How Long Do NIPF Landowners Wait to Reforest after Harvesting?*

Xing Sun[1], Ian A. Munn[2], Changyou Sun[3], and Anwar Hussain[4]

Abstract: Understanding how quickly landowners regenerate their timberlands after harvest is critical to developing policies to improve forest productivity. Using survey data from 81 counties in Mississippi from 1996 to 2006, this study investigated the length of the time interval between harvest and reforestation. Non-parametric duration analysis was used to examine how long NIPF landowners waited to reforest after harvesting. The average time that elapsed from harvest to regeneration was 11 months within the study period. The 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.

Keywords: Duration analysis, non-industrial forest landowners, reforestation delay

Introduction

Reforestation is essential for maintaining productive timberlands. Replanting trees on productive timberlands after harvesting is an effective way to increase the commercial value to non-industrial private forest (NIPF) landowners. Landowners benefit not only financially from higher timber production, but also from more attractive aesthetic landscapes with clear water and enhanced wildlife habitat. However, nearly half (48.5%) of Mississippi NIPF landowners do not reforest their timber following a harvest (Gunter *et al.* 2001).

Timely reforestation is even more important for both timber production and environmental protection. Not replanting after harvesting or delayed replanting may affect timber supply and reduce non-timber outputs and benefits (e.g., clear air and water, soil, wildlife). Softwood removals exceeded growth by approximately 18% in Mississippi in 2002 (Smith *et al.* 2004). This will impact future timber markets. In addition, if the lands are not replanted for a prolonged period of time, water and soil values on the harvested lands may deteriorate and wildlife habitat may degrade. Therefore, time elapsed from harvest to reforestation is a critical indicator of good forest resource management.

---

* This manuscript is publication #FO353 of the Forest and Wildlife Research Center, Mississippi State University.
[1] Graduate Research Assistant, Department of Forestry, Mississippi State University, Box 9681, Mississippi State, MS 39762, xs31@msstate.edu, (662) 325-5812 (v), (662) 325-8726 (fax).
[2] Professor, Department of Forestry, Mississippi State University, Box 9681, Mississippi State, MS 39762, imunn@cfr.msstate.edu, (662) 325-4546 (v), (662) 325-8726 (fax).
[3] Assistant Professor, Department of Forestry, Mississippi State University, Box 9681, Mississippi State, MS 39762, csun@cfr.msstate.edu, (662) 325-7271 (v), (662) 325-8726 (fax).
[4] Assistant Research Professor, Department of Forestry, Mississippi State University, Box 9681, Mississippi State, MS 39762, ahussain@cfr.msstat.edu, (662) 325-4259 (v), (662) 325-8726 (fax).

A number of empirical studies have investigated the impact of various factors such as characteristics of landowners, land, and forest management on landowner reforestation decisions (Amacher *et al.* 2003). However, none has considered the time dimension of reforestation. How long NIPF landowners wait to reforest after harvesting is an important but unanswered question. The answers to this question would be useful in formulating policies to help landowners reforest in a timely manner after harvesting.

Many empirical studies have examined NIPF landowner regeneration. Typically, regeneration studies have relied on a binary choice model (Hyberg and Holthausen 1989; Royer 1987). The typical dependent variable was a binary variable indicating regeneration or no regeneration. Independent variables included land characteristics (e.g., acreage, land type), owner demographics (e.g., income, education, residence), and market factors (e.g., sawtimber price, pulpwood price, reforestation cost).

Royer (1987) used a logistic regression model to estimate the probability of reforestation by southern landowners who had conducted final harvests on 10 or more acres between 1971 and 1981 in 12 southern states. Income, reforestation costs, government cost-sharing, technical assistance, and pulpwood price were highly important determinants of reforestation. Hyberg and Holthausen (1989) also used logistic regression to investigate the harvest timing and reforestation investment decisions of private landowners and obtained similar results.

More recently, Zhang and Flick (2001) used a two-step selectivity model and determined that income and government financial assistance programs increased the probability of reforestation. Gunter *et al.* (2001) determined useful factors for predicting reforestation by NIPF landowners in Mississippi. Landowners more likely to regenerate were those with large ownerships, higher income levels, better education, work in professional or business occupations, white males, and living in larger cities (Gunter *et al.* 2001). Beach *et al.* (2005) showed that both tract size and timber prices had a significant positive effect on reforestation, and among the owner characteristics, income influenced reforestation. Earlier studies explored NIPF landowner reforestation behavior using qualitative response models and identified relevant variables. However, previous research has not explored the time elapsed before regeneration.

This research focused on the interval between harvesting and regeneration by NIPF landowners in Mississippi, a typical southern state where timber plays an important role in the state economy and most of the timberland is owned by NIPF landowners. The objective of this study was to examine how long NIPF landowners waited to reforest after harvesting. Non-parametric duration analysis was employed to examine the time elapsed to regenerate after harvesting.

Conceptual Framework and Survey Data

Analytical Framework

This research used cross-sectional survey data from Mississippi to examine timely regeneration. The survey period covered ten years from 1996 to 2006. Duration analysis was employed to examine the time interval between finishing harvest and beginning reforestation. Duration analysis is a class of statistical methods for studying the occurrence and timing of events (Allison

1995; Greene 2003). The focal variable was the time to regenerate, T, measured as the time between the completion of harvest and the occurrence of regeneration. The event of interest in this study was whether NIPF landowners reforest their harvested timberland within the study period, which is indicated by an additional variable *Status* (*Status* = 1 if regeneration occurred within the study period; *Status* = 0 if not). If an individual did not regenerate within the study period, the observation was censored in the sense that the duration before regeneration was at least the observed interval. Estimation needs to account for the censored nature of the data.

Survey and Sample

The Social Science Research Center at Mississippi State University conducted a phone 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. The records for Hinds County were not available. Since NIPF landowners were the focus of this study, companies and partnerships were excluded. In addition, only NIPF owners with at least 100 acres of land were selected in order to eliminate small landowners with infrequent forest management activities. That yielded a list of about 20,000 owners. Landowner phone numbers were provided by a commercial service. Finally, among landowners with phone numbers, a random sample of 9,925 landowners was selected and used in the phone survey.

During the phone survey, several questions were asked to select landowners relevant for the study objectives. If the landowner owned less than 100 acres or did not harvest during the study period, the phone interview was stopped. Also, landowners who carried out a thinning or a selection cut were excluded. Furthermore, T was measured by the time interval between finishing harvest and beginning regeneration. Landowners who harvested and regenerated within the study period, but could not recall either the harvest date or regeneration date were deleted. If the landowner provided only the season and not an exact month, the mid point of the season was used (i.e., March for Spring, June for Summer, September for Fall, and December for Winter).

Methodology

Non-parametric analysis was employed to analyze the relation between the length of the interval and the time of beginning regeneration (Allison 1995). Non-parametric techniques were used to compute the time elapsed between completion of harvest and beginning of regeneration and plot regeneration and non-regeneration probability. Two non-parametric methods were employed: Kaplan-Meier Product Limit method and Life Table method. The Kaplan-Meier estimation was used to obtain exact non-regeneration probability and the time interval between harvest and regeneration. The function of time elapsed before regeneration and hazard function were estimated with the Life-Table method. The time interval between completion of harvest and beginning of regeneration, T, is expressed as follows:

$$(1) \qquad T = f(x)$$

where T was treated as a random variable.

There are four equivalent ways to describe the continuous probability distribution for *T*. The probability density function (p.d.f.) denoted as $f(t)$ and the cumulative distribution function (c.d.f.) denoted as $F(t)$ are used to estimate parameters of this model. T's probability density function (p.d.f.) and cumulative distribution function (c.d.f.) are mathematically expressed as:

(2) $$f(t) = \frac{dF(t)}{dt} = \lim_{\Delta t \to 0} \frac{\Pr(t \le T < t + \Delta t)}{\Delta t}$$

(3) $$F(t) = \Pr(T \le t) \int_0^t f(x)dx .$$

Equation (3) illustrates the probability that T will be less than or equal to any t value that we examined. In addition to these two functions, the function of time elapsed before regeneration $S(t)$ and hazard function $h(t)$ are commonly used in the duration analysis relevant to the timely regeneration. The function of time elapsed before regeneration $S(t)$ is an unconditional probability distribution and is defined as the probability that the interval between harvesting and regenerating will be greater than *t*. It is expressed mathematically as follows:

(4) $$S(t) = \Pr(T > t) = 1 - F(t) = \int_t^\infty f(x)dx .$$

In this study, this function estimates the probability of non-reforestation beyond any time *t*. $S(t)$ reaches the maximum probability when t equals 0.

Hazard function $h(t)$ is a conditional density distribution and represents the instantaneous rate of reforestation at time *t*, given that the harvested timberland has not been reforested up to *t*. This function is a popular and useful way of describing T distribution in duration analysis (Allison 1995). Its mathematical equation is defined as follows:

(5) $$h(t) = \lim \frac{\Pr(t \le T < t + \Delta t \mid T \ge t)}{\Delta t} = \frac{f(t)}{S(t)} .$$

Equation (5) illustrates the probability that a regeneration event occurs in the small interval between t and $t + \Delta t$ conditional on $T \ge t$. The functions, $f(t)$ and $F(t)$, are used for parameter estimation while $S(t)$ and $h(t)$ are used to answer research questions.

Empirical Results

Survey Results

Of the 9,925 landowners contacted by phone, 2,126 owned less than 100 acres, and 2,132 did not harvest timber in the past 10 years. Consequently, these landowners were excluded from the survey. There were also 1,110 wrong phone numbers. Other reasons for unsuccessful calls included communication problems, refusal to participate, and deceased owners. Hence, there were 2,229 landowners who completed the survey.

There were 1,081 final harvests conducted by these 2,229 landowners. Of these, 695 were replanted by the end of the study period and 386 were not. Of the 695 respondents replanting, 264 did not recall either the harvest date nor regeneration date, whereas another 36 recalled that the harvest date took place later than the regeneration date, which is not feasible, so these observations were excluded from the data analysis. Of the 386 respondents who had not replanted after harvest, 121 of them did not recall the harvest date and another 5 recalled the harvest date not taking place during the survey period. Hence, these observations were also excluded from the data analysis.

After accounting for invalid observations and non-responses, 655 observations were available for statistical analysis. The completion rate was 60.6%. For 395 observations, landowners harvested and then regenerated timberland within the study period, whereas for 260 observations, landowners harvested but did not regenerate by the end of study.

Non-Parametric Duration Analysis

Non-parametric duration analysis estimated the time interval between the completion of the harvest and the beginning of regeneration with an additional consideration: regeneration or no regeneration. The average time elapsed before regeneration (T) was 11 months for harvests that were regenerated within the study period (n = 395). The average time elapsed before regeneration (T) was 44 months for harvests regardless of whether regeneration occurred during the study period for all observations (n = 655).

The probability that a harvested site was not regenerated at time t is shown in Figure 1. This figure depicts the survivor function $S(t)$ at time t_i, the probability of non-regeneration following harvest when the waiting time is greater than t_i. The probability that the landowner had not regenerated after harvest declined as the length of time from completion of the harvest increased. The reduction in the rate sharply decreased until the 25th month. The probability that the tract has not been regenerated after harvest decreased rapidly during the first 25 months, then leveled off.

The probability distribution of estimated hazard function is shown in Figure 2. This figure depicts that the hazard function $h(t)$ at time t_i, the probability of regeneration at a given time following harvest. This probability reached its highest value in the 16th month and decreased thereafter rapidly until the 28th month. In the 28th month, the probability of regeneration was approximately 0.6% and remained less than 1% as the time increased. Along this prediction track, the probability of regeneration approaches zero as the time since harvest increases.

Conclusions

This study surveyed Mississippi NIPF landowners to address timely regeneration of harvested lands. Non-parametric duration analysis was used. The analysis yielded more insightful results in terms of timely regeneration than a simple logistic regression model. Furthermore, this study is the first attempt to use duration analysis to examine effects of various factors on the time interval associated with reforestation decision. The survey revealed that about 40% NIPF landowners in Mississippi did not replant their harvested timberland in past ten years. On average, NIPF landowners that replanted waited 11 months to regenerate after harvest. After the 16^{th} month following harvest, the probability of regeneration decreased until 28^{th} month.

These results need to be qualified by several considerations. First, non-parametric techniques, as the name suggests, drop the formal modeling framework (Greene 2003). Furthermore, they do not consider the impact of other variables on the dependent variable. Therefore, non-parametric duration analysis is the most general of the techniques, but, consequently, the least precise. So, semi-parametric and parametric analyses need to be used to further provide more precise characterization of the relationship between the time interval from harvest to regeneration and various variables influencing the regeneration interval. Second, the intent of this study targets the timely regeneration behavior after harvesting. However, this is just one of several landowner behaviors; other would include the timely harvest behavior and other forestry management practices to provide a more comprehensive look at the landowner behavior.

Literature Cited

Allison, P.D. (1995). *Survival Analysis Using SAS: A practical guide*. Cary, North Carolina. SAS Publishing.

Amacher, G.S., M.C. Conway, and J. Sullivan (2003). Econometric analyses of nonindustrial forest landowners: is there anything left to study? *Journal of Forest Economics* 9(2):137-164.

Beach, R.H., S.K. Pattanayak, J.C. Yang, and B.C. Muray (2005). Econometric studies of non-industrial private forest management: a review and synthesis. *Forest Policy and Economics* 7(3):261-281.

Greene, W.H. (2003). *Econometric Analysis*. Pearson Education, Inc., Delhi, India.

Gunter, J.E., S.H. Bullard, M.L. Doolittle, and K.G. Arano (2001). Reforestation of harvested timberlands in Mississippi: behavior and attitudes of non-industrial private forest landowners. FWRC Research Bulletin # FO 172, Forest and Wildlife Research Center, Mississippi State University. 25p.

Hyberg, B.T., and D.M. Holthausen (1989). The behavior of non-industrial private forest landowners. *Canadian Journal of Forest Research* 19:1014–1023.

Royer, J.P. (1987). Determinants of reforestation behavior among southern landowners. *Forest Science* 33(3):654-667.

Smith, W.B., P.D. Miles, J.S. Vissage, and S.A. Pugh (2004). Forest resources of the United States 2002. *USDA Forest Service Gen. Tech. Rep. NC-241*.

Zhang, D., and W.A. Flick (2001). Sticks, carrots, and reforestation investment. *Land Economics* 77(3):443-456.

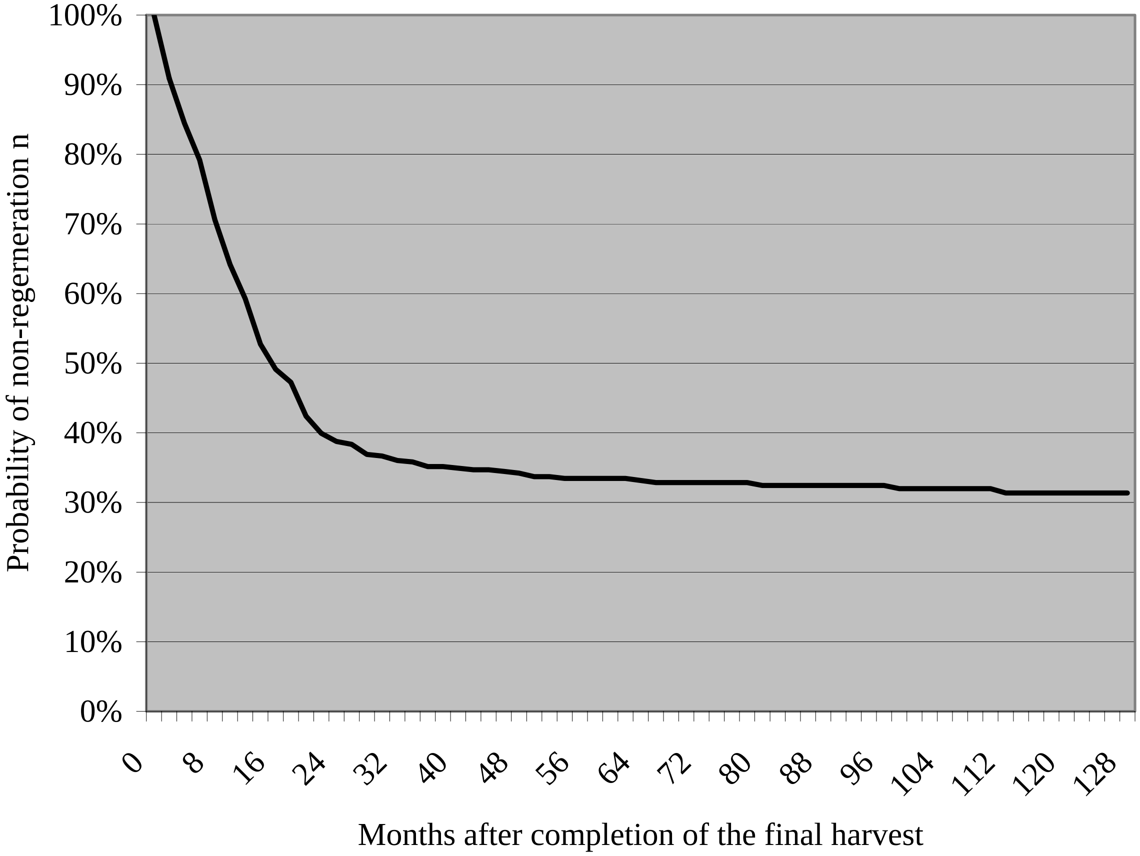

Figure 1. Survival function for regeneration of harvested forest land by Mississippi nonindustrial private forest landowners from 1996 to 2006.

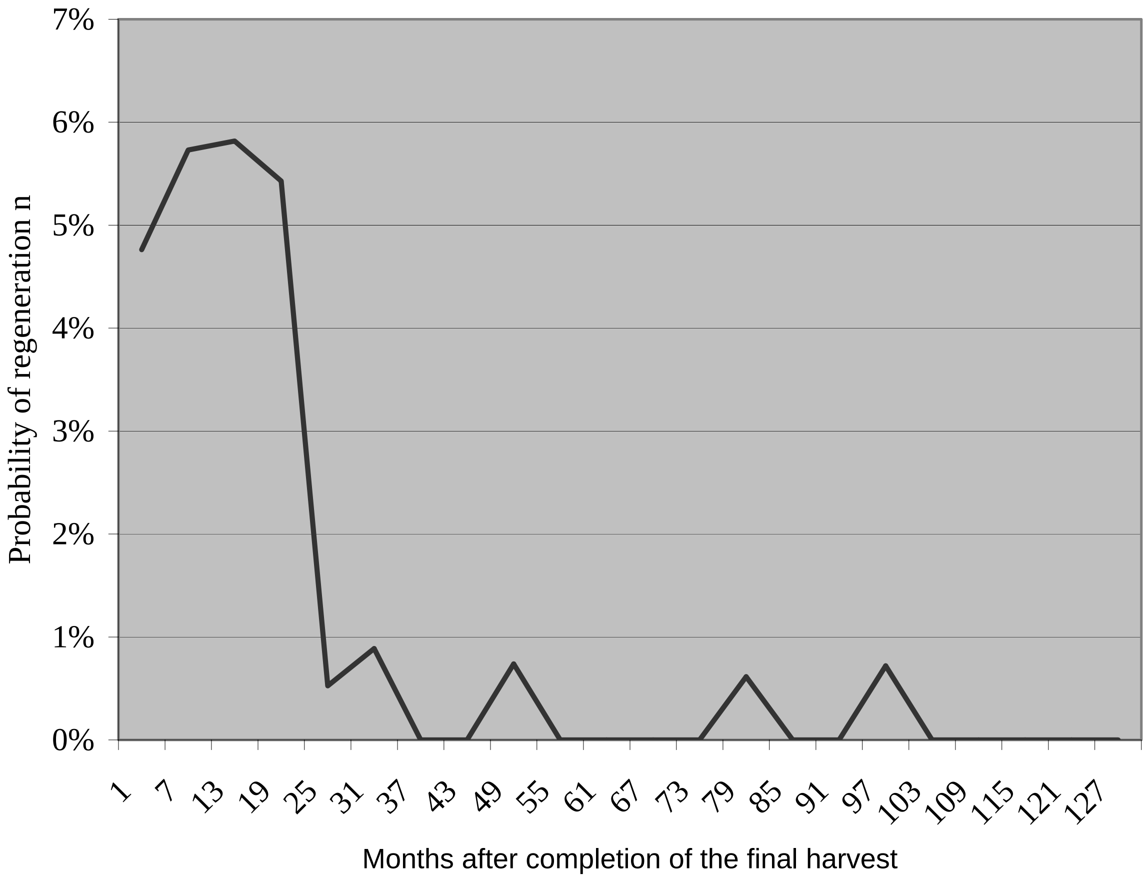

Figure 2. Hazard function for regeneration of harvested forest land by Mississippi nonindustrial private forest landowners from 1996 to 2006.