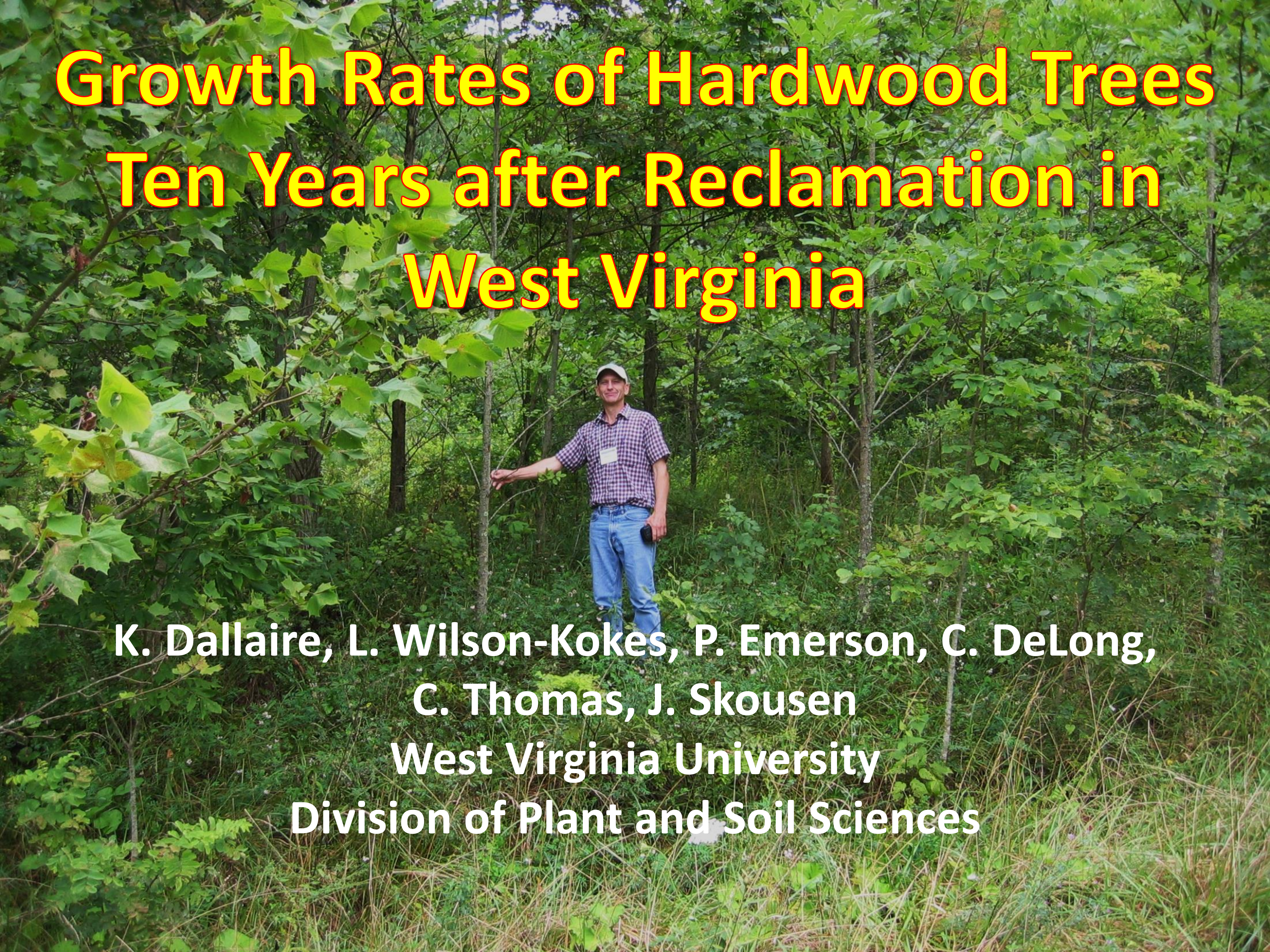


Growth Rates of Hardwood Trees Ten Years after Reclamation in West Virginia

K. Dallaire, L. Wilson-Kokes, P. Emerson, C. DeLong, C. Thomas, J. Skousen
West Virginia University
Division of Plant and Soil Sciences

Kara Dallaire

Lindsay Wilson-Kokes

Coal Mining in Appalachia for decades
Appalachia primarily forested

Early mining methods were suitable for tree re-colonization

Good Substrate
No Grading
No Competing Vegetation


Some of these old mined sites have the best tree growth!

Old uncompacted contour jobs…

…readily reverted back to trees!

1977 - Surface Mining Control and Reclamation Act (SMCRA)

Act was intended to:

- Enhance human safety
- Control erosion
- Improve water quality
- Return the land to AOC

Land was largely put back to pasture and hay land with soil compaction and heavy seeding rates to meet regulations

SMCRA interpretation led to most post mined land being reclaimed to pasture and hayland

Economic benefit from grazing and hay production

But if the land is not managed in a pasture or hayland use …

Heavy groundcover and Compaction resulted in
Grass and Invasive Shrub Wasteland

Unmanaged Hay Land or Pasture

Good for What?

How long to go back to Forest?

Develop Forests on Mined Lands

Benefits of reforestation include:

- wildlife habitat
- commercial wood production
- improve ecosystem diversity
- ecosystem services

ARRI!
Reforestation Initiative

THE APPALACHIAN REGIONAL REFORESTATION INITIATIVE (ARRI)
FOREST RECLAMATION ADVISORY
Forest Reclamation Advisory No. 2 December 2005

Science Team Develop Advisories

THE FORESTRY RECLAMATION APPROACH

Jim Burger[1], Don Graves[2], Patrick Angel[3], Vic Davis[4], Carl Zipper[5]

The Forestry Reclamation Approach (FRA) is a method for reclaiming coal-mined land to forest under the Surface
Act (SMCRA). The
gained from both
experience (Photo
effective regulato
while creating pro
value for their ow
protection, wildli
environmental se

Photo 1. A white oak stand that grew on a pre-SMCRA surface mine in southern Illinois. Observations by
itioners of soil and site
such as this, where
ve contributed to
clamation Approach.

The purpose of this Advisory is to describe the FRA, which is considered by state mining agencies and US Office of Surface Mining to be an appropriate and desirable method for reclaiming coal-mined land to support forested land uses under SMCRA (Angel and others, 2005). The FRA is also supported by members of the ARRI's academic team, which is drawn from Universities in nine states, and by other groups and agencies.

The FRA's Five Steps

The FRA can be summarized in five steps:

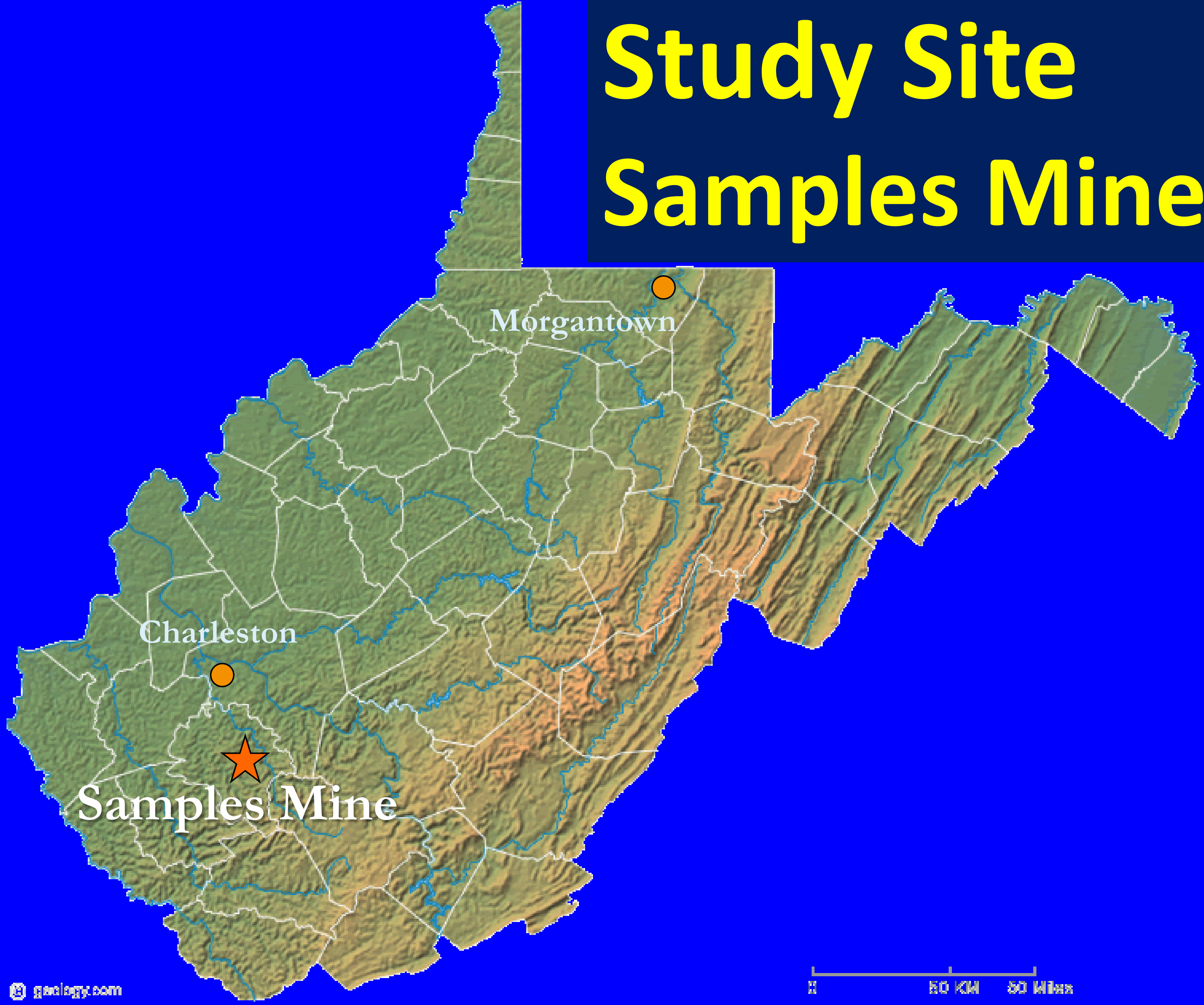
1. Create a suitable rooting medium for good tree growth that is no less than 4 feet deep and

The 5 Steps of FRA

1. Create a suitable rooting medium...
2. Loosely grade the rooting medium...
3. Use compatible ground covers...
4. Plant two types of trees…
5. Use proper tree planting techniques.


Objectives
Evaluate tree growth on:
1) brown sandstone vs. gray sandstone
2) compacted vs. non-compacted areas

Study Site
Samples Mine



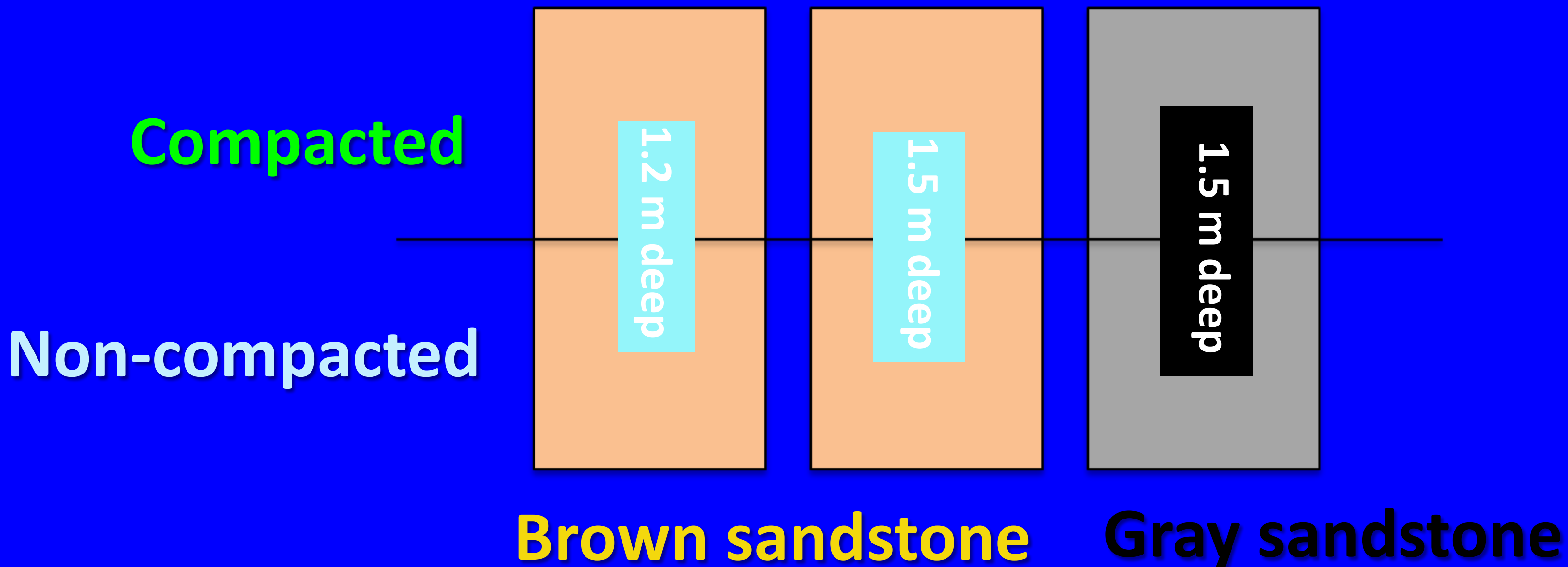
Demonstration Plots

Brown Sandstone

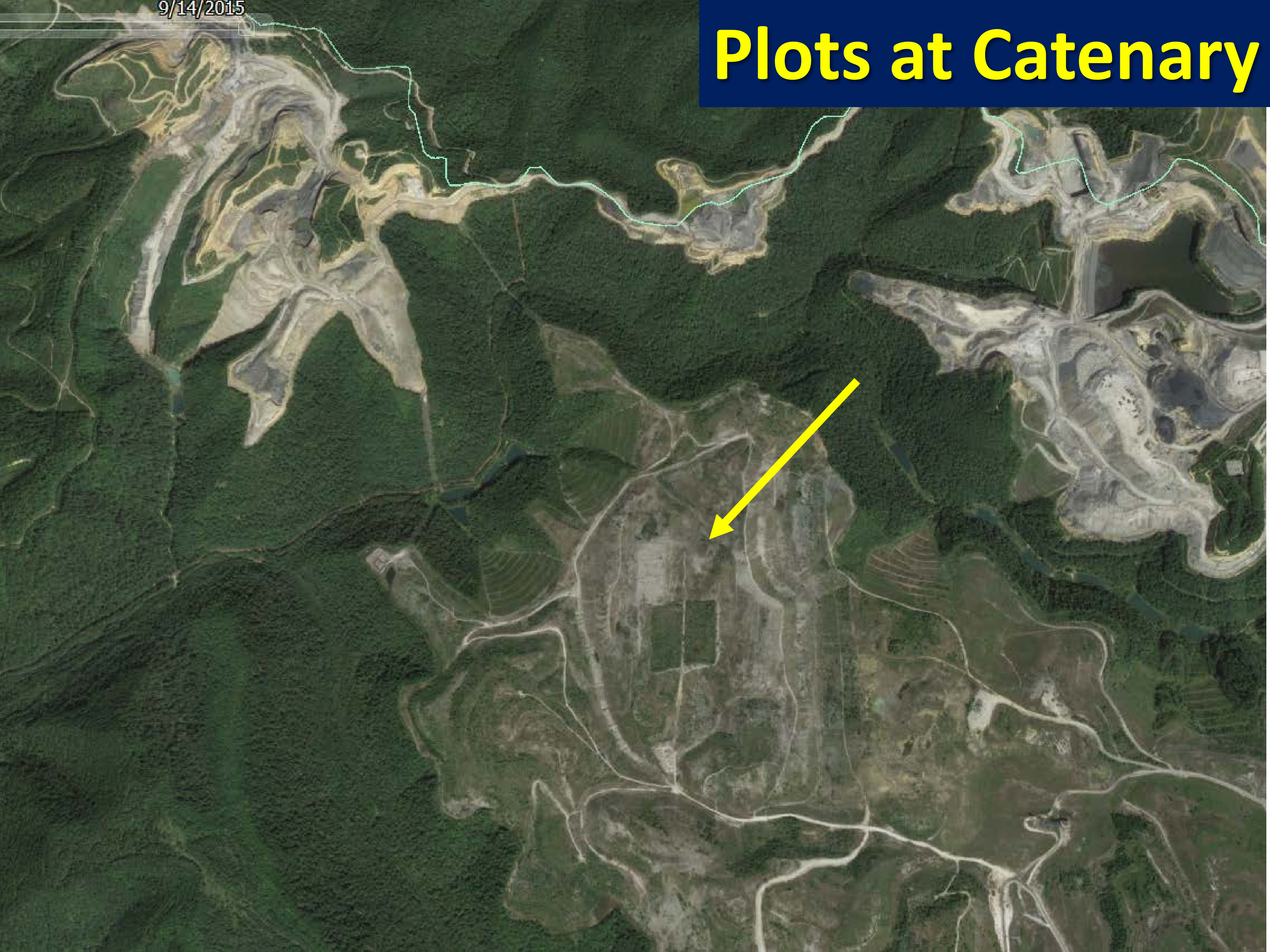
Gray Sandstone

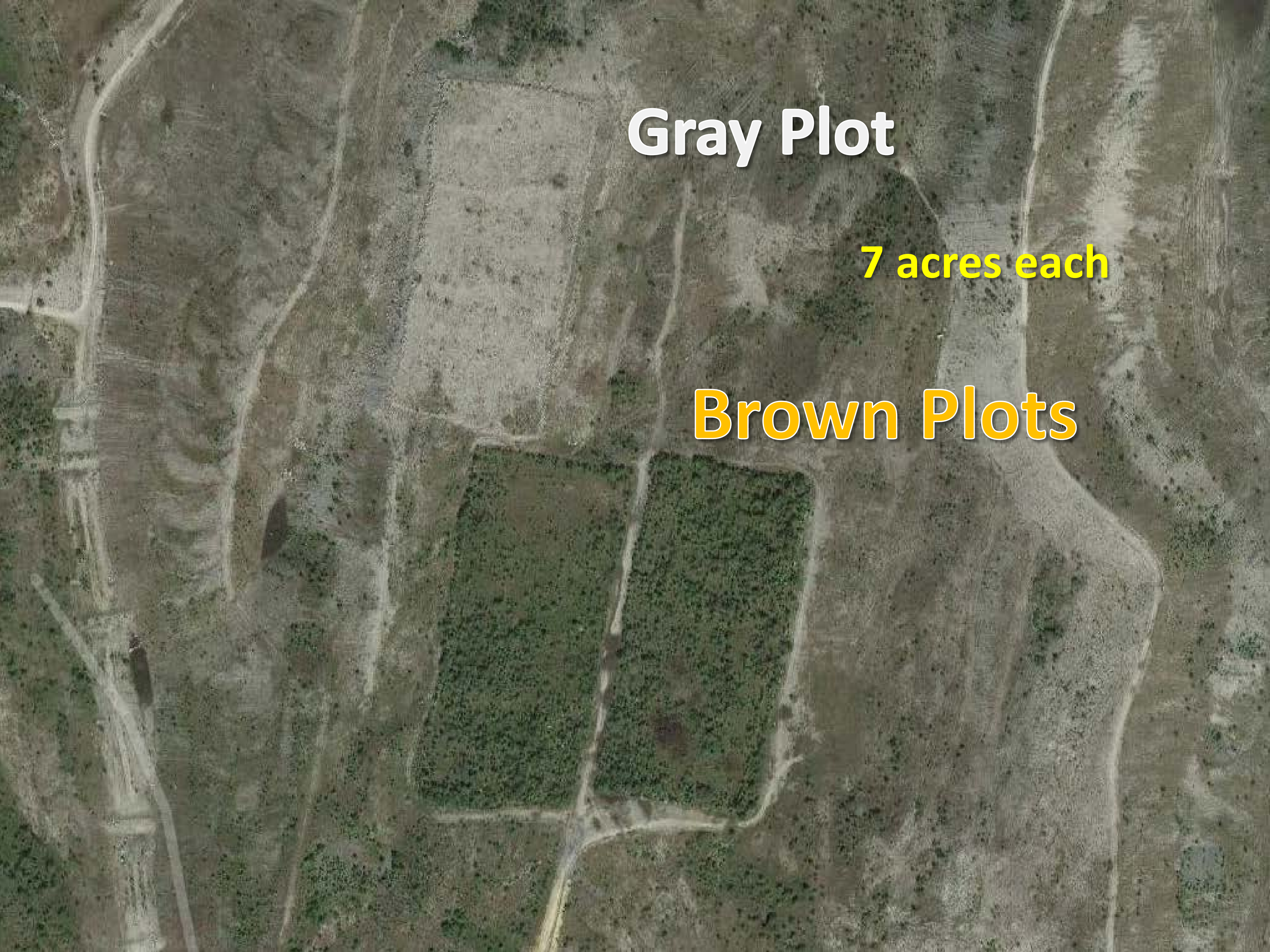
STUDY SITE

- Three 2.8-ha plots.
  - Six treatments:



Plots at Catenary




Gray Plot
7 acres each
Brown Plots

11 Tree Species planted
Commercial Planting

Trees Planted

Species	Total # Planted	% of total planted
Red Oak	3,400	22
White Oak	2,500	16
White Ash	2,500	16
Sugar Maple	1,500	10
Chestnut Oak	1,250	8
Tulip-Poplar	1,250	8
White Pine	1,250	8
Black Locust	465	3
Black Cherry	465	3
Redbud	465	3
Dogwood	465	3
Total	15,510	100 %

EXPERIMENTAL DESIGN

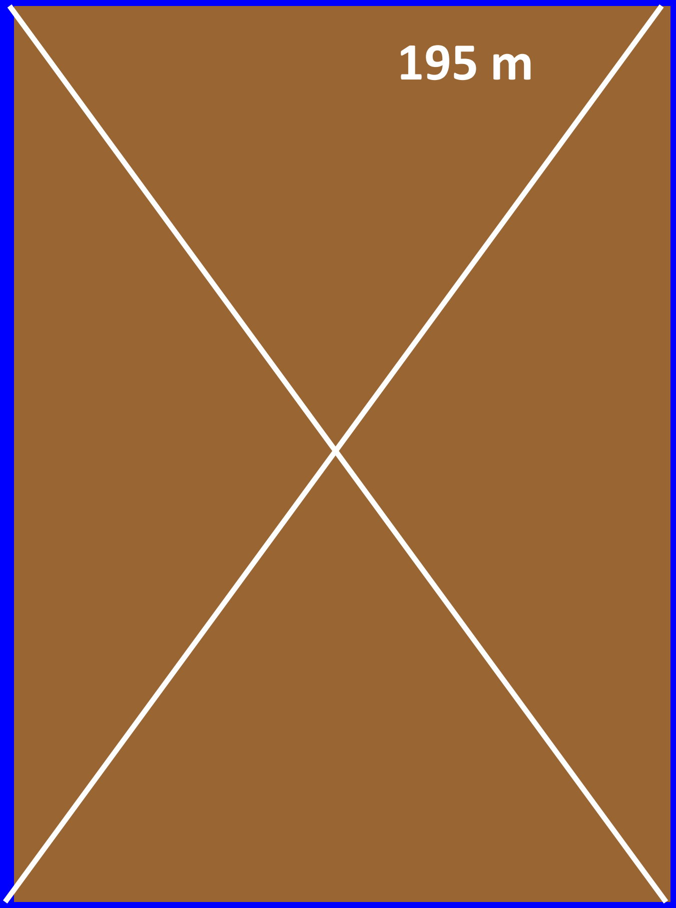
Tree-compatible seeding mix and rate

Rate of Application	
Species	Rate (kg/ha)
Birdsfoot trefoil	11.0
Perennial ryegrass	2.2
Redtop	2.2
Total	15.4

EXPERIMENTAL DESIGN

➢ **Tree sampling method**:

- **Two, 2.7-m wide by 195-m long transects.**
- **Species, height, and diameter recorded.**



SOIL CHEMICAL ANALYSIS

- Top 15 cm of soil collected
- Five randomly selected points along each transect within each treatment.
- pH, extractable nutrients, and electrical conductivity

RESULTS: Soil

Property	pH	EC (ds/m)	Fines (%)
Brown	5.7	0.03	68
Gray	8.0	0.06	36

Hardwood trees like pH from 5-6

More fines means better water and nutrient relations

Soil Rockiness – 2 yrs

Soil Rockiness – 6 yrs

RESULTS: Trees

2015 (10th Yr) average tree growth and survival

Treatment	Volume Index	Survival
	-----cm^3-----	------%-----
Brown	29,751 a	84
Gray	449 b	53

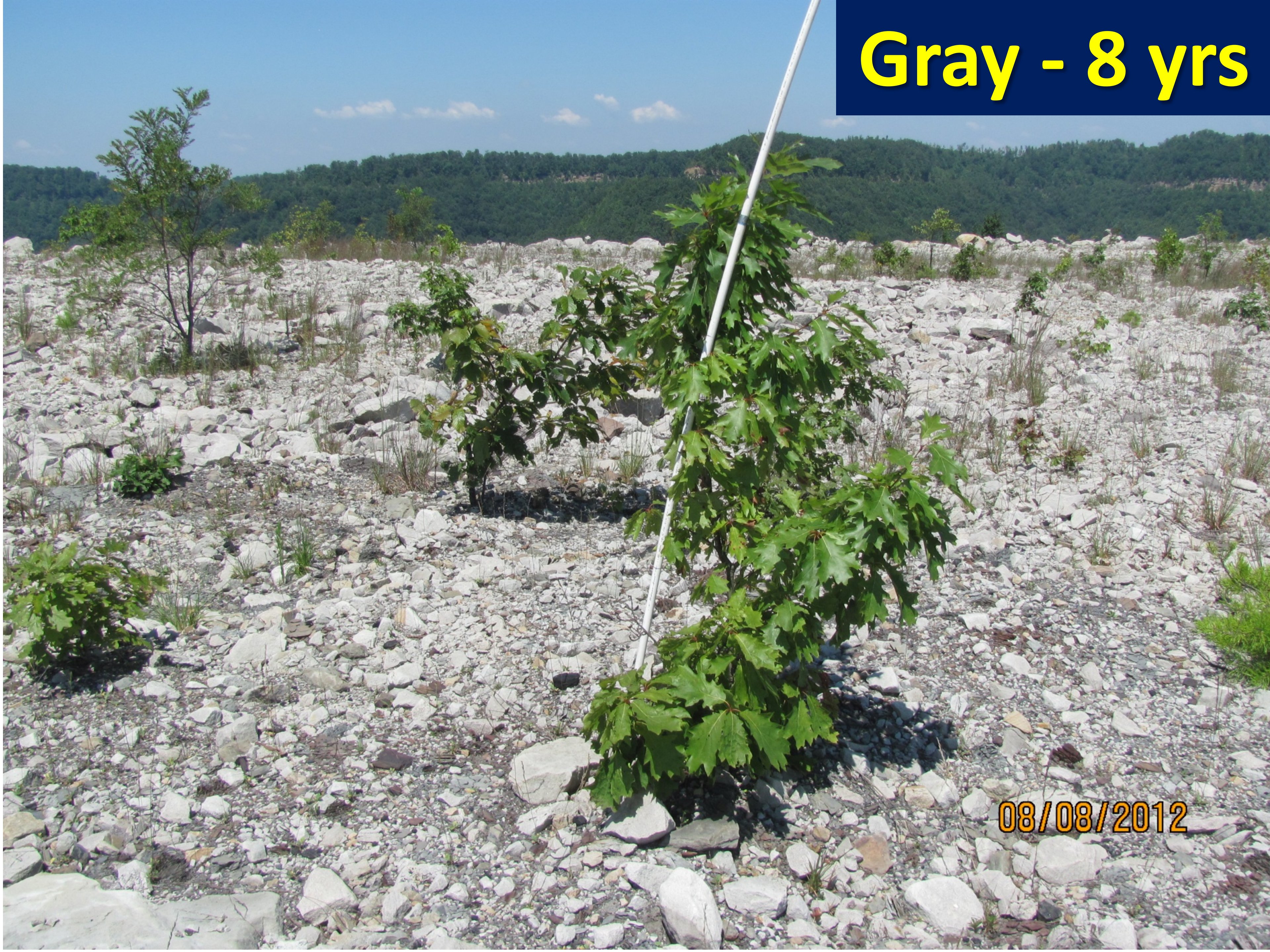
Brown - 2 yrs

Gray - 2 yrs

Brown - 6 yrs

Gray - 6 yrs


Brown - 8 yrs
08/08/2012


Gray - 8 yrs
08/08/2012

Results

2005 - 2015

	Species	All	BC	BL	CO	DW	O	RB	RO	SM	TP	WA	WO	WP
Treat	Year	Volume (cm^3)												
Brown														
	2005	11	18	16	6	14	NA	6	12	11	16	6	16	3
	2006	16	48	54	10	37	NA	8	17	16	15	11	19	7
	2007	216	180	1740	NA	295	NA	116	135	83	109	129	66	155
	2009	1953	945	12565	NA	1060	NA	412	597	191	148	633	217	210
	2010	3085	987	22606	NA	1600	966	556	NA	266	466	710	NA	402
	2011	6689	2158	41184	NA	793	NA	1025	3061	217	1429	992	2104	743
	2012	3556	NA	4618	NA	1027	NA	1400	1838	596	154	1487	6427	6820
	2014	7970	6851	2181	NA	NA	NA	5366	8815	3383	3946	4798	13631	2681
	2015	29751	17294	71892	NA	NA	NA	9985	24539	6220	17841	11623	33491	27320
Gray														
	2005	16	36	14	7	10	NA	24	13	9	31	10	13	8
	2006	26	65	29	13	15	NA	25	20	15	53	18	26	11
	2007	45	108	58	NA	13	NA	7	27	24	115	26	33	27
	2009	125	120	469	NA	14	NA	7	41	28	646	85	92	42
	2010	249	189	2167	NA	1	85	34	NA	17	969	42	NA	51
	2011	263	161	1901	NA	NA	NA	22	76	20	423	90	140	87
	2012	309	NA	413	NA	NA	NA	376	301	6	908	218	285	114
	2014	464	115	756	NA	NA	NA	14	442	992	180	140	469	532
	2015	494	NA	626	NA	NA	NA	242	416	320	429	182	440	792

Results

All Trees

	Species	All	BC	BL	CO	DW	O	RB	RO	SM	TP	WA	WO	WP
Treat	Yea			Volume (cm^3)										
Brown														
	2005	11	18	16	6	14	NA	6	12	11	16	6	16	3
	2006	16	48	54	10	37	NA	8	17	16	15	11	19	7
	2007	216	180	1740	NA	295	NA	116	135	83	109	129	66	155
	2009	1953	945	12565	NA	1060	NA	412	597	191	148	633	217	210
	2010	3085	987	22606	NA	1600	966	556	NA	266	466	710	NA	402
	2011	6689	2158	41184	NA	793	NA	1025	3061	217	1429	992	2104	743
	2012	3556	NA	4618	NA	1027	NA	1400	1838	596	154	1487	6427	6820
	2014	7970	6851	2181	NA	NA	NA	5366	8815	3383	3946	4798	13631	2681
	2015	29751	[illegible]	[illegible]	NA	NA	NA	9985	24539	6220	17841	11623	33491	27320
Gray														
	2005	16	36	14	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	13	8
	2006	26	65	29	13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18	26	11
	2007	45	108	58	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26	33	27
	2009	125	120	469	NA	14	NA	7	41	28	646	85	92	42
	2010	249	189	2167	NA	1	85	34	NA	17	969	42	NA	51
	2011	263	161	1901	NA	NA	NA	22	76	20	423	90	140	87
	2012	309	NA	413	NA	NA	NA	376	301	6	908	218	285	114
	2014	464	[illegible]	[illegible]	NA	NA	NA	14	442	992	180	140	469	532
	2015	494	[illegible]	[illegible]	NA	NA	NA	242	416	320	429	182	440	792

29,751

6 times greater

494

Results

Black Locust

Treat	Species	All	BC	BL	CO	DW	O	RB	RO	SM	TP	WA	WO	WP
	Year						Volume (cm^3)							
Brown														
	2005	11	18	16	6	14	NA	6	12	11	16	6	16	3
	2006	16	48	54	10	37	NA	8	17	16	15	11	19	7
	2007	216	180	1740	NA	295	NA	116	135	83	109	129	66	155
	2009	1953	945	12565	NA	1060	NA	412	597	191	148	633	217	210
	2010	3085	987	22606	NA	1600	966	556	NA	266	466	710	NA	402
	2011	6689	2158	41184	NA	793	NA	1025	3061	217	1429	992	2104	743
	2012	3556	NA	4618	NA	1027	NA	1400	1838	596	154	1487	6427	6820
	2014	7970	6851	2181	NA	NA	NA	5366	8815	3383	3946	4798	13631	2681
	2015	29751	17294	71892	[illegible]	[illegible]	[illegible]	9985	24539	6220	17841	11623	33491	27320
Gray														
	2005	16	36	14	7	10	NA	24	13	9	31	10	13	8
	2006	26	65	29	13	15	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11
	2007	45	108	58	NA	13	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27
	2009	125	120	469	NA	14	NA	7	41	28	646	85	92	42
	2010	249	189	2167	NA	1	85	34	NA	17	969	42	NA	51
	2011	263	161	1901	NA	NA	NA	22	76	20	423	90	140	87
	2012	309	NA	413	[illegible]	[illegible]	NA	376	301	6	908	218	285	114
	2014	464	115	756	[illegible]	[illegible]	NA	14	442	992	180	140	469	532
	2015	494	NA	626	NA	NA	NA	242	416	320	429	182	440	792

71,892

10 times greater

626

Results

	Species	All	BC	BL	CO	DW	O	RB	RO	SM	TP	WA	WO	WP
Treat	Year		Volume (cm³)											
Brown														
	2005	11	18	16	6	14	NA	6	12	11	16	6	16	3
	2006	16	48	54	10	37	NA	8	17	16	15	11	19	7
	2007	216	180	1740	NA	295	NA	116	135	83	109	129	66	155
	2009	1953	945	12565	NA	1060	NA	412	597	191	148	633	217	210
	2010	3085	987	22606	NA	1600	966	556	NA	266	466	710	NA	402
	2011	6689	2158	41184	NA	793	NA	1025	3061	217	1429	992	2104	743
	2012	3556	NA	4618	NA	1027	NA	1400	1838	596	154	1487	6427	6820
	2014	7970	6851	2181	NA	NA	NA	5366	8815	3383	3946	4798	13631	2681
	2015	29751	17294	71892	NA	NA	NA	9985	24539	[illegible]	[illegible]	11623	33491	27320
Gray														
	2005	16	36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31	10	13	8
	2006	26	65	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	53	18	26	11
	2007	45	108	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	115	26	33	27
	2009	125	120	469	NA	14	NA	7	41	28	646	85	92	42
	2010	249	189	2167	NA	1	85	34	NA	17	969	42	NA	51
	2011	263	161	1901	NA	NA	NA	22	76	20	423	90	140	87
	2012	309	NA	413	NA	NA	NA	376	301	6	[illegible]	218	285	114
	2014	464	115	756	NA	NA	NA	14	442	992	[illegible]	140	469	532
	2015	494	NA	626	NA	NA	NA	242	416	320	429	182	440	792

White Oak

33,491

8 times greater

440

Results

	Species	All	BC	BL	CO	DW	O	RB	RO	SM	TP	WA	WO	WP
Treat	Year		Vo[illegible]											
Brown														
	2005	11	18	16	6	14	NA	6	12	11	16	6	16	3
	2006	16	48	54	10	37	NA	8	17	16	15	11	19	7
	2007	216	180	1740	NA	295	NA	116	135	83	109	129	66	155
	2009	1953	945	12565	NA	1060	NA	412	597	191	148	633	217	210
	2010	3085	987	22606	NA	1600	966	556	NA	266	466	710	NA	402
	2011	6689	2158	41184	NA	793	NA	1025	3061	217	1429	992	2104	743
	2012	3556	NA	4618	NA	1027	NA	1400	1838	596	154	1487	6427	6820
	2014	7970	6851	2181	NA	NA	NA	[illegible]	[illegible]	3383	3946	4798	13631	2681
	2015	29751	17294	71892	NA	NA	NA	[illegible]	[illegible]	6220	17841	11623	33491	27320
Gray														
	2005	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9	31	10	13	8
	2006	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15	53	18	26	11
	2007	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24	115	26	33	27
	2009	125	120	469	NA	14	NA	7	41	28	646	85	92	42
	2010	249	189	2167	NA	1	85	34	NA	17	969	42	NA	51
	2011	263	161	1901	NA	NA	NA	22	76	20	423	90	140	87
	2012	309	NA	413	NA	NA	NA	376	301	6	908	218	285	114
	2014	464	115	756	NA	NA	NA	[illegible]	[illegible]	992	180	140	469	532
	2015	494	NA	626	NA	NA	NA	242	416	320	429	182	440	792

Sugar Maple

6,220

20 times greater

320

Black locust

White oak

Brown | **Gray**

Sugar maple

RESULTS: Trees

- Sandstone type significant.
  Brown – 29,751 cm^3 vs Gray - 494 cm^3.
- Compaction significant.
  NC – 28,694 cm^3 vs Comp – 21,751 cm^3.
- Depth not significant.

CONCLUSIONS

Trees grew better on Brown than Gray

Compaction influenced tree growth

Soil pH and fines were better on Brown

So, if all you have is unweathered Gray Sandstone…

Can you improve soil fertility, moisture, and tree growth potential with some amendment?

Hardwood Tree Performance on Amended Brown and Gray Soils After Eight Years

Kara Dallaire, Lindsey Wilson-Kokes, Calene Thomas, Curtis DeLong, Paul Emerson, and Jeff Skousen
West Virginia University
Division of Plant and Soil Science

Bark & Sawmill Waste

BARK MULCH

Waste from sawmill and timber operations

Addition of Organic Matter…

Reduce bulk density
Increase water infiltration/holding capacity
Reservoir of nutrients
Prevent extremes in temperature and moisture

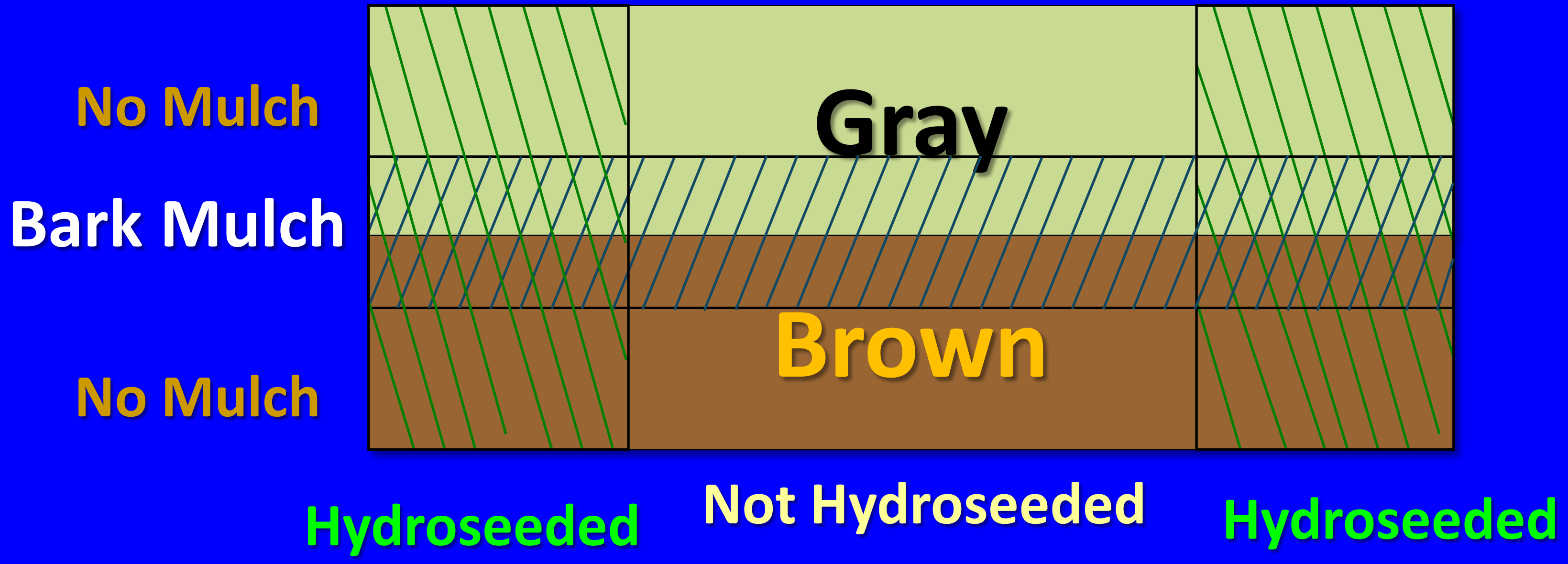

Objective:
Determine changes in tree growth with bark mulch and hydroseeding in brown and gray sandstone.
05/26/2011

Study Site Birch River

EXPERIMENTAL DESIGN

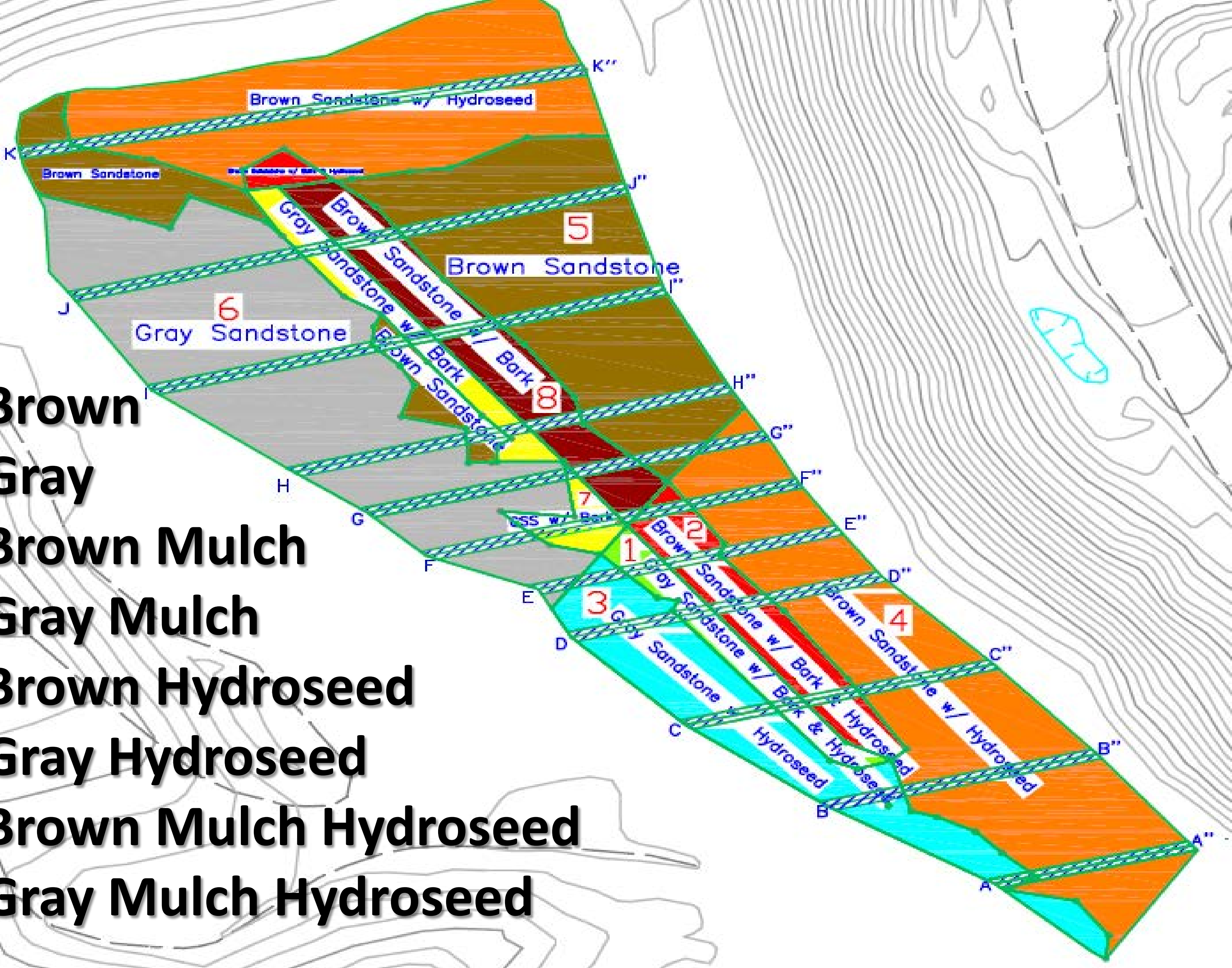
- One 5-ha demonstration plot.
  - Eight treatments:

    G, GM, GH, GMH, B, BM, BH, BMH



Bark Mulch spread down the middle

Bark Mulch spread down the middle



1 Brown

2 Gray

3 Brown Mulch

4 Gray Mulch

5 Brown Hydroseed

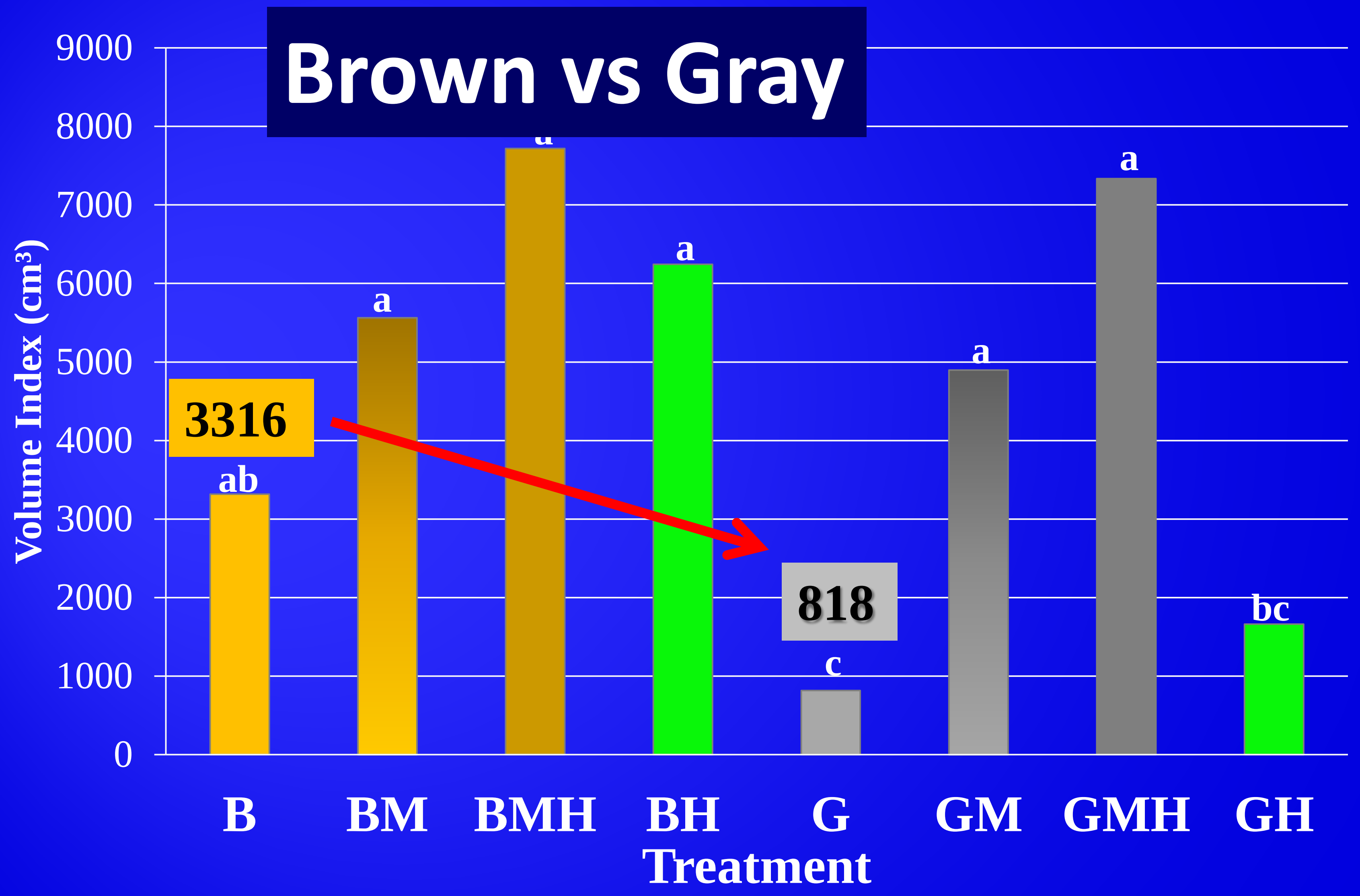
6 Gray Hydroseed

7 Brown Mulch Hydroseed

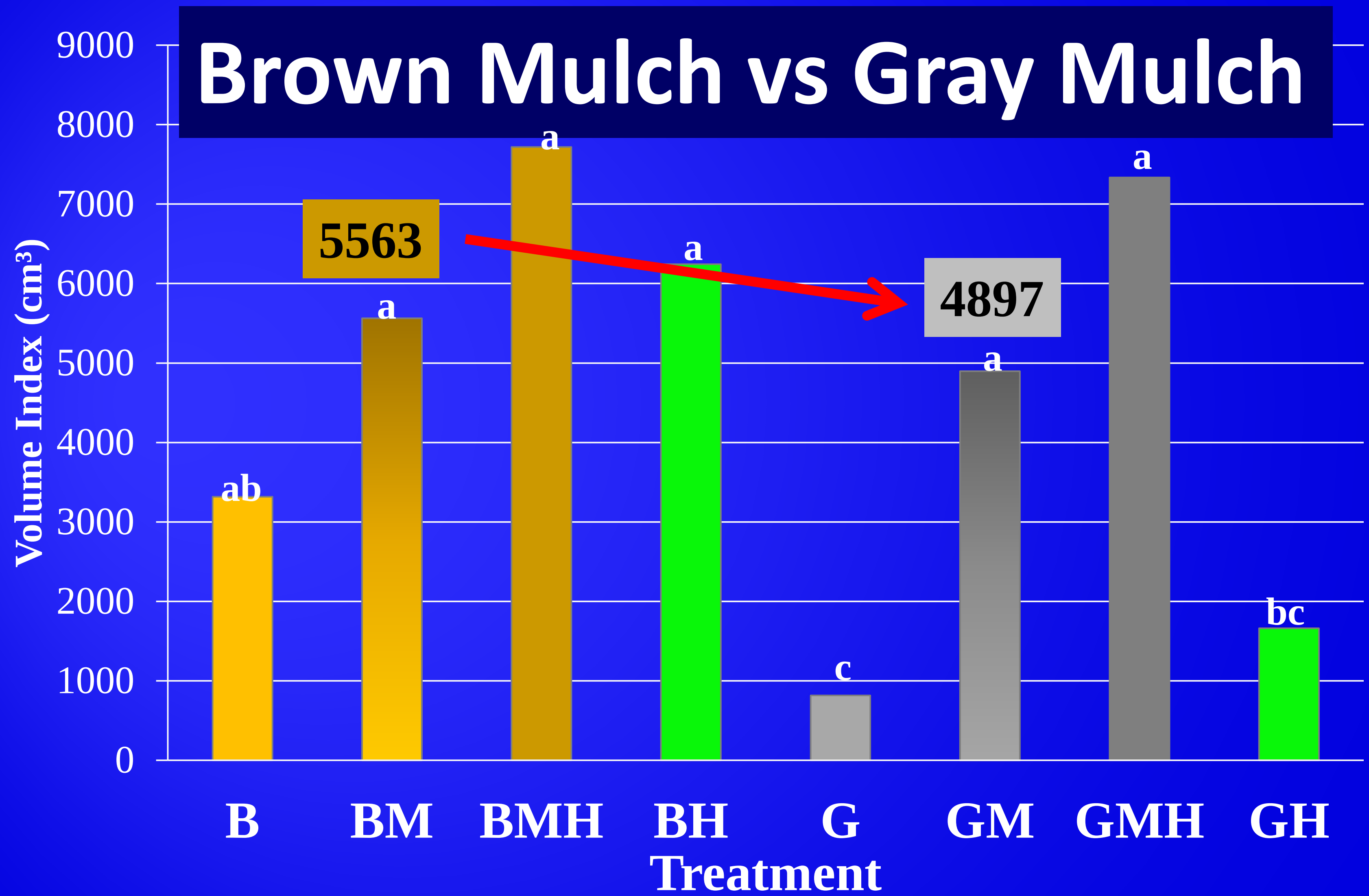
8 Gray Mulch Hydroseed

Transects

RESULTS: Trees 2012 - 6th Yr

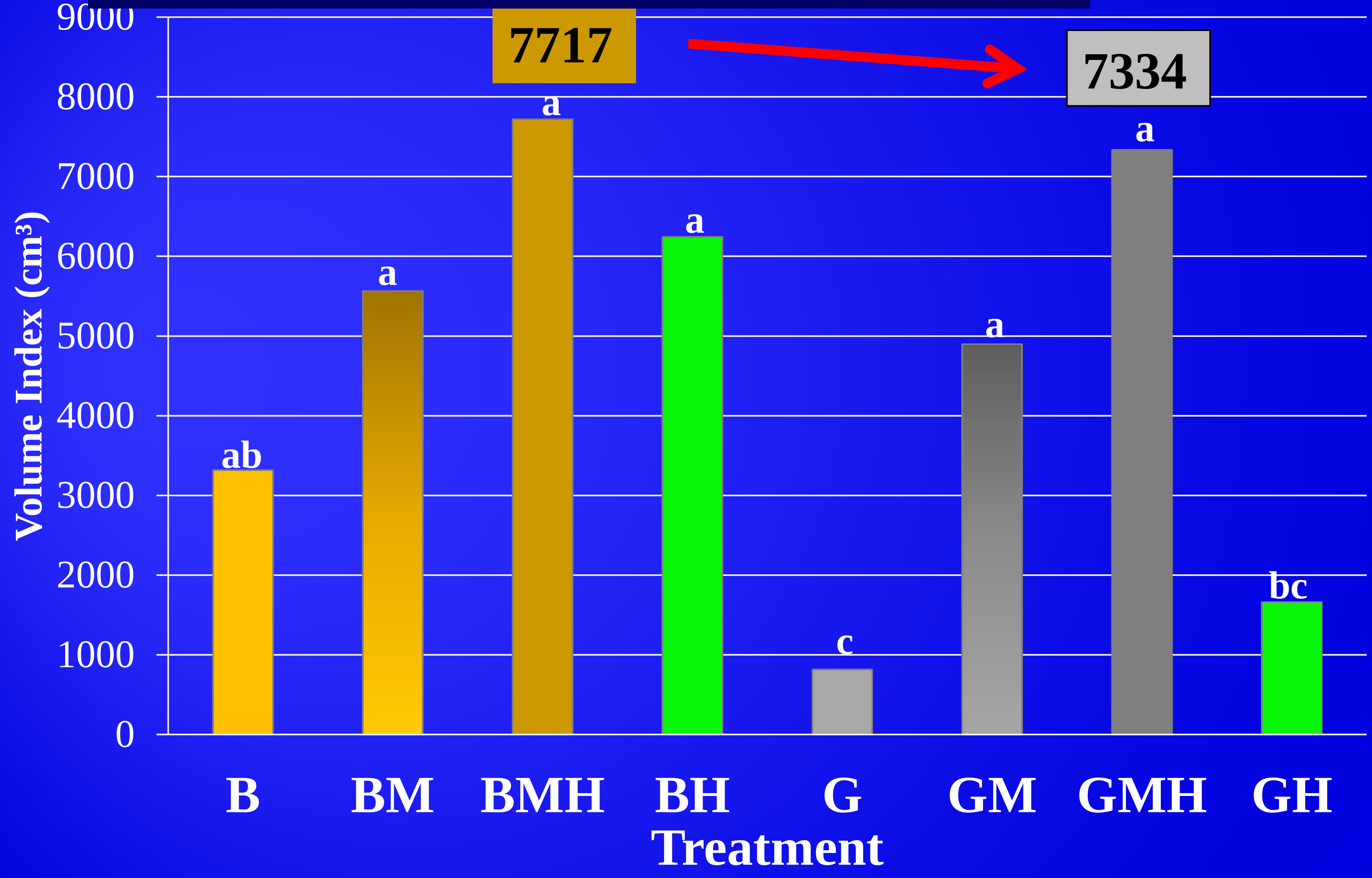


RESULTS: Trees 2012 - 6th Yr



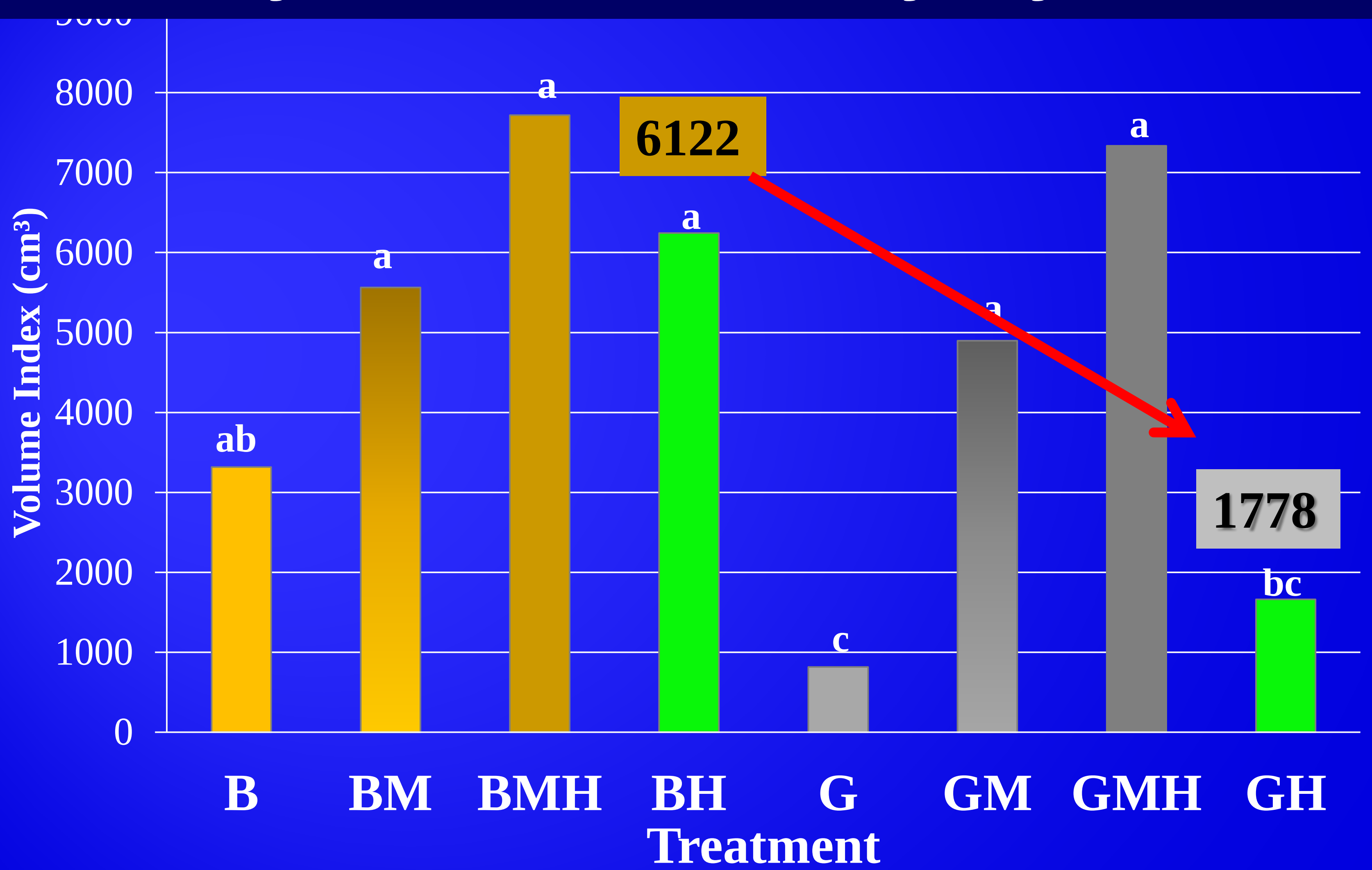
RESULTS: Trees 2012 - 6th Yr

Brown M-H vs Gray M-H



RESULTS: Trees 2012 - 6th Yr

Brown Hydroseed vs Gray HydroSeed




Brown - 8 yrs

Brown Mulch - 8 yrs

Gray - 8 yrs

Gray Mulch - 8 yrs

CONCLUSIONS

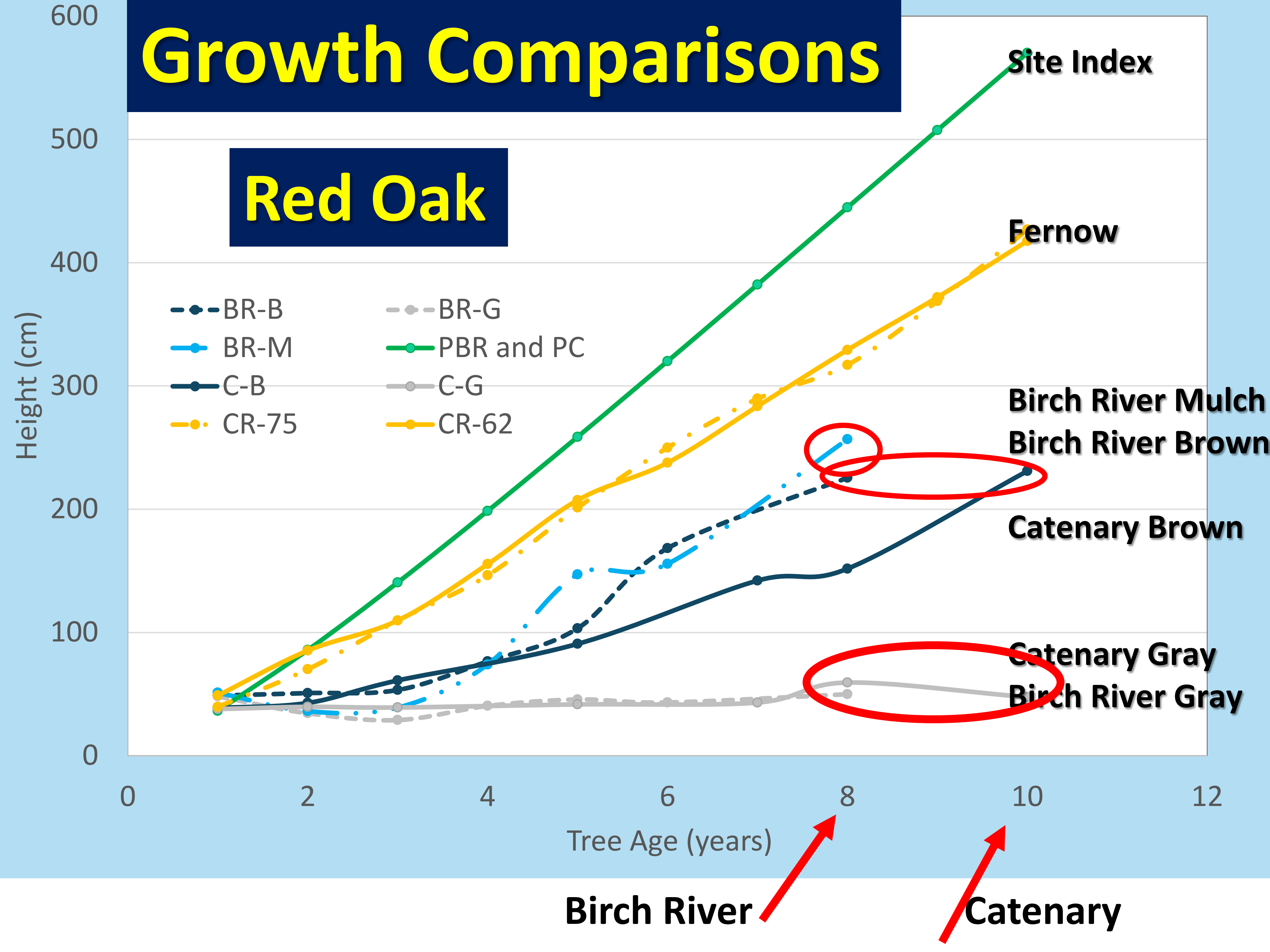
Brown more tree growth than Gray.

Mulch application significantly helped growth, especially on Gray.

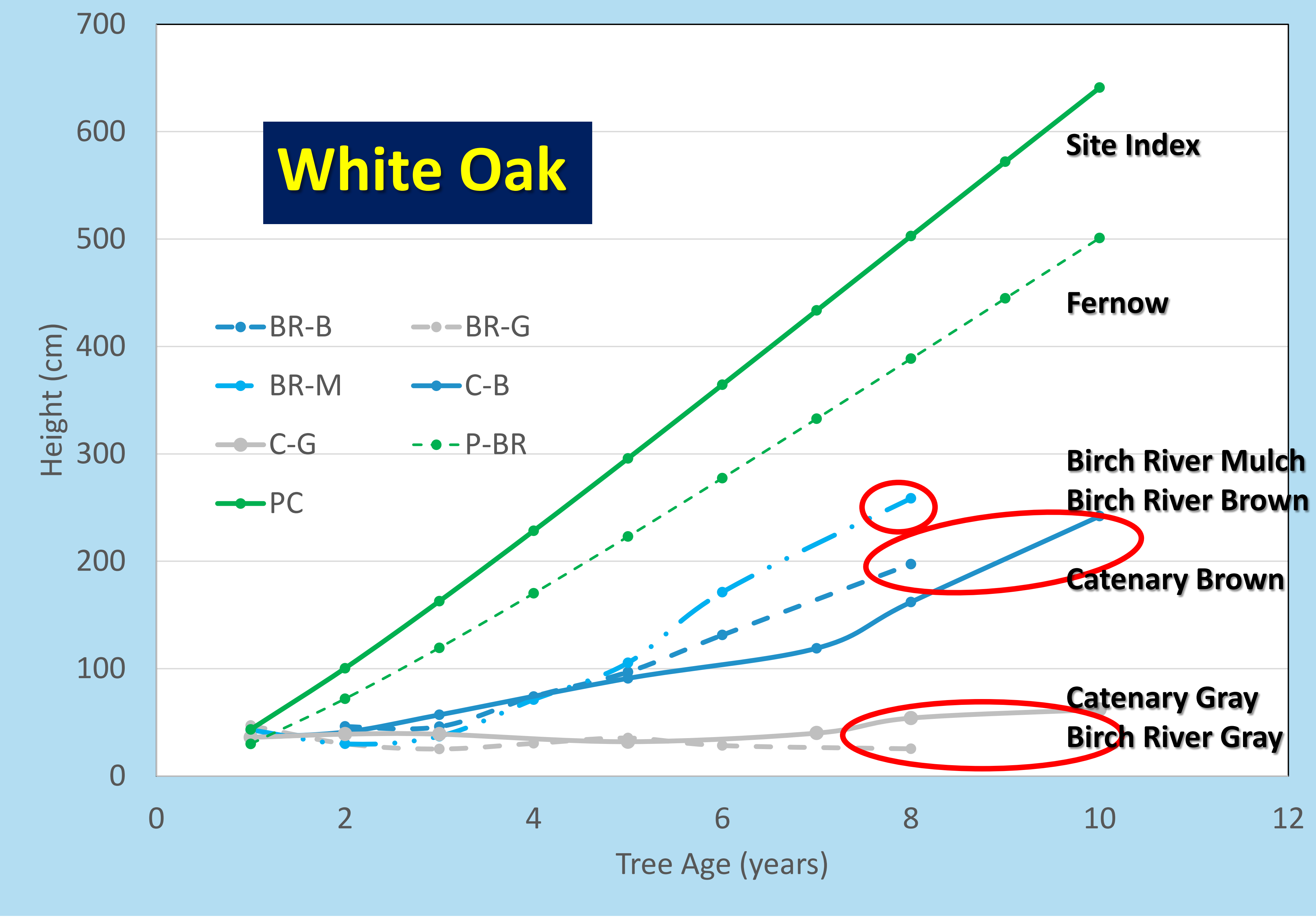
Hydroseed application had a positive effect on tree growth.

- Compare the height of tulip poplar, white oak, and red oak from mined sites to trees growing in unmined conditions

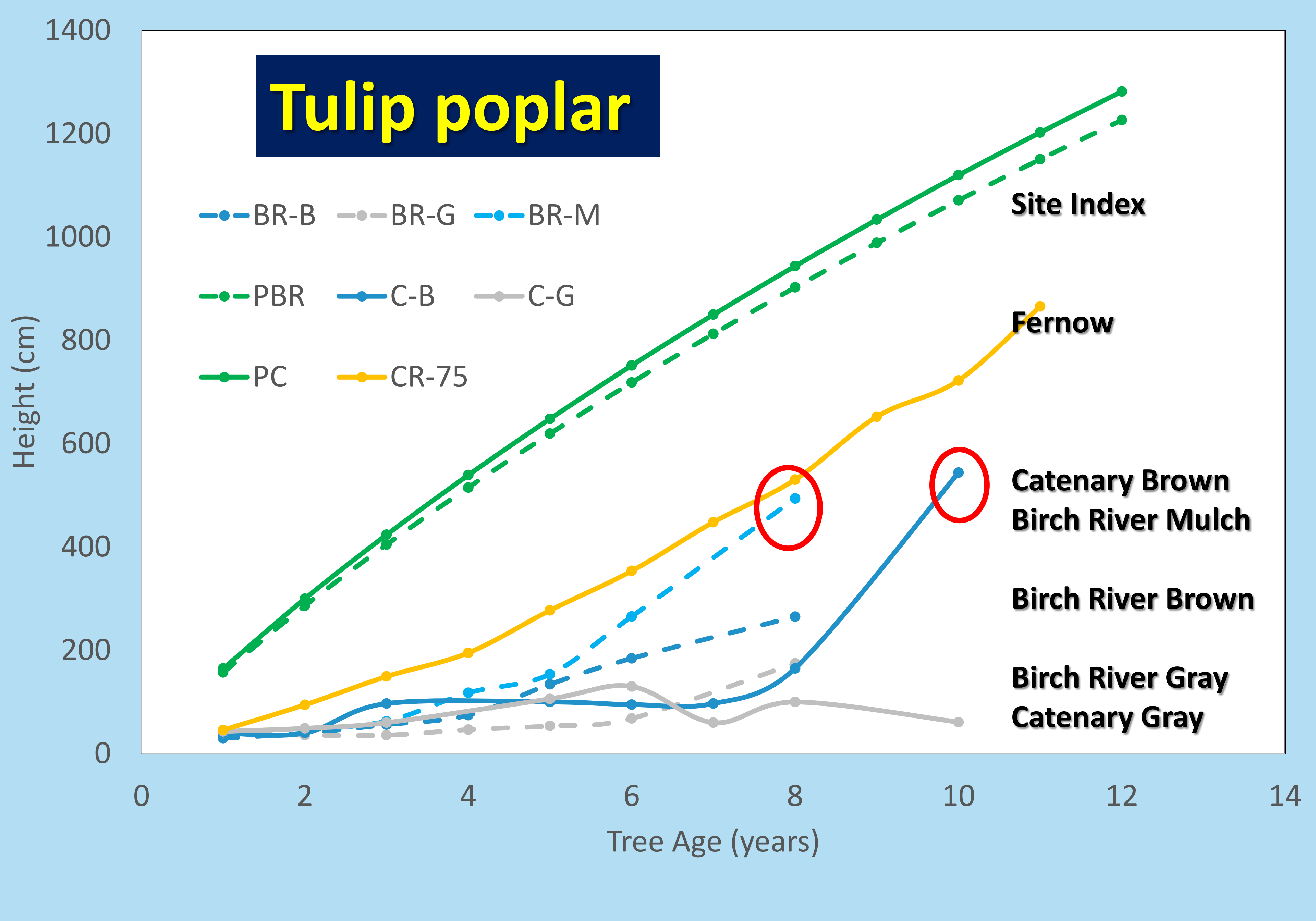
- Looked at tree height data from:
  - Catenary and Birch River Mines
  - Fernow Forest
  - Predicted heights from Web Soil Survey with Site Index information



Growth Comparisons
Red Oak
Height (cm)
600
500
400
300
200
100
0
0
2
4
6
8
10
12
Tree Age (years)
BR-B
BR-G
BR-M
PBR and PC
C-B
C-G
CR-75
CR-62
Site Index
Fernow
Birch River Mulch
Birch River Brown
Catenary Brown
Catenary Gray
Birch River Gray
Birch River
Catenary



White Oak
Height (cm)
700
600
500
400
300
200
100
0
Tree Age (years)
0
2
4
6
8
10
12
BR-B
BR-G
BR-M
C-B
C-G
P-BR
PC
Site Index
Fernow
Birch River Mulch
Birch River Brown
Catenary Brown
Catenary Gray
Birch River Gray



Tulip poplar
BR-B
BR-G
BR-M
PBR
C-B
C-G
PC
CR-75
Site Index
Fernow
Catenary Brown
Birch River Mulch
Birch River Brown
Birch River Gray
Catenary Gray
Height (cm)
Tree Age (years)
0
200
400
600
800
1000
1200
1400
0
2
4
6
8
10
12
14

Conclusions

- Tree Growth on Gray Sandstone - Poor
- Tree Growth on Brown Sandstone - Better
- Tree Growth on mine sites is still lower than growth on undisturbed areas


Comments