

**G**ood Forestry at a Glance is a guide for managing loblolly pine (*Pinus taeda* L.) stands. “Good forestry” means practices that are environmentally sustainable and economically profitable. The guide consists of two tables and management notes. One table deals with naturally regenerated stands of loblolly pine and the other with plantations. Each table combines three key components of sound management:

1. Information on the growth of stands.
2. A schedule of recommended management activities.
3. The costs and returns of every operation.

Along with common operations, forest management should be closely adapted to the specific conditions of each stand. These conditions are most variable at the initial stages of tree growth. For example, if soil is wetter than expected, the first prescribed burning in naturally regenerated stands may be less effective in controlling undesirable vegetation. To account for such contingencies, whenever necessary the guide includes several alternatives and specifies the average probability of each. To continue the example, the excessive competition resulting from the insufficiently hot prescribed burning could require aerial spraying at age 6. It is estimated that such treatment will be needed in 20% of all cases. More diversity is expected during site preparation for plantations. In those cases, the guide includes six alternatives, together with their average probabilities referred to as “probability of application.”

After we designed the structure of the tables, each operation, condition, cost, and return was scrutinized in personal interviews with more than 100 experienced foresters in Arkansas, Louisiana, and Mississippi. Their views on the necessity of chosen operations, sequence, applicability, and financial matters were used to revise and perfect the tables. This procedure makes the presented management guide a summary of combined experience of the leading southern foresters.

## **MANAGEMENT OBJECTIVES**

The recommended practices are consistent with three management objectives: conserving the environment, increasing merchantable yield, and reducing ice damage.

### **Conserving the Environment**

Without a healthy environment, sustainable forest production would not be possible. Environmental conservation is not only a moral obligation; it is also the overriding goal of good forestry. In areas suitable for growing loblolly pine, there is no conflict between intensive forest management and sustainable functioning of forest ecosystems (Haney and Boyce, 1997). The best evidence of the ecosystem's health is the undiminished, indeed increasing, ability of southern forests to produce timber. Unhealthy ecosystems could not sustain the flow of logs and pulpwood we have produced in these ecosystems for about a century.

The proposed activities imitate and enhance natural ways of growing trees. Silvicultural thinning anticipates the death of weaker trees in a stand. Similarly, the main harvest removes the trees that are past their most vigorous period. By harvesting these trees, we provide space for a new generation that is better and more vigorous than those we remove.

### **Increasing Merchantable Yield**

The recommendations focus on relieving the competition occurring within the stand and directing the flow of resources to the more successful, larger, and straighter trees.

The proposed activities yield annual returns of \$45–47 per acre (based on 1996 costs and returns) this is much better than the \$25 that an average landowner throughout the South receives from loblolly pine stands (Dr. Richard Williams, personal communication).

### **Reducing Ice Damage**

Loblolly pines are most vulnerable to ice damage between the 10th and 20th year of growth (Wiley and Zeide, 1991; Amateis and Burkhart, 1996;

Belanger et al., 1996). Increasing stem taper during this period reduces the likelihood of ice damage. This can be achieved by (a) planting on wide spacing 9 x 10 or 8 x 11 ft with large, improved seedlings; (b) vegetation control at an early age (3–5 years); (c) first two thinnings at age 13 and 18 to 60 ft<sup>2</sup> of basal area; (d) subsequent thinnings made at 5-year intervals to 70 ft<sup>2</sup> of basal area; (e) controlling understory hardwoods by chemical spraying after a second commercial thinning; (f) prescribed burning before each thinning, starting with the third thinning; and (g) tailoring management goals to the environment. For example, in the areas with frequent ice storms (such as parishes on the top of iron ore hills in Louisiana), it is better to grow pine on a short rotation for pulpwood rather than for sawlogs.

### ABBREVIATIONS AND DEFINITIONS USED IN THE TABLES

- N is the number of trees per acre (1 acre = 0.4047 hectare).
- DBH is the diameter at breast height in inches (1 inch = 2.54 centimeter).
- BA is basal area per acre in square feet (1 ft<sup>2</sup> = 0.0929 m<sup>2</sup>).
- MBF is 1000 board feet of sawtimber per acre, Doyle scale (1000 board ft = 2.360 m<sup>3</sup>).
- Sawtimber is merchantable pine log volume in trees, with a minimum of 9.6 in. DBH and 7.5 in. top inside bark. Sawtimber must meet log-grade specifications and must be reasonably straight, sound, and at least 12 ft 4 in.
- Cord is 128 ft<sup>3</sup> of pine pulpwood, with bark (3.6224 m<sup>3</sup> of stacked wood with bark).
- Pulpwood is merchantable timber with a minimum DBH of 4.6 in., to a minimum top of 3.5 in. inside bark. Pulpwood also includes wood from log tops (excluding branches), log-sized wood that is too crooked (except short crooks) for sawtimber, and wood that is below minimum log-grade or length to be considered merchantable log volume.
- Long pulpwood is pulpwood logs more than 24 ft in length to the minimum top, which is loaded on a truck and hauled as one piece of wood.
- Short pulpwood is pulpwood logs with more than the minimum top and cut into lengths of 5–10 ft. Short pulpwood is produced at a higher cost than long pulpwood and should have a lower return than long pulpwood.

**ASSUMPTIONS USED IN DEVELOPING THE TABLES**

Annual interest rate .....	6%
Rotation in years .....	planted 35, natural stand 45

**Annual Mortality of Naturally Regenerated Stands**

*Four ice storms during the rotation, about every 10 years*

Mortality from fourth year to sixth year after precommercial thinning ....	1%
Mortality from an ice storm at age 6 .....	3%
Mortality from age 6 to first thinning .....	0.7%
Mortality after first thinning, except in years when ice storms occur .....	0.2%
Mortality from ice storm at age 15 .....	15%

**Annual Mortality of Trees in Planted Stand**

*Three ice storms during the rotation, about every 10 years*

Mortality by end of first year after planting .....	18.0%
Mortality after first year up to an ice storm at age 6 .....	1.0%
Mortality due to ice damage at age 6 .....	3.0%
Mortality in the years from age 7 to 13 .....	0.7%
Mortality from ice storm at age 14 .....	15.0%
Mortality in years after age 14 with no ice storm.....	0.2%

Long-term observations of loblolly pine plots thinned to various densities (Wiley and Zeide, 1991; Wiley and Zeide, 1992) were used as guidelines for estimating tree mortality and growth. Sawtimber and pulpwood volumes were calculated using the "Volume Calculation Program" written by Dr. Michael Shelton, and volume tables can be found in Williams and Hopkins (1968). Table specifications: log volumes are Doyle, trees more than 9.6 inches DBH to 7.5 inches inside the bark, or merchantable sawlog top. Pulpwood is more than 4.6 inches DBH to a top of 3.5 inches inside bark, and pulpwood volume from sawlog (top portion) to 3.5 inches inside bark top using 78 ft<sup>3</sup> per cord as the solid-wood conversion factor.

**COSTS (1996 dollars, per acre)**

Annual property tax .....	2.25
Property tax accrued over rotation.....	478
Planting (plantations only, seedlings, labor, and supervision).....	60

Prescribed (controlled) burning ..... 11

Marking pulpwood thinning ..... 14

Other timber marking, average ..... 13

Marking seed trees to be logged, for audit purposes only  
(if a marked volume is not needed, skip this cost) ..... 9

Precommercial thinning with 10-ft rolling chopper ..... 55

Precommercial thinning with (gas-powered pole-saws)  
includes cutting any overtopping hardwoods, in rows left,  
after rolling chopper misses the desired goal ..... 45

Aerial chemical spraying for release of pine reproduction ..... 70

These costs of silvicultural operations are based on information provided by Dubois et al. (1995, converted to 1996 dollars), interviews of 106 foresters in Arkansas, Louisiana, and Mississippi, and local contractor estimates.

Cost of aerial chemical spraying includes various chemicals and mixes and is the average of a range of costs based on interviews of 106 foresters. It is estimated that 20% of the stands planted and 25% of natural stands will need release from hardwood competition, depending on how successfully the site-prep or precommercial thinning controls the hardwood brush. This percentage is multiplied times the base cost of \$70 for aerial release spraying to decide how much this optional treatment will contribute to the costs of an average acre in this plan.

**Site Preparation for Plantations**

The site preparation costs are based on costs from the 1994 Forest Farmer Manual, 30th edition. They are adjusted for 2.5% and 2.7% inflation, in 1995 and 1996, respectively, rounded to the closest dollar to simulate 1996 dollars. Some costs are modified by the consensus of interviewees' estimates.

**RETURNS (1996 dollars, per acre)**

All returns are based on average 1996 timber prices in the three state study areas as established by 106 interviews on per acre bases.

Sawtimber per MBF (Doyle) ..... 320

Short pulpwood per cord ..... 11

Long pulpwood per cord ..... 20

Returns on annual hunting leases ..... 2

Pulpwood returns from log tops are included in the log returns after the pulpwood stage.

## MANAGEMENT NOTES FOR NATURAL STANDS

*Numbers correspond to the numbered steps in the tables.*

### Sapling Stage

1. (Age 0) Prescribed burning in the autumn, before the seed drop and the main harvest, is recommended to establish natural regeneration by the seed tree method. The burning prepares the seed bed and kills the brush so that the pine seedlings can start even with the hardwood competition. A seed tree cut to four trees per acre ends the previous rotation. The seed tree volume will be counted as volume from the previous rotation. The scarification from the logging will help make a good seed bed after the burn. Regenerating a stand naturally (without planting) is common because of the initial low cost. However, it quite often results in too many saplings (overstocking). Intensive site-prep increases the likelihood that the stand will be overstocked.

The cost of this prescribed burning is considered a part of the cost of the previous rotation, if done before the seed tree cutting, and it may give a tax break, because it may be counted as an expense, not a capital expenditure.

Warning: Burning after the harvest, with logging slash on the ground, risks killing seed trees.

2. (Age 3) Four seed trees per acre, left for 3 years, are logged. Another benefit is that removal of the seed trees will destroy about 10% of the saplings. (Before logging, there will be about 10,000 saplings per acre; after logging, about 9000 saplings). The volume and value of the seed trees are accounted for at the end of the rotation, because the seed trees at the beginning of this rotation belong to the previous rotation.

If the number of pine saplings per acre in the second autumn is about 500–700, enough saplings are present to cut the seed trees in that year, or before the seed fall in the third year. This probably will not avoid overstocking though, because the new seed is usually already on the ground, when an accurate sapling count can be made.

3. (Age 4) Thin the saplings by driving a 10-ft drum chopper through the overstocked reproduction, leaving strips about 1 ft wide. The number of hardwood stems in the overstory is decreased by the same ratio as the pine reproduction. A perfect job would leave 9% of the saplings in the 1-ft leave row. If the stand started with about 9000 saplings, it is still going to end over the desired goal of 445 saplings per acre because of the difficulty in controlling the width of the leave rows.

4. (Age 4) Usually there are too many saplings per acre after the

precommercial thinning with a rolling chopper. In the example in step 3, there were about 1500 saplings per acre. To reduce the risk of damage in the next ice storm, thin the saplings to the desired goal of 445 trees per acre. This will allow the diameter of the trees to grow fast enough to be thinned at age 14. Contract with a crew using gas-powered brush-saws to cut out the smaller and crooked saplings. The remaining, better saplings will be spaced in the leave rows on an average distance of 10 ft. This will leave approximately the desired number of trees.

In the precommercial thinning contract with the brush-saw crew, one should require the cutting of the hardwoods that are overtopping the pine saplings in the rows, as part of the job. This should eliminate a separate release treatment.

5. (Age 6) It is estimated that despite all the described measures, at least 20% of the naturally regenerated and precommercially thinned stands will encounter severe hardwood competition, even when the pines are of the same or greater height than the hardwoods. A chemical aerial spray is useful to decrease the hardwood competition. The hardwood control will ensure vigorous diameter growth of trees and will help prepare the stand to withstand ice storms.

6. (Age 6) If an ice storm occurs at this age, it would bend the pines, causing only moderate damage. Most of the trees will straighten back up in a year or two.

### **Pulpwood Stage**

7. (Age 14) Observations show that heavily thinned stands with vigorous trees suffer much less damage from ice storms during the critical decade in their life, from age 10 to 20. Therefore, the plan is to thin this stand twice to a basal area target of 60 ft<sup>2</sup>. Then, when the most vulnerable age is past, stands will be thinned to 70 ft<sup>2</sup> basal area targets every 5 years.

Thin the stand principally from below and save the best trees. Remove as many diseased, deformed, and forked trees as possible. Those will not make a good log in the future. Try to space the trees left evenly, while maintaining the desired basal area target. About 230 trees per acre should be left after the thinning, spaced on an average of 14 ft apart to meet the basal area density target of 60 ft<sup>2</sup>.

8. (Age 15) The table accounts for a heavy ice storm occurring 1 year after the first thinning. This stand, which has been prepared to withstand ice storms, would sustain some damage, but much less than unprepared stands. In the example, about 35 trees are heavily damaged; of these 65% of the volume

can be salvaged. This volume would be enough to use as short pulpwood and could be salvaged at normal pulpwood rates. One should be conservative in marking trees to be salvaged. Enough basal area should still be left to be able to thin the stand at age 20. Then it will be easier to discern which trees would be the best to save for the future.

Trees with the tops broken in the ice storm could be kept, if they have at least one third of their crown left and could develop at least one 16-ft log. If a localized area in the stand were thinned by the ice damage to below 60 ft<sup>2</sup> basal area, trees with less than one-third of their crown should be saved with as few as five green branches, to help stock the area.

9. (Age 20) The first prescribed burning will reduce the fire hazard, decrease the understory competition from brush, and make the stand more accessible for logging. The burn will also improve visibility, which will facilitate timber marking and provide a better environment for other activities.

Prescribed burning is the cheapest and most natural method to control undesirable vegetation. This burn is the first of a series of burns, scheduled before each harvest, until the end of the rotation. Ice storms and exceptionally wet winters will sometimes interfere with the burning schedule. If a prescribed burn is missed, it needs to be rescheduled as soon as possible.

Three years after logging or an ice storm, a prescribed burn can be made with due caution. A small, non-industrial landowner should contract with the local Forestry Commission [or consultant foresters to do the burning. Some timber companies offer a management assistance program that includes experienced supervision of the burning.]

10. (Age 20) Pulpwood thinning is principally from below; i.e., smaller and poorly formed trees are removed. Remove the trees crippled by the ice storm especially those that can eventually be replaced by better neighbors. After the thinning, there should be about 120 trees left with an average spacing of about 19 ft, to hit the basal area target of 60 ft<sup>2</sup>.

### **Sawtimber Stage**

11. (Age 26) The stand underwent a prescribed burn before the ice storm. If the storm had occurred before the burn, then the burn would have to wait 3 years.

12. (Age 26) Since heavy ice storms often occur once in a decade, it is likely that one will strike around this year. Early thinning and low density of the stand strengthened most of the trees to weather the ice damage. Therefore, the storm would not do a great deal of damage to this stand at this age. We can expect that only one out of four trees might be destroyed. Others may lose

limbs and leaders. At this point the basal area target would be raised to 70 ft<sup>2</sup>, as planned. The cutting cycle is shortened to 5 years for the rest of the rotation. The broken trees should be salvaged and the rest of the stand thinned. In order to reach the basal area target of 70 ft<sup>2</sup> for this stage, about 90 trees should be left per acre, with an average spacing of 22 ft. This salvage cut is the first cut that produces conventional log volume.

13. See “Sapling Stage.”

14. (Age 31) A log thinning is scheduled for this age. After the thinning, there should be 65 trees left per acre, spaced on the average of 26 ft apart for a target of 70 ft<sup>2</sup> basal area.

15. See “Sapling Stage.”

16. (Age 36) A log thinning is scheduled for this age. When the thinning is done, about 50 trees per acre should be left at an average spacing of 30 ft, to hit the basal area target of 70 ft<sup>2</sup>.

17. (Age 38) In the example stand, a heavy ice storm occurs but would not do much damage. The ice would strip off some branches and break some leaders. The log and pulpwood damage would not consist of enough volume to salvage.

18. (Age 41) It is important not to skip this prescribed burning. It is only 4 years until the hardwood understory needs to be completely under control. Hardwoods are the major threat to establishing regeneration for the next rotation.

19. (Age 41) This is the last log thinning. More of the larger trees should be cut this time. Crooked trees and those that whose log height has been ended by ring knots or other log defects should be selected for cutting. Forty trees should be left per acre spaced on an average of 33 ft apart, for the target basal area of 70 ft<sup>2</sup>.

If for some reason this cut is missed, it will make very little difference in the total returns, because the basal area is not very high at this age and will not greatly retard the growth. However, an unfavorable future timber price would lower the return, and a cut at this time would help average the returns.

20. (Age 45) This is the last prescribed burning of the rotation. The burning must be hot enough to ensure a good seed bed for the coming harvest of all trees except four seed trees per acre. Hazard reduction, accessibility, and improved vision for marking are secondary at this point. The brush should be killed to the ground.

Alternative: This last prescribed burning could be skipped, if a reproduction check at age 44 shows enough seedlings in place (between 900 and 1500 per acre). This number of seedlings would likely provide for an acceptable stocking after logging damage (between 350 and 700 per acre). When this

regeneration is established, one can cut all merchantable trees (without leaving seed trees). Then step 21 would be skipped.

**21. (Age 45)** It is time for the main harvest that should leave four seed trees per acre. They should be the tallest trees with straight stems. Trees showing an abundance of cones are preferable. The seed trees should be distributed as evenly as possible. The volume of the seed trees should be accounted for with this rotation for financial calculations.

**23. Total Accrued Compounded Returns** are all revenues received during the rotation, compounded to the end of the rotation.

**24. Total Accrued Compounded Costs** are all costs, including annual property tax, incurred during the rotation, compounded to the end of the rotation. The accrued costs are shown as a range, as the costs depend on which silvicultural options are used.

**25. Net Accrued Compounded Returns** are total accrued compound returns minus total accrued compound costs.

**26. For Annual Average Net Returns (Equal Annual Equivalent)**, all costs and revenues are combined into a single equivalent to all cash flows during the period and spread uniformly over each year of the rotation. All four values and the uncompounded totals shown are per acre.

## MANAGEMENT NOTES FOR PLANTED STANDS

The table and the following management notes refer to a typical loblolly pine plantation on a medium site (site index 85, base 50 years or site index 60, base 25 years). See also "Assumptions Used in Developing the Tables." *Numbers correspond to the numbered steps in the tables.*

### Site Preparation

**1. (Age 0)** Site-prep is the most important step of forest plantation management; it is the foundation on which the forest is built and what is done at that stage affects the stand for many years to come. Costly mistakes can take place at this stage, even under professional supervision. Choose the application with the least cost that produces the smallest amount of disturbance to the environment and leaves the least competition for the young pine trees. To assist in decision-making, some pros and cons of most of the various site-prep applications are presented below.

**1A.** With the introduction of improved herbicides, aerial chemical spraying has become the preferred site-prep method. The prescribed burn following the aerial spraying is intended to remove small brush and debris to give better

access for planting. To be able to burn in a reasonable time, adding a herbicide to the mix to “brown-up” the grass and herbs will be necessary.

Advantages of aerial chemical spraying:

- a. It can be used to treat large areas quickly and effectively and is cost efficient.
- b. The prescription can be tailored to problems associated with specific species to give thorough brush control.
- c. The chemicals do not disturb the soil or site quality if they are properly prescribed and applied according to their label.
- d. Wet ground conditions do not affect the application.

Disadvantages of aerial chemical spraying:

- a. Aerial spraying needs to have large acreage, 40 acres or more, to be cost effective.
- b. If heavy amounts of debris on the ground will impede planting or large standing hardwood is to be deadened (creating a long-term fire hazard), other methods may give better results.
- c. There is danger of spraying adjacent areas, with associated liabilities.
- d. Spraying introduces chemicals into the environment, with the possibility of unknown side effects.
- e. Dry soil conditions and heavy clay soils decrease the effectiveness of some soil-active herbicides.

**1B.** Prescribed burning is the cheapest site-prep method. It is most effective when the brush is 1 inch in diameter or smaller.

Advantages of site-prep burning:

- a. It cheaply kills the brush to the ground to give the pine seedlings an even start with the hardwood brush.
- b. Site-prep burns do not greatly disturb the soil, so not much soil loss occurs.
- c. It can be applied efficiently on small tracts.

Disadvantages of site-prep burning:

- a. It does not kill many of roots of the brush, so sprouting occurs, which reduces the pine sapling growth.
- b. The probability of having to release the pine seedlings later, or putting the plantation at risk of failure, is higher than with other methods.
- c. Application is limited by wet ground and other weather conditions.
- d. The larger hardwood cannot be effectively controlled. It does not

do a good job on hardwood stems more than 4 in. DBH, or on dense stands of 2–5 in. DBH hardwood. If any hardwoods on the tract are more than 6 in. DBH, they probably will not be controlled by this method.

**1C.** Ground mobile chemical spraying with a droplet sprayer and burning is an effective method of site-prep in predominantly small brush under 25–30 ft tall.

Advantages of ground mobile chemical spraying:

- a. This application can be used efficiently on tracts 30 acres or larger. However, extra money will make it possible on smaller tracts. The price per acre will go up rapidly as the acreage of the tracts decreases.
- b. The prescription can be tailored to specific species problems to give thorough brush control.
- c. Chemicals do not disturb the soil and do not cause large increases in soil loss. It has been reported that the forest herbicides available today do not have long-range degrading effects on the soil or site quality if they are properly prescribed and applied according to their label.

Disadvantages of ground chemical spraying:

- a. Hardwood trees taller than 25-30 ft are likely to survive, making it necessary to spend additional money controlling the surviving overtopping trees.
- b. This method takes much more time to apply than aerial spraying and the applications are more expensive.
- c. It requires solid ground conditions.
- d. It introduces chemicals into the environment, with the possibility of unknown side effects.
- e. Accidentally spraying adjacent landowner's timber or crop is a risk.

**1D.** The shearing, bedding, and burning method gives very good control of woody vegetation, but the cost is higher than with chemical spraying. The method does have some advantages that may compensate for the higher cost.

Advantages of shearing, bedding, and burning:

- a. It improves drainage of the soil in the beds and offers good vegetative control.
- b. It improves survival of the seedlings.
- c. More organic materials are incorporated into the soil.
- d. Where the land has been badly rutted from wet-weather logging, bedding tends to help smooth out the ruts.

- e. It improves the growth of the saplings in the early years.

Disadvantages of shearing, bedding, and burning:

- a. Soil must be dry enough to hold heavy machinery to do a good job of bedding, which severely limits this method.
- b. It creates a significant unnatural disturbance of the forest soil, both physically and visually.
- c. It is one of the higher cost site-prep methods available and may produce a lower annual return than some cheaper applications.
- d. It creates such a good seed bed that natural seedlings overstock the plantation if a good seed source is close.

**1E.** The shearing, raking, piling, and burning method is one of the best methods when large amounts of debris are left from logging or when a great amount of large standing timber is left.

Advantages of shearing, raking, piling, and burning:

- a. Good woody vegetative control.
- b. Excellent access for planting, which should help the survival rate of the seedlings.
- c. An opportunity to remove the debris by burning the windrows, or if the tract is in a very sensitive area, to leave the rows unburned.
- d. Good if a large amount of debris from logging exists or a great amount of large non-merchantable standing timber is left.

Disadvantages of shearing, raking, piling, and burning:

- a. It is expensive.
- b. On areas with a thin topsoil layer, which is high in organic matter, this method may lower the site quality if the operator pushes too much soil into the piles.
- c. It creates such a good seed bed that natural seedlings overstock the plantation if a good seed source is close.
- d. Some small brush may not be controlled by the shearing and piling.
- e. It is limited by wet ground conditions.

**1F.** The other methods not discussed individually are: shear-rake-pile-bed-rip, shear only, chemical spray with a backpack, rip only, and tree injection. Each of these methods is used on less than 5% of the stands in this region. They are all useful methods and have a place in site-prep, but because of their low usage, they have been lumped together in this discussion. An average cost per acre for these “other” treatments is used in financial calculations.

The cost of each site-prep method is multiplied by the percentage that that method represents of the total site-prep done in the area studied. These

adjusted costs are then added to calculate a total weighted cost of \$90, used in financial calculations.

### Sapling Stage

2. (Age 1) The winter following the site-prep burn, the tract should be planted with large superior loblolly seedlings, preferably using 9 x 10-ft spacing, or other spacing that will provide about 485 seedlings per acre planted. By the end of the first year, mortality is likely to reduce the stand to about 400 seedlings per acre. To reduce the risk of ice damage, it is necessary to thin early. The goal is to have rapid early growth without completely sacrificing quality and board foot volume in the later part of the rotation. Since the loblolly pine is a prolific seed-producing species, plantations planted adjacent to mature stands have been estimated to become heavily overstocked 25% of the time.

3. (Age 3) Despite all the described measures, about 25% of the plantations will develop severe hardwood competition. An aerial chemicals spray of release strength can eliminate the competition. This would help ensure that the stand will grow large enough to allow thinning in the 13th year. Thinning early is important to assure both high returns and low risk of ice damage.

4. (Age 4) The stand should be precommercially thinned if too many trees become established. By this point, the manager will likely have a good grasp of forestry. Gas-powered brush saws or other suitable methods can be used to do this. Thinning to increase growth is important to reduce the risk of damage in the next ice storm. The saplings should be thinned to about 385 per acre (what the plantation would be after normal mortality at this age). Since we have estimated that only 25% of the plantations would be overstocked, the financial calculation will multiply  $0.25 \times \$45$  (average cost per acre).

5. (Age 6) The example includes an ice storm in the sixth year, which bends these saplings over, but it does not do much damage at this age. Hypothetically, the mortality in year 6 has been estimated to be about 3% as a result of the ice storm.

### Pulpwood Stage

6. (Age 13) The stand density target for the first pulpwood thinning will be 60 ft<sup>2</sup> basal area to help the trees strengthen their boles (trunks) as early as possible. About 225 trees per acre should be left after this first thinning, spaced on the average of about 14 ft apart to meet the basal area density target of 60 ft<sup>2</sup>.

The stand should be thinned mainly from below, i.e., removal of smaller and less promising larger trees. As many diseased, deformed, and forked trees

as possible should be removed. Those trees will not make a log in the future. Every tree left should have some extra crown space, within the 60 ft<sup>2</sup> basal area target.

7. (Age 14) The table accounts for a heavy ice storm at year 14, the year after the first thinning. This stand, which has been prepared for this event, would sustain damage but much less than unprepared stands would. About 35 trees are heavily damaged in the example, and 80% of the volume can be salvaged. This volume would be enough to use as short pulpwood and could be salvaged at normal pulpwood rates. One should be conservative in what is marked to be salvaged. Enough basal area should still be left to thin the stand at the planned age of 19. Then it will be clearer which trees would be the best to save for the future.

Hint: Trees with the tops broken in an ice storm can be kept, if they have at least one-third of their crown left and can produce at least one 16-ft log. If there is a localized area in the stand thinned by ice damage to below 60 ft<sup>2</sup> basal area, trees with less than one-third of their crown should be saved if they have at least five green branches. These trees will help stock with low basal area.

8. (Age 19) Pulpwood is thinned, principally from below. The best trees should be kept, and any trees crippled by the ice storm that can be replaced in the stand with a better tree should be removed, staying within the 60 ft<sup>2</sup> basal area target. After the thinning, there should be about 125 trees left per acre, with an average spacing of 19 ft, for a basal area target of 60 ft<sup>2</sup>. Hardwood pulpwood should be cut along with the pine if there is an operable volume.

### Sawtimber Stage

9. (Age 20) Hardwood competition control with aerial or ground mobile chemical spraying will be necessary in up to 75% of the stands at this age. Wider spacing, heavier thinning and no early prescribed burning will allow the hardwoods to grow faster and slow the growth of the pine. If hardwood competition control were done earlier, it might extend the period of juvenile wood formation. This treatment is more valuable in dry periods than when rain is abundant, but this should increase the growth of the pine stand until the first prescribed burning and a few years beyond. Ground mobile chemical spraying may be used if hardwood saplings do not exceed 25–30 ft in height.

10. (Age 25) Prescribed burning will reduce the fire hazard, decrease the understory competition from brush, and make the stand more accessible for logging. The burn will also enhance visibility, which will ease timber marking and provide a better environment for other activities. Prescribed burning is

the cheapest and most natural method to control undesirable vegetation. This burn is the first of a series of burns scheduled just before each harvest, beginning with age 25. Ice storms and exceptionally wet winters will interfere with the burning schedule. If an ice storm were to occur before the burn, the prescribed burn would have to be rescheduled for age 28. The burn at age 30 should be done to get back on schedule.

Hint: Prescribed burning in a stand this old or older can be done with caution 2–3 years after an ice storm or pulpwood cut. A small non-industrial landowner should contract with the local office of the State Forestry Commission to do the prescribed burning or enter a management assistance program that will provide experienced supervision of the burning. Some consultant foresters also do prescribed burning.

11. (Age 25) At this age it is likely to expect a heavy ice storm. The early thinning and low density of the stand would have strengthened most of the trees, and thus there is little damage. This is the first thinning with any conventional log volume, and the density target changes to 70 ft<sup>2</sup> basal area, since the stand is past the most vulnerable ice damage period. The damaged trees should be salvaged, and the best trees saved. Trees that are too deformed to make logs in the future should be marked and cut, unless they are needed to maintain the prescribed 70 ft<sup>2</sup> basal area. To reach the basal area target of 70 ft<sup>2</sup> for this stage, the stand should have about 85 trees per acre with an average space between of 23 ft.

12. (Age 30) This prescribed burn should not be skipped; it will be only 5 years until the end of the rotation, and the hardwood understory must be completely under control. Remaining hardwood will be the major threat to establishing regeneration at the next rotation. If the hardwood brush is under control, the site-prep will be cheaper for the next rotation.

13. (Age 30) At this last thinning, more of the larger trees should be cut. Crooked trees and those whose merchantable log height is ended should be selected for cutting if the basal area target of 70 ft<sup>2</sup> permits. There should be 65 trees per acre left, spaced on an average of 26 ft apart.

14. (Age 35) This is the last prescribed burning of the rotation. This burning must be hot enough to give good hardwood control when the next rotation starts.

15. (Age 35) This is the end of the rotation, and all merchantable trees

should be harvested. This plan will produce the highest annual return for this stand.

17. Total Accrued Compounded Returns are the returns compounded from the year they occurred until the end of the rotation. Site-prep for the next rotation should be planned.

18. Total Accrued Compounded Costs are the costs compounded from the year they occurred until the end of the rotation, plus annual property tax. The accrued costs are shown as a range, as the costs depend on which silvicultural options are used.

19. Net Accrued Compounded Returns are total accrued compound returns minus total accrued compound costs.

20. For Annual Average Net Returns (Equal Annual Equivalent), all costs and revenues are combined into a single equivalent to all cash flows during the period and spread uniformly over each year of the rotation.

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