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# USING GIS FOR SELECTING TREES FOR THINNING\*

I-Kuai Hung, Benjamin C. McNally, Kenneth W. Farrish, and Brian P. Oswald

## ABSTRACT

Thinning removes trees within a stand to regulate the level of site occupancy and subsequent stand development. Before thinning is applied, foresters determine the amount of residual growing stock, the spatial distribution of the residual trees, and the criteria used to select trees to cut. In this study, a portion of a loblolly pine (*Pinus taeda*) plantation was surveyed through a complete tree tally with the coordinates of each individual tree recorded. The dataset was then processed in a GIS program composed in Arc Macro Language (AML) applying a moving circular quadrat system superimposed over the study area. In each quadrant, tree attributes including DBH (nearest 0.1 inch), basal area ( $\text{ft}^2 \text{ac}^{-1}$ ), and density (trees per unit area) were utilized as determining factors for tree selection. A 3D visualization before and after thinning was created with a goal of equal distribution of trees across the stand.

Key words: Thinning, timber inventory, AML

## INTRODUCTION

### **Thinning**

Thinning is the silvicultural practice of adjusting the number and arrangements of trees in a stand to promote an increase in growth and productivity (Hendee *et al.*, 1995). Proper thinning maximizes the net profit that can be obtained from a stand. Thinning can be employed in different ways depending on the order of removal of trees.

The oldest method is *low thinning* or *thinning from below*, which removes trees from the lower crown classes to mimic the natural mortality of trees in single-canopied stands. Low thinning removes trees that are less than a given standard. This type of thinning is simple and usually leaves trees that have superior growth and vigor. *Crown thinning* is utilized to remove middle to upper crown and diameter classes. This method is also referred to as *thinning from above* and is used to open the canopy for the development of the most promising trees from the similar crown classes. Crown thinning is often used to improve the growth of selected trees without having to sacrifice the quantity of trees produced (Ashton *et al.*, 1997).

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*Selection thinning* focuses on the removal of trees to stimulate the growth of the trees in the lower crown classes. This is often done by selecting dominant trees with rough or defective stem form for thinning. *Geometric thinning* uses a predetermined spacing or pattern to thin a stand. It can be successfully employed in young stands that are of uniform density and quality. Two types of geometric thinning are *spacing thinning*, in which trees are removed at fixed distance intervals, and *row thinning*, in which whole rows of trees are removed from the stand at specific intervals. *Free thinning* can be any combination of the above four thinning methods. It is normally used in stands that are of uneven age, density, or composition. It can be used to remove defective dominants that are scattered in the stand or to produce a stand with a more homogeneous stand canopy (Ashton *et al.*, 1997).

## **Silvopasture**

*Silvopasture* combines timber, forage plants, and livestock production into a single integrated system. The term comes from the combination of the Latin word *silvo* meaning “forest” and *pasture* (Blount *et al.*, 2002). This combination generates high-value timber and forage for livestock (USDA, 1997). Silvopastures can be constructed by two different methods, converting an existing pasture by planting trees or converting tree plantations by thinning the existing trees to the proper parameters. The thinning reduces the amount of canopy of trees that is shading the ground area and achieves the proper amount of sunlight for both trees and grasses.

The purpose of this study is to convert a loblolly pine stand to silvopasture through thinning practice. In order to remove trees of lower crown classes for high-value timber growth and leave the residual trees evenly spaced for forage plants and livestock production, GIS was used to identify the order of removal of trees. With the capability of GIS, the sizes and density of trees and the distances among trees can be calculated to identify the trees to be removed based on the optimum density for a silvopasture.

## **MATERIALS AND METHODS**

### **Study area**

A 3.5-acre portion of a 18-year-old loblolly pine (*Pinus taeda*) plantation in the Fairchild Experimental Forest, Texas Forest Service was proposed to be thinned and converted to a silvopasture system, which is a resource management strategy combining both timber and livestock production. This combination generates high-value timber while providing forage and shelter for livestock. A stand basal area of 40 square feet per acre was assumed to be preferred for silvopasture (USDA, 2000), whereas a well managed pine plantation normally has a minimal stand basal area of 70 square feet per acre.

The loblolly pine stand is located in the western edge of Cherokee County, Texas. During the summer of 2004, the stand was completely tallied. With a total number of 412 trees, tree parameters of diameter at breast height (DBH, measured at 1.3 m above ground),

crown position, logging damage, fork severity, and damaging conditions were measured. The DBH ranged from 4.1 to 19.1 inch with a mean of 10.7 inch. The crown position separated the trees into 50 *dominant* (trees that are above the canopy), 307 *co-dominant* (trees within the canopy), 46 *intermediate* (trees slightly below the canopy), and 9 *suppressed* (trees that have limited access to sun light and are below the canopy). The logging damage (from an earlier thinning) was classified from 1-3 (1 being the least damage and 3 being the worst damage), with 39 trees affected. The fork severity was also graded from 1-3, 1 being high up the tree and 3 being closer to the ground, with 39 trees being affected. Damage conditions describe the instances such as wind damage or sweep in seven trees and were then graded from 1-3, 1 being the least amount and 3 being the worst. The geographic coordinates of tree locations were recorded using a sub-meter GPS unit. Finally, a point dataset of tree locations was created in GIS with all of the attributes measured. Basal area (BA) for each individual tree was then derived from its DBH as the area of cross section at breast height.

### **GIS process**

Since the plantation was completely tallied with not only quantitative but also qualitative attributes recorded on each individual tree, a preliminary selection for removal was applied using attribute query. The purpose of the preliminary removal was to prioritize the thinning practice so that those trees that had undesired characteristics would be removed. Initially, trees with suppressed crown position were removed, followed by trees with damage conditions. Then trees with forks low or midway along the trunk were selected for removal. After the preliminary removal, a residual number of 379 trees (249.28 ft<sup>2</sup> total basal area) remained from the original 412 trees (269.35 ft<sup>2</sup> total basal area) within the 3.5-acre stand.

The next step was to determine the spatial distribution of residual trees after thinning that would optimize the use of space to meet the silvopasture purpose. The ideal result after thinning is to have trees (weighted by basal area) distributed within the landscape as evenly as possible. In order to fulfill this task an AML (Arc Macro Language) program (ESRI, 1999) was compiled in GIS (Figure 1). This program selects one tree and removes it from the point dataset at a time. The process repeats until the user-defined condition is met, which in this study was 40 ft<sup>2</sup> ac<sup>-1</sup> basal area. During the GIS process, a circular area of 10-m buffer distance (defined by the user) was placed on a selected tree at one time. The buffer was used to identify all trees within the circular neighborhood. If 40 ft<sup>2</sup> ac<sup>-1</sup> BA was not met for a buffer area, nearest neighbor distances were calculated from tree to tree within the radius. Finally, a tree was selected to be thinned that had the smallest DBH within the group of trees whose nearest neighbor distances were below the average. Whenever a tree was removed from the point dataset, the program started over. If the total basal area within a buffer was less than 40 ft<sup>2</sup> ac<sup>-1</sup>, the buffer moved to the next tree location for another search until a tree for thinning was selected and removed from the point dataset. This conditional loop continued until the total basal area of the stand was reduced to less than 40 ft<sup>2</sup> ac<sup>-1</sup>.

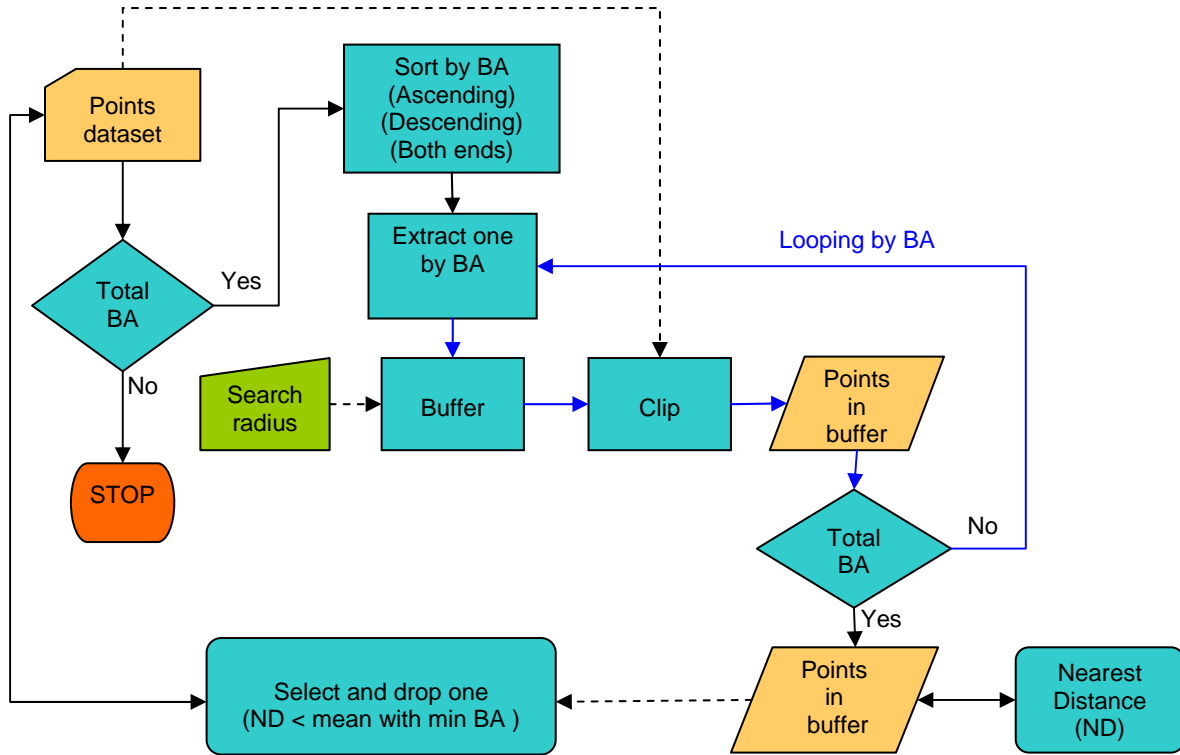


Figure 1. GIS process for thinning tree selection using AML.

Essentially, this is an approach of *thinning from below* since smaller trees are selected to be removed before larger trees are chosen. In the meantime, the spacing of residual trees was taken into consideration due to silvopasture purposes. This method can be defined as a type *free thinning* in combination of *thinning from below* and *geometric thinning*. Therefore, the sequence of locating a search buffer plays a role on the resulting basal area density distribution in the after-thinning landscape. For comparison, three search sequence criteria were integrated in the program as options. One criterion was *search-from-below* that sorts individual tree basal area by *ascending* order. In other words, the smallest tree is the first one to be placed at the center of a search buffer. Another criterion was *search-from-above* that sorts basal area by *descending* order. A third criterion, *search-from-both-ends* was also included, which flips between ascending and descending order whenever a tree is selected to be removed and the program starts over. If a tree is selected to be removed within a search buffer via ascending BA sequence, then the next tree selected will come from descending sequence.

In order to determine the optimum basal area density after thinning, a kernel density surface was created for each of the three search criteria.

$$\hat{f}(x) = \frac{3}{nh^2\pi} \sum_{i=1}^n \left\{ 1 - \frac{1}{h^2} [(x-x_i)^2 + (y-y_i)^2] \right\}^2 \quad (1)$$

The function measures density in a grid by using a sample of known points where  $h$  is the band width or search radius,  $n$  is the total number of points,  $\pi$  is constant, and  $(x-x_i)$  and

$(y-y_i)$  are the deviations in  $x$ -,  $y$ -coordinates between the point  $x$  and the observations  $x_i$  within the band width (Chang, 2003).

In addition, nearest neighbor distance was calculated on each of the point datasets, before the selection process and after three of the criteria. This was used to examine whether a point pattern is clustered, random, or evenly distributed. The  $R$  statistics is calculated based on the ratio between observed average nearest neighbor distance and expected average nearest neighbor distance (Clark and Evans, 1954). The calculation was done by using the tool Average Nearest Neighbor in ArcToolbox of ArcGIS 9.0, ESRI. When  $R$  is equal to one, it reveals that a point pattern comes from a complete spatial randomness without cluster or evenness (O'Sullivan and Unwin, 2003).

## RESULTS AND DISCUSSION

Figure 2 shows the four density surfaces of basal area. All of them were based on the search radius of 10 m, using basal area ( $\text{ft}^2$ ) as the attribute item instead of just reporting number of trees. The output cell size was set as 1 m, which reports basal area density as  $\text{ft}^2 \text{ac}^{-1}$  within a pixel.

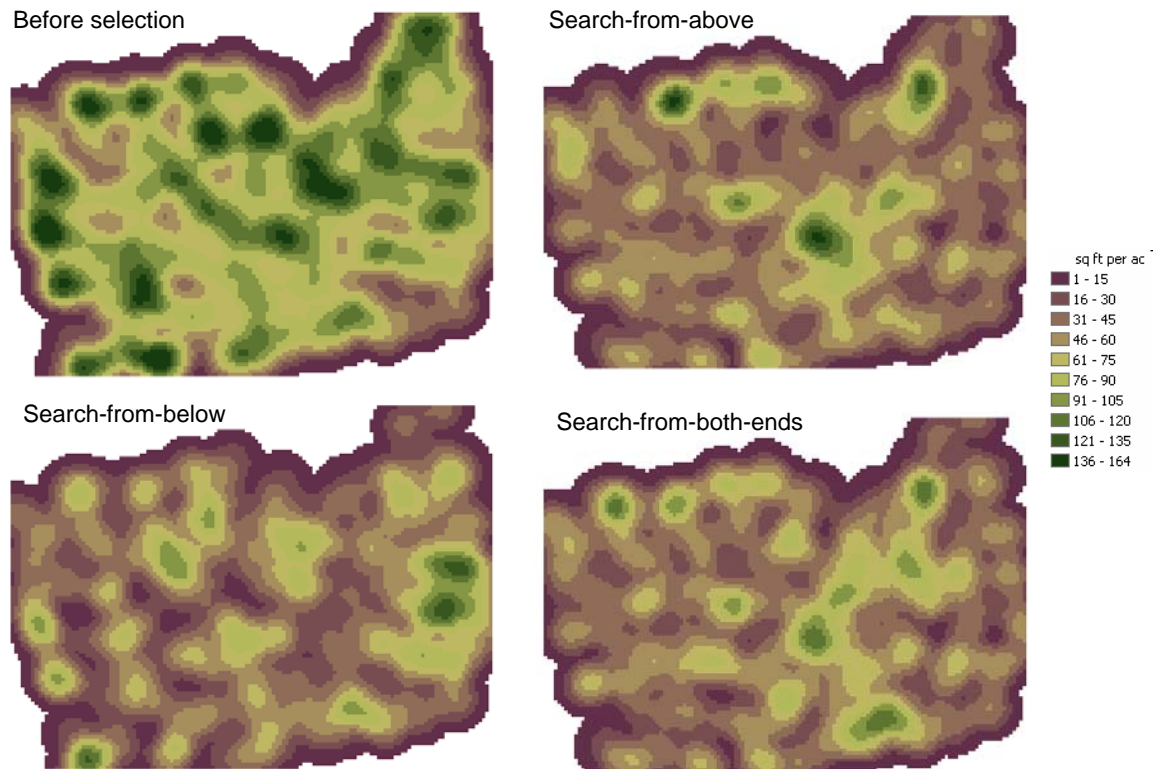


Figure 2. Basal area density surfaces by different search criteria for trees selection.

Through visual assessment on the density surfaces, the pine stand before selection revealed higher variation in basal area compared with those after selection (Figure 2).

Both search-from-above and search-from-below left a few spots of higher density, whereas search-from-both-ends resulted in a more homogeneous density surface. The high density spots left by search-from-below were where larger trees were clustered since those areas were not searched. This was caused because the condition (stand basal area less than 40 ft<sup>2</sup> A<sup>-1</sup>) was met before a search buffer could move to those large trees. On the other hand, the high density spots left by search-from-above were where smaller trees were clustered. Comparatively, search-from-both-ends resulted in a surface without extremely high density spots, which better fit the goal of equal spatial distribution.

Examining the statistics of the basal area density surfaces (Table 1), all three search criteria reduced the mean basal area from 74 to about 42 ft<sup>2</sup> ac<sup>-1</sup>. However, they differed in the standard deviation. Search from both ends resulted in the lowest standard deviation (22.29 ft<sup>2</sup> ac<sup>-1</sup>), which was slightly lower than search from above (22.85 ft<sup>2</sup> ac<sup>-1</sup>). This result reconfirmed the visual assessment that selection by search-from-both-ends will leave the residual trees using the space more evenly.

Table 1. Comparison of search criteria for selecting trees for thinning.

	Density surface (ft <sup>2</sup> ac <sup>-1</sup> )			Nearest neighbor distance (m)			
	<i>Mean</i>	<i>Median</i>	<i>Standard Deviation</i>	<i>Observed mean</i>	<i>Expected mean</i>	<i>R Statistic</i>	<i>Z value</i>
Before selection	74.74	78.75	34.98	3.15	3.15	1.00	0.03
Search from below	42.14	38.86	24.19	5.72	4.80	1.19	4.66
Search from above	42.55	40.25	22.85	4.55	4.30	1.06	1.60
Search from both ends	42.58	40.76	22.29	4.97	4.47	1.11	2.95

When looking at the statistics of nearest neighbor distance, the *R* value of 1.00 for the stand before thinning revealed a point pattern of complete spatial randomness. Initially, the pine seedlings were planted evenly. After years of competition and mortality, the remaining 412 trees constituted a more random pattern on the landscape. For those three selection criteria, all of the *R* values were greater than one, so all three resulted in an evenly distributed pattern after thinning and the values were all positive when converted to *Z* score. Search-from-below attained the largest *Z* score (4.66), which means the tree spacing after thinning is more evenly distributed than the two other alternatives. However, the nearest neighbor distance *R* statistics does not account the basal area of individual tree but only the point location. It should be interpreted in combination of the basal area density surface.

Since the search selection from-both-ends resulted in the lowest standard deviation of basal area density (22.29 ft<sup>2</sup> ac<sup>-1</sup>) and attained a higher *Z* score (2.95) of *R* statistics compared with its counterpart, search-from-above (*Z* = 1.60), it was identified as the optimum density thinning to fulfill the functions of silvopasture. Applying this optimum thinning approach, a total number of 224 trees supporting 269.35 ft<sup>2</sup> basal area will be removed and result in the final status of 188 trees with the average stand basal area of 39.82 ft<sup>2</sup> ac<sup>-1</sup> (Table 2).

Table 2. Stand parameters before and after optimum thinning.

<b>DBH (in)</b>	<b>Before</b>	<b>After</b>
Mean	10.7	11.5
Median	10.6	11.2
Mode	11.2	11.2
Standard Deviation	2.2	1.9
Range	15.0	9.7
Minimum	4.1	8.3
Maximum	19.1	18.0
Count	412	188
<b>BA (ft<sup>2</sup> ac<sup>-1</sup>)</b>	76.96	39.82

Figure 3 shows the DBH frequency distribution before and after the optimum density thinning, which increased the mean value of DBH from 10.7 to 11.5 inch and reduced the range from 15.0 to 9.7 inch. This result increases the homogeneity of the pine stand in tree spacing and standing timber value. A three-dimensional presentation of the pine stand before and after thinning was showed in Figure 4.

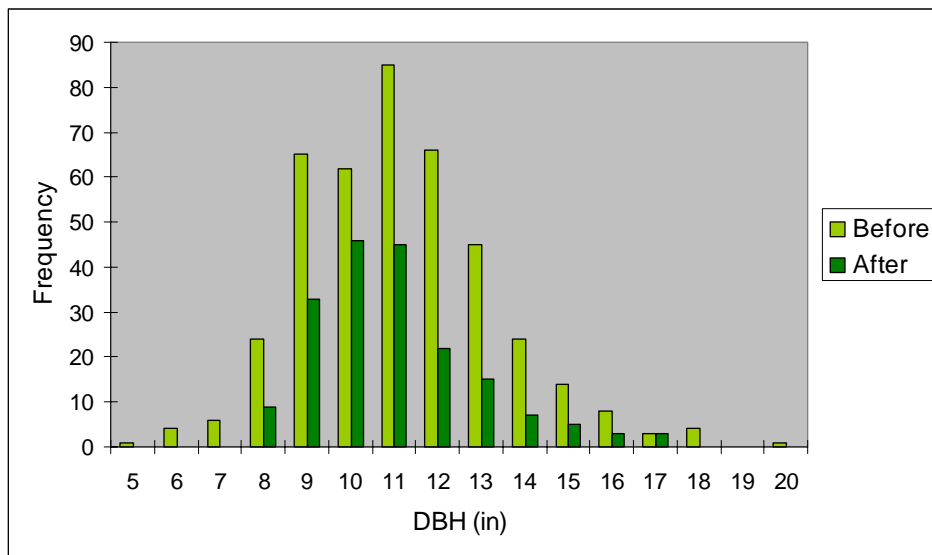


Figure 3. DBH frequency distribution before and after optimum density thinning.



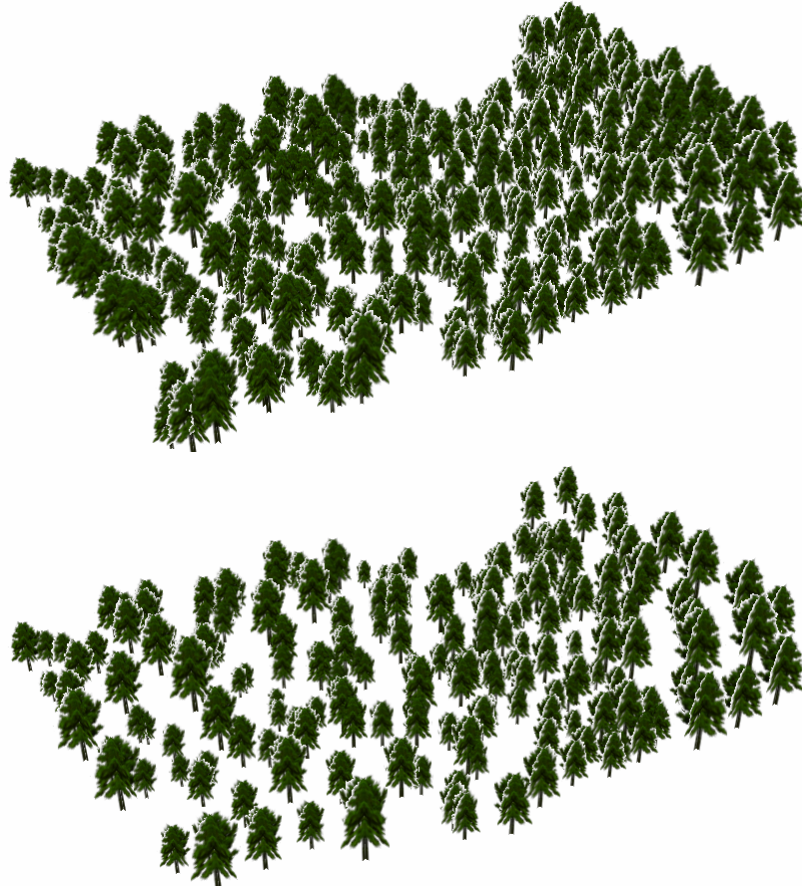


Figure 4. 3D presentation of the pine stand before and after optimum density thinning.

## CONCLUSIONS

Foresters have studied and utilized thinning for long time, mostly from economic aspects, and different thinning approaches have been applied to meet different desired stand structures. With the advances of GPS/GIS, different criteria can be proposed at individual tree level to achieve any optimum condition. Along with the maturing of LiDAR use in natural resources, it is promising that forest stand structure can be identified remotely with limited ground measurement. Once the location and DBH of individual trees are available in GIS, the program can determine the trees to remove for thinning. Equipped with GPS, the resulting GIS dataset would guide the harvest team to locate thinning trees in the field.

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