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...Loblolly Pine Plantations in East Texas...
..Thinned and Unthinned - Total Wood Flow Comparison..
...A Simulation...

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REPORT 45

From
the
East Texas Pine Plantation Research Project
College of Forestry
SFASU
Nacogdoches, TX 75962
June ... 1996

DOES A THINNING INCREASE TOTAL WOOD FLOW?

An illustration of the research question...

For example, let us say there is a loblolly pine plantation in Polk county:

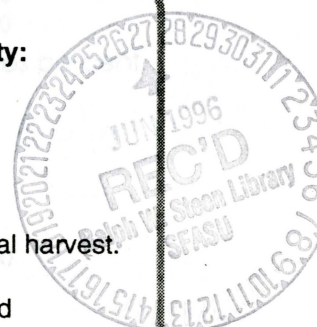
- 5 years old.
- Site index base age 25 years = 60'.
- 500 surviving trees per acre.
- 10% of the stems have fusiform rust galls.
- Landowner plans a 25-year rotation age ... 20 more years until final harvest.

- During this 20-year period, landowner wants to maximize the wood production from the Polk county plantation.

- To accomplish this goal, should the plantation remain unthinned until a final harvest 20 years hence?

- Or to accomplish this goal, should the plantation receive a thinning at some point prior to the final harvest?

- If a thinning is considered, what are the thinning parameters?
 - Timing of thinning?
 - Amount of wood removed at thinning?
 - Growth increases after thinning?



Recent work by the East Texas Pine Plantation Research Project may provide avenues to investigate the research question

.....

Adams, D. E., J. D. Lenhart, A. B. Vaughn and J. Lapongan. 1996. Estimating survival of East Texas loblolly and slash pine plantations infected with fusiform rust. *South. J. Appl. For.* 20(1):30-35.

Lenhart, J. D. 1996. Total and partial stand-level yield prediction for loblolly and slash pine plantations in East Texas. *South. J. Appl. For.* 20(1):36-41.

A SIMULATION MODEL WAS CONSTRUCTED TO DEPICT THE SITUATION AND INVESTIGATE THE RESEARCH QUESTION

Model Components are:

Plantation Parameters

01. Species - loblolly pine plantations.
02. Establish, grow and harvest one rotation.
03. Six possible plantation management schedules.
 - a. Rotation length = 25 yrs ... no thinning ... final harvest only.
 - b. Rotation length = 25 yrs ... thinning @ 10 yrs ... final harvest.
 - c. Rotation length = 25 yrs ... thinning @ 15 yrs ... final harvest.
 - d. Rotation length = 30 yrs ... no thinning ... final harvest only.
 - e. Rotation length = 30 yrs ... thinning @ 15 yrs ... final harvest.
 - f. Rotation length = 30 yrs ... thinning @ 20 yrs ... final harvest.
04. Items defined and set by user.
 - a. Site index (base age 25 yrs).
 - b. Surviving number of trees per acre @ 5 yrs.
 - c. Percentage of trees with fusiform rust stem infections @ 5 yrs.
 - d. Merchantability/Utilization standards ... lower dbh limit & upper stem dob limit.
05. Unit of measure = tons per acre green weight of wood only.

Thinning Specifications

06. Timing of thinnings are listed above.
07. Percent of wood removed at a thinning.
 - a. 25%. c. 50%.
 - b. 33%. d. 67%.
08. Increase in growth of residual trees between thinning and final harvest relative to unthinned growth during same period of time.
 - a. 0%. c. 20%. e. 40%.
 - b. 10%. d. 30%.

Mensurational Concepts

09. Future number of fusiform rust infected & uninfected trees per acre are estimated using the Adams et al. (1996) survival models.
10. For management schedules 3a & 3d (no thinning), yield at rotation age (total wood flow) is estimated using Lenhart (1996) prediction models.
11. For the four management schedules with thinnings, a thinning simulation was designed as:
 - a. Using Lenhart (1996), yields are predicted in year of thinning and year of final harvest.
 - b. Using those two wood flow values as present value & future value plus the number of years between thinning and final harvest as n, a compound growth percentage (interest rate) can be calculated.
 - c. In turn, this growth percentage is increased by the values listed in 8a - 8e above to represent a hypothetical increase in growth of residual trees following a thinning.
 - d. Thinning wood flow is determined by multiplying values listed in 7a - 7d above by the expected yield in year of thinning.
 - e. By subtraction, a residual yield is calculated after each thinning.
 - f. Using the modified growth %s, residual yield is compounded year-by-year for a wood flow at final harvest.
 - g. Total wood flow is the sum of the thinning wood flow plus the final harvest wood flow.
 - h. As a result, for each combination of site index, trees per acre, fusiform rust infection percentage, timing of thinning and rotation age, 20 combinations of simulated total wood flows with thinning are available for comparison to total wood flows with no thinning.

THE SIMULATION MODEL WAS TRANSLATED INTO AN EXCEL SPREADSHEET MODEL

Four specific EXCEL spreadsheets were designed:

- One for each of the four timing of thinning plantation management schedules.
- An unthinned yield prediction system was incorporated into each spreadsheet for the simulation runs.
- In addition to defining plantation parameters on the spreadsheet, the user specifies percent of wood removed and possible increase in growth rates.

THE SIMULATION RUNS

To encompass a reasonable range of loblolly pine plantation parameters, values were set as:

- Site index was defined as 50', 70' & 90'.
- Trees per acre were defined as 300, 500 & 700.
- Percent of fusiform rust infected stems = 10%.

for 9 combinations for the simulation runs of the EXCEL spreadsheets.

In addition, for each timing of thinning situation, percent of wood removed values were set at:
25%, 33%, 50% & 67%.

Finally, hypothetical increases in growth rates were set as: 0%, 10%, 20%, 30% & 40%.

Results are summarized in 9 charts.

CHARTS 1 - 9

The 9 charts are presented on the next 18 pages with 1 chart for each plantation parameter combination.

- Four timings of thinning in each chart.
- Four thinning percent values for each thinning schedule.
- Five growth percent increases for each thinning percent value.

In each of the 80 ellipses on each chart, the difference of
(total wood flow with a thinning) - (total wood flow with no thinning)
is presented.

ANSWER TO THE RESEARCH QUESTION

In East Texas loblolly pine plantations, is the total wood flow from a thinning and a final harvest greater than total wood flow from just a final harvest?

That is, does including one thinning in the rotation have an advantage over no thinning in the production of wood during the rotation?

And the answer in most of the cases examined is no

- A perusal of the charts indicated that the advantage only tended to be with thinning, if the thinning occurred early in the rotation, less wood was removed in the thinning and a relatively high increase in the residual stand growth rate can be expected.

The advantage tends to be better on poorer sites with higher number of trees per acre.

- To maximize the production of wood within a 25-30 yr rotation length, it may be argued that a thinning is not needed. One harvest - a final harvest - may be adequate.

Several caveats...

- Study was limited to the situations within the range of specified plantation parameters.
- Obtaining certain products from thinned trees was not a factor.
- Obtaining certain products from residual trees was not a factor.
- Data on actual response of East Texas loblolly pine plantations to these types of thinnings are not available.
- Cash flows were not a part of this study.

A LOBLOLLY PINE PLANTATION IN EAST TEXAS WITH

- SITE INDEX BASE AGE 25 YRS = 50'
- TREES PER ACRE @ 5 YRS = 300
- PERCENT OF TREES WITH FUSIFORM RUST ON STEM = 10%

Simulated thinned total wood flow per acre relative to unthinned total wood flow per acre in tons.

- Four combinations of timing thinning/final harvest.
 - Four thinning percent values: 25%, 33%, 50% or 67% of tons per acre removed.
 - Five growth response increases after thinning: 0%, 10%, 20%, 30% or 40%.

Values within ellipses = { total wood flow with a thinning } - { total wood flow without a thinning }.

Shaded ellipses indicate situations where thinning may be advantageous.
 Unshaded ellipses indicate situations where thinning may not be advantageous.

A PLANTATION TIMBER MANAGEMENT PLAN (1 OF 4)

ESTABLISH...GROW...THIN AT 10 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 27 tons per acre at 25 yrs.
- Only 8 of 20 situations indicate that a thinning tends to increase total wood flow.
- Less wood removed at 10 yrs, the higher the total wood flow tends to be.
- Increased growth rates between 10-25 yrs appear to be advantageous.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-6	-8	-13	-17
	10%	0	-3	-9	-14
	20%	7	4	-4	-11
	30%	17	12	3	-7
	40%	29	23	11	-2

ANOTHER POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (2 OF 4)

ESTABLISH...GROW...THIN AT 15 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 27 tons per acre at 25 yrs.
- Generally, a thinning at 15 yrs followed by final harvest 10 yrs later does not tend to increase total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-4	-6	-8	-11
	10%	-2	-4	-7	-10
	20%	0	-2	-6	-10
	30%	2	0	-4	-9
	40%	5	2	-2	-7

**A THIRD POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (3 OF 4)
ESTABLISH...GROW...THIN AT 15 YRS ...GROW RESIDUAL...FINAL HARVEST AT 30 YRS**

Comments:

- Total wood flow without a thinning = 34 tons per acre at 30 yrs.
- Only 5 of 20 situations indicate that a thinning tends to increase total wood flow.
- Less wood removed at 15 yrs, the higher the total wood flow tends to be.
- Increased growth rates between 15-30 yrs appear to be advantageous.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-6	-8	-12	-16
	10%	-3	-5	-10	-14
	20%	1	-2	-7	-13
	30%	4	1	-5	-11
	40%	9	5	-2	-9

**AND A FOURTH POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (4 OF 4)
ESTABLISH...GROW...THIN AT 20 YRS ...GROW RESIDUAL...FINAL HARVEST AT 30 YRS**

Comments:

- Total wood flow without a thinning = 34 tons per acre at 30 yrs.
- Generally, a thinning at 20 yrs followed by final harvest 10 yrs later does not tend to increase total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-4	-5	-7	-10
	10%	-2	-3	-6	-9
	20%	-1	-2	-5	-8
	30%	1	-1	-4	-8
	40%	2	1	-3	-7

A Few Thoughts...

- *This loblolly pine plantation is defined as site index 50 base age 25 years and 300 trees per acre at 5 yrs.*
- *Forester wants to maximize total wood flow during the rotation ... to thin or not to thin?*
- *Total wood flows with and without thinnings were calculated and compared.*

- => In general, total wood flow at final harvest with no thinning exceeds a total wood flow consisting of a thinning and a final harvest.
- => The few exceptions tend to have earlier timing of thinning, less tons removed at thinning and higher anticipated increases in residual growth rate following the thinning.

A LOBLOLLY PINE PLANTATION IN EAST TEXAS

WITH

- SITE INDEX BASE AGE 25 YRS = 50'
- TREES PER ACRE @ 5 YRS = 500
- PERCENT OF TREES WITH FUSIFORM RUST ON STEM = 10%

Simulated thinned total wood flow per acre relative to unthinned total wood flow per acre in tons.

- Four combinations of timing thinning/final harvest.
 - Four thinning percent values: 25%, 33%, 50% or 67% of tons per acre removed.
 - Five growth response increases after thinning: 0%, 10%, 20%, 30% or 40%.

Values within ellipses = { total wood flow with a thinning } - { total wood flow without a thinning }.

Shaded ellipses indicate situations where thinning may be advantageous.

Unshaded ellipses indicate situations where thinning may not be advantageous.

A PLANTATION TIMBER MANAGEMENT PLAN (1 OF 4)

ESTABLISH...GROW...THIN AT 10 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 33 tons per acre at 25 yrs.
- Half of 20 situations indicate that a thinning tends to increase total wood flow.
- Less wood removed at 10 yrs, the higher the total wood flow tends to be.
- Increased growth rates between 10-25 yrs appear to be advantageous.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-8	-11	-16	-21
	10%	1	-2	-10	-17
	20%	13	9	-2	-12
	30%	30	23	9	-5
	40%	51	43	24	5

ANOTHER POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (2 OF 4)

ESTABLISH...GROW...THIN AT 15 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 33 tons per acre at 25 yrs.
- Generally, a thinning at 15 yrs followed by final harvest 10 yrs later does not tend to increase total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-5	-7	-11	-15
	10%	-3	-5	-9	-14
	20%	0	-2	-7	-12
	30%	3	1	-5	-11
	40%	7	4	-3	-9

**A THIRD POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (3 OF 4)
ESTABLISH...GROW...THIN AT 15 YRS ...GROW RESIDUAL...FINAL HARVEST AT 30 YRS**

Comments:

- Total wood flow without a thinning = 41 tons per acre at 30 yrs.
- Only 5 of 20 situations indicate that a thinning tends to increase total wood flow.
- Less wood removed at 15 yrs, the higher the total wood flow tends to be.
- Increased growth rates between 15-30 yrs appear to be advantageous.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-8	-10	-15	-20
	10%	-3	-6	-12	-18
	20%	1	-2	-9	-16
	30%	7	3	-6	-14
	40%	12	8	-2	-11

**AND A FOURTH POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (4 OF 4)
ESTABLISH...GROW...THIN AT 20 YRS ...GROW RESIDUAL...FINAL HARVEST AT 30 YRS**

Comments:

- Total wood flow without a thinning = 41 tons per acre at 30 yrs.
- Generally, a thinning at 20 yrs followed by final harvest 10 yrs later does not tend to increase total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-5	-6	-9	-12
	10%	-3	-4	-8	-12
	20%	-1	-3	-7	-11
	30%	1	-1	-5	-10
	40%	3	1	-4	-9

A Few Thoughts...

- *This loblolly pine plantation is defined as site index 50 base age 25 years and 500 trees per acre at 5 yrs.*
- *Forester wants to maximize total wood flow during the rotation ... to thin or not to thin?*
- *Total wood flows with and without thinnings were calculated and compared.*

- => In general, total wood flow at final harvest with no thinning exceeds a total wood flow consisting of a thinning with a subsequent final harvest.
- => The few exceptions tend to have earlier timing of thinning, less tons removed at thinning and higher anticipated increases in residual growth rate following the thinning.

A LOBLOLLY PINE PLANTATION IN EAST TEXAS WITH

- SITE INDEX BASE AGE 25 YRS = 50'
- TREES PER ACRE @ 5 YRS = 700
- PERCENT OF TREES WITH FUSIFORM RUST ON STEM = 10%

Simulated thinned total wood flow per acre relative to unthinned total wood flow per acre in tons.

- Four combinations of timing thinning/final harvest.
 - Four thinning percent values: 25%, 33%, 50% or 67% of tons per acre removed.
 - Five growth response increases after thinning: 0%, 10%, 20%, 30% or 40%.

Values within ellipses = { total wood flow with a thinning } - { total wood flow without a thinning }.

Shaded ellipses indicate situations where thinning may be advantageous.

Unshaded ellipses indicate situations where thinning may not be advantageous.

A PLANTATION TIMBER MANAGEMENT PLAN (1 OF 4) ESTABLISH...GROW...THIN AT 10 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 37 tons per acre at 25 yrs.
- 11 of 20 situations indicate that a thinning tends to increase total wood flow.
- Less wood removed at 10 yrs, the higher the total wood flow tends to be.
- Increased growth rates between 10-25 yrs appear to be advantageous.
- Under these circumstances, a thinning tends to be advantageous.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-9	-12	-18	-24
	10%	3	-1	-10	-19
	20%	21	15	2	-11
	30%	46	37	19	0
	40%	81	68	42	15

ANOTHER POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (2 OF 4) ESTABLISH...GROW...THIN AT 15 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 37 tons per acre at 25 yrs.
- Generally, a thinning at 15 yrs followed by final harvest 10 yrs later does not tend to increased total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-6	-9	-13	-17
	10%	-3	-6	-11	-16
	20%	1	-2	-8	-14
	30%	5	1	-6	-12
	40%	9	5	-3	-10

**A THIRD POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (3 OF 4)
ESTABLISH...GROW...THIN AT 15 YRS ...GROW RESIDUAL...FINAL HARVEST AT 30 YRS**

Comments:

- Total wood flow without a thinning = 47 tons per acre at 30 yrs.
- Only 5 of 20 situations indicate that a thinning tends to increase total wood flow.
- Less wood removed at 15 yrs, the higher the total wood flow tends to be.
- Increased growth rates between 15-30 yrs appear to be advantageous.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-9	-12	-18	-24
	10%	-4	-7	-14	-22
	20%	2	-2	-11	-19
	30%	9	4	-6	-16
	40%	16	11	-1	-13

**AND A FOURTH POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (4 OF 4)
ESTABLISH...GROW...THIN AT 20 YRS ...GROW RESIDUAL...FINAL HARVEST AT 30 YRS**

Comments:

- Total wood flow without a thinning = 47 tons per acre at 30 yrs.
- Generally, a thinning at 20 yrs followed by final harvest 10 yrs later does not tend to increase total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-6	-7	-11	-15
	10%	-3	-5	-10	-14
	20%	-1	-3	-8	-13
	30%	2	-1	-6	-12
	40%	4	1	-5	-11

A Few Thoughts...

- *This loblolly pine plantation is defined as site index 50 base age 25 years and 700 trees per acre at 5 yrs.*
- *Forester wants to maximize total wood flow during the rotation ... to thin or not to thin?*
- *Total wood flows with and without thinnings were calculated and compared.*

=> In general, total wood flow at final harvest with no thinning exceeds a total wood flow consisting of a thinning and a final harvest.

=> The few exceptions tend to have earlier timing of thinning, less tons removed at thinning and higher anticipated increases in residual growth rate following the thinning.

A LOBLOLLY PINE PLANTATION IN EAST TEXAS

WITH

- SITE INDEX BASE AGE 25 YRS = 70'
- TREES PER ACRE @ 5 YRS = 300
- PERCENT OF TREES WITH FUSIFORM RUST ON STEM = 10%

Simulated thinned total wood flow per acre relative to unthinned total wood flow per acre in tons.

- Four combinations of timing thinning/final harvest.
 - Four thinning percent values: 25%, 33%, 50% or 67% of tons per acre removed.
 - Five growth response increases after thinning: 0%, 10%, 20%, 30% or 40%.

Values within ellipses = { total wood flow with a thinning } - { total wood flow without a thinning }.

Shaded ellipses indicate situations where thinning may be advantageous.

Unshaded ellipses indicate situations where thinning may not be advantageous.

A PLANTATION TIMBER MANAGEMENT PLAN (1 OF 4) ESTABLISH...GROW...THIN AT 10 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 94 tons per acre at 25 yrs.
- Only 7 of 20 situations indicate that a thinning tends to increase total wood flow.
- Less wood removed at 10 yrs, the higher the total wood flow tends to be.
- Increased growth rates between 10-25 yrs appear to be advantageous.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-20	-27	-41	-54
	10%	-6	-14	-31	-48
	20%	11	1	-20	-40
	30%	31	19	-6	-32
	40%	55	41	10	-21

ANOTHER POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (2 OF 4) ESTABLISH...GROW...THIN AT 15 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 94 tons per acre at 25 yrs.
- Generally, a thinning at 15 yrs followed by final harvest 10 yrs later does not tend to increase total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-13	-17	-26	-35
	10%	-7	-12	-22	-32
	20%	-1	-7	-18	-30
	30%	5	-1	-14	-27
	40%	12	5	-9	-24

A LOBLOLLY PINE PLANTATION IN EAST TEXAS

- WITH**
- SITE INDEX BASE AGE 25 YRS = 70'
 - TREES PER ACRE @ 5 YRS = 500
 - PERCENT OF TREES WITH FUSIFORM RUST ON STEM = 10%

Simulated thinned total wood flow per acre relative to unthinned total wood flow per acre in tons.

- Four combinations of timing thinning/final harvest.
 - Four thinning percent values: 25%, 33%, 50% or 67% of tons per acre removed.
 - Five growth response increases after thinning: 0%, 10%, 20%, 30% or 40%.

Values within ellipses = { total wood flow with a thinning } - { total wood flow without a thinning }.

Shaded ellipses indicate situations where thinning may be advantageous.

Unshaded ellipses indicate situations where thinning may not be advantageous.

PLANTATION TIMBER MANAGEMENT PLAN (1 OF 4)

ESTABLISH...GROW...THIN AT 10 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 119 tons per acre at 25 yrs.
- Only 7 of 20 situations indicate that a thinning tends to increase total wood flow.
- Less wood removed at 10 yrs, the higher the total wood flow tends to be.
- Increased growth rates between 10-25 yrs appear to be advantageous.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-26	-35	-53	-70
	10%	-7	-17	-40	-62
	20%	16	4	-24	-52
	30%	44	28	-5	-39
	40%	78	58	17	-25

ANOTHER POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (2 OF 4)

ESTABLISH...GROW...THIN AT 15 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 119 tons per acre at 25 yrs.
- Only 3 of 20 situations indicate that a thinning tends to increase total wood flow.
- Generally, a thinning at 15 yrs followed by final harvest 10 yrs later does not tend to increase total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-17	-22	-34	-45
	10%	-9	-16	-29	-42
	20%	-1	-9	-24	-39
	30%	7	-1	-18	-35
	40%	16	7	-12	-31

**A THIRD POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (3 OF 4)
ESTABLISH...GROW...THIN AT 15 YRS ...GROW RESIDUAL...FINAL HARVEST AT 30 YRS**

Comments:

- Total wood flow without a thinning = 144 tons per acre at 30 yrs.
- Generally, a thinning at 15 yrs followed by final harvest 15 yrs later does not tend to increase total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-23	-31	-46	-62
	10%	-12	-20	-39	-57
	20%	0	-9	-31	-52
	30%	14	3	-22	-46
	40%	29	16	-12	-39

**AND A FOURTH POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (4 OF 4)
ESTABLISH...GROW...THIN AT 20 YRS ...GROW RESIDUAL...FINAL HARVEST AT 30 YRS**

Comments:

- Total wood flow without a thinning = 144 tons per acre at 30 yrs.
- Generally, a thinning at 20 yrs followed by final harvest 10 yrs does not tend to increase total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-14	-18	-28	-37
	10%	-9	-14	-24	-35
	20%	-3	-9	-21	-33
	30%	3	-4	-17	-30
	40%	9	2	-13	-27

A Few Thoughts...

- *This loblolly pine plantation is defined as site index 70 base age 25 years and 500 trees per acre at 5 yrs.*
- *Forester wants to maximize total wood flow during the rotation ... to thin or not to thin?*
- *Total wood flows with and without thinnings were calculated and compared.*

- => In general, total wood flow at final harvest with no thinning exceeds a total wood flow consisting of a thinning and a final harvest.
- => The very few exceptions tend to have earlier timing of thinning, less tons removed at thinning and higher anticipated increases in residual growth rate following the thinning.

A LOBLOLLY PINE PLANTATION IN EAST TEXAS WITH

- SITE INDEX BASE AGE 25 YRS = 70'
- TREES PER ACRE @ 5 YRS = 700
- PERCENT OF TREES WITH FUSIFORM RUST ON STEM = 10%

Simulated thinned total wood flow per acre relative to unthinned total wood flow per acre in tons.

- Four combinations of timing thinning/final harvest.
 - Four thinning percent values: 25%, 33%, 50% or 67% of tons per acre removed.
 - Five growth response increases after thinning: 0%, 10%, 20%, 30% or 40%.

Values within ellipses = { total wood flow with a thinning } - { total wood flow without a thinning }.

Shaded ellipses indicate situations where thinning may be advantageous.

Unshaded ellipses indicate situations where thinning may not be advantageous.

A PLANTATION TIMBER MANAGEMENT PLAN (1 OF 4)

ESTABLISH...GROW...THIN AT 10 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 139 tons per acre at 25 yrs.
- Only 7 of 20 situations indicate that a thinning tends to increase total wood flow.
- Less wood removed at 10 yrs, the higher the total wood flow tends to be.
- Increased growth rates between 10-25 yrs appear to be advantageous.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-31	-41	-62	-83
	10%	-7	-20	-46	-73
	20%	22	6	-27	-60
	30%	57	38	-3	-45
	40%	100	76	25	-26

ANOTHER POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (2 OF 4)

ESTABLISH...GROW...THIN AT 15 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 139 tons per acre at 25 yrs.
- Only 3 of 20 harvest schedules indicate that a thinning tends to increase total wood flow.
- Generally, a thinning at 15 yrs followed by final harvest 10 yrs later does not tend to increase total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-20	-27	-40	-54
	10%	-11	-19	-34	-50
	20%	-2	-10	-28	-46
	30%	9	-1	-21	-41
	40%	20	9	-13	-36

**A THIRD POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (3 OF 4)
ESTABLISH...GROW...THIN AT 15 YRS ...GROW RESIDUAL...FINAL HARVEST AT 30 YRS**

Comments:

- Total wood flow without a thinning = 169 tons per acre at 30 yrs.
- Only 5 of 20 situations indicate that thinning tends to increase total wood flow.
- Less wood removed at 15 yrs, the higher the total wood flow tends to be.
- Increased growth rates between 15-30 yrs appear to be advantageous.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-27	-36	-55	-74
	10%	-14	-24	-46	-68
	20%	1	-11	-36	-61
	30%	17	4	-25	-54
	40%	35	20	-13	-46

**AND A FOURTH POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (4 OF 4)
ESTABLISH...GROW...THIN AT 20 YRS ...GROW RESIDUAL...FINAL HARVEST AT 30 YRS**

Comments:

- Total wood flow without a thinning = 169 tons per acre at 30 yrs.
- Generally, a thinning at 20 yrs followed by final harvest 10 yrs later does not tend to increase total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-17	-22	-33	-44
	10%	-10	-16	-29	-42
	20%	-4	-10	-25	-39
	30%	3	-4	-20	-36
	40%	10	2	-15	-32

A Few Thoughts...

- *This loblolly pine plantation is defined as site index 70 base age 25 years and 700 trees per acre at 5 yrs.*
- *Forester wants to maximize total wood flow during the rotation ... to thin or not to thin?*
- *Total wood flows with and without thinnings were calculated and compared.*

- => In general, total wood flow at final harvest with no thinning exceeds a total wood flow consisting of a thinning and a final harvest.
- => The few exceptions tend to have earlier timing of thinning, less tons removed at thinning and higher anticipated increases in residual growth rate following the thinning.

A LOBLOLLY PINE PLANTATION IN EAST TEXAS

WITH

- SITE INDEX BASE AGE 25 YRS = 90'
- TREES PER ACRE @ 5 YRS = 300
- PERCENT OF TREES WITH FUSIFORM RUST ON STEM = 10%

Simulated thinned total wood flow per acre relative to unthinned total wood flow per acre in tons.

- Four combinations of timing thinning/final harvest.
 - Four thinning percent values: 25%, 33%, 50% or 67% of tons per acre removed.
 - Five growth response increases after thinning: 0%, 10%, 20%, 30% or 40%.

Values within ellipses = { total wood flow with a thinning } - { total wood flow without a thinning }.

Shaded ellipses indicate situations where thinning may be advantageous.

Unshaded ellipses indicate situations where thinning may not be advantageous.

A PLANTATION TIMBER MANAGEMENT PLAN (1 OF 4)

ESTABLISH...GROW...THIN AT 10 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 224 tons per acre at 25 yrs.
- Only 6 of 20 situations indicate that a thinning tends to increase total wood flow.
- Less wood removed at 10 yrs, the higher the total wood flow tends to be.
- Increased growth rates between 10-25 yrs appear to be advantageous.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-47	-62	-94	-125
	10%	-16	-34	-73	-112
	20%	21	-1	-49	-96
	30%	63	37	-20	-77
	40%	113	81	13	-55

ANOTHER POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (2 OF 4)

ESTABLISH...GROW...THIN AT 15 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 224 tons per acre at 25 yrs.
- Generally, a thinning at 15 yrs followed by final harvest 10 yrs later does not tend to increase total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-30	-39	-60	-80
	10%	-17	-28	-51	-74
	20%	-4	-16	-42	-68
	30%	11	-3	-32	-62
	40%	27	11	-22	-55

A LOBLOLLY PINE PLANTATION IN EAST TEXAS WITH

- SITE INDEX BASE AGE 25 YRS = 90'
- TREES PER ACRE @ 5 YRS = 500
- PERCENT OF TREES WITH FUSIFORM RUST ON STEM = 10%

Simulated thinned total wood flow per acre relative to unthinned total wood flow per acre in tons.

- Four combinations of timing thinning/final harvest.
 - Four thinning percent values: 25%, 33%, 50% or 67% of tons per acre removed.
 - Five growth response increases after thinning: 0%, 10%, 20%, 30% or 40%.

Values within ellipses = { total wood flow with a thinning } - { total wood flow without a thinning }.

Shaded ellipses indicate situations where thinning may be advantageous.

Unshaded ellipses indicate situations where thinning may not be advantageous.

A PLANTATION TIMBER MANAGEMENT PLAN (1 OF 4)

ESTABLISH...GROW...THIN AT 10 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 288 tons per acre at 25 yrs.
- Only 6 of 20 situations indicate that a thinning tends to increase total wood flow.
- Less wood removed at 10 yrs, the higher the total wood flow will be.
- Increased growth rates between 10-25 yrs appear to be advantageous.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-61	-80	-121	-163
	10%	-20	-44	-94	-145
	20%	28	0	-62	-124
	30%	85	50	-24	-99
	40%	151	109	20	-70

ANOTHER POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (2 OF 4)

ESTABLISH...GROW...THIN AT 15 YRS ...GROW RESIDUAL...FINAL HARVEST AT 25 YRS

Comments:

- Total wood flow without a thinning = 288 tons per acre at 25 yrs.
- Generally, a thinning at 15 yrs followed by final harvest 10 yrs later does not tend to increase total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-39	-51	-77	-104
	10%	-22	-36	-66	-97
	20%	-4	-20	-55	-89
	30%	15	-3	-42	-80
	40%	35	15	-28	-71

**A THIRD POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (3 OF 4)
ESTABLISH...GROW...THIN AT 15 YRS ...GROW RESIDUAL...FINAL HARVEST AT 30 YRS**

Comments:

- Total wood flow without a thinning = 403 tons per acre at 30 yrs.
- Generally, a thinning at 15 yrs followed by final harvest 15 yrs later does not tend to increase total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-62	-82	-124	-166
	10%	-33	-56	-105	-153
	20%	-1	-27	-83	-139
	30%	34	4	-60	-124
	40%	72	37	-35	-107

**AND A FOURTH POSSIBLE PLANTATION TIMBER MANAGEMENT PLAN (4 OF 4)
ESTABLISH...GROW...THIN AT 20 YRS ...GROW RESIDUAL...FINAL HARVEST AT 30 YRS**

Comments:

- Total wood flow without a thinning = 403 tons per acre at 30 yrs.
- Generally, a thinning at 20 yrs followed by final harvest 10 yrs later does not tend to increase total wood flow.

		..... Percent removed at thinning			
		25%	33%	50%	67%
Possible increases in growth rates after thinning	0%	-37	-49	-74	-99
	10%	-23	-36	-64	-93
	20%	-9	-24	-55	-86
	30%	6	-10	-45	-80
	40%	21	3	-35	-73

A Few Thoughts...

- *This loblolly pine plantation is defined as site index 90 base age 25 years and 700 trees per acre at 5 yrs.*
- *Forester wants to maximize total wood flow during the rotation ... to thin or not to thin?*
- *Total wood flows with and without thinnings were calculated and compared.*

- => In general, total wood flow at final harvest with no thinning exceeds a total wood flow consisting of a thinning and a final harvest.
- => The few exceptions tend to have earlier timing of thinning, less tons removed at thinning and higher anticipated increases in residual growth rate following the thinning.