Models for Unfertilized and Fertilized Slash Pine Plantations:

CRIFF B400 and B500 Series

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Summary

In 1996 we presented a set of models for predicting surviving numbers of trees, basal area and dominant height growth in slash pine plantations following fertilization (Bailey, Martin and Jokela, 1996). Those models were fit with data from the CRIFF V100, B300 and B400 studies. In the time since that report, additional CRIFF B400 and B500 series data became available.' Using only the B400 and B500 data for CRIFF soil groups B, C, and D we now introduce a revised system of models that predicts surviving numbers of trees, basal area, dominant height and a diameter distribution based on the Weibull model.

'Thanks to Hank Page and James E. Allen of JSC Container Corporation for compiling and organizing these additional data.

These stand-level models are based on data from the University of Florida CRIFF Cooperative Research Program. Cooperating companies in the program were:

Champion International Corp.
JSC/Container Corp of America
Georgia-Pacific Corp. Gilman Paper Co.
International Paper Co. ITT Rayonier, Inc.
Packaging Corp. of America Procter and
Gamble Cellulose Co. St. Joseph Land and
Development Co. Union Camp Corp.

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Introduction

The Cooperative Research in Forest Fertilization program (CRIFF) at the University of Florida established an extensive, uniform mid-rotation fertilizer trial series (B400's) throughout the lower Coastal Plain of the southeastern United States. The objective of this experiment was to assess fertilizer responses across a range of soil conditions. Hence the study design called for the installation of a large number of individual tests (n=476) replicated on a variety of soil types. Considerable effort went into site selection to ensure the best possible estimate of growth response from the 1 or 2 treatment replicates at each site. These plantations, located primarily in Florida and Georgia, were unthinned and fertilized between the ages of 9 and 15 years. The stand contained a minimum of 300 stems/ac. The fertilizer treatments applied (control, 150 lbs/ac elemental N, and 150 lbs/ac elemental N and 50 lbs/ac elemental P) reflected standard prescriptions for this species.

Pre-treatment site conditions were well documented using soil descriptions along with extensive soil and foliar chemical analyses. The CRIFF program has delineated eight forest soil groups based on soil drainage, texture and the depth to the B horizon. Of these, slash pine plantations are commonly established on four types (CRIFF Soil Groups A, B, C, D) in Flatwoods, broadly spanning very poorly drained to moderately well drained soils classified as Ultisols, Spodosols and Inceptisols. The A and B group soils are commonly associated with wet mineral flats and prairies. They developed in slack water deposits and are commonly fine textured and acutely phosphorus deficient (e.g., Palcaquults, Haplaquults, and Humaquept Great Groups). The C and D group soils developed on coarse textured sediments low in weatherable minerals (e.g. Haplaquod and Haplahumod Great Group).

In the current study, analyses and model development were restricted to slash pine plantations occurring on B, C, and D group soils only. None of the test sites received fertilizer applications previously. No experimental installations were established on A group largely because these site types received P fertilization at-time-of-planting. Limited replications of the experiment were installed on CRIFF E and F group soils (moderately well drained to well drained soils); however, they were not included in the final analyses because these well drained soils contributed to inconsistent model behavior, and loblolly pine is often the preferred species for these soils.

Study Description

The data used for model development came from the CRIFF B400 and B500 series studies. Data from a total of 243 permanent sample plots, remeasured 2 to 6 times over 2 year intervals, were used for the analysis (Table 1). Plot size ranged from 0.063 to 0.138 acres, with a mean of 0.0934 acres. Sample plots were located in 3 different soil types:

B soil subgroup Arenic Paleaquult
C soil subgroup Ultic Haplaquod, and
D soil subgroup Grossarenic Haplaquod.

Each plot was given one of the following treatments:

1. No fertilizer,
2. Nitrogen only (150 #N/ac),
3. Nitrogen and Phosphorus (150# N/ac plus 50 #P/ac).

Treatment age ranged from 9 to 15 with a median of around 12 years. Site index (base age 25) as indicated from initial age and dominant height ranged from 43 to 78 ft with 76% of the plots between 50 and 70 ft. Stand density ranged from 303 to 795 trees per acre.

Table 1: Number of plots in slash pine plantations by initial age, trees per acre and site index (base-age-25).

Table 1 a. Soil Group B

		Site Index					
Age	Trees/acre	< 40	40-49	50-59	60-69	70-79	TOTAL
	<=300						0
	301-400						0
9	401-500				3		3
	501-600				5	1	6
	>600			5	1		6
	TOTAL	0	0	5	9	1	15
	<-300						0
	301-400						0
10	401-500				1	3	4
	501-600				7		7
	>600				1		1
	TOTAL	0	0	0	9	3	12
	<-300						0
	301-400						0
11	401 -500						0
	501-600			8	10	3	21
	>600						0
	TOTAL	0	0	8	10	3	21
	<-300						0
	301-400		1	2	3		6
12	401-500				5	3	8
	501-600			2	5		7
	>600		6	3			9
	TOTAL	0	7	7	13	3	30
	<-300						0
	301-400						0
13	401-500			7	2		9
	501-600						0
	>600		1	8	1	2	12
	TOTAL	0	1	15	3	2	21
	<=300						0
	301-400						0
15	401-500						0
	501-600						0
	>600		1	2			3
	TOTAL	0	1	2	0	0	3
	TOTALS	0	9	37	44	12	102

Table 1 b. Soil Group G

		Site Index					
Age	Trees/acre	< 40	40-49	50-59	60-69	70-79	TOTAL
	<=300						0
	301-400						0
9	401-500			2			2
	501-600			1	4		5
	>600				2		2
	TOTAL	0	0	3	6		9
	<=300						0
	301-400.						0
10	401-500				2		2
	501-600				6	1	7
	>600						0
	TOTAL	0	0	0	8	1	9
	<=300						0
	301-400					2	2
11	401-500			1	1	1	3
	501-600			4	2		6
	>600		4	2	1		7
	TOTAL	0	4	7	4	3	18
	<=300						0
	301-400					4	4
12	401-500			2	8	1	11
	501-600						0
	>600		4	2			6
	TOTAL	0	4	4	8	5	21
	<=300						0
	301-400					3	3
13	401-500			1	3	2	6
	501-600				1		1
	>600			1	1		2
	TOTAL	0	0	2	5	5	12
	<=300						0
	301-400						0
14	401-500			3			3
	501-600						0
	>600						0
	TOTAL	0	0	3	0	0	3
	TOTALS	0	8	19	31	14	72

Table 1c. Soil Group D

		Site Index					
Age	Trees/acre	< 40	40-49	50-59	60-69	70-79	TOTAL
	<-300						0
	301-400						0
9	401-500		2		5	1	8
	501-600		1		3		4
	>600						0
	TOTAL	0	3	0	8	1	12
	<=300						0
	301-400						0
10	401-500			1	7		8
	501-600			5	2		7
	>600						0
	TOTAL	0	0	6	9	0	15
	<=300						0
	301-400				1		1
12	401-500				2		2
	501-600			6			6
	>600						0
	TOTAL	0	0	6	3	0	9
	<=300						0
	301-400			1	6	3	10
13	401-500				13	6	19
	501-600				1	3	4
	>600						0
	TOTAL	0	0	1	20	12	33
	TOTALS	0	3	13	40	13	69

Notation

The following notation will be used to describe each model:

A_1 = age at time 1 (years),

A_2 = age at time 2 (years),

A_f = age at fertilization (years),

H_i = average dominant height at time i (ft),

T_1 = 1 if treatment is N only

0 otherwise,

T_2 = 1 if treatment is N and P

0 otherwise,

S_1 =1 if in soil group C
0 otherwise,

S_2 =1 if in soil group D
0 otherwise,

N_i =trees per acre at time i,

B_i =basal area per acre at time i (ft^2/ac),

S_r =relative spacing, and

n =number of observations.

Analysis Method

The following models were fit using a parameter estimation technique described by Borders (1989) for nonlinear recursive systems of equations. Where the sample size (n) is given, it represents all possible intervals for the projection models except for the survival model. Only the longest interval was used in that case.

Dominant height

Our dominant height model is based on the yield form of Richards' (1959) growth function. A difference formulation (i.e. height at age 2 is a function of height at age 1 and the two ages) represents the unfertilized base of the model. The fertilization response is represented by a difference formulation of a variant of the Pienaar and Rheney (1995) approach to incorporating responses to silvicultural practices. This model can be used to project dominant height between any two ages. The response term is:

$$R_H(A_i) = (0.375379\,T_1 + 0.652099\,T_2)(A_i - A_f)e^{-(A_i - A_f)(0.154525T_1 + 0.100104T_2)}. \quad (1)$$

Combining the response term with the unfertilized base projection model gives:

$$H_2 = \left[(H_1 - R_H(A_1))\left(\frac{1 - e^{-0.060175A_2}}{1 - e^{-0.060175A_1}}\right)^{1.435719}\right] + R_H(A_2). \quad \textbf{(2)}$$

n=2514 R^2=0.9488 $S_{y.x}$=2.58

Survival function

We made an interesting observation when attempting to model survival with the CRIFF B400 and B500 data; the plots experienced little to no mortality. In order to obtain significant parameter estimates, we used data from only the longest interval period on each plot. Soil group D appears to have a greater mortality rate then the other two soil groups.

$$N_2 = N_1 e^{(-0.00637875 - 0.00471268S_2)(A_2 - A_1)} \quad \textbf{(3)}$$

n=243 R^2=0.8957 $S_{y.x}$=37.12

Basal area prediction and projection

Trees per acre and basal area per acre, as measures. of stand density, are both necessary to predict stand yield. The PMRC slash pine basal area model (Pienaar, Shiver and Rheney 1996) was used to develop the unfertilized base of our basal area prediction and/or projection model. The fertilization response is a variant of the Pienaar and Rheney (1995) approach to incorporating responses to silvicultural practices. The fertilization response term is:

$$R_B(A_i) = (1.12915T_1 + 1.68711T_2)(A_i - A_f) \; e^{-(A_i - A_f)(0.09793T_1 + 0.073688T_2 - 0.046995T_1S_1 - 0.055385T_1S_2)} \quad (4)$$

Combining the response term with the unfertilized base prediction model gives:

$$B_i = \left[H_i^{1.281203 + \frac{3.164972}{A_i}}\right]\left[N_i^{0.671421 + \frac{0.58992}{A_i}}\right] e^{-\left\{4.761227 + \frac{12.22963}{A_i}\right\}} + R_B(A_i) \quad (5)$$

n=2514, R^2=0.9032 $S_{y.x}$=7.07

The difference form of the above equation is:

$$B_2 = \left\{B_1 - R_B(A_1)\right\}\left[\left(\frac{H_2}{H_1}\right)^{1.2812}\left(\frac{H_2^{A_2^{-1}}}{H_1^{A_1^{-1}}}\right)^{3.16497}\right]\left[\left(\frac{N_2}{N_1}\right)^{0.5899}\left(\frac{N_2^{A_2^{-1}}}{N_1^{A_1^{-1}}}\right)^{0.67142}\right] e^{-12.22963\left(\frac{1}{A_2} - \frac{1}{A_1}\right)} + R_B(A_2) \quad (6)$$

n=2514, R^2=0.9383 $S_{y.x}$=6.55

Weibull percentiles

Regression equations were developed for the minimum dbh on the plot, and the 25th, 50th, and 95th percentiles. The prediction equations for the 0th, 25th, and 95th percentiles are functions of the 50th percentile as well as whole stand parameters. The models and their associated statistics of fit are as follows:

$$P_{50} = e^{2.619345 + 0.516562 \ln(\frac{B_1}{N_1}) - 0.00195275 A_1 + 0.00040902 H_1 + 0.000023562 N_1} \quad (7)$$

n=2514 R^2=0.9813 $S_{y.x}$=0.1614,

$$P_0 = e^{2.005877 \ln(P_{50}) - 0.652511 \ln(H_1)} \quad (8)$$

n=2514 R^2=0.5820 $S_{y.x}$=0.6193,

$$P_{25} = e^{1.291074 + 1.368227 \ln(P_{50}) - 0.061538 \ln(B_1) - 0.424705 \ln(H_1) - 0.958279 S_r} \quad (9)$$

n=2514 R^2=0.9415 $S_{y.x}$=0.2370,

$$P_{95} = e^{5.2263 - 2.15752 \ln(P_{50}) + 1.503134 \ln(\frac{B_1}{N_1}) - 0.00535425 H_1 + 0.122184 \ln(N_1) + 0.616857 \ln(H_1) + 1.07974 S_r} \quad (10)$$

n=2514 R^2=0.9639 $S_{y.x}$=0.2791.

The parameter recovery technique presented by Bailey, Burgan and Jokela (1989) will produce Wiebull parameters given basal area, trees per acre and the above four percentiles.

Conclusion

It is a common silvicultural practice in the southeastern U. S. Coastal Plain to fertilize slash pine plantations with N or N plus P. This report presents a system of equations that incorporates the effects of fertilization on stand structure by soil type to predict survival, basal area, dominant height and a diameter distribution based on the Weibull model. In the next phase of this study we will develop a stand table projection model so that an initial diameter distribution (or tree list) can be the input to the system of models.

References

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Pienaar, L. V. and J. W. Rheney. 1995. Modeling stand level growth and yield response to silvicultural treatments. For Sci 41(3) 629-638.

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Richards, F. J. 1959. A flexible growth function for empirical use. Jour of Exp Botany 10:290-300.

APPENDIX A 12

Figure A1. Average dominant height over age for site indices of 50 and 70 feet and the three treatments.

Figure A2. Basal area per acre over age for site indices of 50 and 70 feet, the three treatments, and age 12 trees per acre of 350 in soil group B.

Figure A3. Basal area per acre over age for site indices of 50 and 70 feet, the three treatments, and age 12 trees per acre of 350 in soil group C.

Figure A4. Basal area per acre over age for site indices of 50 and 70 feet, the three treatments, and age 12 trees per acre of 350 in soil group D.

Figure A5. Per acre total stem wood volume over age for site indices of 50 and 70 feet and the three treatments in soil group B.

Figure A6. Per acre total stem wood volume over age for site indices of 50 and 70 feet and the three treatments in soil group C.

Figure A7. Per acre total stem wood volume over age for site indices of 50 and 70 feet and the three treatments in soil group D.

Table Al. Results from 1997 analysis of Florida CRIFF data for fertilized slash pine plantations.

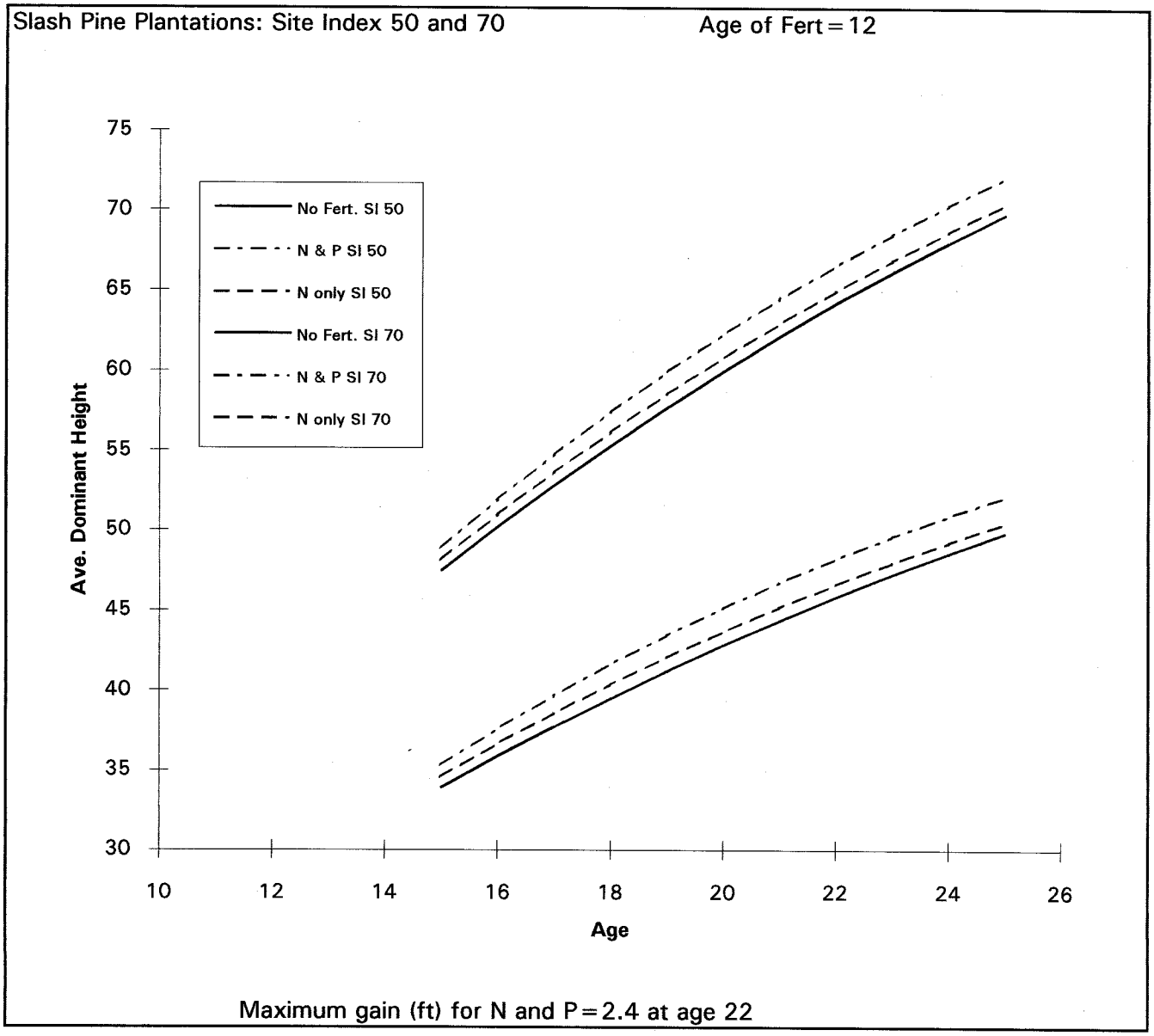
Slash Pine Plantations: Site Index 50 and 70
Age of Fert = 12
No Fert. SI 50
N & P SI 50
N only SI 50
No Fert. SI 70
N & P SI 70
N only SI 70
Ave. Dominant Height
75
70
65
60
55
50
45
40
35
30
10
12
14
16
18
20
22
24
26
Age
Maximum gain (ft) for N and P = 2.4 at age 22

Figure A1

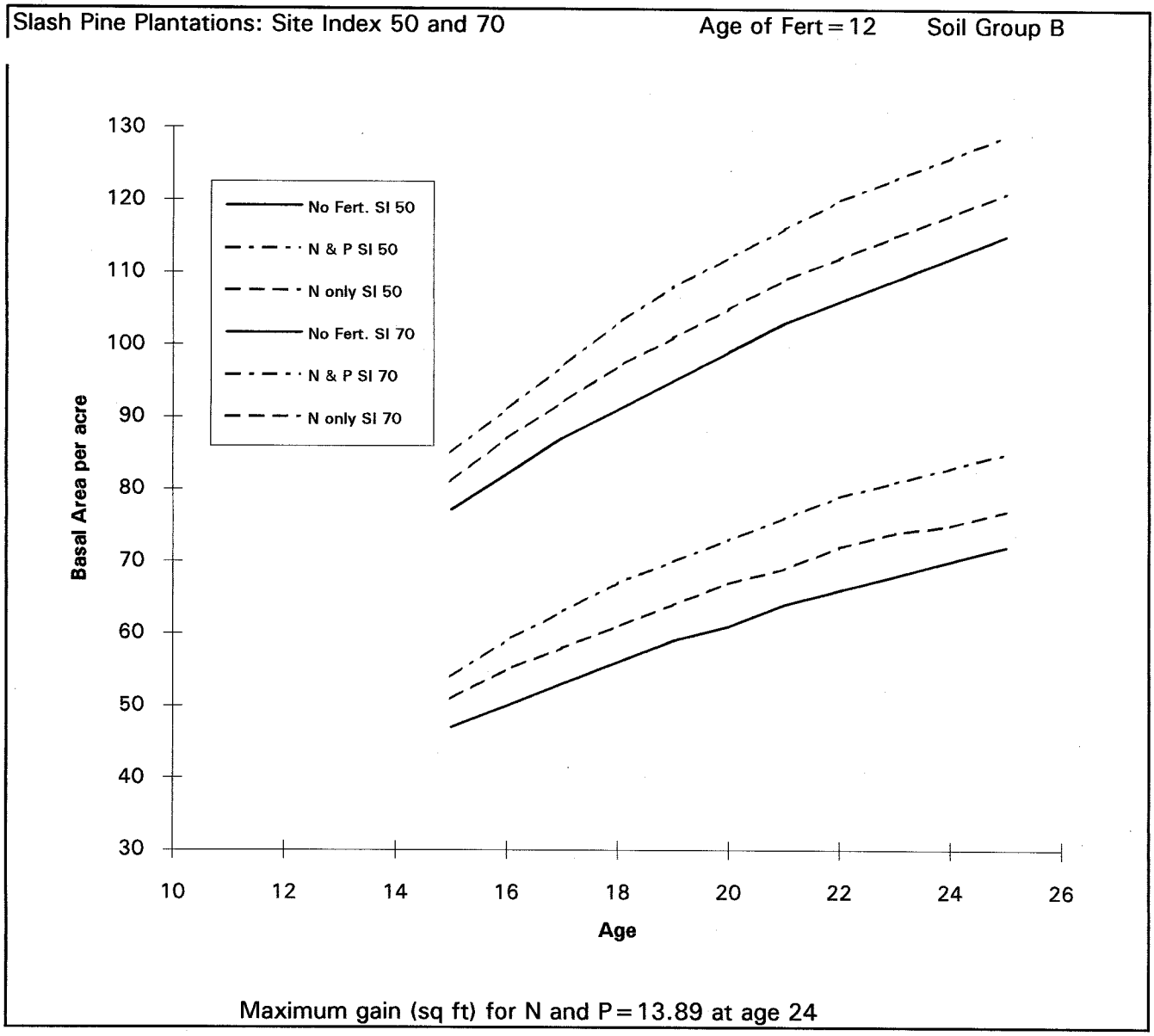
Slash Pine Plantations: Site Index 50 and 70
Age of Fert = 12
Soil Group B
130
120
110
100
90
80
70
60
50
40
30
Basal Area per acre
No Fert. SI 50
N & P SI 50
N only SI 50
No Fert. SI 70
N & P SI 70
N only SI 70
10
12
14
16
18
20
22
24
26
Age
Maximum gain (sq ft) for N and P = 13.89 at age 24

Figure A2

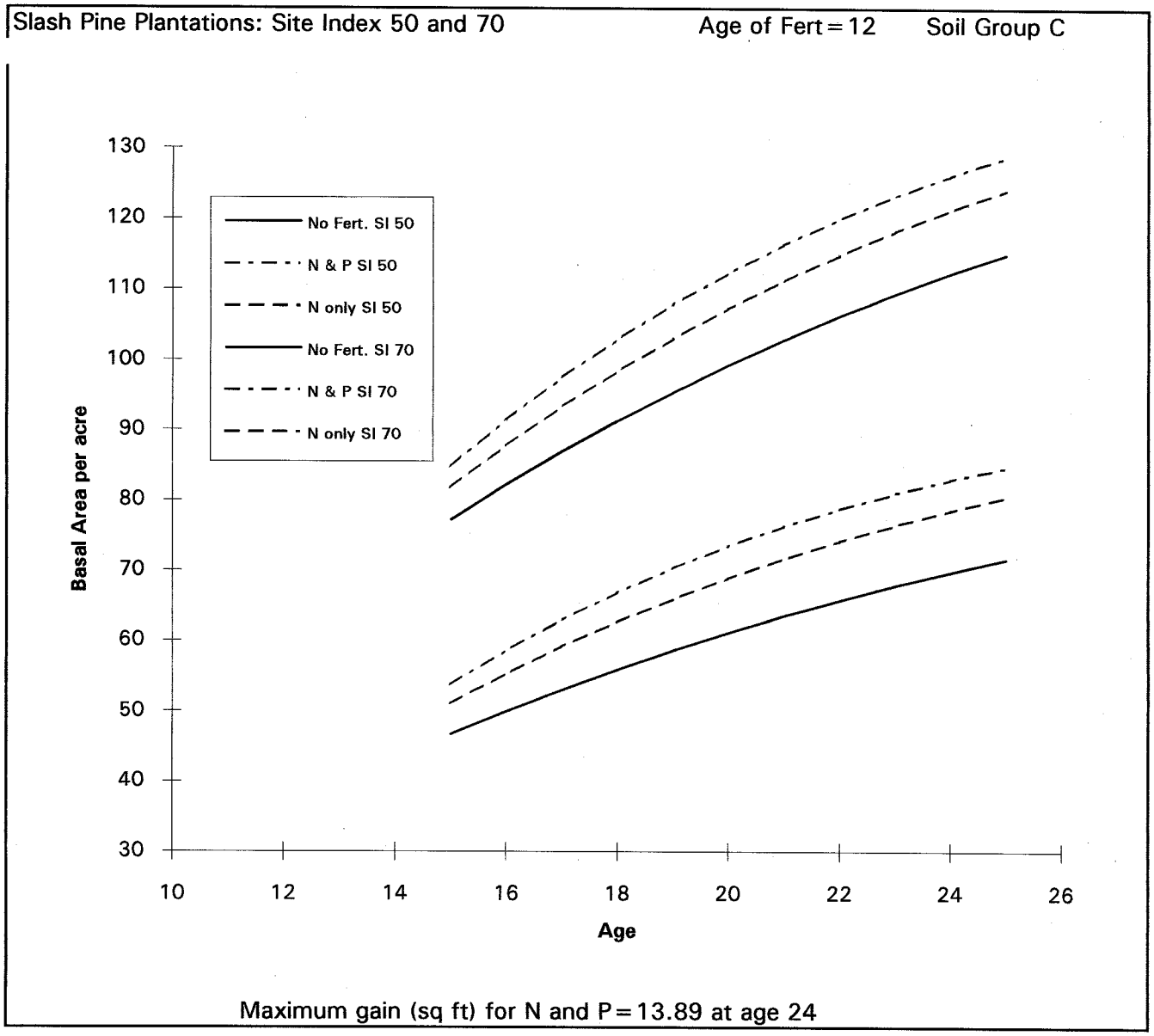
Slash Pine Plantations: Site Index 50 and 70
Age of Fert = 12
Soil Group C
130
120
110
100
90
80
70
60
50
40
30
Basal Area per acre
No Fert. SI 50
N & P SI 50
N only SI 50
No Fert. SI 70
N & P SI 70
N only SI 70
10
12
14
16
18
20
22
24
26
Age
Maximum gain (sq ft) for N and P = 13.89 at age 24

Figure A3

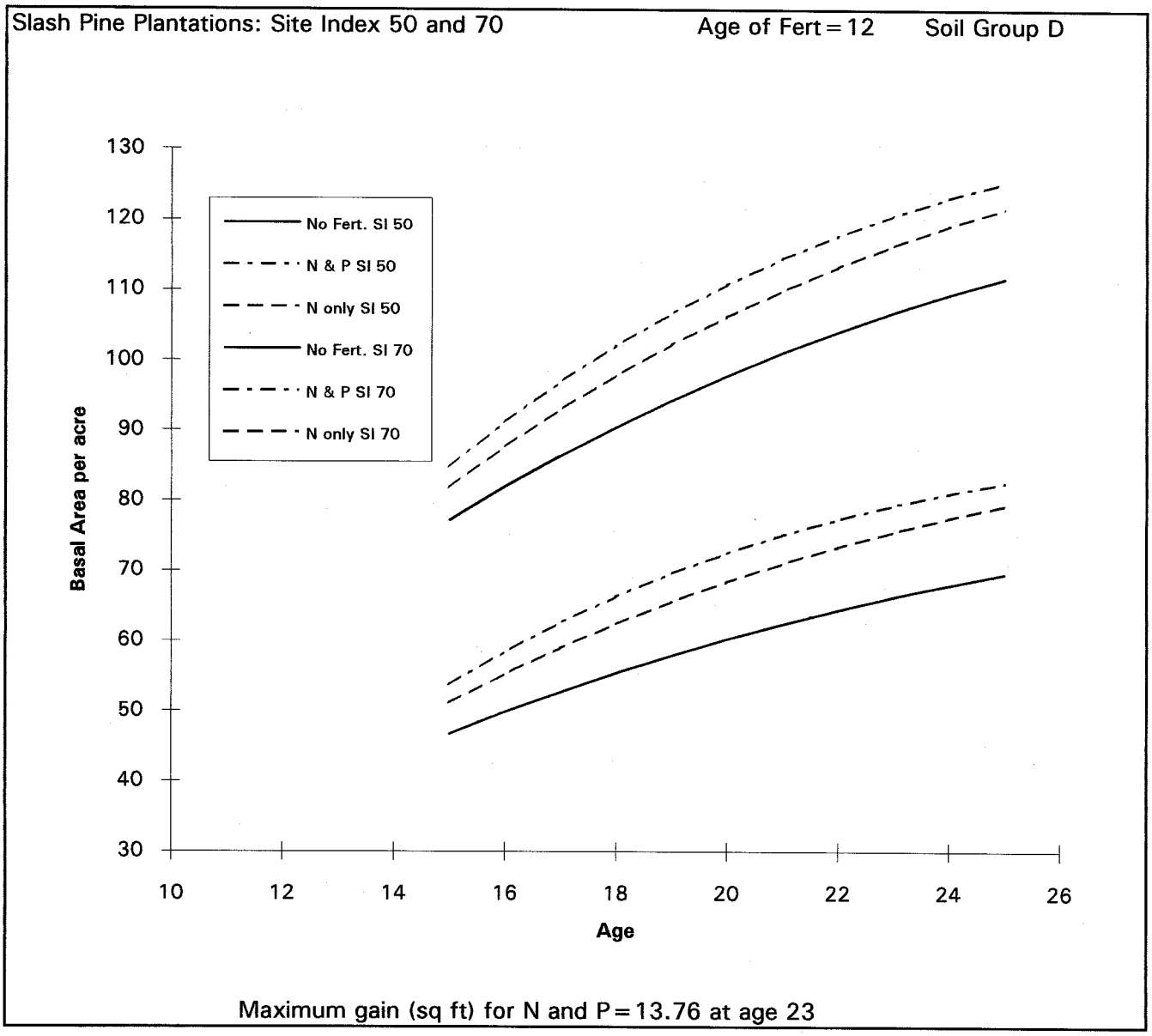
Slash Pine Plantations: Site Index 50 and 70
Age of Fert = 12
Soil Group D
No Fert. SI 50
N & P SI 50
N only SI 50
No Fert. SI 70
N & P SI 70
N only SI 70
Basal Area per acre
130
120
110
100
90
80
70
60
50
40
30
10
12
14
16
18
20
22
24
26
Age
Maximum gain (sq ft) for N and P = 13.76 at age 23

Figure A4

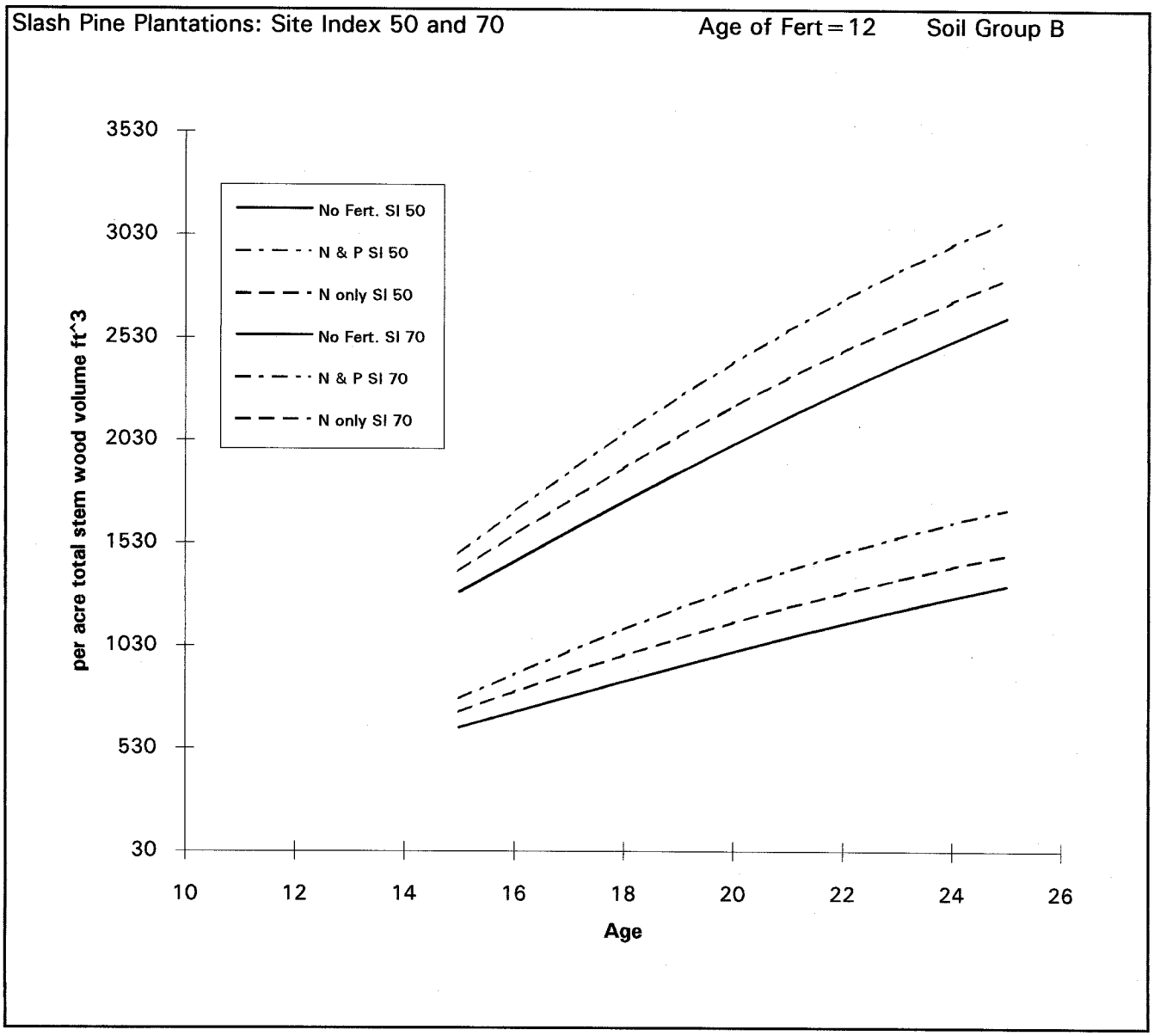
Slash Pine Plantations: Site Index 50 and 70
Age of Fert = 12
Soil Group B
per acre total stem wood volume ft^3
3530
3030
2530
2030
1530
1030
530
30
10
12
14
16
18
20
22
24
26
Age
No Fert. SI 50
N & P SI 50
N only SI 50
No Fert. SI 70
N & P SI 70
N only SI 70

Figure A5

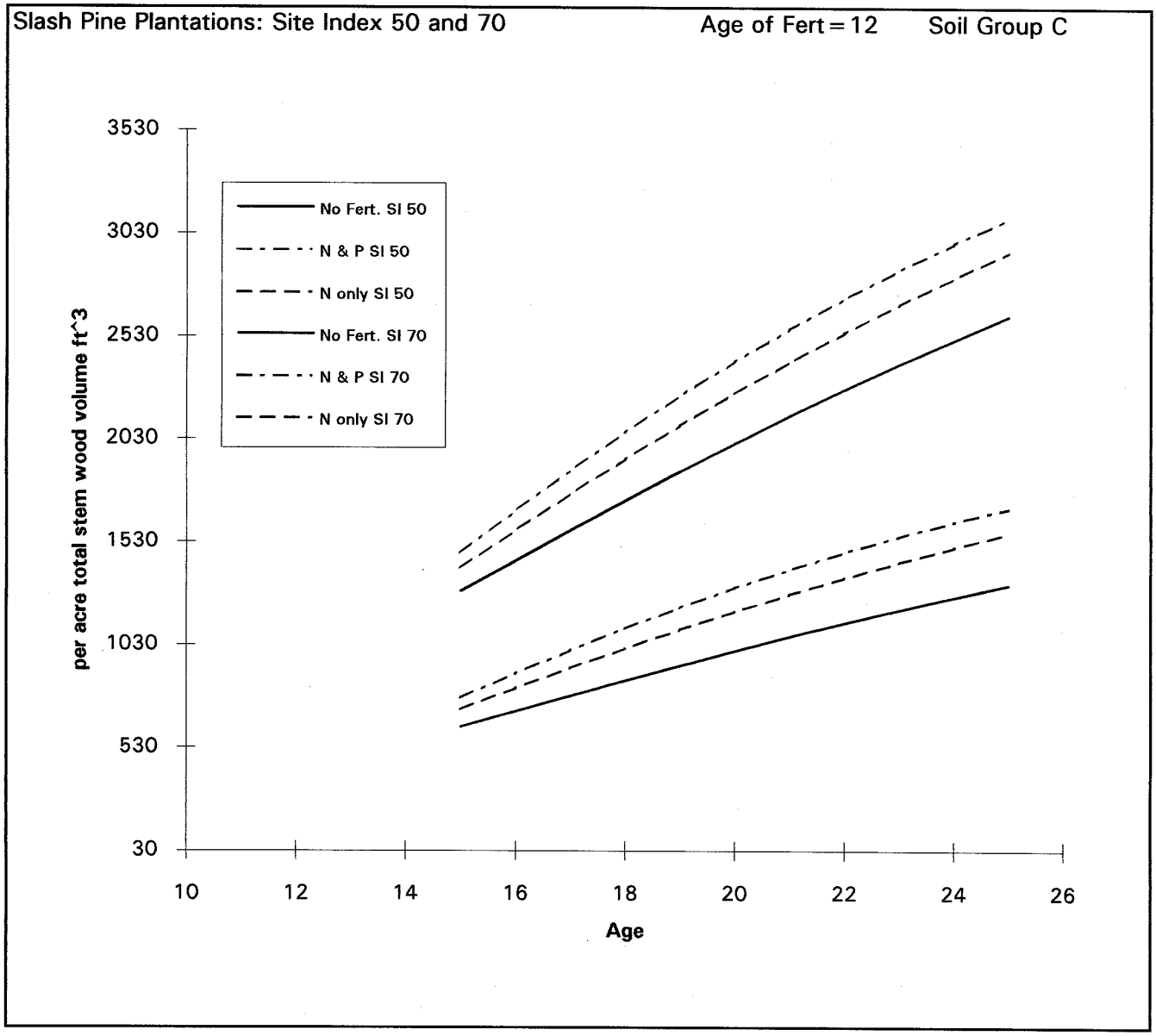
Slash Pine Plantations: Site Index 50 and 70
Age of Fert = 12
Soil Group C
per acre total stem wood volume ft^3
3530
3030
2530
2030
1530
1030
530
30
10
12
14
16
18
20
22
24
26
Age
No Fert. SI 50
N & P SI 50
N only SI 50
No Fert. SI 70
N & P SI 70
N only SI 70

Figure A6

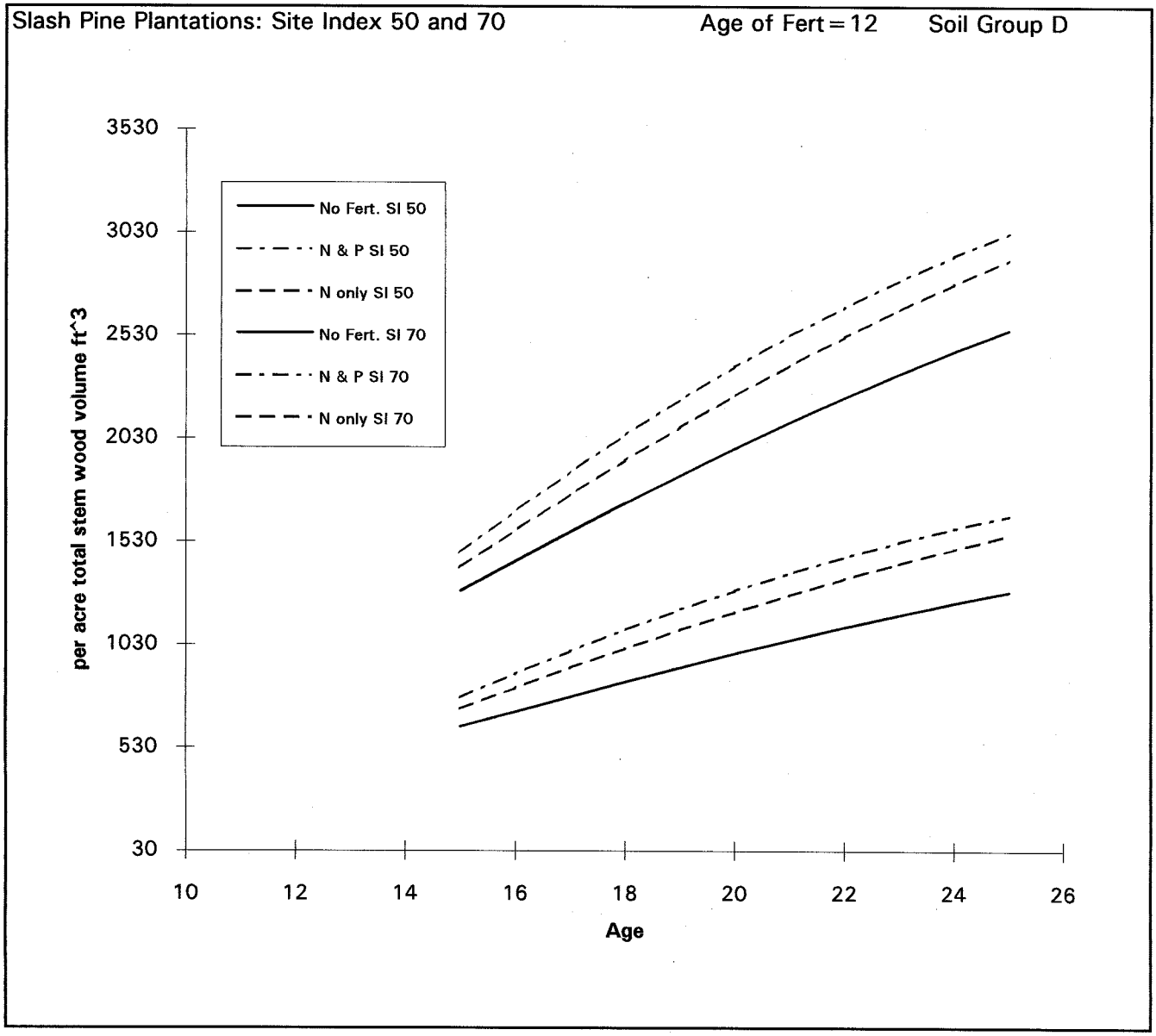
Slash Pine Plantations: Site Index 50 and 70
Age of Fert = 12
Soil Group D
3530
3030
2530
2030
1530
1030
530
30
per acre total stem wood volume ft^3
No Fert. SI 50
N & P SI 50
N only SI 50
No Fert. SI 70
N & P SI 70
N only SI 70
10
12
14
16
18
20
22
24
26
Age

Figure A7

Results from 1997 analysis of Florida CRIFF data for Fertilized Slash Pine Plantations

Site Index=50
Age of Fert.=12
Soil Group B

	Unfertilized		N only		N plus P		N and P % Gain	
AGE	Dom. Ht. (ft)	Basal Area	Dom. Ht. (ft)	Basal Area	Dom. Ht. (ft)	Basal Area	Basal Area	Volume Ft^3
15	33.9	46.7	34.6	50.7	35.3	53.7	15.1%	22.8%
16	35.8	49.9	36.6	54.6	37.6	58.6	17.4%	26.3%
17	37.7	53.0	38.6	58.2	39.7	62.9	18.8%	28.6%
18	39.5	55.8	40.4	61.5	41.6	66.8	19.7%	30.0%
19	41.2	58.6	42.1	64.4	43.4	70.3	20.1%	30.7%
20	42.8	61.1	43.7	67.0	45.1	73.5	20.2%	31.0%
21	44.3	63.5	45.2	69.4	46.7	76.3	20.1%	30.8%
22	45.8	65.7	46.6	71.6	48.2	78.8	19.8%	30.4%
23	47.2	67.8	48.0	73.6	49.6	81.0	19.4%	29.7%
24	48.6	69.8	49.3	75.4	50.9	83.0	18.9 %	28.9%
25	49.8	71.6	50.5	77.0	52.1	84.7	18.3%	28.1%

Site Index=70
Age of Fert.=12
Soil Group B

	Unfertilized		N only		N plus P		N and P % Gain	
AGE	Dom. Ht. (ft)	Basal Area	Dom. Ht. (ft)	Basal Area	Dom. Ht. (ft)	Basal Area	Basal Area	Volume Ft^3
15	47.4	77.1	48.1	81.3	48.9	84.7	9.9%	14.7%
16	50.1	82.1	51.0	87.1	51.9	91.4	11.3%	16.9%
17	52.8	86.8	53.6	92.3	54.7	97.4	12.3%	18.4%
18	55.3	91.2	56.2	97.1	57.4	102.9	12.8%	19.3%
19	57.6	95.3	58.5	101.4	59.9	107.8	13.1%	19.8%
20	59.9	99.2	60.8	105.4	62.3	112.3	13.2%	19.9%
21	62.1	102.8	62.9	109.0	64.5	116.3	13.2%	19.8%
22	64.1	106.2	65.0	112.3	66.5	120.0	13.0%	19.6%
23	66.1	109.3	66.9	115.3	68.5	123.2	12.7%	19.2%
24	68.0	112.3	68.7	118.1	70.3	126.2	12.4%	18.7%
25	69.7	115.0	70.4	120.6	72.0	128.8	12.0%	18.1%

Table A l a

Site Index=50
Age of Fert.=12
Soil Group C

	Unfertilized		N only		N plus P		N and P % Gain	
AGE	Dom. Ht. (ft)	Basal Area	Dom. Ht. (ft)	Basal Area	Dom. Ht. (ft)	Basal Area	Basal Area	Volume Ft^3
15	33.9	46.7	34.6	51.0	35.3	53.7	15.1%	22.8%
16	35.8	49.9	36.6	55.3	37.6	58.6	17.4%	26.3%
17	37.7	53.0	38.6.	59.1	39.7	62.9	18.8%	28.6%
18	39.5	55.8	40.4	62.7	41.6	66.8	19.7%	30.0%
19	41.2	58.6	42.1	65.9	43.4	70.3	20.1%	30.7%
20	42.8	61.1	43.7	68.9	45.1	73.5	20.2%	31.0%
21	44.3	63.5	45.2	71.7	46.7	76.3	20.1%	30.8%
22	45.8	65.7	46.6	74.2	48.2	78.8	19.8%	30.4%
23	47.2	67.8	48.0	76.5	49.6	81.0	19.4%	29.7%
24	48.6	69.8	49.3	78.6	50.9	83.0	18.9%	28.9%
25	49.8	71.6	50.5	80.5	52.1	84.7	18.3%	28.1%

Site Index=70
Age of Fert.=12
Soil Group C

	Unfertilized		N only		N plus P		N and P % Gain	
AGE	Dom. Ht. (ft)	Basal Area	Dom. Ht. (ft)	Basal Area	Dom. Ht. (ft)	Basal Area	Basal Area	Volume Ft^3
15	47.4	77.1	48.1	81.7	48.9	84.7	9.9%	14.7
16	50.1	82.1	51.0	87.7	51.9	91.4	11.3%	16.9%
17	52.8	86.8	53.6	93.2	54.7	97.4	12.3%	18.4%
18	55.3	91.2	56.2	98.3	57.4	102.9	12.8%	19.3%
19,	57.6	95.3	58.5	103.0	59.9	107.8	13.1%	19.8%
20	59.9	99.2	60.8	107.3	62.3	112.3	13.2%	19.9%
21	62.1	102.8	62.9	111.2	64.5	116.3	13.2%	19.8%
22	64.1	106.2	65.0	114.9	66.5	120.0	13.0%	19.6%
23	66.1	109.3	66.9	118.2	68.5	123.2	12.7%	19.2%
24	68.0	112.3	68.7	121.3	70.3	126.2	12.4%	18.7%
25	69.7	115.0	70.4	124.1	72.0	128.8	12.0%	18.1%

Table A 1 b

Site Index=50
Age of Fert.=12
Soil Group D

	Unfertilized		N only		N plus P		N and P % Gain	
AGE	Dom. Ht. (ft)	Basal Area	Dom. Ht. (ft)	Basal Area	Dom. Ht. (ft)	Basal Area	Basal Area	Volume Ft^3
15	33.9	46.7	34.6	51.1	35.3	53.7	15.1%	22.8%
16	35.8	49.8	36.6	55.2	37.6	58.4	17.4%	26.4%
17	37.7	52.6	38.6	59.0	39.7	62.6	18.9%	28.7%
18	39.5	55.4	40.4	62.4	41.6	66.3	19.8%	30.2%
19	41.2	57.9	42.1	65.6	43.4	69.6	20.2%	31.0%
20	42.8	60.2	43.7	68.4	45.1	72.5	20.4%	31.2%
21	44.3	62.4	45.2	71.0	46.7	75.1	20.3%	31.1%
22	45.8	64.4	46.6	73.4	48.2	77.3	20.1%	30.8%
23	47.2	66.3	48.0	75.6	49.6	79.3	19.7%	30.2%
24	48.6	68.0	49.3	77.5	50.9	81.0	19.2%	29.4%
25	49.8	69.5	50.5	79.3	52.1	82.5	18.7%	28.6%

Site Index=70
Age of Fert.=12
Soil Group D

	Unfertilized		N only		N plus P		N and P % Gain	
AGE	Dom. Ht. (ft)	Basal Area	Dom. Ht. (ft)	Basal Area	Dom. Ht. (ft)	Basal Area	Basal Area	Volume Ft^3
15	47.4	77.1	48.1	81.8	48.9	84.7	9.9%	14.7%
16	50.1	81.8	51.0	87.6	51.9	91.1	11.3%	17.0%
17	52.8	86.3	53.6	92.9	54.7	96.9	12.3%	18.5%
18	55.3	90.4	56.2	97.8	57.4	102.0	12.9%	19.4%
19	57.6	94.2	58.5	102.2	59.9	106.7	13.2%	19.9%
20	59.9	97.8	60.8	106.2	62.3	110.8	13.3%	20.1%
21	62.1	101.0	62.9	109.9	64.5	114.4	13.3%	20.0%
22	64.1	104.0	65.0	113.3	66.5	117.7	13.1%	19.8%
23	66.1	106.8	66.9	116.3	68.5	120.6	12.9%	19.4%
24	68.0	109.4	68.7	119.1	70.3	123.1	12.6%	19.0%
25	69.7	111.7	70.4	121.6	72.0	125.3	12.2%	18.4%

Table A 1 c

APPENDIX B

These figures are presented to compare the unfertilized base CRIFF models and PMRC slash pine models (Pienaar, Shiver and Rheney 1996). Using the two models to project dominant height over age, given an initial stand dominant height of 30 at age 10, different site indices result. The CRIFF model gives a site index of 65 and the PMRC model gives a site index of 62 (base age 25).

Predicted per-acre volumes are derived using a "mean tree" approach. Mean diameter at breast height is calculated using basal area and trees per acre. Average tree height and volume are estimated from the appropriate equations in Pienaar, Shiver and Rheney (1996). Multiplying average tree volume times trees per acre give an estimated of total volume per acre.

Figure B1. Average dominant height over age.

Figure B2. Trees per acre over age for age 10 trees per acre of 400 and 600.

Figure B3. Basal area per acre over age for age 10 trees per acre of 400 and 600.

Figure B4.Total volume over age for age 10 trees per acre of 400 and 600.

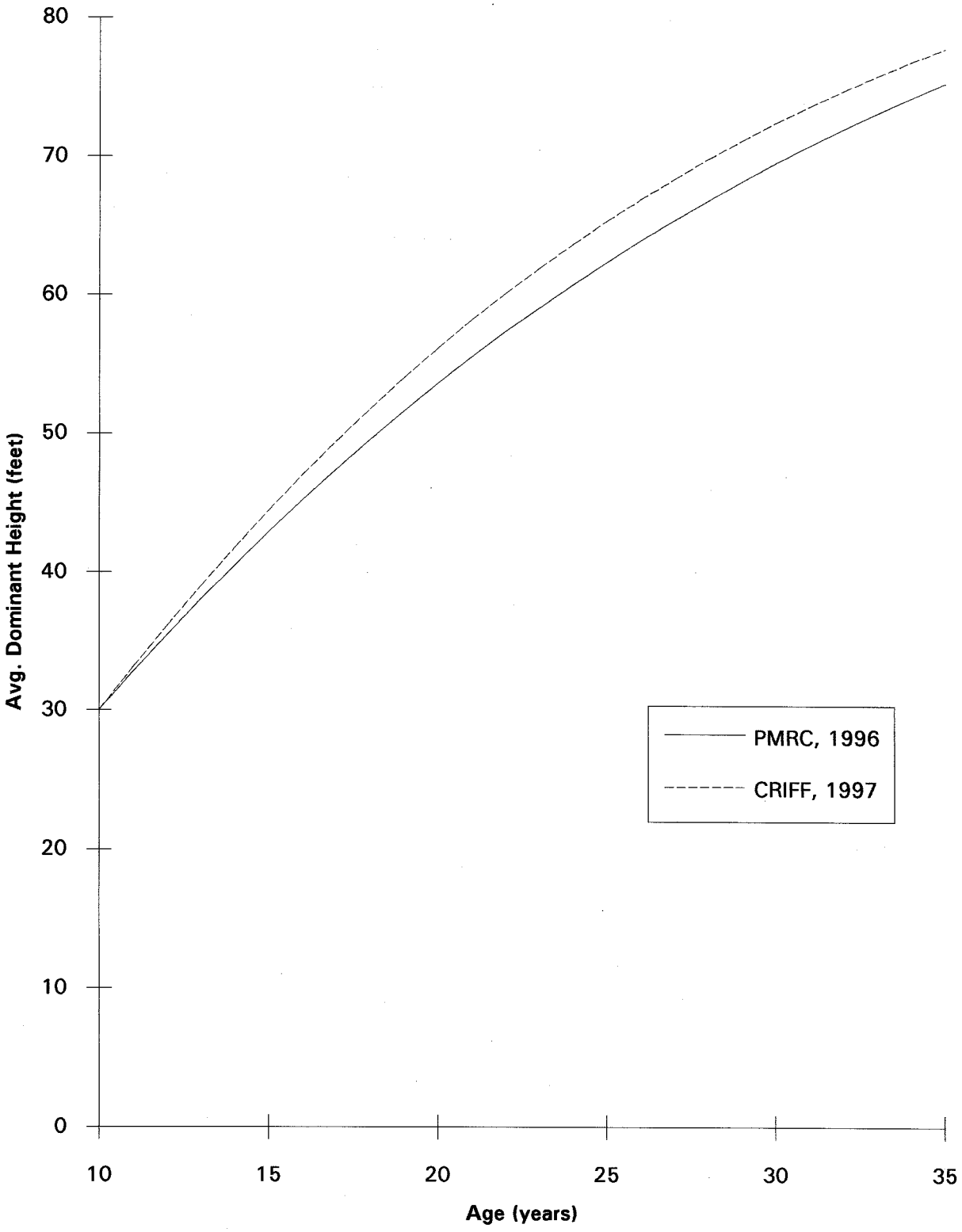
80
70
60
50
40
30
20
10
0
Avg. Dominant Height (feet)
10
15
20
25
30
35
Age (years)
PMRC, 1996
CRIFF, 1997

Figure B1

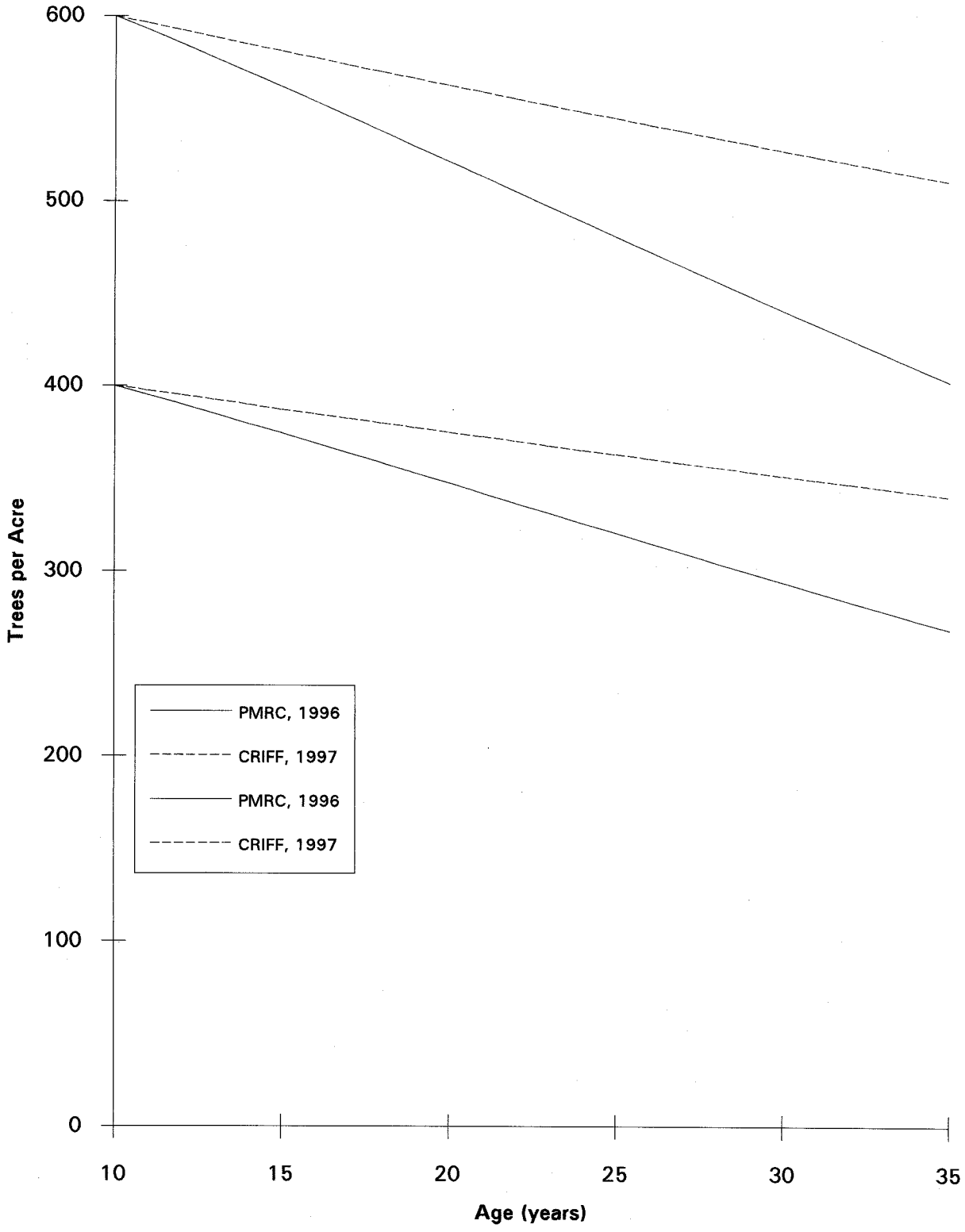
600
500
400
300
200
100
0
Trees per Acre
10
15
20
25
30
35
Age (years)
PMRC, 1996
CRIFF, 1997
PMRC, 1996
CRIFF, 1997

Figure B2

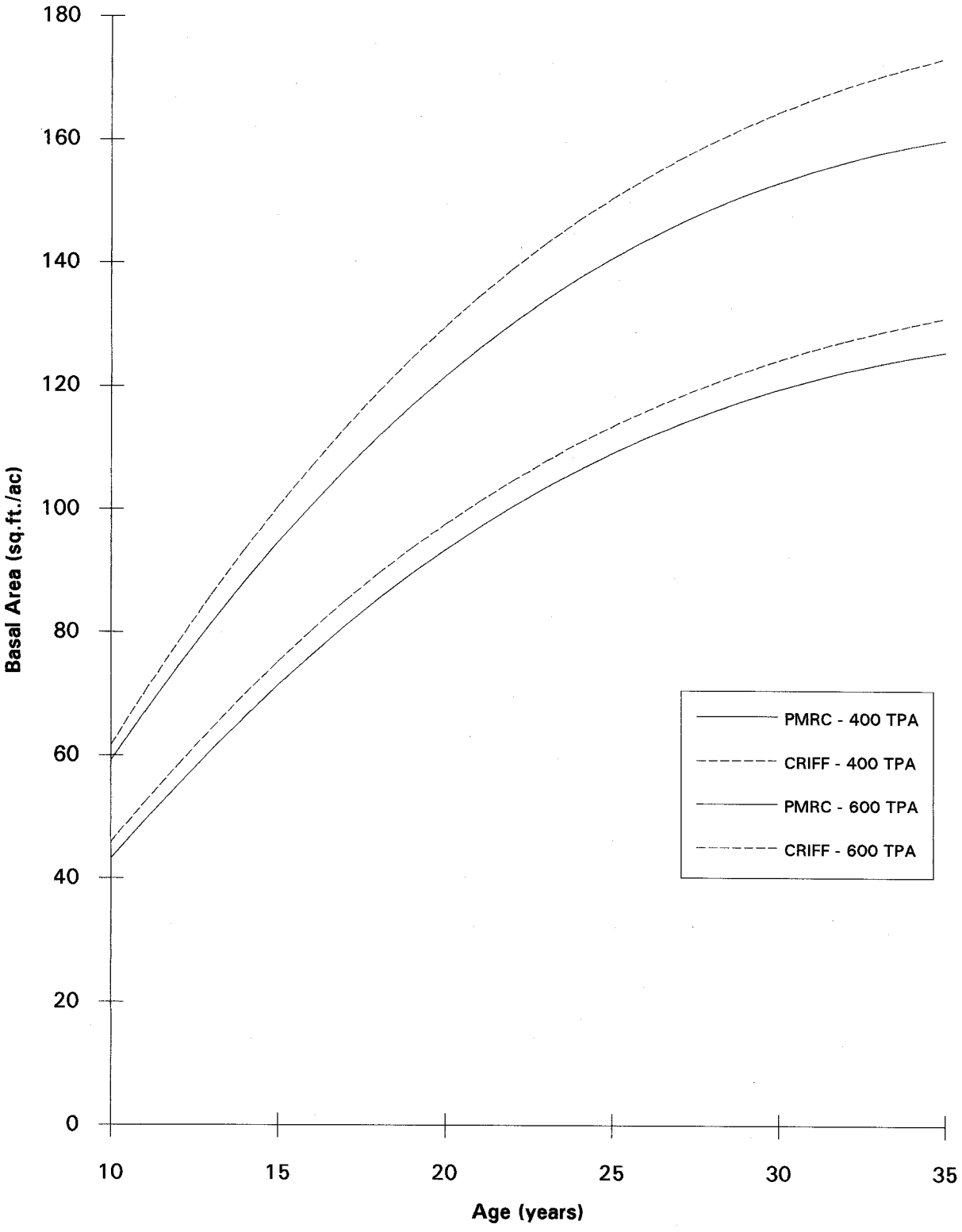
180
160
140
120
100
80
60
40
20
0
Basal Area (sq.ft./ac)
10
15
20
25
30
35
Age (years)
PMRC - 400 TPA
CRIFF - 400 TPA
PMRC - 600 TPA
CRIFF - 600 TPA

Figure B3

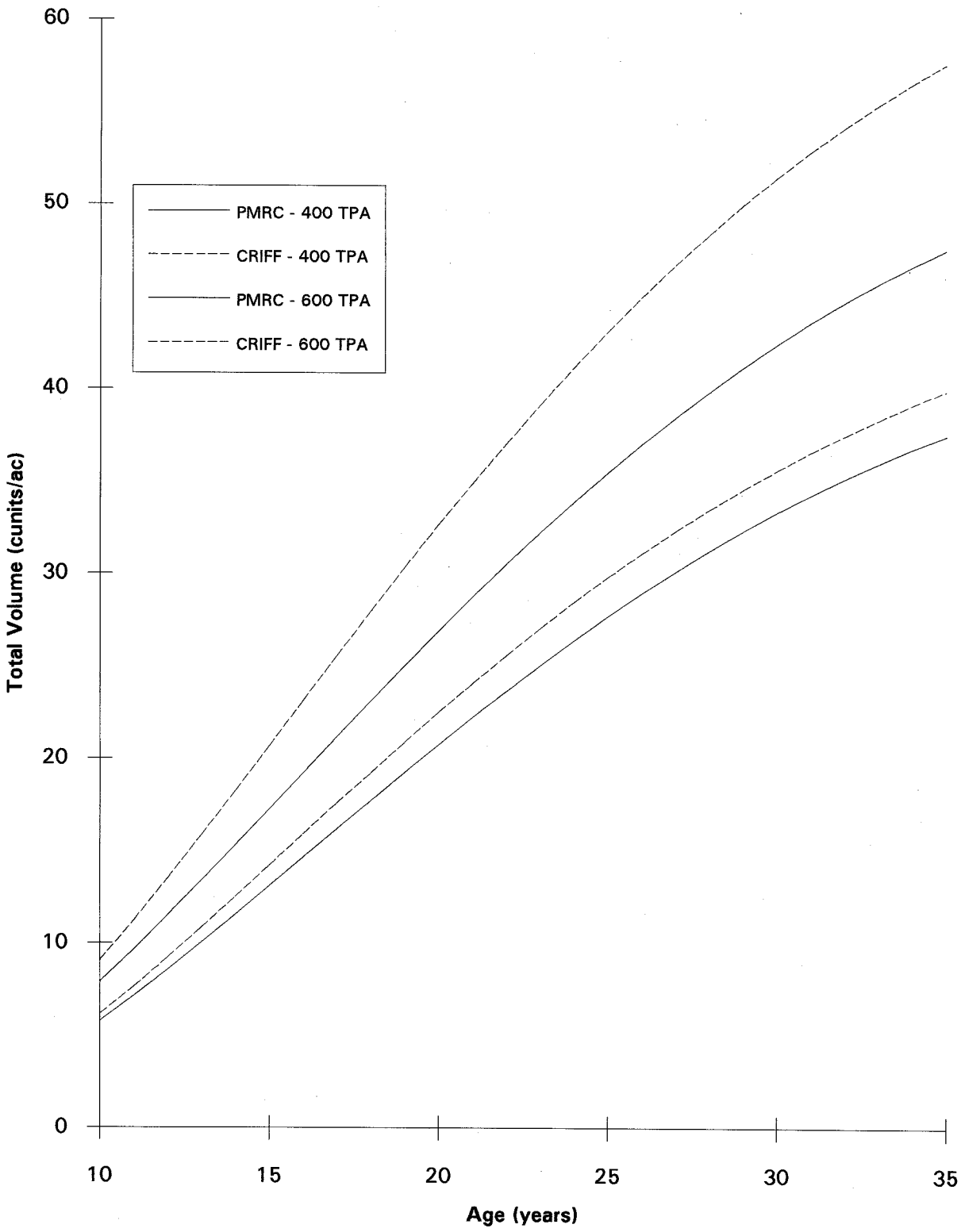
60
50
40
30
20
10
0
Total Volume (cunits/ac)
PMRC - 400 TPA
CRIFF - 400 TPA
PMRC - 600 TPA
CRIFF - 600 TPA
10
15
20
25
30
35
Age (years)

Figure B4