An Investigation of Tree Growth and Colonization on a 19 Year-Old Forestry Reclamation Site

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Introduction/Goals

- Provide a brief overview of the forestry reclamation approach.
- Discuss history of Starfire project.
- Summarize findings on three planted species.
- Summarize findings on volunteer woody plants.

The Forestry Reclamation Approach

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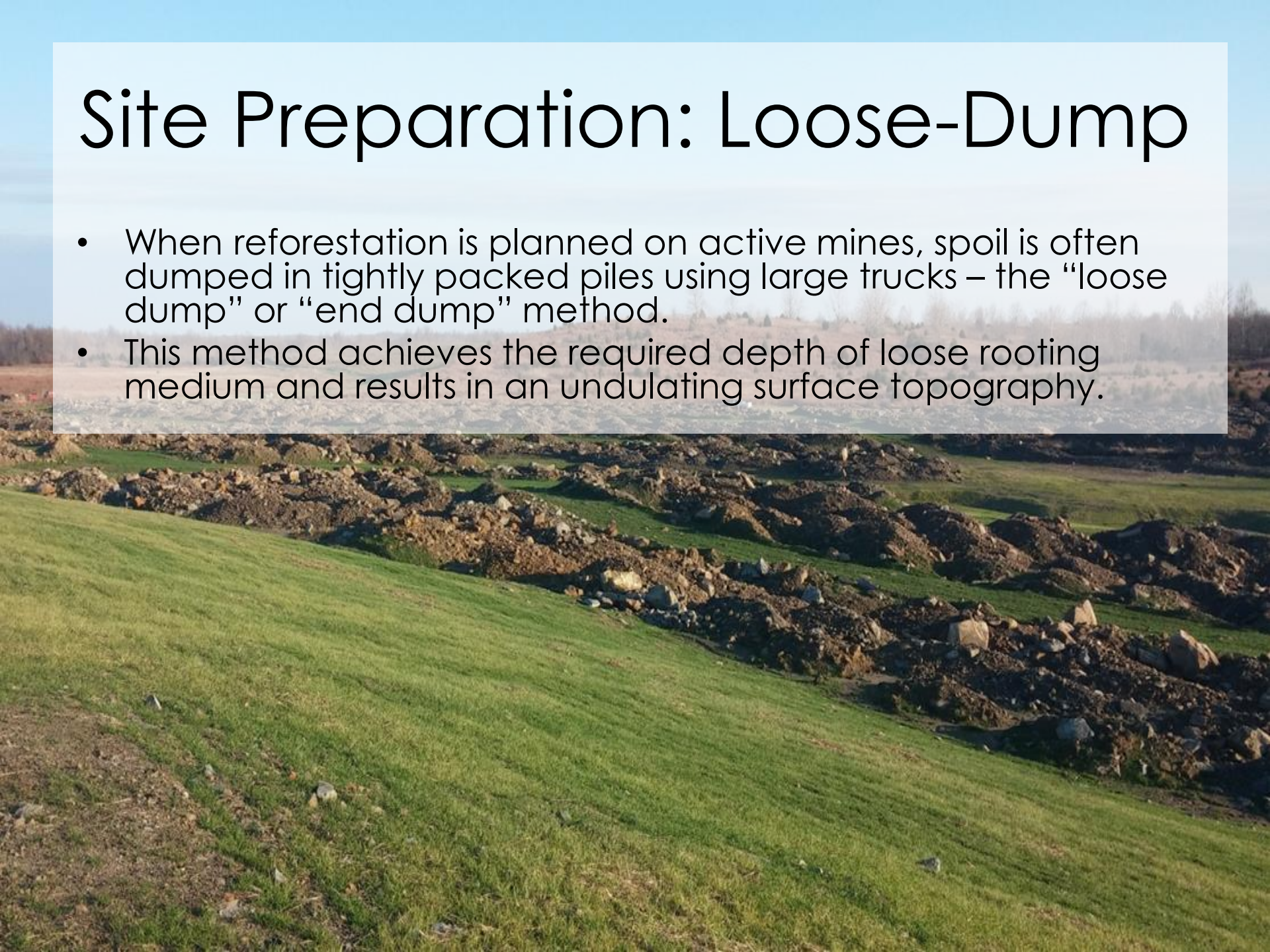
Steps of the Forestry Reclamation Approach

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 comprised of topsoil, weathered sandstone and/or the best available material.
2. Loosely grade the topsoil or topsoil substitute established in step one to create a non-compacted growth medium.
3. Use ground covers that are compatible with growing trees.
4. Plant two types of trees--early successional species for wildlife and soil stability, and commercially valuable crop trees
5. Use proper tree planting techniques.

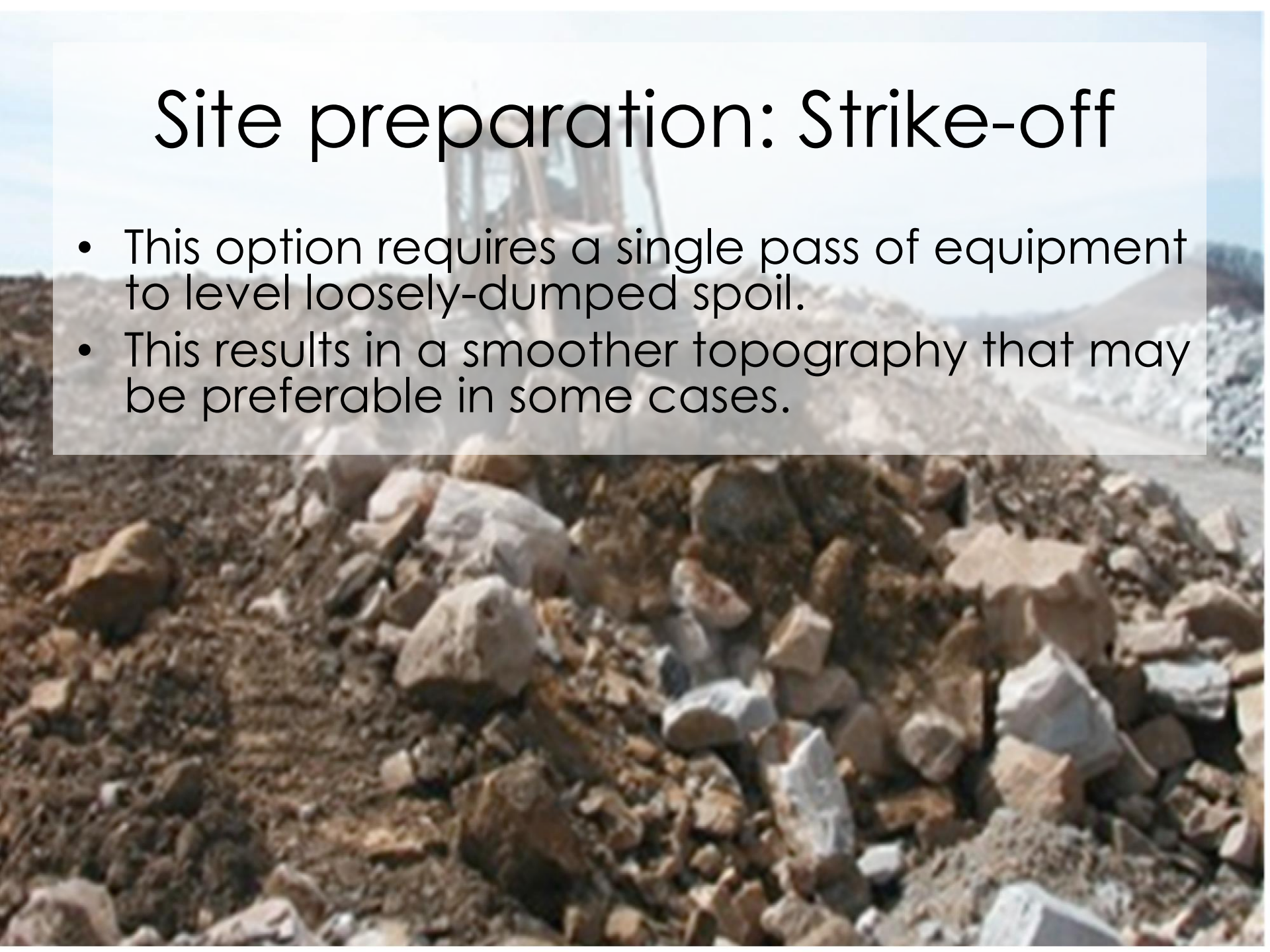
Site Preparation: Loose-Dump

- When reforestation is planned on active mines, spoil is often dumped in tightly packed piles using large trucks – the "loose dump" or "end dump" method.
- This method achieves the required depth of loose rooting medium and results in an undulating surface topography.



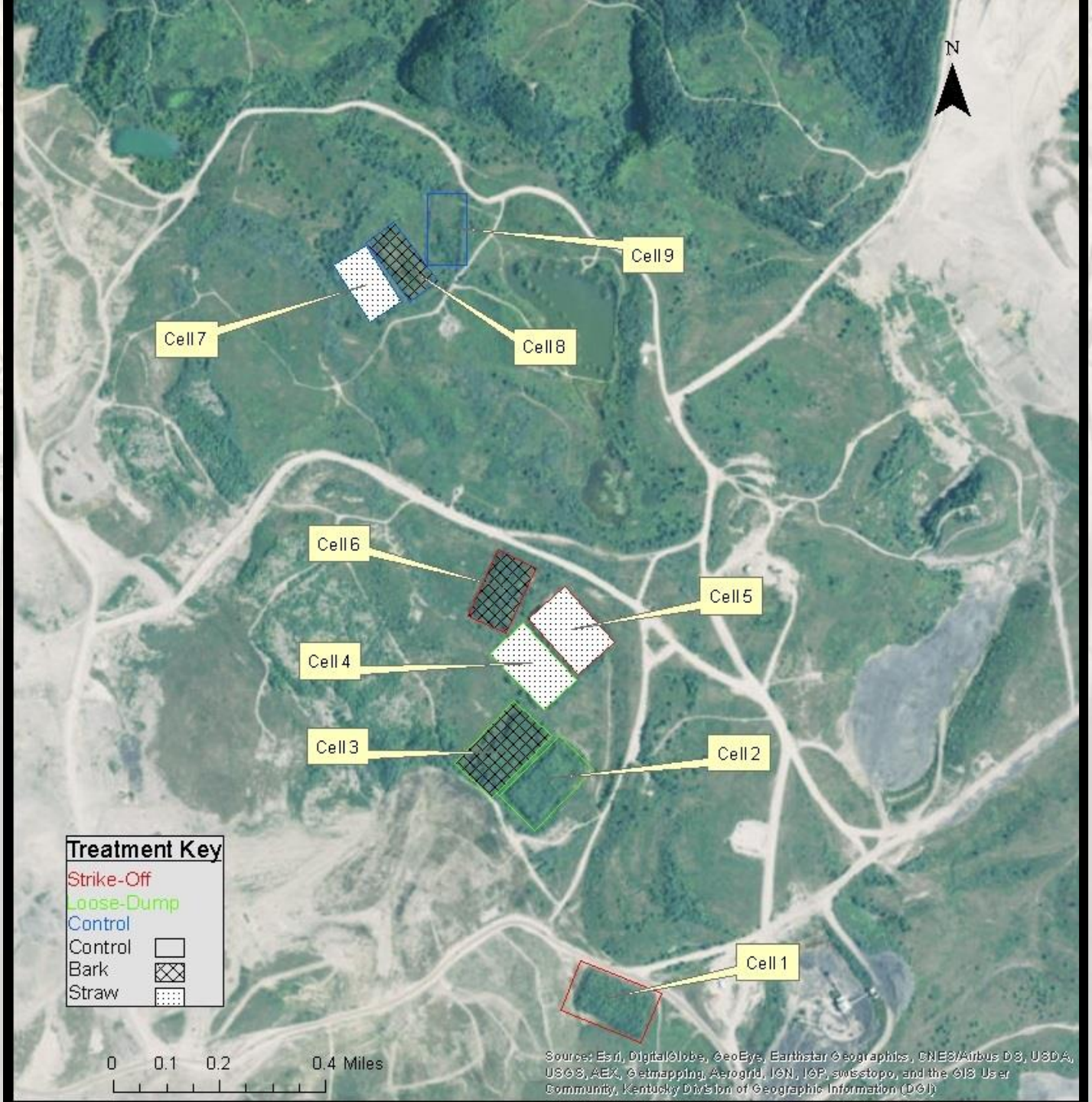
Site preparation: Strike-off

- This option requires a single pass of equipment to level loosely-dumped spoil.
- This results in a smoother topography that may be preferable in some cases.



The Starfire Project

- In 1996, University of Kentucky and government researchers began a reforestation experiment on the Starfire mine in eastern Kentucky.
- The project aimed to investigate the effects of soil compaction and surface amendment on the growth and survival of trees.


N
Cell 9
Cell 7
Cell 8
Cell 6
Cell 5
Cell 4
Cell 3
Cell 2
Cell 1
Treatment Key
Strike-Off
Loose-Dump
Control
Control
Bark
Straw
0 0.1 0.2 0.4 Miles
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Kentucky Division of Geographic Information (DGI)

The Starfire Project

- Plots were divided into 21 .04 ha cells and planted with:
  - Eastern white pine (*Pinus strobus*)
  - White ash (*Fraxinus americana*)
  - Black walnut (*Juglans nigra*)
  - Yellow-poplar (*Liriodendron tulipifera*)
  - White oak (*Quercus alba*)
  - Northern red oak (*Quercus rubra*)
  - Royal paulownia (*Paulownia tomentosa*)

From Angel et al., 2006

Previous Results

Table 1. Mean survival and height for eight year old trees as influenced by subsurface reclamation treatment at the Starfire research complex. Means with the same letter are not significantly different.[†]

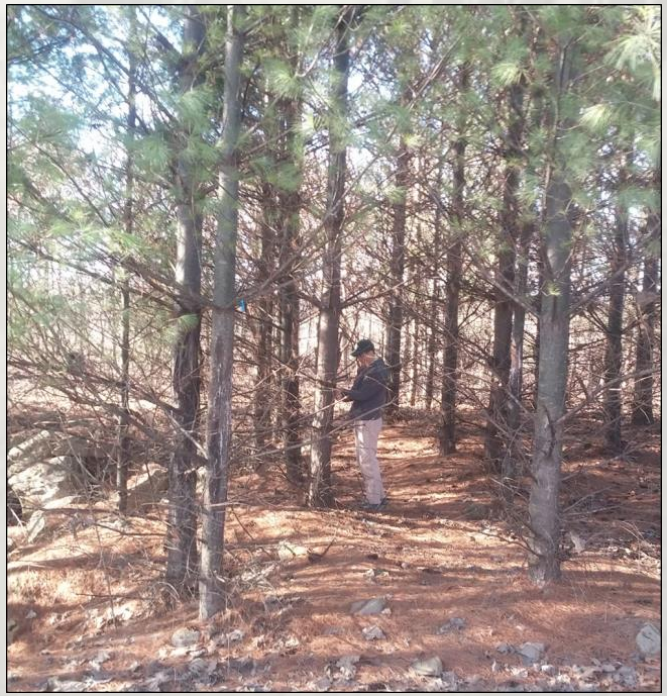
Method	White Oak	White Ash	White Pine	Red Oak	Black Walnut	Yellow Poplar
			Survival (%)			
Compact	21 (a)	80 (a)	3 (a)	18 (a)	18 (a)	10 (a)
Strike-off	69 (b)	81 (a)	50 (b)	64 (b)	55 (b)	52 (b)
Loose-dump	81 (c)	82 (a)	82 (c)	82 (c)	68 (b)	80 (c)
			Height (cm)			
Compact	63 (a)	104 (a)	87 (a)	93 (a)	58 (a)	125 (a)
Strike-off	197 (b)	236 (b)	307 (b)	242 (b)	116 (b)	203 (b)
Loose-dump	217 (b)	308 (c)	431 (c)	278 (b)	184 (c)	276 (c)

[†]Surface treatments pooled to examine subsurface effects; n = 1089 seedlings per subsurface treatment and species.

From Angel et al., 2006

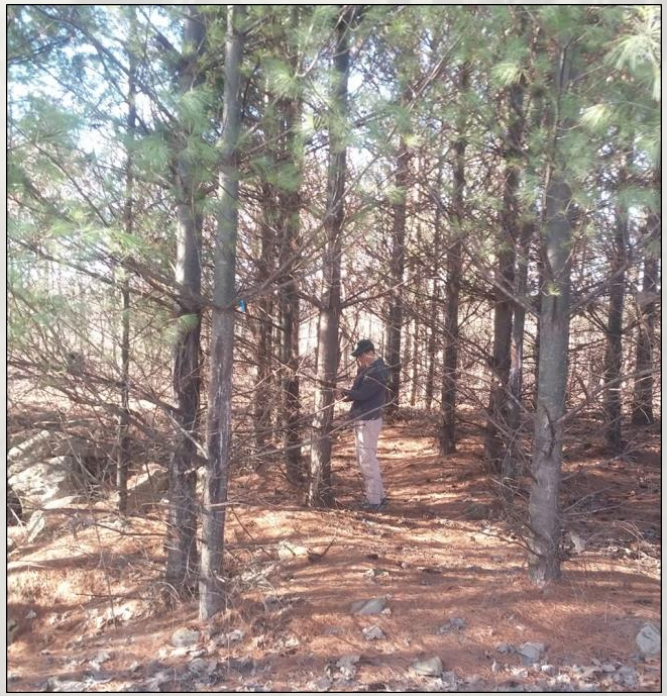
Current Work - Inventory

- We sought to compare the success of trees planted in levels of surface and grading treatments by inventorying the experimental plots.
- Diameter at breast height (DBH) was measured for all live trees.
- Heights of a subset of trees were measured and crown classes were identified.

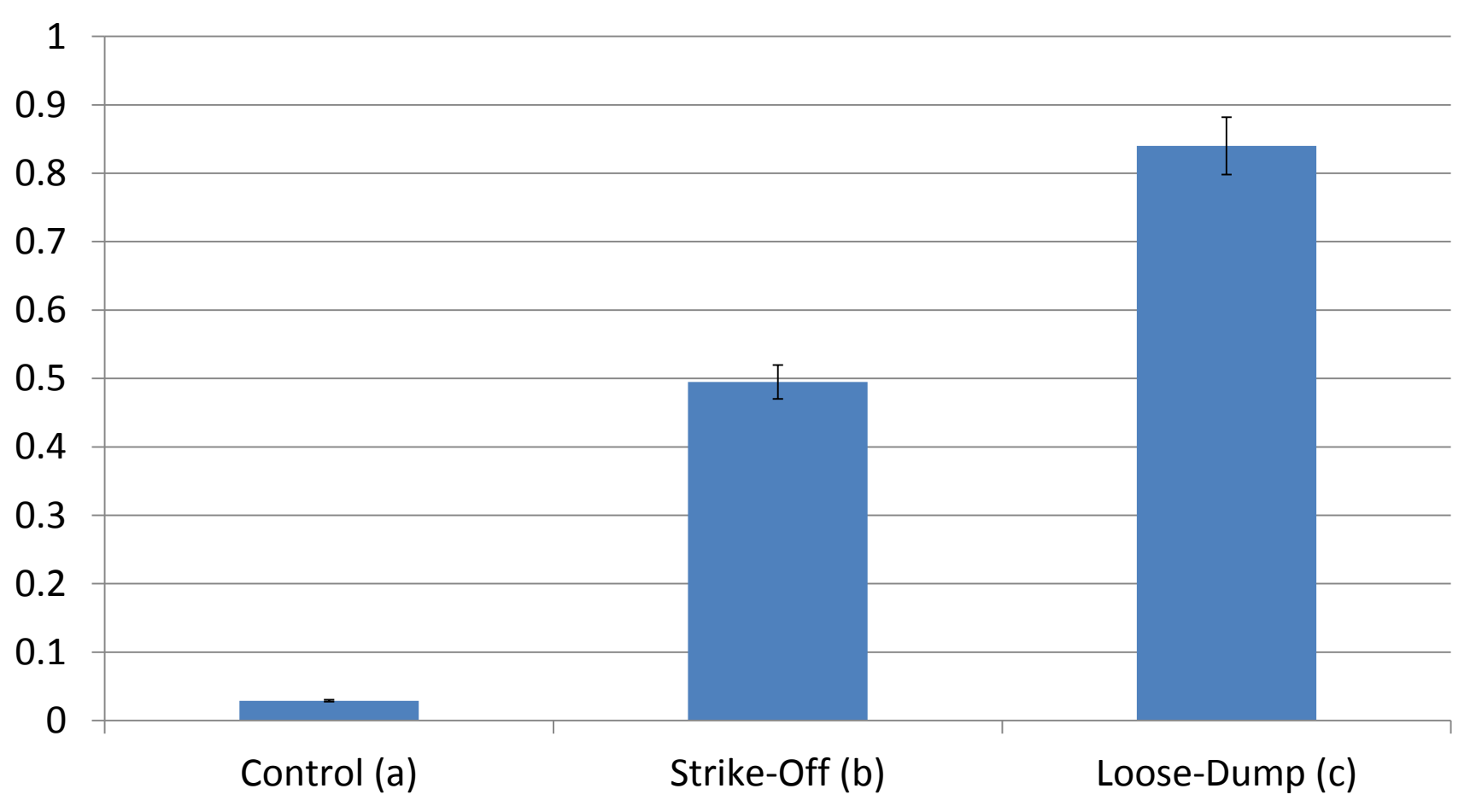


Current Work - Inventory

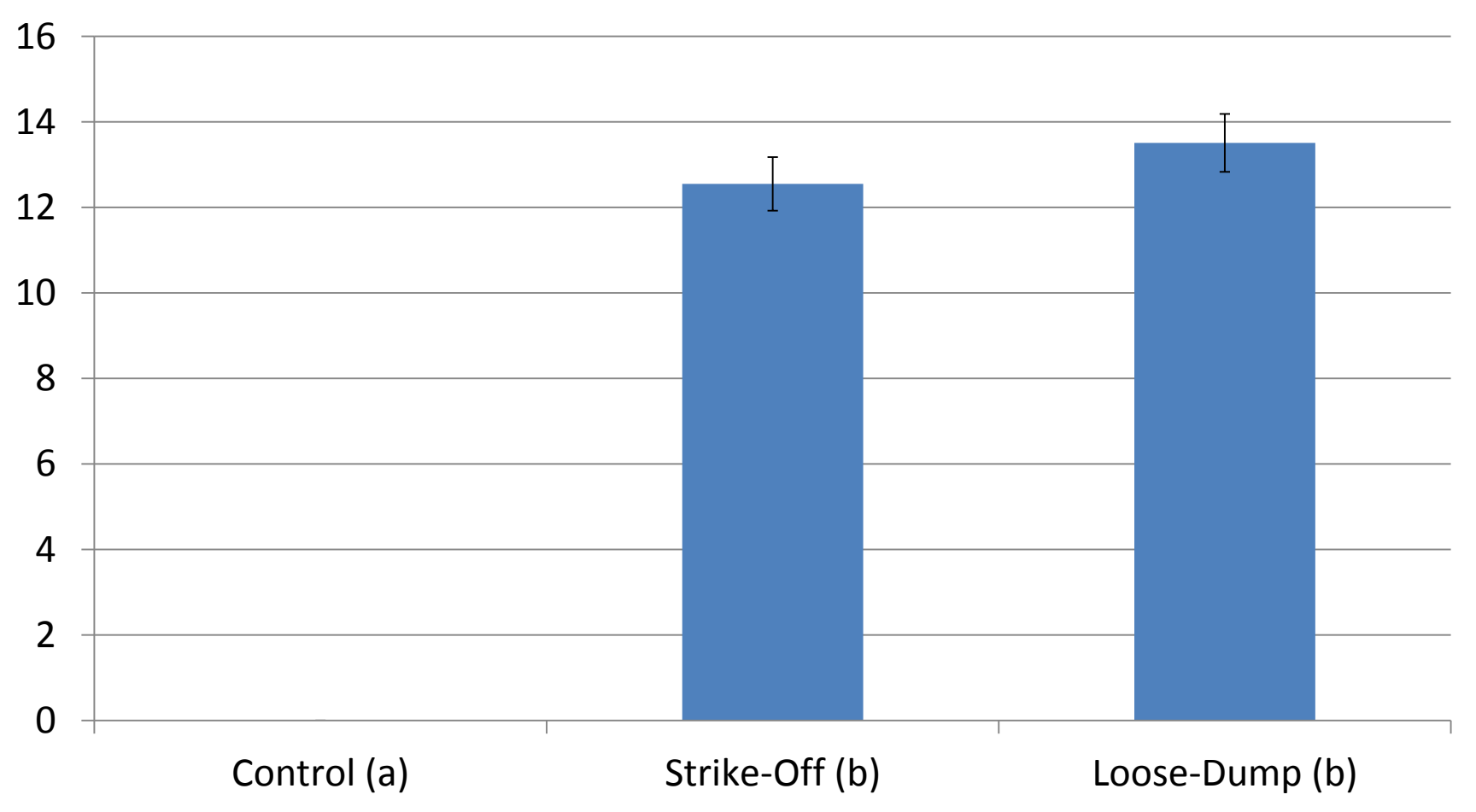
- A mixed model statistical approach was followed.
  - Fixed effects: Grading, Surface Amendment, Interaction
  - Random effect: Plot



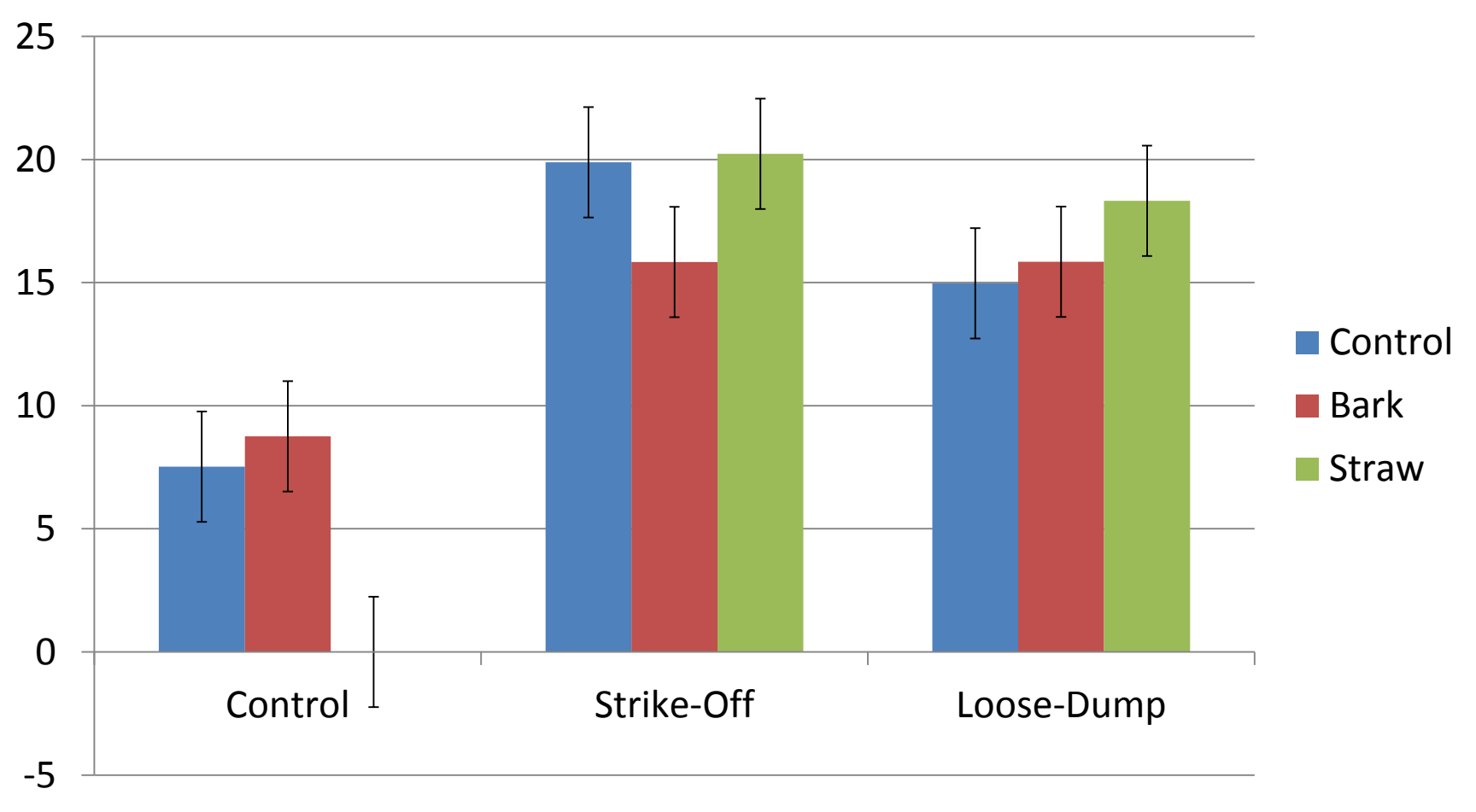
Pinus Strobus Survival



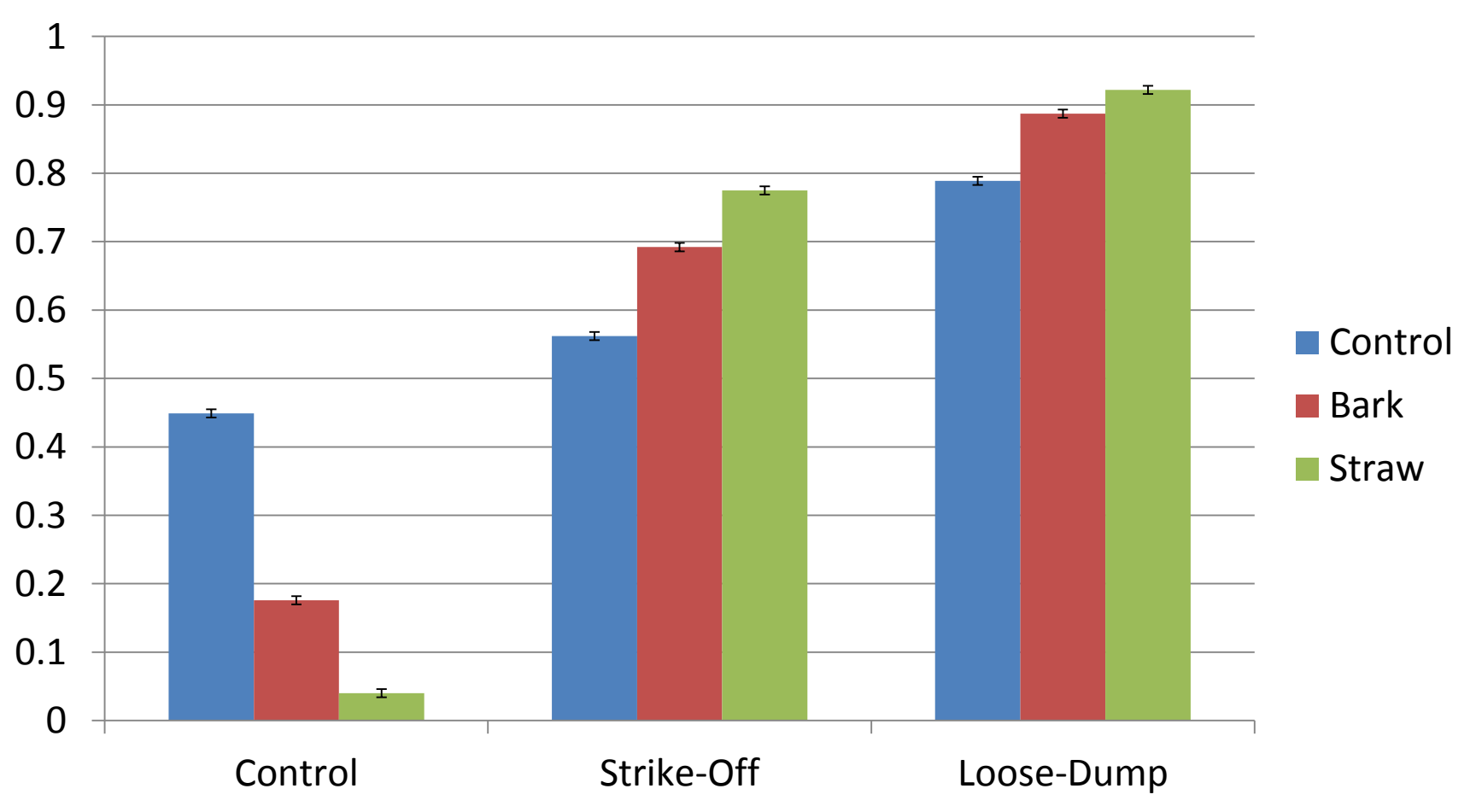
Pinus Strobus Mean Overstory Height (m)



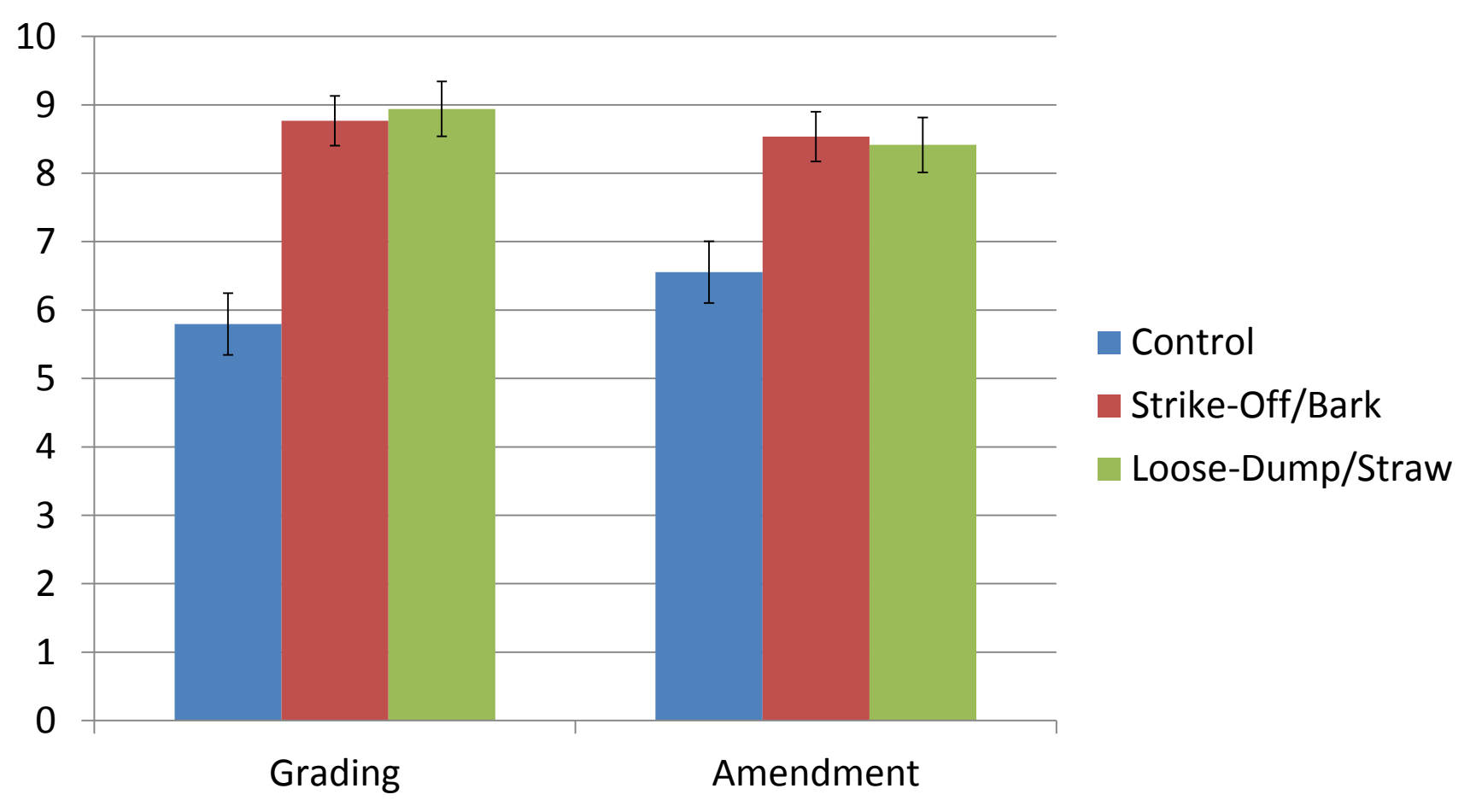
Pinus Strobus DBH (cm)



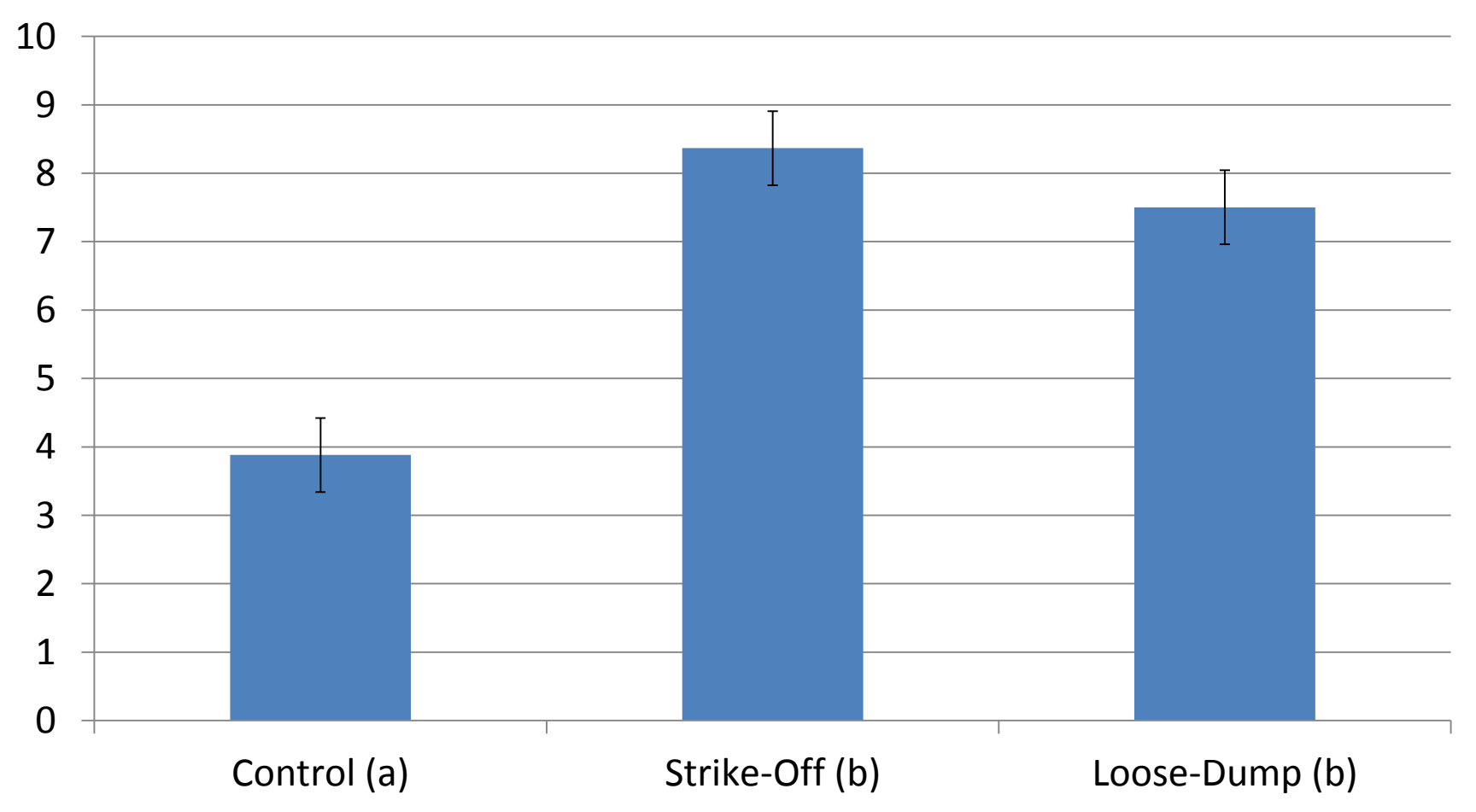
Q. *Alba* Survival



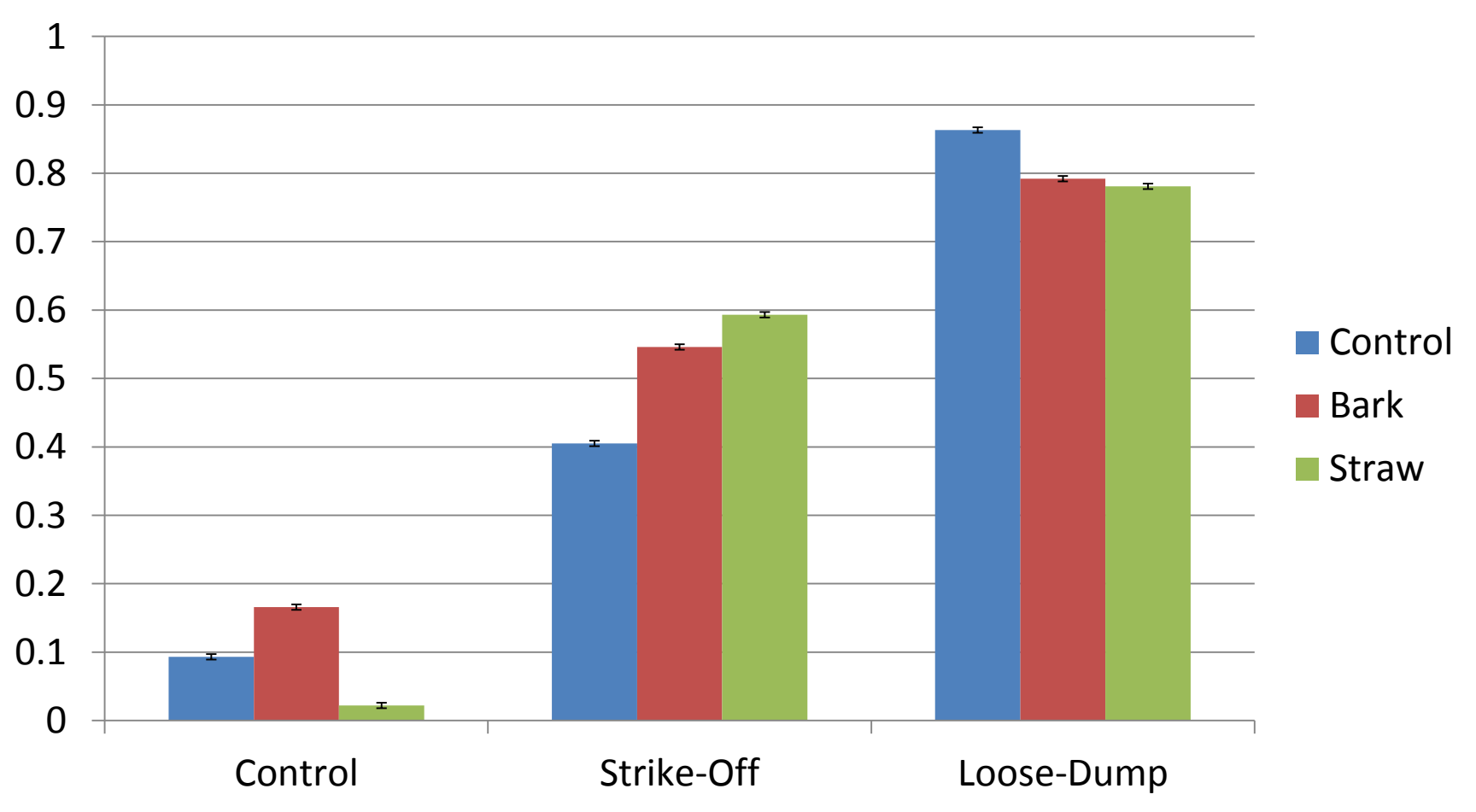
Q. *Alba* Mean Overstory Height (m)



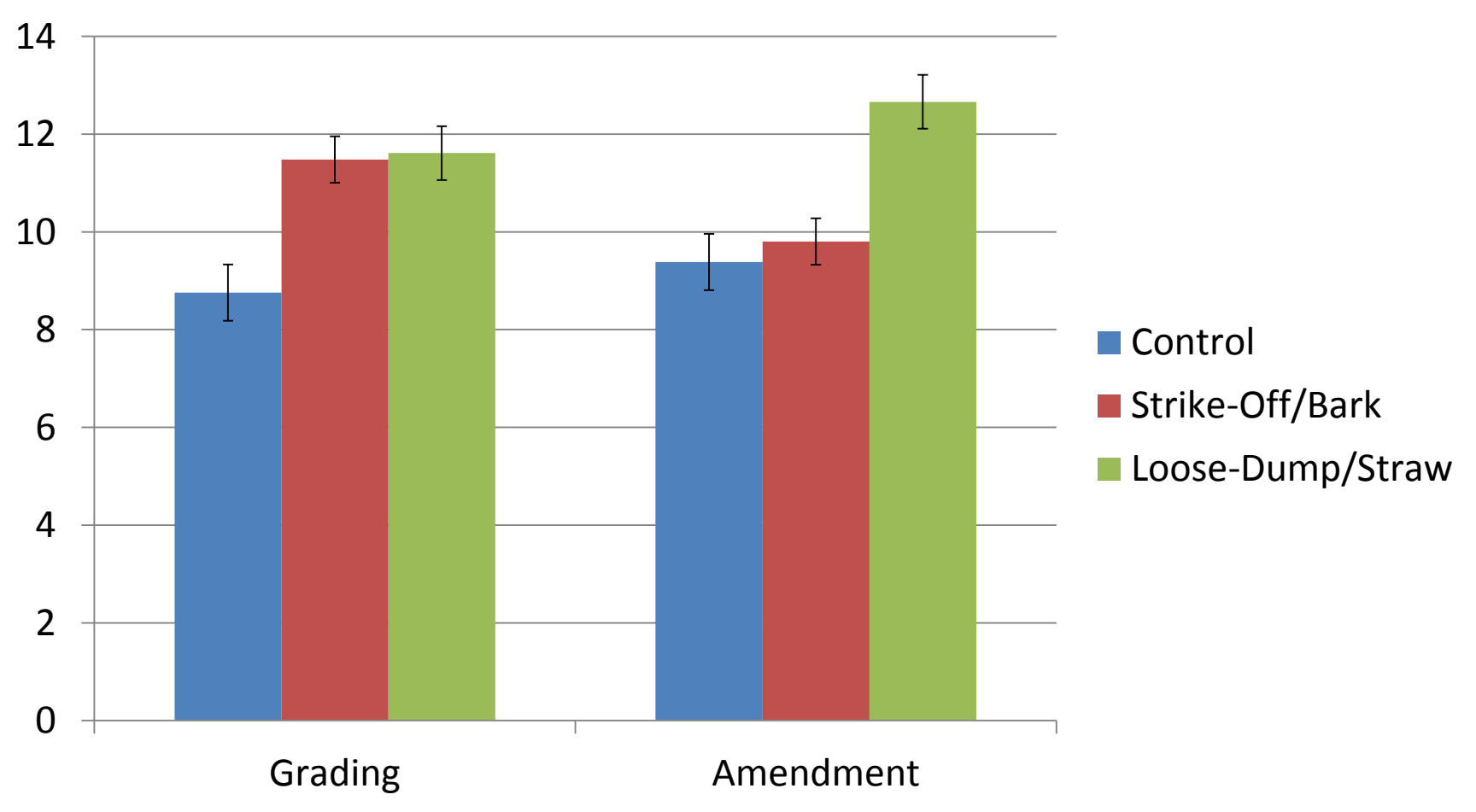
Q. *Alba* Mean DBH (cm)



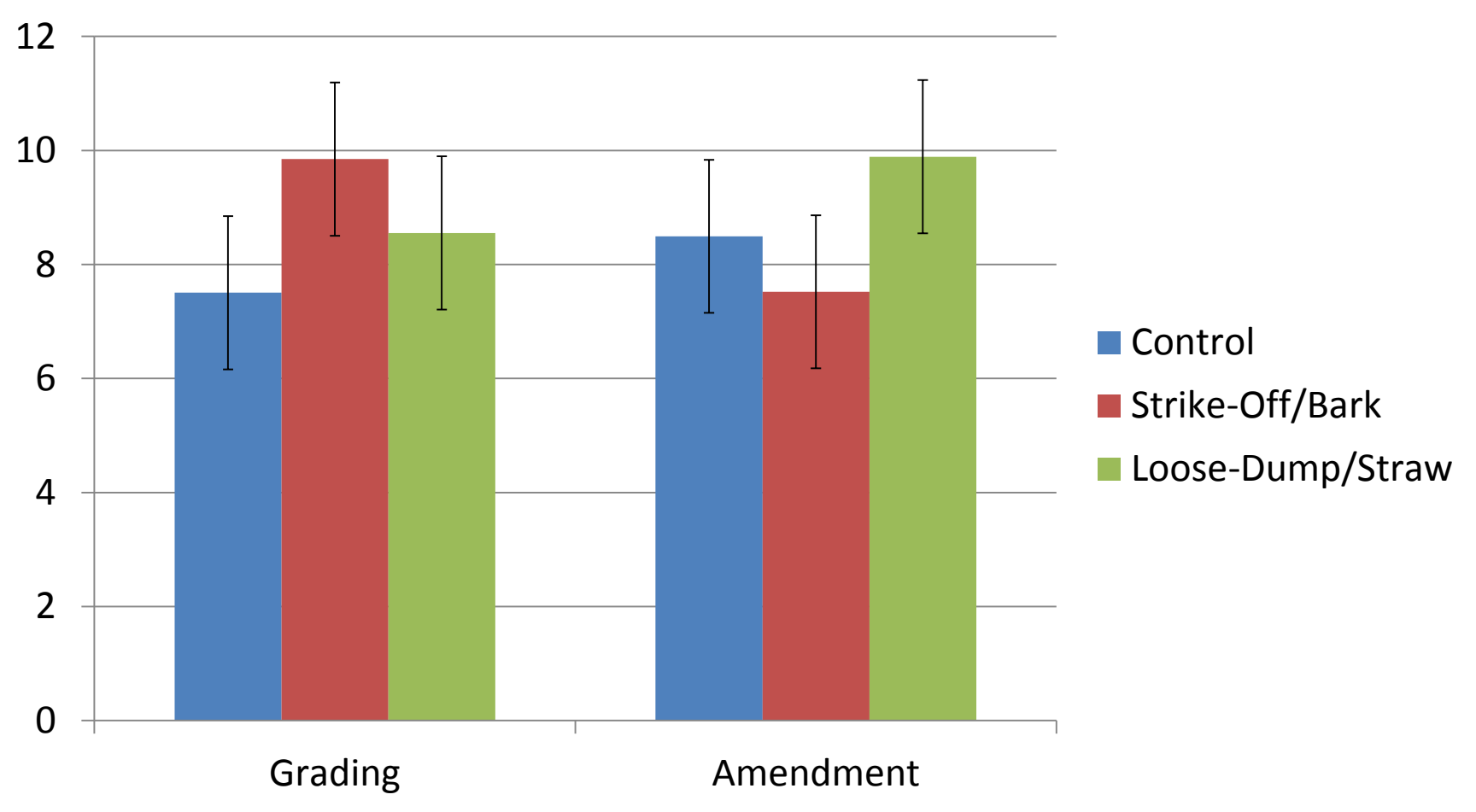
L. Tulipifera Survival



L. Tulipifera Mean Overstory Height (m)

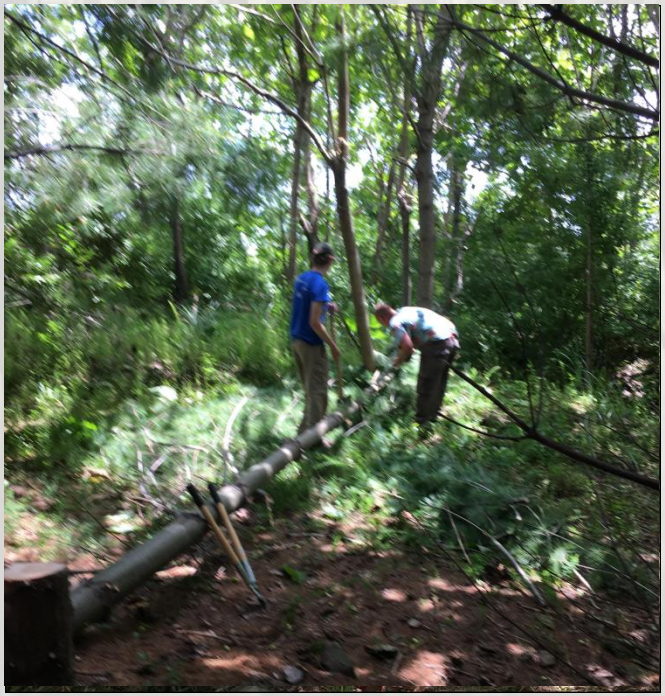


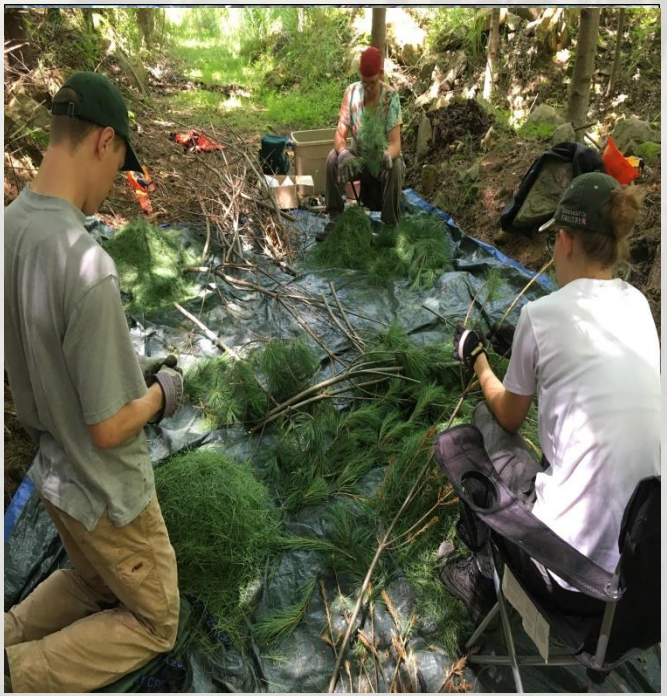
L. Tulipifera Mean DBH (cm)



Biomass Estimation

- We also sought to gauge growth through the estimation of biomass per acre.
- Trees were felled, divided into components, and weighed.



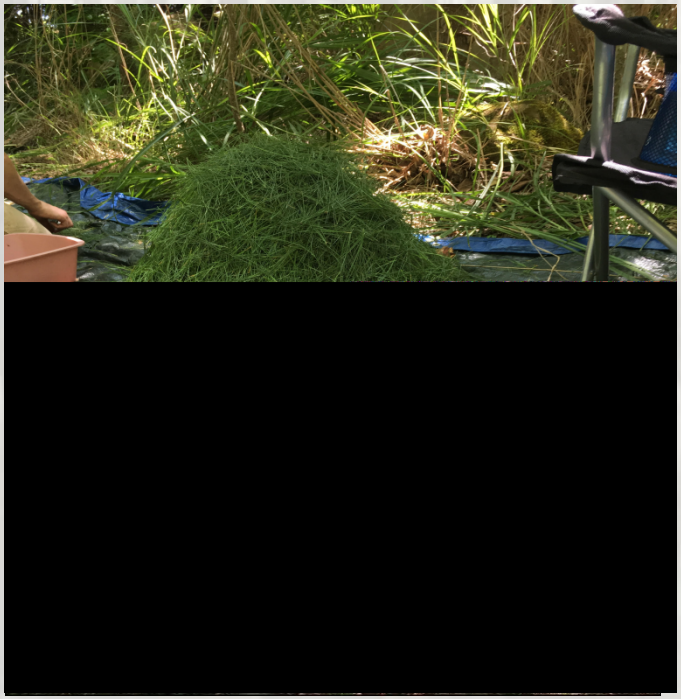


Biomass Estimation

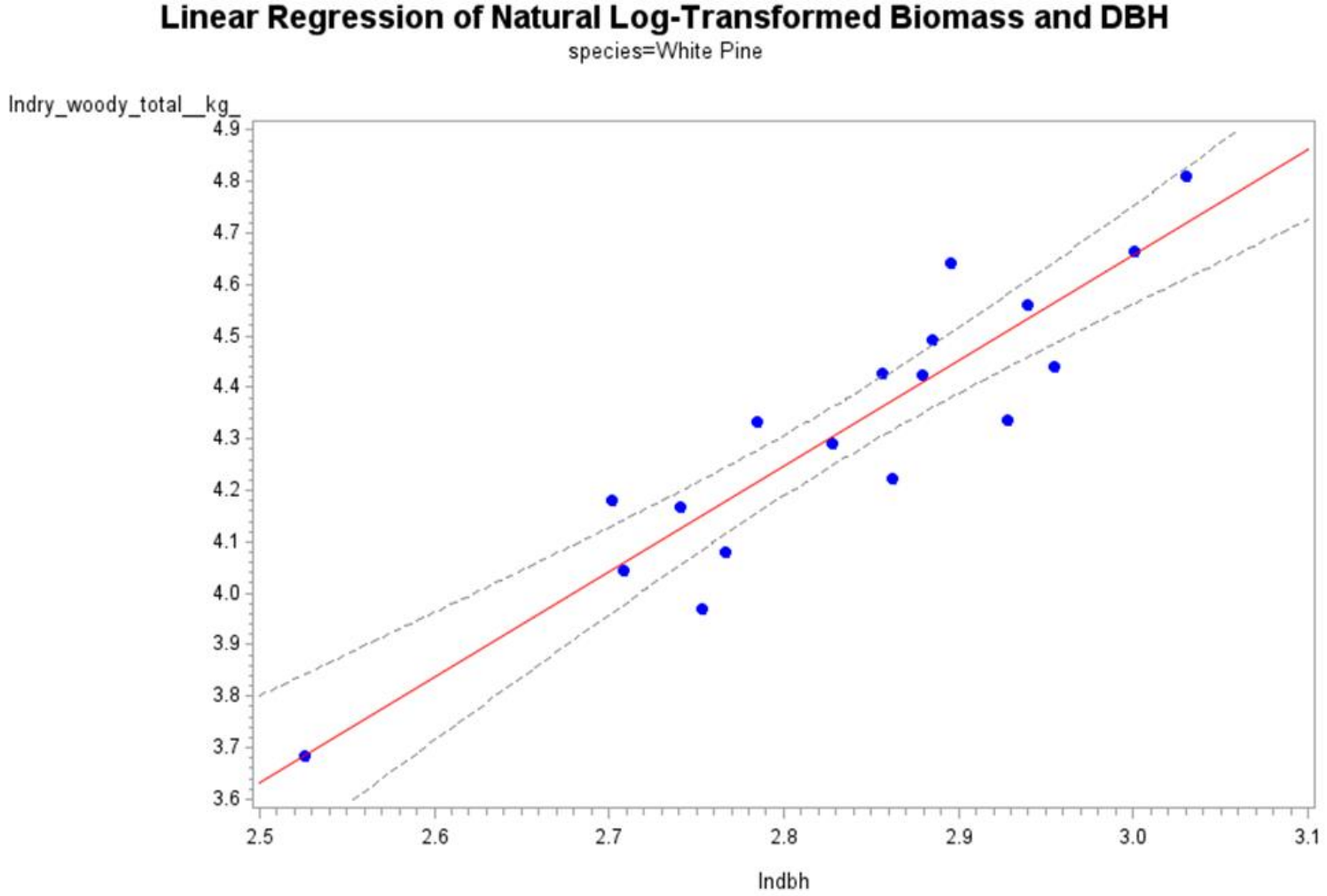
- Subsamples were weighed, dried, and reweighed.
- Dry weights of sampled trees were used to develop regression equations relating DBH to mass.

Biomass Estimation

- A mixed model similar to that used for inventory data was used to test mean values.

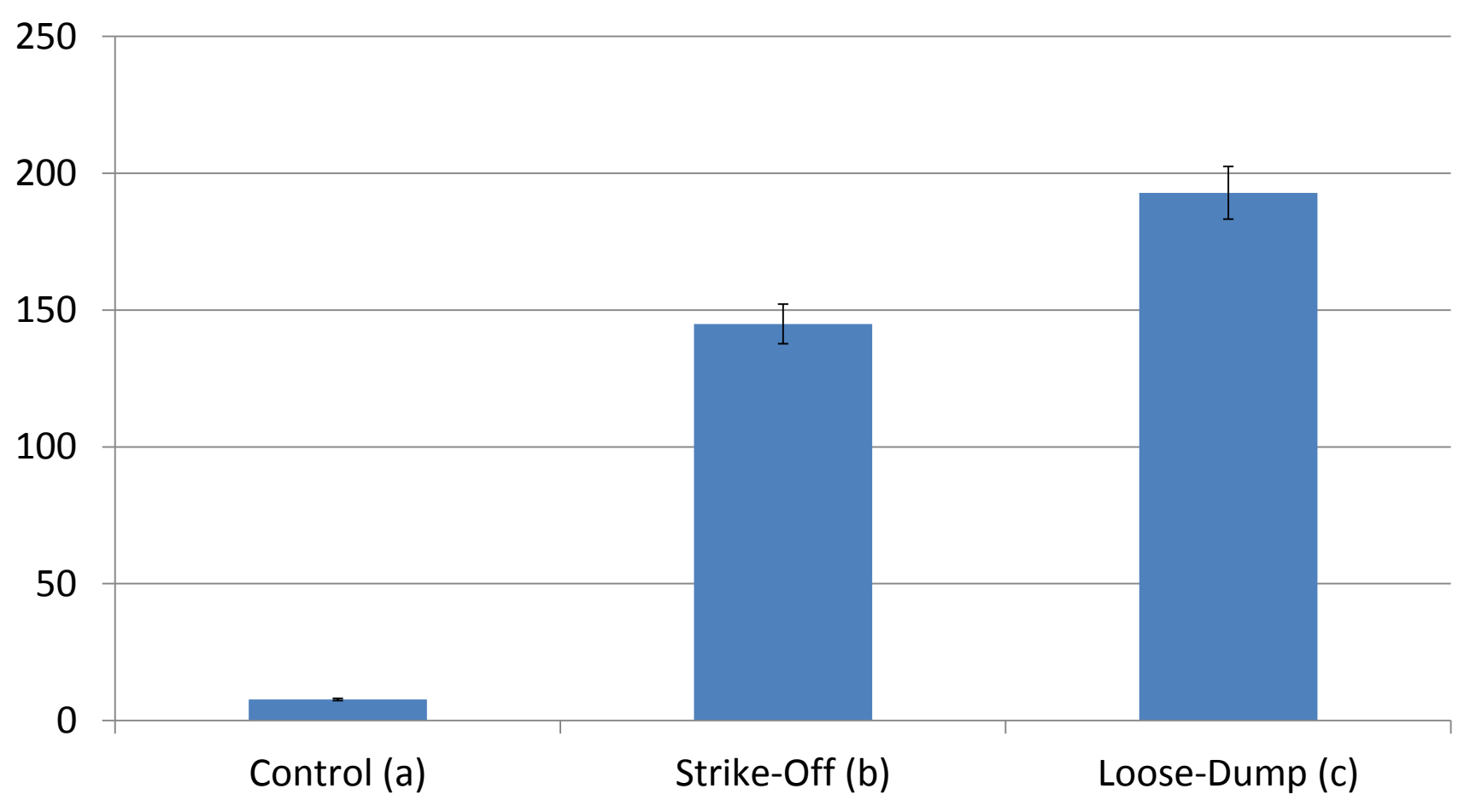


P. Strobus Biomass Regression

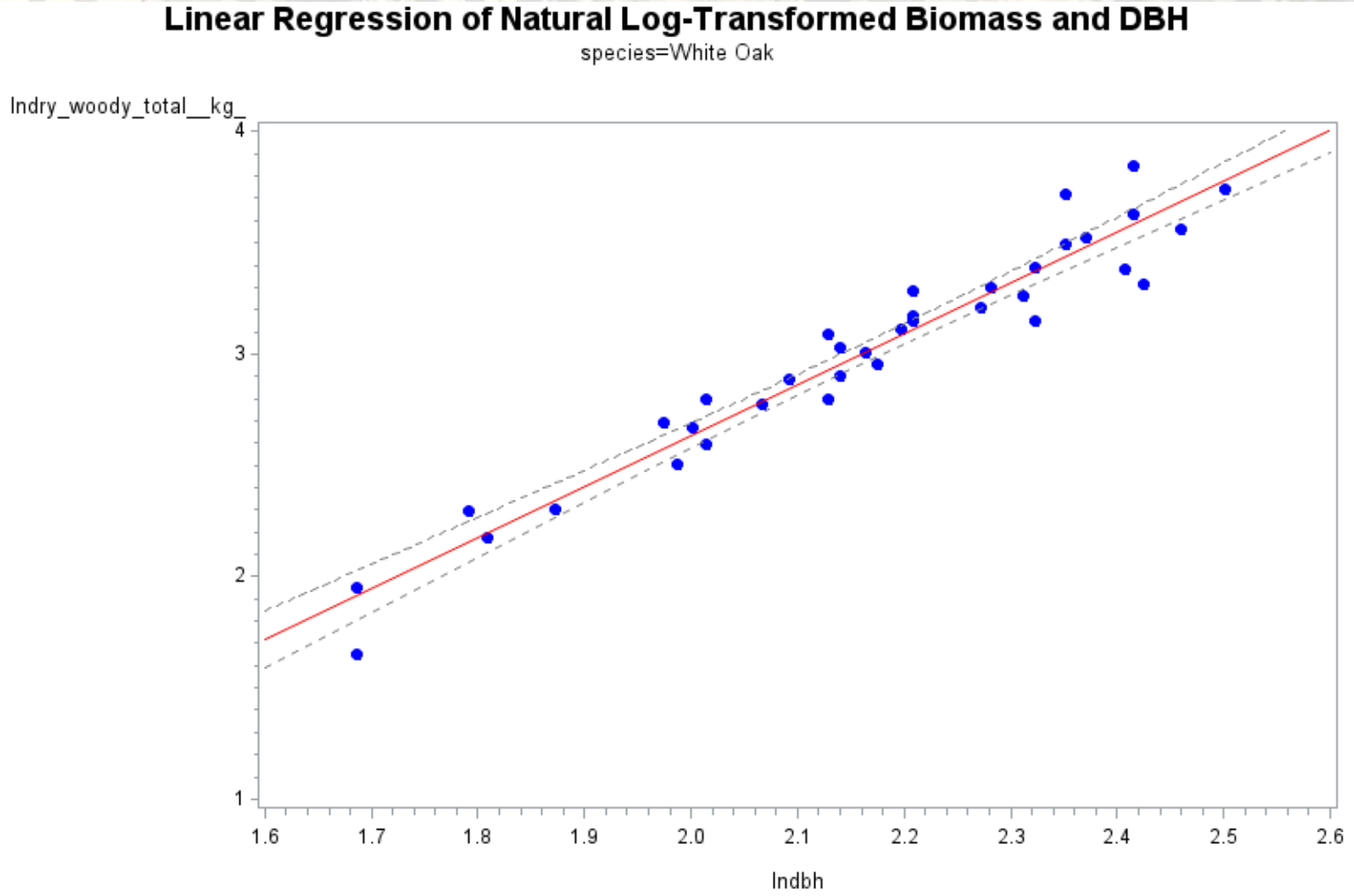


(n= 18, $p<.0001$, $R^2= .843$)

Pinus Strobus Aboveground Biomass Estimate (Mg/ha)

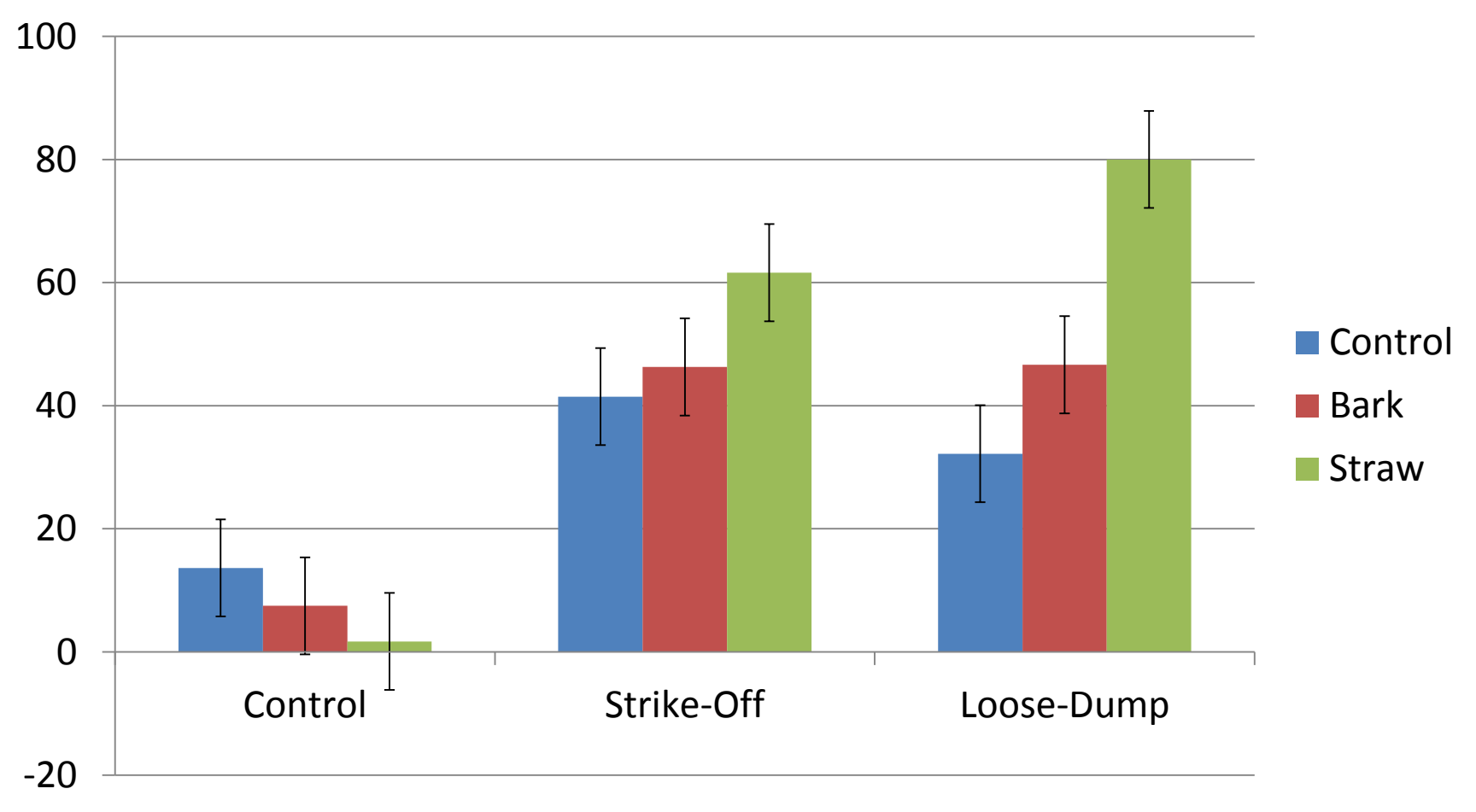


Q. *Alba* Biomass Regression

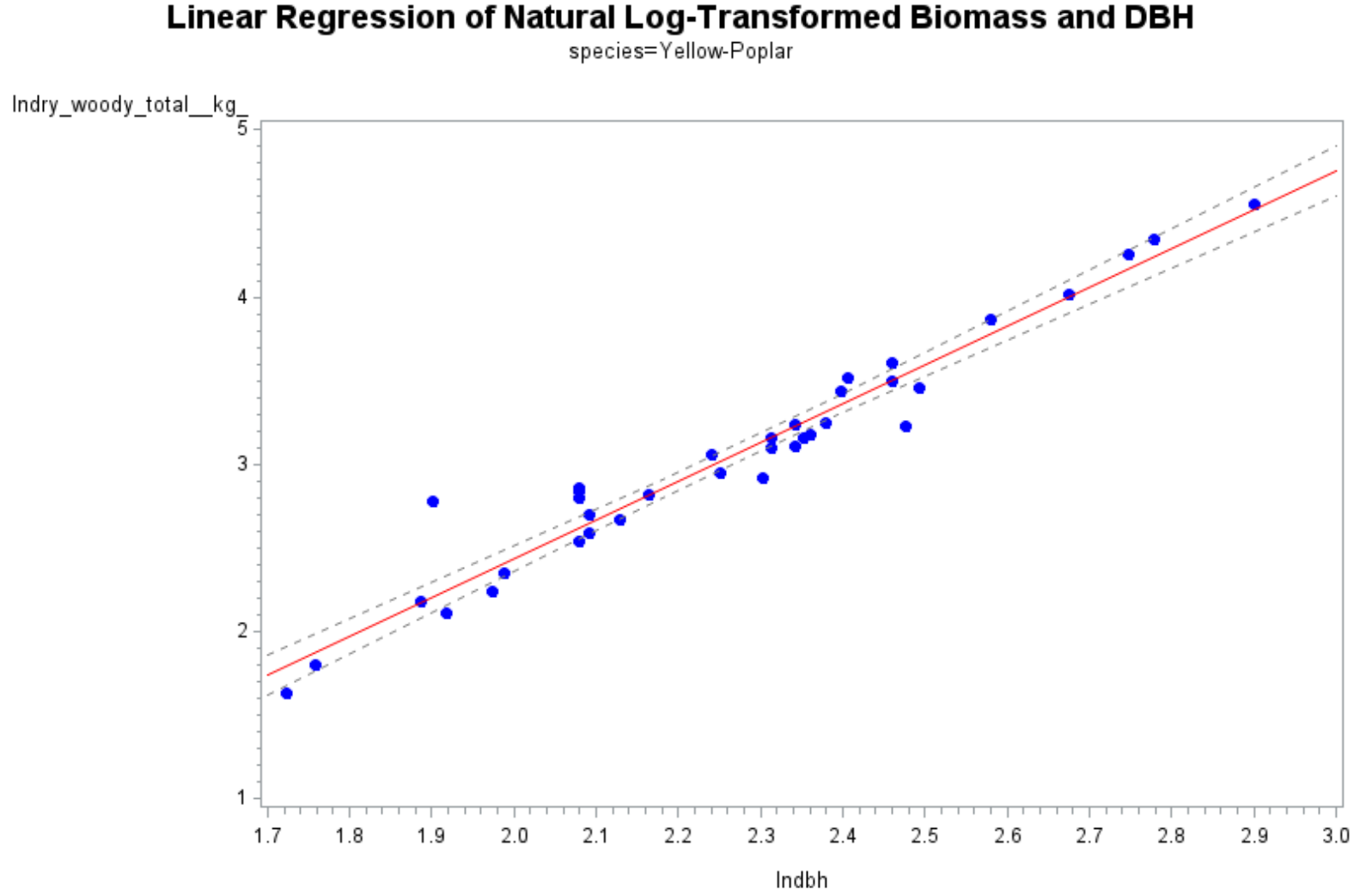


(n= 36, p<.0001, R^2= .936)

Q. *Alba* Aboveground Biomass Estimate

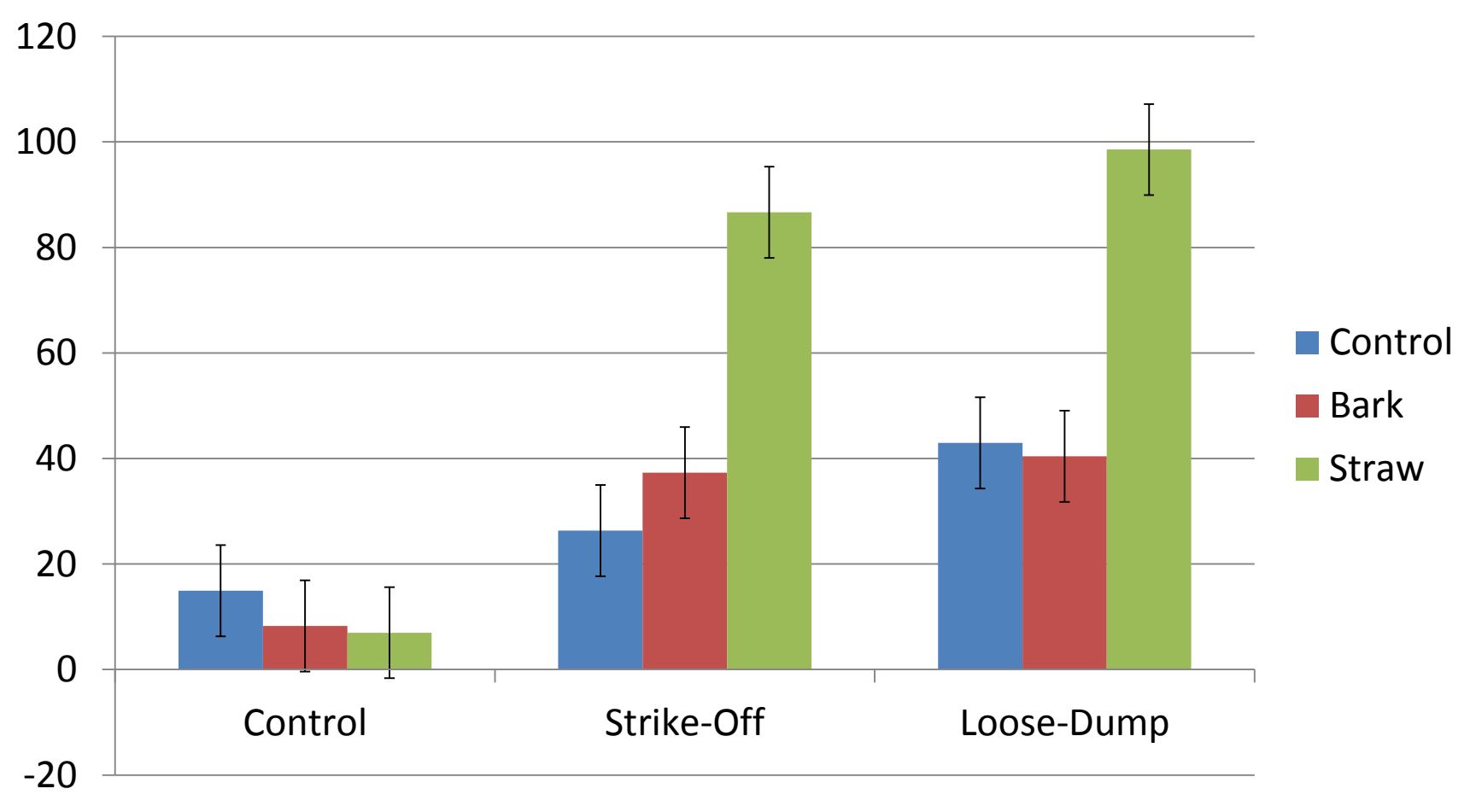


L. Tulipifera Biomass Regression



(n= 36, p<.0001, R^2= .948)

L. Tulipifera Aboveground Biomass Estimate (Mg/ha)



Woody Species Colonization

- We sought to quantify and characterize colonizing plants.
- All woody plants >1 meter in height and with DBH ≥1.0 were included in our survey.
- GLD, DBH, species and condition were all recorded.

Woody Species Colonization

- Differences in stem density and native species proportions were tested using a mixed model.
  - -Fixed effects: Grading, Surface Amendment, Interaction
  - -Random effect: Plot

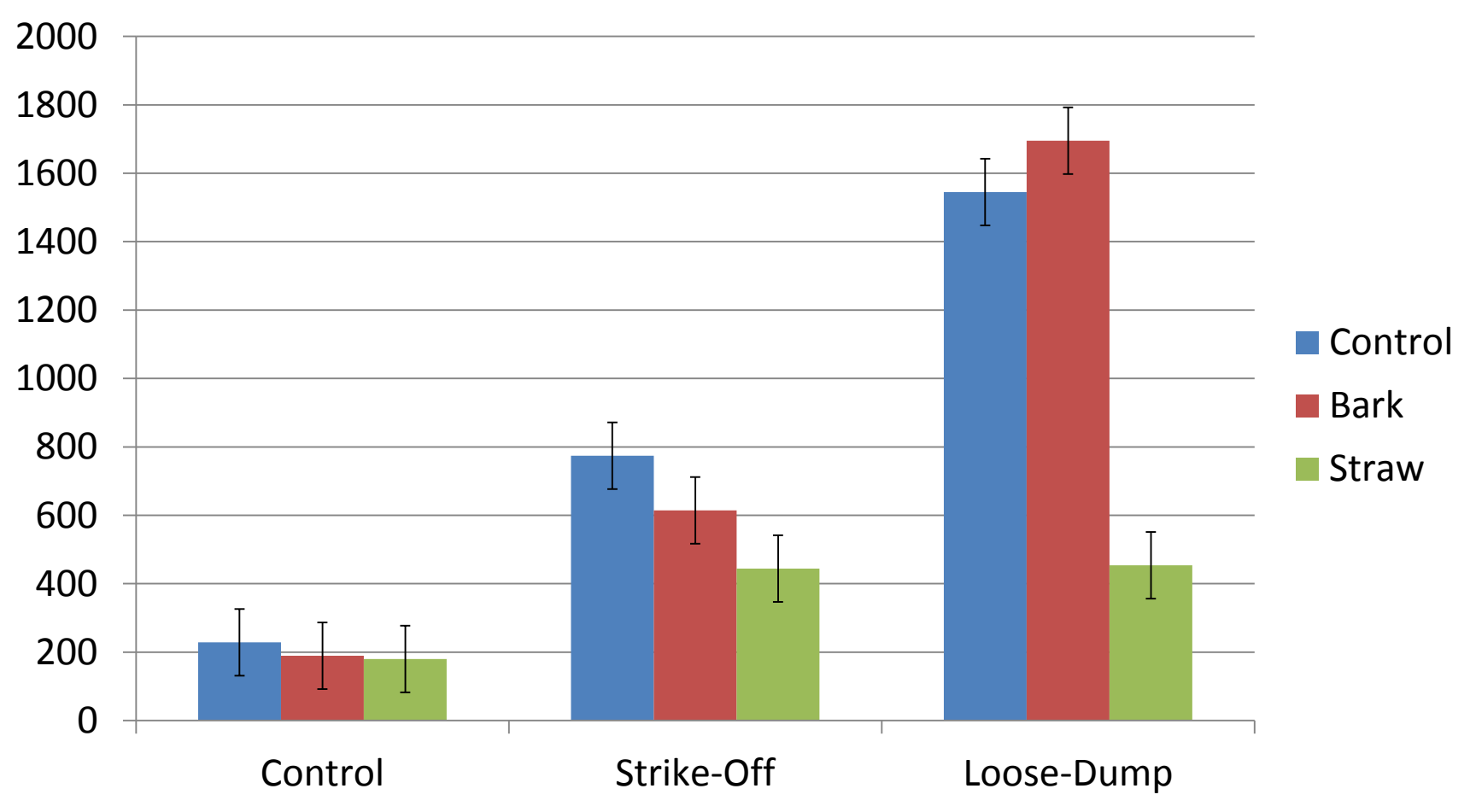
Species Composition

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Sycamore	2543	49.94	2543	49.94
Autumn Olive	663	13.02	3206	62.96
Red Maple	659	12.94	3865	75.90
Tree of Heaven	277	5.44	4142	81.34
Sweet Birch	172	3.38	4314	84.72
Black Cherry	148	2.91	4462	87.63
Sourwood	109	2.14	4571	89.77
Slippery Elm	60	1.18	4631	90.95
Black Locust	57	1.12	4688	92.07
White Ash	46	0.90	4734	92.97
River Birch	45	0.88	4779	93.85
Royal Paulownia	43	0.84	4822	94.70
Yellow-Poplar	41	0.81	4863	95.50

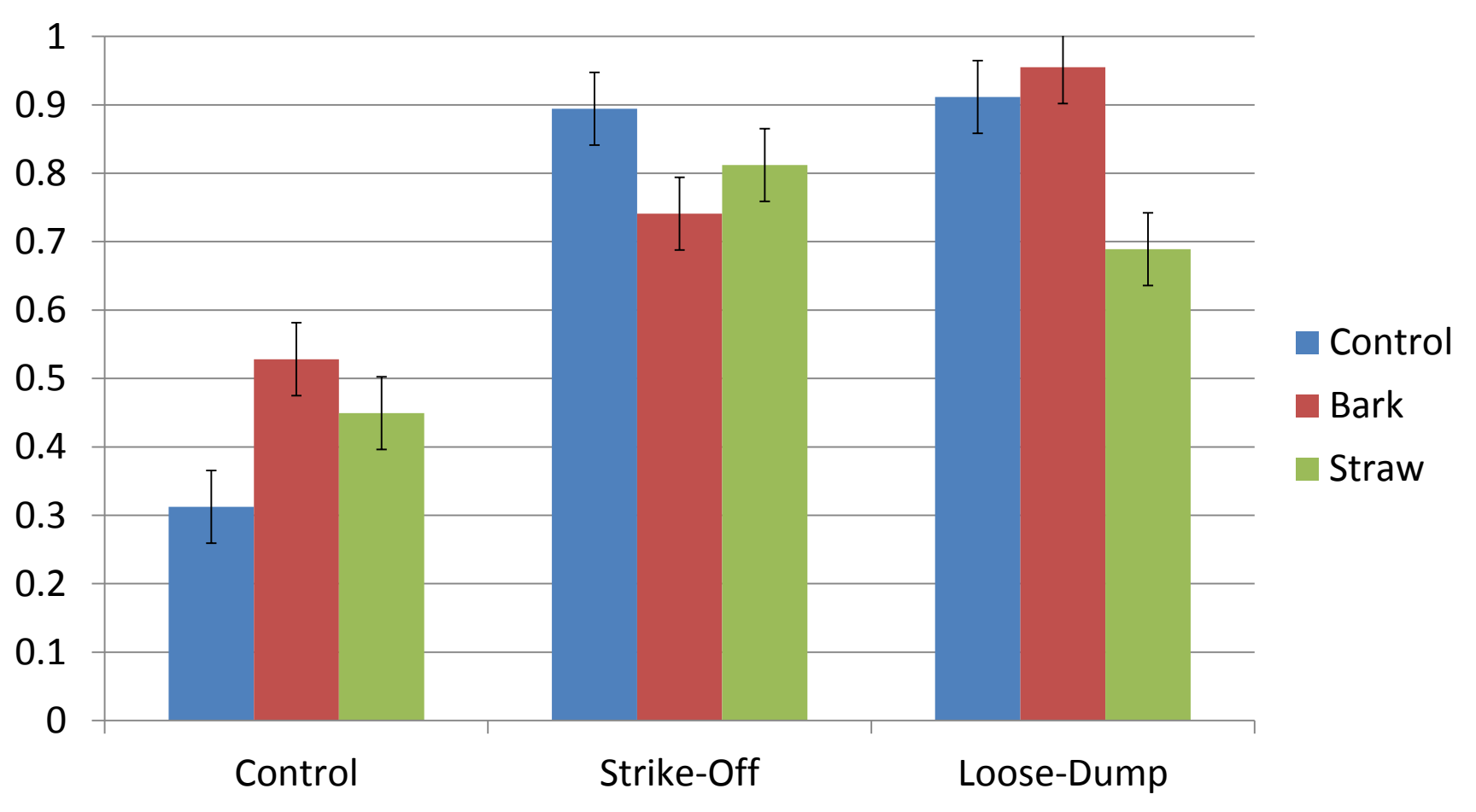
Species Composition

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Redbud	35	0.69	4898	96.19
Black Willow	25	0.49	4923	96.68
Box Elder	24	0.47	4947	97.15
Eastern Red Cedar	23	0.45	4970	97.60
Virginia Pine	23	0.45	4993	98.06
Sassafras	20	0.39	5013	98.45
Sumac	19	0.37	5032	98.82
American Elm	12	0.24	5044	99.06
Flowering Dogwood	9	0.18	5063	99.43
Sugar Maple	5	0.10	5068	99.53
Yellow Birch	5	0.10	5073	99.63
Eastern White Pine	4	0.08	5077	99.71
Winged Elm	3	0.06	5080	99.76
Cottonwood	2	0.04	5082	99.80
Tag Alder	2	0.04	5084	99.84
Callery Pear	1	0.02	5085	99.86
Crabapple	1	0.02	5086	99.88
Eastern Arborvitae	1	0.02	5087	99.90
Elderberry	1	0.02	5088	99.92
Mapleleaf Viburnum	1	0.02	5089	99.94
Mimosa	1	0.02	5090	99.96
Paper Birch	1	0.02	5091	99.98
Red Mulberry	1	0.02	5092	100.00

Stem Density (stems/ha)



Proportion of Native Volunteers



Conclusions

- Both strike-off and loose-dump techniques have allowed for survival and growth of planted trees over a 19-year period.
- Straw/manure mulch and loose-dump preparation result in highest mean biomass for Q. *Alba* and *L. tulipifera*.
- Straw/manure mulch may introduce/ foster growth of competitive herbaceous species.
- Loose-dump plots show significantly more volunteer stems, most of which are desirable native species.

Acknowledgements

- **University of Kentucky Robinson Forest staff**
- **Field technicians**
- **Drs. John Lhotka, Chris Barton, and Jeff Stringer**
- **OSMRE and Dr. Patrick Angel**
- **Kat Sasser**