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Project Report No. 69, Observed Growth and Yield of Loblolly and Slash Pine Plantations in East Texas

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OBSERVED GROWTH AND YIELD OF LOBLOLLY AND SLASH PINE PLANTATIONS IN EAST TEXAS

BY

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REPORT 69

FROM

THE

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ARTHUR TEMPLE COLLEGE OF FORESTRY

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INTRODUCTION

Forestland in East Texas is an estimated 12.1 million acres, with approximately 2.9 million acres (24%) classified as pine plantations on private land. Because pine plantations are typically managed for timber production, information regarding tree growth is needed to make informed management decisions. An understanding of how growth factors such as tree volume, diameter, height and basal area are affected by site index, trees per acre and age in East Texas enables plantation managers to make the management decisions necessary to maximize timber production.

The purpose of this paper is to report observed growth in unthinned loblolly (*Pinus taeda*) and slash (*Pinus elliottii*) pine plantations in East Texas. The following annual growth rates are reported by various age, site index, and trees per acre classes:

- Quadratic mean diameter (inches)
- Average stand height (feet)
- Basal area per acre (square feet)
- Cubic foot volume per acre (wood and bark, ob)

The yield (cubic foot volume per acre) will also be reported by various site index, trees per acre, and age classes.

PLANTATION MEASUREMENTS

Data for this study were collected from permanent research plots maintained by the East Texas Pine Plantation Research Project (ETPPRP). The ETPPRP is a long-term comprehensive research program that has investigated the factors affecting the management of loblolly and slash pine plantations in East Texas since 1982[1]. At this time, 282 plots (196 loblolly plots and 86 slash pine plots) are available for analysis. However, only 49 plots remain intact for remeasurement (40 plots in loblolly pine and 9 in slash pine plantations). Each plot is located in a separate plantation and consists of two subplots. Each subplot is 100 feet square (10,000 ft^2 or 0.23 acres). One subplot is utilized for model development and the other is utilized for model evaluation. A 30-foot wide buffer zone surrounds each plot, so each plot occupies 51,200 ft^2 or 1.18 acres. The plots are measured on a three-year cycle, with 1/3 of the plots being measured each year. As of summer 2013, all loblolly plots have completed eleven measurement cycles and all slash pine plots have completed eleven measurement cycles.

On each plot, all planted pine trees within each subplot are measured for: dbh, total height, height to live crown, and crown class. The presence of fusiform rust and visible

[1] The current support of the following organizations is much appreciated: Campbell Global, Rayonier, RMS, Hancock Group, Arthur Temple College of Forestry and Agriculture.

tree quality is recorded in addition to the site preparation method, landform, slope, geographic location (latitude and longitude from a GPS), and soil characteristics for each subplot. Beginning with the second measurement cycle (1985 – 1987), information about non-planted vegetation has been collected for each subplot.

From these remeasured plots, 2694 loblolly pine and 1143 slash pine observations were available for analysis. Each observation provided the following variables:

- Plantation age at the time of measurement (AGE, years)
- Average total height of the dominant and codominant trees on the plot (HT, feet)
- Site Index (SI, feet, base age 25 years)
- Trees per acre (TPA)
- Basal area per acre (BA, square feet)
- Cubic foot volume wood and bark per acre (CFVWB, total tree).

Each of these variables was summarized into combinations of the following classes:

- Site Index – seven classes: 50, 60, 70, 80, 90, and 100 feet
- Trees per Acre – six classes: 300, 400, 500, 600, 700, 800
- Age – eight classes: 5, 10, 15, 20, 25, 30, 35, 40 years

ANNUAL GROWTH RATES

The following mean annual growth rates (MAI) were calculated for each observation and species:

- $MAI_{QMD} = \frac{\text{Observed QMD}}{\text{AGE}}$
- $MAI_{HT} = \frac{\text{Observed HT}}{\text{AGE}}$
- $MAI_{BA} = \frac{\text{Observed BA}}{\text{AGE}}$
- $MAI_{CFVWB} = \frac{\text{Observed CFVWB}}{\text{AGE}}$

The following periodic annual growth rates (PAI) were calculated for each observation and species:

- $PAI_{QMD} = \frac{\text{Observed QMD}}{3}$
- $PAI_{HT} = \frac{\text{Observed HT}}{3}$

- $PAI_{BA} = \frac{\text{Observed BA}}{3}$
- $PAI_{CFVWB} = \frac{\text{Observed CFVWB}}{3}$

Note that the period length = 3 years.

TABULATED RESULTS

Annual growth rates (MAI and PAI) along with yield were tabulated by the various site index, trees per acre, and age classes for both loblolly and slash pine:

- Overall MAI:
  - Table 1 – Loblolly
  - Table 10 – Slash

- By Site Index Classes:
  - MAI: Table 2 – Loblolly
  - MAI: Table 11 – Slash
  - PAI: Table 3 – Loblolly
  - PAI: Table 12 – Slash

- By Age Classes:
  - MAI: Table 2 – Loblolly
  - MAI: Table 11 – Slash
  - PAI: Table 3 – Loblolly
  - PAI: Table 12 – Slash

- By Trees Per Acre Classes:
  - MAI: Table 2 – Loblolly
  - MAI: Table 11 – Slash
  - PAI: Table 3 – Loblolly
  - PAI: Table 12 – Slash

- By Age and Site Index Classes:
  - MAI: Table 4 – Loblolly
  - MAI: Table 13 – Slash
  - PAI: Table 5 – Loblolly
  - PAI: Table 14 – Slash

- By Site Index and Trees per Acre Classes:
  - MAI: Table 6 – Loblolly
  - MAI: Table 15 – Slash
  - PAI: Table 7 – Loblolly

    - PAI: Table 16 – Slash

- By Age and Trees per Acre Classes:
    - MAI: Table 8 – Loblolly
    - MAI: Table 17 – Slash
    - PAI: Table 9 – Loblolly
    - PAI: Table 18 – Slash

Caution should also be exercised when using values for which sample sizes are small.

GRAPHICAL RESULTS

Annual growth rates (MAI) along with yield were plotted by the various site index, trees per acre, and age classes for both loblolly and slash pine:

- Yield by Age and Site Index Classes:
    - Figure 1 – Loblolly
    - Figure 5 – Slash

- MAI by Age and Site Index Classes:
    - Figure 2 – Loblolly
    - Figure 6 – Slash

- MAI by Site Index and Trees per Acre Classes:
    - Figure 3 – Loblolly
    - Figure 7 – Slash

- MAI by Age and Trees per Acre Classes:
    - Figure 4 – Loblolly
    - Figure 8 – Slash

Table 1. Overall mean annual (MAI) quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot growth for loblolly pine plantations in East Texas.

Statistic	Average Annual Growth	
Diameter (SE)	0.41	(0.002)
Height (SE)	2.70	(0.014)
Basal area (SE)	5.60	(0.053)
Cubic foot volume wood and bark (SE)	114.10	(1.370)

Cubic foot volume yield (SE) = 2185.66 ft^3 (34.16)
(SE) = standard error
Height = average height of dominant and codominant trees
Basal area = square feet per acre
Cubic foot volume wood and bark = total stem cubic feet wood and bark per acre
Average growth and yield values based on 2694 observations

Table 2. Mean yield and mean annual quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth (MAI) by site index (25-year index age), age, and trees per acre classes for loblolly pine plantations in East Texas.

			Average Annual Growth (MAI)				
		Yield (feet³/acre wood and bark)	Quadratic Mean Diameter (inches)	Height (feet)	Basal area (feet²/acre)	Cubic foot volume (per acre, wood and bark)	Observations
Site Index Class							
(feet)	50	349.4	0.3	1.6	1.9	22.7	406
	60	1534.8	0.4	2.5	5.1	86.0	573
	70	2532.8	0.4	2.8	6.1	127.3	1029
	80	3450.6	0.4	3.2	7.3	172.5	524
	90	2998.6	0.5	3.6	7.6	168.4	138
	100	1612.9	0.5	3.8	6.1	122.3	24
Age Class							
(years)	5	102.8	0.4	2.1	2.2	16.7	522
	10	974.4	0.5	3.1	6.7	93.2	526
	15	2108.5	0.5	3.0	7.2	140.1	569
	20	3192.1	0.4	2.8	6.6	160.2	458
	25	3982.0	0.4	2.6	5.9	161.1	313
	30	4440.9	0.3	2.4	4.9	150.1	194
	35	4951.9	0.3	2.2	4.4	144.6	86
	40	4863.6	0.3	2.0	3.6	122.3	26
Trees per Acre							
Class	300	2643.7	0.4	2.6	4.6	112.3	824
	400	2533.1	0.4	2.7	5.9	127.3	706
	500	1964.7	0.4	2.7	6.1	115.9	595
	600	1430.9	0.4	2.7	6.1	101.2	344
	700	1221.4	0.4	2.7	6.2	94.5	158
	800	1002.1	0.4	2.6	6.5	91.4	67

Table 3. Mean periodic (3 year) quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth (PAI) by site index (25-year index age), age, and trees per acre classes for loblolly pine plantations in East Texas.

		Quadratic Mean Diameter (inches)	Height (feet)	Basal area (feet^2/acre)	Cubic foot volume (per acre, wood and bark)	Observations
Site Index Class						
(feet)	50	0.9	5.4	8.4	116.5	406
	60	1.9	12.6	27.1	511.6	573
	70	2.3	16.0	36.4	844.3	1029
	80	2.6	18.9	43.1	1150.2	524
	90	2.4	18.2	37.1	999.5	138
	100	1.5	11.5	22.4	537.6	24
Age Class						
(years)	5	0.6	3.6	4.3	34.3	522
	10	1.7	10.4	22.9	324.8	526
	15	2.2	14.9	35.8	702.8	569
	20	2.6	18.8	43.6	1064.0	458
	25	2.9	21.3	48.1	1327.3	313
	30	3.2	23.9	47.9	1480.3	194
	35	3.3	25.5	50.6	1650.6	86
	40	3.4	26.8	47.7	1621.2	26
Trees per Acre						
Class	300	2.7	17.8	32.4	881.2	824
	400	2.2	15.3	35.4	844.4	706
	500	1.8	12.8	31.2	654.9	595
	600	1.5	10.5	26.2	477.0	344
	700	1.3	9.2	24.1	407.1	158
	800	1.0	7.4	21.3	334.0	67

Table 4. Mean yield and mean annual quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth (MAI) by age and site index (25-year index age) classes for loblolly pine plantations in East Texas.

Statistic	Site Index (feet)	Age (years) 5	10	15	20	25	30	35	40
Quadratic Mean Diameter (inches)	50	0.2	0.4	0.4	0.3	0.3	0.2	0.2	-
	60	0.4	0.5	0.4	0.4	0.3	0.3	0.3	0.2
	70	0.4	0.5	0.5	0.4	0.3	0.3	0.3	0.2
	80	0.5	0.6	0.5	0.4	0.4	0.3	0.3	0.3
	90	0.6	0.6	0.5	0.4	0.4	0.4	0.4	0.4
	100	0.5	0.6	0.6	0.5	-	-	-	-
Height (feet)	50	1.2	2.2	2.1	2.0	1.7	1.4	1.6	-
	60	2.4	2.8	2.7	2.5	2.3	2.1	1.9	1.7
	70	2.6	3.2	3.0	2.8	2.6	2.4	2.1	1.9
	80	3.1	3.7	3.5	3.2	2.9	2.7	2.4	2.2
	90	3.7	4.0	3.9	3.5	3.2	2.9	2.7	2.6
	100	3.3	4.4	4.4	4.3	-	-	-	-
Basal Area ($feet^2$/acre)	50	0.5	3.2	3.5	3.8	3.5	2.8	3.7	-
	60	2.2	5.7	6.3	5.7	5.0	4.0	3.6	3.2
	70	3.0	7.2	7.6	6.7	5.9	4.9	4.4	3.7
	80	4.0	9.0	8.8	7.8	6.7	5.5	4.8	3.7
	90	6.4	10.0	8.9	7.6	6.0	5.2	4.1	2.6
	100	4.1	9.7	9.2	6.8	-	-	-	-
Cubic Foot Volume (per acre, wood and bark)	50	2.1	32.2	47.1	64.3	63.9	51.8	80.8	-
	60	14.6	68.2	106.9	119.4	117.4	104.9	102.6	94.5
	70	22.7	98.6	147.9	159.6	159.7	144.7	135.8	120.2
	80	33.5	141.5	192.9	213.0	208.1	184.6	171.1	133.8
	90	61.1	174.3	223.4	227.1	203.3	195.5	161.3	113.0
	100	40.8	206.2	245.0	240.2	-	-	-	-
Yield ($feet^3$/acre)	50	11.8	334.3	707.6	1237.0	1584.0	1604.8	2667.3	-
	60	94.9	717.9	1601.9	2394.3	2891.1	3129.3	3665.9	3779.1
	70	144.8	1026.0	2235.0	3182.4	3952.9	4259.6	4645.6	4834.4
	80	210.9	1478.7	2893.7	4235.8	5126.9	5463.7	5850.5	5248.3
	90	372.4	1825.3	3401.1	4547.0	5099.9	5800.3	5446.1	4293.1
	100	262.8	2360.8	3530.0	4564.2	-	-	-	-
Observations	50	216	84	57	26	15	6	2	-
	60	91	136	151	96	56	34	8	1
	70	125	175	218	217	153	83	42	16
	80	47	95	112	102	75	59	27	7
	90	29	34	25	15	14	12	7	2
	100	14	2	6	2	-	-	-	-

Table 5. Mean periodic (3 year) quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth (PAI) by age and site index (25-year index age) classes for loblolly pine plantations in East Texas.

Statistic	Site Index (feet)	Age (years) 5	10	15	20	25	30	35	40
Quadratic Mean Diameter (inches)	50	0.3	1.2	1.7	2.1	2.2	2.0	2.4	-
	60	0.7	1.6	2.1	2.4	2.7	3.0	3.3	3.1
	70	0.8	1.8	2.3	2.6	2.9	3.2	3.2	3.2
	80	0.9	1.9	2.4	2.8	3.1	3.4	3.5	3.5
	90	1.2	2.0	2.6	2.9	3.3	3.8	4.0	4.6
	100	0.7	2.5	2.6	3.0	-	-	-	-
Height (feet)	50	1.6	7.1	10.1	12.8	14.4	14.8	17.3	-
	60	4.5	9.3	13.3	16.6	18.6	20.7	22.5	23.3
	70	4.8	10.8	15.3	18.8	21.2	23.3	24.1	25.6
	80	5.5	12.6	17.3	21.4	24.2	26.5	27.9	28.1
	90	6.9	13.8	19.6	23.4	26.8	29.2	30.7	32.9
	100	4.3	16.9	21.2	27.5	-	-	-	-
Basal Area ($feet^2$/acre)	50	0.8	10.9	17.5	24.5	29.3	28.6	40.9	-
	60	4.7	19.7	31.4	37.8	40.9	39.7	42.9	42.7
	70	6.2	24.7	38.3	44.3	49.0	47.9	50.3	49.3
	80	8.0	30.7	43.6	51.5	55.3	53.7	55.0	48.7
	90	12.6	34.2	45.0	50.8	49.8	51.8	46.2	33.4
	100	8.1	37.0	44.0	43.0	-	-	-	-
Cubic Foot Volume (per acre, wood and bark)	50	3.9	111.4	235.9	412.3	528.0	534.9	889.1	-
	60	31.6	239.3	534.0	798.1	963.7	1043.1	1222.0	1259.7
	70	48.3	342.0	745.0	1060.8	1317.6	1419.9	1548.5	1611.5
	80	70.3	492.9	964.6	1411.9	1709.0	1821.2	1950.2	1749.4
	90	124.1	608.4	1133.7	1515.7	1700.0	1933.4	1815.4	1431.0
	100	87.6	786.9	1176.7	1521.4	-	-	-	-
Observations	50	216	84	57	26	15	6	2	-
	60	91	136	151	96	56	34	8	1
	70	125	175	218	217	153	83	42	16
	80	47	95	112	102	75	59	27	7
	90	29	34	25	15	14	12	7	2
	100	14	2	6	2	-	-	-	-

Table 6. Mean yield and mean annual quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth (MAI) by site index (25-year index age) and trees per acre classes for loblolly pine plantations in East Texas.

		Site Index (feet)					
Statistic	Trees per Acre	50	60	70	80	90	100
Quadratic Mean Diameter (inches)	300	0.3	0.4	0.4	0.4	0.4	0.6
	400	0.3	0.4	0.4	0.4	0.5	0.6
	500	0.3	0.4	0.4	0.5	0.5	0.5
	600	0.2	0.4	0.4	0.5	0.5	0.4
	700	0.2	0.4	0.4	0.5	0.5	0.4
	800	0.3	0.3	0.4	0.4	0.6	0.6
Height (feet)	300	1.9	2.5	2.7	3.0	3.2	4.5
	400	1.6	2.5	2.8	3.2	3.8	4.1
	500	1.5	2.5	2.9	3.3	3.9	3.9
	600	1.4	2.6	2.9	3.4	3.8	2.0
	700	1.2	2.6	3.0	3.4	3.8	2.9
	800	1.0	2.4	2.9	3.4	3.9	3.6
Basal Area (feet^2/acre)	300	2.0	4.0	4.9	5.9	5.5	7.9
	400	2.0	5.3	6.3	7.5	8.5	8.0
	500	2.1	5.5	6.8	8.1	8.5	5.4
	600	1.6	6.0	7.0	8.3	7.8	0.5
	700	0.8	6.1	7.2	8.9	9.4	3.0
	800	2.4	5.5	7.3	8.7	11.8	8.0
Cubic Foot Volume (per acre, wood and bark)	300	26.4	77.5	118.4	171.9	176.4	221.6
	400	24.3	90.1	139.7	189.7	200.7	154.0
	500	24.8	88.5	132.5	177.3	165.1	119.0
	600	15.9	89.9	122.3	147.3	118.0	0.0
	700	4.5	92.1	106.4	153.1	139.3	26.6
	800	24.0	80.0	103.6	137.9	151.2	87.0
Yield (feet^3/acre)	300	420.1	1624.8	2785.2	4331.9	4543.4	3421.0
	400	383.7	1661.9	2957.5	3850.4	3277.3	1810.2
	500	433.4	1478.2	2347.4	2993.5	2160.3	1738.3
	600	216.7	1340.4	1881.3	1940.1	1270.7	0.0
	700	36.4	1399.8	1387.0	1966.0	1276.5	173.5
	800	165.0	1184.2	1259.8	1552.4	1274.9	591.6
Observations	300	121	166	306	181	45	5
	400	93	141	300	133	33	6
	500	89	133	237	103	28	5
	600	60	81	111	69	22	1
	700	26	40	56	26	5	5
	800	17	12	19	12	5	2

Table 7. Mean periodic (3 year) quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth (PAI) by site index (25-year index age) and trees per acre classes for loblolly pine plantations in East Texas.

		Site Index (feet)					
Statistic	Trees per Acre	50	60	70	80	90	100
Quadratic Mean Diameter	300	1.3	2.4	2.9	3.2	3.4	2.9
(inches)	400	0.9	2.0	2.4	2.6	2.5	1.8
	500	0.8	1.7	2.0	2.2	1.9	1.3
	600	0.6	1.6	1.7	1.8	1.5	0.1
	700	0.3	1.5	1.5	1.7	1.5	0.5
	800	0.3	1.2	1.3	1.4	1.5	1.0
Height	300	7.4	14.9	18.9	23.3	25.7	22.6
(feet)	400	5.6	12.8	17.1	19.8	19.0	12.7
	500	5.4	11.6	14.5	16.6	14.2	11.3
	600	3.7	10.9	12.3	12.9	10.6	0.7
	700	1.7	10.7	10.5	12.8	10.6	3.4
	800	1.7	8.9	9.3	10.2	9.8	6.4
Basal Area	300	9.7	25.2	35.4	46.4	43.8	38.9
($feet^2$/acre)	400	9.1	28.7	40.9	47.1	42.1	28.5
	500	10.1	27.5	36.5	42.1	33.4	21.9
	600	6.3	27.2	32.6	33.2	24.4	0.2
	700	1.6	28.3	27.7	35.3	28.1	5.6
	800	4.5	24.1	26.8	30.7	30.3	17.1
Cubic Foot Volume	300	140.0	541.6	928.4	1444.0	1514.5	1140.3
(per acre, wood and bark)	400	127.9	554.0	985.8	1283.5	1092.4	603.4
	500	144.5	492.7	782.5	997.8	720.1	579.4
	600	72.2	446.8	627.1	646.7	423.6	0.0
	700	12.1	466.6	462.3	655.3	425.5	57.8
	800	55.0	394.7	419.9	517.5	425.0	197.2
Observations	300	121	166	306	181	45	5
	400	93	141	300	133	33	6
	500	89	133	237	103	28	5
	600	60	81	111	69	22	1
	700	26	40	56	26	5	5
	800	17	12	19	12	5	2

Table 8. Mean yield and mean annual quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth (MAI) by age and trees per acre classes for loblolly pine plantations in East Texas.

Statistic	Trees per Acre	Age (years) 5	10	15	20	25	30	35	40
Quadratic Mean Diameter (inches)	300	0.4	0.5	0.5	0.4	0.4	0.3	0.3	0.3
	400	0.4	0.5	0.5	0.4	0.3	0.3	0.3	0.2
	500	0.3	0.5	0.4	0.4	0.3	0.2	0.2	-
	600	0.3	0.5	0.4	0.3	0.3	-	-	-
	700	0.3	0.5	0.4	0.3	0.3	-	-	-
	800	0.4	0.5	0.4	0.3	-	-	-	-
Height (feet)	300	2.2	2.8	2.9	2.8	2.7	2.5	2.3	2.0
	400	2.1	3.0	3.0	2.9	2.6	2.3	2.1	2.0
	500	2.1	3.1	3.0	2.8	2.4	1.9	1.5	-
	600	2.2	3.2	2.9	2.8	2.3	-	-	-
	700	2.2	3.2	3.0	2.6	2.4	-	-	-
	800	2.1	3.4	3.0	2.6	-	-	-	-
Basal Area ($feet^2$/acre)	300	1.4	4.3	5.4	5.4	5.0	4.7	4.3	3.6
	400	2.1	6.3	7.3	6.9	6.4	5.4	4.8	3.7
	500	2.1	7.0	7.9	7.3	6.3	4.4	4.1	-
	600	2.3	7.8	8.0	7.8	6.3	-	-	-
	700	2.7	8.4	8.8	7.6	6.0	-	-	-
	800	3.6	10.2	10.3	7.8	-	-	-	-
Cubic Foot Volume (per acre, wood and bark)	300	10.2	58.2	103.9	133.9	145.9	149.0	144.9	122.5
	400	16.4	87.6	143.7	170.4	177.7	158.3	146.6	118.1
	500	15.4	97.4	156.0	175.7	160.2	109.6	88.5	-
	600	16.8	108.5	151.1	181.1	152.7	-	-	-
	700	20.2	118.2	171.5	165.6	140.6	-	-	-
	800	30.2	148.5	195.5	157.3	-	-	-	-
Yield ($feet^3$/acre)	300	63.6	609.1	1550.6	2684.8	3640.3	4400.5	4978.7	4878.7
	400	104.7	921.4	2174.6	3408.2	4408.3	4705.2	4965.8	4487.6
	500	96.1	1018.0	2357.8	3511.1	3889.3	3212.2	2920.4	-
	600	99.6	1129.3	2246.8	3490.8	3628.8	-	-	-
	700	121.6	1243.4	2638.9	3242.1	3375.2	-	-	-
	800	176.9	1524.7	2863.9	2927.5	-	-	-	-
Observations	300	76	106	145	153	119	134	66	25
	400	108	117	152	138	118	53	19	1
	500	130	133	145	112	67	7	1	-
	600	107	100	89	40	8	-	-	-
	700	63	53	28	13	1	-	-	-
	800	38	17	10	2	-	-	-	-

Table 9. Mean periodic (3 year) quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth (PAI) by age and trees per acre classes for loblolly pine plantations in East Texas.

Statistic	Trees per Acre	Age (years)							
		5	10	15	20	25	30	35	40
Quadratic Mean Diameter (inches)	300	0.7	1.7	2.4	2.9	3.2	3.4	3.5	3.4
	400	0.7	1.8	2.3	2.6	2.8	2.9	2.9	2.8
	500	0.6	1.7	2.2	2.4	2.5	2.3	2.4	-
	600	0.5	1.6	2.0	2.2	2.2	-	-	-
	700	0.5	1.6	2.0	2.1	2.1	-	-	-
	800	0.5	1.6	1.9	1.9	-	-	-	-
Height (feet)	300	3.8	9.5	14.4	18.9	22.3	24.7	26.2	26.8
	400	3.8	10.3	15.1	19.1	21.6	22.7	23.7	24.8
	500	3.5	10.4	15.2	18.8	19.6	18.2	17.0	-
	600	3.4	10.8	14.6	17.9	18.0	-	-	-
	700	3.4	10.9	15.2	17.0	18.9	-	-	-
	800	3.3	11.3	14.9	15.9	-	-	-	-
Basal Area ($feet^2$/acre)	300	2.8	14.9	26.5	36.0	41.8	45.9	49.5	47.7
	400	4.2	21.6	36.5	45.7	52.7	53.6	54.5	47.2
	500	4.1	23.9	39.3	48.3	51.2	42.9	45.5	-
	600	4.3	26.4	39.5	50.0	49.5	-	-	-
	700	5.1	29.1	44.8	49.6	48.3	-	-	-
	800	6.5	34.3	50.2	48.4	-	-	-	-
Cubic Foot Volume (per acre, wood and bark)	300	21.2	203.0	516.9	894.9	1213.4	1466.8	1659.6	1626.2
	400	34.9	307.1	724.9	1136.1	1469.4	1568.4	1655.3	1495.9
	500	32.0	339.3	785.9	1170.4	1296.4	1070.7	973.5	-
	600	33.2	376.4	748.9	1163.6	1209.6	-	-	-
	700	40.5	414.5	879.6	1080.7	1125.1	-	-	-
	800	59.0	508.2	954.6	975.8	-	-	-	-
Observations	300	76	106	145	153	119	134	66	25
	400	108	117	152	138	118	53	19	1
	500	130	133	145	112	67	7	1	-
	600	107	100	89	40	8	-	-	-
	700	63	53	28	13	1	-	-	-
	800	38	17	10	2	-	-	-	-

Table 10. Overall mean annual (MAI) quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot growth for slash pine plantations in East Texas.

Statistic	Average Annual Growth	
Diameter (SE)	0.42	(0.003)
Height (SE)	2.77	(0.017)
Basal area (SE)	4.38	(0.068)
Cubic foot volume wood and bark (SE)	97.93	(1.929)

Cubic foot volume yield (SE) = 1756.09 (44.03)
(SE) = standard error
Diameter = quadratic mean diameter in inches
Height = average height of dominant and codominant trees
Basal area = square feet per acre
Cubic foot volume wood and bark = total stem cubic feet wood and bark per acre
Average annual growth values based on 1143 observations

Table 11. Average yield and mean annual (MAI) quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth by site index (25-year index age), age, and trees per acre classes for slash pine plantations in East Texas.

			Average Annual Growth (MAI)				
		Yield (feet³/acre wood and bark)	Quadratic Mean Diameter (inches)	Height (feet)	Basal area (feet²/acre)	Cubic foot volume (per acre, wood and bark)	Observations
Site Index Class							
(feet)	50	789.6	0.3	1.9	2.0	40.4	111
	60	1688.4	0.3	2.4	3.5	80.1	68
	70	2161.3	0.4	2.7	4.3	106.7	303
	80	2481.8	0.4	3.0	5.1	131.7	368
	90	1270.3	0.5	3.1	5.5	100.3	135
	100	411.8	0.5	2.9	3.9	47.9	158
Age Class							
(years)	5	121.6	0.4	2.4	2.4	20.2	226
	10	853.0	0.5	3.0	5.3	81.9	244
	15	1836.3	0.4	3.0	5.5	122.3	224
	20	2819.2	0.4	2.9	5.0	142.2	238
	25	3307.2	0.4	2.7	4.1	134.8	133
	30	3222.3	0.4	2.5	3.0	109.5	57
	35	3205.8	0.3	2.4	2.2	91.9	16
	40	2895.8	0.3	2.2	1.7	73.0	5
Trees per Acre							
Class	300	1913.7	0.4	2.8	3.6	93.6	606
	400	1764.4	0.4	2.9	5.1	109.3	211
	500	1723.8	0.4	2.7	5.2	107.0	151
	600	1523.7	0.4	2.9	6.1	109.2	96
	700	790.2	0.4	2.5	4.4	63.1	56
	800	1062.0	0.3	2.2	5.6	84.5	23

Table 12. Mean periodic (3 year) quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth (PAI) by site index (25-year index age), age, and trees per acre classes for slash pine plantations in East Texas.

		Quadratic Mean Diameter (inches)	Height (feet)	Basal area (feet²/acre)	Cubic foot volume (per acre, wood and bark)	Observations
Site Index Class						
(feet)	50	1.7	11.2	11.3	263.2	111
	60	2.2	15.4	22.7	562.8	68
	70	2.4	16.6	26.7	720.4	303
	80	2.4	17.3	29.4	827.3	368
	90	1.7	11.0	20.6	423.4	135
	100	0.9	5.8	9.4	137.3	158
Age Class						
(years)	5	0.7	4.0	4.5	40.5	226
	10	1.6	10.0	18.0	284.3	244
	15	2.2	14.8	27.2	612.1	224
	20	2.6	18.9	33.0	939.7	238
	25	2.9	22.1	33.1	1102.4	133
	30	3.4	24.6	29.4	1074.1	57
	35	3.9	28.1	25.9	1068.6	16
	40	4.3	29.1	22.7	965.3	5
Trees per Acre						
Class	300	2.5	16.9	22.2	637.9	606
	400	1.8	12.7	24.6	588.1	211
	500	1.5	11.1	24.2	574.6	151
	600	1.4	10.0	24.5	507.9	96
	700	0.9	6.3	14.6	263.4	56
	800	1.0	7.2	20.9	354.0	23

Table 13. Mean yield and mean annual quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth (MAI) by age and site index (25-year index age) classes for slash pine plantations in East Texas.

Statistic	Site Index (feet)	Age (years) 5	10	15	20	25	30	35	40
Quadratic Mean Diameter (inches)	50	0.2	0.3	0.4	0.3	0.3	0.3	0.4	0.4
	60	0.3	0.5	0.4	0.3	0.3	0.3	0.3	0.4
	70	0.3	0.5	0.5	0.4	0.4	0.4	0.3	0.3
	80	0.3	0.5	0.5	0.4	0.4	0.4	0.3	0.3
	90	0.4	0.5	0.5	0.4	0.4	0.4	-	-
	100	0.4	0.6	0.5	-	-	-	-	-
Height (feet)	50	0.9	1.8	2.3	2.1	2.2	2.2	2.4	2.2
	60	1.5	2.6	2.6	2.5	2.3	2.2	2.2	2.3
	70	2.0	2.7	2.8	2.8	2.7	2.5	2.4	2.1
	80	2.2	3.0	3.1	3.1	2.9	2.8	2.5	2.2
	90	2.4	3.3	3.5	3.3	3.2	3.1	-	-
	100	2.7	3.6	3.7	-	-	-	-	-
Basal Area ($feet^2$/acre)	50	0.8	1.7	2.9	2.5	2.5	1.5	0.5	0.8
	60	1.0	3.4	4.2	5.0	3.0	2.7	1.5	1.1
	70	1.5	4.4	5.0	4.7	4.1	3.5	2.7	3.0
	80	1.6	5.5	5.9	5.6	4.7	3.1	2.6	3.0
	90	2.7	6.1	8.0	6.7	4.3	3.5	-	-
	100	2.9	7.1	8.5	-	-	-	-	-
Cubic Foot Volume (per acre, wood and bark)	50	5.4	20.6	55.6	56.2	70.1	50.2	20.3	33.1
	60	6.9	49.7	82.2	121.2	84.5	83.1	52.9	45.1
	70	10.8	61.1	102.1	129.6	134.0	126.3	108.2	126.8
	80	11.7	83.6	136.6	169.3	166.4	126.2	112.6	127.1
	90	22.6	100.2	194.7	209.4	185.5	157.6	-	-
	100	25.3	116.6	241.6	-	-	-	-	-
Yield ($feet^3$/acre)	50	32.0	213.6	828.3	1117.9	1722.8	1482.5	714.0	1304.4
	60	45.7	569.3	1294.2	2396.1	2164.5	2442.5	1769.1	1715.4
	70	73.0	664.0	1535.1	2595.5	3307.4	3713.2	3715.1	5070.8
	80	75.3	899.2	2067.8	3351.2	4035.4	3721.6	4006.0	5084.2
	90	145.1	1038.3	2776.7	3905.9	5007.5	4571.0	-	-
	100	149.5	1112.9	3686.6	-	-	-	-	-
Observations	50	22	21	21	18	16	9	2	2
	60	6	8	13	16	15	7	2	1
	70	17	46	64	100	45	24	6	1
	80	22	67	104	96	56	16	6	1
	90	36	70	19	8	1	1	-	-
	100	123	32	3	-	-	-	-	-

Table 14. Mean periodic (3 year) quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth (PAI) by age and site index (25-year index age) classes for slash pine plantations in East Texas.

Statistic	Site Index (feet)	Age (years) 5	10	15	20	25	30	35	40
Quadratic Mean	50	0.3	1.0	1.8	2.1	2.5	3.4	4.2	4.8
Diameter (inches)	60	0.5	1.7	1.9	2.3	2.7	3.0	3.8	4.6
	70	0.6	1.6	2.2	2.6	3.0	3.5	3.8	3.5
	80	0.7	1.7	2.3	2.7	3.1	3.6	4.0	3.9
	90	0.9	1.7	2.3	2.7	3.5	3.7	-	-
	100	0.7	1.7	2.4	-	-	-	-	-
Height (feet)	50	1.4	5.9	11.3	14.0	18.2	21.7	28.7	29.4
	60	2.6	9.7	13.4	16.6	19.2	21.2	25.0	29.0
	70	3.9	9.4	14.1	18.6	22.2	24.6	27.4	28.5
	80	4.2	10.4	15.7	20.3	23.9	27.4	29.7	29.2
	90	4.9	11.0	16.4	20.7	28.4	30.3	-	-
	100	4.2	10.9	18.8	-	-	-	-	-
Basal Area	50	1.3	5.8	14.5	16.8	20.7	15.0	5.7	10.4
(feet²/acre)	60	2.1	13.0	22.0	32.9	25.6	26.6	16.5	13.6
	70	3.1	15.6	24.7	31.5	34.0	34.6	30.8	39.9
	80	3.3	19.4	29.5	36.9	37.9	30.6	30.9	39.4
	90	5.7	20.7	37.9	41.6	39.0	33.5	-	-
	100	5.4	21.9	43.4	-	-	-	-	-
Cubic Foot Volume	50	10.7	71.2	276.1	372.6	574.3	494.2	238.0	434.8
(per acre, wood	60	15.2	189.8	431.4	798.7	721.5	814.2	589.7	571.8
and bark)	70	24.3	221.3	511.7	865.2	1102.5	1237.7	1238.4	1690.3
	80	25.1	299.7	689.3	1117.1	1345.1	1240.5	1335.3	1694.7
	90	48.4	346.1	925.6	1302.0	1669.2	1523.7	-	-
	100	49.8	371.0	1228.9	-	-	-	-	-
Observations	50	22	21	21	18	16	9	2	2
	60	6	8	13	16	15	7	2	1
	70	17	46	64	100	45	24	6	1
	80	22	67	104	96	56	16	6	1
	90	36	70	19	8	1	1	-	-
	100	123	32	3	-	-	-	-	-

Table 15. Mean yield and mean annual quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth (MAI) by site index (25-year index age) and trees per acre classes for slash pine plantations in East Texas.

Statistic	Trees per Acre	Site Index (feet) 50	60	70	80	90	100
Quadratic Mean Diameter (inches)	300	0.3	0.4	0.4	0.4	0.5	0.6
	400	0.2	0.3	0.4	0.4	0.5	0.5
	500	0.2	0.3	0.4	0.4	0.5	0.5
	600	0.4	0.3	0.4	0.4	0.5	0.5
	700	0.4	0.3	0.3	0.5	0.4	0.4
	800	0.3	0.3	0.4	0.4	0.4	0.2
Height (feet)	300	2.0	2.5	2.7	3.0	3.1	3.3
	400	1.6	2.5	2.7	3.0	3.1	3.0
	500	1.4	2.0	2.7	2.9	3.2	2.9
	600	2.4	2.3	2.6	2.9	3.2	2.9
	700	1.5	2.1	2.3	2.9	2.7	2.7
	800	0.0	1.9	2.5	2.6	2.1	1.8
Basal Area ($feet^2$/acre)	300	1.7	2.8	3.6	4.2	4.0	4.0
	400	2.0	4.0	5.1	6.0	5.6	3.4
	500	2.0	3.7	5.5	6.7	6.8	3.8
	600	6.3	6.3	6.6	7.4	7.2	4.9
	700	2.3	5.7	5.7	8.6	5.7	3.2
	800	0.5	5.0	7.7	6.6	4.1	0.7
Cubic Foot Volume (per acre, wood and bark)	300	38.2	67.4	95.1	121.7	80.0	59.9
	400	48.3	91.3	125.2	139.7	103.6	37.6
	500	35.3	79.2	132.7	168.8	128.9	45.7
	600	121.2	165.8	153.6	144.9	114.9	68.0
	700	20.1	135.2	119.0	138.4	76.9	30.1
	800	0.0	76.9	118.0	108.0	30.6	2.1
Yield ($feet^3$/acre)	300	817.3	1484.4	2020.0	2533.6	1170.6	579.5
	400	1069.7	1882.0	2402.0	2312.3	1281.7	275.3
	500	667.0	1655.7	2656.2	2975.3	1619.6	357.0
	600	1616.1	3766.2	2919.8	2059.5	1211.7	663.3
	700	109.3	2647.9	1982.9	1673.2	785.7	203.0
	800	0.0	1055.1	1478.5	1538.4	183.5	6.2
Observations	300	75	42	206	220	44	19
	400	8	9	40	83	39	32
	500	16	7	25	38	28	37
	600	4	2	18	17	15	40
	700	6	5	6	4	8	27
	800	2	3	8	6	1	3

Table 16. Mean periodic (3 year) quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth (PAI) by site index (25-year index age) and trees per acre classes for slash pine plantations in East Texas.

		Site Index (feet)					
Statistic	Trees per Acre	50	60	70	80	90	100
Quadratic Mean Diameter (inches)	300	2.1	2.6	2.6	2.7	1.8	1.5
	400	1.1	2.0	2.1	2.1	1.7	0.9
	500	1.0	1.5	2.0	2.0	1.7	0.9
	600	1.5	2.2	1.9	1.8	1.5	1.0
	700	0.4	1.7	1.5	1.7	1.1	0.6
	800	0.1	1.1	1.4	1.3	0.8	0.2
Height (feet)	300	13.5	17.0	17.6	19.1	11.8	8.9
	400	8.6	15.4	15.6	15.0	11.1	5.5
	500	6.9	11.0	15.1	15.5	11.4	5.6
	600	10.1	17.5	14.8	12.4	10.1	6.5
	700	2.2	12.9	10.8	11.3	7.3	3.9
	800	0.0	7.4	9.8	9.3	4.3	1.8
Basal Area ($feet^2$/acre)	300	11.1	18.9	23.7	27.3	16.6	11.5
	400	13.8	26.3	31.1	30.7	20.9	7.6
	500	11.5	23.8	33.5	37.0	26.0	8.9
	600	27.0	47.3	38.7	32.9	24.0	13.3
	700	3.7	36.8	29.7	33.2	17.0	6.1
	800	0.2	22.2	30.5	26.6	8.2	0.7
Cubic Foot Volume (per acre, wood and bark)	300	272.4	494.8	673.3	844.5	390.2	193.2
	400	356.6	627.3	800.7	770.8	427.2	91.8
	500	222.3	551.9	885.4	991.8	539.9	119.0
	600	538.7	1255.4	973.3	686.5	403.9	221.1
	700	36.4	882.6	661.0	557.7	261.9	67.7
	800	0.0	351.7	492.8	512.8	61.2	2.1
Observations	300	75	42	206	220	44	19
	400	8	9	40	83	39	32
	500	16	7	25	38	28	37
	600	4	2	18	17	15	40
	700	6	5	6	4	8	27
	800	2	3	8	6	1	3

Table 17. Mean yield and mean annual quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth (MAI) by age and trees per acre classes for slash pine plantations in East Texas.

Statistic	Trees per Acre	Age (years) 5	10	15	20	25	30	35	40
Quadratic Mean Diameter (inches)	300	0.4	0.5	0.5	0.4	0.4	0.4	0.3	0.3
	400	0.4	0.5	0.4	0.4	0.3	0.3	-	-
	500	0.4	0.5	0.4	0.3	0.3	0.3	-	-
	600	0.4	0.5	0.4	0.3	0.3	-	-	-
	700	0.4	0.5	0.4	0.3	-	-	-	-
	800	0.3	0.4	0.3	-	-	-	-	-
Height (feet)	300	2.3	2.9	2.9	2.9	2.7	2.5	2.4	2.2
	400	2.5	3.1	3.1	2.9	2.6	2.2	-	-
	500	2.3	3.0	3.0	2.8	2.5	2.1	-	-
	600	2.6	3.2	3.1	2.7	2.4	-	-	-
	700	2.4	3.1	2.9	2.5	-	-	-	-
	800	1.6	2.5	2.7	-	-	-	-	-
Basal Area ($feet^2$/acre)	300	1.6	3.6	4.2	4.1	3.7	2.9	2.2	1.7
	400	2.3	5.6	6.2	6.2	5.2	4.8	-	-
	500	2.3	6.1	6.9	6.6	6.3	5.6	-	-
	600	3.3	8.0	8.0	7.5	6.6	-	-	-
	700	2.9	8.6	8.3	7.2	-	-	-	-
	800	1.8	7.1	8.9	-	-	-	-	-
Cubic Foot Volume (per acre, wood and bark)	300	14.2	55.4	94.5	118.3	124.4	105.7	91.9	73.0
	400	19.9	87.0	138.7	177.1	166.2	152.2	-	-
	500	18.6	96.9	156.6	189.6	200.2	181.3	-	-
	600	29.4	127.0	183.8	207.8	199.9	-	-	-
	700	23.0	132.1	179.3	177.0	-	-	-	-
	800	11.1	89.9	192.2	-	-	-	-	-
Yield ($feet^3$/acre)	300	94.7	584.4	1433.7	2354.7	3060.6	3110.8	3205.8	2895.8
	400	122.2	907.7	2036.7	3453.8	4002.6	4454.4	-	-
	500	108.5	988.8	2337.9	3794.4	4889.5	5439.1	-	-
	600	182.9	1317.0	2748.1	4161.3	4997.1	-	-	-
	700	127.9	1370.3	2698.4	3484.0	-	-	-	-
	800	57.0	954.8	3064.0	-	-	-	-	-
Observations	300	50	99	122	152	109	53	16	5
	400	43	61	48	43	13	3	-	-
	500	47	39	27	30	7	1	-	-
	600	37	30	17	8	4	-	-	-
	700	40	6	5	5	-	-	-	-
	800	9	9	5	-	-	-	-	-

Table 18. Mean periodic (3 year) quadratic mean diameter, average dominant and codominant height, basal area, and cubic foot volume growth (PAI) by age and trees per acre classes for slash pine plantations in East Texas.

Statistic	Trees per Acre	Age (years) 5	10	15	20	25	30	35	40
Quadratic Mean Diameter	300	0.8	1.7	2.3	2.7	3.0	3.5	3.9	4.3
(inches)	400	0.7	1.7	2.1	2.5	2.5	2.6	-	-
	500	0.6	1.5	2.0	2.3	2.6	2.6	-	-
	600	0.7	1.6	2.0	2.2	2.4	-	-	-
	700	0.5	1.6	1.9	2.1	-	-	-	-
	800	0.4	1.3	1.8	-	-	-	-	-
Height	300	4.6	9.8	14.7	19.1	22.5	24.9	28.1	29.1
(feet)	400	4.1	10.4	15.0	19.0	20.7	21.2	-	-
	500	3.8	10.1	14.6	18.4	20.6	21.3	-	-
	600	4.3	10.6	15.2	18.2	20.0	-	-	-
	700	3.3	10.5	14.5	16.4	-	-	-	-
	800	2.2	8.4	14.2	-	-	-	-	-
Basal Area	300	3.5	12.5	21.3	27.4	30.1	27.9	25.9	22.7
($feet^2$/acre)	400	4.4	18.9	30.0	40.1	41.9	46.6	-	-
	500	4.2	20.4	34.3	44.0	51.5	56.0	-	-
	600	6.5	27.1	39.8	50.1	54.8	-	-	-
	700	5.0	29.3	41.7	47.2	-	-	-	-
	800	2.9	24.5	46.9	-	-	-	-	-
Cubic Foot Volume	300	31.6	194.8	477.9	784.9	1020.2	1036.9	1068.6	965.3
(per acre, wood	400	40.7	302.6	678.9	1151.3	1334.2	1484.8	-	-
and bark)	500	36.2	329.6	779.3	1264.8	1629.8	1813.0	-	-
	600	61.0	439.0	916.0	1387.1	1665.7	-	-	-
	700	42.6	456.8	899.5	1161.3	-	-	-	-
	800	19.0	318.3	1021.3	-	-	-	-	-
Observations	300	50	99	122	152	109	53	16	5
	400	43	61	48	43	13	3	-	-
	500	47	39	27	30	7	1	-	-
	600	37	30	17	8	4	-	-	-
	700	40	6	5	5	-	-	-	-
	800	9	9	5	-	-	-	-	-

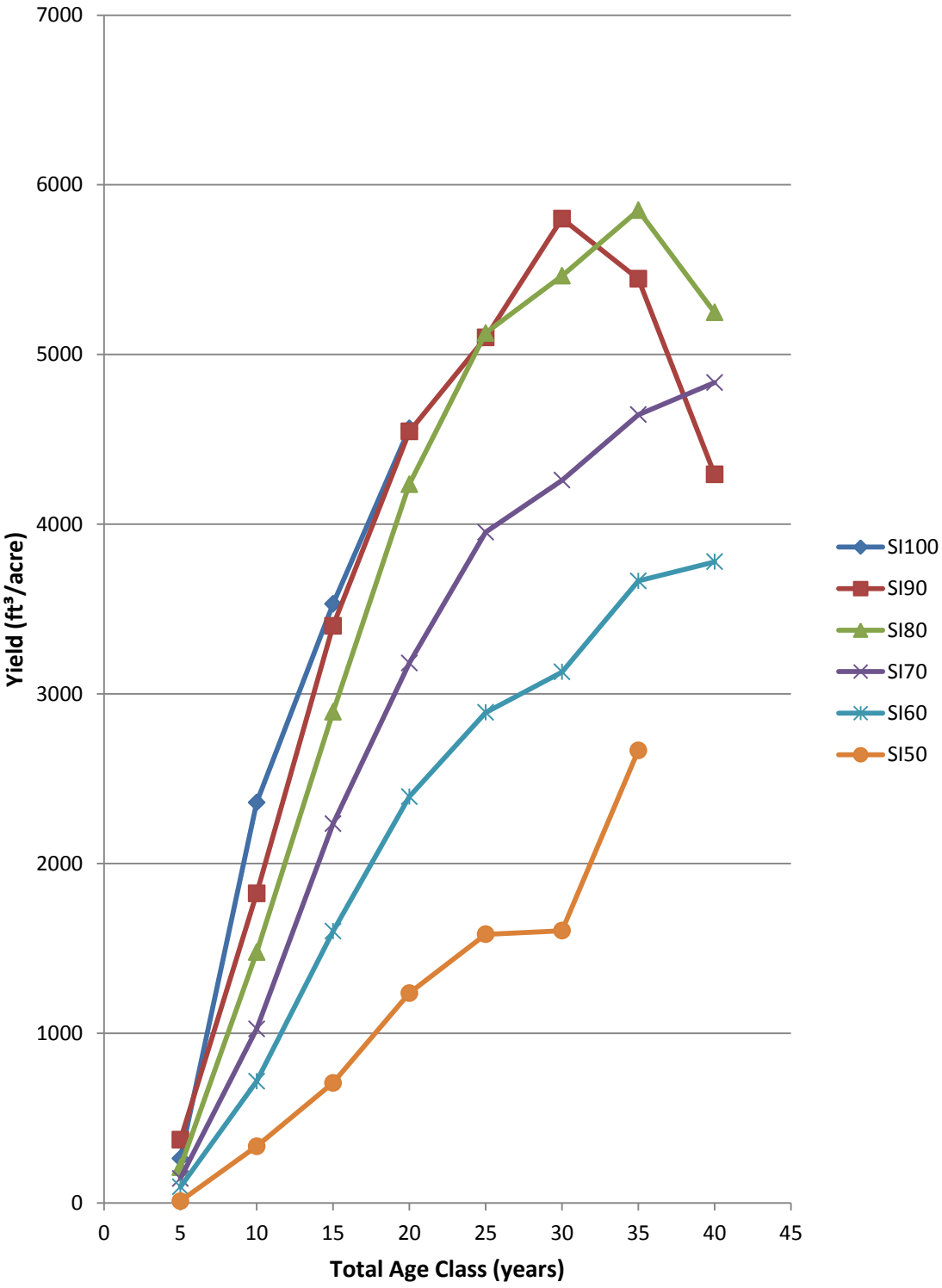

Figure 1. Observed yield (cubic foot volume per acre wood and bark) by total age (years) and site index (25-year index age) classes for loblolly pine plantations in East Texas.

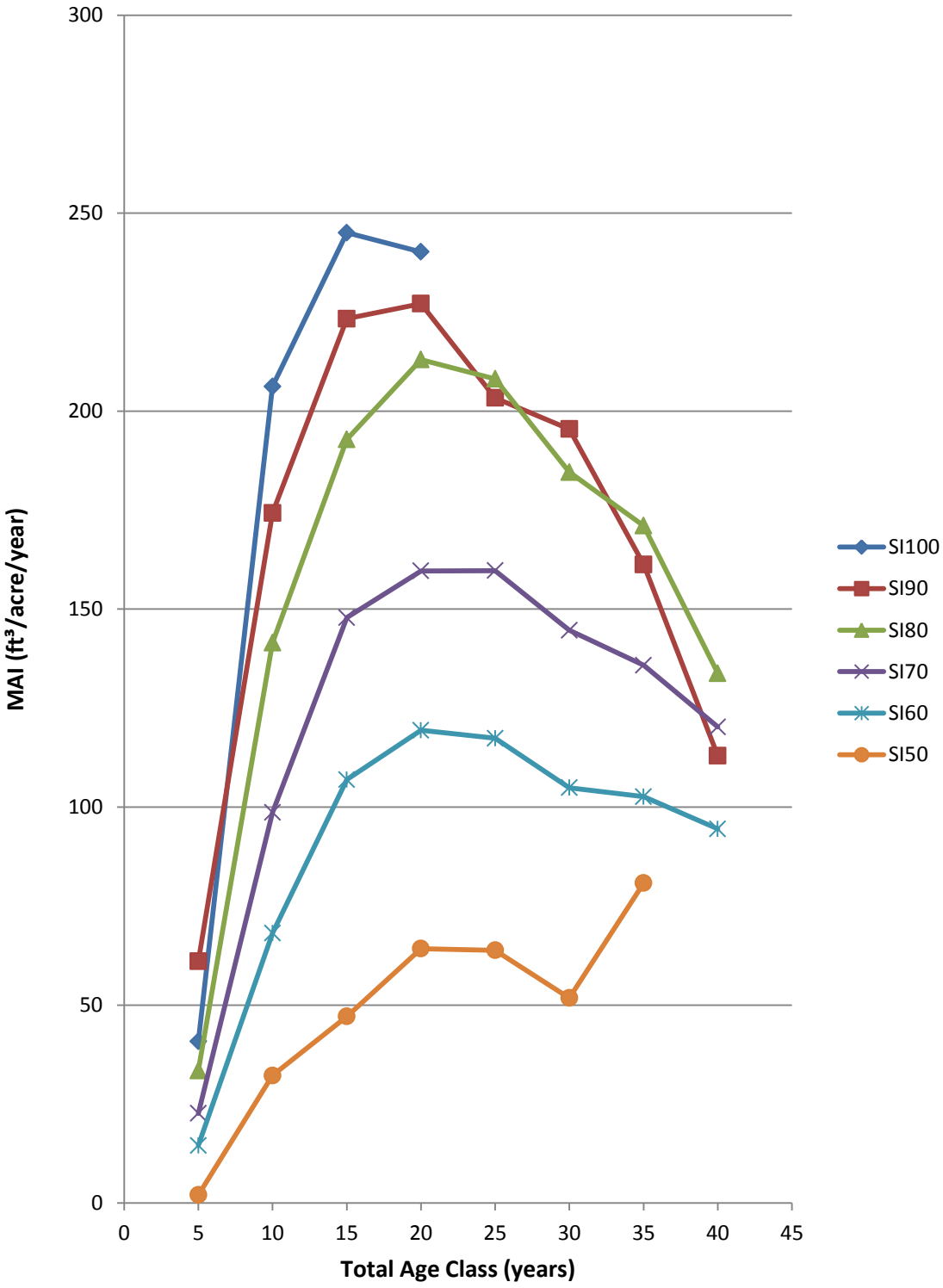

Figure 2. Observed mean annual volume growth (MAI, cubic foot volume per acre wood and bark) by total age (years) and site index (25-year index age) classes for loblolly pine plantations in East Texas.

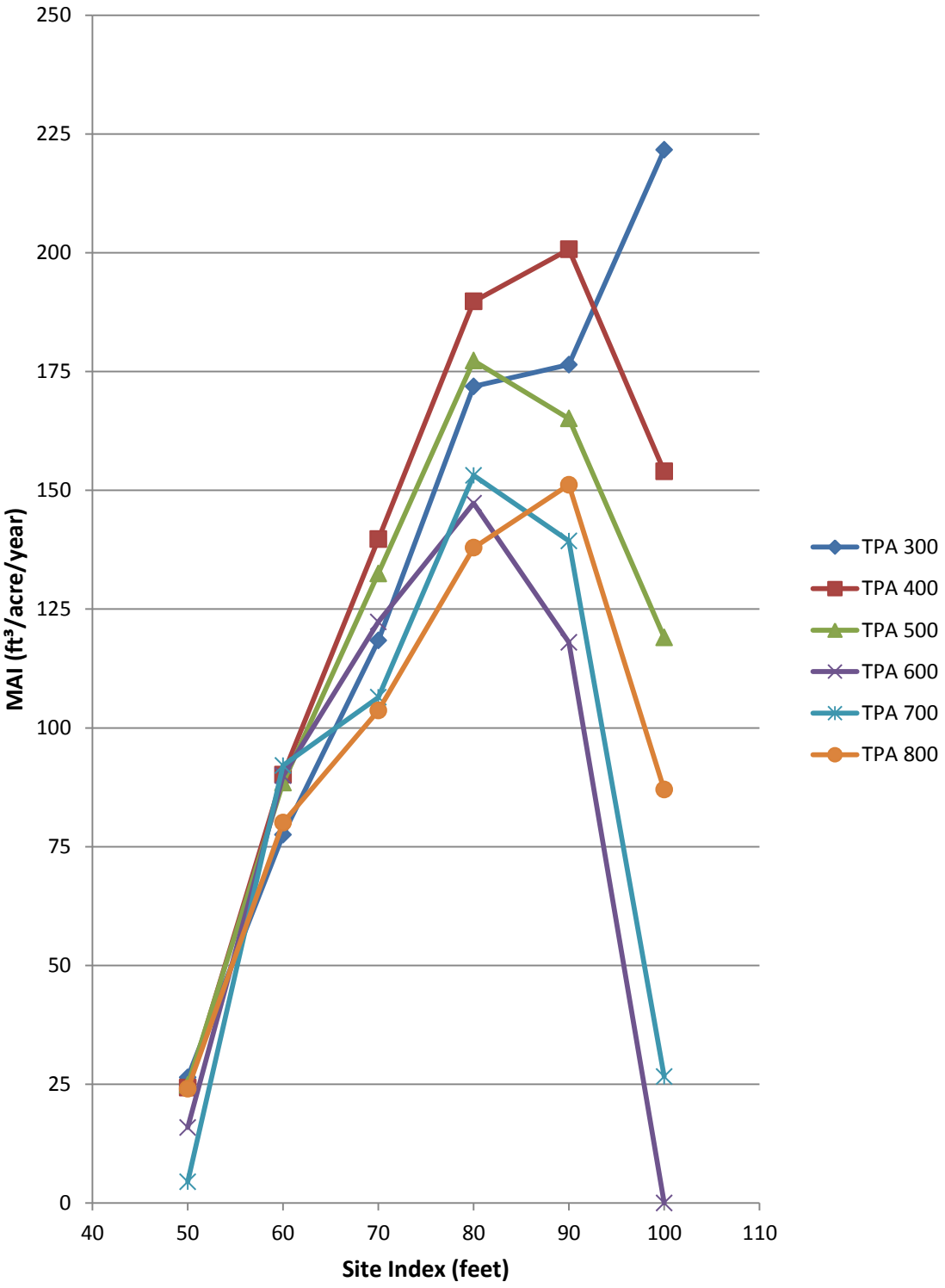

Figure 3. Observed mean annual volume growth (MAI, cubic foot volume per acre wood and bark) by site index (25-year index age) and trees per acre classes for loblolly pine plantations in East Texas.

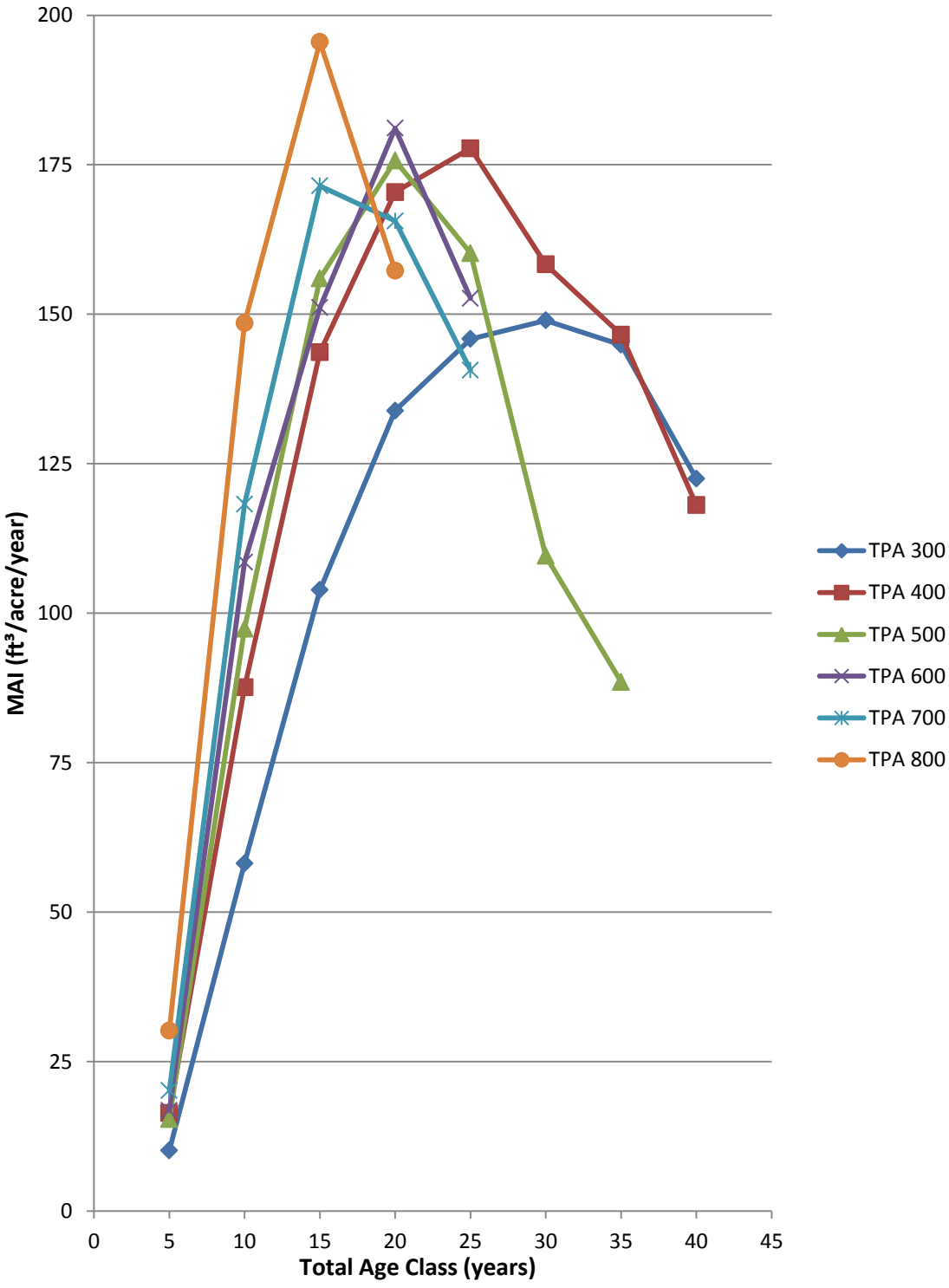

Figure 4. Observed mean annual volume growth (MAI, cubic foot volume per acre wood and bark) by total age (years) and trees per acre classes for loblolly pine plantations in East Texas.

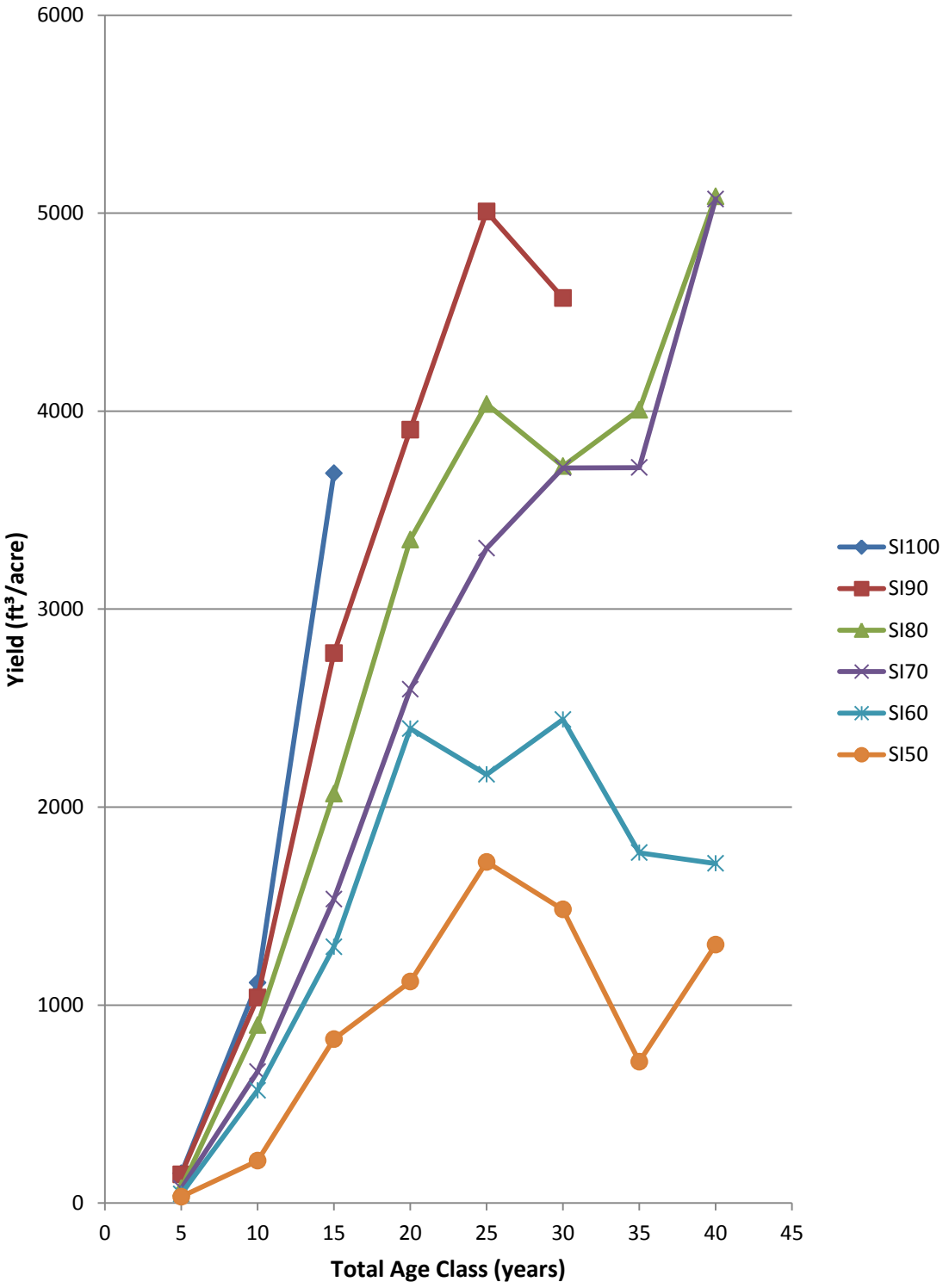

Figure 5. Observed yield (cubic foot volume per acre wood and bark) by total age (years) and site index (25-year index age) classes for slash pine plantations in East Texas.

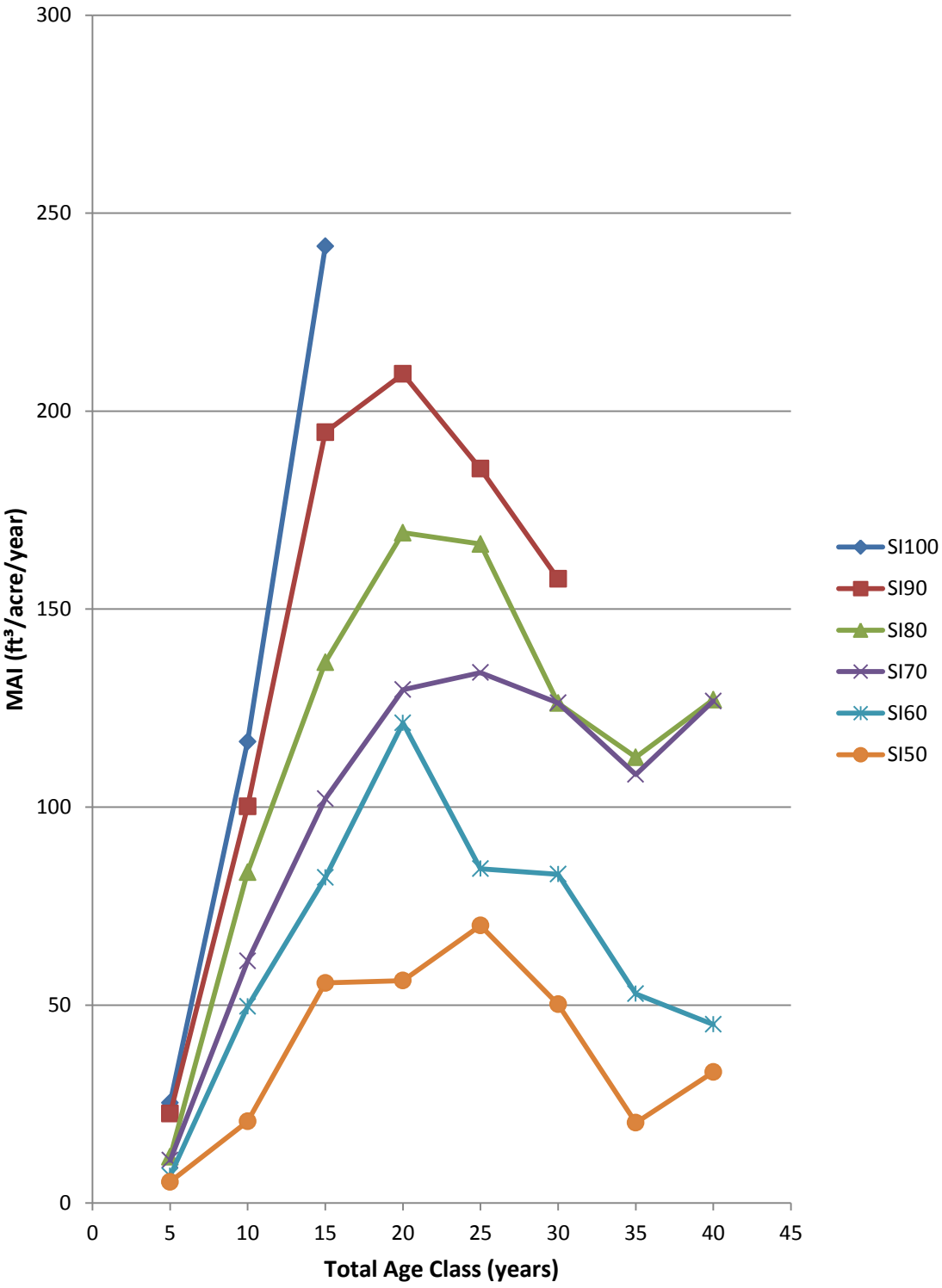

Figure 6. Observed mean annual volume growth (MAI, cubic foot volume per acre wood and bark) by total age (years) and site index (25-year index age) classes for slash pine plantations in East Texas.

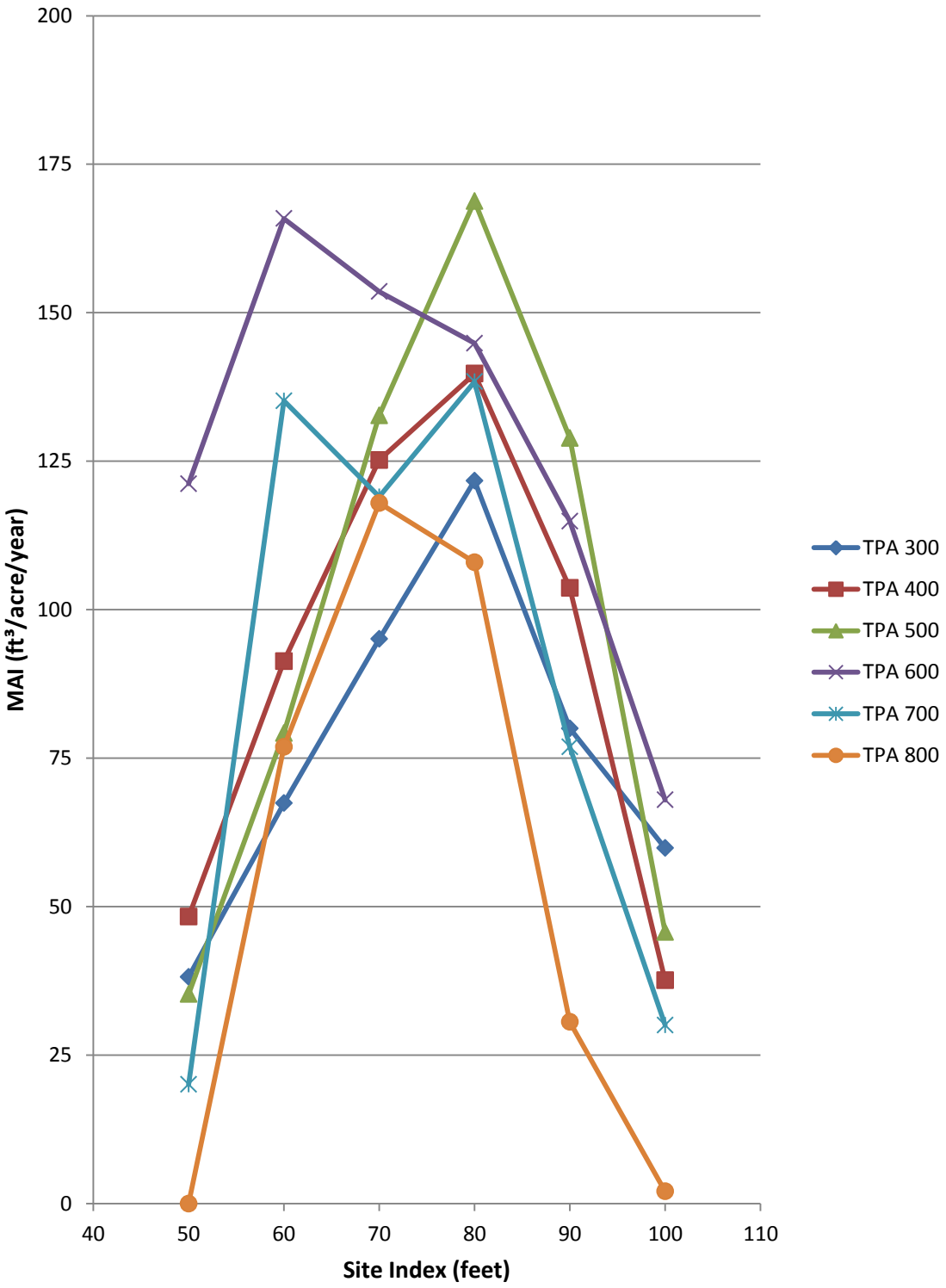

Figure 7. Observed mean annual volume growth (MAI, cubic foot volume per acre wood and bark) by site index (25-year index age) and trees per acre classes for slash pine plantations in East Texas.

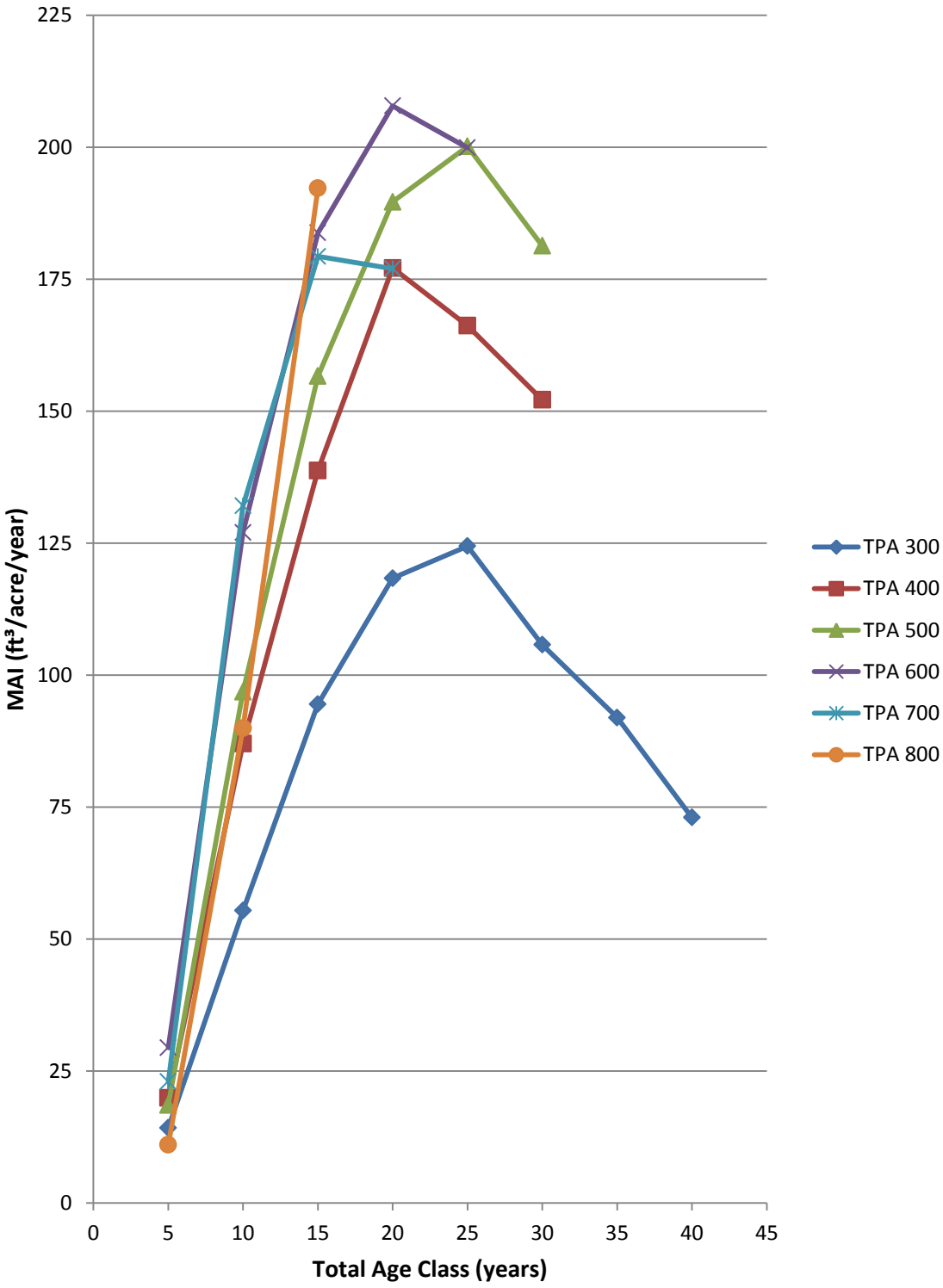

Figure 8. Observed mean annual volume growth (MAI, cubic foot volume per acre wood and bark) by total age (years) and trees per acre classes for slash pine plantations in East Texas.