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The influence of the form of tenure on reforestation in British Columbia

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Abstract

This paper describes the results of an empirical investigation of the variation in reforestation among different types of forest tenure in British Columbia. Indicators of management, based on available statistical information about not satisfactorily restocked (NSR) lands and artificial reforestation on cutover lands, are compared across four major forms of tenure, ranging from relatively secure private holdings to relatively short-term volume licenses. Data on a large number of cutblocks under each form of tenure are analyzed to examine the extent to which differences in reforestation are attributable to the form of tenure, natural attributes of the land and other factors. The results indicate that, on private lands, NSR land occurs less frequently and comprises a smaller portion of cutover lands, and planting is done more often and more promptly, than on licensed Crown lands. Generally, the findings support the proposition that reforestation is significantly influenced by the form of forest tenure, and that more intensive resource management is fostered by more secure forms of tenure. © 1997 Elsevier Science B.V.

Keywords: Property rights; Economic incentive; Forest practices; Policy; Logistic regression

1. Introduction

In Canada, where most forest land remains in provincial government ownership, the form of tenure available to timber enterprises has always been at the center of forest policy debate (Pearse, 1976; Haley and Leitch, 1992). New concerns about the system of rights to resources have been kindled recently as the end of the original natural timber approaches and present rates of harvest appear unsustainable in many regions. Provincial governments have developed a variety of licensing arrangements intended to engage private forest companies in the management of public (Crown) forests, and the policy question is whether these tenure arrangements are sufficient to encourage companies to manage public forests at a level that will realize their potential productivity.

Traditional forms of leases and licenses issued to timber companies over Crown forest may be more suitable for parceling out rights to harvest natural

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timber than for managing new crops. Thus, timber companies consistently press for greater security of tenure in order to facilitate long-term planning and investment in forestry and related infrastructure development. The argument, usually, is that those who utilize forests must have secure, long-term rights to resources, otherwise they cannot be expected to invest in future crops and adopt forest practices that only yield benefits over long periods. This view is widely held and well documented, and is the basis for much criticism of existing forest tenure arrangements (Pearse, 1993). But, hitherto, there has been very little empirical evidence to support the suggested relationship between forest tenure and forest practices.

While empirical studies have been made of the influence of land tenure and management in agriculture (Anderson and Lueck, 1992; Feder and Onchan, 1987; Feder et al., 1988), studies on the effect of forest tenure (or ownership) have primarily been focused on stumpage price (Jackson, 1987; Munn and Randal, 1995), timber sale profit (Leal, 1995), land value (Zhang, 1994, 1996), and silvicultural investment (Zhang and Pearse, 1996). Few studies have touched the issue of tenure and forest practices especially reforestation, and analyses of the effect of different forms of tenure on forest management practices in Canada have been limited to subjective assessments or interviews (Luckert, 1988; Luckert and Haley, 1990; Beuter, 1994).

This paper offers some empirical information on this issue. It reports the results of statistical analysis of some indicators of reforestation performance across a variety of forest tenures. It begins, in Section 2, with some background information and an explanation of the approach taken in the study. A brief description of the analytical model and the data used precedes a discussion of the findings of the statistical analysis. Section 6 notes some implications of the results and draws conclusions.

2. Background and approach

For purposes of this study, we examined evidence on reforestation under the four most important forms of forest tenure in British Columbia. Table 1 lists these tenures along with their characteristics most relevant in determining the economic security they afford their holders.

British Columbia's Tree Farm Licenses are typically large, geographically defined sustained yield units, within which the licensee has the exclusive right to harvest the allowable cut and to develop and manage the forest. These licenses combine Crown lands with private lands and Timber Licenses held by the licensees. Private lands outside Tree Farm Licenses are subject to different government regulations. To avoid distortions due to different regulatory requirements on other private lands, we confined our observations on private lands to those within Tree Farm Licenses.

Our second form of tenure is Crown land within Tree Farm Licenses. This is regarded as the most secure form of private rights over Crown forest.

Timber Licenses are old forms of tenure with varying terms, intended to give the holder time to remove the original timber according to an approved plan, and then expire. Some are included within Tree Farm Licenses; when they expire they become part of the other Crown lands within the license.

Forest Licenses convey a right to harvest a specified volume of timber each year within a broad administrative area. The specific tracts to be harvested are identified from time to time, but the licensee does not have an exclusive right to a defined area for the term of the license. Forest Licenses have shorter terms than Tree Farm Licenses, but both are renewable on an 'evergreen' basis: that is, the licensee has a right to call for a new license to replace his existing license when its term is only partly expired (Pearse, 1976). So far, all applications for replacement licenses have been accepted, but recent legislation requires applicants to forfeit 5% of the authorized allowable annual cut upon replacement.

All these forms of tenure are subject to similar silvicultural regulations. In September 1987, these regulations were changed in important respects, making all licensees and owners responsible for ensuring reforestation by natural or artificial means after logging, and for bearing the cost (Zhang, 1994; Zhang and Pearse, 1996). Accordingly, to avoid distortions resulting from regulatory change, we confined our observations to areas logged after September 1987.

These four forms of forest tenure differ in the various dimensions of property rights — duration,

Table 1
Some characteristics of tenure relevant to economic security of its holder

Form of tenure	Term	Renewability	Rights conveyed	Governmental charges
Private lands in Tree Farm Licenses	Forever	Not applicable	All freehold rights	Property taxes on timber harvested
Crown lands in Tree Farm Licenses	25 years	Replaceable every 10 years	Allowable annual harvest for a defined area	Stumpage on timber harvested
Timber Licenses	Varies	Not renewable	Original timber within a defined area	Royalty on timber harvested
Forest Licenses	25 years	Replaceable every 5 years	Allowable annual harvest	Stumpage on timber harvested

exclusivity, comprehensiveness, transferability, and economic benefits conferred on the holder (Cooter and Ulen, 1988; Pearse, 1990; Posner, 1992). However, with respect to the features that determine the security of the holders' rights — the term, renewability, definition of his resource rights, his obligation to share financial returns with the government and the scope for regulatory intervention — private lands are most beneficial to the holder and Forest Licenses are least beneficial. Timber Licenses lack the 'evergreen' renewal provisions of Tree Farm Licenses and Forest Licenses, but they convey exclusive rights to a defined area, which Forest Licenses do not (Zhang, 1994, 1996). Thus, our four types of tenure can be considered to be listed above roughly in order of declining security of the rights they afford their holders.

To assess differences in forest management under different forms of tenure, we need some consistently measurable indicators of management performance. In principle, the economic efficiency of management should be measured by comparing the costs of forest production with the timber values produced under each form of tenure, over periods long enough to capture all the relevant costs and benefits. The most efficient intensity of management is that at which the marginal cost is equal to the marginal benefits produced. This kind of analysis is not possible in most regions of Canada because of varying proportions of original natural timber, alterations made to the tenure system over the years, and changes in regulatory requirements, among other things. Accordingly, we have sought indicators or proxies of management performance that can be observed and measured using recent statistical information.

Zhang and Pearse (1996) analyzed the differences in silvicultural expenditures on forest lands under these same four forms of tenure. They found that firms invest more in long-term forest production under more secure forms of tenure.

The influence of tenure on forest management can be assessed, not only in terms of the inputs (such as investment), but also in terms of the outputs or products of management effort. This latter approach is taken in the present paper. We examined data on a large sample of recently cutover lands ('cutblocks') under various forms of tenure to identify several indicators of reforestation performance, namely:

- The occurrence of land that is not satisfactorily reforested. These are lands that fail to meet provincial standards of reforestation following logging or other disturbance, classified as Not Satisfactorily Restocked (NSR) lands (Pearse et al., 1986).
- The percentage of cutover lands that is Not Satisfactorily Restocked (% NSR).
- Whether the cutover land was planted (PLANTING).
- Where planting was done, the time taken to complete it following logging (PLANTIME).

3. The analytical model

The objective of this study was to determine whether these indicators of management performance bear a statistically significant relationship to the form of forest tenure. The basic hypothesis is that licensees will perform better, in terms of reforestation, if their rights are relatively secure and long-term (Pearse, 1976; Posner, 1992).

As discussed earlier, regulation requires all licensees and owners to ensure reforestation to a specific standard within a prescribed period after logging. Why do we expect that lands are not reforested to the same degree? This is because, reforestation regulation, like other regulations, is very general and only has a minimum standard. It applies to all site index, location, and does not have species specification. Subject to this basic result, tenure holders have a wide latitude in selecting reforestation method (e.g., artificial or natural regeneration), species, and time to reforest. They can be expected to choose the most suitable species and reforest quickly (and thus ensuring NSR lands will not occur) only where they can generate extra benefits in excess of the extra costs, and where their rights afford sufficient long-term security to allow them to capture the benefits.

The structural model that provided the basis for statistical analysis can be expressed in the following four equations [1]:

$$\text{NSR} = f(T, I, C, L, S, F, D) \quad (1)$$

$$\%\text{NSR} = f(T, I, C, L, S, F, D) \quad (2)$$

$$\text{PLANTING} = f(T, C, L, S, F, D) \quad (3)$$

$$\text{PLANTIME} = f(T, I, C, L, S, F, D) \quad (4)$$

where: T = the form of tenure; I = investment in silviculture in the cutblock since it was logged, in constant 1992 CND\$/ha; C = the characteristics of the cutblock, including its size and site quality; L = regional location of the cutblock (distance to market); S = the species composition of the new forest crop; F = the character of the firm holding the tenure; D = date of logging. Eq. (1) states that the likelihood of a cutblock containing NSR lands depends on the form of tenure, silvicultural expenditures since the cutblock was logged, the natural attributes of the cutblock, its location, the dominant species being established, and the time since it was logged. The same independent variables appear in Eqs. (2) and (4) to explain the percentage NSR and the time taken to reforest after planting, PLANTIME.

Eq. (3) explains whether cutblocks are planted in terms of the same variables, except that the silvicultural investment variable is excluded. This avoids the direct correlation between planting and silvicultural investment, which results from the fact that over half of all silvicultural spending is on planting (Zhang and Pearse, 1996).

These equations are designed to reveal, through statistical regression, the influence of the form of forest tenure and other factors on the four indicators of reforestation performance. Eqs. (1) and (3) contain qualitative dependent variables that were estimated by means of logistic regression [2]. The maximum-likelihood method was used to find the functional form for Eqs. (2) and (4). The choice of variables in these equations was made based on the economic and silvicultural theories. Overall, there are four categories of economic variables (T, I, L and F), two categories of silvicultural or biological variables (C, S), and one time variable (T). The underlying reasons for choosing individual variables are given in Section 4.

4. Data

The unit of observation for this study is a cutblock, which is a tract of forest designated by the Ministry of Forests for harvesting. Each cutblock is a separate obligation of the tenure holder, who is required to report, annually and sometimes every four months, all preharvest silviculture prescription information, harvesting and silvicultural activities on each.

Data were obtained from the Ministry of Forests, 1993 on 2311 cutblocks. All were logged after September 1987 (when new regulations assigned to

[1] These four equations appear as nonlinear seemingly unrelated regressions. However, only Eqs. (1) and (3) have the same number of observations (see below). Nonlinear seemingly unrelated regressions were run for those two equations. Although the hypothesis of no contemporaneous dependence between equations cannot be rejected at the 10% level, the results are not much different from those reported in this paper.

[2] The linear logistic function has the form

$$\log(p/1-p) = \alpha + \beta' X$$

where p is the probability of an event occurrnig, α is the intercept parameter, and β is the vector of slope parameters. So

$$p = \exp(\hat{\alpha} + \hat{\beta}' X)/(1 + \exp(\hat{\alpha} + \hat{\beta}' X))$$

where $\hat{\alpha}$ and $\hat{\beta}$ are estimates of the intercept and slope parameters.

Eqs. (1) and (3) were also estimated using the linear probit function. The results are similar to those reported below.

holders of all forms of tenure the responsibility and cost of silviculture) and before December 1989. The data included all the information compiled up to May 15, 1993, covering all silvicultural activities on the cutblocks for at least four and half years following logging. The study period also covers all entire business cycle, from the crest of the late 1980s to the trough of the early 1990s.

The sampled cutblocks were located on lands held under four firms of forest tenure: 46 on private lands within Tree Farm Licenses, 306 on Timber Licenses, 601 on other Crown lands within Tree Farm Licenses, and 1377 on lands harvested under Forest Licenses (although not all observations were used in all equations) [3].

Of the independent variables in the four equations, that for the form of tenure, T, is of special interest here. Forest Licenses were treated as the base for comparison. The other tenures were represented by three dummy variables, which took the value of unity when a specific form of tenure was applied, and zero otherwise.

The hypothesis that holders of forest tenure achieve higher levels of management performance, when their rights to the resources are more secure, suggests that the coefficients of the tenure variables will be negative for private lands in Tree Farm Licenses, other Crown lands in Tree Farm Licenses and Timber Licenses in Eqs. (1) and (2) and Eq. (4), and positive in Eq. (3), because these tenures convey more secure and more clearly defined rights than do the volume-based Forest Licenses (Zhang and Pearse, 1996). The variables for private lands in Tree Farm Licenses in these four equations are expected to be statistically significant. The silvicultural investment variable, I, is expected to be negative in Eqs. (1) and (2), and positive in Eq. (4).

The characteristics of the cutblocks, C, were measured in terms of their size, site quality, and biogeoclimatic zone. Their size was measured in hectares. The sign of this variable, SIZE, is expected to be positive in Eq. (1) because regeneration failures (and thus NSR lands) are more likely to occur in large cutblocks. Its sign is likely to be positive in Eqs. (3) and (4) also, since natural regeneration is less successful and artificial regeneration (planting) is practised more often in larger cutblocks. Its sign is expected to be negative in Eq. (2) since, by definition, the bigger the cutblock size, the smaller the percentage NSR.

Three categories of site quality were identified — good, medium and poor — and two dummy variables were used for good (S_G) and medium (S_M) site qualities to capture the impact of site quality on reforestation performance. The sign of these two variables is expected to be negative in Eqs. (1) and (2) since, everything else being equal, it is easier to regenerate forests on good and medium quality lands than on poor quality lands. The sign of these two variables in Eqs. (3) and (4) should be positive, because it is easier to control herbaceous weeds on good and medium sites when artificial regeneration is adopted, and when it is chosen, it is usually done soon after logging to minimize competition from other vegetation.

The observations were grouped into four biogeoclimatic zones. Dummy variables were assigned to three of these — the coastal Douglas-fir, coastal western hemlock and montane hemlock zone (Z_1), the Engelmann spruce — subalpine fir, montane spruce and subboreal spruce zone (Z_2), and the interior Douglas-fir zone (Z_3). Each was given a value of unity when it applied and zero otherwise, and compared with the fourth zone — the interior cedar-hemlock zone. These three variables are expected to be negative in Eqs. (1) and (2) since they represent the relatively wet biogeoclimatic zones that tend to regenerate more readily. NSR lands should have less chance to occur, and if they occur, they should only have a small portion. Forest managers often rely on natural regeneration in these wet zones. This makes the signs of these variables negative in Eq. (3). However, where planting is done in these zones, it is done quickly after logging to avoid competition from other vegetation, given these variables a positive sign in Eq. (4).

The cutblocks fell into two broad regions: (a) the Vancouver Forest Region and (b) the southern inte-

[3] Some Timber Licenses are included within Tree Farm Licenses and some are not, and the distribution of the sampled cutblocks between the two categories is not known. However, the timber harvested from all Timber Licenses in the province is about equally divided between those within and those outside Tree Farm Licenses (Zhang, 1994).

Table 2
Reforestation performance indicators and their main values

Performance indicator	Definition	Mean value	Standard deviation
NSR	Occurrence of Not Satisfactorily Restocked lands	0.10	0.30
	(dummy 0.10 variable: 1 if NSR land; 0 otherwise)		
% NSR	Percentage of Not Satisfactorily Restocked lands	62.74	0.75
	(ha of NSR ÷ total ha in the cutblock)	62.74	0.75
PLANTING	Occurrence of planting	0.75	0.43
	(dummy: 1 if planting; 0 otherwise)		
PLANTIME	Time taken to plant	34.93	12.44
	(number of months after logging to completion of planting)		

rior (the Kamloops and Nelson Forest Regions combined). However, analysis revealed such high correlation between these regions and biogeoclimatic zones that this location variable was dropped.

Regeneration methods and results differ among species (Smith, 1986). The species composition of the forest crop being established was classified by the percentage of the dominant species — balsam, cedar, Douglas-fir, hemlock and spruce in each cutblock. 'Other species', including pine, cypress and hardwood, provided the basis for comparison.

The character of the firm holding the tenure was identified as either a small firm or a large integrated forest products company, the latter being among the top 20 companies which collectively hold more than 74% of the committed allowable annual cut in the province. A dummy variable (PRODUCER) was given a value of unity when the tenure holder was one of these large integrated firms, and zero otherwise. The sign of PRODUCER is expected to be negative in Eqs. (1), (2) and (4), but positive in Eq. (3), because large firms are more committed to long-term forest production.

The date of logging of each cutblock (DATE) was identified as the number of months since January 1987. The expected signs of the variables for species and logging date were not obvious. A number of other explanatory variables were investigated, but were found to be not statistically significant.

Table 2 presents the mean value and standard deviation of each of the dependent variables — the reforestation performance indicators — for all cutblocks combined. These results indicate that NSR lands occurred on 10% of the cutblocks and, on these cutblocks, amounted to 62.7% of the total cutblock area. Some 75% of the cutblocks were planted, and planting was completed, on the average, 35 months after logging.

Table 3 shows the differences in the mean values of the performance indicators among the four tenure categories. As expected, the occurrence of NSR lands was lowest on private lands in Tree Farm Licenses

Table 3
Mean values of reforestation performance indicators by form of tenure

Variable	Private lands in Tree Farm Licenses		Other Crown lands in Tree Farm Licenses		Timber Licenses		Forest Licenses	
	Mean value	Standard deviation	Mean value	Standard deviation	Mean value	Standard deviation	Mean value	Standard deviation
NSR	0.04	0.21	0.09	0.29	0.09	0.29	0.10	0.31
% NSR	24.56	17.37	54.11	32.72	60.76	36.49	66.28	32.76
PLANTING	0.89	0.32	0.76	0.43	0.72	0.45	0.74	0.44
PERIOD	32.95	13.46	31.11	14.05	37.83	11.29	36.10	11.47

and highest on Forest Licenses, so was percentage NSR. In addition, planting took place most frequently on private lands and least frequently on Forest Licenses, and the average time taken to complete planting was longest on Forest Licenses and Timber Licenses. While the relative values of these indicators for Timber Licenses and other Crown lands in Tree Farm Licenses are not consistent, most fall between those for private lands and Forest Licenses, lending support to the hypothesis that more secure tenure fosters improved management performance. However, because other factors differ among the four forms of tenure, inferences about the effect of tenure on forest practices call for additional econometric analysis.

5. Empirical findings

Tables 4–7 and Figs. 1–4 present the results of the statistical analysis.

5.1. Occurrence of NSR lands

Table 4 shows the results of the logistic regression of the equation for the occurrence of NSR, Eq. (1). Private lands in Tree Farm Licenses have a significant negative influence on the probability of NSR lands occurring. The coefficients for other Crown lands in Tree Farm Licenses and Timber Licenses are also negative, but not significantly different from zero at the 20% level.

The effect of the form of tenure on the probability of occurrence of NSR lands is illustrated in Fig. 1. These relationships are based on the results in Table 4. To produce Fig. 1, the continuous variables were fixed at their mean values, and the others based on assumptions of medium soil quality, a Z_1 biogeoclimatic zone and large integrated firms. The logistic equation was transformed to compute the probability of NSR land occurring in cutblocks of each form of tenure as shown.

The coefficient for silvicultural investment is negative and significant at the 10% level. This is to be expected, since the main silvicultural cost is reforestation that reduces the occurrence of NSR lands.

The results in Table 4 reveal other factors associated with the occurrence of NSR lands, including regenerating balsam, cedar, Douglas-fir hemlock and spruce relative to 'other species', certain biogeoclimatic zones and larger cutblocks. Good and medium sites have a negative influence on the probability of NSR lands occurring, relative to poor site qualities.

The probability of occurrence of NSR lands is lower, the later the date at which the cutblock was logged. This may reflect more attention to reforestation in recent timber operations, and the lack of survey information on some of the most recently logged areas. Although the coefficient of PRODUCER has a counterintuitive sign, it is not significant at the 20% level, indicating that the size of the company holding the tenure does not affect the probability of occurrence of NSR lands.

Table 4
Results for logistic equation for the occurrence of NSR lands (Eq. (1))

Variable	Coefficient	Wald X^2 ratio
Tenure (and investment)		
Private lands in Tree Farm License	−0.9529	1.7632[a]
Other Crown lands in Tree Farm License	−0.0761	0.1645
Timber License	−0.2461	0.9235
Investment	−0.0439	9.6718[c]
Species composition		
Balsam	0.0074	19.9560[c]
Cedar	−0.0028	1.4571
Douglas-fir	0.0044	3.3896[b]
Hemlock	0.0092	12.1771[c]
Spruce	0.0028	2.7912[a]
Characteristics of the cutblock		
S_G	−1.0466	9.0426[c]
S_M	−0.7146	8.1048[c]
Z_1	−0.8115	6.5627[c]
Z_2	−0.1202	0.2504
Z_3	0.9549	13.1048[c]
SIZE	0.1316	6.1522[c]
Others		
PRODUCER	0.1275	0.5402
DATE	−0.6574	9.2888[c]
INTERCEPT	1.8148	5.0138[c]
$-2 \log L$	92.987	
Score	100.871	
Observations	2311	

[a] Significant at the 20% level.
[b] Significant at the 10% level.
[c] Significant at the 5% level.

Table 5
Results for linear–log equation for the percentage of NSR lands (Eq. (2))

Variable	Coefficient	t-ratio
Tenure (and investment)		
Private lands in Tree Farm License	−0.3131	−1.362[a]
Other Crown lands in Tree Farm License	−0.0611	−0.732
Timber License	−0.0032	−0.050
Investment	0.0401	−2.445[c]
Species composition		
Balsam	−0.0008	−1.651[b]
Cedar	−0.0008	−1.225
Douglas-fir	−0.0005	−0.675
Hemlock	−0.0002	−0.154
Spruce	0.0010	1.995[b]
Characteristics of the cutblock		
S_G	−0.1277	−1.238
S_M	−0.0147	−0.202
Z_1	0.1197	0.921
Z_2	0.0038	0.053
Z_3	−0.0198	−0.227
SIZE	−0.0952	−4.299[c]
Others		
PRODUCER	−0.0747	−0.180
DATE	0.0975	1.443[a]
INTERCEPT	0.7998	2.922[c]
R^2	0.2334	
R^2-adjusted	0.1655	
D.W.	1.7730	
Observations	2311	

[a] Significant at the 10% level, two-tailed test.
[b] Significant at the 5% level, two-tailed test.
[c] Significant at the 1% level, two-tailed test.

5.2. Percentage of NSR lands

To strengthen the results in Table 4, Eq. (2) examines the relationship between the amount of NSR land that occurs in cutblocks and the cutblock size. Eq. (2) was estimated using a linear-log function form in which the continuous independent variables take the form of natural logarithms. For this equation, we used only the 210 observations which indicated the presence of NSR lands.

The results in Table 5 support those in Table 4. The form of tenure, silvicultural investment, cutblock size, species, character of the tenure holder, and logging date significantly influence the percentage of NSR lands. All these variables, except DATE, have the expected signs. The explanation for the change in sign for the date of logging is less clear.

The results are consistent with our general hypothesis. All the other tenures showed lower percentage NSR than did Forest Licenses. For private lands in Tree Farm Licenses, the difference was significant at the 10% level. The difference of the percentage of NSR lands among forms of tenure is illustrated in Fig. 2.

5.3. Planting

Table 6 presents the results of the logistic regression for the occurrence of planting, as expressed in Eq. (3). Private lands in Tree Farm Licenses are positively related to the probability of cutblocks having been planted, and are significant at the 10% level. The coefficients for Timber Licenses and other

Table 6
Results for logistic equation for planting (Eq. (3))

Variable	Coefficient	Wald X^2 ratio
Tenure		
Private lands in Tree Farm License	0.8223	3.1986[a]
Other Crown lands in Tree Farm License	0.1180	0.4965
Timber License	0.0202	0.0265
Species composition		
Balsam	−0.0064	31.0041[b]
Cedar	0.0020	1.5557
Douglas-fir	0.0044	6.0102[b]
Hemlock	−0.0055	9.9999[b]
Spruce	0.0030	4.9898[b]
Characteristics of the cutblock		
S_G	0.5126	3.8980[b]
S_M	0.0831	0.1605
Z_1	−0.2149	1.0544
Z_2	−0.3306	4.2332[b]
Z_3	−1.5182	65.0669[b]
SIZE	0.1315	6.4733[b]
Others		
PRODUCER	−0.0523	0.1982
DATE	−0.1107	0.5844
INTERCEPT	0.5078	0.8024
$-2 \log L$	180.144	
Score	184.341	
Observations	2311	

[a] Significant at the 10% level.
[b] Significant at the 5% level.

Table 7
Results for linear–linear equation for the time taken to complete planting (Eq. (4))

Variable	Coefficient	t-ratio
Tenure (and investment)		
Private lands in Tree Farm License	−6.3596	−3.711[c]
Other crown lands in Tree Farm License	−5.3314	−9.003[c]
Timber License	−3.7579	−4.395[c]
Investment	0.0011	2.879[c]
Species composition		
Balsam	0.0369	1.767[a]
Cedar	0.0537	2.957[c]
Douglas-fir	0.0111	0.679
Hemlock	0.0257	1.523[a]
Spruce	0.0219	2.797[c]
Characteristics of the cutblock		
S_G	1.9650	1.651[a]
S_M	4.4036	4.248[c]
Z_1	5.2516	4.381[c]
Z_2	0.1386	0.195
Z_3	0.7948	0.711
SIZE	0.0371	3.792[c]
Others		
PRODUCER	−1.1033	−2.015[b]
DATE	−0.7591	−21.120[c]
INTERCEPT	43.4653	29.230[c]
R^2	0.3489	
R^2-adjusted	0.3424	
D.W.	1.6210	
Observations	1732	

[a]Significant at the 10% level, two-tailed test.
[b]Significant at the 5% level, two-tailed test.
[c]Significant at the 1% level, two-tailed test.

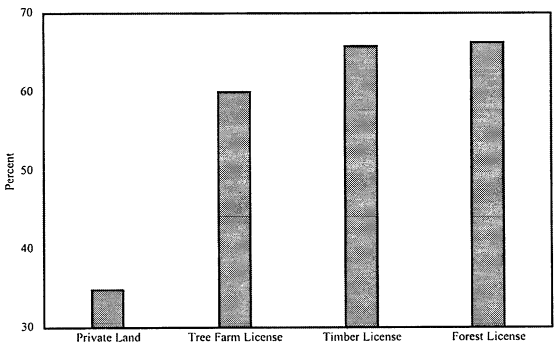

Fig. 2. Percent NSR lands where not satisfactorily restocked lands occur.

Crown lands in Tree Farm Licenses are insignificant at this level. The relationship between the form of tenure and the probability of cutblocks having been planted is illustrated in Fig. 3, which reflects the findings in Table 6 assuming fixed values for the other variables, as in Fig. 1.

The coefficients for the species variables show that, in comparison with ‘other species’, Douglas-fir and spruce contribute positively, and balsam and hemlock negatively, to the probability of planting at the 10% level. This is likely a reflection of the more frequent use, in artificial reforestation, of Douglas-fir and spruce than ‘other species’, and the heavier dependence on natural regeneration for balsam and hemlock (Blackstock, 1994, pers. comm.).

A higher probability of cutblocks having been planted is associated with larger cutblocks and good site quality (the positive influence of medium site

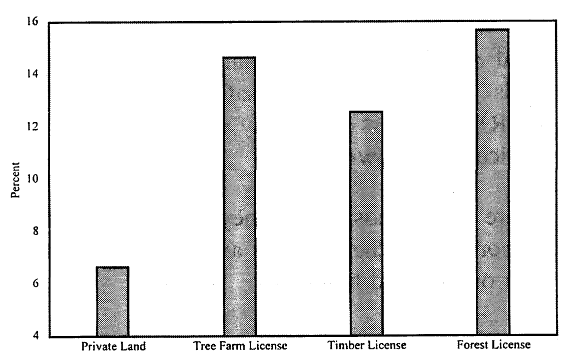

Fig. 1. Probability of occurrence of not satisfactorily restocked land.

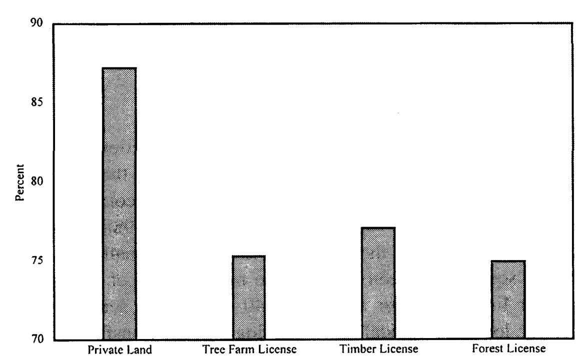

Fig. 3. Probability of planting.

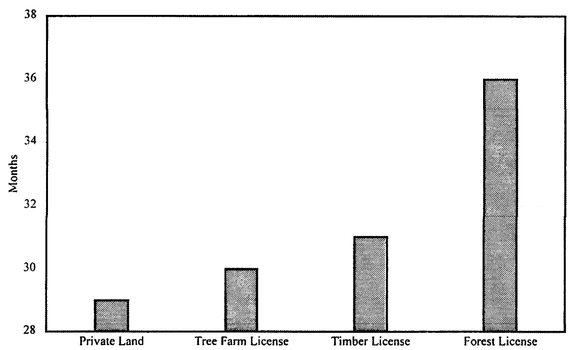

Fig. 4. Months following logging to complete planting.

quality is insignificant at the 10% level). The biogeoclimatic zone is also significant. The date at which logging took place suggests an insignificant downward trend in planting during the study period. The size of the company holding the tenure, also does not significantly affect the probability of planting.

5.4. Planting time

Eq. (4) was estimated using 1732 observations of cutblocks where the operator chose to plant, rather than depend on natural regeneration (The observations for natural regeneration are irrelevant to the dependent variable in this equation.). The functional form of the equation was selected by applying the Box-Cox technique to the most common functional forms, which indicated superiority of the linear form [4]. The regression results appear in Table 7.

The coefficients for the tenure variables indicate that the form of tenure is significant in determining the time taken to complete artificial reforestation. The negative coefficients for private lands in Tree Farm Licenses, other Crown lands in Tree Farm Licenses and Timber Licenses are all significant at the 5% level. These results imply that private lands in Tree Farm Licenses are regenerated, on average, in 29 months after logging, other Crown lands in Tree Farm License lands in 30 months, and Timber Licenses in 31 months — all shorter than the mean regeneration period of 36 months for Forest Licenses (Fig. 4).

The regeneration period is strongly related to the species regenerated. The significantly positive coefficients for balsam, Douglas-fir and hemlock indicate that it takes longer for these species (but not cedar and spruce) to be planted than 'other species' (probably because planting on sites suited to these species is less urgent than others). As expected, site quality, cutblock size, and character of the operating company all appear as significant factors. The date of logging is also significant, and suggests that the time it takes to complete planting became longer over the study period. Differences among biogeoclimatic zones are not significant.

6. Conclusions

The statistical analyses in this paper support the hypothesis that more secure forms of tenure over forest land lead to higher standards of reforestation performance insofar as this is reflected in more intensive silviculture. This is particularly so in the comparison between private lands and Crown lands managed under the various forms of licenses examined. Thus, our examination of cutover Crown lands, harvested and managed under licensing arrangements, with private lands subject to the same silvicultural regulations, reveals that:

lands classified as not satisfactorily restocked (NSR) occur less frequently on private lands than on licensed Crown lands;

where NSR lands occur, they comprise a smaller proportion of the cutover area on private lands than on licensed lands;

operating companies more frequently plant cutover areas on their private lands than on their licensed Crown lands;

[4] Since maximizing the Box-Cox likelihood function is equivalent to minimizing the residual sum of squares for the regression where the independent variable is divided by its geometric mean prior to transformation (Spitzer, 1982; Judge et al., 1988: Palmquist and Danielson, 1989), the function form with the smallest residual sum of squares has been chosen. The residual sum of square was 162 for linear; 164 for semi-log; 240 for inverse semi-log; and 230 for log-linear model. Thus the logarithmic transformation is consequential with respect to the dependent variable, but inconsequential to the independent variables.

where planting is done, it is completed in a shorter time following logging on private lands than on licensed Crown lands.

Performance among the three categories of licenses is mixed. The two forms that convey exclusive rights to a defined area over the term of the license show a shorter planting than licenses that do not. However, the variables representing them are not significant in other three equations. Their signs nevertheless are consistent with our hypothesis that lands managed under the least secure form of tenure (Forest Licenses), contain NSR lands more often and in higher proportions, and are planted less frequently.

These findings confirm claims that the form of tenure influences reforestation and that more secure tenure fosters improved management practices. The results must be interpreted cautiously, however. The security of a property right depends on many attributes, such as its term, renewability, exclusivity, governmental charges, scope for regulatory intervention, and the way it has come to be regarded by the licenser and the courts. The four types of tenure examined in this study differ in all these respects, and it is their combined effect which determines their holders' perceptions of the security of their rights. For purposes of policy design, it would be useful to separate and measure the influence of each attribute of tenure on the holders' behavior, but that must be left for further research.

Finally, our findings should not be interpreted as demonstrations of the relative efficiency of forest management under different forms of tenure. We have not examined the optimum intensity of management, and it is not always the case that further reduction in NSR, more planting or more rapid reforestation will contribute to improved resource management in an economic or biological sense. Our measures are simply indicators of differences in reforestation performance among types of tenure, which are only suggestive of inefficiencies and distortions due to the tenure system.

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