

social sciences

# An Evidence-Based Review of Timber Harvesting Behavior among Private Woodland Owners

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Understanding private woodland owner (PWO) timber harvesting behavior is essential for predicting potential timber supply, as PWOs could be an increasingly important source. This evidence-based review synthesizes more than 100 peer-reviewed articles, government reports, and dissertations from 1970 to 2014 from North America and Europe. Our broad research question was “To what extent is actual PWO timber harvesting behavior understood?” Our objectives were to (1) identify how past research analyzed actual harvesting behavior, (2) describe the evolution of these methods, (3) determine the extent to which previous research linked landowners’ stated intentions to actual harvesting behavior, and (4) evaluate the significant predictors of PWO timber harvesting. This evidence-based review found that parcel size, harvest price, and distance from residence were the most common significant predictors of harvesting intention. Many studies purportedly studied behavior, but most measure stated attitudes without measuring observable harvesting behaviors. A better understanding of PWO behavior will inform timber supply prediction and support forest management outreach.

**Keywords:** private woodland owner, timber harvesting, theory of planned behavior, typology, timber supply

The properties of private woodland owners (PWOs) (also known as nonindustrial private landowner [nonindustrial private forestland], small-scale forest owners, forest farms, family forest owner, and private forest landowners<sup>1</sup>) (Harrison et al. 2002) provide countless societal and ecosystem benefits in North America and Europe. This is especially true for the southeastern and northern United States, where private owners possess 58 and

55% of the forestland, respectively (Butler 2008). Even in the Rocky Mountain region of the United States, where private owners have only 16% of the forestland (due to a large federal ownership component), they often control the most productive and accessible forest (Butler 2008). In Europe, data are available by country, and PWOs can be a dominant ownership type, particularly in the northern countries. For example, private woodland ownership in Sweden and Fin-

land is estimated at 50 and 60%, respectively, encompassing 68 and 39 million acres (Metla 2013, Swedish Forest Agency 2013).

Of these ecosystem benefits, timber harvesting could arguably have the most wide-ranging impact on forest systems and social systems through timber supply. For example, even though PWOs have only about 35% of total US forestland (Butler 2008), they produce 50–60% of all harvested timber (Adams et al. 2006). Similarly, European PWOs produce 20–90% of the total timber harvested (Schmithüsen and Hirsch 2010), depending on the country. Although the total timber supply can be estimated using USDA Forest Service Forest Inventory Analysis (FIA) data and remote sensing techniques such as LiDAR, the *actual* timber supply is more difficult to estimate because PWOs may or may not choose to harvest timber on their woodland (Butler et al. 2010, Markowski-Lindsay et al. 2012). There is now relatively broad consensus that many woodland owners do not own their woodland for the sole purpose of harvesting

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timber (Kilgore et al. 2014). Rather, they own land for a variety of reasons, some of which eventually lead to timber harvesting (Butler 2008). Like their American counterparts, PWOs in Europe also own their forestland for reasons beyond harvesting timber (Hujala et al. 2007, Dhubbáin et al. 2010, Fischer et al. 2010).

The timber harvesting behavior of PWOs has been an important question for forest stakeholders such as public and private foresters, the forest products industry, and conservation groups who want to anticipate harvesting levels and encourage sustainable harvesting practices on privately owned land. Not surprisingly, then, PWO timber harvesting has had a long and fruitful history of research, including several literature reviews that examine aspects of PWO harvesting. Some have analyzed the economic literature on the decision to harvest, concentrating on utility maximization (Amacher et al. 2003, Beach et al. 2005). Others have examined the evolution of research on PWOs more generally (Egan 1997, Fischer et al. 2010). Egan (1997) concluded that research has shifted from viewing PWOs as problematic timber harvesters to understanding the multiple objectives of PWOs. Fischer et al. (2010) discussed the similarities and differences between PWO research in the United States and Sweden, noting that the research methods and findings are remarkably similar in both countries. However, these and other reviews lack a comprehensive examination of timber harvesting behavior research specifically, and all are in need of an update.

Although several studies suggest a mixed-method approach to study PWO timber harvesting behavior (Bliss and Martin 1989, Egan and Jones 1995, Majumdar et al. 2008), the use of more than one method is rare. Furthermore, field visits to landowners who decide to harvest are often not practical or feasible so research often relies on surveys that measure self-reported past harvesting behavior or the future intent to harvest. Given this restriction, an understanding of actual harvesting behavior is central to an understanding of PWO timber supply or availability. Timber harvesting behavior is influenced by exogenous (e.g., timber price or forest damage) factors and endogenous (e.g., attitudes, values, debt to income ratio) factors (Lönstedt 1997).

Although harvesting data would provide measurable output on harvesting behavior, it is not publicly available for PWOs in the United States, despite some states programs that collect these data for the purposes of management or tax incentive programming (Kilgore and Blinn 2004, McDonald et al. 2006).

We use an evidence-based method to rigorously review the timber harvesting literature and examine the link between intentions and actual behaviors in PWO research. Specific objectives were 4-fold and aimed to (1) identify how past research defined and analyzed actual harvesting behavior, (2) describe the evolution of these theories and methods, (3) determine the extent to which previous research measured actual harvesting behavior, and (4) evaluate the significant predictors of PWO timber harvesting. It is hoped that this review can stimulate further discussion of timber harvesting behavior, the impact of harvesting behavior on timber supply, and the use of novel methods to validate studies of attitudes toward or intention to harvest. Understanding PWO timber harvesting behavior is critical to predicting timber supply, fine-tuning outreach and extension efforts, and creating connections in an increasingly fragmented forested landscape.

## Methods

The literature from studies in North America and Europe was examined using the search term “timber harvesting” in tandem with any word representing a PWO (e.g., family forest owner, private forest

landowner) (Table 1). Although we defined timber harvesting more strictly as removal of merchantable timber beyond personal use (Table 1), we included any article that had the phrase “timber harvesting,” as some articles did not define timber harvesting precisely. A search using synonyms such as “cut,” “removal,” or “roundwood” did not yield additional results. North America and Europe were chosen because of their similar forestry practices, economic systems, and landowner values. We used network sampling (Babbie 2012), beginning with the Web of Science, JSTOR, Ingenta, and Google Scholar databases and pulled citations from articles until there were no longer relevant citations to view, from 1970 to 2014. Literature review data are available to the public on the University of Maine Dataverse (Silver 2014) and in Supplemental Table S1. We reviewed research across all ownership sizes. In addition to the type of owner, there is an inconsistent size threshold for including a PWO in sampling efforts. Some sampling efforts include forest holdings of less than 50 acres (Hull et al. 2004, Kendra and Hull 2005), whereas the National Woodland Owner Survey (NWOS) defines a threshold of >0.4 ha (1 acre) and sometimes includes only 4.0 ha (10 acres) or more in analyses (Butler et al. 2005).

We used a systematic evidence-based review format to meet our objectives. Evidence-based frameworks originated in medicine with three key components: the research question, the systematic review of

## Management and Policy Implications

We present a review of private woodland owner (PWO) timber harvesting behavior that suggests that the PWO decision to harvest timber is not yet well understood. PWOs are an important part of the timber base, particularly in the eastern United States, and their management decisions will have a significant impact on forest ecosystems and the forest products industry. The most reliable predictors of harvesting intention include characteristics such as outreach activity participation and harvest price. Many studies categorized PWOs into typologies, and all studies found that there was a “production-oriented” landowner category. However, only five peer-reviewed studies (6% of the studies examined) that measured actual harvesting behavior were identified. Although many PWOs intend to harvest and those intentions can be measured and used to predict production-oriented individuals, managers are advised to rely on high evidence studies that measure actual behavior to strengthen outreach services and understanding of the true PWO timber availability. Furthermore, state-level policymakers should orient their outreach and incentive programs using actual behavioral studies. State-level forest managers should use behavioral studies in concert with data on volume and age-class distributions to estimate sustainable timber removal levels.

Supplementary data are available with this article at <http://dx.doi.org/10.5849/jof.14-089>.

**Table 1. Inclusion categories and criteria used to evaluate studies included in this review.**

Inclusion category	Inclusion criteria
Subject or ownership type	Private, nonindustrial landowner. The following terms were included: family forest, private forest owner, nonindustrial, small woodland owner, small woodlot owner
Activity	Timber harvesting defined as “the removal of merchantable timber beyond personal use” <sup>1</sup>
Parcel size	All sizes
Treatment	Survey, interview, field visit, empirical or theoretical model, agent-based model
Outcome variable	Timber harvesting attitude, intention, or behavior

<sup>1</sup> The search also used synonyms such as “cut,” “removal,” or “roundwood.”

relevant evidence, and active dissemination of findings (Pullin and Stewart 2006, Petrokofsky et al. 2011). They are built on the premise that reliability increases as information moves from anecdotal and “expert opinion” to the level of meta-analyses and systematic reviews, with case studies and randomized controlled trials in the middle (Petrokofsky et al. 2011). This style of review is meant to weigh evidence, provide an unbiased evaluation, and strengthen decisionmaking and policy. There are only a handful of evidence-based reviews in forestry research (e.g., Peppin et al. 2011, Petrokofsky et al. 2011). Our broad research question for this evidence-based review was “To what extent is actual PWO timber harvesting behavior understood?” We assigned categories to reflect what aspect of timber harvesting was measured: self-reported attitudes, self-reported behavioral intentions, predicted or potential (from modeling), self-reported past behavior, and actual measured behavior (Table 2). We also assigned quality of evidence ratings to each article, with the highest quality being studies that measured actual behavior and the lowest quality assigned to articles measuring only attitudes (Table 2). We did not perform a meta-analysis of these articles, but rather summarized the measured variables that were correlated to the intention to harvest timber. We analyzed the literature for agreement on predictors for the intention to harvest and strength of evidence in these studies.

Each reference was also coded in a database for methods, study area, main findings, and the following subcategories: timber harvesting, management plans, woodland owner organizations/stewardship programs, and typologies. These subcategories helped determine the main themes present in the research, although all related to landowner timber harvesting behavior more broadly. An article was included under the timber harvesting cate-

gory if the primary focus of the article was determining timber harvesting behavior. The typology category was not mutually exclusive of the other three categories if the typology was used to better understand timber harvesting, management plans, or participation in woodland owner organizations. To analyze the evolution of research methods, we divided the literature into two even sampling periods: 1970–1992 and 1993–2014.

## Results

The literature search resulted in 128 articles (Supplemental Table S1), 87 of which directly addressed timber harvesting behavior (Figure 1, level 1 “PWO timber harvesting literature”). Most level 2 articles (Figure 1) focused on regions within the United States ( $n = 54$ ), but there were studies from Europe, including Finland ( $n = 6$ ) and Sweden ( $n = 4$ ), and a study from Canada ( $n = 1$ ). The US regions not well represented were the intermountain west and southwestern states, indicating a need for more research on PWOs in these contexts. Management plans ( $n = 11$ ) and woodland owner organization ( $n = 11$ ) were also a study focus. Finally, the typology category included 27 articles whose main goal was to create a landowner typology (Figure 1, level 2 “Main focus”). Level 2 articles often were classified in multiple categories. For example, a typology of PWOs might also focus on the effect of a management plan on landowner behavior.

### Harvesting Behavior Definition and Analysis

Timber harvesting was rarely defined in the literature. Only one-third of the level 2 timber harvesting articles ( $n = 87$ ) described timber harvesting. The most common definition was “sold timber” or “produce timber for sale,” but some definitions included words such as thinning, coppicing, partial

cut, or timber stand improvement. Harvesting behavior was defined and analyzed using a variety of methods, but the most common was a quantitative mailed survey (32%,  $n = 28$ ) of landowner demographic characteristics, management activities, and attitudes or intentions toward management, followed by empirically based models (18%,  $n = 16$ ) in the economics literature (Figure 1, level 2 “Main focus”). Thirty-seven articles included information on how far in the past and future (e.g., “5 years ago,” or “in the next 10 years”) respondents were asked about their timber harvesting attitudes, intentions, and past harvesting activities. Time frames ranged from 1 year to the entire ownership tenure, but the most common were 5 and 10 years in the past and future.

Of the level 2 papers that measured timber harvesting specifically ( $n = 87$ ), we found that 26% ( $n = 23$ ) measured attitudes toward harvesting, 41% ( $n = 36$ ) measured behavioral intentions, 20% ( $n = 17$ ) measured potential behavior, 48% ( $n = 42$ ) measured past harvesting activities, and only 10% ( $n = 9$ ) measured actual behaviors by using actual harvest data, field visits, or interviews. Attitudes, intentions, and behaviors were sometimes combined when past behaviors were measured (e.g., Creighton et al. 2002), whereas in other cases they were clearly separated in the methods and results (e.g., Hogl et al. 2005).

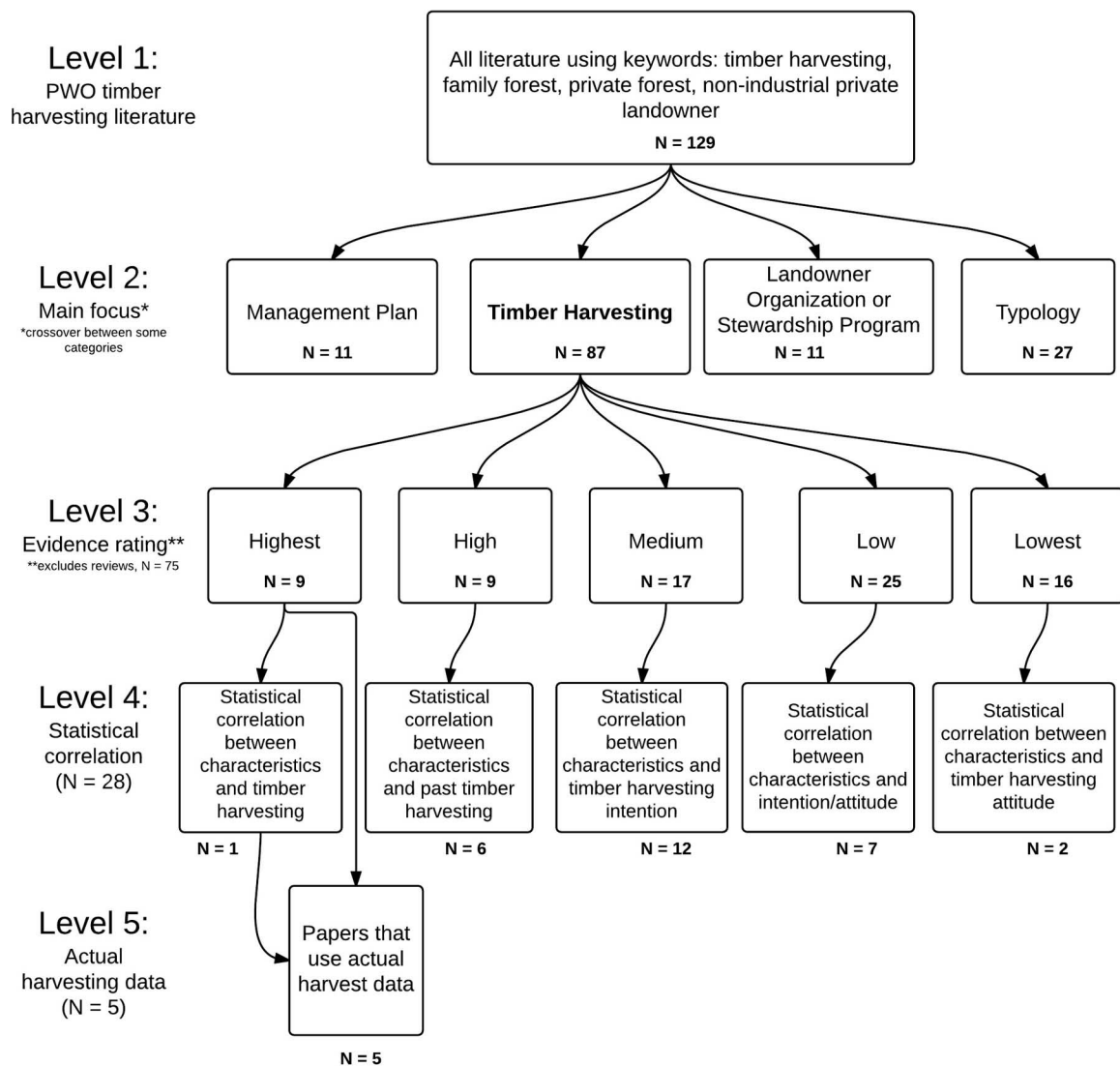
Very little distinction was made between small and large PWOs, except to note the long-standing conclusion that timber harvesting is positively related to the size of the forested parcel (Cleaves and Bennett 1995, Conway et al. 2003). Only one study found no significant relationship between the size of the parcel and harvesting (Bliss et al. 1997), but this study measured clearcutting as the only type of timber harvesting. Of the 84 articles that focus on timber harvesting behavior, about one-third (Figure 1, level 4 “Statistical correlation”) used a statistical technique (e.g., logistic regression, tobit models, and multivariate regression) that predicted timber harvesting intent or behavior using multiple independent variables. Logistic regression was often the analysis tool used on empirical survey-based data of PWO demographics and attitudes/intentions toward timber harvesting. The outcome was a binary decision to harvest timber.

### Evolution of Research Methods

In the first half of the sample (1970–1992), the largest proportion of studies were

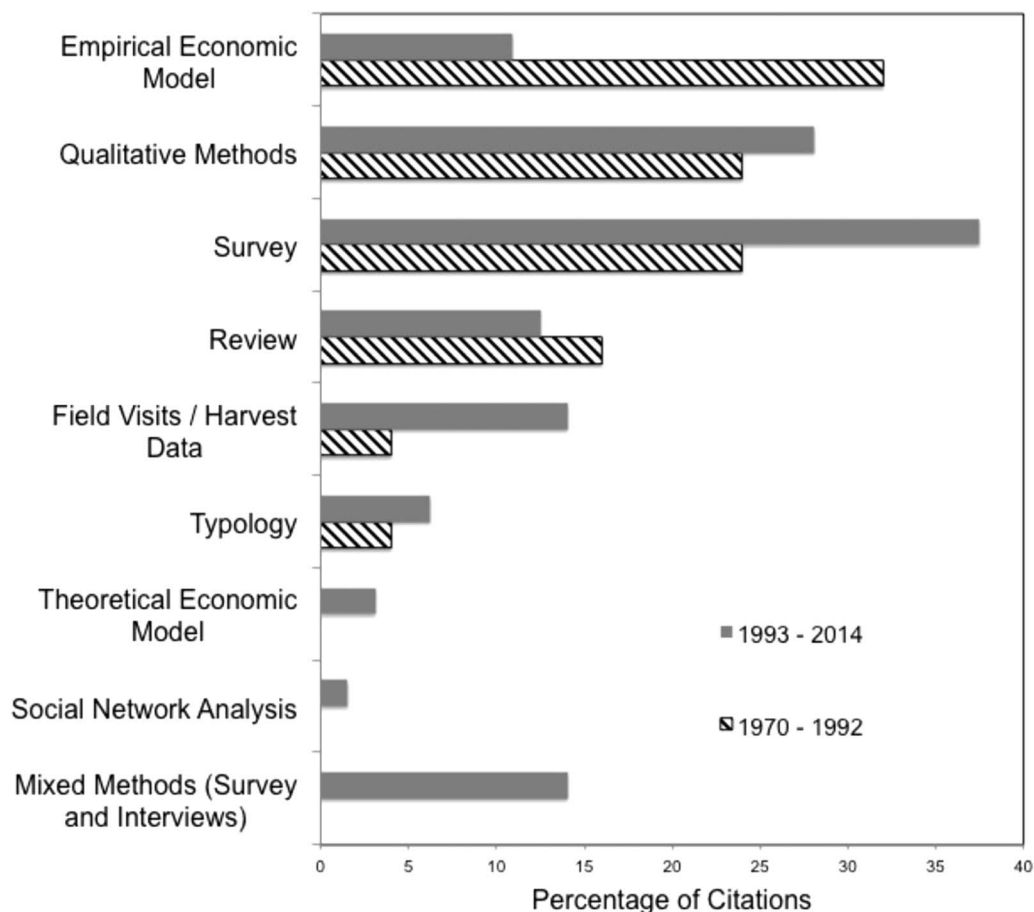
**Table 2. Criteria for categorizing how past research defined and analyzed harvesting behavior and criteria for assigning a quality of evidence rating.**

Definition	Criteria for harvesting behavior analysis	Criteria for link between attitudes, intentions, and behaviors	Quality of evidence
Attitude	Attitudes measured via survey or interview tools	Survey or interview data on attitudes toward and intention to harvest timber	Lowest
Behavioral intention	Intention to harvest measured via survey or interview tools	Longitudinal design, measuring the same population, but different individuals over time <i>or</i> survey/interview data on past harvesting behavior	Low
Potential harvest	Attitudes and stated intentions measured in a survey tool and used in an empirical model to predict harvesting behavior	Longitudinal design, remeasuring the same landowners over time on intention <i>or</i> attitude <i>or</i> an empirical model to predict behavior	Medium
Past harvest	Past harvesting activities measured via survey or interview tools	Survey or interview data on stated intention combined with analysis of harvest data <i>or</i> actual (not self-reported) harvest data combined with ownership characteristics to predict harvesting	High
Actual harvest	Harvest data, field visit	Survey or interview data on stated intention combined with a follow-up field visit to the landowner's woodland	Highest



**Figure 1. The hierarchy of article selection, inclusion, rating, and statistical correlation. Level 1 includes all articles found using the search terms “timber harvest/ing,” and all versions of private woodland owner (e.g., nonindustrial private forestland, family forest owner, and PWO). Level 2 groups the articles by their main focus. There is crossover between focus areas as an article, for example, might contain both a landowner typology and results on management plan efficacy. Level 3 groups the level 2 articles by evidence rating, excluding review articles. Level 4 identifies articles that tested statistical relationships between landowner characteristics and timber harvesting. Level 5 contains articles that used actual harvesting data, one with statistical correlation between variables and four that do not use statistical correlation techniques.**





**Figure 2.** Percentage of citations by method and study design for timber harvesting behavior literature (level 2,  $n = 87$ ) from 1970 to 1993 ( $n = 25$ ) and 1993 to 2014 ( $n = 62$ ).

**Table 3.** Typology cluster titles, grouped into six categories.

Category	Cluster titles	Citations
Production	Timber Agriculturalist, Forest Utilitarian, Investor, Timber Manager, Timber Producer, Classic Owner, Economically Interested, Self-interested, Farmer Forest Owner, Income from Forestry, Economist	22
Protection	Timber Conservationist, Resource Conservationist, Self-employed, Resident Conservationist, John Muir, Nontimber, Naturalists, Preservationist	15
Consumption/Amenity Recreationists	Forest Environmentalist, Poor Rural Residents, Amenities, Small Towners, Henry David Thoreau, Consumptive, Retreat Range Pragmatist, Forest Recreationist, Affluent Weekenders, Utilities, Hobby Owner, Conceptually Interested Owner, Urban Forest Owner, Free Time and Hobbies, Traditionalist, Woodland Retreat, Nontimber, Private Consumer, Enthusiasts	12 21
Passive	Passive Owner, Indifferent Farmer, Disinterested Owner, Jane Doe, Ready to Sell, Individualists	13
Multiobjective	Multiobjective Owner, Multifunctional, Part-time/Previous Farmers, Working the Land	15

Categories are from Boon et al. (2004) and Urquhart and Courtney (2011);  $n = 25$ . Two articles were excluded for relevance only to cross-boundary cooperation and not land management objectives or timber harvesting.

empirical economic models. By the second half (1993–2014), there was an increase in qualitative research and surveys on self-reported attitudes and intentions (Figure 2). As a general method, surveys were used during both time periods, but the constructs measured by these surveys changed in the second sampling period. Before 1993, there was no evidence of social network methods or mixed-method studies that used qualita-

tive, quantitative, or field visit/harvest data methods (Figure 2).

The first PWO typology appeared in 1981 as a means to categorize landowners for more targeted outreach and assistance (Kurtz and Lewis 1981). Subsequent studies also attempted to address the timber harvesting behavior of PWOs by grouping or clustering these owners by particular factors. The most common variable used to group

owners is their ownership objective, typically measured by a self-reported survey. On average, these typologies include 3.8 groups and many of the typologies have significant similarities in their categorization, despite being conducted in various geographic locations, using different techniques, and using different input variables to form the categories (Table 3). Boon et al. (2004) and Urquhart and Courtney (2011) used hierarchic

and nonhierarchical factor analysis and discriminant analysis to validate the use of independent variables from factor analysis to predict category membership, providing strong evidence for clustering based on PWO management objectives. Using their broad categories as a guide, 25 typologies were assembled into the 6 common categories described by Boon et al. (2004) and Urquhart and Courtney (2011), excluding 2 articles that reviewed a selection of PWO typologies. The *production* category was found in 88% of the typology articles (Table 3). This category includes landowners who actively manage their woodland or have economic values and attitudes toward woodland ownership. The *protection* category was present in 60% of studies including landowners who own land for conservation reasons, either to protect it from development or enjoy nontimber amenities (Table 3). The *consumption/amenity* category was found in 48% of studies. This was typically the smallest category, including landowners who enjoyed nontimber amenities above all else. The word consumption was used by Urquhart and Courtney to denote landowners who “consume” the values of their land (e.g., privacy and nontimber products) as opposed to “produce” timber. The *recreationist* category was found in 84% of studies. This category included woodland owners who valued their land most for recreational, hobby, or retreat purposes. The *passive* category was present in 52% of studies. These woodland owners are mostly indifferent to their woodland, are more agriculturally inclined, or are ready to sell the property. Finally, the *multiobjective* category was found in 60% of studies with at least one third of landowners belonging to that category. Typologies and categorization techniques are a powerful way to understand the objectives and motivations of landowners and tailor outreach accordingly. Timber harvesting objectives were a significant factor in most of the typology studies, typically splitting landowners into a production or multiobjective category.

These methodological advances were in parallel with a distinct shift toward measurement of landowner intention to harvest timber by self-reported surveys. Young and Reichenbach (1987) established the social psychological link between attitudes and behaviors found in the theory of reasoned action (later the theory of planned behavior [TPB]) within the timber harvesting literature. This study was the first published arti-

cle to frame PWO timber harvesting behavior using this theory, and subsequent research fully adopted this theoretical model and associated quantitative survey-based study design (Figure 2). There are other alternative social psychological models available (e.g., the values-beliefs-norms theory or goal framing theory), but none were used in the timber harvesting literature (Stern 2000, Lindenberg and Steg 2007). Of the 66 articles examined after 1987, only 15% explicitly mentioned TPB as the theoretical framework, yet many other articles measured components of the TPB, such as knowledge, attitudes, behavioral intentions, and norms to better understand behavior without specifically mentioning the theory.

### Link between Stated Attitudes and Observed Behaviors

The PWO timber harvesting literature in the 1970s and 1980s typically made a distinction between harvesting and “intent to harvest” (e.g., Larsen and Gansner 1973). However, after the TPB (Ajzen 1985) was firmly established in the literature, a social psychological link was established between attitudes and behaviors that allowed authors to extrapolate intent to harvest as a proxy for harvesting. Authors began labeling their studies as “behavioral” in nature, although their methods measured stated attitudes through quantitative surveys or intent to perform a behavior through qualitative interviews (e.g., Hyberg and Holthausen 1989).

Despite the popularity of the TPB, there have been several critiques of its use for understanding the behavior of PWOs. Egan and Jones (1995) point out inconsistencies between a survey and resurvey of the harvesting intentions and behaviors of PWOs. In another study, the link between a “mental variable” and “observed silvicultural behavior” was thought to be tenuous and requiring more examination (Karppinen 1998). The PWO harvesting decision was not found to manifest in actual silvicultural realities or translate into a harvesting behavior.

Of the 87 articles that addressed timber harvesting behavior directly (Figure 1, level 2 “Main focus”), only 5 used actual harvesting data to “ground-truth” stated or intended attitudes toward harvesting timber (level 5 “Actual harvesting data”; Karppinen 1998, Munsell et al. 2009, Dhuháin et al. 2010, Knoop and Rickenbach 2011, Maker et al. 2014). However, four additional articles received the highest evidence rating for

their work addressing the link between intention and behavior (Egan and Jones 1993, 1995, Rosen 1995, Turner et al. 1977). In fact, using the evidence rating system described in Table 2, the majority of level 2 timber harvesting papers had low or the lowest evidence of measuring actual timber harvesting behavior (47%, combined). These studies also did not measure the link between attitude, intention, and behavior. Only 10% of the level 2 studies examined either explicitly measured behavior or assessed the correlation between attitude, intention, and behavior (Figure 1).

### Variables That Predict Timber Harvesting

Of the level 2 timber harvesting papers, 28 used some type of statistical analysis (e.g., linear regression or logistic regression) to predict the intention or actual harvesting of timber (Figure 1, level 4 “Statistical correlation”). However, only one of the level four article received the “highest” evidence rating for following up with a silvicultural audit (Dhuháin et al. 2010). Therefore, the significant predictors of timber harvesting, determined to be significant by the authors of each individual article, are actually significant predictors of the intention or attitudes toward timber harvesting.

Notably, 16 studies found that parcel size/total forested acres significantly predicted actual and intentional timber harvesting. Harvesting price per acre was also significantly and positively related to the intention to harvest timber. Absenteeism or distance from the owner’s residence to the woodland was significantly and negatively related to timber harvesting (Rickenbach and Kittredge 2009) (Table 4). Both income and farmer occupation status positively and negatively influenced timber harvesting. This finding indicates that increased income does not necessarily imply increased timber harvesting and those landowners who are farmers may or may not be interested in harvesting timber from their land. When a variable was found to relate both positively and negatively to the decision to harvest timber, most authors concluded there was an unmeasured mitigating factor that might influence some PWOs, but not others, to harvest given a particular characteristic.

When empirically based PWO characteristics were used to predict timber harvesting behavior, evidence ratings suggest the most reliable predictors, both positively and negatively, were age, parcel size, extension

**Table 4. Significant predictors in the decision to harvest timber by PWOs from literature that statistically examined intention to harvest or actual harvesting behavior (level 4,  $n = 28$ ).**

Variable	No. of citations	Influence	Evidence ratings (no. of citations and direction of influence)
Parcel size/forested acres	16	+	High (6), medium (5), low (5)
Income	8	+/-	High (1 positive; 2 negative), medium (2 negative), low (2 positive, 1 negative)
Harvest price per acre	7	+	High (7)
Absentee owner/distance from residence	6	-	High (1), medium (3), low (2)
Farmer	6	+/-	High (1 negative), medium (2 positive, 2 negative), low (1 negative)
Years of formal education	5	+	High (3), medium (2)
Age	5	-	High (2), medium (2), low (1)
Contact with a forester/technical assistance	4	+	High (1), medium (2), low (1)
Years the land has been in the family/inheritor/years owned	4	+	High (1), medium (2), low (1)
White collar occupation	3	+	High (3)
Management plan	3	+	High (1), medium (1), low (1)
Nontimber ownership objectives/amenity objectives	3	-	Medium (1), low (2)
Timber production ownership objective	3	+	Highest (1), medium (1), low (1)
Extension activity attendance/cooperation with Forest Service	2	+	Highest (1), high (1)
Timber stock	2	+	High (2)
Site value tax/site quality	2	+	High (1), medium (1)
Proportion of household income from forest	2	+	Medium (2)
Membership or contact with a wood owners association	2	+	Medium (1), low (1)
Debt-to-income ratio	2	+	High (1), medium (1)

Variables are in order of most to least citations.

activity participation, a timber production ownership objective, a management plan, white collar occupation, years of formal education, debt-to-income ratio, and site value tax. Characteristics like membership in a woodland organization, farmer occupation, and nontimber amenity objectives have not been thoroughly tested in the literature using methods that rigorously measure harvesting behavior (Table 4).

## Discussion

The definitions and methods in the PWO timber harvesting literature have changed over time in response to new techniques and evolving definitions of what it means to be a PWO. Since the 1970s, researchers have separated these nonindustrial owners as a unique category due largely to their ownership objectives and their desire to own woodland for more reasons than just timber harvesting, but terminology and inclusion characteristics have been inconsistent. To study this unique ownership category, PWO timber harvesting scholars have primarily used economic modeling and mail survey techniques to understand the intentions and behaviors of landowners. Many of the economic studies of PWO timber harvesting behavior, including those that distinguish utility and profit maximizers, make assumptions about the financial needs of landowners. Reported income and debt are typically used in modeling efforts (Amacher et al. 2003). Although these empirical economic models and survey-based methods

provide insight to the relationships between demographic characteristics and the intention to harvest, more high-evidence studies are needed to understand the link between these characteristics and actual harvesting. Furthermore, a better understanding of the factors that drive timber harvesting behavior will help managers and policymakers move beyond traditional demographics to an understanding of how to tailor outreach programs to PWOs.

As research methods have evolved, the typology approach emerged as a potentially useful tool for local or state outreach efforts. PWOs can hold multiple motivations or goals for ownership, and they can often overlap and thus not be mutually exclusive. However, when reported using typology categories, they tend to imply different types of landowners that express predominant preferences. These preferences help outreach programs better meet the preferences of PWOs. However, of the more than 20 studies using some type of category analysis to describe the timber harvesting behavior of PWOs, none have included actual observed or documented harvesting behaviors but rather relied on ownership objectives, intentions, or attitude. Although typologies are helpful in understanding how PWOs might share similar goals and objectives, it is not clear whether there is strong behavioral insight in the existing PWO typology literature. Future research could incorporate actual harvesting data into the construction of typologies. Furthermore,

many studies fail to communicate how a manager or outreach professional would practically assign PWOs into these categories. The utility of typologies could be increased by communicating how they can be put to use in a policy or extension context.

The use of mixed methods in the PWO timber harvesting literature increased over our sampling period. Eight studies (level 2 "Main focus," 9%) used more than one method. Mixed-method options include the use of qualitative semistructured interviews with a follow-up survey, the Delphi approach, or a mix of surveys and ground-truthing to uncover the difference between stated and actual behaviors (Egan et al. 1995), although we did not include empirical economic models that used a quantitative survey for input data as a mixed-methods study. Despite this increase, we recommend more mixed-method approaches to understand PWO timber harvesting behavior, particularly measuring actual harvesting behavior instead of the intention or stated decision to harvest timber. A mixed-methods approach allows the researcher to combine quantitative assessments of large landowner samples with in-depth exploration of the cognitive factors that lead to an actual harvest.

One significant hurdle to understanding PWO timber harvesting behavior is the lack of longitudinal or case cohort studies of woodland owners (Belin et al. 2005). Ide-



ally, these studies follow the same cohort of subjects over time to determine trends. This type of study could be particularly useful for timber harvesting behavior for the following reasons: harvesting decisions occur over relatively long time spans; determining whether intended behaviors translate to actual behaviors is more robust if the same woodland owner is resurveyed rather than assuming correlation between two randomly selected survey populations; and woodland owner financial and personal circumstances are incredibly dynamic and prone to abrupt changes. Despite the potential benefits of a longitudinal study design, only two PWO research studies (Turner et al. 1977, Rosen 1995) used this technique. Longitudinal studies are time and resource intensive, and study subjects can choose not to participate, to move, to sell their land, or to pass the land to an heir by the time of a second or third remeasurement. Researcher turnover at universities and organizations can also affect the continuation of long-term studies. Furthermore, participation in a longitudinal study may influence PWO behavior, potentially prompting the PWO to cut more (or less), hire a forester, or try to match his or her previous responses. There are, however, increasing attempts to at least repeatedly measure the same population to look for trends over time, particularly using the National Woodland Owner Survey in the United States (Pan et al. 2007).

Currently, the TPB (Ajzen 1991) is the most prominent research theory in natural resource management for understanding human behavior. The TPB has worked well in predicting behaviors such as voting, blood donation, choice of religion, and contraceptive use (Kraus 1995). More specifically, the attitude-behavior correlation is much stronger when attitudes and intentions are easy to recall and relatively stable over time (Glasman and Albarracín 2006). However, critics claim that the model only works on behaviors that require no skill and immediately follow the formation of intention (i.e., short-term planning) because the model implies a very simplistic causal structure (Liska 1984). TPB has been applied to human dimensions of natural resources by predicting intentions or understanding preferences and willingness to pay or act. For example, TPB has been used to understand hunting intentions and behaviors (Hrubes et al. 2001). In addition to application of TPB to timber harvesting behavior, it has also been used in contingent value forest economics research



**Figure 3. A field visit to the Wells Demonstration Forest, owned by a private woodland owner near Orono, Maine, in October 2013. This woodland owner is actively managing this forest through repeated thinning and the occasional biomass harvest. Photo by Pam Wells.**

to predict willingness to pay for forest regeneration abatement (Rekola 2001). Although TPB is a reasonable choice for understanding the timber harvesting intention of landowners, the link between intention and behavior is poorly understood for PWOs.

To address the link between PWOs' stated attitudes and actual timber harvesting behaviors, we assigned the highest evidence rating to articles that measured actual harvesting behavior rather than self-reported past harvests or intention to harvest in the future. Many studies that purportedly study behavior (using the term "behavior" in the title, results, or discussion) are actually studies of attitudes and intentions toward timber harvesting. The studies that measure actual harvesting behavior suggest a number of conflicting results. Woodland owners who do not intend to cut timber often do (Knoot and Rickenbach 2011). Contrarily, woodland owners who intend to harvest often do not harvest (Turner et al. 1977). This phenomenon could be due to the large amount of time that occurs between setting the behavioral intention and actually deciding to harvest timber. Surveys often ask respondents about their intention to harvest in the next 5 or 10 years, but it could be longer than that before a landowner can harvest. This discrepancy could be a result of unpredictable exogenous factors such as natural disturbances, inheritance, divorce, retire-

ment, or medical bills. Furthermore, woodland owners who had previously articulated a decision to harvest in an interview or survey on being resurveyed indicated that they had not actually harvested (Egan and Jones 1993). Finally, the link between objectives and actual behaviors has not been specifically measured in the typology literature (Dhubháin et al. 2007). We strongly recommend deeper investigation of the link between stated intentions and actual harvesting behaviors and, when possible, measurement of the actual harvesting behavior in studies of PWOs. Furthermore, forest managers and policymakers should interpret the literature cautiously when predicting available timber supply and creating assistance programs for PWOs.

Despite the gap in knowledge of actual harvesting behavior, empirically based PWO characteristics were statistically tested by the authors of each individual article to predict the timber harvesting intention. The most reliable predictors of a timber harvesting intention or attitude (Table 4) were justified based on observations such as the likelihood that income from timber will be helpful for alleviating debt, the likelihood that education leads to a better awareness of options and resources, and the likelihood that having a management plan suggests an active landowner who may be interested in managing timber, encouraged to harvest by foresters, or required to harvest as a



part of a current use program. The most frequently tested characteristic was parcel size. This is not surprising considering the economies of scale associated with larger properties (i.e., the property is more attractive to a logger). Only one of the examined studies that found statistical relationships between variables and timber harvesting was given the highest evidence rating. However, the majority were medium and high, providing strong support for the *intention* to harvest. Variables such as parcel size, age, extension participation, and timber harvesting ownership objectives can be used by managers and policymakers to guide outreach and harvesting policy because they have been well studied and tested rigorously. However, variables with a low evidence rating and few citations (e.g., contact with a forester, years owned, and membership in a woodland organization) should not be used in policy formation and outreach design until further tested.

Given the inconsistency in the literature, it is important that researchers use consistent and explicit definitions of timber harvesting, confirm that landowners understand timber harvesting (as opposed to personal firewood use), and consider using a consistent time scale in survey and interview questions. The recommended approach is actually measuring timber harvesting behavior either through field visits (e.g., Figure 3) or spatially explicit harvesting data. Finally, using statistical methods to test the relationships between PWOs and timber harvesting behavior is highly recommended, but ideally using actual harvesting as the dependent variable. Until there are high evidence studies of PWO timber harvesting behavior, it is difficult to predict how this ownership group will manage their woodland and how their actions may affect the health of the ecosystem on a landscape scale.

## Conclusions

The forest products industry relies on a timber supply that is increasingly dependent on the decisions made by PWOs, particularly if large companies divest themselves of land or public forest managers reduce cutting levels. However, it is increasingly clear that PWOs do not own their forest primarily for timber production. With such diverse ownership objectives, understanding timber harvesting behavior will provide industry with a sense of expected timber supply. However, relying on studies that measure the intention to harvest timber is unlikely to provide accurate results. Rather, supply esti-

mates should rely only on those studies that provide information on actual harvesting behavior. Although measures of actual harvesting behavior are difficult to obtain, they are critical to our understanding of the harvesting decision made by PWOs. The decision to harvest timber by PWOs is inherently complex and uncertainty will remain; however, measurement of actual behavior is likely to reduce this uncertainty beyond that of studies measuring behavioral intention.

When actual harvesting behavior is not measurable, it may still be helpful to understand which landowner characteristics may predispose them to intend to harvest timber. Typologies help sort landowners into groups based, in part, on timber harvesting objectives. Moreover, individual behavior will probably have a high degree of variability, but aggregating PWO behavior, perhaps at the county level, may be a research tool to aid outreach and management efforts. Statistical relationships involving demographics and land characteristics suggest that PWOs are more likely to intend to harvest timber if they receive good harvest prices, have a management plan, are well educated, own good timber stock, and participate in extension programming. However, this intention may not lead to an actual decision to harvest. There is an opportunity to improve PWO timber harvesting behavior research by measuring and understanding actual harvesting decisions and advancing in the field of decision science and environmental behavior.

## Endnote

1. The term private woodland owner (PWO) includes all classifications of private forest owner, but excludes ownerships by commercial forestry companies, timber investment management organizations (TIMOs), and real estate investment trusts (REITs) (Smith et al. 2009).

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