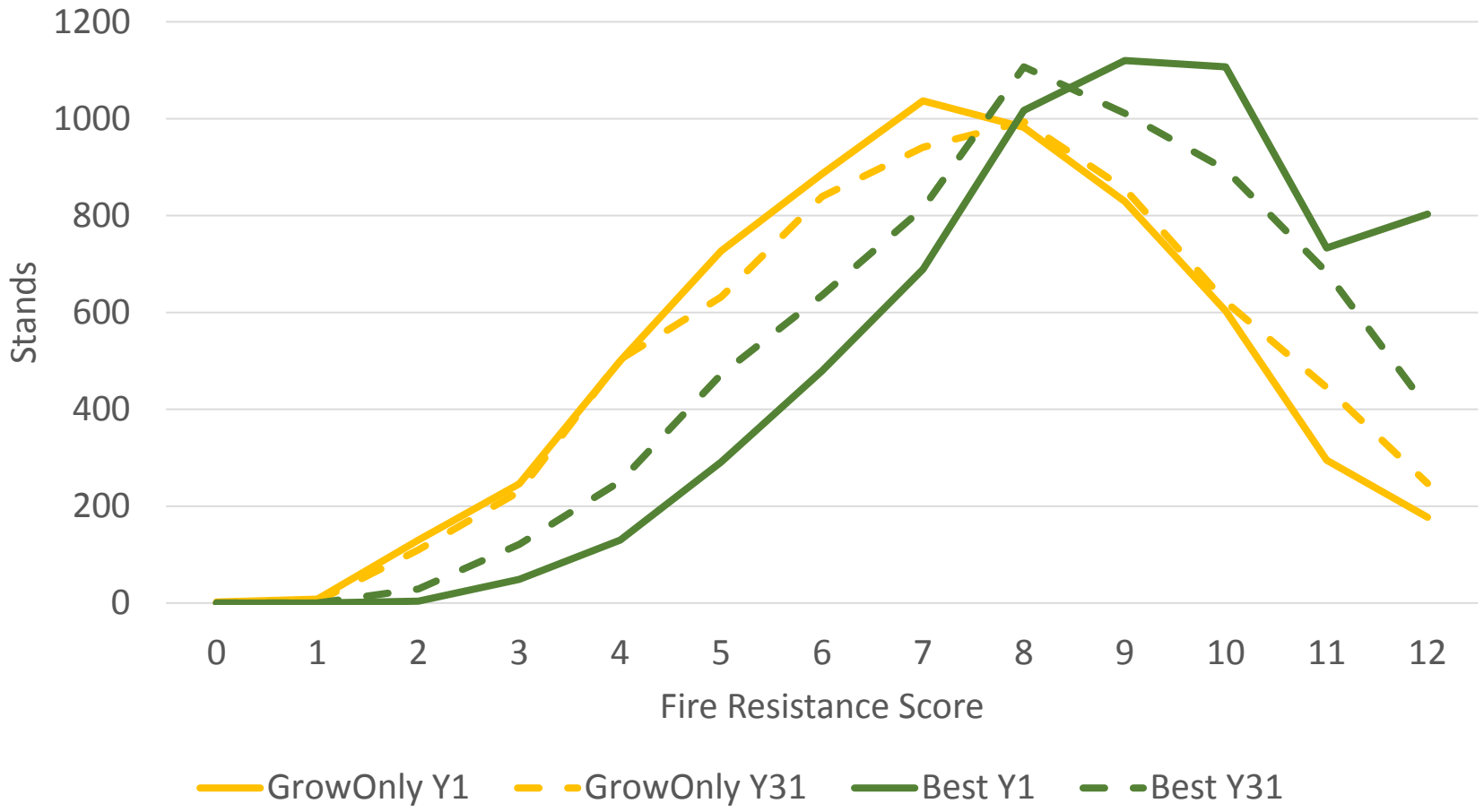
Fire resistance score most improved with lower residual over/understory

Rx No. DBH max	Resid. BA ft^2 or TPA	Under-story TPA	Net Revenue	Mean Score Change	Percent of Acres
Improvement cuts on 6.9 million multi-story acres					
Rx1: 21”	100 BA	150	111	1.2	6%
Rx2: 21”	80 BA	0	-427	1.7	63%
Rx3: 19”	80 BA	222	121	1.2	5%
Rx4: 32”	85 BA	222	939	1.2	3%
Rx8: NA	100 BA	150	1,614	1.2	5%
Rx9: NA	80 BA	0	319	1.7	57%
Commercial thins on 13.7 million single-story acres					
Rx5: NA	150 BA	50	-573	1.2	18%
Rx6: NA	90 tpa	20	770	1.7	58%
Rx7: NA	194 tpa	0	-986	1.3	17%

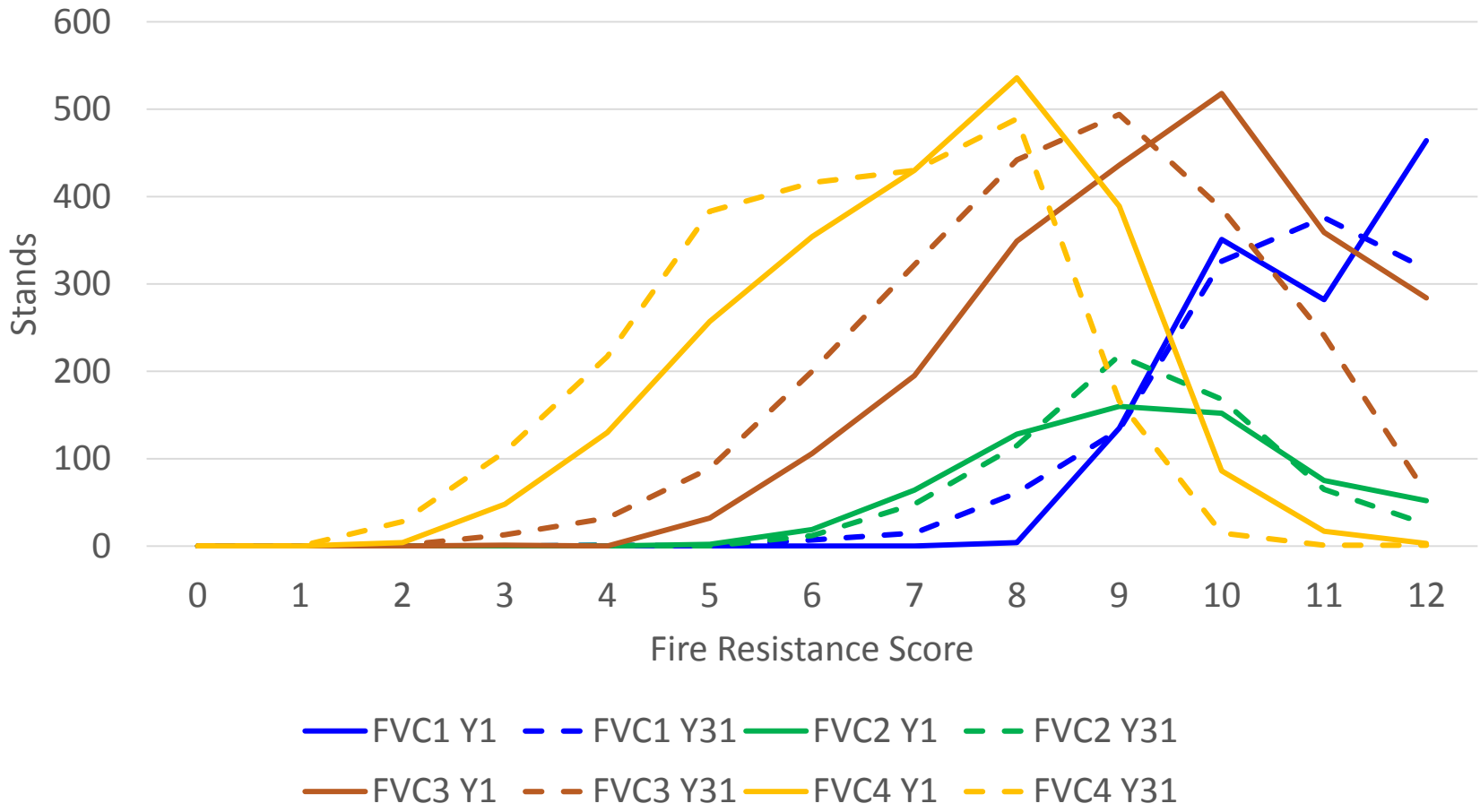
Subscore Outcomes for Package 2 Improvement Cut on Multi-story Stands



Treatment improves resistance over 30 years

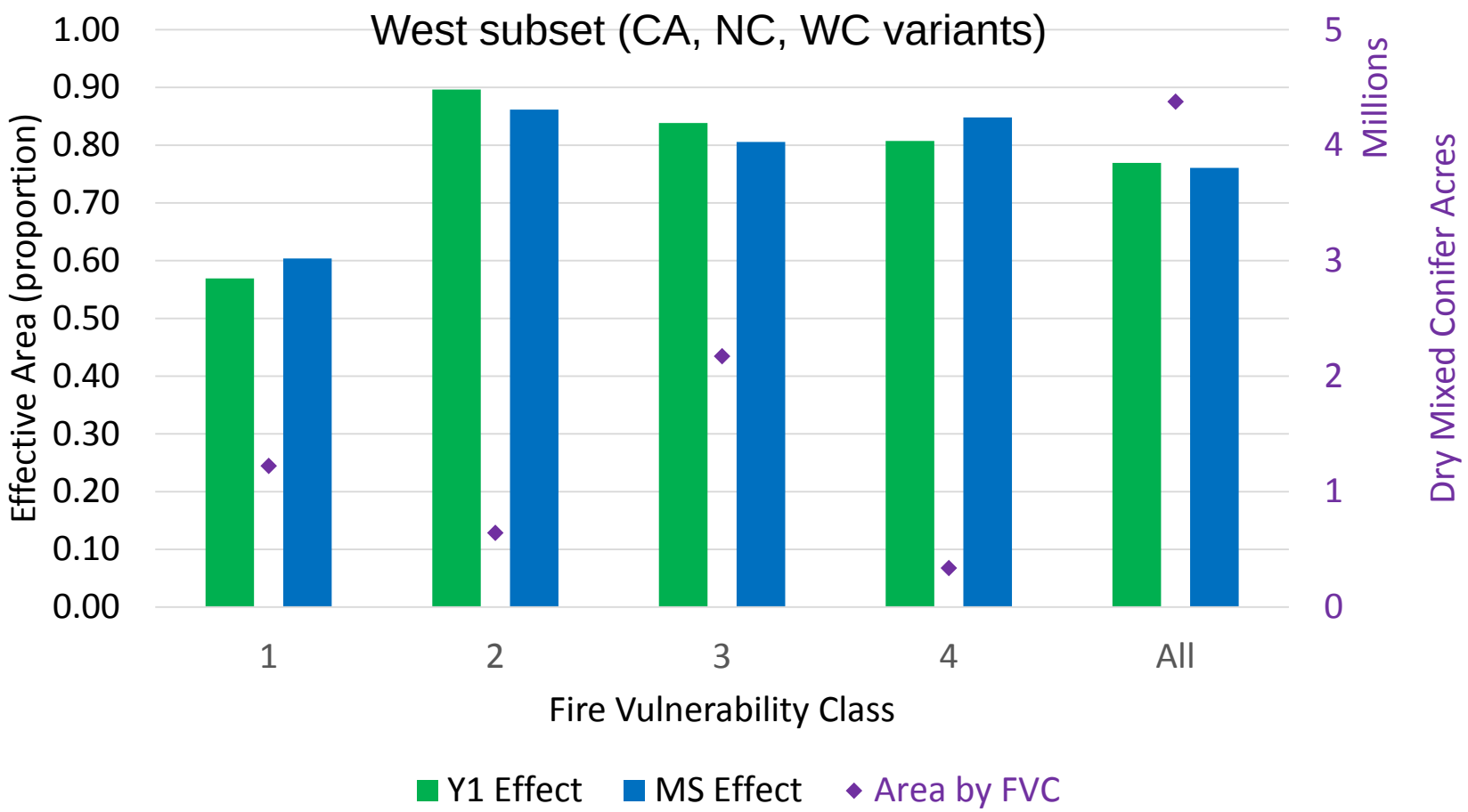


Treatment longevity by FVC

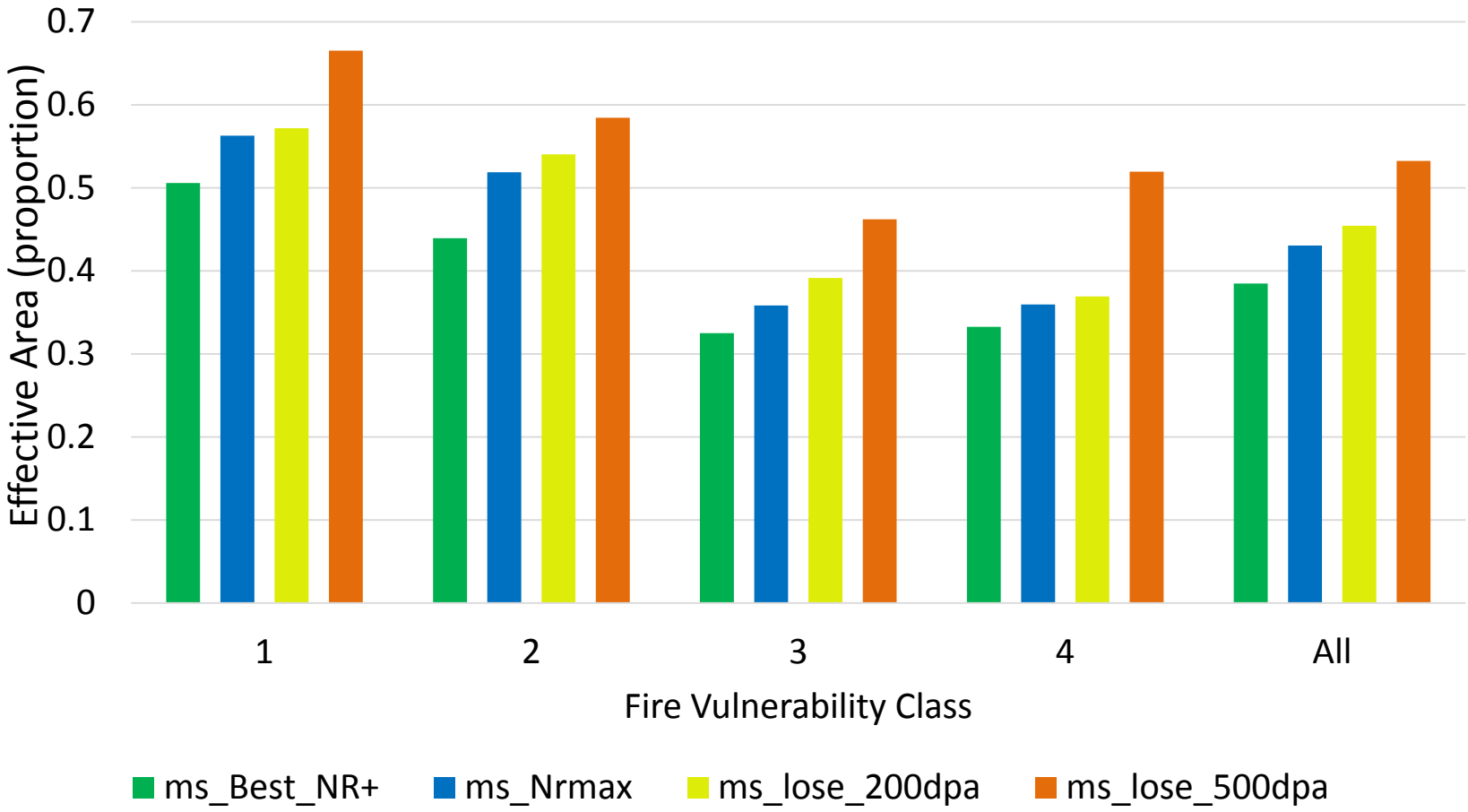


Most acres have effective treatments

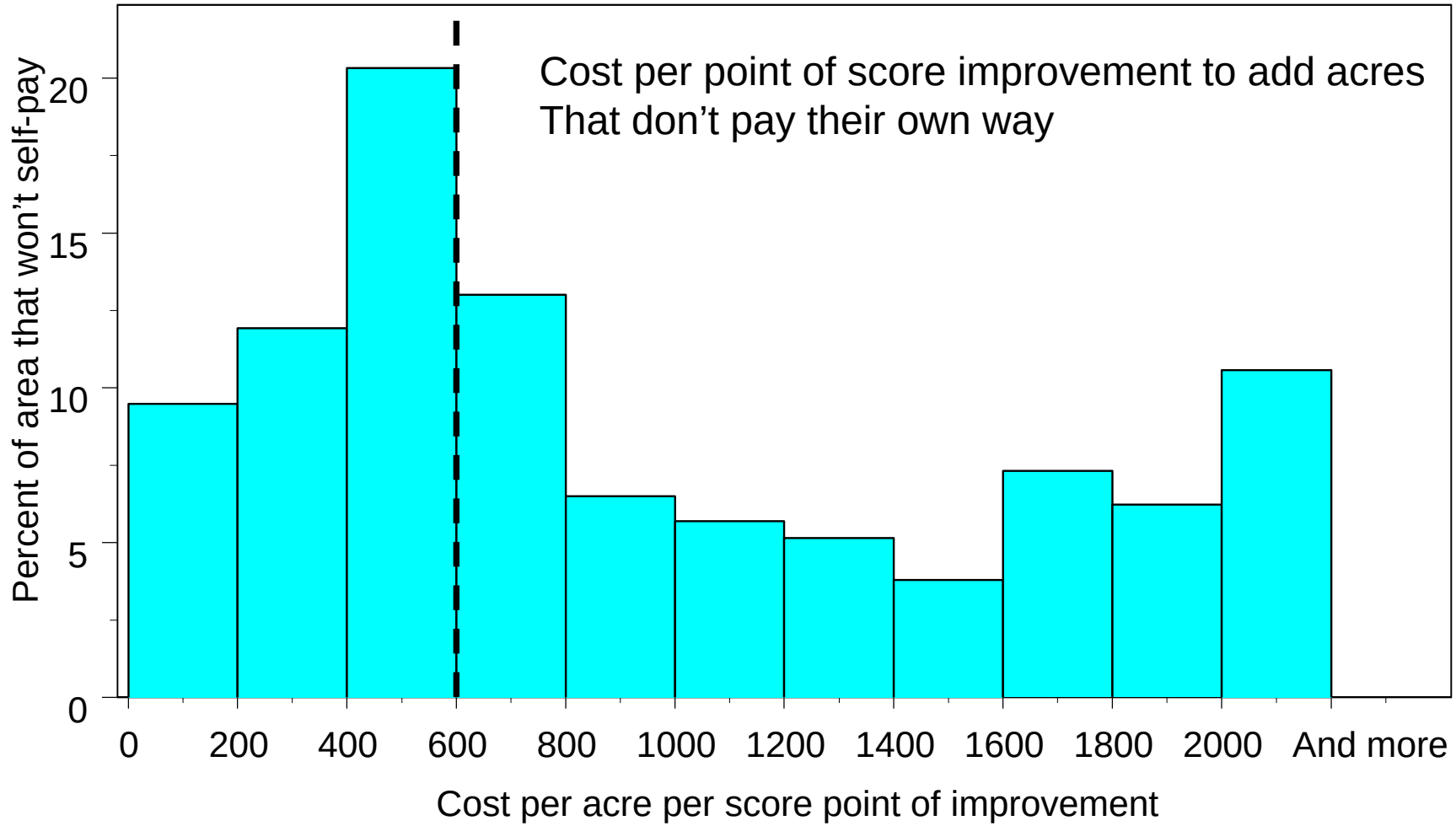
Over a third have >1 effective option



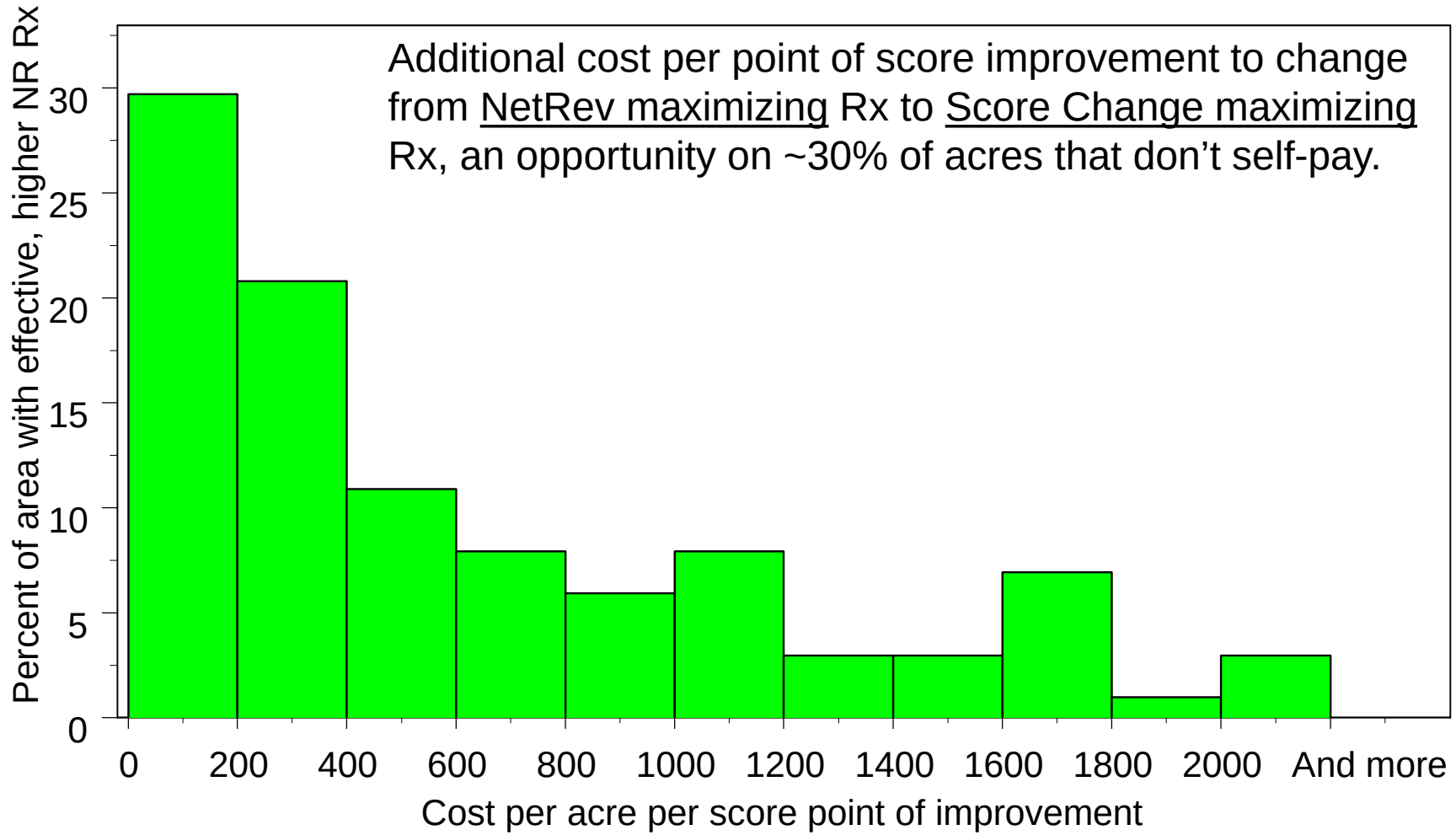
Less than ½ of treatable acres self-pay



$600 subsidy ↑ treatment from 42 → 64% of treatable area



Can further improve score with Rx switch



More intense treatment more successful in short and long run

Rx No. DBH max	Resid. BA ft^2 or TPA	Under-story TPA	Net Revenue	Score Change	Percent of Acres
Commercial thins on 13.7 million single-story acres					
5: NA	150 BA	50	-573	1.2	18%
6: NA	90 tpa	20	770	1.7	58%

Rx 6 more "intense" because generally less residual density
Rx 6 applies on more acres (including those lacking 150 ft^2 BA)
Considering only stands where both are implementable:

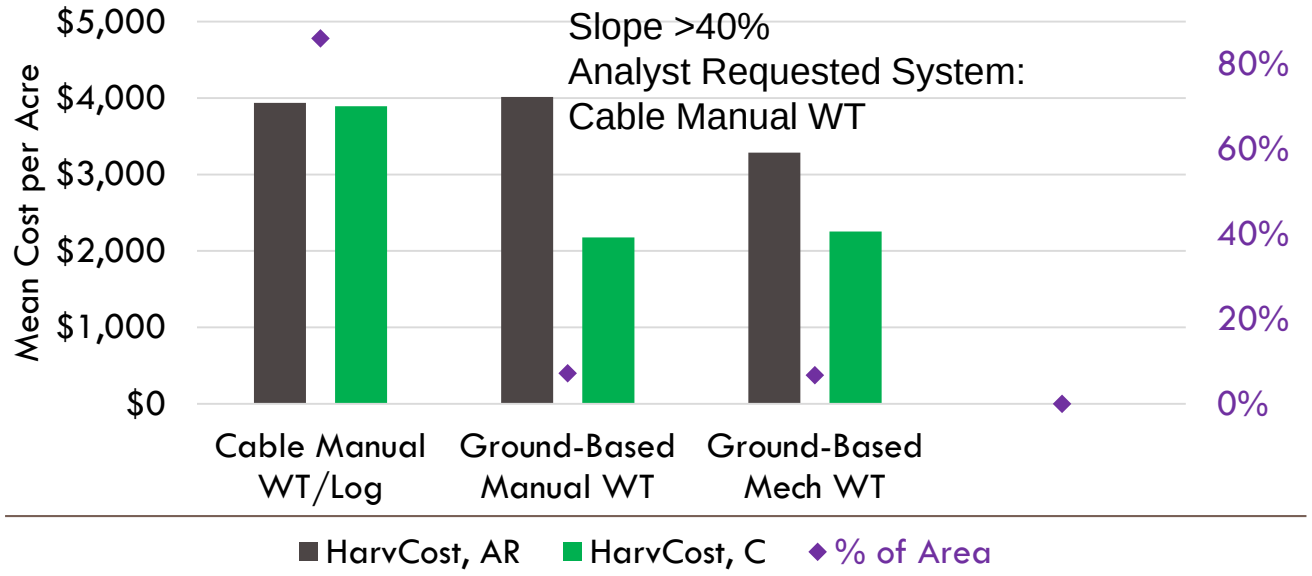
	Acres @Year 1	Acres @Year 31
Rx 5 Best or tie	4,167,624	4,221,841
Rx 6 Best or tie	7,509,172	6,847,678

No DBH cap sometimes best; more NetRev

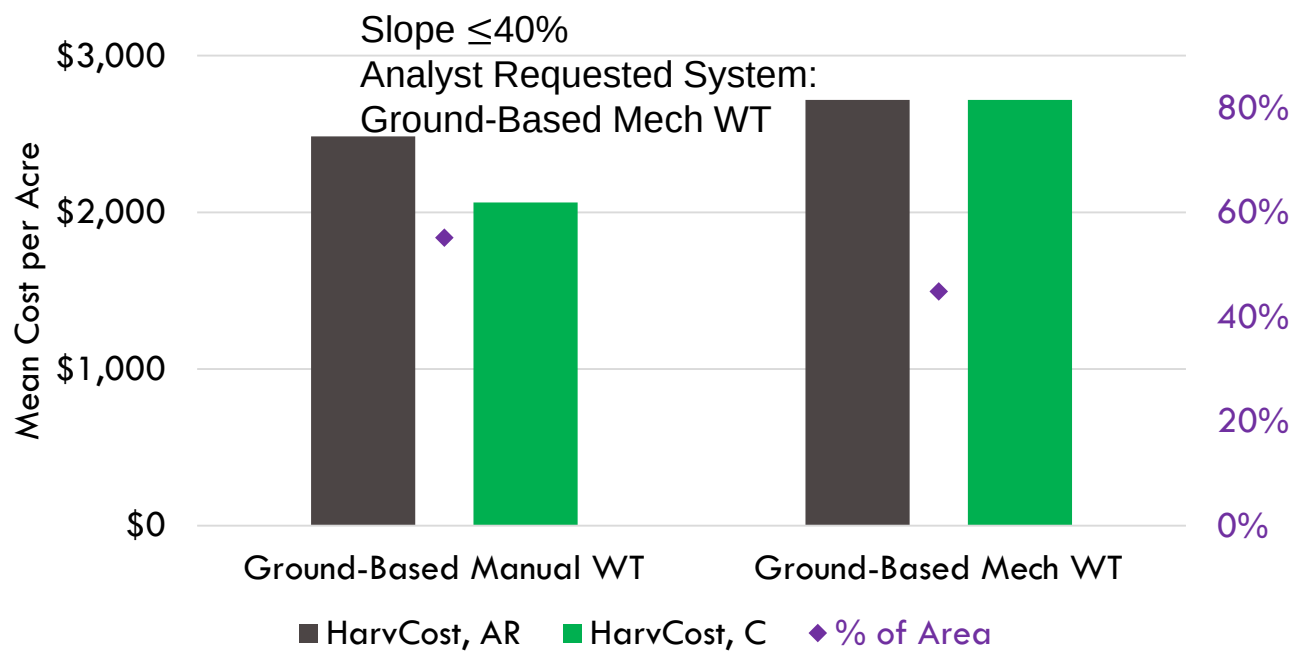
Rx No. DBH max	Resid. BA ft^2 or TPA	Under-story TPA	Net Revenue	Score Change	Percent of Acres
Improvement cuts on 6.9 million multi-story acres					
2: 21"	80 BA	0	-427	1.7	63%
9: NA	80 BA	0	319	1.7	57%

Best mean score improvement	Acres	Avg Net Rev/ac for Rx 2	Avg Net Rev/ac for Rx 9	Score Change 2	Score Change 9
2: (21" cap)	945,520	$510	$3,637	2.0	0.9
9: (no DBH cap)	484,341	$1,272	$5,908	0.9	2.0
Equal	3,639,025	-$597	-$351	1.6	1.6

Analyst requested vs Cheapest cost harvest Systems for CA Rx 9



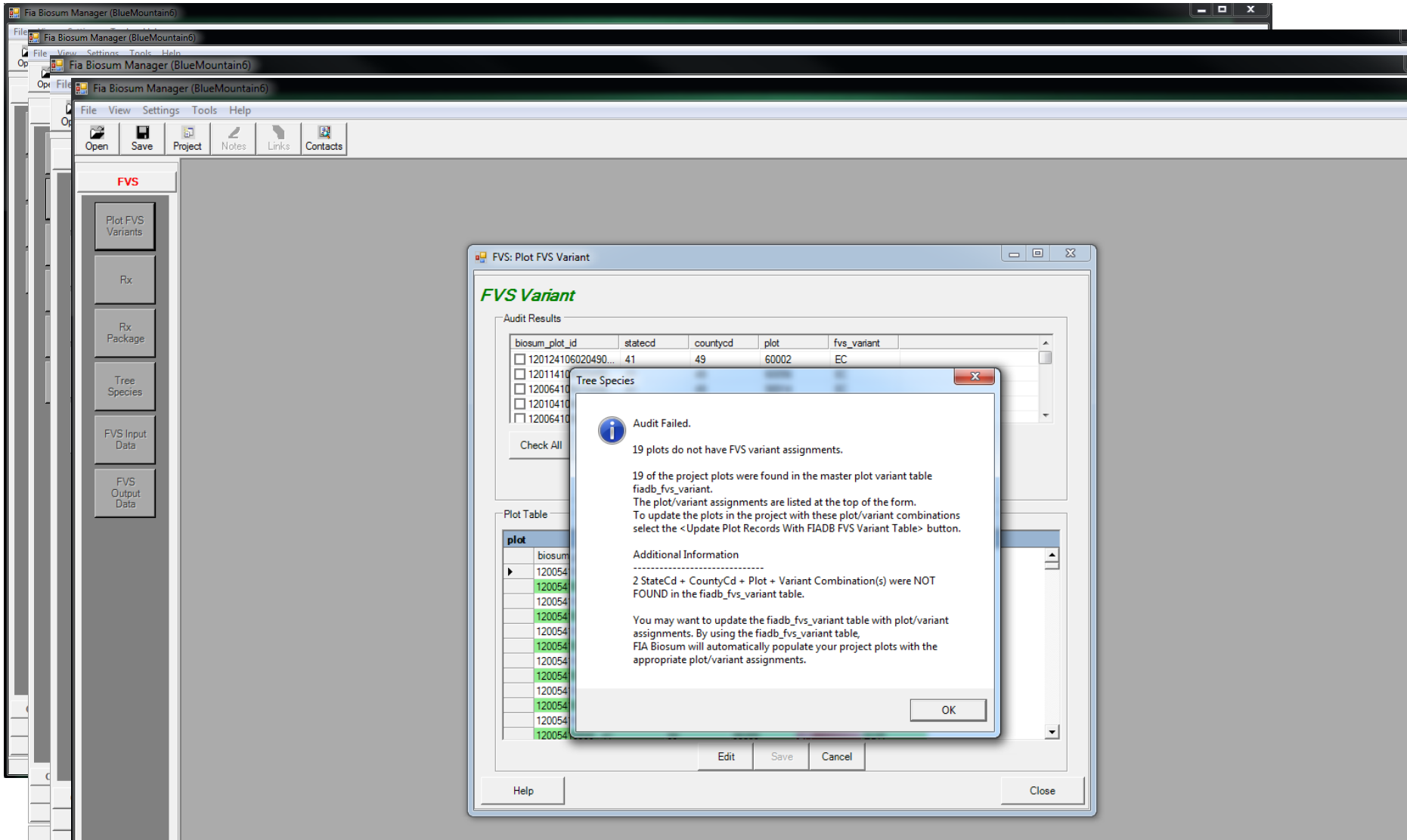
- Avg ↑ NetRev ~ $5
  - Before accounting for Δ surface fuel treatment costs



Conclusions

- BioSum tool eases exploration of treatment economics
- A successful treatment can be devised for most acres
  - But can be self-paying on less than half of those
  - Subsidies could increase area treated substantially
  - Some improvement in fire resistance lasts for decades
- Canopy base height and bulk density are most easily modified; resistant species basal area not so much
- Percent mortality volume hard to affect, but volume killed by fire reduced by moving wood to products

BioSum software available now!



Gratitude to many!

- BioSum development funded by

PNW RMA & FSD Programs	Oregon Dept. of Forestry
Joint Fire Sciences Program	California Energy Commission

- Intellectual contributions from:

R. Jamie Barbour	Larry Potts	Benktesh Sharma
Terrie Jain	Lesley Bross	Bill Stewart
Dale Weyermann	Sara Loreno	Guy Pinjuv
Glenn Christensen	Conor Bell	Rob Keefe
Peter Daugherty	Olaf Kuegler	Jonathan Sandquist
Roger Fight	Demetrios Gatziolis	Tina Mozelewski
Carlin Starrs		

- Questions? http://www.biosum.info