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Project Report No. 64, Observed Growth and Yield of Loblolly and Slash Pine Plantations in East Texas

Dean W. Coble
Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, dcoble@sfasu.edu

Shiaolin Cheng

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

BY

SHIAOLIN CHENG

AND

DEAN W. COBLE

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FROM

THE

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ARTHUR TEMPLE COLLEGE OF FORESTRY

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INTRODUCTION

The amount of forestland in east Texas has been estimated at 11.8 million acres, with approximately 2.5 million acres classified as pine plantations. The majority of these plantations are owned by forest industry (71 percent), while non-industrial private forest landowners represent the next largest shareholder (23 percent). Pine plantations are typically managed to produce timber, so information is needed to make informed management decisions. Growth is one piece of information that managers often rely upon in their decision-making process.

The purpose of this paper is to report observed growth in unthinned loblolly and slash 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.

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, 180 plots (125 for loblolly and 55 for slash pine) are intact and available for analysis. 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 2002, all plots have completed seven measurement cycles.

On each plot, all planted pine trees within each subplot were measured for: dbh, total height, height to live crown, and crown class. The presence of fusiform rust and visible tree quality was also recorded. The site preparation method, landform, slope, geographic location (latitude and longitude from a GPS), and soil characteristics were also recorded

[1] The support of the following organizations is much appreciated: Temple-Inland Forest Corporation, International Paper Company, Arthur Temple College of Forestry.

for each subplot. Beginning with the second measurement cycle (1985 – 1987), information about non-planted vegetation was collected for each subplot.

From these remeasured plots, 1046 loblolly pine and 475 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 ten tallest 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).
- Cubic foot volume wood only per acre (CFVW, total tree).

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

- Site Index – six classes: 50, 60, 70, 80, and 90 feet
- Trees per Acre – four classes: 300, 400, 500, 600
- Age – six classes: 5, 10, 15, 20, 25, 30 years.

ANNUAL GROWTH RATES

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

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

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

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

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

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 Trees Per Acre 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 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

Note that in some cases growth is negative, which occurs when mortality exceeds growth. Caution should also be exercised when using values for which sample sizes are small.

GRAPHICAL RESULTS

Annual growth rates (MAI and PAI) 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 diameter, height, basal area and cubic foot growth (MAI) for loblolly pine plantations in East Texas.

Measure	Average annual growth
Diameter	0.4
Height	3.3
Basal area	6.0
Cubic foot volume	98.5
Cubic foot volume wood bark	122.2
Cubic foot volume - Yield	2009.6

Diameter = quadratic mean diameter in inches
Height = average height of 10 tallest trees in area
Basal area = square foot per acre
Cubic foot volume = total stem cubic foot wood without bark per acre
Cubic foot volume wood bark = total stem cubic feet wood and bark per acre
Cubic foot volume - Yield
Average annual growth values based on 1046 observations

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

	Average annual growth						
	Diameter (in.)	Height (ft)	Basal area (sq.ft)	Cubic foot volume (wood and bark)	Cubic foot volume (wood only)	Yield (Cubic foot vol wood and bark)	Observations
Site Index (ft)							
50	0.3	2.3	2.3	28.4	21.2	423.0	101
60	0.4	2.9	4.9	87.9	69.2	1491.8	218
70	0.4	3.3	6.3	131.0	105.0	2225.5	414
80	0.5	3.8	7.4	165.2	135.1	2722.6	220
90	0.5	4.3	7.7	163.4	132.9	2299.0	93
Trees per acre							
300	0.4	3.1	4.7	105.7	86.8	1925.2	262
400	0.4	3.3	6.1	134.4	109.7	2412.9	270
500	0.4	3.3	6.5	130.5	104.7	2111.0	262
600	0.4	3.5	6.7	117.6	92.1	1560.1	252
Age							
5	0.3	3.0	1.3	9.1	6.1	43.6	99
10	0.5	3.5	5.5	68.6	50.8	595.9	248
15	0.5	3.5	7.3	139.9	110.8	1843.3	282
20	0.4	3.3	6.9	169.2	139.3	3049.3	259
25	0.4	2.9	6.0	168.7	141.9	3803.7	112
30	0.3	2.7	5.3	167.5	143.5	4660.6	46

Table 3. Periodic annual diameter, height, basal area and cubic foot volume growth (PAI) by site index, trees per acre and age classes for loblolly pine plantations in East Texas.

	Average annual growth					
	Diameter (in.)	Height (ft)	Basal area (sq.ft)	Cubic foot volume (wood and bark)	Cubic foot volume (wood only)	Observations
Site Index (ft)						
50	0.4	2.4	4.5	80.1	62.8	101
60	0.4	2.6	6.2	151.0	123.7	218
70	0.4	3.0	7.5	225.6	190.7	414
80	0.4	3.5	8.0	268.8	231.0	220
90	0.5	5.1	9.8	298.4	253.8	93
Trees per acre						
300	0.4	2.9	4.9	162.5	139.8	262
400	0.4	3.1	6.8	221.0	189.7	270
500	0.4	3.1	8.0	231.6	194.6	262
600	0.4	3.5	9.4	231.8	189.9	252
Age						
5	0.4	3.1	5.1	124.4	102.8	99
10	0.7	4.2	10.8	165.9	126.6	248
15	0.4	3.5	9.3	266.2	220.4	282
20	0.2	2.6	5.3	247.9	218.5	259
25	0.2	1.8	3.4	198.8	180.6	112
30	0.2	2.1	0.7	137.3	140.0	46

Table 4. Mean annual diameter, height, basal area and cubic foot volume growth (MAI) and yield by age and site index classes for loblolly pine plantations in East Texas.

Measure	Site index (ft)	AGE 5	10	15	20	25	30
Diameter	50	0.1	0.2	0.3	0.2	-	-
	60	0.2	0.3	0.4	0.3	0.3	0.2
	70	0.2	0.4	0.4	0.4	0.3	0.3
	80	0.3	0.5	0.5	0.4	0.4	0.3
	90	0.4	0.6	0.6	0.5	0.4	0.4
Height	50	1.9	1.7	1.8	1.7	-	-
	60	2.2	2.5	2.5	2.3	1.9	1.8
	70	2.5	3.0	3.0	2.8	2.6	2.3
	80	3.2	3.7	3.7	3.4	3.1	2.8
	90	4.1	4.5	4.6	4.3	3.6	3.7
Basal area	50	0.2	0.7	1.6	1.9	-	-
	60	0.4	1.9	3.9	3.8	2.9	2.7
	70	0.4	3.8	5.9	5.7	4.9	4.7
	80	1.4	6.2	8.0	7.3	6.4	5.7
	90	3.3	8.8	9.8	8.5	7.0	5.3
Cubic foot volume (wood & bar)	50	0.6	4.8	15.9	24.8	-	-
	60	1.6	16.0	52.3	62.0	49.8	45.6
	70	2.0	38.7	92.3	117.3	117.1	123.1
	80	8.4	77.5	125.3	182.7	185.4	180.4
	90	26.9	128.6	231.1	263.7	248.1	208.9
Cubic foot volume (wood only)	50	0.4	3.2	11.3	18.4	-	-
	60	1.0	11	39.1	47.9	38.7	35.3
	70	1.2	27.7	70.7	93.7	95.9	102.5
	80	5.5	57.4	157.8	150.7	156.4	154.6
	90	18.5	97.6	188.8	224.5	216.5	186.6
Cubic foot yield	50	2.9	45.2	218.3	435.0	-	-
	60	7.7	11.0	706.2	1126.5	1135.3	1186.3
	70	8.9	338.6	1204.7	2119.4	2690.0	3407.5
	80	39.9	679.2	2093.9	3295.2	4156.9	5009.6
	90	128.9	1084.3	2957.7	4685.1	5737.9	5957.7
Observations	50	9	6	6	4	-	-
	60	9	21	18	10	6	1
	70	17	53	63	39	20	10
	80	47	137	170	195	81	31
	90	17	31	25	11	5	4

Table 5. Periodic annual diameter, height, basal area and cubic foot volume growth (PAI) by age and site index classes for loblolly pine plantations in East Texas.

Measure	Site index (ft)	AGE 5	10	15	20	25	30
Diameter	50	0.3	0.5	0.4	0.3	0.2	0.1
	60	0.3	0.6	0.4	0.2	0.2	0.2
	70	0.4	0.7	0.4	0.2	0.2	0.2
	80	0.4	0.8	0.4	0.2	0.2	0.1
	90	0.5	0.8	0.4	0.3	0.2	0.3
Height	50	2.6	2.8	2.3	2.2	1.0	1.7
	60	2.8	3.5	3.0	2.3	1.7	1.6
	70	3.3	4.1	3.5	2.6	2.0	2.4
	80	3.2	4.7	3.8	3.1	3.0	1.8
	90	3.8	6.1	5.5	4.4	2.4	2.7
Basal area	50	4.4	4.9	6.1	4.7	4.1	1.3
	60	4.6	7.4	8.6	5.4	3.7	2.6
	70	6.2	11.0	10.0	5.8	4.1	3.2
	80	4.5	13.9	9.8	5.8	4.9	2.4
	90	5.3	16.8	10.7	5.0	3.6	3.0
Cubic foot volume (wood & bar)	50	103.9	70.6	100.4	117.8	92.7	63.7
	60	109.9	95.0	187.5	201.6	162.1	164.3
	70	162.2	162.4	281.6	254.6	227.4	227.0
	80	115.8	218.1	330.0	341.0	343.5	219.0
	90	110.6	306.6	444.3	385.3	279.9	348.6
Cubic foot volume (wood only)	50	85.1	54.3	77.2	95.4	75.2	54.1
	60	90.2	70.7	149.6	171.9	141.9	148.9
	70	135.4	122.8	231.8	222.1	204.9	210.5
	80	96.4	166.4	278.4	307.2	317.4	207.5
	90	89.9	239.0	383.4	356.1	264.3	341.0
Observations	50	18	32	29	14	5	1
	60	17	52	63	47	18	9
	70	27	82	105	124	53	9
	80	20	51	59	53	17	8
	90	17	31	25	10	5	1

Table 6. Mean annual diameter, height, basal area and cubic foot volume growth (MAI) and yield by site index and trees per acre for loblolly pine plantations in East Texas.

Measure	Trees per acre	Site Index				
		50	60	70	80	90
Diameter	300	0.2	0.4	0.4	0.5	0.5
	400	0.1	0.3	0.4	0.4	0.6
	500	0.2	0.3	0.4	0.4	0.5
	600	0.2	0.2	0.3	0.4	0.5
Height	300	1.7	2.4	2.8	3.4	4.1
	400	1.8	2.4	2.9	3.3	4.4
	500	2.0	2.4	2.9	3.4	4.4
	600	1.9	2.2	2.9	3.6	4.4
Basal area	300	0.8	2.3	3.3	5.6	6.6
	400	0.2	2.6	4.7	6.5	8.4
	500	1.8	3.3	5.3	7.2	7.8
	600	1.2	2.4	5.3	7.3	7.9
Cubic foot volume (wood & bar)	300	7.4	33.1	60.5	130	190.3
	400	1.1	33.2	80.7	152.9	195.4
	500	20.9	41.5	95.1	149.8	158.7
	600	12.2	28.4	80.5	134.5	128.9
Cubic foot volume (wood only)	300	5.2	25.2	47.9	106.9	162.2
	400	0.7	24.9	63.1	125.6	160.9
	500	15.4	30.8	75.0	120.9	127.9
	600	8.8	20.9	61.6	106.1	100
Cubic foot yield	300	104.7	538.2	1103.7	2358.8	3644.2
	400	8.4	498.1	1317.9	2879.7	2848.7
	500	328.5	624.6	1688.2	2432.4	2057.2
	600	178.0	436.9	1113.0	1851.9	1319.7
Observations	300	14	24	49	157	18
	400	4	15	50	177	24
	500	4	17	52	172	17
	600	3	9	51	155	34

Table 7. Periodic annual diameter, height, basal area and cubic foot volume growth (PAI) by site index and trees per acre for loblolly pine plantations in East Texas.

Measure	Trees per acre	Site Index				
		50	60	70	80	90
Diameter	300	0.4	0.4	0.4	0.4	0.4
	400	0.4	0.4	0.3	0.3	0.6
	500	0.4	0.4	0.4	0.4	0.4
	600	0.3	0.4	0.4	0.5	0.6
Height	300	2.4	2.9	3.0	3.5	5.0
	400	2.6	2.6	3.0	3.4	4.7
	500	2.4	2.7	3.1	3.8	4.5
	600	2.4	2.9	3.2	3.8	5.6
Basal area	300	4.2	4.9	6.3	7.3	6.5
	400	5.5	6.7	7.1	6.6	10.7
	500	6.7	6.8	8.5	9.3	8.6
	600	4.5	7.3	9.2	10.3	13.6
Cubic foot volume (wood & bar)	300	73.9	125.1	206.2	255.3	331.4
	400	107.1	164.8	241.3	283.9	326.3
	500	116.3	172.2	237.3	330.3	279.9
	600	94.6	160.6	243.1	259.2	319.3
Cubic foot volume (wood only)	300	57.9	103.4	176.2	221.2	298.7
	400	85.2	135.2	206.8	251.6	277.3
	500	91.0	142.1	198.0	283.8	238.9
	600	76.5	129.2	200.7	213.8	259.0
Observations	300	43	41	94	44	16
	400	21	57	112	46	22
	500	22	55	110	52	17
	600	13	53	84	66	34

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

Measure	Trees per acre	AGE 5	10	15	20	25	30
Diameter	300	0.3	0.5	0.5	0.4	0.4	0.3
	400	0.3	0.5	0.5	0.4	0.4	2.8
	500	0.3	0.5	0.5	0.4	0.3	0.3
	600	0.3	0.5	0.4	0.4	0.3	-
Height	300	2.7	3.3	3.3	3.2	3.0	2.7
	400	2.9	3.4	3.5	3.3	3.0	2.8
	500	3.0	3.4	3.5	3.3	2.8	2.5
	600	3.2	3.8	3.6	3.2	2.7	-
Basal area	300	0.7	3.7	5.3	5.4	5.1	4.6
	400	0.9	4.8	7.0	7.1	6.5	5.8
	500	1.4	5.7	7.8	7.6	6.6	5.9
	600	1.7	6.9	8.5	8.0	6.5	-
Cubic foot volume (wood & bar)	300	4.2	47.3	103.3	133.6	149.5	152.0
	400	5.6	59.3	136.0	173.6	186.4	183.9
	500	10.3	67.0	148.1	188.8	174.4	163.8
	600	11.7	89.1	163.0	189.3	166.7	-
Cubic foot volume (wood only)	300	2.8	35.2	82.2	110.5	126.7	131.3
	400	3.6	44.0	108.0	143.1	156.9	157.8
	500	7.0	49.2	117.1	155.3	145.0	137.5
	600	7.9	66.1	128.7	154.5	138.0	-
Cubic foot yield	300	20.3	423.3	1366.2	2411.85	3393.2	4260.8
	400	25.6	518.7	1790.9	3120.4	4217.3	5174.7
	500	50.0	579.4	1950.6	3421.1	3881.5	4375.0
	600	56.1	765.5	2144.4	3382.7	3631.1	-
Observations	300	17	49	63	71	44	18
	400	16	55	62	77	41	19
	500	23	63	72	72	23	9
	600	43	81	85	39	4	-

Table 9. Periodic annual diameter, height, basal area and cubic foot volume growth (PAI) by age and trees per acre classes for loblolly pine plantations in East Texas.

Measure	Trees per acre	AGE 5	10	15	20	25	30
Diameter	300	0.3	0.7	0.5	0.3	0.2	0.3
	400	0.4	0.7	0.4	0.2	0.2	0.1
	500	0.2	0.7	0.4	0.2	0.2	0.2
	600	0.4	0.6	0.3	2.5	0.2	-
Height	300	2.9	3.8	3.5	2.8	2.3	2.6
	400	3.1	4.0	3.7	2.7	2.1	2.0
	500	2.9	4.1	3.5	2.8	1.9	1.4
	600	3.4	4.5	3.3	2.5	1.8	-
Basal area	300	3.4	7.1	7.8	5.2	4.0	2.6
	400	4.2	9.6	9.6	5.9	4.4	2.4
	500	5.2	11.6	10.0	5.9	3.9	3.1
	600	6.0	13.2	9.7	5.3	4.9	-
Cubic foot volume (wood & bar)	300	75.8	106.8	215.0	221.9	224.5	204.0
	400	89.6	145.8	277.1	268.9	251.9	215.4
	500	130.4	174.2	284.9	286.4	203.3	182.3
	600	153.3	208.8	281.3	263.9	237.8	-
Cubic foot volume (wood only)	300	61.8	81.2	178.4	194.5	204.5	192.0
	400	72.7	111.3	230.2	236.3	228.0	202.0
	500	108.0	132.6	235.6	252.3	181.9	165.1
	600	127.5	159.6	232.6	232.0	211.2	-
Observations	300	17	49	63	66	36	7
	400	16	55	62	74	38	13
	500	23	63	72	70	20	8
	600	43	81	84	38	4	-

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

Measure	Average annual growth
Diameter	0.4
Height	3.3
Basal area	4.5
Cubic foot volume	72.4
Cubic foot volume wood bark	97.7
Cubic foot volume - Yield	1557.7

Diameter = quadratic mean diameter in inches
Height = average height of 10 tallest trees in area
Basal area = square foot per acre
Cubic foot volume = total stem cubic feet wood without bark per acre
Cubic foot volume wood bark = total stem cubic foot wood and bark per acre
Cubic foot volume - Yield
Average annual growth values based on 475 observations

Table 11. Mean annual diameter, height, basal area and cubic foot volume growth (MAI) and yield by site index, trees per acre and age classes for slash pine plantations in East Texas.

	Average annual growth						
	Diameter (in.)	Height (ft)	Basal area (sq.ft)	Cubic foot volume (wood bark)	Cubic foot volume (wood only)	Yield (cubic foot vol wood & bark)	Observations
Site Index (ft)							
50	0.2	1.9	1.1	16.1	11.2	284.0	26
60	0.4	2.8	3.1	51.6	36.5	804.5	44
70	0.4	3.2	4.3	91.1	67.2	1524.3	158
80	0.5	3.5	5.2	124.5	93.5	2066.8	177
90	0.5	4.1	5.5	104.4	75.7	1292.7	70
Trees per acre							
300	0.4	3.2	3.5	86.1	65.3	1546.2	252
400	0.5	3.5	5.4	117.2	86.6	1783.3	86
500	0.4	3.5	5.7	114.5	83.2	1635.8	65
600	0.4	3.5	6.0	100.0	70.4	1257.7	72
Age							
5	0.4	3.4	1.8	13.8	8.2	63.4	46
10	0.5	3.4	4.4	57.1	38.3	476.2	114
15	0.5	3.4	5.6	114.7	83.5	1515.3	131
20	0.4	3.3	5.0	135.2	103.0	2452.5	111
25	0.4	3.0	4.2	130.3	102.0	2870.9	60
30	0.4	2.9	2.9	108.9	88.2	3054.2	13

Table 12. Periodic annual diameter, height, basal area and cubic foot volume growth (PAI) by site index, trees per acre and age classes for slash pine plantations in East Texas.

	Average annual growth					
	Diameter (in.)	Height (ft)	Basal area (sq.ft)	Cubic foot volume (wood & bark)	Cubic foot volume (wood only)	Observations
Site Index (ft)						
50	0.4	2.5	2.7	58.0	42.8	26
60	0.4	2.6	3.8	81.5	60.2	44
70	0.4	2.8	4.7	146.6	114.2	158
80	0.4	3.3	5.0	191.6	153.2	177
90	0.5	4.4	6.7	186.3	142.5	70
Trees per acre						
300	0.4	3.0	3.0	121.8	98.9	252
400	0.4	3.4	6.3	198.6	154.9	86
500	0.4	3.3	6.7	196.5	150.5	65
600	0.4	3.6	8.5	203.7	151.1	72
Age						
5	0.4	3.5	3.5	70.9	52.8	46
10	0.6	3.9	7.5	121.0	83.9	114
15	0.4	3.4	6.5	207.8	159.5	131
20	0.3	2.9	3.3	190.9	157.7	111
25	0.3	2.1	2.2	159.9	137.2	60
30	0.2	1.8	-2.1	12.2	21.8	13

Table 13. Mean annual diameter, height, basal area and cubic foot volume growth (MAI) and yield by age and site index classes for slash pine plantations in East Texas.

Measure	Site index (ft)	AGE					
		5	10	15	20	25	30
Diameter	50	0.2	0.1	0.3	0.3	0.3	-
	60	0.3	0.4	0.4	0.3	0.3	0.3
	70	0.3	0.5	0.5	0.4	0.4	0.4
	80	0.4	0.5	0.5	0.4	0.4	0.4
	90	0.4	0.6	0.5	0.5	0.4	0.4
Height	50	2.2	1.4	2.0	2.1	2.0	-
	60	2.6	2.8	2.9	2.8	2.6	2.2
	70	2.9	3.2	3.3	3.1	3.0	2.7
	80	3.4	3.7	3.7	3.5	3.2	3.1
	90	4.0	4.2	4.1	3.9	3.9	3.4
Basal area	50	0.7	0.3	1.2	1.6	1.7	-
	60	0.6	2.6	5.0	4.5	3.8	1.6
	70	1.3	3.8	5.1	4.8	4.1	3.0
	80	2.0	5.3	5.9	5.4	4.7	3.0
	90	2.4	6.2	7.9	6.3	4.9	3.6
Cubic foot volume (wood & bar)	50	4.0	1.9	13.1	26.5	33.6	-
	60	3.4	26.8	82.4	98.1	97.3	56.4
	70	8.6	45.3	97.3	123.9	122.1	105.5
	80	15.4	72.0	127.9	152.6	153.2	118.3
	90	19.7	91.2	180.8	200.4	193.0	147.5
Cubic foot volume (wood only)	50	2.2	1.1	8.6	18.7	24.5	-
	60	1.9	17.0	57.2	71.6	73.6	45.7
	70	5.0	29.8	69.9	93.6	94.9	84.7
	80	9.1	48.5	93.8	117.0	120.9	96.7
	90	11.9	62.4	133.5	156.8	156.1	120.7
Cubic foot Yield	50	19.8	15.9	175.3	482.4	738	-
	60	15.0	217.4	1086.6	1753.7	2104.4	1859.9
	70	40.8	385.3	1300.7	2281.0	2670.8	2975.7
	80	75.6	603.7	1706.2	2747.7	3388.0	3257.6
	90	88.7	745.6	2309.6	3652.3	4439.5	3983.6
Observations	50	2	6	8	6	4	-
	60	7	17	8	6	5	1
	70	9	34	49	38	21	7
	80	6	36	46	56	29	4
	90	22	21	20	5	1	1

Table 14. Periodic annual diameter, height, basal area and cubic foot volume growth (PAI) by age and site index classes for slash pine plantations in East Texas.

Measure	Site index (ft)	AGE 5	10	15	20	25	30
Diameter	50	0.2	0.4	0.4	0.3	0.3	-
	60	0.3	0.5	0.4	0.3	0.2	0.2
	70	0.3	0.6	0.4	0.3	0.3	0.3
	80	0.4	0.7	0.4	0.3	0.3	0.3
	90	0.5	0.7	0.4	0.3	0.3	0.2
Height	50	2.2	2.7	2.9	1.9	2.3	-
	60	2.8	3.0	2.8	1.9	1.5	0.5
	70	3.1	3.6	3.1	2.6	1.4	1.9
	80	3.4	4.2	3.5	3.1	2.5	2.3
	90	4.0	4.7	4.3	4.8	8.0	0.5
Basal area	50	0.7	3.2	2.9	2.8	2.2	-
	60	1.8	4.1	7.0	3.8	1.3	-1
	70	5.0	6.8	6.3	3.2	2.2	-1
	80	3.4	9.1	6.4	3.3	2.6	-4.5
	90	3.6	10	8.7	3.1	-4.1	-3.5
Cubic foot volume (wood & bar)	50	4.0	75.9	40.6	62.4	86.1	-
	60	55.5	48.2	156	138.1	64.7	-21.7
	70	136.9	98.2	181.2	173.0	124.4	76.5
	80	103.0	151.5	223.2	211.4	206.3	-60.3
	90	46.1	177.7	352.0	315.5	332.7	-114
Cubic foot volume (wood only)	50	2.2	57.0	27.5	46.2	66.9	-
	60	44.0	31.5	113.1	107.9	53.4	-13.1
	70	104.1	67.0	137.1	141.5	105.9	73.7
	80	80.6	105.3	173.3	175.9	177.8	-34.1
	90	31.6	124.8	253.7	271.4	315.2	-83.1
Observations	50	2	6	8	6	4	-
	60	7	17	8	6	5	1
	70	9	34	49	38	21	7
	80	6	36	46	56	29	4
	90	22	21	20	5	1	1

Table 15. Mean annual diameter, height, basal area and cubic foot volume growth (MAI) and yield by site index and trees per acre classes for slash pine plantations in East Texas.

Measure	Trees per acre	Site Index				
		50	60	70	80	90
Diameter	300	0.3	0.4	0.4	0.5	0.5
	400	0.1	0.3	0.4	0.5	0.5
	500	-	0.4	0.3	0.5	0.5
	600	0.3	0.3	0.4	0.5	0.4
Height	300	1.9	2.7	3.1	3.5	4.0
	400	1.0	2.8	3.2	3.6	4.1
	500	-	2.8	3.1	3.6	4.0
	600	2.4	2.9	3.2	3.6	4.1
Basal area	300	1.1	2.0	3.6	4.2	5.2
	400	0.1	2.3	4.6	6.1	5.7
	500	-	3.5	4.2	7.2	6.0
	600	1.4	6.1	6.4	6.9	4.9
Cubic foot volume (wood & bar)	300	17.1	35.0	82.2	112.2	132.3
	400	0.6	35.6	94.6	143.3	109.6
	500	-	53.6	93.2	159.2	106.2
	600	7.5	99.5	115.8	104.5	79.7
Cubic foot volume (wood only)	300	11.9	25.3	61.8	86.0	101.5
	400	0.3	24.5	69.1	107.1	79.2
	500	-	37.2	68.5	117.2	75.6
	600	4.1	69.3	82.5	71.9	56.1
Cubic foot yield	300	305.9	612.4	1472.7	2044.3	2199.2
	400	4.5	520.3	1547.7	2311.3	1233.4
	500	-	753.8	1614.7	2340.3	1209.4
	600	37.3	1456.5	1617.0	1101.2	835.9
Observations	300	24	24	90	101	13
	400	1	3	24	40	18
	500	-	8	16	22	19
	600	1	9	28	14	20

Table 16. Periodic annual diameter, height, basal area and cubic foot volume growth (PAI) by site index and trees per acre classes for slash pine plantations in East Texas.

Measure	Trees per acre	Site Index				
		50	60	70	80	90
Diameter	300	0.3	0.4	0.4	0.4	0.4
	400	0.6	0.4	0.3	0.4	0.5
	500	-	0.4	0.3	0.4	0.5
	600	0.3	0.3	0.4	0.5	0.5
Height	300	2.4	2.4	2.7	3.3	4.8
	400	4.4	2.9	2.9	3.3	4.2
	500	-	2.6	2.9	3.2	4.2
	600	2.4	2.9	3.1	3.8	4.4
Basal area	300	2.6	1.8	3.4	3.1	2.8
	400	5.8	3.3	5.5	6.5	7.4
	500	-	5.2	4.4	7.5	8.2
	600	1.4	8.1	8.6	10.4	7.4
Cubic foot volume (wood & bar)	300	55.1	37.6	116.7	153.6	188.9
	400	176.8	55.2	166.1	231.0	195.1
	500	-	97.8	155.4	263.5	195.1
	600	7.5	192.9	221.1	240.4	168.3
Cubic foot volume (wood only)	300	40.4	28.5	93.4	126.7	159.1
	400	137.9	39.0	128.4	183.2	147.7
	500	-	70.6	120.9	205.8	145.1
	600	4.1	142.6	165.4	176.4	124.7
Observations	300	24	24	90	101	13
	400	1	3	24	40	18
	500	-	8	16	22	19
	600	1	9	28	14	20

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

Measure	Trees per acre	AGE					
		5	10	15	20	25	30
Diameter	300	0.3	0.5	0.5	0.4	0.4	0.4
	400	0.4	0.5	0.5	0.4	0.4	0.3
	500	0.4	0.5	0.4	0.4	0.4	-
	600	0.4	0.5	0.4	0.3	0.3	-
Height	300	2.7	3.2	3.2	3.3	3.0	2.9
	400	3.6	3.5	3.7	3.3	3.1	2.8
	500	3.5	3.6	3.6	3.3	3.1	-
	600	3.6	3.5	3.5	3.1	2.9	-
Basal area	300	0.5	2.7	3.8	4.1	3.7	2.8
	400	1.9	4.5	6.5	6.1	6.1	4.8
	500	1.9	5.3	6.9	7.2	6.9	-
	600	2.2	6.5	8.5	8.3	7.6	-
Cubic foot volume (wood & bar)	300	2.9	35.4	75.8	112.2	114.5	104.2
	400	15.3	60.3	139.1	169.6	186.0	165.2
	500	14.7	72.1	146.3	194.5	210.9	-
	600	16.5	81.1	174.2	208.6	206.6	-
Cubic foot volume (wood only)	300	1.6	23.9	55.2	85.9	90.2	84.6
	400	9.2	40.6	101.9	129.2	144.1	130.8
	500	8.8	48.6	106.3	147.1	162.8	-
	600	9.8	53.7	125.7	154.8	156.5	-
Cubic foot yield	300	12.2	302	1004.2	2037.2	2552.1	2923.2
	400	70.6	493.1	1804.3	3110.9	4004.8	4626.3
	500	69.8	612.9	1936.0	3491.1	4517.6	-
	600	74.9	660.2	2340.2	3750.1	4339.1	-
Observation	300	7	46	63	76	48	12
	400	9	21	31	16	8	1
	500	10	21	18	14	2	-
	600	20	26	19	5	2	-

Table 18. Periodic annual diameter, height, basal area and cubic foot volume growth (PAI) by age and trees per acre classes for slash pine plantations in East Texas.

Measure	Trees per acre	AGE					
		5	10	15	20	25	30
Diameter	300	0.3	0.6	0.4	0.3	0.3	0.3
	400	0.5	0.6	0.4	0.2	0.3	0.2
	500	0.4	0.6	0.3	0.2	0.2	-
	600	0.4	0.6	0.3	0.2	0.2	-
Height	300	2.8	3.9	3.2	3.0	2.0	1.7
	400	3.7	3.9	3.6	2.4	2.7	3.0
	500	3.6	4.0	3.3	2.5	1.5	-
	600	3.6	3.7	3.6	3.4	2.3	-
Basal area	300	1.4	4.8	4.6	2.6	1.4	-2.4
	400	3.4	7.8	7.7	3.6	6.0	2.3
	500	3.9	8.6	7.9	4.8	2.5	-
	600	4.0	11.2	9.9	7.7	5.7	-
Cubic foot volume (wood & bar)	300	39.9	79.1	138.6	161.3	122.3	-6.5
	400	58.6	129.3	244.3	207.6	338.4	237.1
	500	77.6	148.2	266.2	262.5	209.9	-
	600	83.9	166.7	322.4	386.4	297.5	-
Cubic foot volume (wood only)	300	31.4	55.4	106.5	134.7	106.9	6.2
	400	42.0	90.3	188.3	171.5	281.9	208.9
	500	57.7	103.4	204.8	213.6	179.2	-
	600	62.7	113.6	245.0	306.8	243.0	-
Observations	300	7	46	63	76	48	12
	400	9	21	31	16	8	1
	500	10	21	18	14	2	-
	600	20	26	19	5	2	-

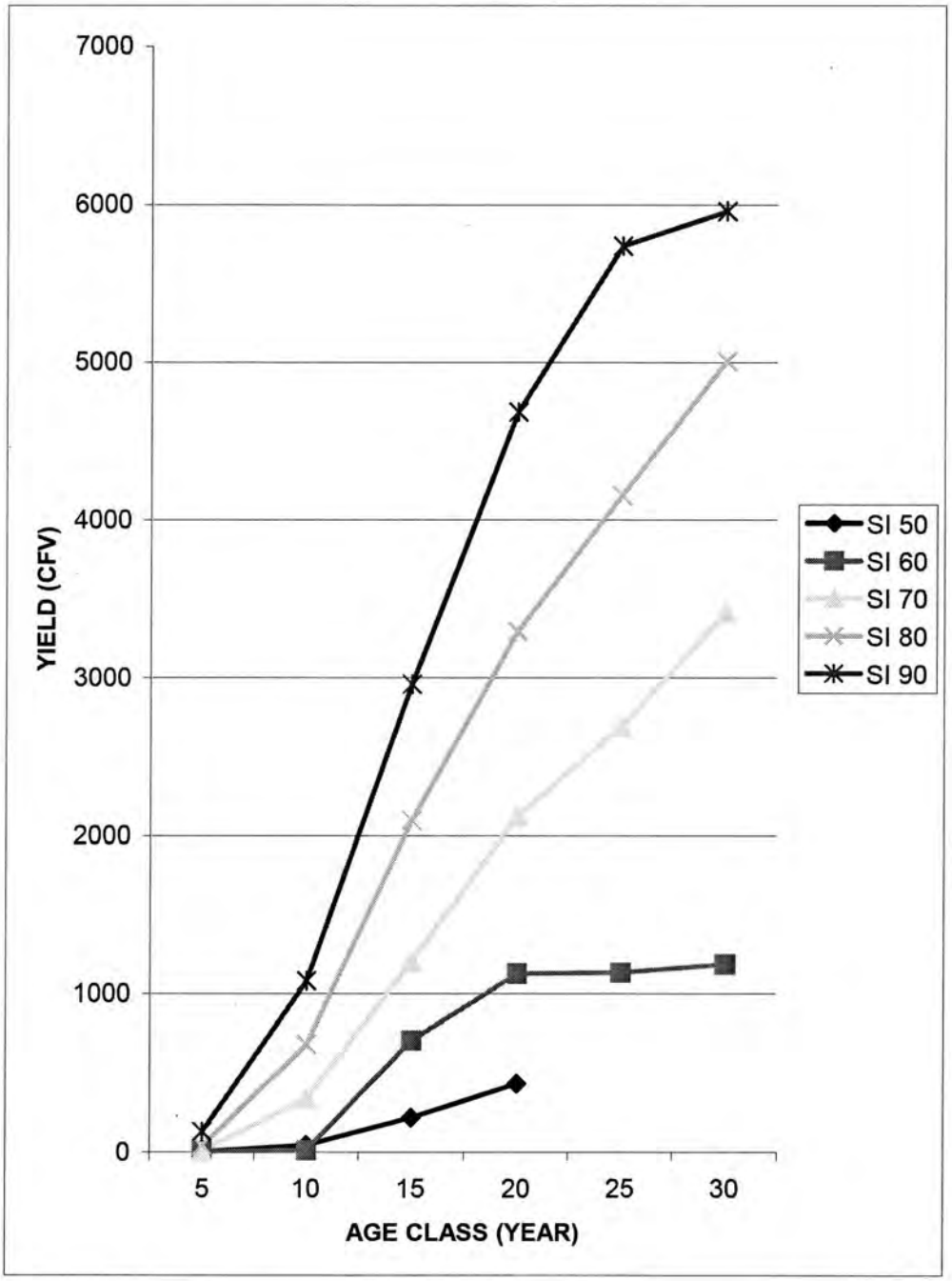

Figure 1. Observed yield (cubic foot volume per acre wood and bark) by age and site index classes for loblolly pine plantations in East Texas.

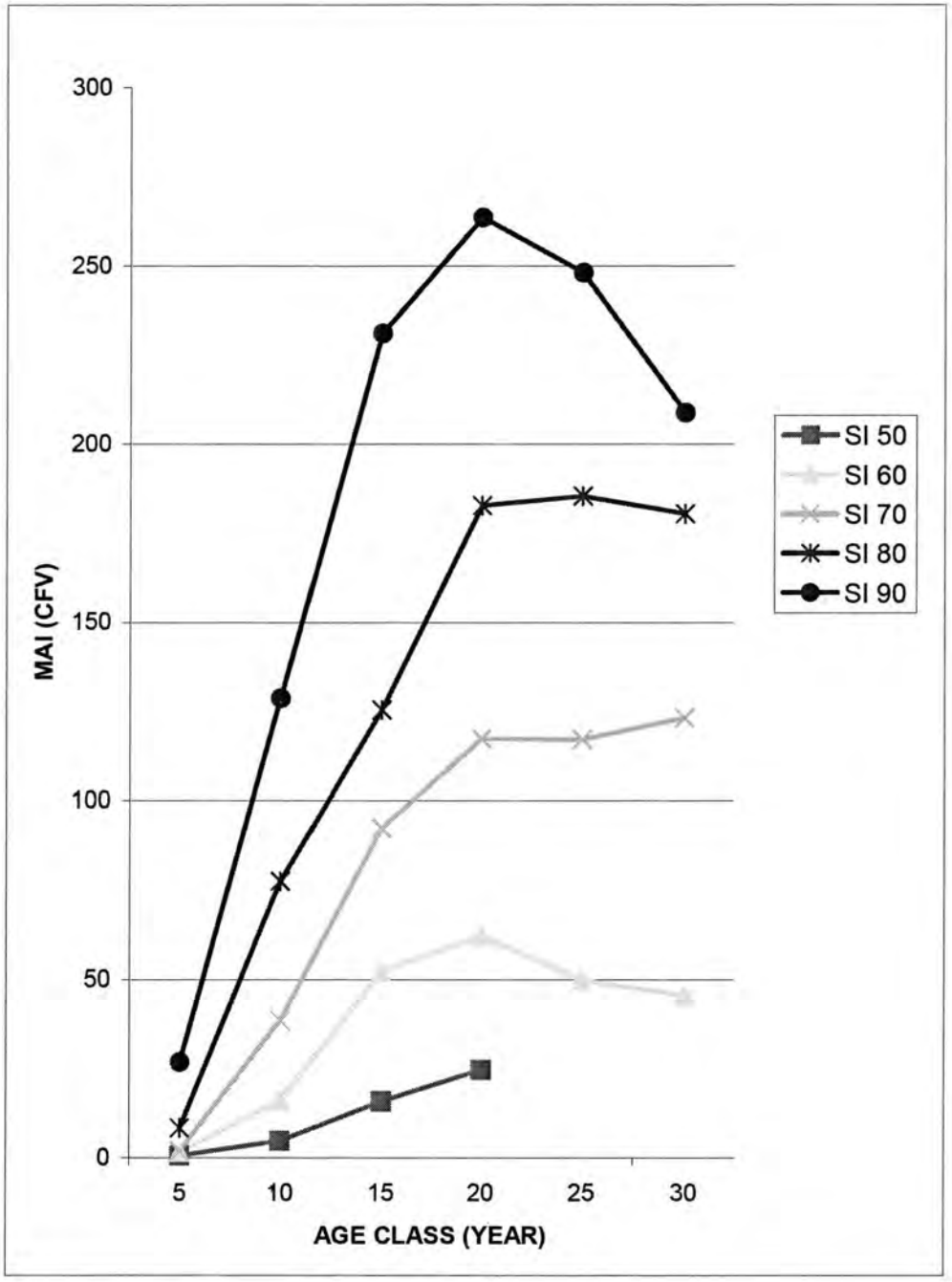

Figure 2. Observed mean annual volume growth (MAI, cubic foot volume per acre wood and bark) by age and site index classes for loblolly pine plantations in East Texas.

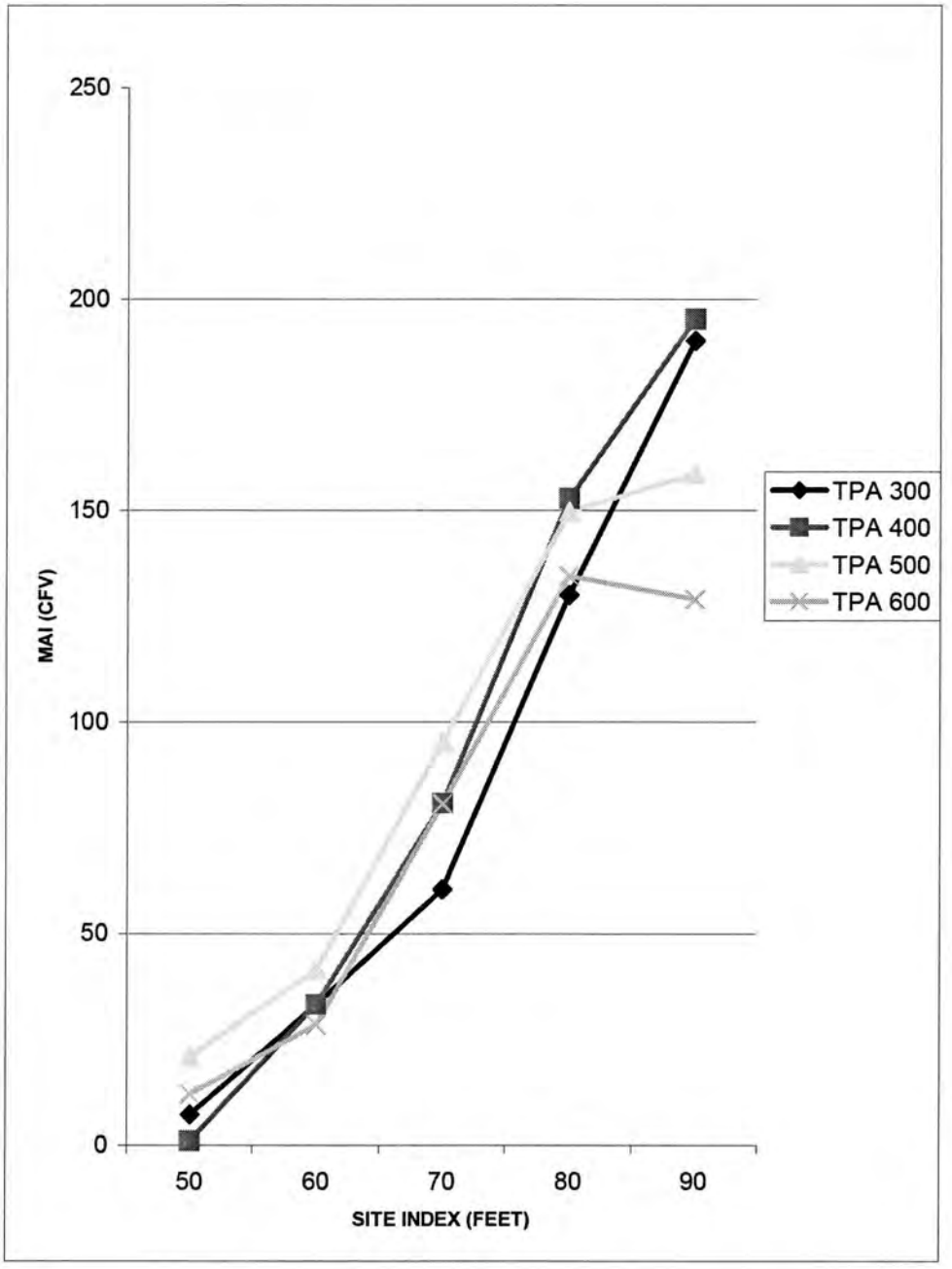

Figure 3. Observed mean annual volume growth (MAI, cubic foot volume per acre wood and bark) by site index and trees per acre classes for loblolly pine plantations in East Texas.

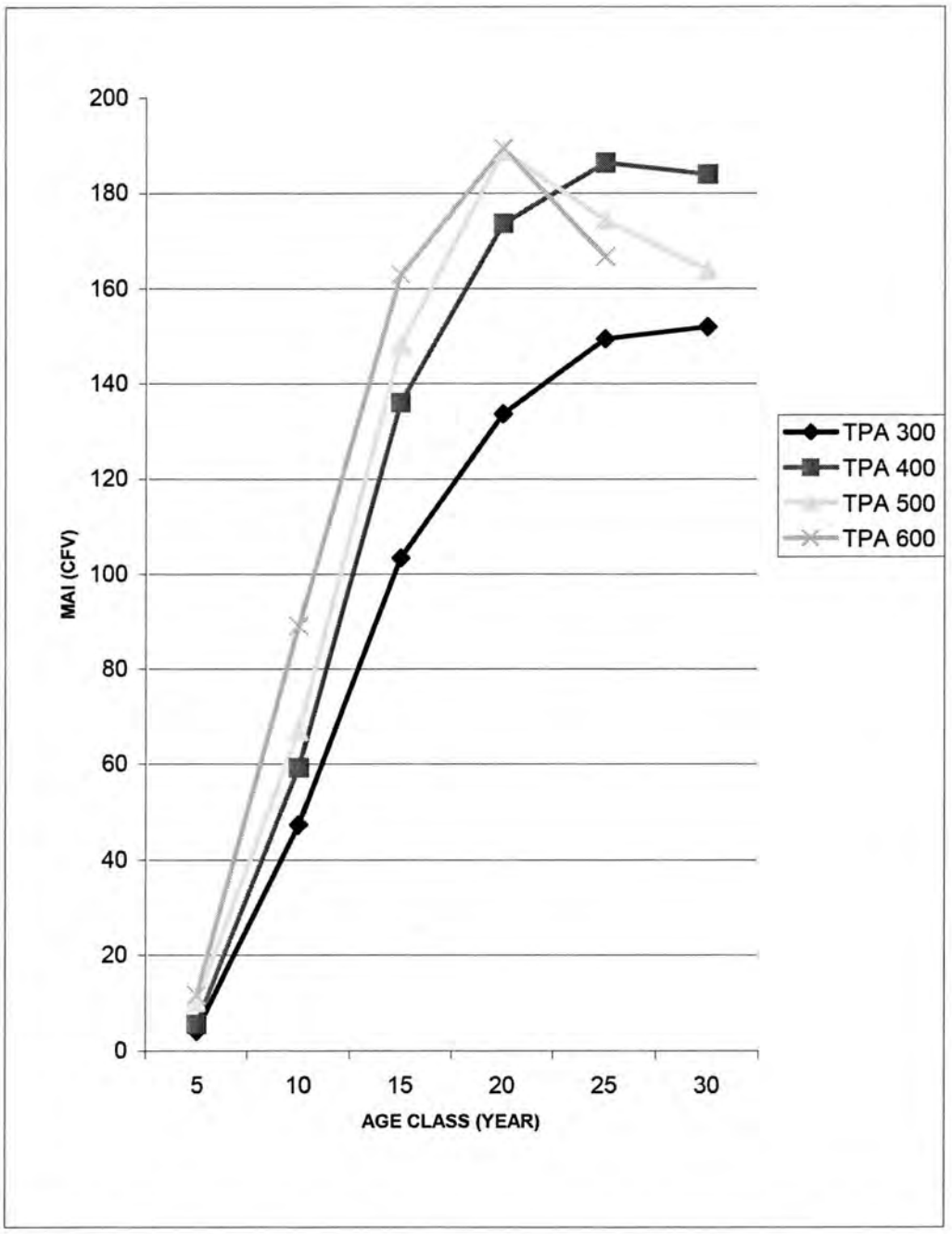

Figure 4. Observed mean annual volume growth (MAI, cubic foot volume per acre wood and bark) by age and trees per acre classes for loblolly pine plantations in East Texas.

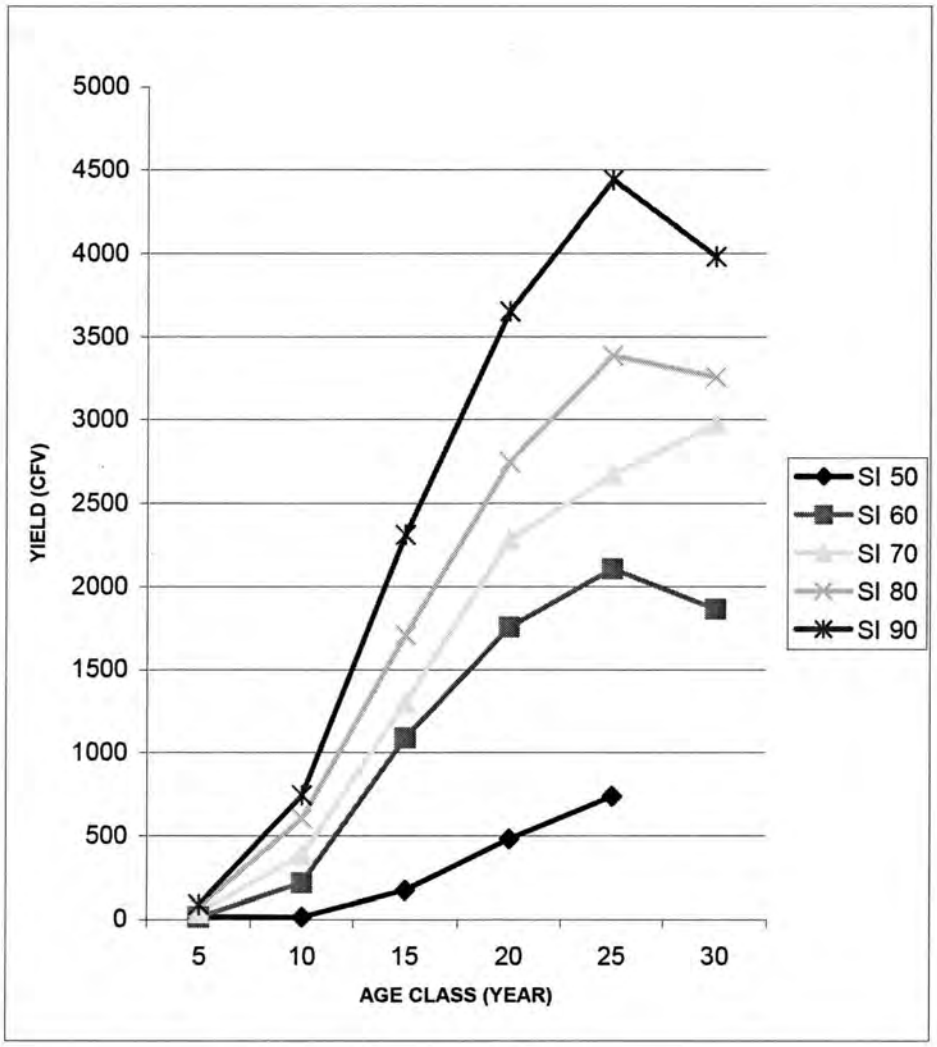

Figure 5. Observed yield (cubic foot volume per acre wood and bark) by age and site index classes for slash pine plantations in East Texas.

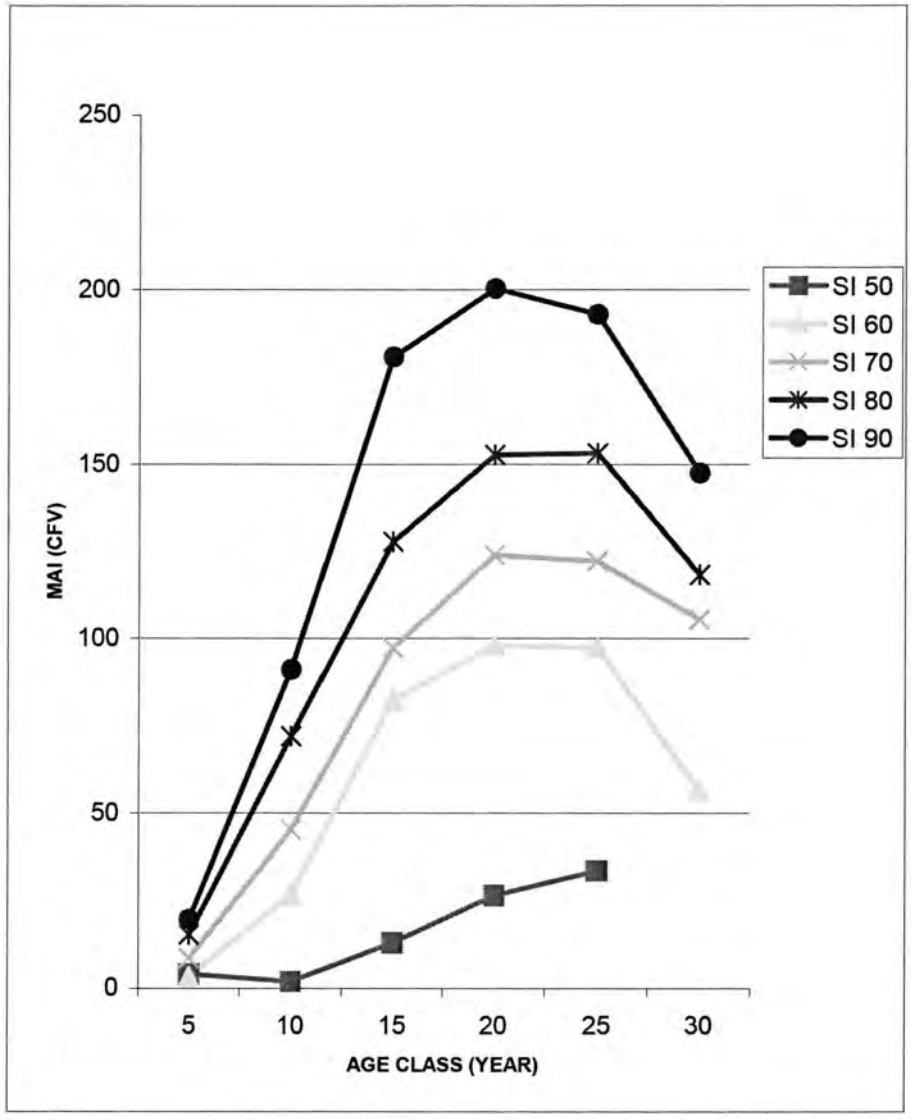

Figure 6. Observed mean annual volume growth (MAI, cubic foot volume per acre wood and bark) by age and site index classes for slash pine plantations in East Texas.

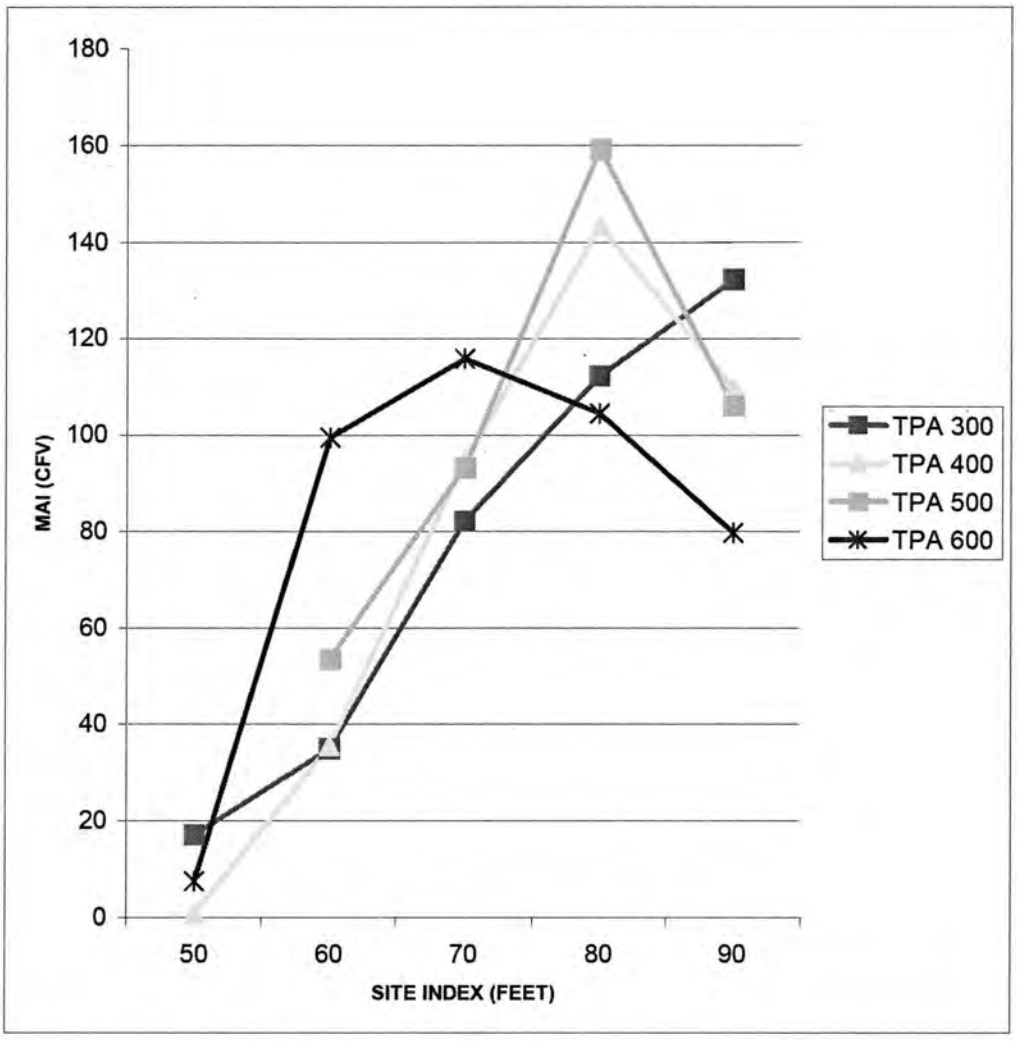

Figure 7. Observed mean annual volume growth (MAI, cubic foot volume per acre wood and bark) by site index and trees per acre classes for slash pine plantations in East Texas.

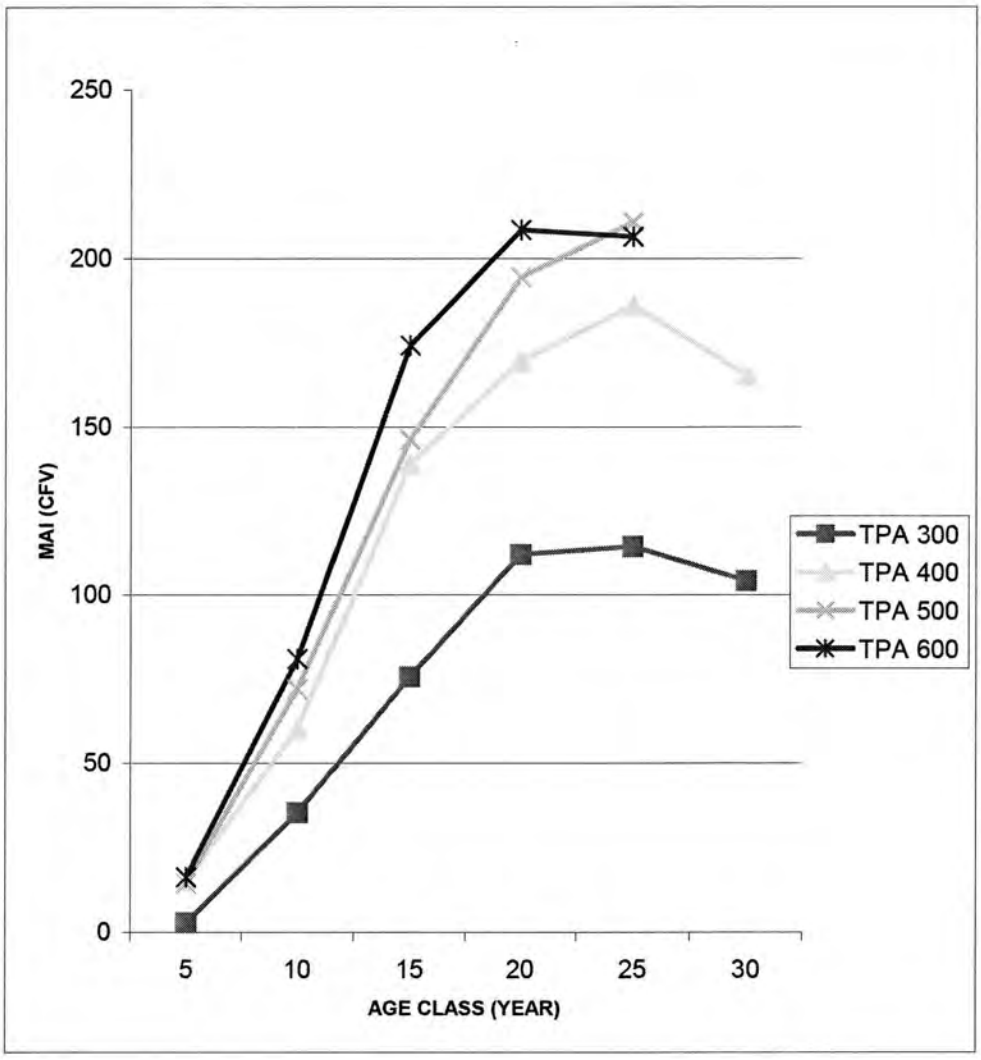

Figure 8. Observed mean annual volume growth (MAI, cubic foot volume per acre wood and bark) by age and trees per acre classes for slash pine plantations in East Texas.