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Effects of site preparation on timber and non-timber values of loblolly pine plantations

Jianbang Gan [a,*], Stephen H. Kolison Jr. [a], James H. Miller [b], Tasha M. Hargrove [a]

[a] *Department of Agricultural Sciences, Tuskegee University, Tuskegee, AL 36088, USA*

[b] *USDA Forest Service, Southern Research Station, Auburn University, Auburn, AL 36849, USA*

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Abstract

This study evaluated the timber and non-timber values of the forest stands generated by four site preparation methods tested in the Tuskegee National Forest 15 yr earlier. The timber values of the forest stands were assessed with the timber yields predicted by the SE TWIGS model. Non-timber benefits were evaluated through the Contingent Valuation Method. Two hundred residents randomly selected from three counties surrounding or near the National Forest were interviewed. The survey results indicate that the majority (62%) of the respondents felt that the National Forest should be managed for both timber and non-timber products. Of the four site preparation methods, the soil-active herbicide method was projected to produce the highest timber value. For non-timber benefits, the respondents preferred the forest stand without site preparation to those generated using chainsaw felling, soil-active herbicide, and tree injection methods. When both timber and non-timber values are considered, no site preparation is in general the best alternative that seems to meet the desires of the various groups of citizens with different or even conflicting preferences over timber and non-timber products. © 1998 Elsevier Science B.V.

Keywords: Economic analysis; Contingent valuation; Multi-attribute assessment; National forest; Regeneration

1. Introduction

Extensive literature has been established on the effect of site preparation on tree growth and yield (Minore and Weatherly, 1990; Miller et al., 1991; Glover and Zutter, 1993; Greene and Lowe, 1993; Pienaar and Rheney, 1993a,b; Knowe and Stein, 1995) and financial returns of timber production (Dangerfield and Edwards, 1991; South et al., 1995). On the other hand, studies on how site preparation will affect non-timber values of forests are very limited. Recent decades have witnessed an increasing public demand for non-timber products and services from forests, particularly from public forests. In fact, national forests in the US are required to be managed for 'multiple uses', including timber and non-timber uses. To more comprehensively evaluate silvicultural practices like site preparation and to better meet the public's diverse demands for forest resources, there is a need to assess the effect of site preparation methods on non-timber as well as timber values of forest stands.

* Corresponding author. Tel.: +1-334-727-8321; fax: +1-334-727-8552; e-mail: jigan@acd.tusk.edu.

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Experimental plots treated with four site preparation techniques were established 15 yr earlier in the Tuskegee National Forest, located in southeastern Alabama, USA. This experiment was designed to study the long-term effect of site preparation treatments on loblolly pine (*Pinus taeda* L.) plantations. Each of the site preparation treatments has generated a specific structure of forest stands, which have various timber and non-timber values. This paper is to report the timber and non-timber values of the forest stands and to compare the four site preparation treatments in terms of these values.

This paper is organized as follows. Section 2 will demonstrate methods used to establish forest stands, evaluate timber and non-timber values, and rank site preparation methods. In Section 3, we will discuss the results of this study. And, conclusions will be presented in Section 4.

2. Methods

2.1. Establishment of research plots

In 1980, 16 research plots (each 0.5 ha) were established using four different site preparation methods in a recently-harvested mixed stand in the Tuskegee National Forest. Only pines > 10 cm dbh were harvested and all hardwoods were left. The site preparation methods tested were: (1) no site preparation, (2) chainsaw felling of all woody plants taller than 60 cm, (3) herbicide tree injection with Pathway (picloram +2, 4-D) of both hardwoods and pines > 5 cm dbh, and (4) soil-active herbicide (Velpar) applied in a spot-grid. After site preparation, loblolly pine seedlings (1-0) were hand planted on all plots using a 2.4 m × 2.4 m spacing. The experiment was a randomized complete block design with four replications. The site index (base 50 yr) ranged from 24 to 29 m for the four blocks. This forest is in the loam hills of the hilly coastal plain physiographic province, and all blocks were on upper and lower slopes (Miller and Robinson, 1995).

After 15 years, these site preparation methods have yielded different forest stands. The no site preparation method has produced mixed-unevenaged forest stands with one quarter of the BA in hardwoods. The chainsaw felling method has resulted in mixed-evenaged stands with about one half the BA in hardwoods. The tree injection method has yielded mixed-evenaged stands with one quarter of the BA in hardwoods. And the soil-active herbicide has generated mixed-unevenaged stands with mostly loblolly pine (only 5% hardwoods).

2.2. Determination of timber values

The timber yield of the forest stands treated with the four site preparation methods was projected using the SE TWIGS model version 6.1 (Bolton and Meldahl, 1990a,b). Two rotation lengths, 40 and 70 yr, were used due to the considerations that the optimal economic rotation age is about 40 yr and that the current rotation age used in the National Forest is around 70 yr. No thinning was assumed in predicting timber yield. The volumes of both sawtimber and pulpwood were estimated. Because of the lack of a market for the hardwood sawtimber, it was converted to pulpwood yield. In addition to timber yield, economic return from timber production was also evaluated using the criteria of Net Present Value (NPV) and Annual Equivalent Revenue (AER). Timber (both sawtimber and pulpwood) prices were taken from Timber-Mart South. With the projected timber yields and the average monthly prices, the mean timber value of the stands generated by each site preparation treatment was calculated.

The costs of the four site preparation methods were estimated based on current Forest Service contracts, average regional costs from Forest Farmer's Manual (Dubois et al., 1995), and experiment records (Miller and Glover, 1993). The estimated site preparation costs were zero for no site preparation, US$124 ha^{-1} for chainsaw felling, US$191 ha^{-1} for tree injection, and US$90 ha^{-1} for soil-active herbicide, respectively. The seedling price was estimated to be US$0.064 per seedling. And, planting costs were US$96 ha^{-1} for no site preparation and US$94 ha^{-1} for chainsaw felling, tree injection, and soil-active herbicide. With the timber values at the final harvest and the costs of the stand establishment and management, the economic return for timber production was determined. A 4% real discount rate was used, as recommended for the US Forest Service (Row et al., 1981). No taxes or land rent were included in the economic analysis.

2.3. Valuation of non-timber benefits

Unlike timber, non-timber products such as amenities and biodiversity do not have prices. Several methods for valuing non-priced benefits and attributes exist. In this study, the non-timber benefits of the forest stands were evaluated using the Contingent Valuation Method (Cummings et al., 1986; Mitchell and Carson, 1989). This widely used method is to induce respondents to release their preferences for a specific non-priced good by directly asking them the amount of their willingness-to-pay for the good. Two hundred persons randomly selected from three counties surrounding or near the Tuskegee National Forest were interviewed by using a carefully designed survey questionnaire. Land ownership status of the interviewees was not required. These counties were Macon, Lee, and Montgomery counties in Alabama, which ranged from rural to cosmopolitan. During the interviews, the interviewees were presented with four enlarged (0.20 m × 0.25 m), color photographs that presented the 15-yr old forest stands resulting from the four silvicultural treatments. The interviewees were asked to give their preferences and the dollar value that they were willing to pay for various non-timber benefits in each of the forest stands. The non-timber benefits valued by the interviewees included aesthetic value, picnic, hiking/walking/cycling, camping, hunting, bird watching, wildlife habitats, water protection, biodiversity, and mushroom/berries. The questions regarding the willingness-to-pay were open-ended, i.e., no monetary value or range was suggested in the questionnaire. The interviewees were given no information on how the forest stands were generated. In other words, they were not told that chemicals were used in the tree injection and soil-active herbicide methods. Further, the respondents were informed that the management of the National Forest was fully financed by taxes. The color photos used for the interviews were taken in April 1995. The interviews were conducted from April to December 1995 by seven trained interviewers (Hargrove et al., 1996; Gan et al., 1997).

2.4. Comparison of site preparation methods

A multi-attribute assessment approach was used to rank the four site preparation methods in terms of the timber and non-timber values of the forest stands generated. This approach enables an individual to select among choices with different attributes (Keeney and Raiffa, 1976). Usually, a weighted-additive utility function is used in a multi-attribute assessment. In general, for multiple attribute measures x_1, x_2, ..., x_n, the weighted-additive utility function can be specified as:

$$\mu(x_1, x_2, \ldots, x_n) = \sum_{i=1}^{n} w_i \mu_i(x_i) \quad (1)$$

where w_i is the weight for the ith attribute with $w_i >= 0$ and $\sum_{i=1}^{n} w_i = 1$. One disadvantage of the weighted-additive utility function is that all the weights must be known in prior. The weights are sometimes difficult to determine, particularly when many decision makers are involved; in our case, taxpayers who share different sets of weights. To overcome this problem, we used an algorithm which requires only partial information on the weights (Kirkwood and Sarin, 1985). The approach proposed by Kirkwood and Sarin requires only an ordering of the importance of the attributes, not the exact values of the weights for the attributes. However, this approach has its limitation, too. Using the partial information on the weights may result in an inability to distinguish the ranking of some alternatives.

Two attributes, timber and non-timber benefits, were included in this study. The four site preparation methods were compared by using two sets of the parameters: (1) the ratios of the timber and non-timber values to the establishment costs of the forest stands, and (2) the net present value of timber production and non-timber values. The use of the first set of the parameters implies that the forest establishment costs are jointly borne by timber and non-timber production. When using the second set of the parameters, we allocated all the establishment costs to timber production. Before applying the multi-attribute assessment approach, the value of each attribute was transformed to an index value ranging from 0 to 10 to overcome the unit difference in the

Table 1
Projected timber values of the forest stands treated with different site preparation methods at ages 40 and 70 using current prices and costs

Site preparation method	Timber value (US$ ha^{-1})	
	40-yr rotation	70-yr rotation
No site preparation	4868	10,053
Chainsaw felling	4026	10,068
Tree injection	5172	10,875
Soil-active herbicide	6089	11,357

attributes. Then, the multi-attribute algorithm was employed to find the efficient set of alternatives and to rank the alternatives.

3. Results

3.1. Timber values

With the inventory data at age 15 from the 16 plots, timber yield at ages 40 and 70 was predicted using the SE TWIGS model. According to the projected volumes of sawtimber, soil-active herbicide will produce the greatest volume, followed by the tree injection, no site preparation, and chainsaw felling methods for both 40- and 70-yr rotations. The soil-active herbicide method will also generate the highest timber value at both 40- and 70-yr rotations, whereas the chainsaw felling method and the no site preparation method will produce the lowest timber value at the 40- and 70-yr rotation, respectively (Table 1).

Economic return from timber production is presented in Table 2. The intensive site preparation does pay off in timber production at a short rotation. Based on the NPV or AER from timber production at a 4% real discount rate, the soil-active herbicide method is most profitable at the 40-yr rotation, but the no site preparation method is the best alternative at the 70-yr rotation. All NPV's and AER's decrease markedly as rotations are lengthened from 40 to 70 yr. The no site preparation method outperforms other three site preparation methods at a long rotation in terms of the economic return of timber production. This is because difference in timber yields resulting from various site preparation methods are thought to diminish with increasing in stand age; and this concept is ingrained in the SE TWIGS model and others. Also, as the rotation age increases, a small reduction in site preparation cost incurred at the beginning of the rotation period can offset a large amount of revenue at the end of the rotation.

3.2. Non-timber values

Sixty-two percent of the interviewees indicated that the National Forest should be managed for both timber and non-timber products. Among the non-timber products identified, wildlife habitat, water protection, and hiking/walking/cycling were ranked as the top three most important non-timber benefits from the Tuskegee National Forest by the respondents. According to the respondents' preferences, timber was ranked the fifth most important among all benefits.

The values (willingness-to-pay) of the non-timber products released by the respondents are presented in Table 3. In terms of the total values of the non-timber products, forest stands generated by the no site preparation method were valued markedly higher than those resulting after chainsaw felling, tree injection, and soil-active herbicide use. Means of the willingness-to-pay for all the non-timber products

Table 2
Economic return from timber production with 40- and 70-yr rotations[a]

Economic indicator	No site preparation	Chainsaw felling	Tree injection	Soil-active herbicide
Net present Value (US$ ha^{-1})	810/442[b]	514/321	561/306	978/437
Annual equivalent Value (US$ ha^{-1} yr^{-1})	40.93/18.87	25.96/13.76	34.58/13.07	49.38/18.75

[a]No taxes or land rent were included.
[b]40-yr rotation/70-yr rotation.

Table 3
Non-timber values of the forest stands generated by different site preparation methods

Site preparation method	Non-timber value (US$ person^{-1})
No site preparation	338
Chainsaw felling	269
Tree injection	250
Soil-active herbicide	249

were US$249, US$250, US$269, and US$338 per person for the forest stands generated by the soil-active herbicide, tree injection, chainsaw felling, and no site preparation, respectively.

3.3. Rankings of the site preparation methods

Three scenarios were considered in ranking the site preparation methods. These scenarios were: (1) timber and non-timber values are considered to be equally important, (2) timber values are recognized to be more important than non-timber values, and (3) non-timber values are thought to be more important than timber values.

A unique solution from the multi-attribute algorithm for each scenario was found. All the four site preparation methods were distinguishably ranked under all the three scenarios. When the ratios of the timber and non-timber values to the forest establishment costs are used as the parameters for ranking, the most preferred is the no site preparation method for both 40- and 70-yr rotations regardless of the preferences over timber and non-timber values. This implies that the no site preparation method is the best alternative for all the groups of the respondents, even those with different or conflicting preferences over timber and non-timber products. At the 70-yr rotation, even the order of the ranking of the four site preparation methods is exactly the same across the three scenarios. Again, the best alternative is no site preparation, consistently followed by soil-active herbicide, chainsaw felling, and tree injection (Table 4). The high non-timber values of the forest stands produced by the no site preparation method outweigh their low timber values relative to the stands generated by other site preparation methods even when timber values are considered to be more important than non-timber values.

Table 4
Rankings of the site preparation methods based on the ratios of the timber and non-timber values to the forest establishment costs

Site preparation method	$w_t = w_n$[a]	$w_t \gg w_n$[b]	$w_t \ll w_n$[c]
40-yr rotation			
No site preparation	1	1	1
Chainsaw felling	3	4	3
Tree injection	4	3	4
Soil-active herbicide	2	2	2
70-yr rotation			
No site preparation	1	1	1
Chainsaw felling	3	3	3
Tree injection	4	4	4
Soil-active herbicide	2	2	2

[a]Timber and non-timber values are equally important.
[b]Timber values are more important than non-timber values.
[c]Non-timber values are more important than timber values.

When the net present value of timber production at a 4% real discount rate and the non-timber values are used for ranking, the best alternative is also the no site preparation method except the scenario when timber values are considered to be more important than non-timber values at the 40-yr rotation. If timber values are given a higher priority than the non-timber values, the best site preparation method is soil-active herbicide, and no site preparation becomes the second best alternative (Table 5).

Table 5
Rankings of the site preparation methods based on the net present value of timber production at a 4% real discount rate and the non-timber values

Site preparation method	$w_t = w_n$[a]	$w_t \gg w_n$[b]	$w_t \ll w_n$[c]
40-yr rotation			
No site preparation	1	2	1
Chainsaw felling	4	4	2
Tree injection	3	3	4
Soil-active herbicide	2	1	3
70-yr rotation			
No site preparation	1	1	1
Chainsaw felling	3	3	2
Tree injection	4	4	4
Soil-active herbicide	2	2	3

[a]Timber and non-timber values are equally important.
[b]Timber values are more important than non-timber values.
[c]Non-timber values are more important than timber values.

4. Conclusions and discussion

The four site preparation methods affect differently the timber and non-timber values of the forest stands they generate. The soil-active herbicide method has the highest projected timber value at both 40- and 70-yr rotations, while the forest stand resulting from no site preparation is most preferred by the respondents in terms of the non-timber benefits. According to the net present value of timber production only (at a 4% real discount rate), the most profitable site preparation alternative is the soil-active herbicide method at the 40-yr rotation and the no site preparation method at the 70-yr rotation.

The majority of the respondents felt that the National Forest should be managed for both and timber and non-timber products. When both timber and non-timber value are considered, the best site preparation method is the no site preparation option. A single exception is the 40-yr rotation when all the establishment costs are borne by timber production, and when timber has a higher priority than non-timber products, then the soil-active herbicide method offers the best outcome. Therefore, in general, the no site preparation method is the alternative that can satisfy the goals of the groups with different preferences over timber and non-timber products. However, it should be noted that no site preparation was used after a partial harvest of only pines > 10 cm dbh. The residual pines and hardwoods left after harvest formed a major stand component after 15 yr, unlike the results that may occur from more complete harvest. Also, pine seedlings were planted at a regular spacing on all treatments, including the no site preparation plots.

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