Coppicing evaluation in the Southeast U.S. to determine harvesting methods for bioenergy production

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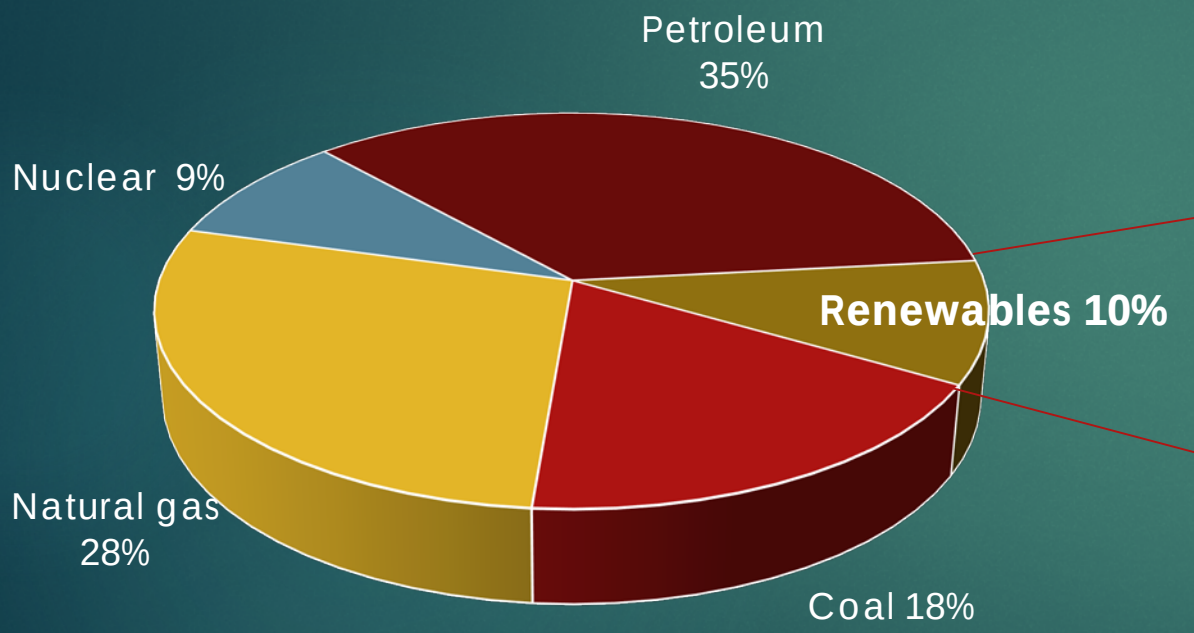
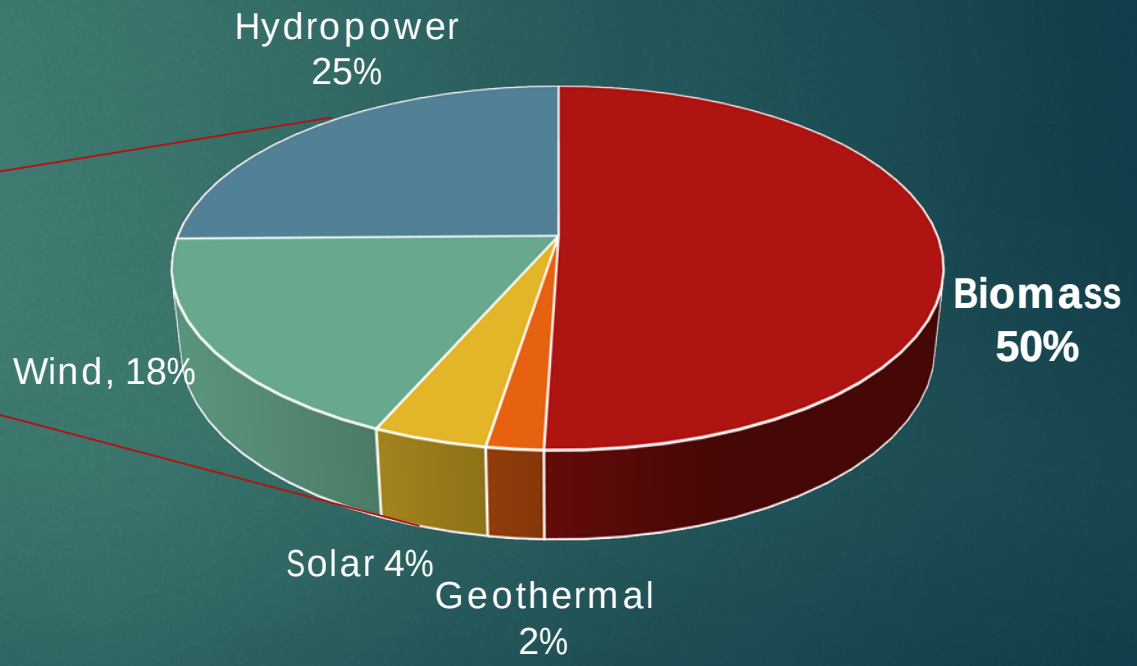
U.S. Energy consumption (2014): 98.3 Quadrillion BTU



U.S. Renewable Consumption: 9.6 Quadrillion BTU



Source: NREL 2014

Short rotation woody crops (SRWC)

- Plantations established to grow lignocellulosic material (wood) for energy production purposes.
- Intensively-managed plantations
- Rotations can be shortened to as little as 3 years due to the ability to coppice. (U.S. Department of Energy, 2011).

Coppice ability:

Challenge: Harvesting multi-stem trees:

- Generally time consuming
- Current absence of specialized machinery.

Objectives:

- The objective of this study is to monitor coppicing development of SRWC in the southeastern United States.
- **Specific goals:**
  - To determine whether stem crowding and growth of SRWC are affected by season of harvesting.
  - To examine how clump dimension could affect subsequent harvesting operations.
  - To examine the potential differences on the final yield of multi-stem trees versus single-stem coppice trees.

Methods:

Experimental sites:

Eucalyptus urograndis
Eucalyptus

Populus deltoides
Cottonwood

Site description:

Eucalyptus (Florida):

- Density: 1820/ha
- Size: 0.8 ha ~2 acres
- Age of trees when harvested: 2 years
- Harvesting dates:

  (Winter plot): December,2013;

  (Summer plot): May, 2014

Site description:

Cottonwood (Arkansas):

- Density: 2600/ha
- Size: 0.8 ha ~2 acres
- Age of trees when harvested: 3 years
- Harvesting dates:

  (Winter plot): March, 2014;

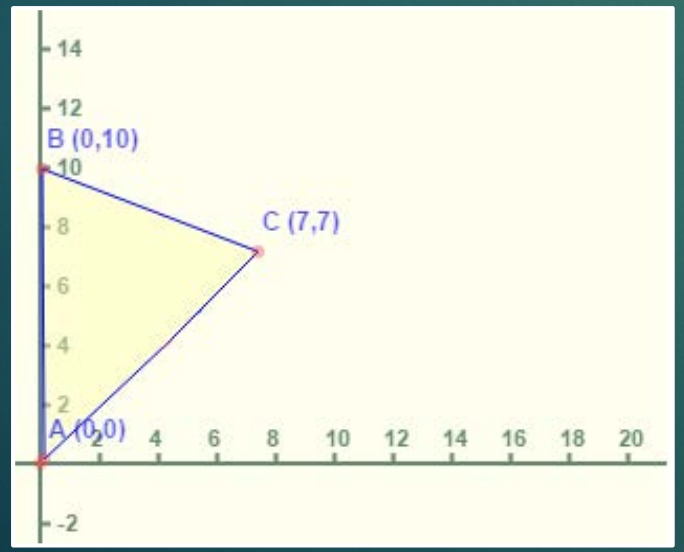
  (Summer plot): June, 2014

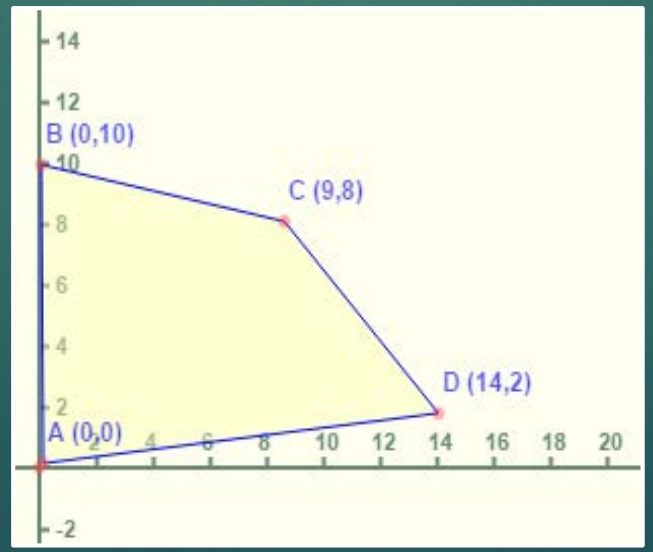
Evaluation schedule: Growing degree days (GDD)

Assessments	Location	Species	GDD ≈ Months (summer plots)	GDD ≈ Months (winter plots)
1st Evaluation	Florida	*E. urograndis*	5460 ≈ 6	2935 ≈ 5
	Arkansas	*P. deltoides*	3760 ≈ 7	4440 ≈ 7
2nd Evaluation	Florida	*E. urograndis*	17,630 ≈ 24	17,190 ≈ 24
	Arkansas	*P. deltoides*	11,073 ≈ 23	11,201 ≈ 22

Clump Dimension Analysis

- Data collected during second evaluations: 2-year-old
- 2-dimensional ruler (i.e. X & Y) for data collection
- Each dot represent one stem growing from the same stump.





Grabbing arm limitation:

Companies consulted:

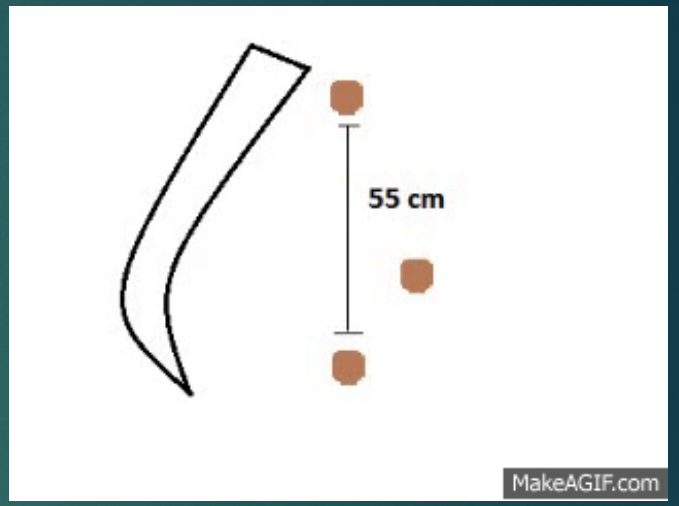
- FECON
- DFM

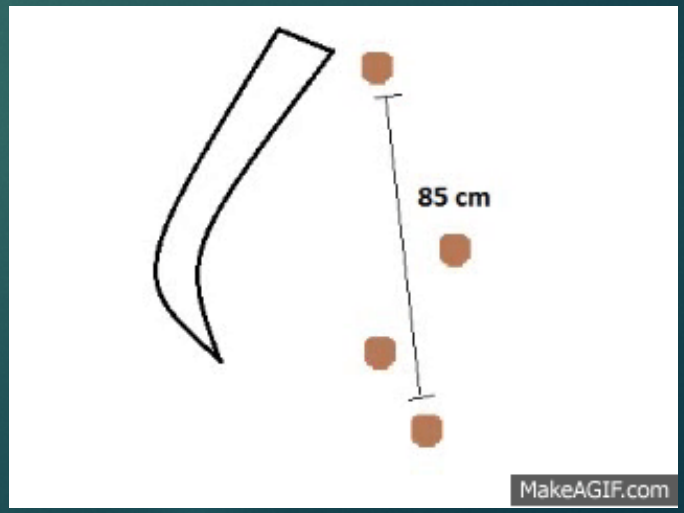
Specifications:

- Length: 76 cm; ~ 30 in

- Height: 1.5 m above ground

Threshold: 76 cm





Data collection:

- Growth parameters: Height and DBH
- Stump survival
- Stem crowding and mortality of stems
- Stump damage and stump diameter

Results:

Stump mortality

Eucalyptus urograndis:

Winter harvest

~0% mortality

Age	Live stumps	Live stems
Harvesting	431	431
6-month-old	395	1673
2-year-old	393	1042

Summer harvest

~0% mortality

Age	Live stumps	Live stems
Harvesting	435	435
6-month-old	331	1515
2-year-old	329	835

Stump mortality

Populus deltoides:

Winter harvest

~0% mortality

Age	Live stumps	Live stems
Harvesting	401	401
6-month-old	386	1047
2-year-old	383	497

Summer harvest

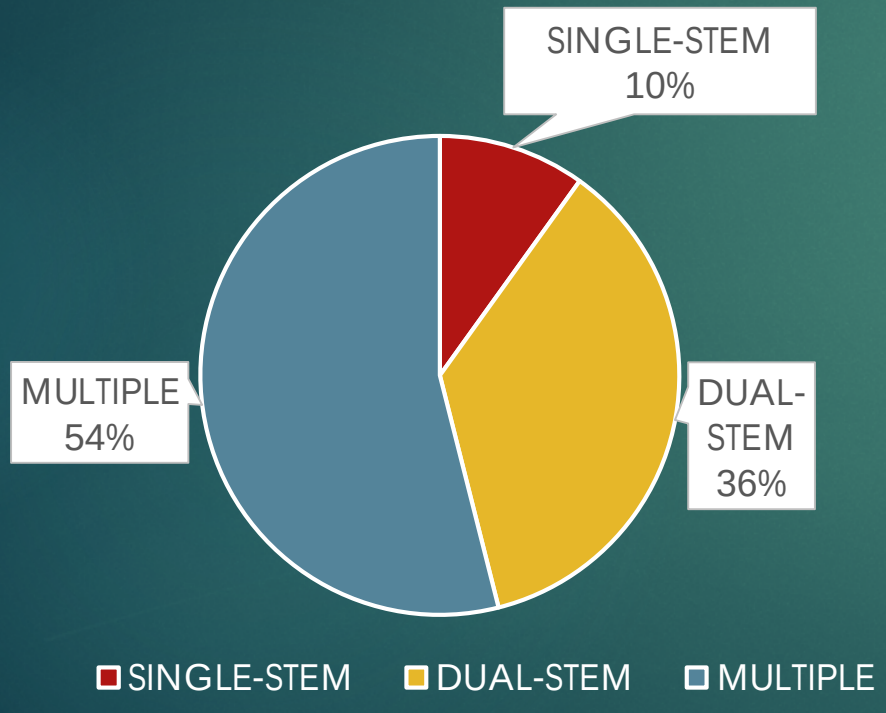
~5% mortality

Age	Live stumps	Live stems
Harvesting	425	425
6-month-old	207	566
2-year-old	196	288

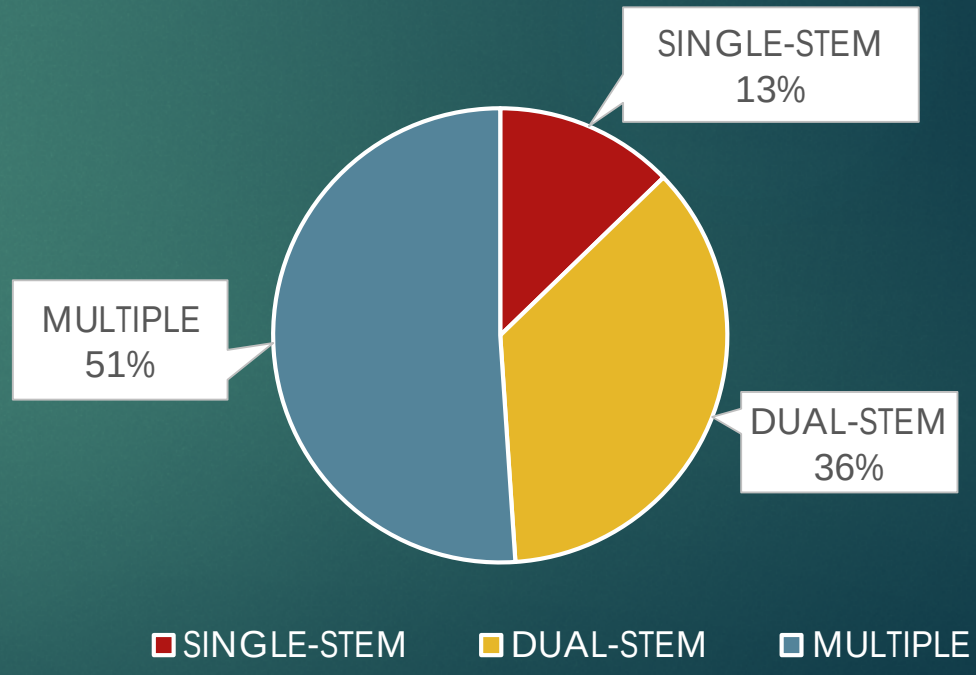
Stem crowding

***Eucalyptus urograndis*:**

Winter harvest plot



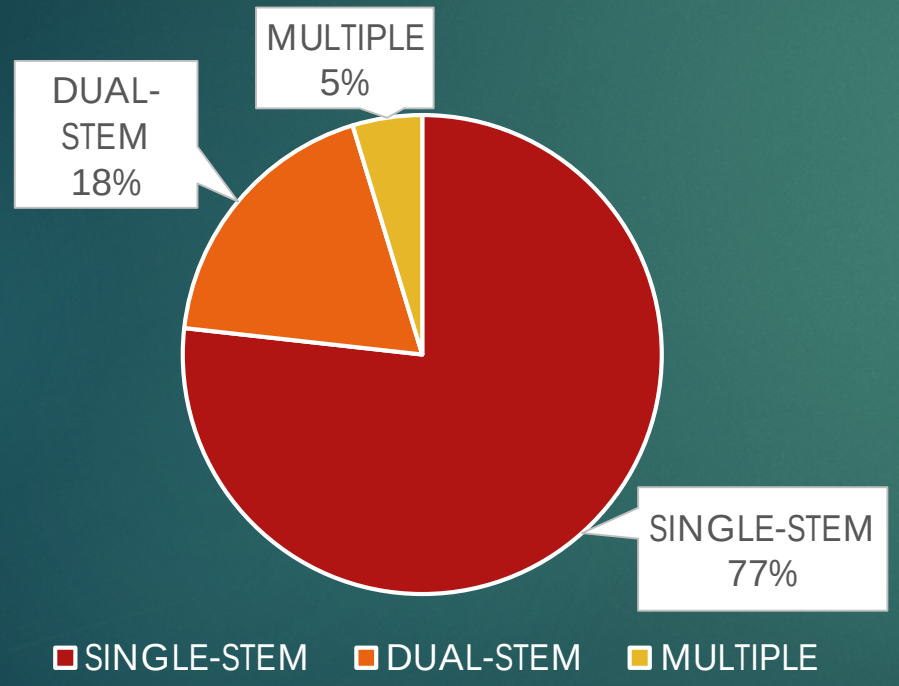
Summer harvest plot



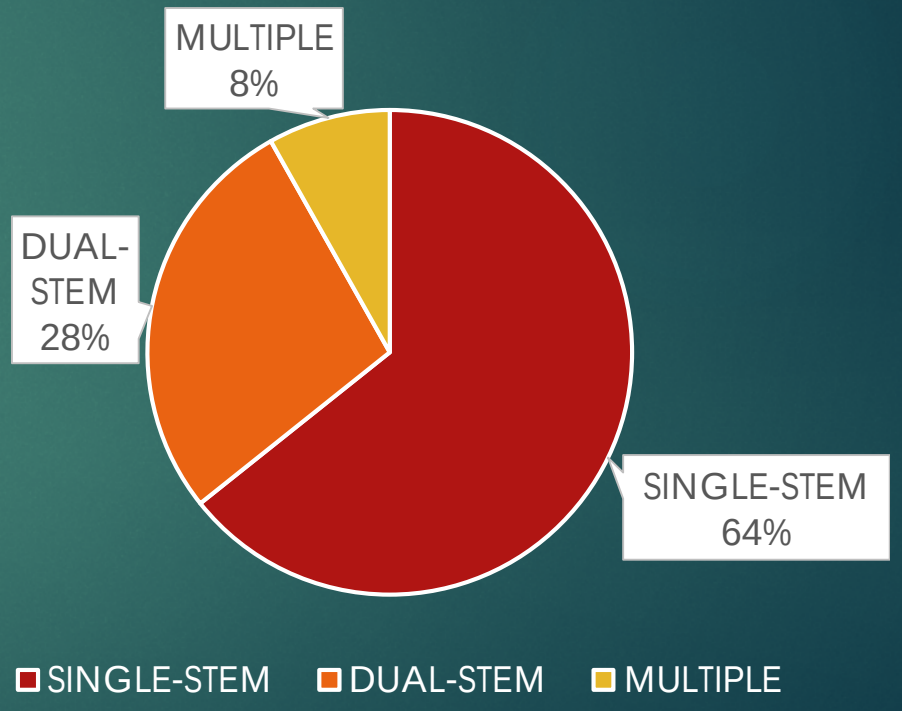
Stem crowding

***Populus deltoides*:**

Winter harvest plot



Summer harvest plot



Clump dimension

***Eucalyptus urograndis*:**

Winter harvest plot

Operation	Distance apart (cm)
Max	135
Median	33
Mean	35
Mode	25

Challenge	
Criteria	Stump counting
> 76 cm	4
Percentage	1%

Summer harvest plot

Operation	Distance apart (cm)
Max	118
Median	33
Mean	34
Mode	25

Challenge	
Criteria	Stump counting
> 76 cm	4
Percentage	1%

Clump dimension

***Populus deltoides*:**

Winter harvest plot

Operation	Distance apart (cm)
Max	69
Median	23
Mean	27
Mode	23

Challenge	
Criteria	Stump counting
> 76 cm	0
Percentage	0%

Summer harvest plot

Operation	Distance apart (cm)
Max	116
Median	30
Mean	32
Mode	30

Challenge	
Criteria	Stump counting
> 76 cm	2
Percentage	1%

Growth Parameters & Yield

DBH and height means of stems by harvesting season at age 2:

Species	Harvesting season	Total nº stems	DBH (cm)	Height (m)	SD. DBH	SD. Height
E. urograndis	Summer	835	5.50 ± 0.16	10.94 ± 0.19	2.40	2.85
	Winter	1042	5.73 ± 0.13	12.7 ± 0.19	2.20	3.16
P. deltoides	Summer	288	2.01 ± 0.15	3.70 ± 0.14	1.27	1.23
	Winter	497	3.03 ± 0.10	5.27 ± 0.12	1.24	1.38

*CI of means generated at a = 0.05

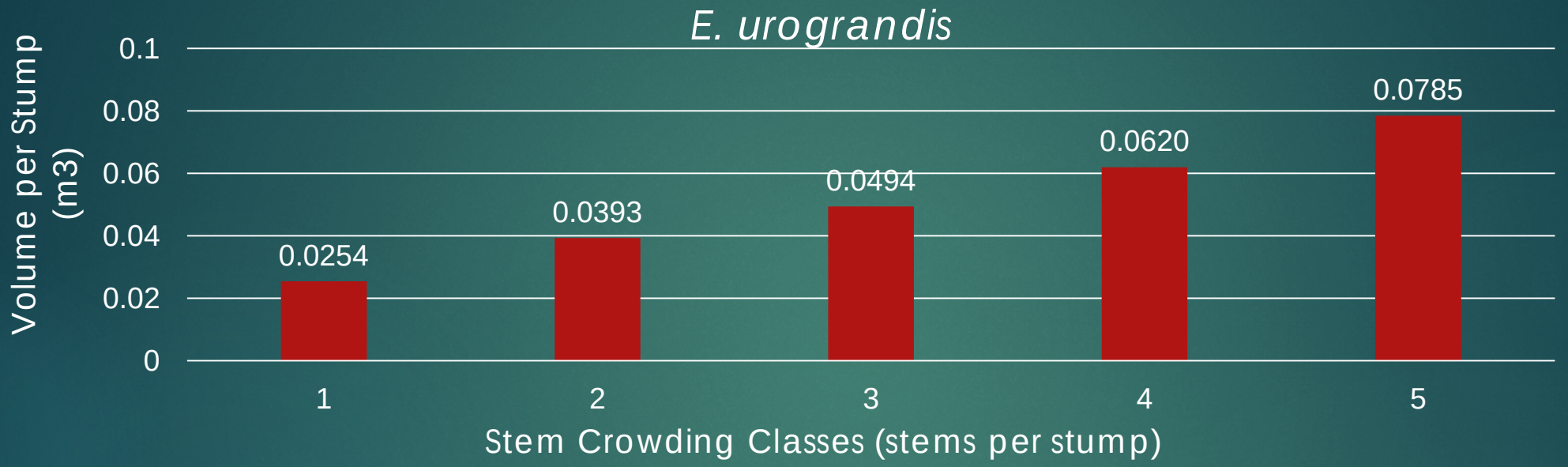
Growth Parameters & Yield

Yield results per species and season of harvesting:

Species	Harvesting season	Final yield (m^3/hectare)	Mean (m^3/stem)	Mean (m^3/stump)
E. urograndis	Summer	32.82	0.0159 ± 0.0009	0.0403 ± 0.0029
	Winter	48.19	0.0187 ± 0.0008	0.0496 ± 0.0026
P. deltoides	Summer	1.68	0.0025 ± 0.0001	0.0036 ± 0.0003
	Winter	4.67	0.0037 ± 0.0001	0.0049 ± 0.0002

*CI of means generated at a = 0.05

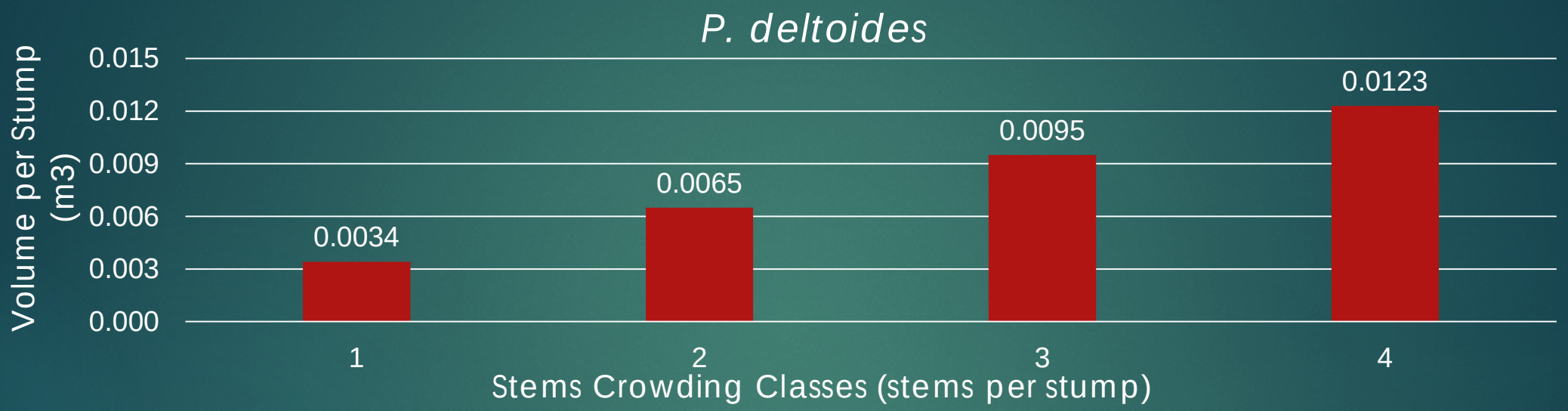
Yield at stump level



Least Squares Means for effect stems_stump Pr > |t| for H0: LSMean(i)=LSMean(j) Dependent Variable: Volume/stump					
i/j	1	2	3	4	5
1		0.0002	<.0001	<.0001	<.0001
2	0.0002		<.0001	<.0001	<.0001
3	<.0001	<.0001		0.0001	0.0005
4	<.0001	<.0001	0.0001		0.1678
5	<.0001	<.0001	0.0005	0.1678	

*The p-values found at the encounter of columns *i* and *j* represent the significance of the means being compared. That is, if p-value > 0.05, the means from the classes in each column being compared are not statistically different.

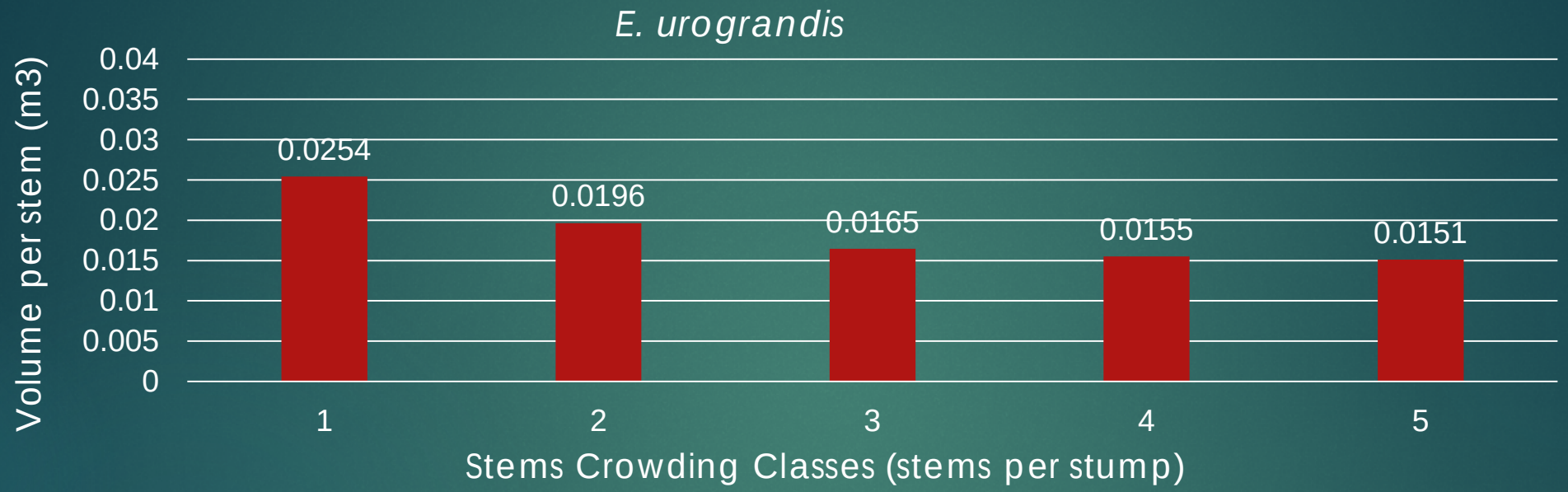
Yield at stump level



Least Squares Means for effect stems_stump Pr > |t| for H0: LSMean(i)=LSMean(j) Dependent Variable: Volume/stump				
i/j	1	2	3	4
1		<.0001	<.0001	<.0001
2	<.0001		<.0001	<.0001
3	<.0001	<.0001		0.0015
4	<.0001	<.0001	0.0015	

*The p-values found at the encounter of columns *i* and *j* represent the significance of the means being compared. That is, if p-value > 0.05, the means from the classes in each column being compared are not statistically different.

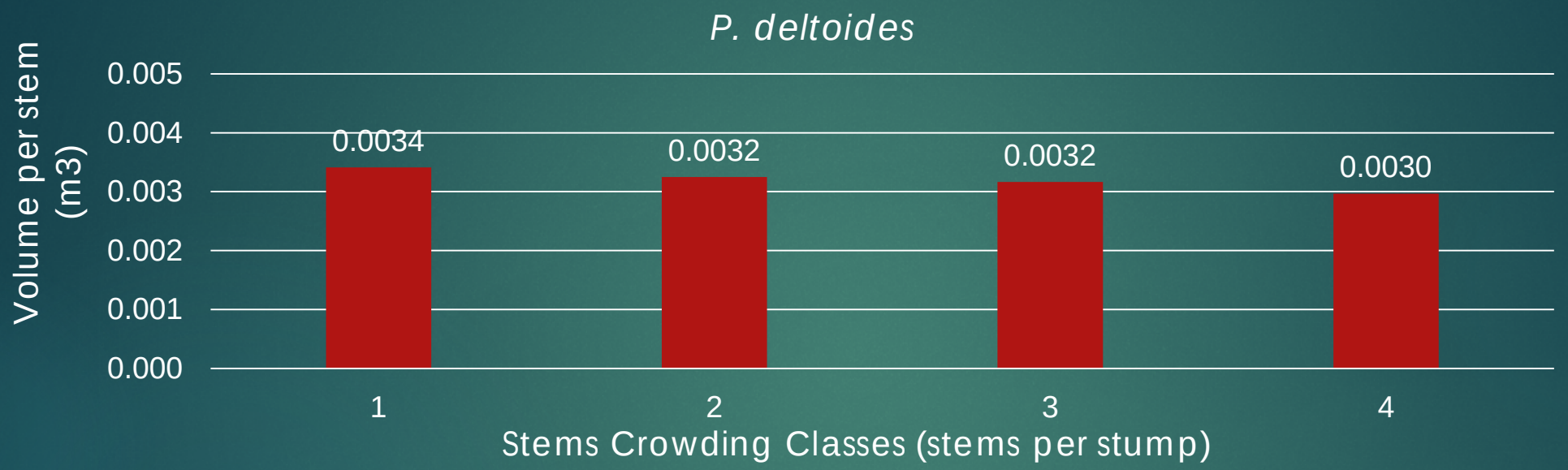
Yield at stem level



Least Squares Means for effect stems_stump Pr > |t| for H0: LSMean(i)=LSMean(j) Dependent Variable: Volume/stem					
i/j	1	2	3	4	5
1		0.0002	<.0001	<.0001	0.0095
2	0.0002		0.0051	0.0058	0.5545
3	<.0001	0.0051		0.9322	0.9918
4	<.0001	0.0058	0.9322		1
5	0.0095	0.5545	0.9918	1	

*The p-values found at the encounter of columns *i* and *j* represent the significance of the means being compared. That is, if p-value > 0.05, the means from the classes in each column being compared are not statistically different.

Yield at stem level



Least Squares Means for effect stems_stump Pr > |t| for H0: LSMean(i)=LSMean(j) Dependent Variable: Volume/stump				
i/j	1	2	3	4
1		0.7595	0.8956	0.8075
2	0.7595		0.9961	0.9464
3	0.8956	0.9961		0.9871
4	0.8075	0.9464	0.9871	

*The p-values found at the encounter of columns *i* and *j* represent the significance of the means being compared. That is, if p-value > 0.05, the means from the classes in each column being compared are not statistically different.

Conclusions:

- Once successfully coppiced, stump mortality is minimal.
- Higher above ground volume in winter plots of both species.
- Season of harvest did not affect stem crowding nor clump dimension.

Conclusions:

- With both species and seasons of harvest we noted that harvesting multi-stem coppiced trees with current technology is feasible.

- Yield results showed that the accumulation of stems per stump will increase the final volume, without necessarily decreasing the size of the stems.

Acknowledgments:

Questions:

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