Chapter 4

Optimal Stand Management

Traditional and Neotraditional Solutions

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The traditional Faustmann (1849) model has served as the foundation of economic theory of the firm for the forestry production process. Since its introduction over 150 years ago, many variations of the Faustmann have been developed which relax certain assumptions of the traditional model, including constant prices, risk neutrality, zero production and management costs, and the single management objective. We describe the traditional Faustmann and provide an overview of the neotraditional Faustmann and Hartman (1976) models. We then use the neotraditional Hartman model to develop testable hypotheses regarding harvest response to timber, land, and amenity values from forests. Using data from the North Carolina coastal plain, we test for inclusion of several often omitted variables in models of industrial and nonindustrial harvest behavior.

1. TRADITIONAL AND NEOTRADITIONAL OPTIMAL HARVEST MODELS

Efforts to model maximization of economic returns from forest land began with a treatise by Faustmann (1849). Faustmann derived a formula for determining the economically optimal rotation length for timber production alone. This model assumed a constant price for a single wood output and had no input costs other than a constant and known price of capital. In 1999 a symposium was held to mark 150 years since the publication of Faustmann's seminal paper (Brazee 2001). Several of the papers from this symposium have been published and are included in this summary.

Sills and Abt (eds.), Forests in a Market Economy, 41-57.

Faustmann's model, also referred to as land expectation value (LEV) maximization, languished in obscurity in forestry circles in America until the middle of the 1900s (Gaffney 1957). Practical applications continue to be limited because owners of forest land have other objectives in addition to maximizing income from timber (Gregory 1972). Early data for private landowners showed a consistently longer rotation for nonindustrial private forest (NIPF) landowners than for industrial landowners. The other objectives are one explanation for the variation in rotation ages.

In addition, the real world is more complicated than this model. Based solely on forest outputs for which there are functioning markets in the economy, LEV may not be the appropriate maximization criterion for a vast share of the land-owning population. Nonetheless, models simplify the world in ways that can reveal the relationships among many or all of the important factors affecting observed phenomena. This section describes the latest stand-level models of economic optimization for private landowners.

The traditional Faustmann model assumes bare land and determines the rotation length of an even-aged stand that maximizes the discounted timber revenues minus timber production costs, for the first and all subsequent rotations, assuming constant prices and a known timber yield production function. This approach can be adjusted to include factors that bring the model closer to the reality of forest product and land markets (table 4.1). These neotraditional Faustmann models (table 4.2) may include input costs (e.g., Hyde 1980, Nautiyal and Williams 1990), values other than timber (e.g., Hartman 1976), stochastic prices (e.g., Norstrøm 1975), or production risk (e.g., Martell 1980). Another type of neotraditional Faustmann model addresses uneven-aged management, which is in the spirit of Faustmann but must be derived and tested differently (e.g., Adams and Ek 1974).

Tub/e 4.1. Development of the traditional Faustmann model

Author	Innovation
Faustmann (1849)	First development
Gaffney (1957)	Rediscovery in United States
Samuelson (1976)	Second rediscovery in United States
Binkley (1981)	Used Faustmann to derive supply
Heaps (1984)	Steady-state optimal is Faustmann

Efforts to understand optimal harvest decisions have been along two central tracks: normative and positive analyses (table 4.2). Normative analyses are theoretical developments of the Faustmann and variants. One objective of these theoretical analyses is to provide a tool for landowners that incorporates more real-world factors into decision models. Positive analyses of the timber harvest decision model have been reflective attempts to understand whether behavior of timberland owners is consistent with

Table 4.2. Normative and positive analyses of neotraditional Faustmann model

Innovation	Normative	Positive
Variable inputs	Hyde (1980)	
	Jackson (1980)	
	Chang (1 983, 1998)	
	Nautiyal and Williams (1990)	
Nontimber outputs	Hartman (1976)	Max and Lehman (1988)
	Binkley (1981)	Dennis (1989, 1990)
	Strang (1983)	Kuuluvainen and Salo (199 1)
	Calish et al (1978)	Provencher (1995, 1997)
	Swallow and Wear (1993)	Lee (1997)
	Plantinga and Birdsey (1994)	Newman and Wear (1993)
	Plantinga (1998)	Kuuluvainen and Tahvonen (1999)
	Dole (1999)	Prestemon and Wear (2000)
	Tahvonen and Salo (1999)	Pattanayak et al. (2002)
	Englin et al. (2000)	Pattanayak et al. (chapter 14)
	Koskela and Ollikainen (2001)	
Uncertainty	Norstrøm (1975)	
	Martell (1980)	
	Routledge (1980)	
	Reed (1984)	
	Lohmander (1988)	
	Brazee and Mendelsohn (1988)	
	Clarke and Reed (1989)	
	Thomson (1992)	
	Gong (1994, 1999)	
	Yin and Newman (1995a, 1995b, 1997)	
	Yin and Newman (1996)	
	Forboseh et al. (1996)	
	Abildtrup et al. (1997)	
	Willassen (1998)	
	Brazee and Bulte (2000)	
	Lohmander (2000)	
	Fina et al. (2001)	
	Zhang (2001)	
	Buongiomo (2001)	
Risk aversion	Caulfield (1988)	
	Pukkala and Miina (1997)	
	Gong (1998)	
	Peltola and Knapp (2001)	
	Uusivori (2002)	
Uneven-aged	Adams and Ek (1974)	Raunikar et al. (2000)
	Buongiomo and Michie (1980)	Scarpa et al. (2000)
	Bare and Opalach (1987)	
	Buongiomo and Lu (1990)	
	Lu and Buongiomo (1993)	
	Buongiomo et al. (1994)	

theories developed by normative models. Both kinds of analyses are useful because they serve as complements: Normative analyses provide tools, positive analyses evaluate their usefulness and test the importance of other potential factors in decisions, and then normative models are updated to reflect the new knowledge.

Many of the studies in table 4.2 do not directly analyze or test the Faustmann but address various assumptions of the traditional model. Seminal works in this area include Faustmann (1849), Samuelson (1976), Hartman (1976), and Binkley (1981). Samuelson is basically a rediscovery of the Faustmann model, Hartman was the first to address nontimber outputs, while Binkley, using a household production framework, incorporated landowner characteristics into the decision framework. Other papers using the household production model include Max and Lehman (1988) and Dennis (1989, 1990). Several papers use optimal control methods, which have been shown by Heaps (1984) to converge to the Faustmann model in the steady state. Some of the papers directly address the incorporation of Faustmann models into market analyses (e.g., Binkley 1993, Brazee and Mendelsohn 1988). Swallow and Wear (1993) and Tahvonen and Salo (1999) address multiple stands, including adjacency issues.

As noted by many studies, both normative and positive, the traditional Faustmann has many limitations. We recognize and discuss several of these limitations, including (1) variable inputs, (2) nontimber outputs, (3) uncertainty, (4) risk aversion, and (5) uneven-aged management.

The first addition to the traditional models was the inclusion of variable inputs and input costs. Because the algebra for optimal solutions is complicated, in most models these inputs are ignored. Yet, it is commonly recognized that these inputs matter to the optimal harvest decision.

The second neotraditional innovation was the addition of nontimber outputs to the decision framework. Hartman (1976) demonstrated that a stand with age-based amenity outputs would be harvested later or not harvested at all. Because NIPF landowners are assumed to value amenity outputs, several studies have tested for the influence of amenities on harvest decisions. These tests all suffer from the use of proxies to measure amenity outputs.

A third limitation of the traditional Faustmann model stems from its reliance on static and known prices and production functions. Analyses attempting to correct this shortcoming are primarily normative (see table 4.2), focusing on stochasticity of output and input prices. Efforts to evaluate optimal strategies in the context of multiple investment vehicles include Redmond and Cubbage (1988) and Zinkhan et al. (1992). While these efforts lie outside the Faustmann and variants, they represent a potential approach that would broaden the stochastic harvest timing models cited above. Other refinements of the traditional Faustmann address variations in timber yield resulting from uncertainty regarding stand growth functions and from random natural events.

Fourth, the traditional Faustmann does not address risk aversion, and the majority of neotraditional analyses assume risk neutrality. Because there is positive value to managing risk, the risk-averse case is relevant to many producers. Dispersion of returns, in fact, plays a central role in portfolio theory (Lintner 1965, Sharpe 1964). Hence, it seems appropriate to understand the effect of risk aversion on optimal decisions.

A normative study in forestry by Caulfield (1988) used stochastic dominance analysis to improve timber harvest decisions of risk-averse timberland owners. Putting the forest investment in the context of other possible investments is another innovation (Wagner et al. 1995, Washburn and Binkley 1990, Zinkhan et al. 1992). Positive analyses searching for evidence that risk-averse behavior is accounted for in the production decision are lacking. However, evidence of higher discount rates for private timberland owners than for industrial landowners (Prestemon and Wear 2000) is consistent with risk aversion (Lintner 1965, Sharpe 1964). Positive analyses of the effects of production and other kinds of risk would be useful in revealing the qualitative implications for management, would suggest the value of mitigating risk, and would be beneficial in attempts to understand quantitatively the aggregate effects of risk on producers with different ownership characteristics. Those kinds of studies could lead to improved understanding of aggregate supply behavior.

Faustmann and its neotraditional variants do not apply to uneven-aged forests. Uneven-aged management is used to address biological diversity and minimize visual and ecological impacts of forest management and is becoming increasingly important as a management tool in the United States, The work on the economics of uneven-aged management has been both normative and positive. Normative models are based on growth models, and positive analyses measure how closely the harvest behavior of owners of multi-aged stands conforms to a criterion analogous to LEV. No work has been done to develop a model to empirically evaluate the effects of uncertainty or risk aversion on optimal decision making under uneven-aged management.

Although many advances have been made to include real-world phenomena in the land value maximization decision in both even-aged and uneven-aged timber production, a fully stochastic model for both is lacking. Ultimately, if the correct stand-level optimization model for timber growing includes nontimber values, risk aversion, production risk, and price stochasticity, then these inclusions should have implications for what appears in specifications of aggregate market models. Aggregate market models would then need to be updated from the traditional specification. The result of better aggregate models would be more accurate and spatially refined timber market and land use projection models (e.g., Abt et al. 2000, Adams and Haynes 1980), enabling new kinds of research into the market and land use effects of demographic, macroeconomic, and public policy changes.

2. THE HARTMAN MODEL: A NEOTRADITIONAL FAUSTMANN

The Hartman model (1976) modified the traditional Faustmann model by including amenity outputs. According to Hartman's calculus, a stand with amenity values in standing timber may be harvested later or may never be harvested. This could have important implications for timber supply modeling and in understanding the market and economic welfare implications of policies and catastrophic shocks. In econometric analyses of timber harvesting behavior, if such values affect the production decisions of landowners but are not included in empirical specifications, then incorrect inferences on the effects of included variables might result. If the Hartman model is an accurate reflection of timber production decisions of a large proportion of NIPF landowners, then this could help explain differences in harvest timing between these two broad classes of owners.

In this section we develop a model to test whether amenity values influence private harvest decisions. We model southern pine harvesting in the North Carolina coastal plain for the period 1983-1989. Harvest choice is modelled as a function of timber values, land values, and amenity proxies. The obvious risk in choosing a proxy for amenity values it that the hypotheses are joint: if we find that our measures of amenity values are not significantly related to the harvest decision, then we cannot be sure whether this is because the measure is incorrect or because amenities truly play no role in the decision. On the other hand, if we find that measures of amenity values are significantly related to the harvest decision, and in the manner hypothesized (i.e., high amenity values are negatively associated with the harvest decision), then we can conclude that these values are linked to the harvest decision and should be accounted for when evaluating the response of landowners to market shocks and government policies.

The bare land Hartman land value (HLV) can be characterized as:

$$HLV = \frac{\sum_{j=1}^{J} V_j e^{-rt} - k + \int_{t=1}^{T} A(x) e^{-rx} dx}{1 - e^{-rt}} \qquad 4.1$$

where V_j is the timber value for product j ($j = 1,\ldots,J$), k are establishment costs, t ($t = 1,\ldots T$) is the age of the stand, r is the discount rate, and A are the age-dependent stand-level amenities. For an existing stand, this model is modified through the inclusion of discounted current stand values and by discounting the HLV from harvest of the current stand back to today. We posit that in every period, landowners compare the benefits of harvesting (π_t^1) with the benefits of delaying harvest (π_t^0). The benefits include the revenues from the current stand of timber as well as the benefits and costs of the delay of future rotations and the benefits and costs of amenities from both current and future rotations.

We define the binary variable, y_t, as:

$$Yt = \begin{cases} 1 \ \text{if} \ y_t^* = \pi_t^1 - \pi_t^0 > 0 \\ 0 \ \text{otherwise} \end{cases} \qquad 4.2$$

Thus, if the net benefits of harvesting today are greater than the net benefits of delaying harvest, the landowner will harvest, and the observed variable, y_t, will equal 1. The latent variable y_t^* is equivalent to an intertemporal value comparison. We can specify the harvest decision as a function of the latent variable:

$$\begin{aligned} y_t^* = {} & [V_t(a) - \rho V_t(a+m)] + [A(a) - \rho A(a+m)] + \\ & [HLV(a) - \rho HLV(a+m)] + \varepsilon^1 - \varepsilon^0 \end{aligned} \qquad 4.3$$

where V_t(a) is a vector of timber product revenues at time t for age a, m is the number of years between decisions, $A(a)$ is the amenity utility derived from a stand of age a, $\rho = (1 + r)^{-1}$, and ϵ_i is the error associated with inaccurately calculating the benefits associated with current harvest (1) or future harvest (0). The errors in equation 4.3 may be associated with inaccurate calculations by the landowner or with factors unobserved by the analyst but observed by the landowner.

This model incorporates (1) different values for pulpwood and sawtimber; (2) different estimates for nonindustrial and industrial landowners; (3) the value of future infinite series of rotations, which is often dismissed in empirical tests as being too small to have an influence on the harvest decision although this is precisely what makes the LEV model different from the Fisherian model of net present value; and (4) proxies for the Hartman old growth, a parklike vegetation profile that has a dense ground cover and overstory.

We hypothesize that current timber and land values will positively correlate with harvesting, while future timber and land values will negatively correlate with harvesting. Opposite results will hold for current and future rotation values of amenities, where higher levels of current amenities will correlate with lower harvesting and higher levels of future amenities will correlate with decreased harvesting. However, because North Carolina's coastal plain forests are managed fairly intensively for timber, at least compared with forests of other regions of the United States, we hypothesize that industrial harvest behavior would not be influenced by amenity values.

3. DATA AND ESTIMATION

In decision-making, landowners are assumed to compare the present with the expected future. We explicitly recognized that harvest decisions are based on changes in all stand attributes: current stumpage values, LEVs, and amenity values. In addition, because we do not have adequate data regarding the expected amenity conditions, we use only the current values for the vegetative profile as a proxy for Hartman's parklike stand conditions. The determination of the amenity values is described below.

The empirical version of equation 4.3 is:

$$y_t^* = \beta_0 + \beta_1 V(a) + \beta_2 V(a+m) + \beta_3 LEV(a) + \beta_4 LEV(a+m) + \beta_5 A(a) + \varepsilon_t \qquad 4.4$$

where t indexes time, a is the age at the initial survey and $a + m$ is the age of the stand at the final survey, V is timber revenues from both sawtimber and pulpwood, LEV includes only timber as an output, A is a vector of vegetative profile proxies for amenities, and ρ is the discount rate.

Data for all variables except timber prices and future product volumes were taken from the USDA Forest Service's Forest Inventory and Analysis (FIA) surveys of the forests of the coastal plain of North Carolina. Sampled stands were measured during the summers of 1983 and 1989 so that the time elapsed between periods was 6 years (m = 6).

While standing volumes of sawtimber and pulpwood in period t were observed for all sampled stands, expected volumes in period $t + m$ were not (actual volumes were not available for the harvested stands). The expected period $t + m$ volumes were estimated by fitting quadratic models of pulpwood and sawtimber volume to unharvested stands. These quadratic equations predicted 1989 volumes of pulpwood and sawtimber as a function of 1983 volumes, 1983 stand age in years, 1983 stand basal area, and 1983 site index (base age 50).

Harvest (y_t, in equation 4.4) was specified as a binary (1,0) variable indicating whether or not the stand was harvested between 1983 and 1989, Partially cut stands were dropped from the data set.

LEV was calculated by assuming an infinite series of rotations identical to the current rotation. Thus, the current and expected timber values were used, and a plantation establishment cost of $150/acre was assumed. The revenues were discounted using a 5% rate.

Based on the Hartman vision of parklike stands, we used stand structure variables from the FIA inventory data to construct overstory, shrub, and ground cover vegetation profiles. Using data for trees and all other vegetation, we calculated the percent of space occupied by ground covers (0 to 2 feet), shrubs (2 to 15 feet), and overstory (80+ feet).

Stumpage price data were obtained from Timber Mart-South (Norris Foundation 1977-1989). Real stumpage prices for both t (1983) and $t + m$ (1989) were $11 .OO per cord for pulpwood and $158.60 per thousand board feet for sawtimber. Constant real prices reflect our assumption that timberland owners in North Carolina in the mid-1980s did not expect real increases in prices for southern yellow pine pulpwood and sawtimber. Variation by stand occurs because stumpage volumes differ by stand and by year, resulting in a different timber value for each oservation. The differences in stand volumes result from differences in growth and variation in the mix of sawtimber and pulpwood across stands.

4. RESULTS

The results of the estimation of equation 4.4 are shown in table 4.3 for industrial landowners and table 4.4 for NIPF landowners. A series of models was estimated to examine model response to severe multicollinearity expected in the estimations. The χ^2 statistics indicate that all the models are significant.

Table 4.3 shows the results of four estimations of the probability of harvest by industrial landowners. The models do indicate multicollinearity may be influencing the standard errors for LEV and timber values, with both current and future expected values significant in the timber only and LEV only models but insignificant in the timber plus LEV model. The addition of the amenity characteristics, which are not significant influences on industrial

Table 4.3. Estimates of harvest choices by industrial owners of southern pine stands in the coastal plain of North Carolina between 1983 and 1989 (n = 268)

Variable	Timber	LEV	Timber plus LEV	Timber plus LEV plus amenity
Intercept	-0.1217	-0.0902	-0.063 1	-0.0509
	0.0356”	0.0292	0.0309	0.0492
Timber value (1983)	0.0004 *		0.0003	0.0003 *
	0.0001		0.0002	0.0002
Expected timber value (1989)	-0.0003 *		-0.0002	-0.0002 *
	0.0001		0.0001	0.0001
LEV (1983)		0.0003 *	0.0002	0.0002
		0.0001	0.0001	0.0001
Expected LEV (1989)		-0.0003 *	-0.0001	*0.0000*
		0.0001	0.0002	0.0002
Ground cover occupancy (O-2 feet)				0.0007
				0.0008
Shrub layer occupancy (2- 15 feet)				-0.0010
				0.0009
Overstory occupancy (>80 feet)				-0.00 18
				0.0016
Log-likelihood	-57.777	-55.306	-53.447	-51.638
χ^2	il.108	16.050	19.769	23.386
Significance level	0.004	0.000	0.006	0.001
Pseudo-R^2	0.274	0.396	0.359	0.364

* significant at the 5% level
“Standard errors in italics

harvest choices, alters the results slightly to return the timber values to significance.

Industrial landowners respond as expected to current timber values by increasing their harvests, while an increase in future timber values reduces harvests. Similarly, it appears that these landowners also respond as if they were aware of LEV, by increasing harvests with a higher LEV and reducing harvests with a higher future LEV. While it is likely that few landowners, industrial or NIPF, actually calculate the LEV for any of their timber stands, we are testing whether or not their behavior is consistent with wealth maximization as represented by LEV. We conclude that industrial harvest choices are consistent with maximizing LEV. As expected, industrial landowners do not respond to the proxies for amenity characteristics.

Table 4.4 shows similar results for NIPF landowners, with significant χ^2 statistics and pseudo-R^2 ranging from 0.34 to 0.39. Current and expected future timber values were not significant in any of the models. Current and expected future LEV were significant in the models. Again, as with industrial landowners, increases in LEV led to increased probability of harvest, and higher expected LEV led to decreased probability of harvest. Thus, landowners delayed harvest when future LEV increased, holding current LEV constant.

The hypothesized Hartman effect is given some support with these results. The Hartman model proposes that harvest will be delayed if standing timber has value. In this analysis, we developed ecological proxies for a parklike stand condition-dense ground cover and overstory and limited vegetation in the shrub layer (2 to 15 feet above ground). We hypothesized that a dense shrub layer, which corresponds to the area most likely to block human visibility while standing, would be undesirable, and thus a landowner's probability of harvest would increase with increasing shrub density. The estimated coefficients on ground cover and shrub layer are not significant at the 5% level but do have the correct sign. Multicollinearity is also possible with these ecological proxies, with higher ground cover and lower shrub density occurring naturally with higher overstory density.

Dense overstory significantly influences NIPF harvest choices, with more overstory corresponding to lower harvest probability. The overstory measure used, vegetative occupancy over 80 feet, is highly correlated with stand age. Older stands are expected to be taller and have denser overstory at this height (excluding true old growth stands, which rarely occur in coastal plain southern pine stands). Thus, in the absence of other variables, harvest and overstory should be positively correlated. However, including timber values and LEV to explicitly account for the impacts of age on increasing value, we found a negative correlation between overstory and harvest probability.

5. CONCLUSIONS

Stand-level economic optimization theory has advanced substantially in the last quarter century, an effort that has permitted the development and

Table 4.4. Estimates of harvest choices by NIPF owners of southern pine stands in the coastal Plain of North Carolina between 1983 and 1989 (n = 45 1)

Variable	Timber	LEV	Timber plus LEV	Timber plus LEV plus amenity
Intercept	*-0.3280*	*-0.2 150*	-0.3046	-0.3132
	0.0320 [a]	*0.0202*	0.0324	*0.0587*
Timber value (1983)	0.000 1		-0.0003	*-0.0002*
	0.0002		*0.0002*	*0.0002*
Expected timber value (I 989)	*0.0001*		*0.0003*	*0.0003*
	0.0002		*0.0002*	*0.0002*
LEV (1983)		0.0007 *	*0.0007* *	*0.0006* *
		0.0002	*0.0003*	*0.0003*
Expected LEV (1989)		-0.0007 *	-0.0010 *	*-0.0009* *
		0.0003	*0.0004*	*0.0004*
Ground cover occupancy (O-2 feet)				*-0.0007*
				0.0011
Shrub layer occupancy (2-l 5 feet)				*0.0005*
				0.0010
Overstory occupancy (>80 feet)				-0.0019 *
				0.0009
Log-likelihood	-225.480	-23 1.406	*-225.480*	-219.466
χ^2	26.219	14.367	*26.219*	38.248
Significance level	0.000	*0.001*	*0.001*	0.000
Pseudo-R^2	*0.342*	*0.342*	*0.373*	*0.387*

*significant at the .05 level
[a] Standard errors in italics

refinement of economics-based timber supply projection models. From these advancements, we now have a better understanding of the effects of incorporating other inputs, other outputs, and price and production risks into the harvest decision model. Most work on the harvest decision model has been normative, describing optimal choices with additional complexity of the neotraditional Faustmann models. More recently, positive analyses have found statistical evidence that traditional and neotraditional models can be used to represent harvest choices made by land managers.

In this chapter, we developed a test of a neotraditional Hartman model. The model and data we used indicated that both the traditional and neotraditional models can be used to explain harvest decisions by NIPF landowners. For industrial landowners, the addition of the neotraditional Hartman elements (amenity proxies) did not improve the model, nor were any of the individual measures significant in predicting industrial harvest choices in the coastal plain of North Carolina.

One important result from our tests is that LEV may be an important predictor of harvest choices, especially choices made by NIPF landowners. Because the calculations for this value are complex and dynamic, and because the value of future rotations is small when compared to the value of the current rotation, most empirical research does not include a measure of LEV. A third reason for not including LEV is that NIPF landowners are assumed to be unaware or incapable of understanding and calculating LEV for a stand of trees. We found, however, that private landowners behave *as if* they had knowledge of LEV and, in particular, knowledge of how changes in LEV affect the decision to harvest.

Our tests also demonstrated the use of ecosystem measures as proxies for amenity values. The results support our use of vegetative occupancy at over 80 feet as a measure of a desirable amenity. We did not find statistical support for private landowner valuation of ground cover or shrub layer as proxies for Hartman's parklike stands. One possibility is collinearity between the overstory, shrub, and ground cover layers. Difficulties associated with these proxies include (1) the maintained assumption that amenity values increase with the age of the stand, (2) the use of vegetation measures that may represent the amenity values but may also represent other omitted variables in the model, (3) the inclusion of only current amenity conditions, and (4) the use of a 5% discount rate to calculate current and future LEV.

Overall, the models explained significant variation in harvest decisions of NIPF and industrial landowners of pine stands in the coastal plain of North Carolina. Considering the potential multicollinearity, both timber value and land value should be included in future tests of harvest choices. Ecosystem characteristics are influential in predicting harvest decisions only of NIPF landowners, and to the extent that these characteristics can proxy for amenity values, the Hartman neotraditional model can represent NIPF landowner harvest behavior.

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