How promptly nonindustrial private forest landowners regenerate their lands after harvest: a duration analysis

Xing Sun, Ian A. Munn, Changyou Sun, and Anwar Hussain

Abstract: Understanding factors that influence how promptly landowners regenerate their timberlands after harvest, if at all, is critical to developing policies to improve forest productivity. Mississippi forest landowners with over 100 acres (1 acre = 0.404 ha) of forestland were surveyed in 2006 to collect harvest and regeneration data from 1996 to 2006. This study investigated the length of the time interval between harvest and reforestation. Nonparametric duration analysis was used to examine how long nonindustrial private forest landowners waited to reforest after harvesting. Parametric duration analysis was used to examine factors that influenced the length of this period. The mean time elapsed from harvest to regeneration was 11 months for landowners that regenerated their lands. The instantaneous probability of regeneration reached its highest value in the 16th month after harvest and, thereafter, decreased steadily until the 28th month, after which the probability of regeneration was essentially nil. Interest in timber production, employing a consultant, and ownerships that were predominantly pine forest types were factors associated with substantially shorter reforestation times. Lower stumpage prices and higher reforestation costs were associated with substantially longer reforestation times.

Résumé : Il est crucial de comprendre les facteurs qui influencent la rapidité avec laquelle les propriétaires fonciers régénèrent leurs forêts après une récolte, s'ils le font, pour développer des politiques visant à améliorer la productivité de la forêt. Les propriétaires forestiers du Mississipi possédant plus de 100 acres (1 acre = 0,404 ha) de forêt ont fait l'objet d'une enquête en 2006 pour collecter des données de récolte et de régénération de 1996 à 2006. Cette étude porte sur l'intervalle de temps entre la récolte et le reboisement. L'analyse non paramétrique de la durée a été utilisée pour examiner combien de temps les propriétaires de forêt privée non industrielle ont attendu pour reboiser après une récolte. L'analyse paramétrique de la durée a été utilisée pour étudier les facteurs qui influencent la durée de cette période. Le temps moyen écoulé entre la récolte et le reboisement était de 11 mois pour les propriétaires qui ont reboisé leurs terres. La probabilité instantanée de régénération culminait au cours du 16^{e} mois après la récolte puis diminuait régulièrement par la suite pour devenir nulle après le 28^{e} mois. L'intérêt pour la production de matière ligneuse, impliquant le recours à un consultant, et la possession de terres occupées principalement par des forêts de pin étaient des facteurs associés à des délais de reboisement significativement plus courts. Des prix du bois sur pied plus faibles et des coûts de reboisement plus élevés étaient associés à des délais de reboisement substantiellement plus longs.

[Traduit par la Rédaction]

Introduction

Regenerating forestland after final harvest is fundamental to sound forest management. Providing for adequate regeneration, either through artificial or natural methods, is essential for maintaining productive timberlands. Landowners benefit monetarily from increased timber production, and at the same time, society benefits from restored forest-based environmental services such as providing aesthetic landscapes, clean water, enhanced wildlife habitat, and recreational opportunities. Given that regeneration is fundamental to sound forest management, it follows that the timing of regeneration is also critical. Site preparation and planting costs may increase with time if these activities are delayed (Sessions et al. 2004). Furthermore, if harvested sites are not regenerated promptly, water, soil, and amenity values may deteriorate and wildlife habitats may degrade (Granskog et al. 2002; Trani 2002). Therefore, the time elapsed before reforestation is a critical indicator of good forest management.

Many studies have investigated landowner reforestation behavior (Amacher et al. 2003; Beach et al. 2005). In general, these studies modeled landowner reforestation decisions as a binary choice: regenerate or not regenerate. Explanatory variables usually included land characteristics (e.g., ownership size and land type), owner demographics (e.g., household income, education, and residence), and market factors (e.g., sawtimber price, pulpwood price, and reforestation costs). For example, Royer (1987), employed logistic regression to model reforestation probabilities. Income, reforestation costs, government cost-sharing, technical assistance, and pulpwood price were highly significant determinants of reforestation. Hyberg and Holthausen (1989) also used logistic regression to investigate harvest-timing and reforestation-investment decisions of private landowners

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and obtained similar results. Other modeling approaches included Zhang and Flick (2001), who estimated a two-step selectivity model and found income and government financial assistance programs positively related with increased reforestation probabilities. Gunter et al. (2001), using nonparametric techniques, found landowners who regenerated were more likely to have larger ownerships, higher income levels, and more education. Also, they were more likely to reside in urban areas, be white males, and be employed in professional or business occupations.

In aggregate, the literature on nonindustrial private forest (NIPF) regeneration suggests that the likelihood of replanting decreases as the time since harvest completion increases. Site preparation and replanting costs increase with time (Sessions et al. 2004), and higher reforestation costs result in lower reforestation probabilities (Royer 1987; Hyberg and Holthausen 1989); thus, it is reasonable to infer that landowners are less likely to replant as the time since harvesting increases. However, previous studies have not investigated this time dimension as a factor influencing landowner replanting decisions. Given that landowners do not always replant promptly (Amacher et al. 2003), important unanswered questions include how long do NIPF landowners wait to replant after harvesting, the factors that affect the time interval between harvest and replanting; and whether the probability of replanting changes over time. Answers to these questions would be extremely useful in fine tuning policies intended to improve reforestation rates among NIPF landowners. Currently, federal incentive programs such as the Forestland Enhancement Program (www.fs.fed.us/spf/coop/programs/loa/flep.shtml accessed March 18, 2008) and state incentive programs such as Mississippi's Forest Resources Development do not specifically address or consider time delays in the allocation of benefits (Granskog et al. 2002). Therefore, the objective of this study is to determine how long NIPF landowners wait to reforest after harvesting (if at all), what factors affect this interval, how much each factor contributes to the probability of reforestation, and to what extent each factor affects the interval length.

Methods

We assume that NIPF landowners are utility maximizers, and we model their reforestation decisions accordingly. This approach has been commonly adopted in the forestry literature (Amacher et al. 2003). (For examples, see Hyberg and Holthausen 1989; Nagubadi et al. 1996.) Specifically, landowners maximize their expected utility by choosing to replant their harvested forestland at time T, where T can take on values from 1 to ∞; with ∞ implying that the landowner chooses never to replant. The value of T that maximizes landowner utility is a function of a vector of variables, $\boldsymbol{x}_i$, that is composed of land and ownership characteristics, landowner demographics, harvest characteristics, and market factors. Conceptually, the model is expressed as

$$[1] \qquad T_i = f(\boldsymbol{x}_i) + \varepsilon_i$$

where i is the ith individual and ε is the associated error term.

Unlike most typical utility models, T is not a binary variable, and thus, the model cannot be estimated using standard logit or probit regression techniques. Instead, we employ duration analysis, which is a class of statistical methods that investigates survival times, i.e., the occurrence and timing of events (Allison 1995; Greene 2003). The phrase "survival time" derives from early applications in medical research when the interval of interest was typically that between a medical treatment and the patient's demise. Duration analysis techniques can accommodate situations where the interval may not be complete at the end of the study period. In the case of medical research, the patient may still be living at the end of the study. When this occurs, the observation is censored in the sense that the survival time is at least the observed interval within the study period. To accommodate such situations, an additional variable, δ, is defined as an indicator variable that is assigned a value of 1 if the interval ends within the study period and a value of 0 otherwise. Estimation needs to account for the censored nature of the data.

There are four equivalent ways to describe the continuous probability distribution for T. Two of these, the probability density function denoted as $f(t)$ and the cumulative distribution function denoted as $F(t)$, are used to estimate model parameters. Mathematically, they can be expressed as

$$[2] \qquad f(t) = \frac{\mathrm{d}F(t)}{\mathrm{d}t} = \lim_{\Delta t \to 0} \frac{\Pr(t \leq T < t + \Delta t)}{\Delta t}$$

$$[3] \qquad F(t) = \Pr(T \leq t) = \int_0^t f(x)\mathrm{d}x$$

In addition to these two functions, the survivor function $S(t)$ and hazard function $h(t)$ are used in duration analysis. $S(t)$ is an unconditional probability distribution defined as the probability that the interval of interest will be greater than t. It is expressed mathematically as

$$[4] \qquad S(t) = \Pr(T > t) = 1 - F(t) = \int_t^\infty f(x)\mathrm{d}x$$

In this study, $S(t)$ provides the probability that a harvested site will not be regenerated by time t and is at its maximum when $t = 0$.

The $h(t)$ is a conditional density distribution and in this study represents the instantaneous rate of regeneration at time t, given that regeneration has not occurred prior to time t. This function is a popular and useful way of describing the distribution for T in duration analysis (Allison 1995). It is defined as

$$[5] \qquad h(t) = \lim \frac{\Pr(t \leq T < t + \Delta t | T \geq t)}{\Delta t} = \frac{f(t)}{S(t)}$$

In this study, $h(t)$ is the probability that regeneration occurs in the small interval between t and $t + \Delta t$ conditional on $T \geq t$. Overall, these four functions provide the theoretical basis for empirical duration analysis. Both nonparametric and parametric analytical techniques were employed in this study. Nonparametric analysis was used to examine the probability of regeneration occurring over time after the harvest has been completed. Parametric analysis was employed to examine the effect of explanatory variables on timely reforestation behavior.

Nonparametric duration analysis

Nonparametric techniques can be used to compute survival time and plot the survival probability. In this study, survival time is the time elapsed between completion of harvest and beginning of regeneration. $S(t)$ is the probability that reforestation has not occurred by time t, where t can be any nonnegative number. Kaplan–Meier estimation (KM) is the most widely used method for estimating survival functions to obtain exact survival proportions and survival times and has a solid theoretical justification (Allison 1995). If all NIPF landowners regenerated their harvested lands within the study period, the KM estimator $\widehat{S}(t)$ is just the sample proportion of observations that have not been regenerated by t. The KM estimator is then defined as

$$[6] \qquad \widehat{S}(t) = \prod_{j:\, t_j \le t} \left[1 - \frac{d_j}{n_j}\right]$$

where at each time t_j, there are n_j observations. Of these, n_j have been regenerated (Allison 1995):

$$[7] \qquad \widehat{\mu} = \sum_{j=1}^{k} \widehat{S}(t_{j-1})(t_j - t_{j-1})$$

where t_0 is defined to be zero and k represents distinct event times. When the largest observed time is censored, this sum underestimates the mean. The standard error of $\widehat{\mu}$ is estimated as

$$[8] \qquad \widehat{\sigma}(\widehat{\mu}) = \sqrt{\frac{m}{m-1}\sum_{j=1}^{k-1}\frac{A_j^2}{n_j s_j}}$$

where prior to t_j, s_j has been not regenerated.

$$[9] \qquad A_j = \sum_{i=j}^{k-1} \hat{S}(t_i)(t_{i+1} - t_i)$$

$$[10] \qquad m = \sum_{j=1}^{k} d_j$$

The KM estimator provides a sound basis for analysis and does not depend on the grouping of the data into a certain number of intervals. The disadvantage of the KM method is that, to accurately interpret the results, the study period must be sufficiently long as to include all the interval times. If the study period is not long enough to include all interval times, some observations will be censored, i.e., the interval of interest was not completed before the end of the study period and cannot be assigned a value.

The Life Table (LT) method, which is used to estimate $S(t)$ and $h(t)$ in this study, avoids this problem, and accommodates censored observations. In the LT method, the study period can be as long or short as needed: consider intervals $[t_j, t_{j+1}]$, as for KM estimator, except all intervals are relatively long. Let c_j be the number of landowners who do not regenerate during the interval. Because intervals are long, we can replace n_j by $n_j - (c_j/2)$ when estimating the survival function. The LT estimator is defined as

$$[11] \qquad \widehat{S}(t_i) = \prod_{j=1}^{i-1}\left(1 - \frac{d_j}{n_j - \frac{c_j}{2}}\right)$$

where, for interval i, t_i is the start time.

Nonparametric analysis, as the name suggests, drops the formal modeling framework (Greene 2003). Furthermore, it does not consider the impact of other variables on the dependent variable. Parametric analysis can provide a more complete characterization of the relationship between T and various variables influencing the regeneration interval.

Parametric duration analysis

Parametric duration analysis produces estimates of parametric regression models based on the accelerated failure time (AFT) model (Allison 1995). The AFT model describes a relationship between survival functions of any two individuals. For individuals i and j, the AFT model is expressed as

$$[12] \qquad S_i(t) = S_j(\phi_{ij} t) \text{ for all } t$$

where ϕ_{ij} is a constant that is specific to the pair (i, j).

Parametric duration analysis estimates a model similar to an ordinary linear regression model (Allison 1995). Let T_i be a random variable denoting the time interval, and x_{i1}, x_{i2}, ..., x_{ij} be the j explanatory variables for the ith individual. Then, the model is

$$[13] \qquad \log T_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + ... + \beta_k x_{ik} + \sigma\varepsilon_i$$

where β_0, β_1, ..., β_k and σ are parameters to be estimated and ε_t is a random disturbance term with variance σ. The log transformation ensures that predicted values of T are positive, regardless of the values of x and β. Thus, exponentiating both sides of the above equation gives an alternative way of expressing the model:

$$[14] \qquad T_i = \exp(\beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + ... + \beta_k x_{ik} + \sigma\varepsilon_i)$$

Depending on the data, ε can take on a number of different distributions. Regardless of the distribution selected, all model forms are estimated by the method of maximum likelihood (Allison 1995). Because this study included censored observations, the likelihood function is expressed as follows:

$$[15] \qquad L = \prod_{i=1}^{n} [f_i(t_i)]^{\delta_i} [S_i(t_i)]^{1-\delta_i}$$

where n is the number of observations; t_i is the time interval of interest or the time of censoring; and δ_i, and $f(t_i)$, and $S(t_i)$ are as previously defined.

It is generally easier to work with the natural logarithm of the likelihood function to maximize eq. 15 because the logarithm is an increasing function, so whatever maximizes the logarithm also maximizes the original function (Greene 2003). Thus, taking the logarithm of both sides of eq. 15, the likelihood function is expressed as follows:

$$[16] \qquad \log L = \sum_{i-1}^{n} \delta_i \log[f_i(t_i)] + \sum_{i-1}^{n} (1-\delta_i) \log[S_i(t_i)]$$

Once a particular model is chosen, appropriate expressions related to β can be substituted for $f(t_i)$ and $S(t_i)$.

In parametric survival analysis, coefficient signs reveal the direction of the relationship (Allison 1995). For example, for binary variables, positive coefficients indicate that those with a value of one take longer to regenerate than those with a value of zero, whereas negative coefficients indicate the opposite. In contrast, the numerical values of the estimated coefficients are not directly informative. Simple transformations of the coefficients provide the odds ratios, which have interpretive values. For dummy variables, the odds ratio, e^{β}, provides the estimated ratio of the expected (mean) survival times for the two groups. For quantitative variables, the odds ratio, $100(e^{\beta} - 1)$, gives the percent increase in expected survival time for each one-unit increase in the variable (Allison 1995).

Data

Mississippi NIPF landowners were surveyed in 2006 to collect harvest and regeneration data from 1996 to 2006. Mississippi is a typical southern state where timber plays an important role in the state economy, and most timberland is owned by NIPF landowners. The Social Science Research Center at Mississippi State University conducted the telephone survey during July and August of 2006. The survey sample was drawn from a database of landowner records in Mississippi. The database covered 81 of the 82 counties in Mississippi. NIPF landowners were the study focus, so companies and partnerships were excluded. In addition, only NIPF landowners with at least 100 acres (1 acre = 0.404 ha) of land were selected to eliminate small landowners with infrequent forest management activities. That yielded a list of about 20 000 landowners. Telephone numbers were provided by a commercial service agency. Finally, among landowners with telephone numbers, a random sample of 9925 landowners was selected and used in the survey.

At the beginning of the survey, two questions were asked to eliminate landowners not relevant for this study. Because land records are sometimes incorrect, landowners were asked if they owned ≥100 acres in Mississippi. Landowners were also asked if they had conducted a timber harvest in the period 1996 to 2006. Respondents who replied no to either of these questions were thanked, and the survey was terminated.

Questionnaire and variables

The survey questionnaire was designed to collect information about the harvesting and regeneration behavior of Mississippi landowners during 1996–2006. Questions about each harvesting and regeneration event, land and ownership characteristics, and landowner demographics supplied much of the information needed for the empirical analysis (Table 1). The two dependent variables, T and δ, were constructed from the reported dates of harvest and regeneration. T was the interval length in months between the completion of harvest and the beginning of regeneration. If the landowner provided only the season and not an exact month for either of these events, the midpoint of the season was used (i.e., March for spring, June for summer, September for fall, and December for winter). If the harvest had not been regenerated during the study period, δ was set equal to zero; otherwise, δ was set equal to one.

The independent variables were selected to mirror factors identified as significant determinants of replanting behavior in previous research, as discussed in the Introduction. These variables consisted of four groups: land and ownership characteristics, landowner demographics, harvest characteristics, and market factors. Variable definitions are presented in Table 1. Four variables were used to represent land and ownership characteristics: acreage (acres owned), forest type (pine or other), ownership length (years), and timber (a measure of interest in timber production). Seven variables represented landowner demographics: age (years), education (Bachelors degree or not), income (dollars), race (white or other), gender (male or female), membership (membership in forestry organizations), and residence (residing on/off the forested property). Three variables represented characteristics of the harvest: harvest acreage (acres), harvest date, and consult (participation of a consulting forester). Finally, three variables were constructed from nonsurvey data to represent market factors: sawtimber price, pulpwood price, and reforestation cost. Nominal prices for sawtimber and pulpwood at the time of harvest were obtained from Timber-Mart South from 1996 to 2006. Nominal costs for forestry practices in the southern United States at the time of harvest were obtained from the cost and cost trends series produced on 2 year intervals (Dubois et al. 1997; Dubois et al. 1999; Dubois et al. 2001; Dubois et al. 1995; Dubois et al. 2003; Smidt et al. 2005). For the unreported years, cost was calculated by averaging the costs over adjacent years. Reforestation costs included chemical site preparation and hand planting. Real prices and costs (adjusted for inflation, expressed in 1996 dollars) were calculated by dividing their nominal values by the producer price index. Thus, sawtimber price, pulpwood price, and reforestation cost were expressed in real terms.

Results

Of the 9925 landowners contacted by phone, 2126 owned <100 acres, and another 2132 did not harvest timber in the past 10 years. These landowners were excluded from the survey. There were also 1110 incorrect telephone numbers. Other reasons for unsuccessful calls included communication problems, refusal to participate, and deceased owners. In total, 2229 landowners completed the survey for a response rate of 48.9%, i.e., 2229/(9925 – 2126 – 2132 – 1110).

There were 1081 final harvests conducted by these 2229 landowners. Of these harvests, 695 had been replanted by the end of the study period, and 386 had not. For 264 of the harvests that had been replanted, the landowner did not recall either the harvest date or regeneration date, and another 36 reported the harvest date after the regeneration date, so these observations were excluded from the analysis. For 121 of the harvests that had not been replanted, the landowner did not recall the harvest date, and another 5 reported a harvest date outside the survey period. Hence, these observations were also excluded from the analysis. At the end, 655

Table 1. Summary statistics of variables used in the duration analysis of nonindustrial private forest landowner regeneration behavior in Mississippi from 1996 to 2006 (n = 655).

Variable	Definition	Mean	SD
Dependent variables			
T	Time from finishing harvest to beginning regeneration (month)	28.246	35.928
δ	Dummy variable assigned a value of 1 if the landowner replanted; 0 otherwise	0.603	—
Land and ownership characteristics			
Acreage	Total acreage owned by the landowner	559.669	938.201
Forest type	Dummy variable assigned a value of 1 if pine is the dominant forest type; 0 otherwise	0.331	—
Ownership length	Years of land ownership	32.266	18.624
Timber	Dummy variable assigned a value of 1 if the landowner is strongly interested in timber production; 0 otherwise	0.795	—
Landowner demographics			
Age	Landowner age	64.570	12.008
Education	Dummy variable assigned a value of 1 if the landowner has a bachelor degree or better; 0 otherwise	0.505	—
Income	Household income before taxes in 2005 ($, ×1000)	66.382	28.908
Race	Dummy variable assigned a value of 1 if Caucasian; 0 otherwise	0.960	—
Gender	Dummy variable assigned a value of 1 if male; 0 otherwise	0.795	—
Membership	Dummy variable assigned a value of 1 if the landowner is a member of the Mississippi Forestry Association or any of its associated County Forestry Associations; 0 otherwise	0.295	—
Residence	Dummyvariable assigned a value of 1 if the landowner resides on forestland; 0 otherwise	0.501	—
Harvest characteristics			
Harvest acreage	Harvested acreage for each harvest activity	98.208	123.768
Harvest date	Time (month) from beginning harvest to end of the study period	65.413	40.901
Consult	Dummy variable assigned a value of 1 if a consultant handled the harvest; 0 otherwise	0.545	—
Market factors			
Sawtimber price	Sawtimber real price (base = 1996)	40.769	4.671
Pulpwood price	Pulpwood real price (base = 1996)	8.866	3.289
Reforestation cost	Reforestation real cost (base = 1996)	104.229	9.439

harvests were available for statistical analysis. Of these, 395 had been regenerated within the study period, and 260 harvests had not been regenerated.

The mean elapsed time before regeneration (T) was 11 months for uncensored observations, i.e., harvests that were regenerated within the survey period (n = 395). Including censored observations, i.e., harvests that were not regenerated before the end of the study period, the mean interval length was 28 months for all harvests (n = 655). As described above, 60.3% of the 655 harvests were replanted during the study period. Conversely, about 39.7% were not replanted. The mean acreage owned was 560 acres. For 33.1% of respondents, pine was the predominant forest type. The mean length of ownership was 32 years. Most landowners (79.5%) were interested in timber production.

On average, respondents were 65 years old with household incomes of $66 382. About one-half of respondents (50.5%) had a bachelor's degree or better. In addition, 96% were Caucasian, and 79.5% were male. About 29.5% belonged to a forestry organization, and 50.1% resided on their forestland. The mean harvest size was 98 acres. A total of 357 landowners hired consultants to handle the harvest. Finally, over the study period, sawtimber averaged $40.77/t; pulpwood averaged $8.87/t; and reforestation costs averaged $104.23/acre in real terms.

Results from nonparametric duration analysis

The graph $S(t)$ depicts the probability that a harvested site had not been regenerated by time t (Fig. 1). This probability decreased rapidly initially, then flattened out at approximately 28 months. The graph of $h(t)$ depicts the probability a harvest site that has not been regenerated will be regenerated at time t (Fig. 2). This probability increased until the 16th month and, thereafter, decreased rapidly until the 28th month and remained <1% from then on. Along this prediction track, the probability of regeneration approached zero as the time since harvest increased.

Results from parametric duration analysis

The lognormal distribution was used for estimation because it best fits the distribution for T. Through preliminary analysis, the shape parameter of the generalized gamma model was very close to 0 (i.e., 0.072), which indicated that the lognormal model should be employed (Allison 1995). The results of parametric duration analysis are reported in Table 2.

Among land and ownership characteristics, only forest type and timber were significant, and both were negative. If pine was their predominant forest type, landowners took less time to regenerate than others. Landowners interested in timber production regenerated more rapidly than noninter-

Fig. 1. Probability over time that nonindustrial private forest landowners have not regenerated after a timber harvest based on Mississippi NIPF timber harvests from 1996 to 2006.

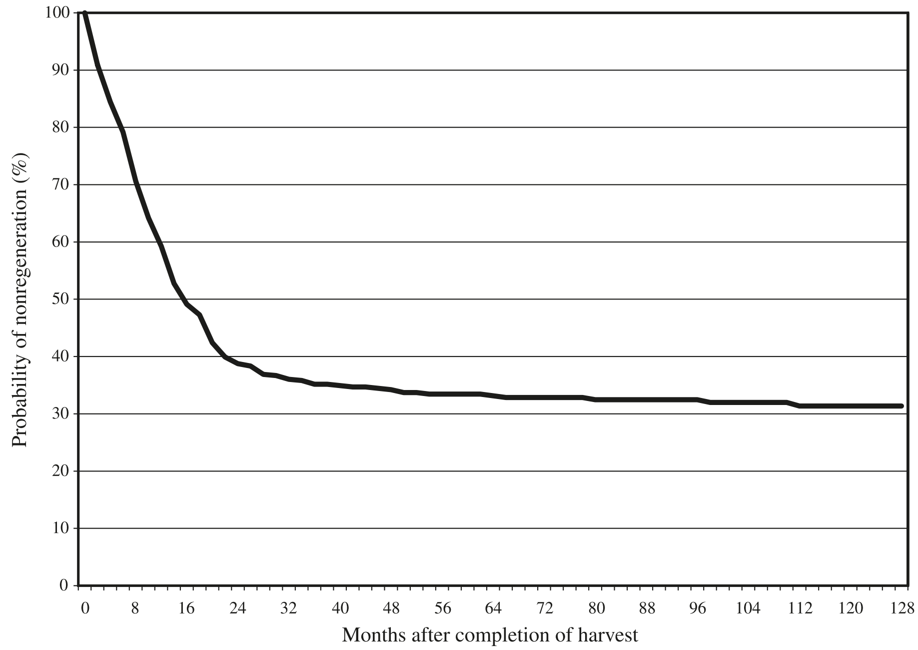
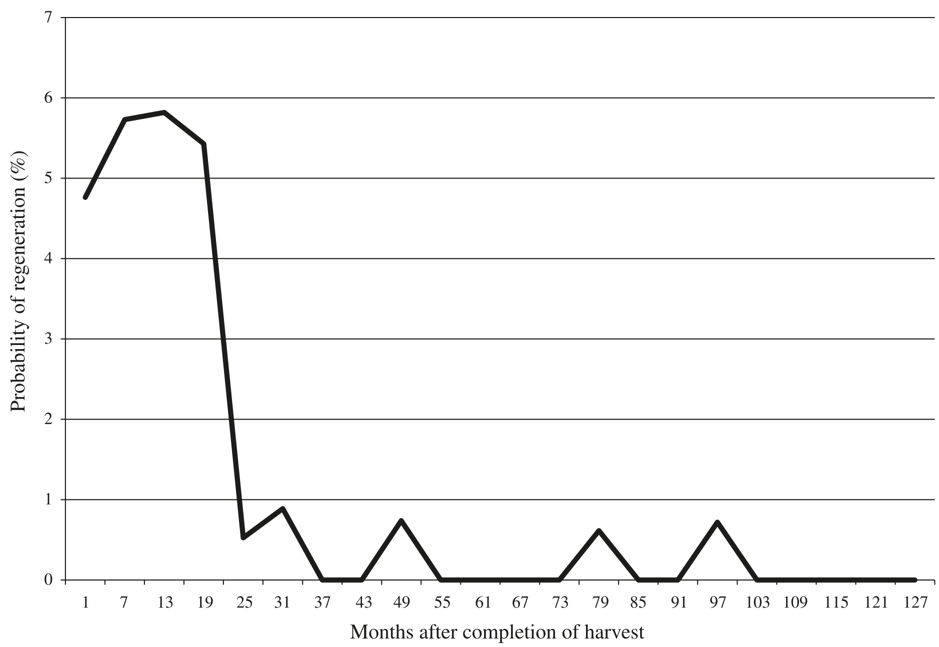


Fig. 2. Probability that nonindustrial private forest landowners will regenerate a harvested site at a specific time, given that the site has not yet been regenerated, based on Mississippi NIPF timber harvests from 1996 to 2006.



ested landowners. The odds ratios for these two variables were 0.566 and 0.185, respectively. Therefore, the predicted regeneration period for landowners whose predominant forest type was pine was 43.4% shorter than landowners with other forest types predominant. The predicted regeneration period for landowners interested in timber production was 81.5% shorter than other landowners.

Among landowner demographic variables, only race and residence were significant, and both had negative coefficients, with odds ratios of 0.314 and 0.605, respectively. Caucasian landowners waited 68.6% less time to regenerate than other landowners. The predicted regeneration period for those living on their forestland was 39.5% shorter than for those who did not. Among the harvest characteristics, only consult was significant. The odds ratio was 0.438; thus, for landowners who used a consultant, the regeneration period was 56.2% shorter than those who did not.

Finally, all market factors had significant impacts on the regeneration period. Sawtimber price and pulpwood price negatively influenced the regeneration period, and reforestation cost had a positive effect, with odds ratios equal to 0.962, 0.926, and 1.046, respectively. Therefore, each addi-

Table 2. A parametric survival model of factors that influence how long Mississippi NIPF landowners take to regenerate their forestland after harvesting during the period 1996–2006.

Variable	Coefficient	*t*	Odds ratio
Constant	4.247***	8.230	69.895
Land and ownership characteristics			
Acreage	–0.0001	1.620	1.000
Forest type	–0.570***	12.340	0.566
Ownership length	–0.007	2.540	0.993
Timber	–1.689***	58.660	0.185
Landowner demographics			
Age	0.003	0.140	1.003
Education	–0.001	0.000	0.999
Income	–0.0007	0.050	0.999
Race	–1.157**	6.500	0.314
Gender	–0.018	0.010	0.982
Membership	–0.086	0.250	0.918
Residence	–0.503***	9.750	0.605
Harvest characteristics			
Harvest acreage	–0.0002	0.090	1.000
Harvest date	–0.001	0.020	0.999
Consult	–0.825***	25.660	0.438
Market factor			
Sawtimber price	–0.039**	4.650	0.962
Pulpwood price	–0.077**	5.130	0.926
Reforestation cost	0.045***	8.880	1.046
Log likelihood	–954.942		

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

tional dollar increase in sawtimber price was associated with a 3.8% decrease in predicted regeneration period. Each additional dollar increase in pulpwood price was associated with a 7.4% decrease in the predicted regeneration period. Each additional dollar increase in reforestation cost was associated with a 4.6% increase in the predicted regeneration period.

Summary and discussion

This study employed nonparametric and parametric duration analysis to investigate how quickly landowners regenerated their timberlands after harvest and what factors influenced the length of this interval. This study is the first to use duration analysis to examine the timing of silvicultural operations. In doing so, it reveals interesting aspects of reforestation behavior with important policy implications that were previously unknown.

The nonparametric results paint an interesting picture of reforestation behavior. Consistent with previous research (e.g., Gunter et al. 2001), ~40% of the surveyed NIPF landowners did not replant after harvesting. However, unlike previous research, this study sheds light on the timing of reforestation activities. For those landowners who replanted, most did so within 1 year, and virtually all replanted within 2 years. Given that planting is largely confined to the winter months, landowners really have one window of opportunity a year. There are many unavoidable reasons that landowners may miss this window during the first year. For example, if harvesting is completed late in the year, site preparation may not be complete before winter arrives. Likewise, where pales weevils (*Hylobius pales* (Herbst)) are a problem, delaying replanting until the second winter after harvest is a commonly accepted control practice. Even with the best of intentions, a sizeable portion of landowners would still be replanting in the second winter after harvesting. These results indicate that, in general, landowners who intend to replant do so promptly. The implication for policymakers is that programs intended to promote replanting should be streamlined to avoid bureaucratic delays. Landowners waiting on assistance typically delay reforestation by ≥1 year (Nodine 1993). An unintended consequence of assistance programs is that, because of the long delays, the probability of replanting by landowners who ultimately do not receive assistance decreases substantially.

The parametric results are largely consistent with previous studies in that factors associated with shorter intervals between harvesting and replanting are those previously found associated with higher replanting probabilities, e.g., interest in timber production, employing a consulting forester, having predominantly pines, higher stumpage prices, residing on forestlands, and race (Hyberg and Holthausen 1989; Royer 1987). Similarly, reforestation costs lengthened the replanting interval, consistent with lower replanting probabilities found in previous studies (Brooks 1985; Royer 1987; Hyberg and Holthausen 1989). The estimated coefficients and associated odds ratios for some of the significant variables have important policy implications for decreasing planting delays and improving overall reforestation rates.

Stumpage prices and reforestation costs potentially have the greatest impact on timely reforestation. Although the marginal impacts of a one unit change in these variables are relatively small compared with the other significant variables, stumpage prices and reforestation costs are relatively volatile compared with the other explanatory variables[2]; thus, large changes in prices and costs over time are more likely than for the other explanatory variables. A \$4/t increase in price of sawtimber, a 10% shift from the mean value over the study period, translates to a 4 month increase in the mean planting interval of 28 months. An additional 4 month delay for tracts not planted by 20 months essentially decreases the probability that these tracts will be replanted to virtually zero (see Fig. 2). Coupled with the nonparametric results, that tracts not replanted within 2 years are very unlikely to be replanted at all; the implication is that, if prices remain low over a period of more than 2 years, tracts not planted because of adverse prices are unlikely to be replanted when prices improve. From a policy perspective, promoting landowner assistance programs during periods of low stumpage prices is critical.

Consult is another key variable. Landowners employing consultants are more likely to replant and do so substantially faster than landowners who do not employ consultants. Given that 45.5% of landowners did not employ consultants to handle their timber sales, promoting consultant involvement to landowner groups would be an effective policy tool to encourage prompt reforestation among NIPF landowners.

The relatively large odds ratio for timber suggests that generating interest in timber production among landowners would be a fruitful policy approach to enhance reforestation. However, the percentage of landowners currently not interested in timber production is very small (20.5%). Identifying those landowners would be difficult. In addition, many landowners may be unlikely to change in this regard because of preferences for recreation, aesthetics, or other nonmarket values.

Similarly, forest type, despite its relatively large odds ratio, has limited policy value. To decrease planting delays by changing the predominant forest type to pine would require converting mixed pine–hardwoods and upland hardwood stands to pines. Landowners interested in timber production have probably already done so, and the remaining landowners are unlikely to adopt conversion practices for reasons mentioned previously.

Race and reesidence also have large marginal impacts on reforestation times but do not suggest viable policy venues. Non-Caucasians represent a very small portion of the timberland-owning population, and encouraging reforestation within this segment of the population may be justifiable on equity grounds; however, the impact on timely reforestation at the landscape level would be minor. Landowners that do not reside on their forestland represent a substantially larger segment of the population; however, the reasons that resident landowners reforest more quickly than nonresidents is very likely linked to issues associated with their continuous presence on their lands, e.g., aesthetics. Short of encouraging landowners to reside on their lands, designing policies to improve replanting rates by addressing differences between residents and nonresidents is not likely to be a productive venue for improving reforestation efforts.

In conclusion, duration analysis has provided some key insights into the reforestation period and factors that impact its length. Timing is a critical component of reforestation behavior that has been ignored in previous research. To be effective, policies must emphasize prompt reforestation and avoid imposing delays on potential participants. Periods of low stumpage prices, in particular, warrant particular attention. Involvement of consultants, or other professional foresters, appears to be a highly effective venue to decrease planting delays. Future research should examine regional and (or) species differences, other potentially influential factors such as government support programs, and the effect of key dates such as when harvests are completed. Duration analysis is a very effective tool for analyzing forestry issues where time is a concern. Reforestation delays are an obvious application. Silvicultural treatments where the duration of the response varies, such as fertilization and herbicide applications, are a potentially fruitful area. There are a number of other socioeconomic issues where the technique would also be relevant. Rotation lengths, ownership tenure, and hunting lease turnover are some examples.

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[2] For an illustration of this volatility, see the Market News Quarterly report in any issue of Timber Mart-South for quarterly changes in stumpage prices. Sawtimber prices ranged from \$51.37/t to \$31.30/t over the study period.

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