Management templates for increased biodiversity and economics in intensively managed loblolly pine plantations

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I. Introduction

There are a number of stand-level management practices that can support increased biodiversity in intensively managed loblolly pine (*Pinus taeda*) plantations.[1] These practices include thinning, prescribed burning, less intensive site preparation, longer rotations, and others (for a complete review see Zobrist et al. 2005b). For best results, many of these practices can be used in combination with each other, though timing is important. For landowners or managers interested in supporting greater biodiversity in their plantations, it can be useful to summarize these practices into a set of specific but flexible guidelines or management "templates."

From a private landowner's perspective, it is particularly useful to identify templates that will support increased biodiversity while maintaining an acceptable economic return. Some practices for increasing biodiversity are complimentary with timber production and economic goals, while others involve some level of trade-off (Allen et al. 1996, Hunter 1990). An approach for creating templates for achieving biodiversity and economic goals has been developed for riparian zone management in the Pacific Northwest (Zobrist et al. 2004, 2005a, 2005c). Using this approach, we have developed an example template for southern loblolly pine plantations as a demonstration of how the approach developed in the Pacific Northwest can be used to address biodiversity issues in other regions. In this report we will describe how the template approach was applied to southern conditions, examine the biodiversity and economic outcomes of the example template, and discuss additional southern applications of this template process.

II. Identifying biodiversity and economic criteria

The key to supporting biodiversity is to provide structural diversity (Allen et al. 1996, Harris et al. 1979, Marion et al. 1986, Sharitz et al. 1992). Ultimately this is best achieved at the landscape level, but structural diversity can also be increased at the stand level to provide significant benefits to biodiversity. The natural longleaf pine (*Pinus palustris*) forests that historically covered much of the South had high levels of structural diversity. These stands were characterized by open overstories that allowed light to reach the forest floor. Frequent, low-intensity fires prevented dense midstories and shrub layers from developing and stimulated the understory vegetation (Noss 1988, Van Lear et al. 2004). The resulting understories had a rich herbaceous layer that had a diversity of native plants and provided necessary food, cover, and ground-level structures for a broad suite of wildlife.

An open pine stand with a minimal midstory and a diverse understory provides a good structural target that is likely to support high levels of biodiversity on appropriate sites. In order to assess management practices relative to this structure, the structure must be quantified. Hedman et al. (2000) established a dataset of "benchmark" plots that were characteristic of historic, open longleaf pine stands (*Figure 1*). The structural attributes of these plots can be used to create a

[1] Because of the commercial importance of loblolly pine as well as the number of acres in plantations in the South, we assume that this will be this species to which our template is applied.

quantitative target of desired stand conditions.[2] Potential management plans can then be assessed based on whether or not they produce structural conditions that are statistically similar to this target (Gehringer in press). While the Hedman dataset is somewhat small to do a robust statistical analysis, it provides a reasonable target range to demonstrate an example loblolly pine template.

Figure 1: An example of the benchmark conditions measured at International Paper's Southlands Forest (stand 400-053) by Hedman et al. (2000). The open, park-like structure of this uneven-aged longleaf pine-wiregrass stand supports a rich, herbaceous understory that provides habitat for a wide range of game and non-game wildlife species. Photograph taken by Craig Hedman.

Four key structural attributes were identified from the benchmark plot dataset: the density in trees per acre (TPA) and the quadratic mean diameter (QMD) of larger trees, and the density and QMD of smaller trees. Trees with a diameter at breast height (DBH) greater than 8 inches were considered larger trees, and those less than 8 inches in DBH were considered small trees.[3] The distributions of values for these four attributes when considered at the same time may be used to create a four-dimensional target region. The four-dimensional target can be represented visually

[2] The benchmark plots included longleaf, loblolly, and slash pine (*Pinus elliottii*) stands (natural and plantation). It was assumed that the target structural attributes would be applicable multiple pine species.

[3] The gap between the upper DBH limit for the small tree sub-target and the lower DBH limit for the large tree sub-target was motivated by a consideration of the diameter distributions for the targeted benchmark stands. The distributions were typically bimodal with the trough between the modes occurring within the interval from 5 to 10 inches. The total TPA for a stand is, therefore, larger than would be obtained by combining the TPA values for small and large tree sub-targets.

by splitting the large tree and small tree density and QMD components into sub-targets that can be plotted in two dimensions (*Figure 2*). The elliptical region in each sub-target represents an approximate 95% acceptance level, and this is the region that encompasses the central 95% of the target data, assuming a normal distribution. By using only the central 95% of the target, the influence of the most extreme outlying values in the target dataset are reduced. An observed stand structure that simultaneously falls within these two elliptical sub-target regions is statistically similar to the benchmark plots.

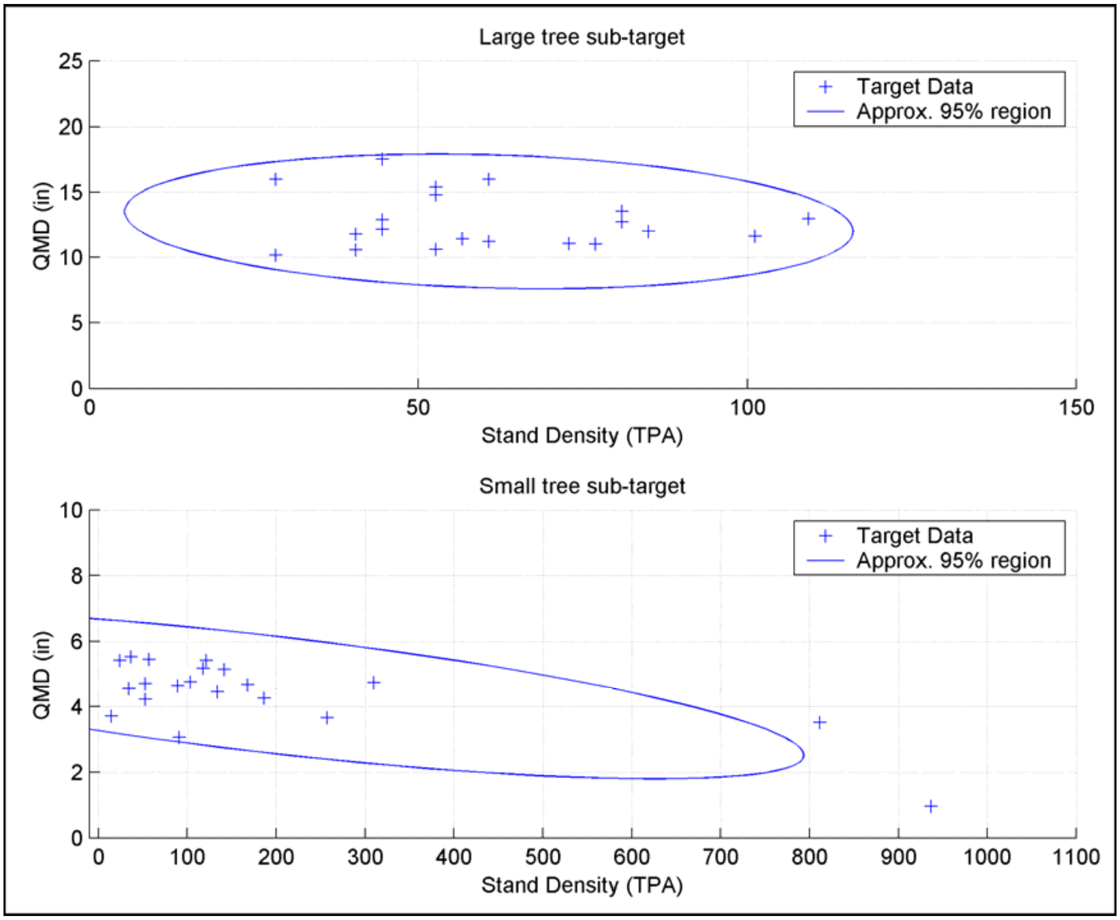

Figure 2: The 4-dimensional stand structure target is split into larger tree and smaller tree stand density and QMD sub-targets that can each be plotted visually in two dimensions. The ellipses represent approximate 95% acceptance regions for each sub-target. When comparing this target data to the one for Douglas-fir (see Zobrist et al. 2005c), the limitations of the pine dataset become clear as there are few data points outside of the 95% acceptance area.

The four-dimensional target provides a high degree of discrimination between the benchmark and non-benchmark plots. By including both a larger tree and a smaller tree component in the target, we can assess stands to make sure that they have an open pine canopy but have not developed a dense midstory. To be in the target, an observed stand must have some larger trees, but not too many or too few, while also having smaller trees in a midstory or understory, but again not too many or too few. The percent time over a 100-year simulation that predicted stand structures fall within the 95% target region was used as a specific biodiversity criterion for assessing potential template.

There are several metrics that can be used as economic performance criteria. Soil expectation value (SEV), or bare land value, is the net present value of a complete forest rotation repeated in perpetuity given a target rate of return (Klemperer 1995). This is perhaps the most important single economic criterion, as it reflects the economic performance of the initial investment in establishing a plantation given an expected management regime. This will be the metric of most relevance for landowners implementing a template that starts from bare land.

SEV is also relevant for landowners starting with mid-rotation stands, as at some point they will reach rotation end and be faced with the decision of whether or not to continue the template for additional rotations. Thus, SEV is the best indicator of long-term economic acceptability. However, landowners with mid-rotation stands may also be interested in the overall forest value (FV), which is also known as land and timber value (Klemperer 1995). FV includes SEV along with the net present value of the expected costs and revenues to hold the existing timber through the end of the current rotation, including the opportunity cost of using the land. In developing templates, we used SEV as the primary economic criterion but also considered FV for mid-rotation stands. In both cases, 5% was used as the target real rate of return, which is typical for financial analysis calculations.

III. Simulating management alternatives

The next step in developing templates is to define potential management alternatives. We established nine different alternatives that were intended to represent a range of management prescriptions that a private landowner might use if intending to harvest a minimum of some small sawtimber (chip and saw) at the end of the rotation. The first alternative was a 25-year chip and saw rotation, while the other eight were sawtimber rotations ranging from 35 to 55 years. Each alternative included a commercial thinning at age 15 in which every 5th row was removed, along with additional thinning from below to remove a total of 30% of the stand volume.

The sawtimber rotations included subsequent thinnings from below starting at age 25. To balance the frequency needed to maintain an open canopy with the economic viability of the operation, we used thinning intervals of either 10 or 15 years. We used two different thinning intensities, leaving a residual basal area (BA) of either 60 or 80 ft^2/acre. The complete list of alternatives is below. *Table 1* shows a management timeline of each alternative.

1. 25-year chip and saw rotation
2. 35-year sawtimber rotation with 10-year thinning interval to 60 ft^2/acre BA
3. 35-year sawtimber rotation with 10-year thinning interval to 80 ft^2/acre BA
4. 40-year sawtimber rotation with 15-year thinning interval to 60 ft^2/acre BA
5. 40-year sawtimber rotation with 15-year thinning interval to 80 ft^2/acre BA
6. 55-year sawtimber rotation with 10-year thinning interval to 60 ft^2/acre BA
7. 55-year sawtimber rotation with 10-year thinning interval to 80 ft^2/acre BA
8. 55-year sawtimber rotation with 15-year thinning interval to 60 ft^2/acre BA
9. 55-year sawtimber rotation with 15-year thinning interval to 80 ft^2/acre BA

Table 1: Management timeline for each alternative. Common to all alternatives is a 30% thinning at age 15. Final, clear-cut harvest occurred at 25, 35, 40 or 55 years. Mid-rotation thinning varied in timing and intensity.

Alt	Year								
	15	20	25	30	35	40	45	50	55
1	Thin 30%		Clear-cut						
2	Thin 30%		Thin 60 BA		Clear-cut				
3	Thin 30%		Thin 80 BA		Clear-cut				
4	Thin 30%		Thin 60 BA			Clear-cut			
5	Thin 30%		Thin 80 BA			Clear-cut			
6	Thin 30%		Thin 60 BA		Thin 60 BA		Thin 60 BA		Clear-cut
7	Thin 30%		Thin 80 BA		Thin 80 BA		Thin 80 BA		Clear-cut
8	Thin 30%		Thin 60 BA			Thin 60 BA			Clear-cut
9	Thin 30%		Thin 80 BA			Thin 80 BA			Clear-cut

Each management alternative was simulated using the Landscape Management System (LMS). LMS provides a user-friendly interface that integrates existing and publicly available growth, treatment, and visualization models (McCarter et al. 1998). One of the growth models that LMS interfaces with is the USDA Forest Service's Forest Vegetation Simulator (FVS). For our simulations we used the Southern Variant of FVS (Donnelly et al. 2001, Stage 1973, Wykoff et al. 1982).

Simulations were begun on a representative inventory from a 10-year-old plantation that was one of the benchmark plots (stand 300-030). The 25-year site index was 55. To be compatible with LMS, we converted this to a 50-year site index of 73 using a factor of 1.32 (North Carolina Division of Forest Resources 1988). We further increased the site index to 80 in the growth model to account for intensive management practices (Siry et al. 2001).

For each thinning operation, it was assumed that in addition to thinning the crop trees, all non-crop trees over 5 inches DBH were removed except for a small component (13 TPA) of desirable, mast-producing hardwoods (black cherry, hickory, and various oaks). For trees under 5 inches DBH, 40% of the stems were removed at the time of thinning to simulate mortality from being crushed, etc. during the operation. In the absence of understory vegetation control, heavy, repeated thinnings can result in an undesirable hardwood midstory that inhibits the understory (Hunter 1990, Schultz 1997). For our simulations, we assumed that prescribed burning was done every 5 years starting at age 20. This was not directly represented in our simulations. Rather, the impacts of burning on understory tree composition were indirectly represented by not simulating the natural hardwood ingrowth that would be expected after thinning treatments, assuming that such ingrowth would be killed or suppressed by burning.

Using LMS projections, stand structure relative to the target conditions can be assessed over time. Economic metrics for each alternative can be computed using an integrated financial analysis program called Economatic. An imbedded bucking algorithm is used to divide harvested trees into different log sorts based on user-defined parameters. User-defined log prices are then applied, and revenue calculations are imported into Economatic. Economatic then applies additional user-defined costs and revenues (such as planting and prescribed burning costs) and calculates both SEV and FV.

For these simulations, we used 1st quarter 2005 average stumpage prices for Georgia Region 2 (Timber Mart-South 2005). Since LMS volume outputs were in cubic feet, we converted board foot prices to cubic foot prices using a factor of 5 board feet/cubic foot (North Carolina Division of Forest Resources 1988). Prices per cord were converted using a factor of 75 cubic feet/cord (Timber Mart-South 2005). Cost assumptions included $13.25/acre for prescribed burning (Dubois et al. 2003) and $8/acre annual property taxes and overhead costs (Siry 2002). SEV was calculated retrospectively by assuming a $215/acre cost for planting and site preparation (Dubois et al. 2003, Siry 2002) at the beginning of the rotation (10 years prior to the beginning of the simulations on the 10-year-old representative inventory). All financial calculations were done before income taxes.

IV. Results

The percent time in target over a 100-year simulation, along with SEV/acre and FV/acre, is summarized for each alternative in *Table 2*. Alternative 1, the 25-year chip and saw rotation, never achieved structure similar to the target; it also had the lowest economic performance. SEV for this alternative was negative, indicating that, given our assumptions, investing in this rotation would not earn the target real rate of return of 5%. Shorter rotations generally have favorable economic returns. Our results may reflect several factors. The growth model computes volume based on a minimum 4-inch top, which can underestimate the volume of small-diameter pulp and chip and saw logs. The historically low current pulp price ($18.40/cord) was also a likely factor.

FV figures are higher than SEV, as they include the existing 10-year-old inventory for which establishment costs are sunk. The 35 and 45-year rotations (Alternatives 2-5) reached the target less than 25% of the time, but tended to perform well economically, with Alternative 5 performing the best. The 55-year rotations (Alternatives 6-9) had the most time in the target and had moderate economic performance. The stumpage values used to compute SEV and FV, along with harvested volume, are summarized in *Table 3* and *Table 4* respectively.

Table 2: Comparison of time in target over 100 years, SEV/acre, and FV/acre for each alternative.

Alternative	% Time in Target	SEV/Acre	FV/Acre
1	0%	($20)	$418
2	14%	$423	$1,140
3	14%	$480	$1,233
4	24%	$466	$1,210
5	14%	$619	$1,459
6	48%	$305	$947
7	48%	$413	$1,124
8	48%	$382	$1,074
9	38%	$415	$1,127

Table 3: Total harvest revenue by year for each alternative.

Alternative	Year								
	15	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**
1	$107		$905						
2	$107		$375		$2,990				
3	$107		$263		$3,432				
4	$107		$375			$4,253			
5	$107		$263			$5,412			
6	$107		$375		$634		$755		$4,477
7	$107		$263		$746		$1,206		$5,408
8	$107		$375			$1,656			$5,004
9	$107		$263			$1,750			$5,741

Table 4: Total harvested volume (cubic feet) by year for each alternative.

Alternative	Year								
	15	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**
1	435		2,965						
2	435		1,533		2,439				
3	435		1,073		3,141				
4	435		1,533			2,973			
5	435		1,073			3,772			
6	435		1,533		721		518		2,526
7	435		1,073		896		758		3,289
8	435		1,533			1,158			2,918
9	435		1,073			1,409			3,593

For each alternative, the simulation cycles that achieved the target conditions are shaded in *Table 5*. This gives some insight as to which management strategies were most successful in producing target structures. All of the sawtimber rotations reached the target after the second commercial thinning. All of the alternatives that were thinned to 60 ft^2/acre of BA remained in the target until final harvest, as did those that were thinned to 80ft^2/acre of BA at 10-year intervals. When thinned to 80ft^2/acre at 15-year intervals (Alternative 9), the stand fell out of the target 10 years after the second thinning. This suggests that heavier or more frequent thinnings are necessary to maintain the target structure. The alternatives in which thinning was done to 80 ft^2/acre (3,5,7,9) produced a better economic return than the comparable alternatives that were thinned to 60ft^2/acre (2,4,5,8). Thus, thinning more frequently to 80 ft^2/acre might be a good way to balance objectives. In each case, the overall time in target was limited by the rotation age.

Table 5: The management timelines from Table 1 with shaded areas indicating the simulation cycles for which the target conditions were achieved.

Alt	Year								
	15	20	25	30	35	40	45	50	55
1	Thin 30%		Clear-cut						
2	Thin 30%		Thin 60 BA		Clear-cut				
3	Thin 30%		Thin 80 BA		Clear-cut				
4	Thin 30%		Thin 60 BA			Clear-cut			
5	Thin 30%		Thin 80 BA			Clear-cut			
6	Thin 30%		Thin 60 BA		Thin 60 BA		Thin 60 BA		Clear-cut
7	Thin 30%		Thin 80 BA		Thin 80 BA		Thin 80 BA		Clear-cut
8	Thin 30%		Thin 60 BA			Thin 60 BA			Clear-cut
9	Thin 30%		Thin 80 BA			Thin 80 BA			Clear-cut

Aside from Alternative 1, which performed the worst relative to both criteria, increasing the percent time in target will involve some level of economic trade-off relative to Alternative 5, which had the highest SEV. The performance of each alternative relative to the two primary template criteria, time in target and SEV, are plotted in *Figure 3* to show a visual comparison of the trade-offs.

As shown in *Figure 3*, maximizing the time in target (Alternatives 6-8) involves a trade-off with SEV. One way this trade-off might be minimized is through increased hunting lease revenue. Hunting leases can provide forest landowners in the South with significant supplemental revenue, especially for landowners who provide high-quality habitat (Baker and Hunter 2002, Johnson 1995, Jones et al. 2001). Using time in target as an indicator of habitat quality, landowners who provide more time in target may earn hunting lease premiums. *Figure 4* shows what the relative trade-offs for each alternative would be assuming the following hunting lease rates: $4/acre for less than 20% time in target, $8/acre for 20-40% time in target, and $12/acre for greater than 40% time in target.[4] The trade-offs still exists, but they are reduced for the alternatives that have the most time in target, which may make these costlier alternatives more acceptable to private landowners.

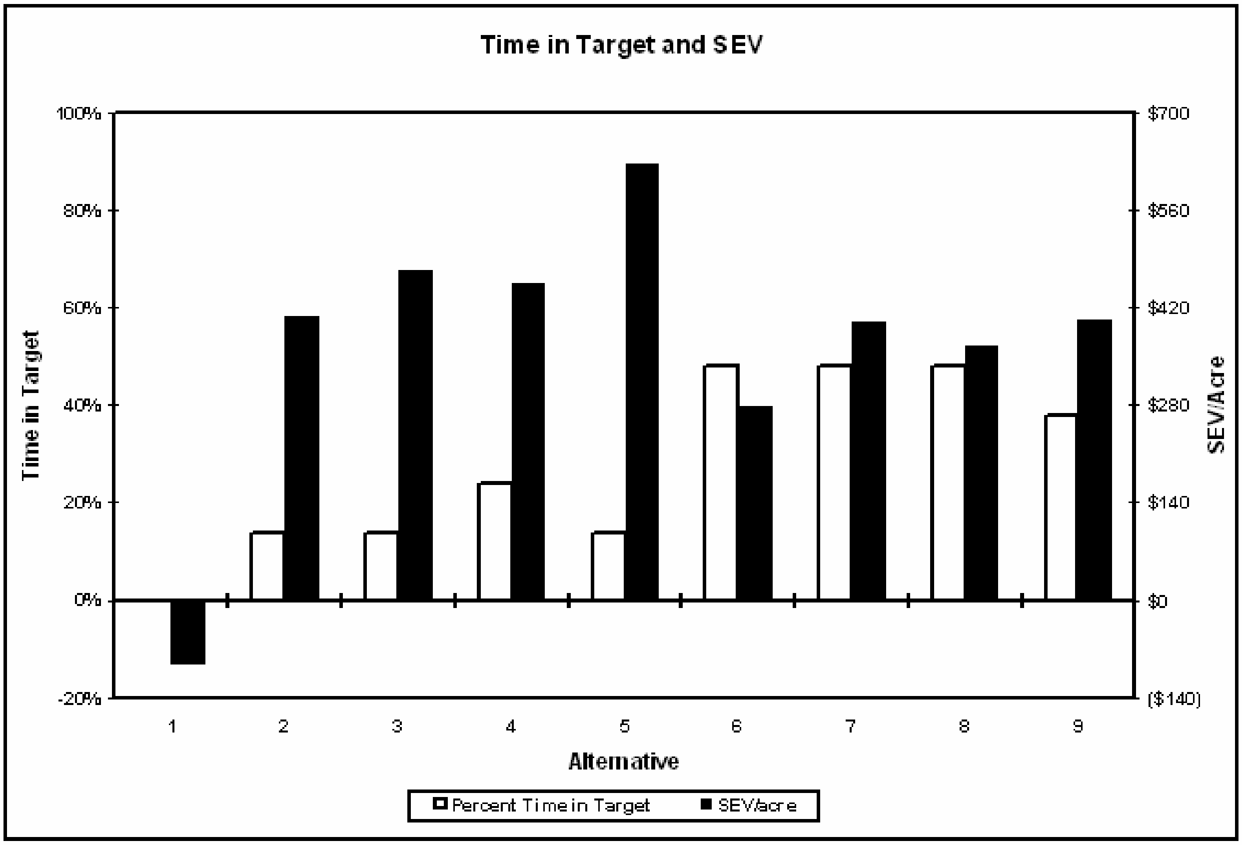

Figure 3: The percent time in target over 100 years plotted together with the SEV/acre for each alternative illustrates some of the trade-offs between biodiversity and economic return.

Quantifying the trade-offs between time in target and SEV can help identify the best template options from our 9 alternatives. *Table 6* summarizes the SEV cost (assuming hunting lease premiums) for each alternative as the difference relative to the maximum possible (Alternative 5). Both the total cost and the cost per percent time in target are given.

Three alternatives emerged from *Table 4*, illustrating a range of template options. The lowest cost template would be Alternative 5, for landowners who want to provide some level of biodiversity but not sacrifice economics. Of the alternatives that provided a higher percent of time in target, Alternative 4 was the lowest cost alternative and may be desirable for landowners who want to make a small improvement in biodiversity but cannot afford significant costs. Alternative 7 had the lowest overall cost/benefit ratio and thus produced the desired structure most efficiently. For supporting significantly increased biodiversity while maintaining a competitive economic performance, this may be the overall most desirable template option.

[4]Average net revenues for hunting lease in Mississippi were reported as $4.59/ac for 1997-98 (Jones et al. 2001). We believe that quality habitat can generate as much as $12-$15/acre.

Figure 5 illustrates the projected stand development from age 10 to 55 under Alternative 7. Complete stand development projections for each alternative are shown in the Appendix.

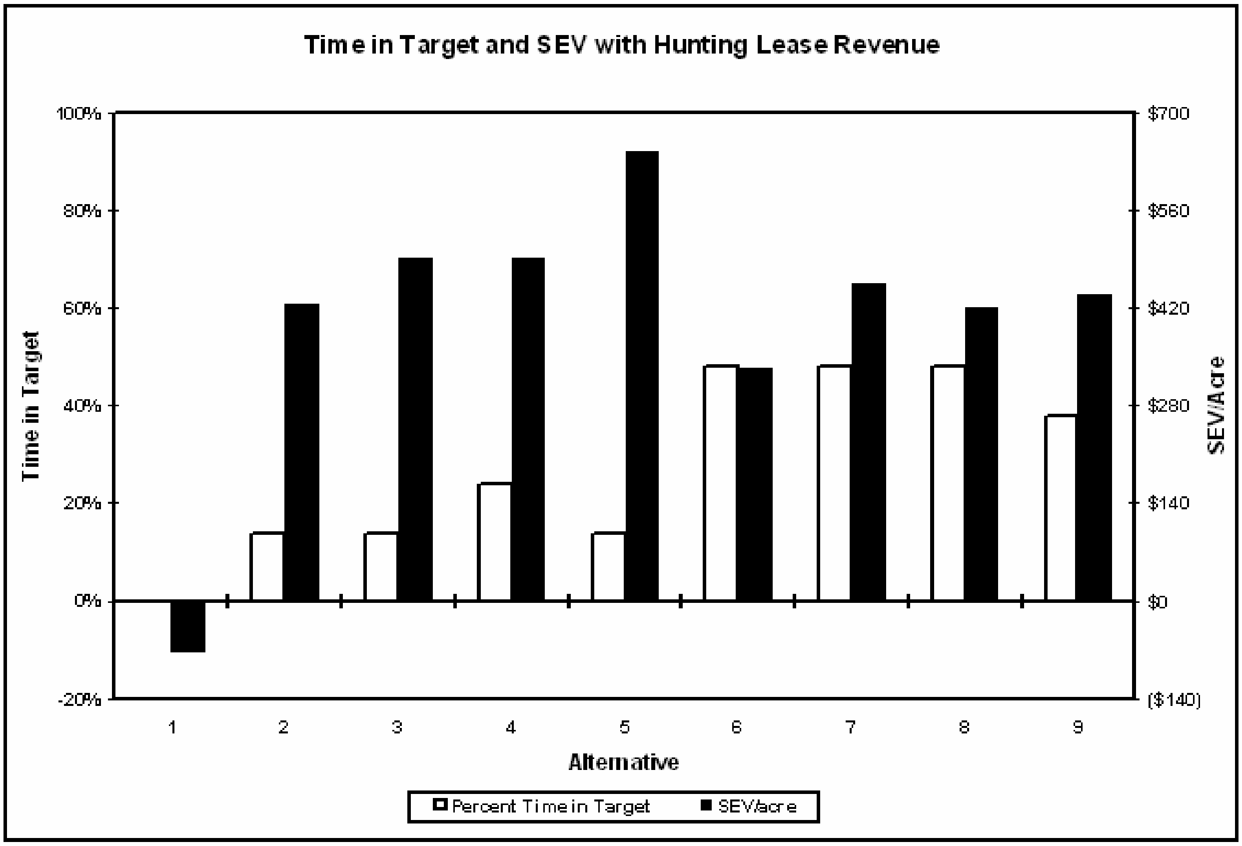

Figure 4: The percent time in target over 100 years plotted together with the SEV/acre for each alternative assuming hunting lease premiums, which can reduce economic trade-offs for alternatives with high time in target scores.

Table 6: Comparison of the SEV costs (as the difference relative to the maximum possible) and percent time in target over 100 years for each alternative.

Alternative	% Time in Target	SEV/Acre	SEV Cost	Cost/% in target
1	0%	($2)	$639	N/A
2	14%	$442	$195	$13.93
3	14%	$499	$138	$9.86
4	24%	$503	$134	$5.58
5	14%	$637	$0	$0
6	48%	$360	$277	$5.77
7	48%	$469	$168	$3.50
8	48%	$438	$199	$4.15
9	38%	$452	$185	$4.87

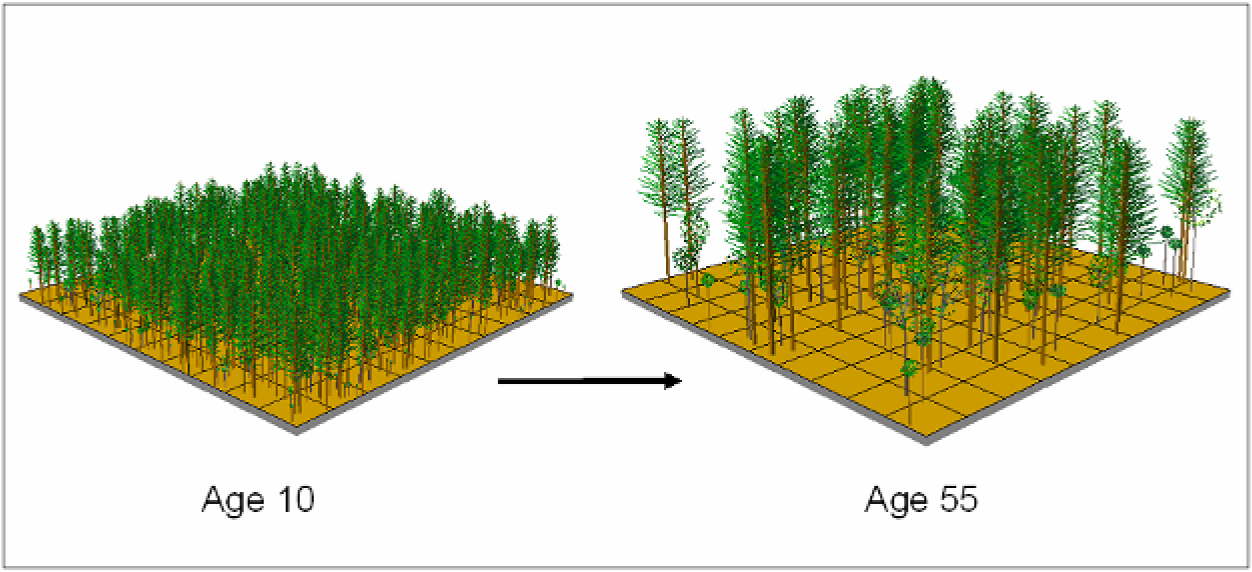

Figure 5: Projected stand development from age 10 to 55 under Alternative 7.

V. Template applications

The thinning and burning regime of Alternative 7 (*Table 7*) can potentially support significantly increased biodiversity in intensively managed loblolly pine plantations. When implementing such a template, several guidelines should be considered. One of the most important considerations is land use history. Old-field sites lack seed- and rootstock-banks (Baker and Hunter 2002). Plantations established on these sites are unlikely to develop a diverse, productive understory regardless of overstory management (Hedman et al. 2000). Thus, templates like this should only be applied to plantations established on cutover lands. Plantations on old field sites may be best managed for maximum timber production, as these sites will not likely support high levels of biodiversity.

Table 7: Thinning and burning timeline for Alternative 7.

Year	15	20	25	30	35	40	45	50	55
Alt 7	Thin 30%		Thin 80 BA		Thin 80 BA		Thin 80 BA		Clear-cut
		burn	burn	burn	burn	burn	burn	burn	burn

Additional management practices can be used in conjunction with a template like this to promote increased biodiversity. Moderate intensity site preparation may provide a reasonable balance of understory diversity and cost effectiveness (Locascio et al. 1990). Fertilization can promote biodiversity by improving understory food production in thinned stands (Hunter 1990, Hurst and Warren 1982). Snags and downed wood provide important habitat structures that should be retained as much as possible (Allen et al. 1996, Dickson and Wigley 2001, Lohr et al. 2002). Retaining riparian buffers will also promote biodiversity (Baker and Hunter 2002, Dickson and Wigley 2001).

Site specific factors should be taken into account when considering the frequency and timing of burning. Some suggest in general to burn before thinning, as it makes thinning easier (Hurst et al. 1980) and there will not be heavy fuel loads at the time of burning to cause the fire to burn too hot (Van Lear et al. 2004). When possible and practical, varying the season and frequency of prescribed burning can increase diversity and favor a broader suite of species (Robbins and Myers 1992). Likewise, leaving patches of unburned areas can favor some wildlife (Landers 1987, Moorman 2002). For both thinning and burning, mast-producing hardwoods like hickories and oaks should be retained if possible to provide food for wildlife (Johnson et al. 1975, Melchiors 1991).

The template presented above is just one example management strategy for supporting increased biodiversity while maintaining viable economics. The template incorporates some key basic principles for increasing biodiversity, such as longer rotations, early and frequent thinning, and prescribed burning. There are many possible variations of this proposed template that could achieve as good or better results. In particular, even longer rotations may provide for greater biodiversity. The time in target scores for the alternatives that we examined were ultimately limited by rotation length. SEV values for some of the 55-year alternatives were still competitive, especially if hunting lease premiums were assumed. Rotations longer than that can likely still achieve acceptable economic returns and may be desirable for landowners who are willing to incur additional costs to support higher levels of biodiversity. Earlier, more frequent, or heavier thinnings may also achieve target conditions sooner than the alternatives that we examined.

Most importantly, the template presented above successfully demonstrates an approach for developing sustainable management solutions that support increased biodiversity while maintaining economic viability. With additional data to quantify the desired conditions, a more robust target can be developed, which will be helpful for further refining this example template and generating additional templates. Ultimately a spectrum of management templates is needed to be applicable to a wide range of site conditions and to give landowners choices as they balance biodiversity and economic objectives.

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Metric equivalents

When you know:	**Multiply by:**	**To find:**
Cubic feet (ft^3)	0.0283	Cubic meters
Feet (ft)	0.3048	Meters
Inches (in)	2.54	Centimeters
Square feet per acre (ft^2/ac)	0.229	Square meters per hectare
Trees per acre (TPA)	2.471	Trees per hectare

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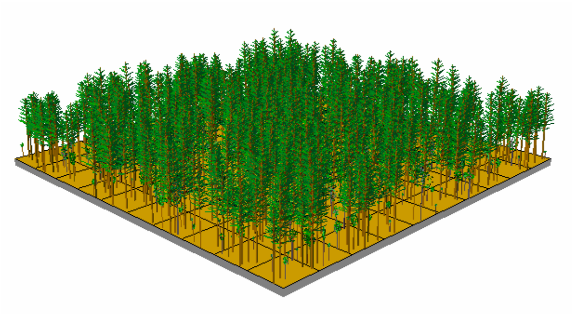
Appendix: Stand development projections

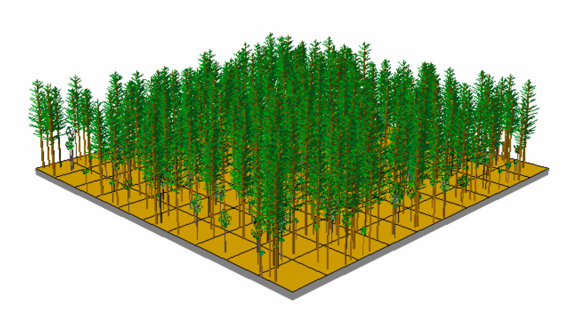
Below are projections of each management alternative over time using LMS and the Stand Visualization System (McGaughey 1997).

Alternative 1:

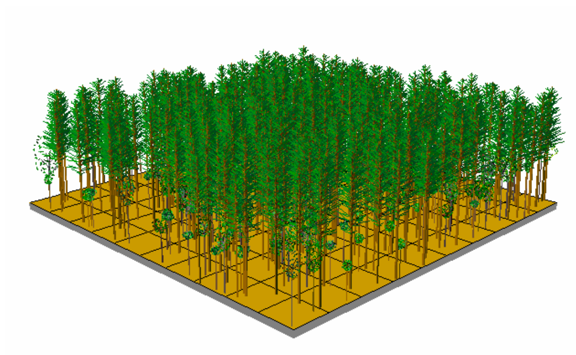
- 30% thin at age 15
- Clear-cut at age 25



Age 10



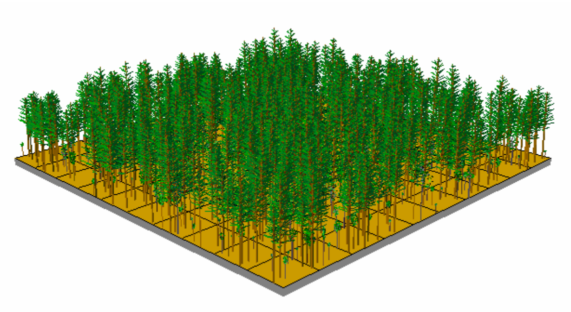
Age 15



Age 25

Alternative 2:

- 30% thin at age 15
- Thin to 60 BA at age 25
- Clear-cut at age 35



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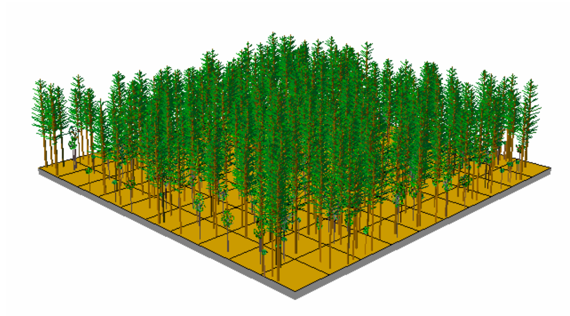

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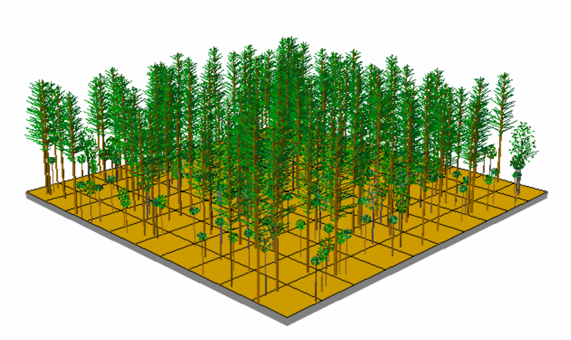

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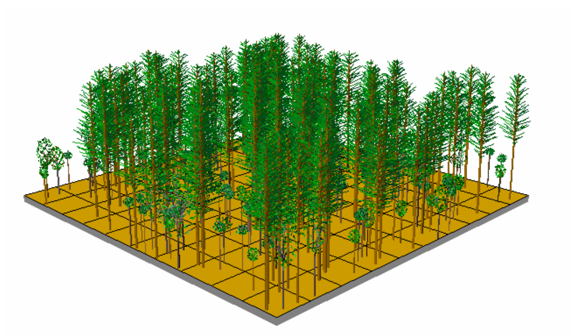
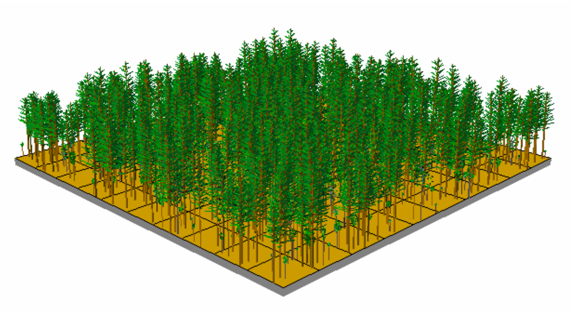


Age 35

Alternative 3:

- 30% thin at age 15
- Thin to 80 BA at age 25
- Clear-cut at age 35



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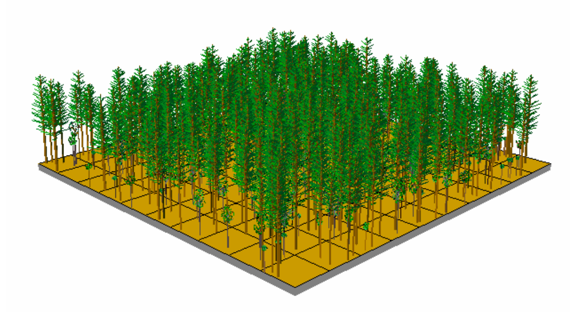

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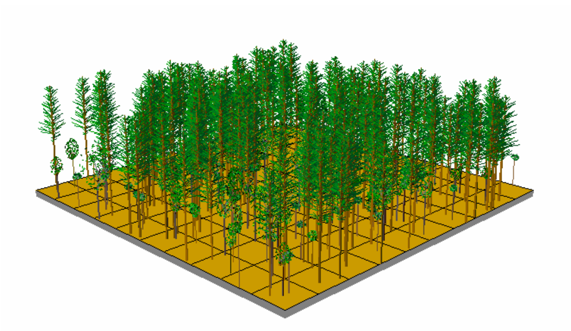
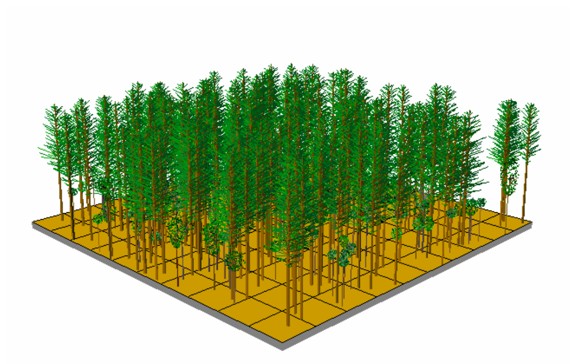


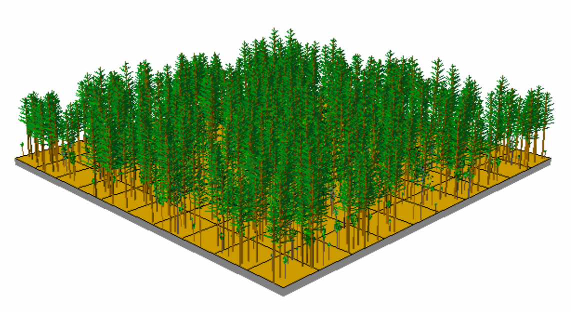
Age 25



Age 35

Alternative 4:

- 30% thin at age 15
- Thin to 60 BA at age 25
- Clear-cut at age 40



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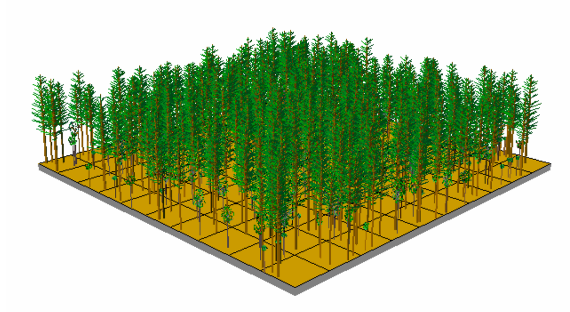

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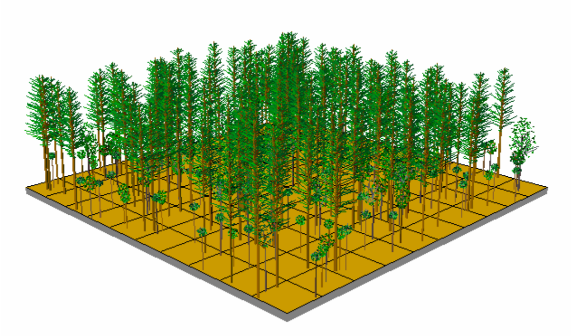
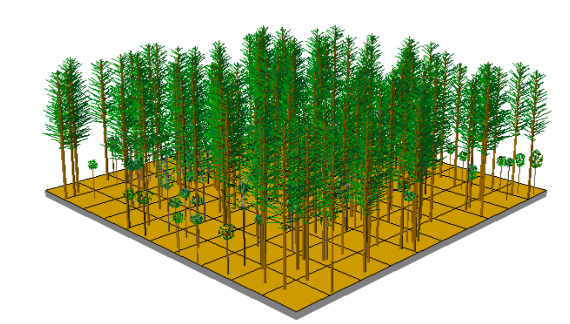


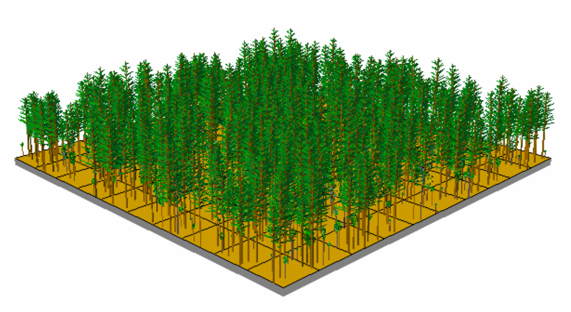
Age 25



Age 40

Alternative 5:

- 30% thin at age 15
- Thin to 80 BA at age 25
- Clear-cut at age 40



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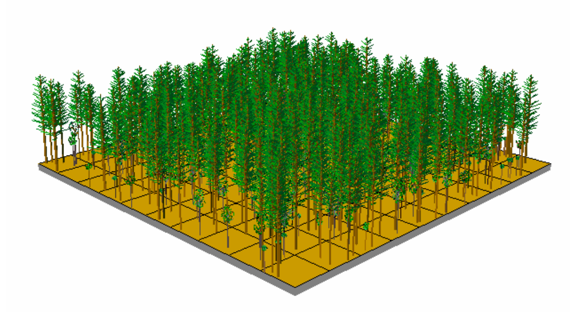

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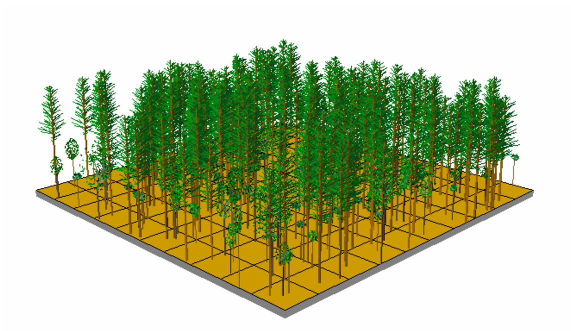
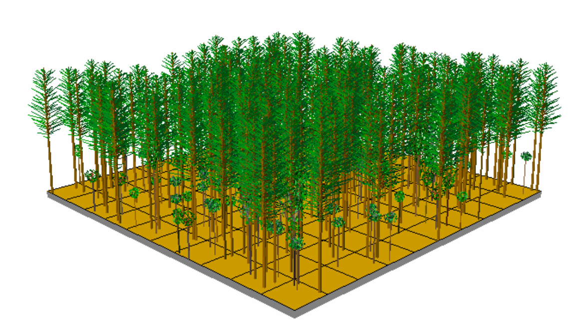


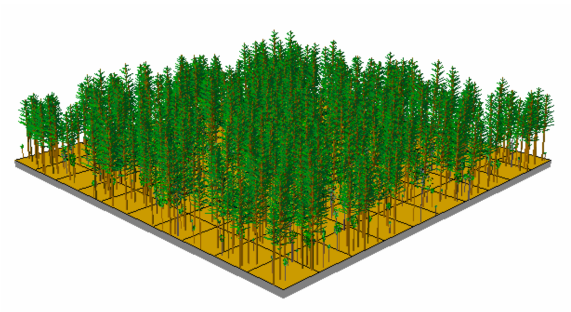
Age 25



Age 40

Alternative 6:

- 30% thin at age 15
- Thin to 60 BA at age 25
- Thin to 60 BA at age 35
- Thin to 60 BA at age 45
- Clear-cut at age 55



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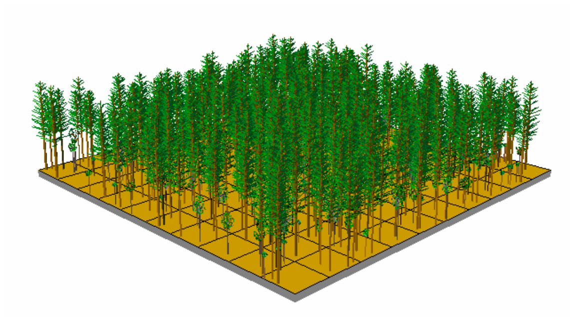
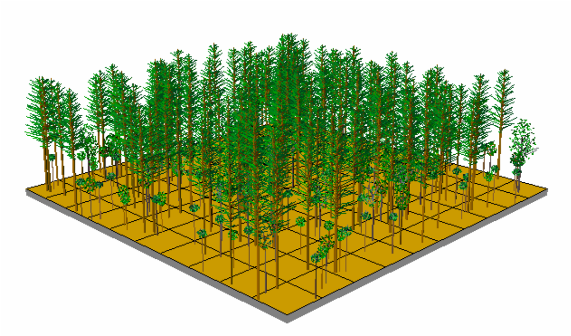


Age 15



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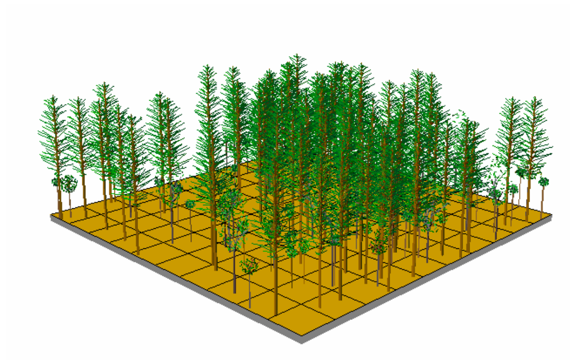
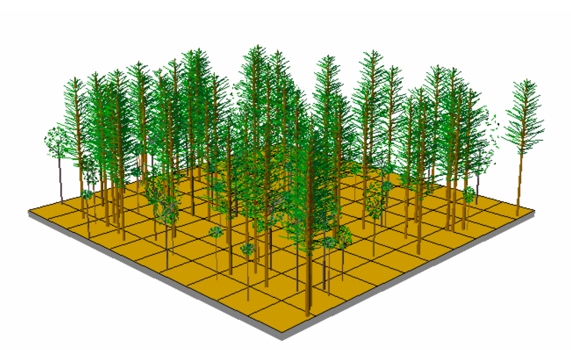
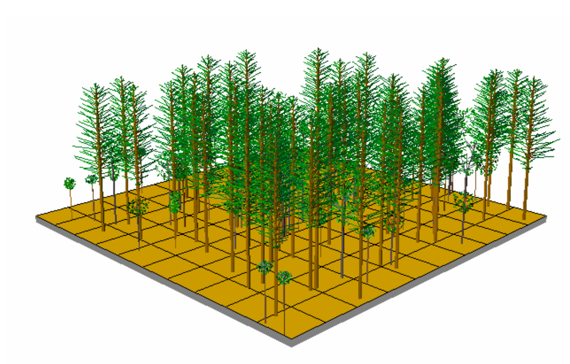


Age 35



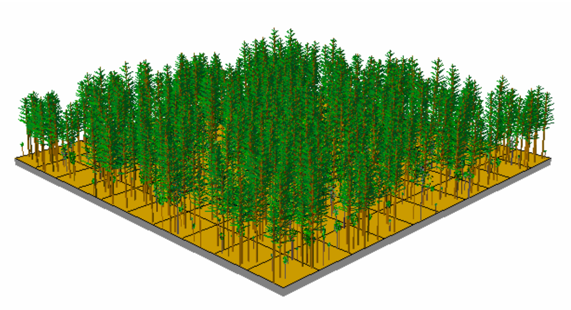
Age 45



Age 55

Alternative 7:

- 30% thin at age 15
- Thin to 80 BA at age 25
- Thin to 80 BA at age 35
- Thin to 80 BA at age 45
- Clear-cut at age 55



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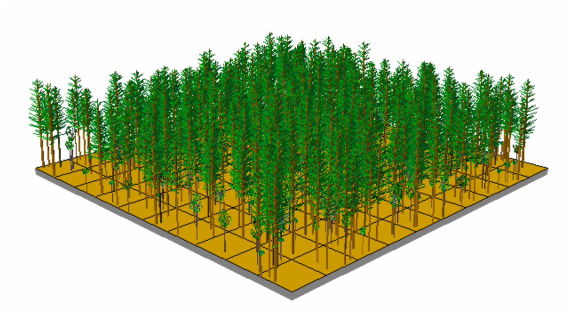
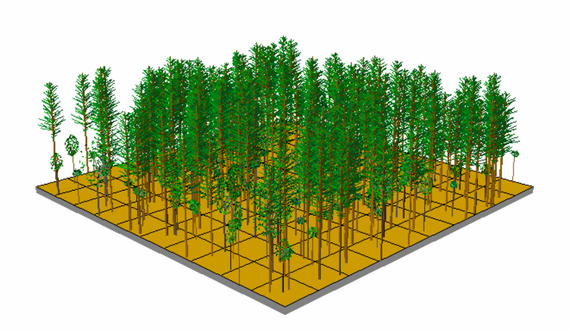


Age 15



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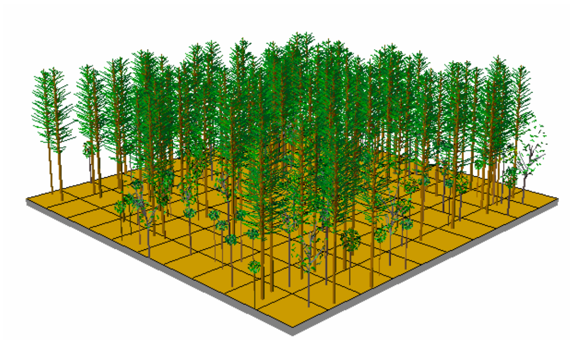
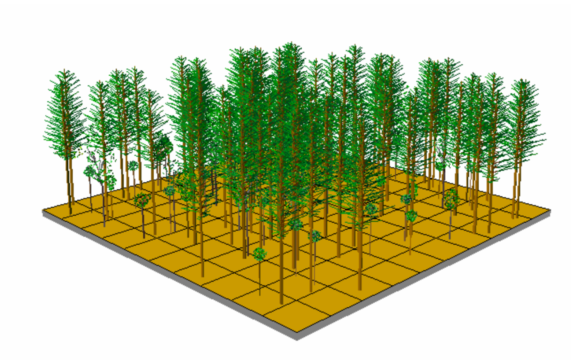
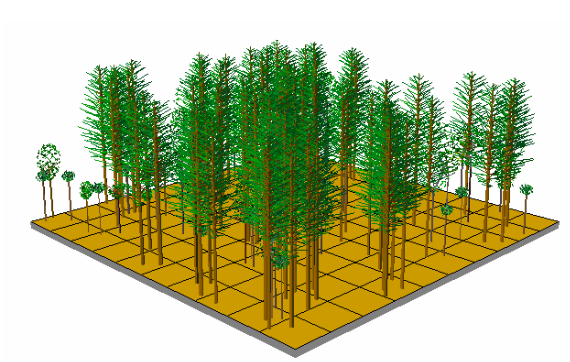


Age 35



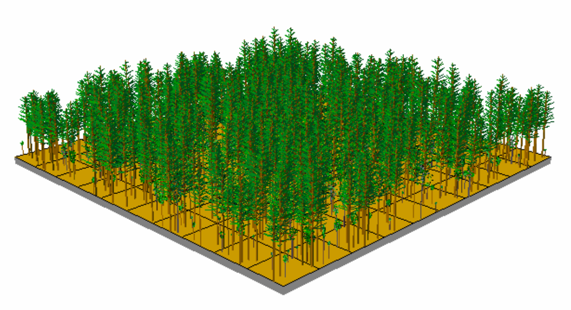
Age 45



Age 55

Alternative 8:

- 30% thin at age 15
- Thin to 60 BA at age 25
- Thin to 60 BA at age 40
- Clear-cut at age 55



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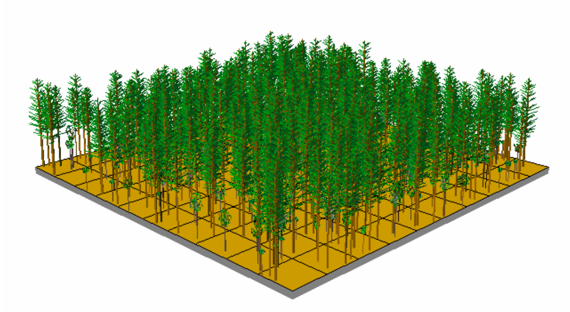

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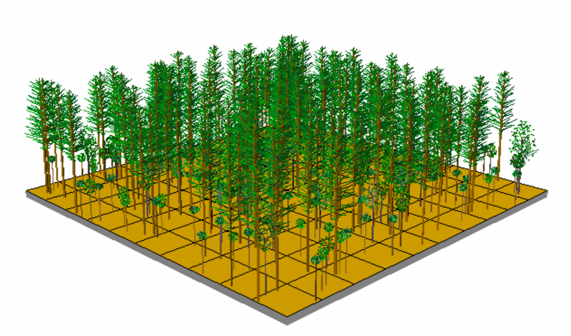

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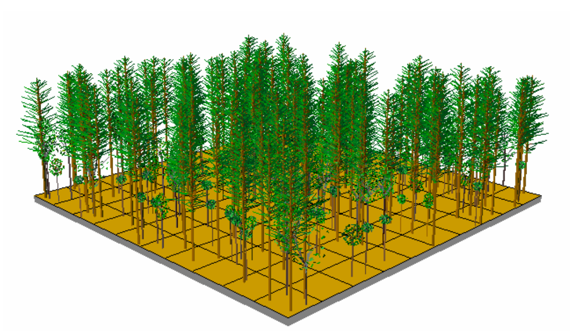

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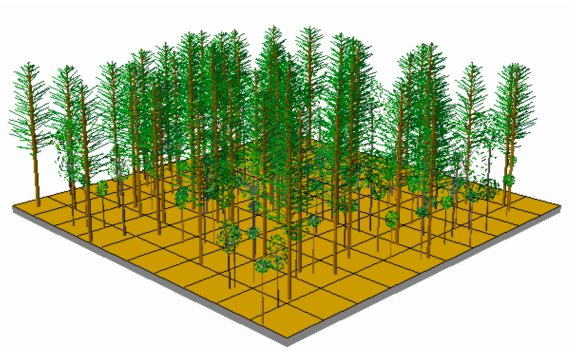

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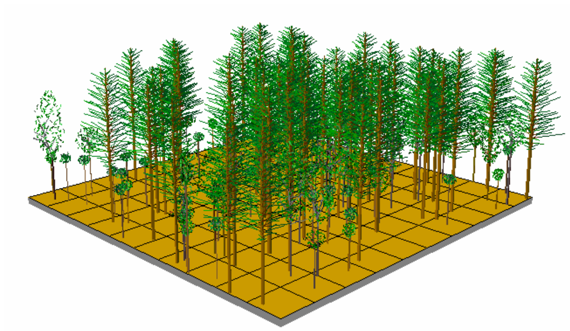
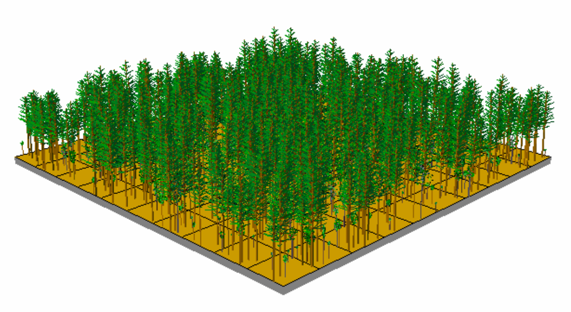


Age 55

Alternative 9:

- 30% thin at age 15
- Thin to 80 BA at age 25
- Thin to 80 BA at age 40
- Clear-cut at age 55



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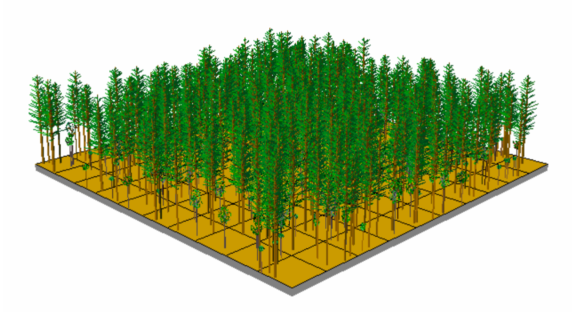

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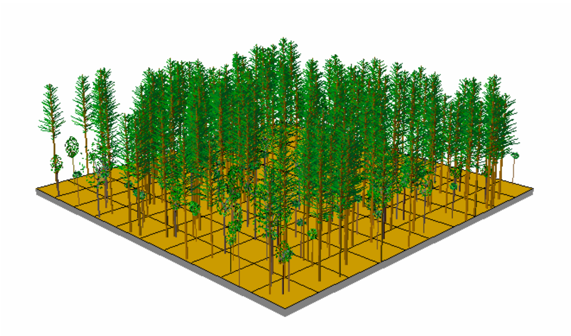

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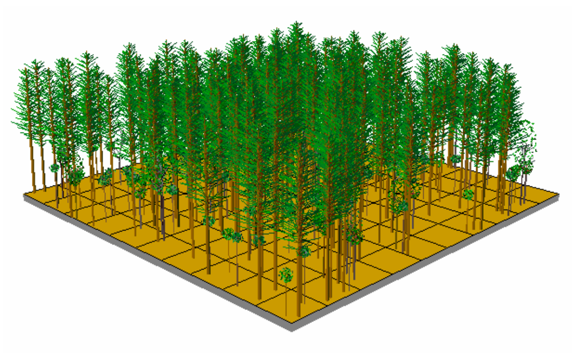

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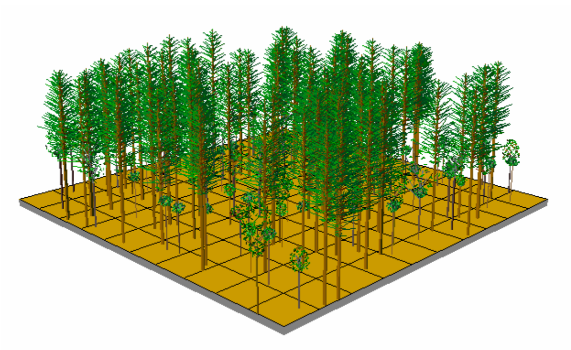

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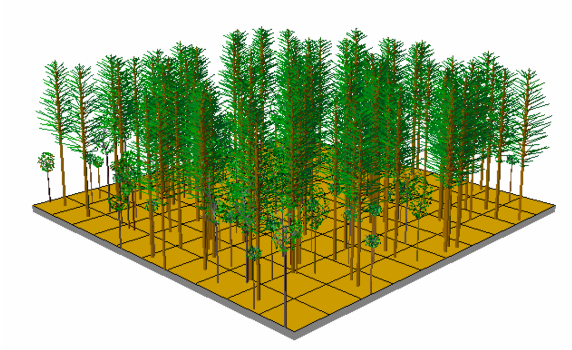

Age 55