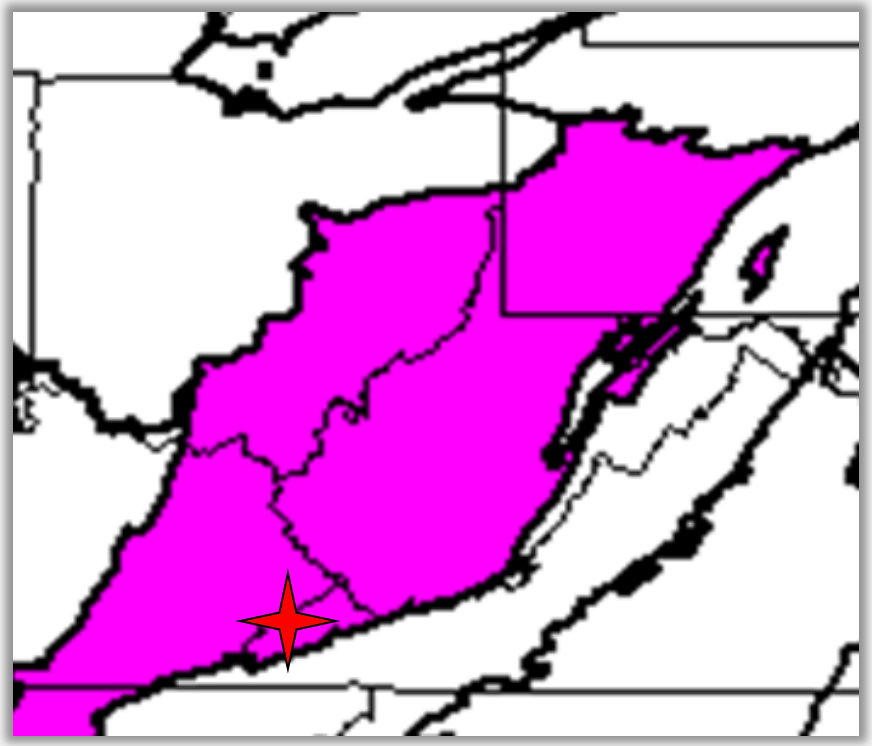
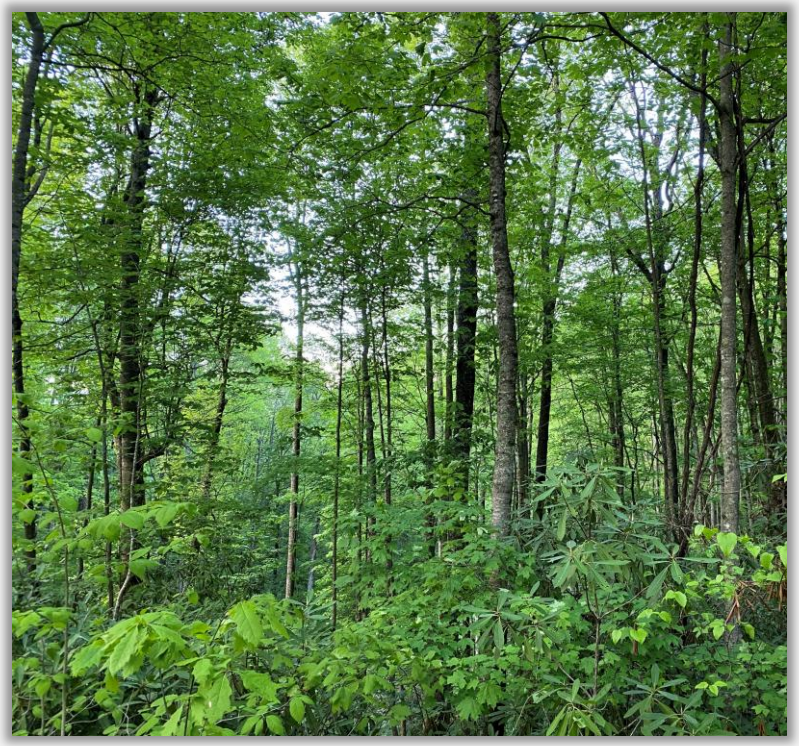
FOREST DEVELOPMENT SEVENTEEN YEARS AFTER SURFACE MINE RECLAMATION IN VIRGINIA

Chris Fields-Johnson, PhD, CUCF, BCMA

Background

Powell River Project
Wise County, Virginia





Appalachian Coal Basin

Mixed Mesophytic Forest

Study Location

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Background

- Appalachian Coal Surface Mining

- ~1.5 Million Acres Impacted
- Large portion abandoned without successful reforestation

- Forestry Reclamation Approach (FRA) developed to improve reforestation success

- FRA Goals to Restore:
  - Native tree species diversity
  - Forest productivity

- Research Objectives:
  - Test FRA methods at operational scale
    - Best final grading methods?
    - Best groundcover mixtures?

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Background

Clearing, Drilling, and Blasting

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Background

Overburden and Coal Removal

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Background

Coarse Overburden Placement

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SMCRA 1977: Restore “Approximate Original Contour”

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FRA Steps

1) Cap with at least four feet of topsoil or mainly weathered sandstone

2) Minimize soil compaction during final grading

3) Plant groundcovers that don't out-compete trees

4) Plant mix of mid-to-late succession native trees

5) Plant high-quality trees with professional hand planters

Background

Fine Overburden Placement (non-soil), Hydroseeding, Bare Root Tree Planting

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Background

Let it grow!

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Repeat photography 5 and 6 years after FRA planting

Background

Let it grow!

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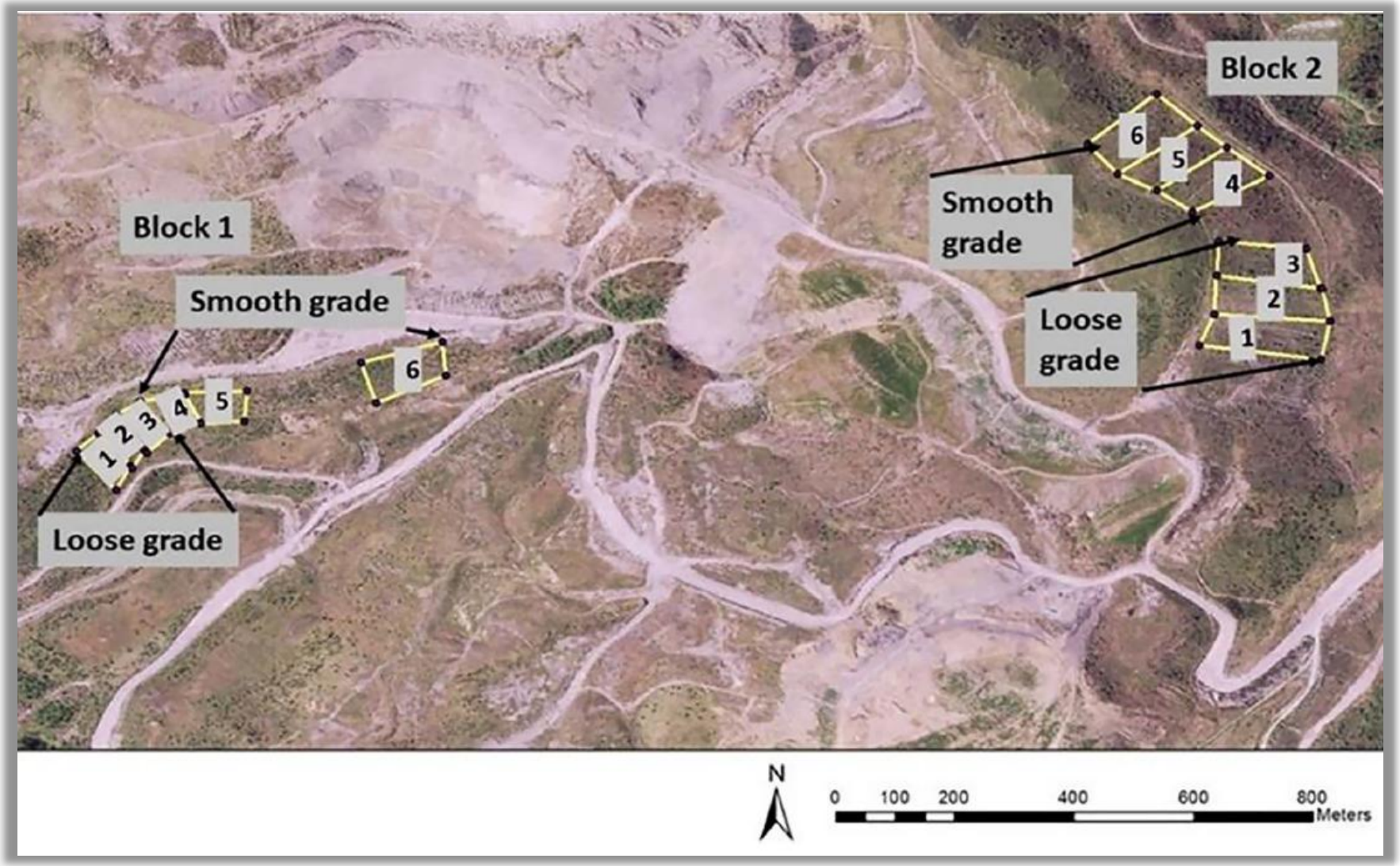
White oak at 7 years, Eastern white pine at ~25 years

Methods

Can we grow a productive, mixed, native forest in overburden spoils of a coal surface mine?

- 3 Blocks, RCBD
  - Block 3 Re-mined between 2011-2014
- 2 Grading Treatments
  - Loose - 1 Pass
  - Smooth - Many Passes
- 3 Groundcover Treatments
  - Annual Ryegrass
  - Conventional
  - Tree Compatible



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Methods

Trees hand planted as bare root seedlings, no shelters, 2008-2009

Tree type and species	Planting density (trees ha^{-1})
Crop trees	
White ash (*Fraxinus americana* L.)	205
White oak (*Quercus alba* L.)	205
Sugar maple (*Acer saccharum* Marsh.)	205
Black cherry (*Prunus serotina* Ehrh.)	205
Red oak (*Quercus rubra* L.)	205
Chestnut oak (*Quercus prinus* L.)	205
Black oak (*Quercus velutina* Lam.)	205
Yellow-poplar (*Liriodendron tulipifera* L.)	124
Wildlife and nurse trees	
Gray dogwood (*Cornus racemosa* Lam.)	54
Red mulberry (*Morus rubra* L.)	25
Redbud (*Cercis canadensis* L.)	54
White pine (*Pinus strobus* L.)	91
Shagbark hickory (*Carya ovata* (Mill.) K. Koch)	62

Groundcovers hydroseeded, 2007-2008

Annual Ryegrass Only	Rate
Seed Mix:	($kg\ ha^{-1}$)
Annual ryegrass (*Lolium multiflorum*)	22
Wood Cellulose Fiber	1680

Tree-Compatible Mix	Rate
Seed Mix:	($kg\ ha^{-1}$)
Annual ryegrass (*Lolium multiflorum*)	22
Perennial ryegrass (*Lolium perenne*)	11
Timothy (*Phleum pretense*)	6
Birdsfoot trefoil (*Lotus corniculatus*)	6
Ladino clover (*Trifolium repens*)	3
Weeping Lovegrass (*Eragrostis curvula*)	2
Wood Cellulose Fiber	1680

Conventional Mix	Rate
Seed Mix:	($kg\ ha^{-1}$)
Rye grain (*Secale cereale*)	34
Orchardgrass (*Dactylis glomerata*)	22
Perennial ryegrass (*Lolium perenne*)	11
Korean lespedeza (*Lespedeza cuneata*)	6
Birdsfoot trefoil (*Lotus corniculatus*)	6
Ladino clover (*Trifolium repens*)	6
Redtop (*Agrostis gigantea*)	3
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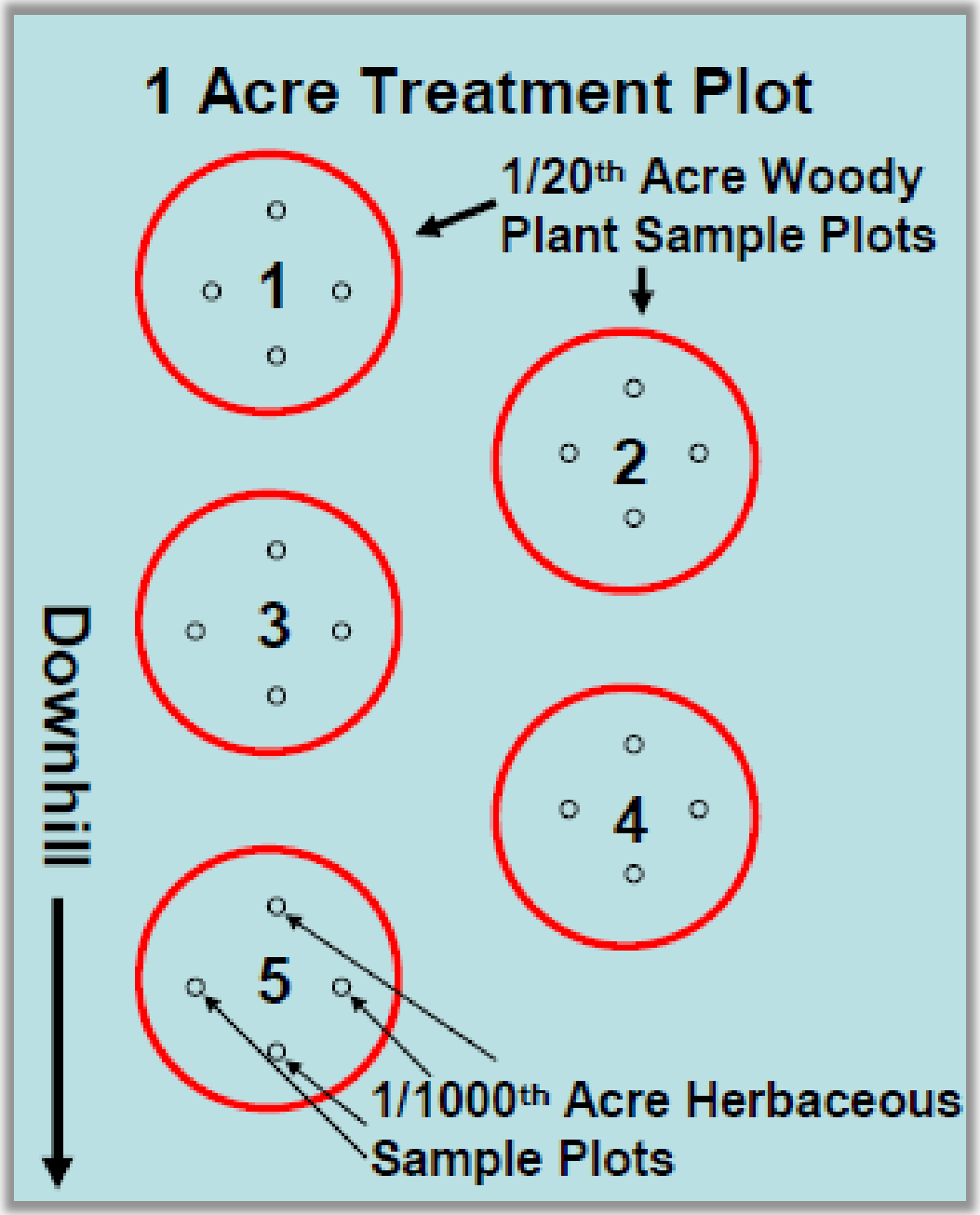
Methods

- Each treatment plot 1 acre+ in area
- Repeat sampling of 1/20th acre woody sampling plots, 5 per treatment plot
  - 2008, 2009, 2014, 2025
- 2025 Sampling Focus:
  - Measuring maximum tree heights by species to determine Forest Site Index at 16 years
  - Measuring maximum tree DBHs by species for comparison
  - Measuring percentage canopy coverage by species to determine forest composition



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Results

Survival and Canopy of Planted Species

2008 Drought Year

	2008 Planting	2008 Survival	2009 Planting	2009 Survival	2014 Survival	2025 Canopy
Species	trees ha^{-1}	%	trees ha^{-1}	%	%	%
Gray Dogwood	54	50%	27	113%	950%	10%
Eastern White Pine	91	6%	85	127%	143%	9%
Tulip-poplar	124	27%	91	71%	80%	8%
White Oak	205	58%	86	73%	77%	6%
Black Cherry	205	45%	112	79%	90%	6%
Red Oak	205	43%	117	53%	39%	5%
White Ash	205	67%	67	68%	90%	3%
Sugar Maple	205	14%	177	51%	58%	3%
Black Oak	205	32%	140	95%	68%	3%
Redbud	54	50%	27	66%	67%	3%
Chestnut Oak	205	33%	138	57%	57%	2%
Red Mulberry	25	49%	13	87%	117%	1%
Shagbark Hickory	62	4%	59	18%	31%	1%
Total / Average	**1,845**	**39%**	**1,139**	**74%**	**135%**	**60%**

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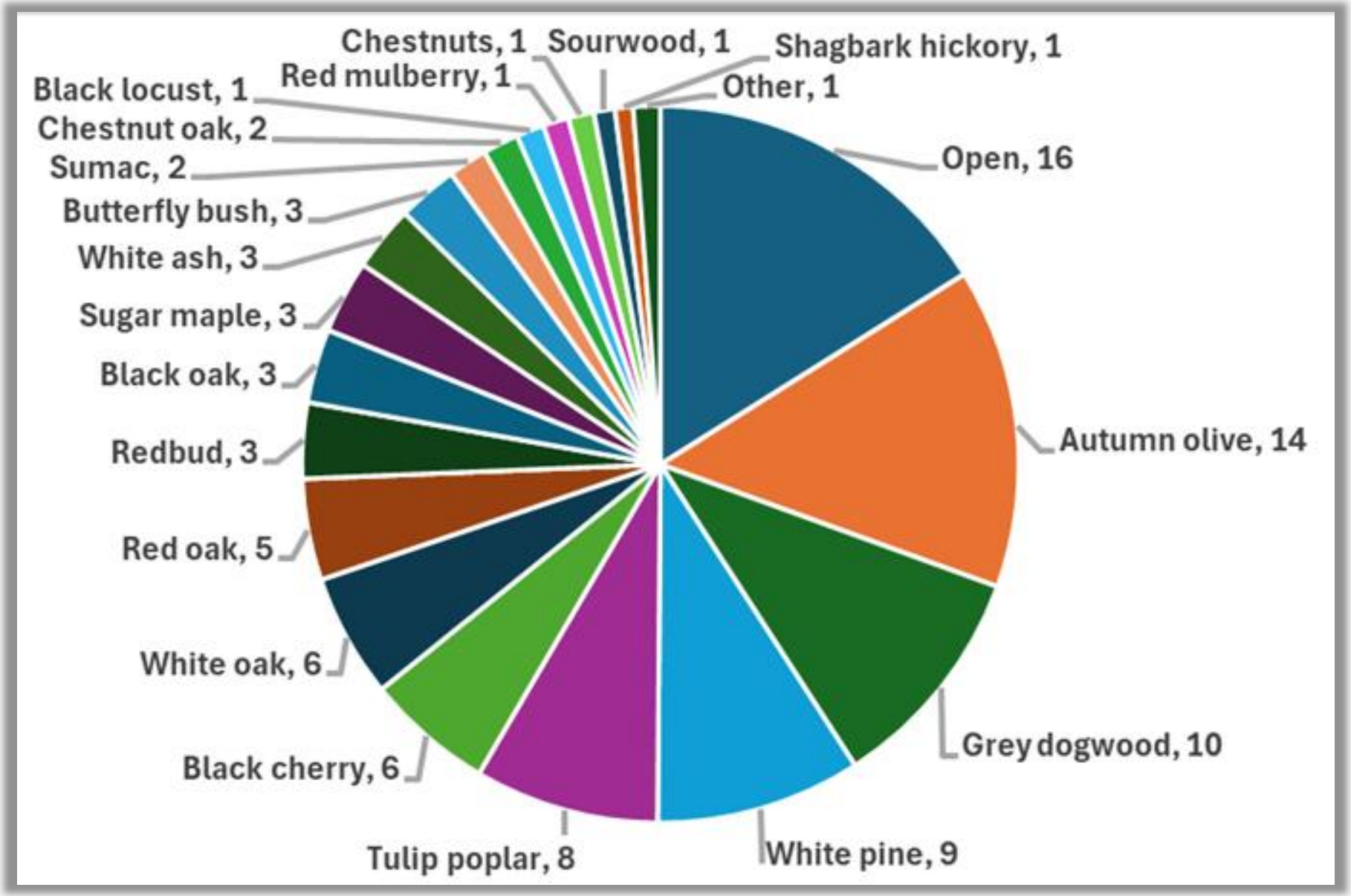
Results

2025 Canopy Percentage by Species

Canopy composition for dominant and codominant plants

All planted species living in the canopy



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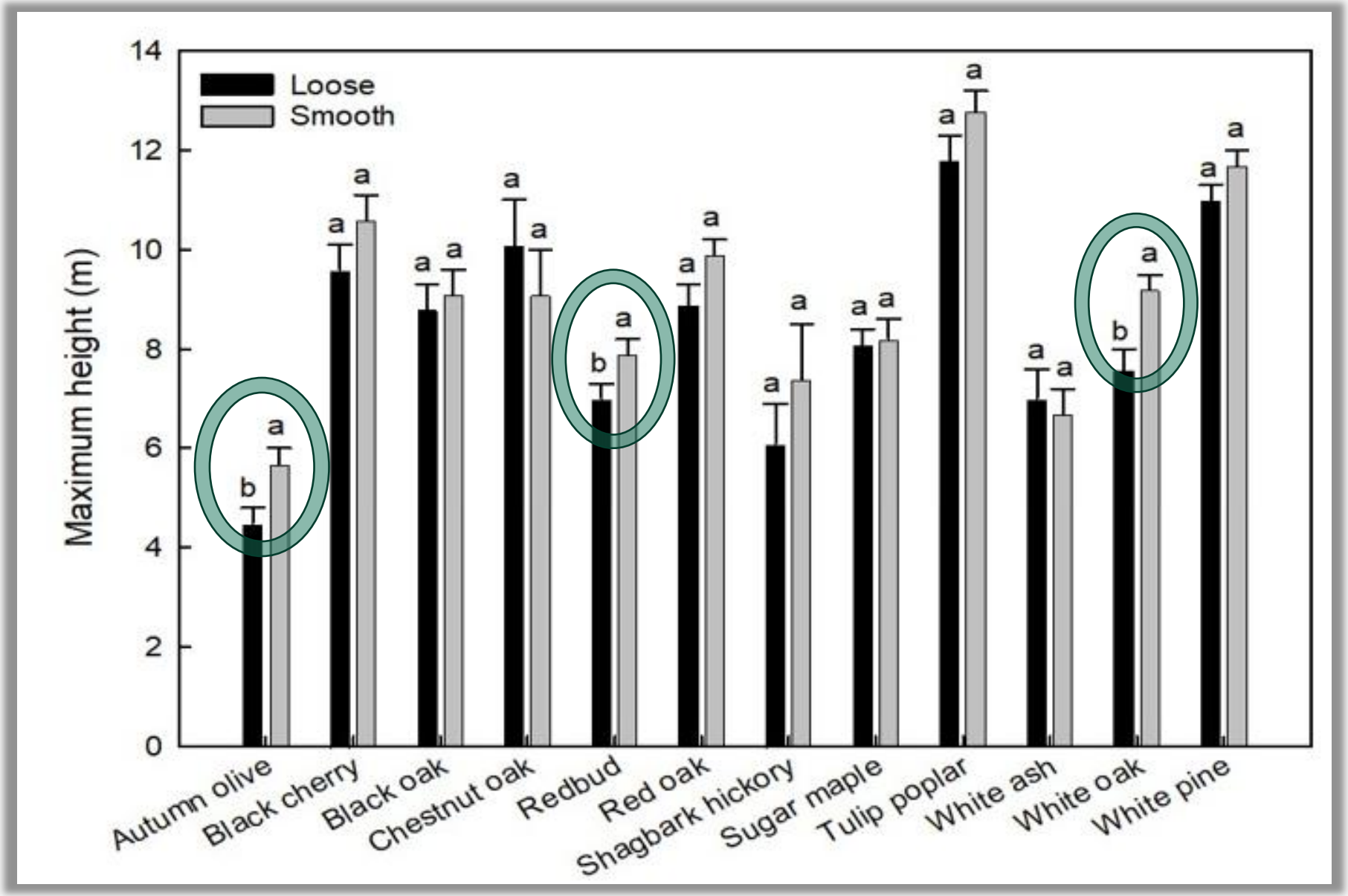
Results

Maximum Heights by Grading and Species

Some species taller with Smooth Grading

No overall effect



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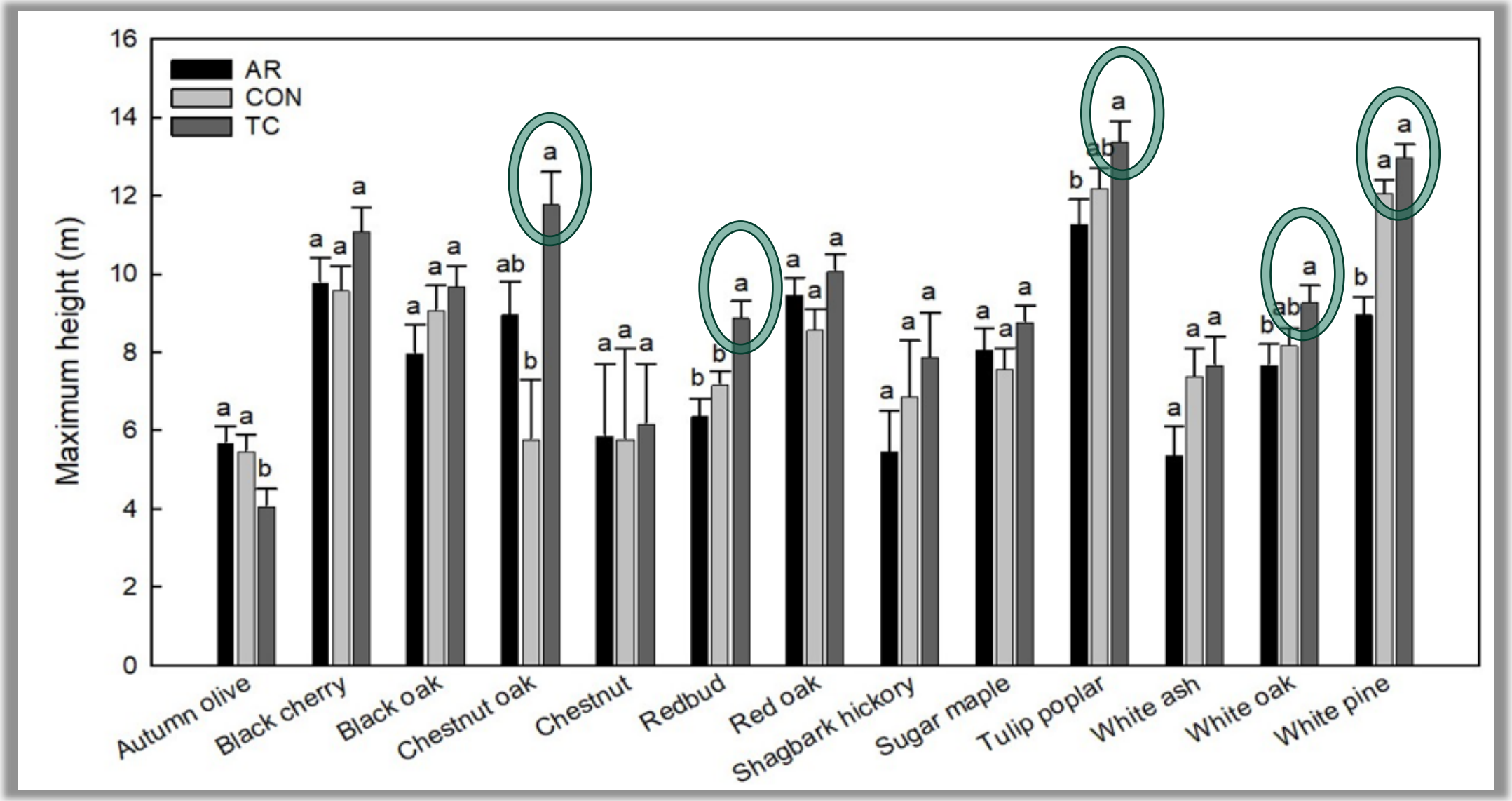
Results

Maximum Heights by Groundcover and Species

Some species taller with Tree Compatible Mix

No overall effect



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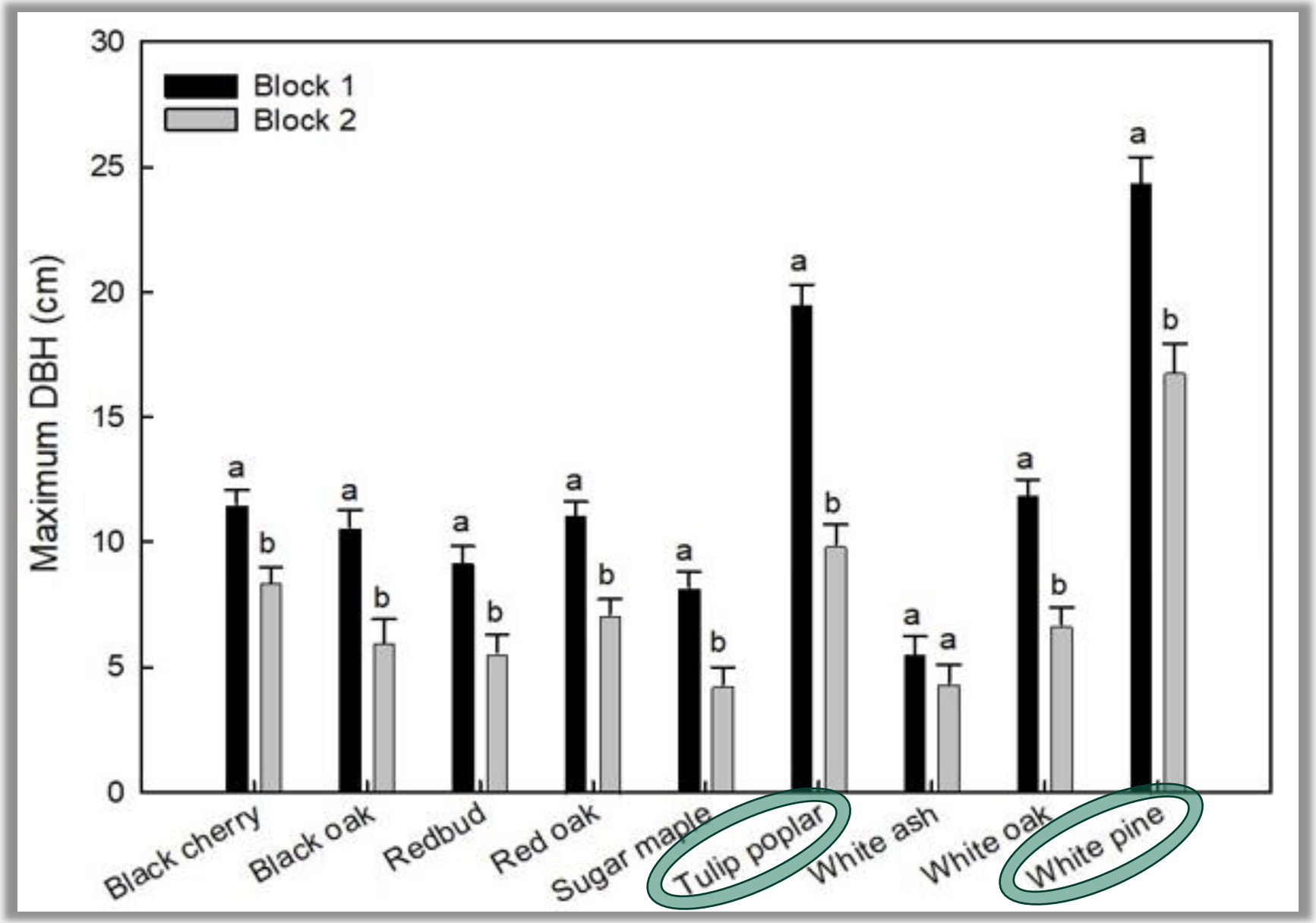
Results

Maximum DBH by Block and Species

Nearly all species had larger diameter in Block 1

Tulip poplar and Eastern White Pine emerge as dominant timber species



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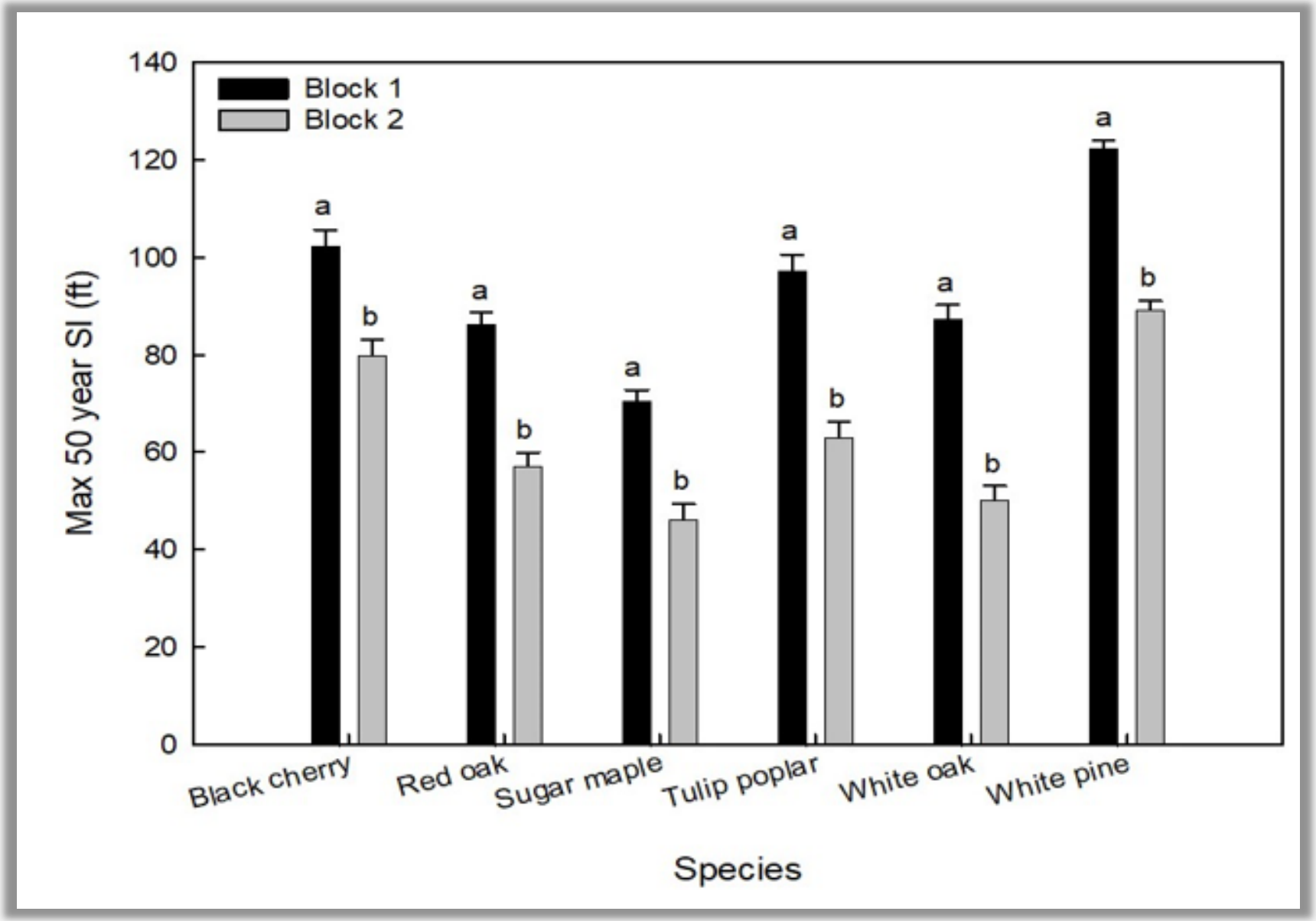
Results

- Block 1 had a consistently higher SI than Block 2
- Block 1 soil pH 5.72 vs 7.44 for Block 2
- Block 1 Fine soil (<2mm) 48% vs 36% for Block 2
- Block 1 had better soil-forming material than Block 2
- Block 2 had Elk impacts

50-yr Mean Site Index by Block & Species



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Results

50-yr Site Index by Treatments & Species

Grading Type	Loose Grading						Smooth Grading					
Groundcover	Conventional		Tree Compatible		Annual Ryegrass		Conventional		Tree Compatible		Annual Ryegrass	
Block	1	2*	1	2	1	2*	1	2	1	2	1	2
Tuliptree	104	86	98	92	98	60	122	104	122	78	104	92
Eastern White Pine	132	101	132	121	126	12	132	107	126	107	121	107
White Oak	101	32	101	75	101	30	81	81	97	75	107	75
Northern Red Oak	108	30	102	76	102	50	96	70	88	82	102	82
Black Cherry	117	77	123	111	117	103	103	103	137	103	111	103
Sugar Maple	77	51	83	71	91	31	77	57	83	57	77	65

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Results

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Black Cherry	117	77	123	111	117	103	103	103	137	103	111	103
Sugar Maple	77	51	83	71	91	31	77	57	83	57	77	65

- No significant differences by grading and groundcover treatments
- Block 1 Significantly Greater SI than Block 2
- Tuliptree max SI = 122, on Tree Compatible & Smooth
- Eastern White Pine 132, White Oak 107, Northern Red Oak 108, Black Cherry 137

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Results

50-yr Site Index by Treatments & Species

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- Tuliptree max SI = 122, on Smooth for Conventional and Tree Compatible
  - Many of these plots are over-performing predicted Site Indices

- Tuliptree SI predicted on soil series maps:
  - Shelocta-Kaymine = 99 (nearby mapped mined land soil)
  - Cloverlick-Shelocta-Highsplint = 90 (undisturbed productive nearby soil)
  - Cloverlick-Shelocta = 95 (undisturbed productive nearby soil)
  - Lobdell Silt Loam = 96 (regional glacial outwash alluvium)

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Results

Elk Damage Concentrated on Block 2

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Results

O and A Soil Horizons are Well-formed

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Conclusions

- Goals for high levels of productivity and diversity are being achieved
  - All planted tree species are alive and contributing to canopy
  - Site Indices are higher than for nearby undisturbed soils
  - Tulip poplar and Eastern white pine dominate timber volume

- Grading method did not significantly affect most outcomes
  - It is possible to plant successfully on smooth-graded sites

- Groundcover choice also did not consistently affect many outcomes
  - It is possible to plant successfully into established groundcovers

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Conclusions

- Block effects were consistently significant in affecting outcomes
  - Spoil selection for soil forming is of overriding importance
  - Herbivory is a major factor to monitor and prevent
  - Both blocks were successfully reforested!

- Re-planting trees in 2009 after the initial survey likely resulted in much better survival and canopy coverage through today
  - Perfrome initial survival surveys after first growing season
  - Replanting to re-stock stands may lead to better project outcomes given unpredictable weather etc.
  - Don’t think that subsequent cohorts cannot catch up
    - Play the numbers and be an R-strategist!

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Repeat Photography

Block 1, Loose, Annual Ryegrass

2009

2025

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Repeat Photography

Block 1, Loose, Conventional

2009

2025

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Repeat Photography

Block 1, Loose, Tree Compatible

2009

2025

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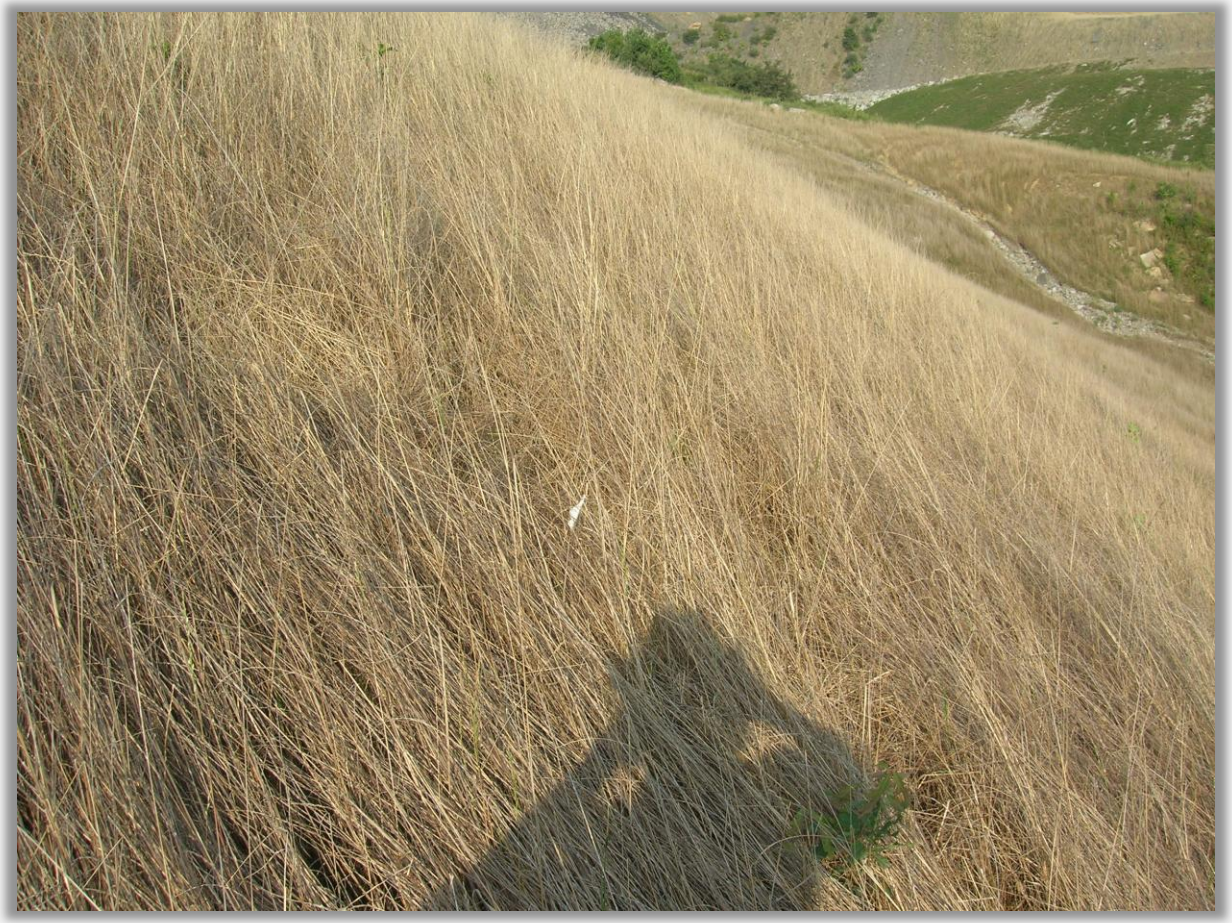
Repeat Photography

Block 1, Smooth, Annual Ryegrass



2009

2025

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Repeat Photography

Block 1, Smooth, Conventional

2009

2025

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Repeat Photography

Block 1, Smooth, Tree Compatible

2009

2025

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Repeat Photography

Block 2, Loose, Annual Ryegrass

2009

2025

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Repeat Photography

Block 2, Loose, Conventional

2009

2025

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Repeat Photography

Block 2, Loose, Tree Compatible

2009

2025

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Repeat Photography

Block 2, Smooth, Annual Ryegrass

2009

2025

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Repeat Photography

Block 2, Smooth, Conventional

2009

2025

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Repeat Photography

Block 2, Smooth, Tree Compatible

2009

2025

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Aerial Photography

2025, Block 2, Plots 1, 2 & 3

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