One Size Does Not Fit All: Relationships Between Size of Family Forest Holdings and Owner Attitudes and Behaviors

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Abstract

An estimated 10 million families, individuals, trusts, and estates own 39% of the forestland in the United States, excluding interior Alaska. Using segmented regression, the relationships between size of forest holdings and the attitudes and behaviors of these family forest ownerships were tested using data from the 2018 iteration of the USDA Forest Service's National Woodland Owner Survey. All of the 16 variables tested have significant relationships with size of forest holdings and 13 have one or more breakpoints, ranging from 40 to 5,854 ac, where the relationships between the variables change. Timber as a reason for owning, timber harvesting activities, management plan, advice received, land certified, tax program participation, cost-share, recreation, land tenure, recreation, taxes and heirs as concerns, land transfer, and income from forestland have positive relationships to size of forest holdings; resident ownership has a negative relationship; and wildlife as a reason for owning and owner age have mixed relationships.

Keywords

Family Forest Owners; National Woodland Owner Survey (NWOS); United States (US, USA); USDA Forest Service; Forest Inventory and Analysis; segmented regression

Introduction

One out of every three acres of forestland in the United States is owned by families, individuals, trusts, and estates, collectively referred to as family forest ownerships (Butler et al. 2020). They own more forestland than the Federal government, corporate ownerships, including timber investment management organizations (TIMOs) and real estate investment trusts (REITs), or any other ownership group in the U.S. (Figure 1). The forest ownership patterns vary across the country, with private ownerships dominating in the east and public ownerships dominating in the west, but the patterns are often complex and there are large acreages of family forests across most of the U.S. (Figure 2).

An estimated 10 million family forest ownerships [standard error (SE) = 0.2] collectively control 272 million acres of forestland[1] (SE = 1.7) across the U.S., excluding interior Alaska (Butler et al. 2020). The number of family forest ownerships and the associated acreage has decreased in recent years. Between 2013 (Butler et al. 2016b) and 2018 (Butler et al. 2020) the estimated number of ownerships decreased by 10% and the associated acreage decreased by 5%. The overall area of forestland across all ownerships also decreased between 2012 and 2017 (Oswalt et al. 2019), but not as precipitously. The causes of the losses of family forests need to be investigated, but there are indications that some of the loss is due to sale or conversion to corporations, including limited liability companies, and deforestation (Caputo et al. 2020).

Family forest ownerships differ in terms of attitudes, behaviors, demographics, and basic ownership characteristics, but there are broad patterns that can help us understand this important group of ownerships. One of the most important attributes is size of forest holdings. It is arguable that this is the single most powerful predictor because it directly influences many activities and is correlated with numerous other characteristics. Size of holdings has been shown to be correlated with timber harvesting behavior (Silver et al. 2015; Beach et al. 2005), reforestation and timber stand improvements (Beach et al. 2005), management of invasive plants (Clarke et al. 2019), general forest management activities (Floress et al. 2019), some ownership objectives (Butler et al. 2016a), legacy and land tenure (Markowski-Lindsay et al. 2017, 2018), and enrollment in preferential property tax (Meier et al. 2019), technical assistance (Kaetzel et al. 2009), and carbon sequestration (Dickinson et al. 2012) programs.

In the U.S., the size of family forest holdings ranges from a single acre to many thousands of acres. In terms of ownerships, 89% (SE = 4.5) of them have holdings of less than 50 acres of forestland (Figure 3). But in terms of acreage, 72% (SE = 2.6) of the acres are in holdings of 50 or more acres of forestland. The overall distribution of size of holdings has remained relatively constant over the past decade, but there have been decreases in the percentage of acreage in holding of less than 500 ac and increases in the percentage of acreage in holdings of 500+ ac.

[1] Based on the USDA Forest Service, Forest Inventory and Analysis program's national definition of forestland: "Land that has at least 10 percent crown cover by live tally trees of any size or has had at least 10 percent canopy cover of live tally species in the past, based on the presence of stumps, snags, or other evidence. To qualify, the area must be at least 1.0 acre in size and 120.0 feet wide." (USDA Forest Service 2016).

These comparisons only include the states for which data are available from the 2006 (Butler 2008), 2013 (Butler et al. 2016b), and 2018 (Butler et al. 2020) iterations of the NWOS (i.e., excludes Alaska, Hawaii, Nevada, West Oklahoma, West Texas, and Wyoming). The sampling procedures have not substantively changed among these iterations. The methods for estimating sampling errors for the 2018 NWOS have been updated (Butler and Caputo 2020), but the changes do not impact estimates of totals or percentages.

The average size of family forest holdings differs across the U.S. (Figure 4). In Connecticut, Massachusetts, New Jersey, Hawaii, and New Hampshire, the average (mean) size is less than 10 ac. In Montana, Wyoming, Georgia, Mississippi, New Mexico, Texas, Louisiana, Oklahoma, and Alabama, the average size is over 50 ac. These averages include all family forest ownerships with 1+ ac of forestland, and the values are commensurately higher if a different minimum threshold is used, such as 10+ ac (Figure 4B).

This article highlights results from the 2018 USDA Forest Service, National Woodland Owner Survey (NWOS) with an emphasis on exploring relationships between size of family forest holdings and landowner characteristics, including ownership objectives, timber harvesting, management practices, program participation, and demographics. These variables were selected to represent a broad range of ownership characteristics with an emphasis on variables that have been the subject of previous research. The importance of size of forest holdings is something that most practicing foresters know; the information presented here will help elucidate these relationships and provide additional insights. Summaries of all data collected as part of the 2018 NWOS are available in Butler et al. (2020) and through the NWOS website (www.fia.fs.fed.us/nwos). It is hoped that this information will help the design and implementation of effective policies, programs, and services aimed at family forest ownerships.

Methods

National Woodland Owner Survey

The NWOS is a component of the USDA Forest Service, Forest Inventory and Analysis (FIA) program and is tasked with quantifying private landowner attributes ranging from number of landowners and size of holdings to reasons for owning and demographics. The 2018 NWOS was implemented by the Family Forest Research Center (www.familyforestresearchcenter.org) – a joint venture between the USDA Forest Service, Northern Research Station and the University of Massachusetts Amherst (UMass), Department of Environmental Conservation. All methods were approved through the processes established by the U.S. Office of Management Budget (OMB) and the UMass Internal Review Board. Summaries of the implementation and estimation procedures are provided below with more detailed information available in Butler et al. (2020) and Butler and Caputo (2020).

The NWOS sample design is a derivative of the FIA sample design (Bechtold and Patterson 2005) and can be summarized as an area-based sample design with inclusion probabilities proportional to size of holdings. The initial sample was drawn from the FIA plots and was augmented to reach the target of 250 respondents per state. The sampling protocol involved: dividing a state into hexagons; randomly locating a sample point in each hexagon; determining the land use at each sample point; and identifying the ownership from publicly available property ownership records. To determine the land use, the FIA inventory plots that were potentially forested were, where permission was granted, visited and the land use was verified on the ground using FIA field protocols (USDA Forest Service 2018). For the NWOS augmentation points, high-resolution aerial photography was used to classify the land use. The family forest ownerships identified through this process formed the sample for the results presented in this article.

The NWOS data reported here were assigned a nominal date of 2018, but were collected over two years, 2017 and 2018, and covered all of the U.S. except interior Alaska due to sampling frame limitations. Implementation methods followed the Tailored Designed Method (Dillman, Smyth, and Christian 2014). This involved up to four waves of contacts for each potential respondent: a pre-notice postcard; a first questionnaire packet mailed approximately one week later; a reminder/thank you postcard mailed approximately five days later; and, approximately two weeks later, a second questionnaire packet was mailed to those who had not responded. The questionnaire packets included a cover letter, a questionnaire, and a postage-paid reply envelope. Prior to implementation, cognitive interviews were conducted to test questionnaire wording and pre-testing was done to test implementation methods. A copy of the final questionnaire is available at: www.fia.fs.fed.us/nwos/quest.

The survey had an overall cooperation rate of 40%, yielding 9,524 valid responses from family forest ownerships that were used in the analyses presented here. To test for nonresponse bias, 1,048 randomly selected ownerships that did not respond to the mailings were contacted over the phone and asked a subset of the questionnaire questions. Of the variables tested, 61% did not significantly differ ($a = 0.05$) between the mail and telephone respondents (Butler et al. 2020). Of the remaining variables, none differed with a large effect size (*Cohen's d* ≥ 0.8). Overall, there appears to be little nonresponse bias, but those responding via phone were slightly less active on their land and less sure of future plans, and the results may slightly over-represent active owners and those with more certainty about the future of their land. Item nonresponse was addressed using multiple imputation (Buuren 2018).

Population-level estimates were calculated using weights incorporating the survey design, response rates adjustments, unit nonresponse adjustments, and multiple imputations (Butler and Caputo 2020). The base weights were the inverse of the inclusion probabilities, which were a function of the acres of forestland owned, the area of forestland in the stratum, and sampling intensity. The stratum forest areas were set to equal corresponding FIA plot-based estimates. The weights account for the area-based design characteristic of the sample design, which results in owners with larger holdings being more likely to be included in the sample. A propensity scoring method (Brick 2013) was used to adjust weights for potential unit nonresponse biases. Variances associated with point estimates were estimated using a bootstrapping approach (Efron and Tibshirani 1986).

Segmented Regression

Segmented regression (Muggeo 2003), also known as breakpoint analysis or broken-line regression, was used to test for non-linear relationships between size of holdings and the variables of interest. As opposed to traditional regression techniques that assume a constant relationship among variables across values (i.e., the same intercepts, coefficients, and error terms), segmented regression allows for differentiated relationships for observations in different ranges, e.g., different relationships for ownerships with smaller versus larger forest holdings.

The primary variable of interest for this article is size of forest holdings. The distribution of size of forest holdings in the population and in the sample is highly skewed. A natural log transformation of this variable produces a distribution that is much more normally distributed (Figure 5), an assumption for numeric variables in many statistical models, and it is this log-transformed variable that is used as a predictor in the models presented below. In terms of the NWOS sample (n = 9,518), 9% of the respondents have forest holdings of 1-9 ac, 39% have holdings of 10-99 ac, 39% have holdings of 100-999 ac, and 13% have holdings of 1,000 ac or more.

The variables analyzed in conjunction with size of holdings are described in Table 1. These variables were selected to represent different dimensions of ownership attributes that have been discussed in previous research, were available from the NWOS dataset, and were limited in number to be parsimonious and not generate an overwhelming number of models. The ownership objectives, concerns, and likelihood of transferring variables were asked on the NWOS using 5-point Likert scales and were recoded to binary variables coded as 1 if important or very important, concern or great concern, likely or very likely, depending on the question, and 0 otherwise.

A total of 16 segmented regression models were analyzed with size of holdings as the sole independent (or righthand side) variable. Logistic regression models were used for the binary variables and ordinary least squares regression was used for the other variables. Breakpoints were identified using a sequential approach. A first model, with no breakpoints, was created, the existence of a breakpoint was assessed using a Score statistic, and if a significant (*p-value* < 0.05) breakpoint was found, a segmented regression analysis was used to identify the breakpoint value (Muggeo 2003). This process was repeated until no additional, significant breakpoints were found. Initial starting values used were ln(10) and ln(100). Sensitivity to starting values was tested by increasing and decreasing start values for three models, having their primary residence associated with their forestland, timber harvesting for sale in the previous five years, and recreation on the forestland in the previous five years, with no significant differences found among the resulting breakpoints. Modeling was implemented using the glm (R Core Team 2019) and segmented (Muggeo 2008) functions in the R statistical environment.

In addition to the regression models, population-level summary statistics for each of the variables of interest were generated for four size classes: 1-9, 10-99, 100-999, and 1,000+ ac. The thresholds for these size classes are based on a log scale and are consistent with the threshold minima used in Butler et al. (2020).

Results

An estimated 62% of the family forest ownerships in the U.S. have forest holdings that are 1-9 ac in size, but 58% of the family forest acres are in holdings of 100 ac or more. The mean forest holding size is 28 ac per ownership (SE = 0.7; median = 5 ac). Looking just at family forest ownerships with 10+ ac of forestland, the mean holding size is 69 ac per ownership (SE = 0.9; median = 27 ac).

Looking across all family forest ownerships (Table 2, “Total (1+)” column), it is apparent that wildlife is important for most owners, many own forests as part of their primary residence, owners have multiple concerns related to their land, most have owned their land for a long time, and many are relatively advanced in age. It is also evident that most owners have not recently conducted a commercial timber harvest, do not have a management plan, have not recently received advice about their forestland, have not participated in traditional forestry assistance programs, and do not receive appreciable amounts of their annual income from their forestland. These statements are accurate in terms of both ownerships and acres, but the statistics can be quite different in terms of the two units. For example, 8% of the family forest ownerships have commercially harvested trees in the previous five years, but collectively they control 28% of the family forestland. These differences are smaller when examining 10+ ac ownerships and are negligible within the constrained size bins reported in Table 2.

All of the variables tested are significantly related to size of forest holdings (i.e., *p-values* < 0.05 for the size of forest holding variable in the initial regression models). The averages for these variables across four size classes (1-9, 10-99, 100-999, and 1,000+ ac) are shown in Table 2 and the regression relationships, including breakpoints, are summarized in Figure 6. Additional details on the breakpoints and regression models are included in the Supplemental Materials.

The descriptive statistics show strong relationships for most of the variables tested across the *a priori* size classes (Table 2). As opposed to the statistics for the 1+ and 10+ ac totals, the values and patterns in terms of acres and ownerships are very similar within each size class. The values for most variables increase as size class increases, and sometimes dramatically. Having timber production as an important or very important ownership objective, having harvested trees for sale in the previous five years, having a written forest management plan, and having received forest management advice in the previous five years have considerable increases across size classes. For example, only 4% of the ownerships with1-9 ac and 13% of the ownerships with 10-99 ac have harvested trees for sale in the previous five years, but the percentages increase to 32% and 45% for ownerships with 100-999 and 1,000+ ac, respectively.

Having wildlife as an important or very important reason for owning forestland, having taxes or heirs as concerns or great concerns, and recreating on their forestland are high across the range of size classes, but these too show higher values for larger classes. For example, the proportions of ownerships having wildlife as an important or very important reason for owning forestland goes from 70% for 1-9 ac ownerships to 76% for 10-99 ac ownerships to 80% for ownerships in the 100-999 and 1,000+ ac classes.

Having their land green certified, participating in tax programs, and cost-share enrollment are generally low across size classes, but the probabilities increase across size classes. For example, 3% of the ownerships in the 1-9 ac size class report participation in a preferential property tax program versus 16%, 26%, and 35% for ownerships in the 10-99, 100-999, and 1,000+ ac classes, respectively.

Having their primary residence associated with their forestland is the only variable that consistently decreases across size classes, but it is relatively common across all classes. The percentage of ownerships having their primary residence associated with their forestland goes from 77% for 1-9 ac ownerships to 43% for ownerships with 1,000+ ac.

The descriptive results and segmentation models are largely in agreement, as expected, but the regression models allow for much more nuanced examination of the relationships. All of the relationships between size of holdings and the variables of interest in the regression models are significant (i.e., correlated with size) and the confidence bands are relatively tight, but the intercepts, slopes, and numbers of breakpoints vary substantially across models (Figure 6). The dominant pattern is a sharper increase up to the breakpoint followed by a continued, but slower, increase, but this pattern varies by model. The x-axis across all of the charts in Figure 6 are on a log scale, as is acres in the models, due to the distribution of size of forest holdings (Figure 5); this means that a straight-line relationship is actually exponential in nature.

The number of breakpoints (i.e., points at which there are significant, structural changes in the relationships between the variables) varies from no breakpoints for having received forest management advice in the previous five years, land tenure, and being concerned or greatly concerned about being able to hold onto land for future generations to two breakpoints for owner age and percentage of income derived from their forestland; all other models have one breakpoint. But again, even in the absence of any breakpoints, there are still significant relationships between the variables of interest and size of holdings, it is just that the relationships do not significantly change over the range of size of holdings. The values of the breakpoints range from 40 ac for having a home associated with their forestland to 1,737 ac for participation in a cost-share program.

Having a home associated with their forestland is the only attribute that has a consistent, negative relationship with size of holdings (Figure 6A). The predicted probability goes from 0.8 at 1 ac to 0.6 at 40 ac. The probability continues to decrease with size after this 40-acre breakpoint, but at a slower rate (i.e., slope of -0.4 up to 40 ac and -0.2 after 40 ac).

Rating timber production as an important or very important reason for owning forestland has a low predicted probability for smaller parcels (Figure 6B). The probability rises quickly until the 278-acre breakpoint, after which the probability continues to increase, but at a slower rate. The predicted probability crosses the 0.5 threshold (i.e., 50/50 probability) around 1,000 ac.

The predicted probability for rating wildlife as an important or very important reason for owning forestland is high (i.e., over 0.6) across the range of size holdings. The predicted probability is 0.6 for 1 ac and rises to 0.8 at 67 ac. After that breakpoint, the predicted probability has a slight negative relationship to size of holdings.

The predicted probability of having harvested timber for sale in the previous five years begins low (0.02), but then rises quickly (Figure 6D). The increase in the predicted probability is precipitous up to the 442-ac breakpoint and then continues to rise, but at a more modest rate. Harvesting probability crosses the 0.5 threshold at around 2,000 ac.

The predicted probability of having a written forest management plan is relatively low across all holding sizes and does not cross the 0.5 threshold until almost 10,000 ac (Figure 6E). The predicted probability goes from 0.01 to 0.3 between 1 and 130 ac. The rate of increase continues after the 130-ac breakpoint, but more slowly.

The predicted probability of having received forest management advice in the previous five years has a linear relationship with size of forest holdings and no identified breakpoints (Figure 6F). The predicted probability ranges from 0.05 to 0.9 and crosses the 0.5 threshold at about 1,000 ac.

The predicted probability of having their forestland certified, participating in a tax program, or participating in a cost-share program is low across virtually all holding sizes (Figures 6G, 6H, and 6I). For all of these models, the probabilities increase until the breakpoints and then the increases damper for certification and tax programs and the relationship reverses (i.e., becomes negative) for cost-share. The breakpoints for these models range from 60 ac for tax programs to 529 ac for certification to 1,737 ac for cost-share. Tax programs is the only one of these models that approaches the 0.5 threshold and it does not do so until nearly 100,000 ac.

Land tenure has a linear relationship with size of forest holdings and no identified breakpoints (Figure 6J). The predicted tenures range from 21 to 31 years.

The predicted probability of recreating on their land in the previous five years is above 0.5 for all size holdings (Figure 6K). The predicted probability is 0.6 for 1 ac and rises rapidly to 0.9 at 142 ac. It then essentially levels off.

Citing high property taxes or keeping land intact for future generations as concerns or great concerns have high (i.e., above 0.5) predicted probabilities across all holding sizes (Figures 6L and 6M). The tax concern probability is about 0.8 between 1 and 85 ac and then begins to climb after this breakpoint to a top predicted probability of 0.9. The legacy concern probability ranges from 0.6 to 0.9 with no identified breakpoints.

Transferring some or all of their land in the next five years has a low predicted probability across all size holdings and does not cross the 0.5 threshold, although it does get close for the largest size holdings (Figure 6N). The predicted probability is 0.1 at 1 ac, it rises to 0.2 at 1,700 ac, and then increases more rapidly following this breakpoint to a maximum value of nearly 0.5.

Owner age has a nonlinear relationship with size of holding with predicted ages that range from 56 to 74 years (Figure 6O). The predicted age goes from 61 to 66 from 1 to 85 ac, then it remains relatively flat until it begins to decrease at the second breakpoint of 5,854 ac.

The predicted percentage of income from forestland is low across most size holdings (Figure 6P). The predicted percentage is less than 2% until 112 ac. After this breakpoint, the predicted percentage begins to increase. At 685 ac, the predicted value is 8%. After this second breakpoint, the predicted percentage increases faster and reaches a zenith of 42% at 100,000 ac.

Discussion

Summarizing the variables examined in this article, America's family forest owners tend to be more interested in amenity than financial objectives, they are not participating in traditional forestry programs, they have multiple concerns related to their land, and they tend to be older. But there are substantial differences depending on size of forest holdings.

Size of forest holdings is a powerful predictor of many family forest ownership attributes and is conceivably *the* most powerful predictor of family forest ownership attributes. The results presented here help validate this assumption, which is also well supported by previous studies (Silver et al. 2015; Beach et al. 2005; Floress et al. 2019). These relationships are important in terms of understanding family forest owners and designing and implementing efficacious programs, services, and policies.

For example, participation by family forest ownerships in carbon sequestration programs is an increasingly important topic (Khanal et al. 2016; Kelly, Gold, and Tommaso 2017) and size of holdings has an important impact on who is participating. At least how most of the programs are currently structured, there are substantial costs or other barriers for enrolling and monitoring associated with the programs that make it difficult for ownerships with holdings of less than a few thousand acres to participate, but there are efforts to develop alternative approaches, such as the Family Forest Carbon Program (American Forest Foundation 2020). Similarly, many forest certification programs have substantial barriers to entry for ownerships with smaller holdings and as a result, some have turned to group certification approaches (Boakye-Danquah and Reed 2019).

There are significant relationships between size of forest holdings and all of the variables tested, but the magnitudes of these relationships (i.e., the slopes in the regression models) and the numbers and values of the breakpoints vary. Although there are relationships with size, some variables have predicted probabilities that are consistently high (e.g., above 0.5) across the size spectrum, some are consistently low (e.g., below 0.5), and some that span a wide range of values. Identifying where the predicted probabilities cross the 0.5 probability threshold can be particularly insightful and may represent tipping points.

For participation in tax programs, owning forestland as part of a residence, and having wildlife as an ownership objective, the breakpoints are relatively low, less than 100 ac. The residency breakpoint is at 40 ac, which happens to coincide with a standard land subdivision in parts of the U.S. where the Public Land Survey System, also known as the Township and Range system, was used to divide land for settlement. Although wildlife as an ownership objective is high across holding sizes, this is one of the few variables tested where the direction of the relationship changes with the probability decreasing, albeit slightly, after the 67-acre breakpoint.

Minimum acreage thresholds exist for most preferential property tax programs (Kilgore et al. 2018) and for many other incentive and assistance programs. The minima help focus programs on the greatest number of acres (i.e., the smaller number of ownerships who own the greater percentage of acres) and consequently gain efficiencies through economies of scale. Many of these programs also have implicit or explicit timber production objectives, and these minima help focus the programs on the more financially viable acres. But these program designs may also exclude some of the most vulnerable ownerships – i.e., those with smaller holdings. If parcellation, development, and other threats are occurring on smaller parcels, exclusion from these programs could exasperate the problems. As with all policies, it is important to identify where the limited resources will accomplish the most to meet the program goals.

Concerns regarding taxes are also well documented (Meier et al. 2019). The results here support this general finding and show this concern is high across size holdings, but is highest among owners with the largest holdings. This makes sense given that smaller parcels can have higher per acre tax assessments (due to location and other factors), larger holdings may have substantial total tax burdens due to large acreages, and property taxes are due every year, regardless of whether income is generated from the land.

The two variables tested that are directly related to timber production, timber as an important or very important ownership objective and timber harvesting in the previous five years, have breakpoints at 278 and 442 ac, respectively. The probabilities for these attributes are low for ownerships with smaller holdings and increase rapidly with size of holdings up to the breakpoints where the increase decelerates. The predicted probabilities of both of these reach 0.5 around 1,000 ac and never reach 0.75, even for the largest size categories. As the timber harvesting variable is constrained to the previous five years, this will show a lower probability versus looking at whether an ownership has ever harvested. That being said, this variable is an indicator of active/frequent timber harvesters, it allows for better tracking over time, and it better deals with issues related to land tenure.

Forest management plans and advice are often related to timber management. Management plans has breakpoint at 130 ac and crosses the 0.5 probability threshold around 10,000 ac and having received advice in the previous five years has no breakpoints and crosses the 0.5 probability threshold around 1,000 ac. Although the likelihood of having a management plan increases with size, the overall probability is low for most ownerships and this may reflect the disconnect between management plans and owners' objectives discussed by Kittredge (2009) and VanBrackle (2015). Having received advice in the previous five years is more likely than having a management plan, but it too is generally low. This value will certainly be higher if the timeframe for receiving advice is expanded, but regardless, there is a lot of room for increased communications with owners across the size spectrum.

Another variable related to timber harvesting, and also other revenue streams, is percentage of annual income generated by their forestland. The predicted percentage is very low until 113 ac when it begins to increase, and this increase accelerates after 686 ac. But it remains low across most holding sizes with the predicted value not reaching 10% until about 1,000 ac.

One of the reasons for these observed relationships with the timber-related variables is economies of scale. For financial activities, such as timber harvesting, the per acre (or per volume) harvested costs are very high for small holdings, they decrease as size increases, and eventually they reach an asymptote. This is due to the costs of moving logging equipment, transaction costs, and other factors. Indeed, some studies suggest that holdings below a certain threshold are not financially viable (D'Amato et al. 2010), but of course this threshold will vary depending on forest and market conditions.

Recreation, including hunting, is a common and well-documented activity on family forestlands in the U.S. (Caputo and Butler 2017), as well as in other countries (Lawrence et al. 2020), and is common across holding sizes. The probability is lower, but still over 0.5, for smaller holdings, but it quickly increases and approaches an asymptote of over 0.9 after the 145-acre breakpoint.

Land transfer has a very high breakpoint value, 1,700 ac, with a rapid increase in probability of transferring land after this breakpoint. The relationship with land transfer may be related to the fact that the NWOS asks about the likelihood of transferring some or all of their land. Although there are no data from the NWOS to verify it, it is reasonable to assume that owners with larger holdings are more likely to have separate parcels or portions of parcels that they may be interested in selling or transferring, without disposing of all of their land assets.

The probability of participating in a cost-share program is relatively low across holding sizes, but the direction of the relationship switches at the 1,737-acre breakpoint and becomes negative. The specific reasons need to be further investigated, but the largest ownerships may not qualify or compete well for the cost-share programs, they may have other ways to pay for the activities, the programs may be less attractive or poorly suited to their needs, or economies of scale may make these programs less necessary for them.

Landowner age has two breakpoints, but the predicted age is relatively high across holding sizes. Interestingly, the predicted age begins to decrease for ownerships with especially large holdings (i.e., $\geq$ 5,854 ac). The age of the owners, the likelihood of transferring land, and the importance of these shifts for the future of family forests makes intergenerational land transfer and related topics of great importance, and some recent efforts have been focusing on them (Markowski-Lindsay et al. 2018).

Three variables, having received advice, land tenure, and concerns related to keeping land intact for heirs, show no breakpoints. But again, this does not imply there are no relationship to size of holdings, it is just that the relationships are linear and continuous.

The results of this study have analytical implications. The relationships between size of holdings and various attributes are often strong and nonlinear. Given the underlying distribution of family forest ownerships (Figure 5), a log-transformation is a useful first step for creating a variable that has characteristics closer to a normal distribution and the analytical advantages that provides. Segmenting the population by size of holdings and creating separate models for each segment may better illuminate patterns. A challenge is finding the appropriate breakpoint(s) and this will vary depending on the objectives of the study. The methods used here present one approach for identifying the breakpoints. Another analytical approach may be to use non-parametric models, such as classification and regression trees, that do not rely on the same assumptions as traditional regression methods.

Most previous research that has developed family forest ownership typologies has done so from the perspective of ownership objectives (Ficko et al. 2019). This approach has proven useful for many projects, but objectives alone can only go so far in explaining attitudes and behaviors. Snyder et al. (2019) segmented family forest ownerships into two categories, ownerships with 1-9 and 10+ ac of forestland, and found that some attributes varied significantly between these groups and some did not. A hybrid approach for creating ownership typologies that brings together landowner (e.g., attitudes) and land (e.g., size of holdings) attributes should be explored.

The models presented in the paper are, by design, very simple. This allows for the relationships with size of forest holdings to be more easily observed. But fuller models are needed to fully explore the relationships for specific topics. Depending on the topic, it may be useful to also include variables related to geography, past activities, demographics, association membership, and other landowner and land characteristics along with variables related to policies and markets.

The results presented here summarize an array of attitudes and behaviors at each holding size, but there is of course variability at each point across the size spectrum. For example, even though the predicted probability of timber harvesting for small holdings is low, it certainly does happen, it is just that it is probabilistically less likely to happen than for ownerships with larger holdings. As with all models, there is also uncertainty associated with the results both in terms of the underlying data and the models themselves. This latter fact is reflected in the confidence intervals associated with the estimates.

The specific thresholds identified here vary by attribute, but will likely change to some degree given different datasets. As such, it would be useful to rerun these analyses to see how consistent the breakpoints are with other populations or for the same population at other points of time. Indeed, size of forest holdings are continually changing, through parcelization and consolidation, and the changes in sizes of holdings may also be important to consider (Kilgore and Snyder 2016).

The focus of the discussion has been in terms of ownerships, but it is important to also consider the differences between ownerships and acres. This is especially true given the differences in distributions in terms of these two units (Figure 3). The analyses presented here take into account size of holdings, but the implications in terms of the landscape need to be considered. As presented in Table 2, there can be substantial differences in the percentages of ownerships that have a specific attribute versus the percentage of the forestland that they own. For example, an estimated 11% of the family forest ownerships have received advice about their forestland in the previous five years, but collectively they control 34% of the family forestland. Both are legitimate ways of looking at family forest statistics, but the “best” metric will depend on the specific topic of interest, and often both should be considered. These differences largely disappear when ownerships are segmented by size of holdings, as is done in Table 2.

Many of the dependent variables tested are undoubtedly correlated with each other, e.g., timber harvesting for sale in the previous five years and having timber production as an important or very important ownership objective. This does not negate the validity of the models presented, which were developed to look expressly at the relationships between these variables and size of holdings, but these correlations and additional dependent variables would need to be considered when developing more detailed models aimed at more fully explaining specific attributes.

A number of studies have used surrogates for size of forest holdings. For example, Wear et al. (1999) and Vickery et al. (2009) showed that population density is negatively correlated with timber availability. This relationship is in part due to the relationship between population density and size of forest holdings. Other factors likely related to size of forest holdings are amenity features, such as distance to water or public lands (Snyder et al. 2007), land value for alternative uses, such as agriculture and development, markets for timber and other resources, land use policies, and land settlement patterns (i.e., historical ownership patterns), but additional research is needed to verify the relationships.

The importance of size of forest holdings has been demonstrated not just in the U.S., but in numerous other nations that have ownership patterns that are similar to the U.S. In regards to other developed countries, strong relationships have been shown between size of holdings and various landowner attributes in, for example, Australia (Harrison and Herbohn 2005), France (Petucco, Abildtrup, and Stenger 2015), and Norway (Bashir, Sjølie, and Solberg 2020). But size is also germane in developing countries and countries in transition. In the international literature, there is reference to “small-scale” forestry (Harrison, Herbohn, and Niskanen 2002) and extensive examination of how forests contribute to human sustenance and livelihoods, and the relationships with size of holdings are often included.

Conclusions

The results from the 2018 NWOS reinforce the fact that family forest ownerships are multi-faceted. Of the estimated 10 million family forest ownerships across the U.S., who collectively control 272 million ac of the nation’s forestland (more than any other ownership group!), most of the ownerships are in smaller (< 10 ac) holdings, but most of the acres are in larger (≥ 100 ac) holdings. Size of forest holdings is significantly associated with all of the attributes tested, and most, but not all, have one or more size breakpoints. The fact that the numbers and values of the breakpoints differ shows that there is no universal threshold and that variation in breakpoint values is objective-dependent – there is no one size that fits all for understanding landowner attitudes, management behaviors, analyzing ownership data, or designing and implementing programs, policies, and services. For topics such as timber harvesting, it may make sense to focus on larger forest holding, while for topics such as parcellation it may make sense to focus on smaller forest holdings, and for topics such as wildfire mitigation there is justification for focusing based on location and site conditions regardless of size of holdings.

The ideal approach to classifying or segmenting owners depends on one’s objective. The traditional approach for classifying (private) forest ownerships used by the USDA Forest Service is based on a combination of legal ownership structure and ownership objectives. Neither of these are simple to consistently implement across a broad-scale. An alternative is to use size of forest holdings. This approach needs to be carefully considered in terms of implications for maintaining historical data series and the feasibility of collecting these data for all ownerships sampled (not just respondents), but these issues are likely addressable. Regarding a minimum acreage for reporting, the USDA Forest Service has a 1-acre minimum for defining forestland, and this should be carried forth in the ownership definitions. As there are no universal breakpoints, data should continue to be provided in formats that allow for different thresholds to be used by different end-users.

The relationships between holding size and forest owner attributes have important implications for many of forestry's biggest challenges including wildfire, invasive species, timber supply, restoration, resiliency, and keeping forests as forests. These challenges are dynamic and so too are family forest ownerships. As owners' needs and attitudes change and as forests are bought and sold, opportunities will arise for holdings to be parcelized and consolidated and for associated attributes to change. Forest policies should be designed to provide owners what they need, when they need it, how they want it to help them continue to provide the myriad benefits provided by family forests from across the spectrum of forest holding sizes.

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Supplemental Materials

Appendix I. Breakpoints for segmented regression models relating size of family forest holdings and selected variables from the 2018 USDA Forest Service, National Woodland Owner Survey.

Appendix II. Summaries of regression models relating size of family forest holdings and selected variables from the 2018 USDA Forest Service, National Woodland Owner Survey.

Tables Captions

Table 1. Variables from the USDA Forest Service, National Woodland Owner Survey used to analyze relationships between size of forest holdings and family forest ownership attitudes and behaviors.

Variable name	Description	Units/coding
LN_ACRES	Natural log of size of forest holding	Natural log of acres
HOME	Part of primary residence	1 = Yes; 0 = No
OBJ_TIMBER	Timber production is rated an important or very important on a 5-point Likert scale	1 = Yes; 0 = No
OBJ_WILDLIFE	Wildlife habitat is rated an important or very important on a 5-point Likert scale	1 = Yes; 0 = No
HARVEST	Harvested timber for sale in the previous 5 years	1 = Yes; 0 = No
PLAN	Has a written forest management plan	1 = Yes; 0 = No
ADVICE	Has received forest management advice in the previous five years	1 = Yes; 0 = No
CERTIFED	Enrolled in a forest certification program	1 = Yes; 0 = No
TAX_PROGRAM	Enrolled in a preferential forest property tax program	1 = Yes; 0 = No
COST_SHARE	Enrolled in a forest cost-share program	1 = Yes; 0 = No
TENURE	Length of land tenure	Years
REC	Owner or spouse has recreated on their forestland in the previous 5 years	1 = Yes; 0 = No
CNC_TAXES	Property taxes are a concern or great concern, on a 5-point Likert scale	1 = Yes; 0 = No
CNC_HEIRS	Ability to keep land intact for future generations is a concern or great concern, on a 5-point Likert scale	1 = Yes; 0 = No
TRANSFER	Likely or very likely, on a 5-point Likert scale, to sell or transfer some or all of their forestland in the next 5 years	1 = Yes; 0 = No
AGE	Age of the owner who is the primary decision maker	Years
FOREST_INCOME	Percentage of household's income derived from their forestland	Percent

Table 2. Summaries of selected variables, weighted by ownerships and acreage, for family forest ownerships by size of holdings, U.S., 2018. For continuous variables, the summary statistics are weighted means; for categorical variables, the summary statistics are weighted proportions where the attribute is present (i.e., value = 1). Standard errors are listed parenthetically next to the estimates.

		Size of forest holdings (ac)											
Variable	Units	1-9		10-99		100-999		1,000+		Total (1+ ac)		Total (10+ ac)	
HOME	Ownerships	0.77	(0.02)	0.63	(0.01)	0.51	(0.01)	0.43	(0.02)	0.71	(0.02)	0.62	(0.01)
(proportion)	Acres	0.75	(0.02)	0.60	(0.01)	0.48	(0.01)	0.41	(0.02)	0.53	(0.01)	0.52	(0.01)
OBJ_TIMBER	Ownerships	0.05	(0.01)	0.18	(0.01)	0.41	(0.01)	0.45	(0.02)	0.11	(0.01)	0.21	(0.01)
(proportion)	Acres	0.05	(0.01)	0.23	(0.01)	0.45	(0.01)	0.45	(0.02)	0.34	(0.01)	0.37	(0.01)
OBJ_WILDLIFE	Ownerships	0.70	(0.03)	0.76	(0.01)	0.80	(0.01)	0.80	(0.02)	0.73	(0.02)	0.77	(0.01)
(proportion)	Acres	0.69	(0.02)	0.78	(0.01)	0.79	(0.01)	0.81	(0.02)	0.78	(0.01)	0.79	(0.01)
HARVEST	Ownerships	0.04	(0.01)	0.13	(0.01)	0.32	(0.01)	0.45	(0.02)	0.08	(0.01)	0.16	(0.01)
(proportion)	Acres	0.04	(0.01)	0.16	(0.01)	0.36	(0.01)	0.43	(0.02)	0.28	(0.01)	0.30	(0.01)
PLAN	Ownerships	0.01	(0.00)	0.08	(0.01)	0.25	(0.01)	0.38	4	0.05	(0.00)	0.11	(0.00)
(proportion)	Acres	0.02	(0.00)	0.12	(0.01)	0.27	(0.01)	0.42	(0.02)	0.23	(0.01)	0.24	(0.01)
ADVICE	Ownerships	0.06	(0.01)	0.15	(0.01)	0.33	(0.01)	0.61	(0.02)	0.11	(0.01)	0.18	(0.01)
(proportion)	Acres	0.06	(0.01)	0.19	(0.01)	0.38	(0.01)	0.62	(0.02)	0.34	(0.01)	0.36	(0.01)
CERTIFIED	Ownerships	0.01	(0.01)	0.02	(0.00)	0.05	(0.00)	0.10	(0.01)	0.01	(0.00)	0.02	(0.00)
(proportion)	Acres	0.00	(0.00)	0.02	(0.00)	0.06	(0.00)	0.10	(0.01)	0.05	(0.00)	0.05	(0.00)
TAX_PROGRAM	Ownerships	0.03	(0.01)	0.16	(0.01)	0.26	(0.01)	0.35	(0.02)	0.09	(0.01)	0.17	(0.01)
(proportion)	Acres	0.04	(0.01)	0.19	(0.01)	0.29	(0.01)	0.32	(0.02)	0.24	(0.01)	0.26	(0.01)
COST_SHARE	Ownerships	0.01	(0.00)	0.02	(0.00)	0.11	(0.01)	0.30	(0.02)	0.02	(0.00)	0.04	(0.00)
(proportion)	Acres	0.00	(0.00)	0.03	(0.00)	0.14	(0.01)	0.31	(0.02)	0.12	(0.00)	0.13	(0.01)
TENURE	Ownerships	19.53	(0.70)	23.95	(0.40)	25.69	(0.36)	27.36	(0.78)	21.33	(0.48)	24.21	(0.35)
(years)	Acres	20.05	(0.59)	24.33	(0.32)	25.90	(0.34)	27.83	(0.70)	25.30	(0.22)	25.69	(0.23)
REC	Ownerships	0.65	(0.04)	0.87	(0.01)	0.96	(0.00)	0.96	(0.01)	0.74	(0.02)	0.88	(0.01)
(proportion)	Acres	0.73	(0.02)	0.90	(0.01)	0.96	(0.00)	0.97	(0.01)	0.92	(0.00)	0.94	(0.00)
CNC_TAXES	Ownerships	0.73	(0.04)	0.77	(0.01)	0.80	(0.01)	0.83	(0.02)	0.74	(0.02)	0.77	(0.01)
(proportion)	Acres	0.76	(0.02)	0.77	(0.01)	0.81	(0.01)	0.86	(0.01)	0.80	(0.01)	0.80	(0.01)
CNC_HEIRS	Ownerships	0.66	(0.03)	0.73	(0.01)	0.80	(0.01)	0.83	(0.02)	0.69	(0.02)	0.74	(0.01)
(proportion)	Acres	0.68	(0.02)	0.75	(0.01)	0.81	(0.01)	0.84	(0.01)	0.78	(0.01)	0.79	(0.01)
TRANSFER	Ownerships	0.14	(0.02)	0.15	(0.01)	0.18	(0.01)	0.18	(0.02)	0.15	(0.01)	0.15	(0.01)
(proportion)	Acres	0.13	(0.02)	0.15	(0.01)	0.19	(0.01)	0.23	(0.02)	0.18	(0.01)	0.18	(0.01)
AGE	Ownerships	62.57	(0.69)	64.55	(0.30)	66.41	(0.31)	66.30	(0.53)	63.43	(0.44)	64.81	(0.26)
(years)	Acres	62.19	(0.55)	65.31	(0.25)	66.55	(0.26)	66.36	(0.48)	65.78	(0.17)	66.04	(0.17)
FOREST_INCOME	Ownerships	0.28	(0.10)	0.83	(0.09)	3.62	(0.21)	16.70	(1.03)	0.67	(0.07)	1.29	(0.08)
(percent)	Acres	0.47	(0.19)	1.03	(0.10)	5.05	(0.32)	21.99	(1.33)	6.41	(0.31)	6.84	(0.33)

Figure Captions

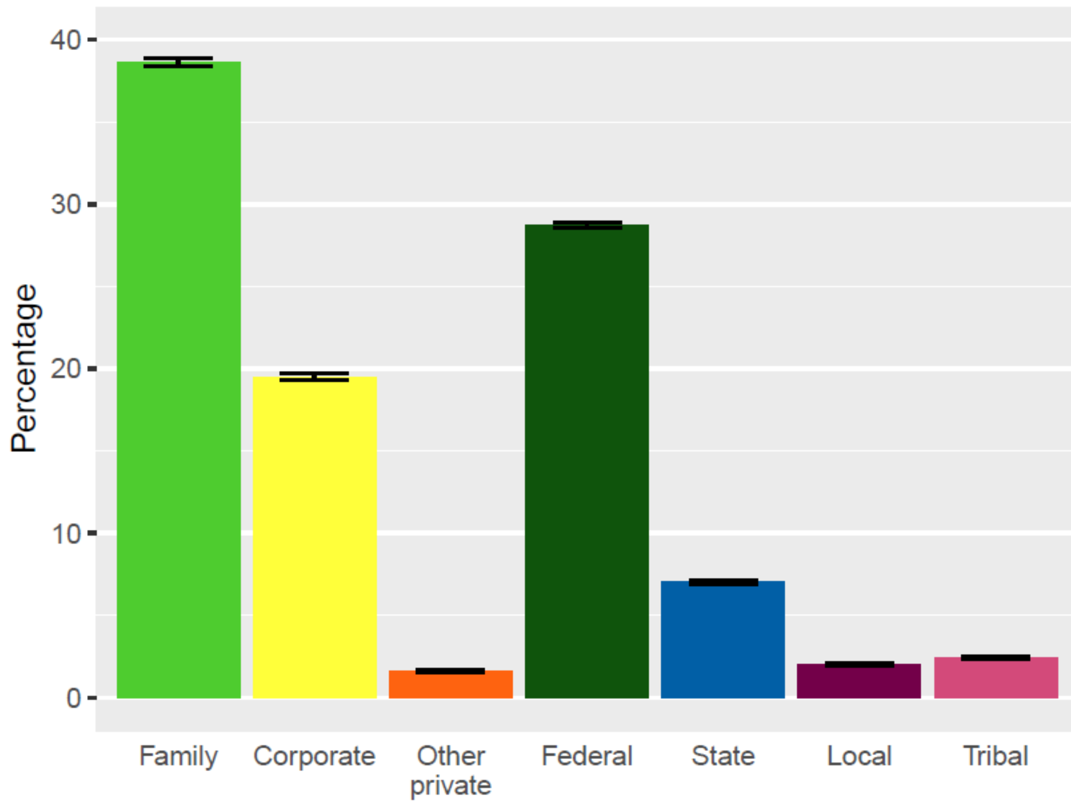


Figure 1. Forest area by ownership category, U.S.*, 2018 (Butler et al. 2020). Error bars represent 95% confidence intervals.

* Excluding interior Alaska.

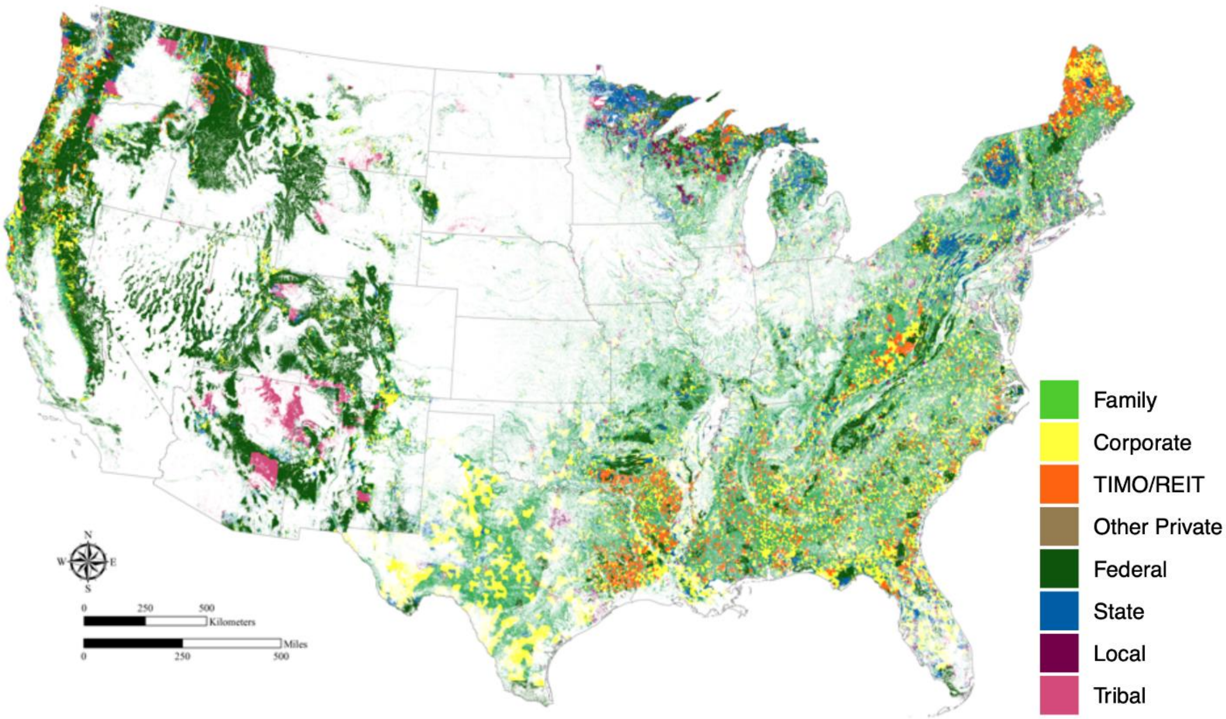


Figure 2. Forest ownership, U.S., 2018 (Sass, Butler, and Markowski-Lindsay 2020).

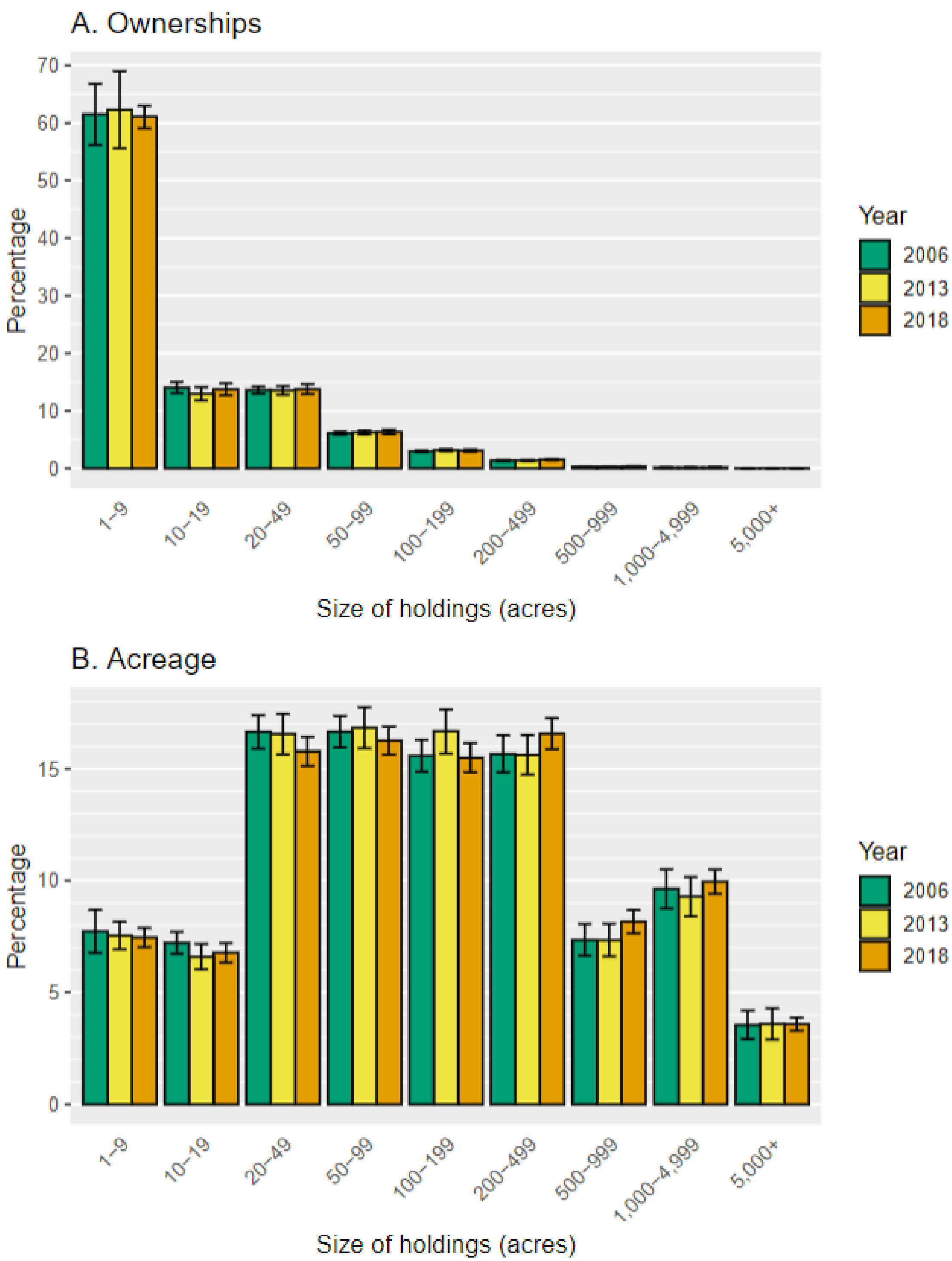


Figure 3. Distribution of A.) number of family forest ownerships and B.) family forest acreage by size of forest holdings, U.S., 2006 (Butler 2008), 2013 (Butler et al. 2016b), and 2018 (Butler et al. 2020).

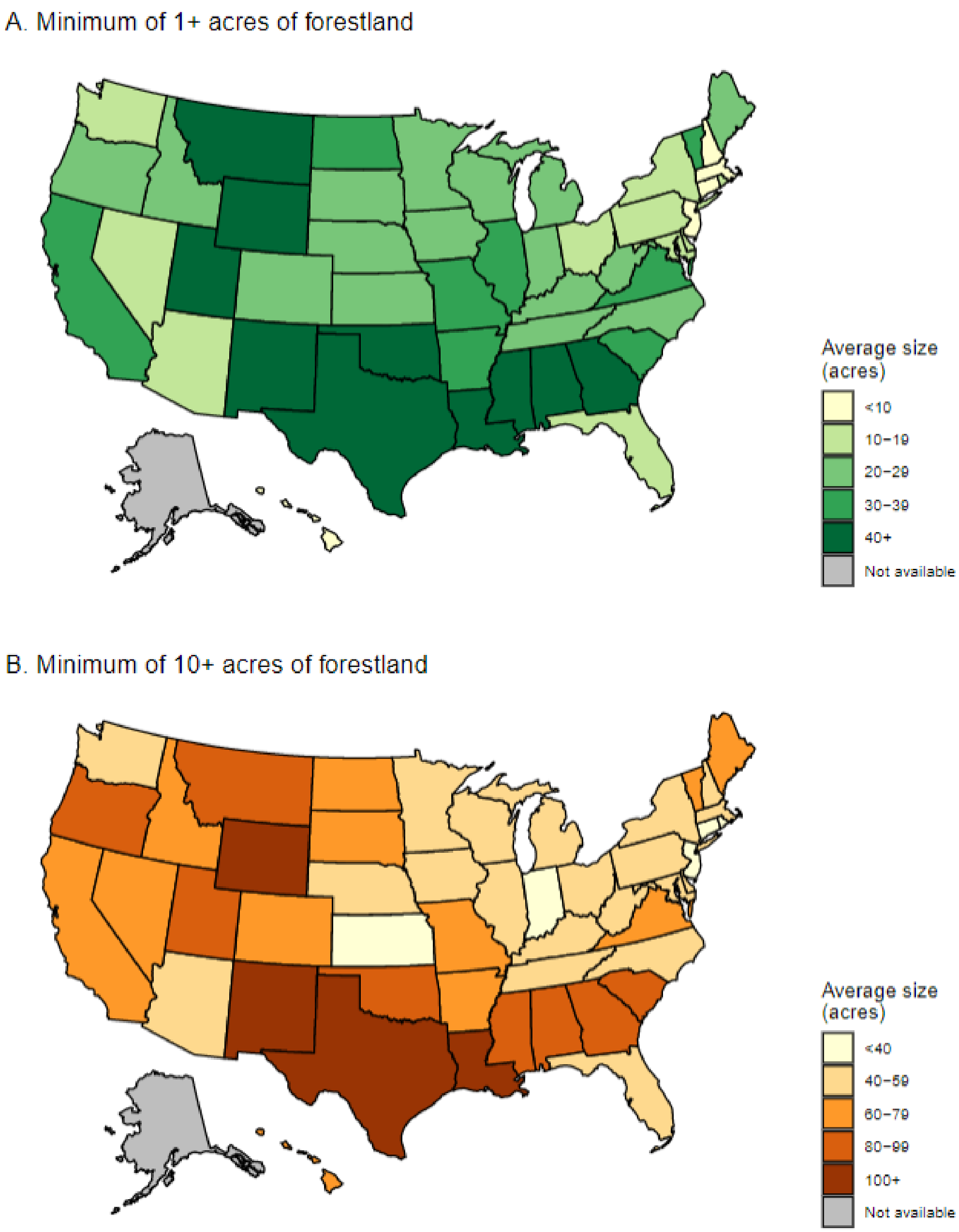


Figure 4. Mean size of family forest holdings for family forest ownerships with A) 1+ and B) 10+ acres of forestland, U.S., 2018 (Butler et al. 2020).

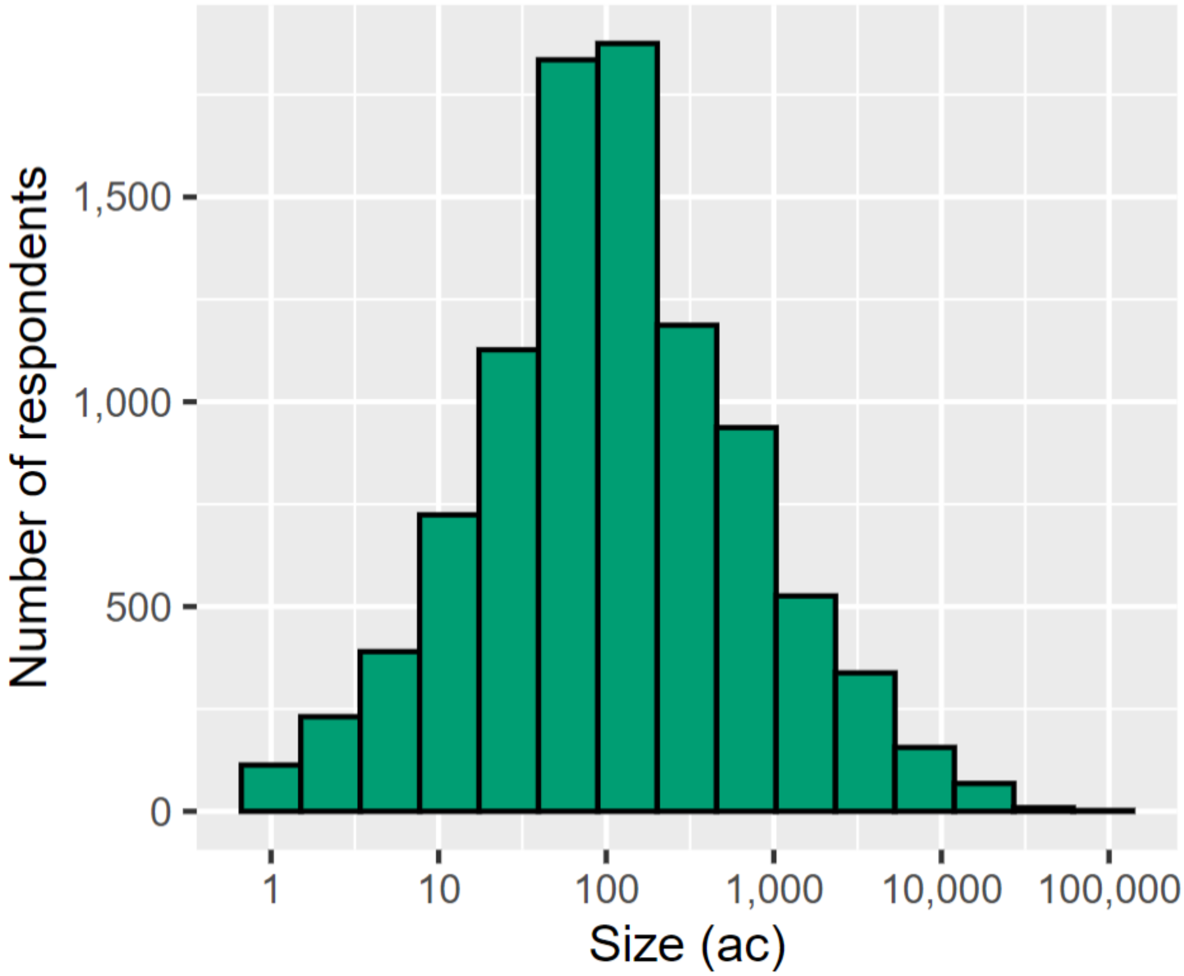
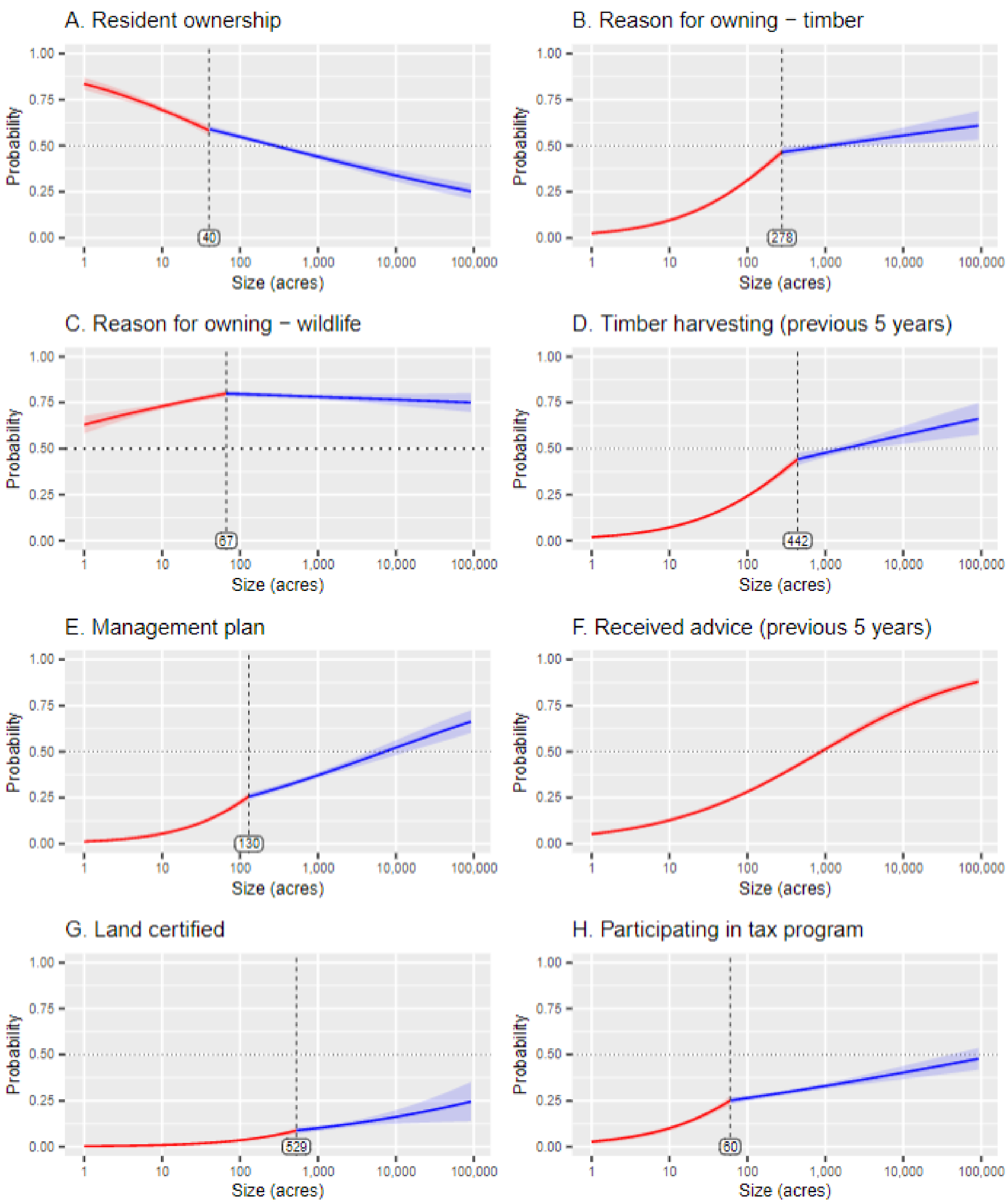


Figure 5. Number of family forest ownership respondents to the USDA Forest Service, National Woodland Owner Survey by size of forest holdings, U.S., 2018.


A. Resident ownership
B. Reason for owning − timber
C. Reason for owning − wildlife
D. Timber harvesting (previous 5 years)
E. Management plan
F. Received advice (previous 5 years)
G. Land certified
H. Participating in tax program
Probability
0.00
0.25
0.50
0.75
1.00
Size (acres)
1
10
100
1,000
10,000
100,000
40
278
67
442
130
529
60

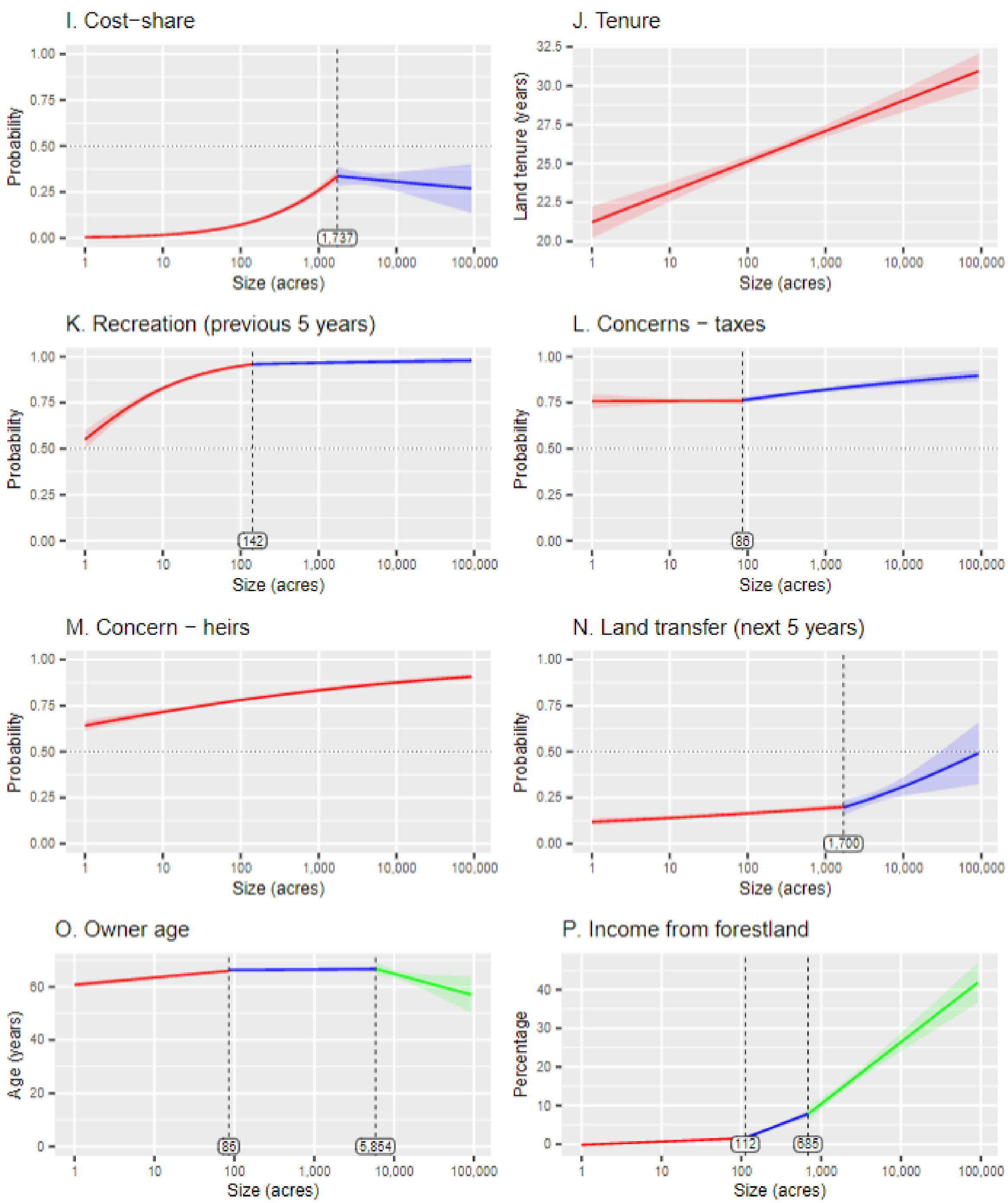


Figure 6. Predicted values for segmented regression models relating size of family forest holdings and selected variables, U.S., 2018. The x-axes are on a log scale, ribbons depict 95% confidence intervals, colors represent different segments, vertical dashed lines are breakpoints labelled with the breakpoint values, and horizontal dotted lines, where applicable, are probabilities = 0.5.

Supplemental Materials

Appendix I. Breakpoints for segmented regression models relating size of family forest holdings and selected variables from the USDA Forest Service, National Woodland Owner Survey, U.S., 2018.

Variable	Breakpoint number	Breakpoint value	Standard error	p-value
HOME	1	3.69	0.47	<0.001
OBJ_TIMBER	1	5.63	0.15	<0.001
OBJ_WILDLIFE	1	4.2	0.34	<0.001
HARVEST	1	6.09	0.2	<0.001
PLAN	1	4.87	0.2	<0.001
ADVICE*	--	--	--	--
CERTIFIED	1	6.27	0.47	0.001
TAX_PROGRAM	1	4.10	0.18	<0.001
COST_SHARE	1	7.46	0.20	<0.001
TENURE*	--	--	--	--
REC	1	4.96	0.32	<0.001
CNC_TAXES	1	4.45	0.57	0.001
CNC_HEIRS*	--	--	--	--
TRANSFER	1	7.44	0.59	0.007
AGE	1	4.44	0.31	<0.001
AGE	2	8.67	0.27	0.03
FOREST_INCOME	1	4.72	0.21	<0.001
FOREST_INCOME	2	6.53	0.21	0.003

* No breakpoints detected.

Appendix II. Summaries of regression models relating size of family forest holdings and selected variables from the USDA Forest Service, National Woodland Owner Survey, U.S., 2018.

Model	Type*	Range for LN_ACRES Min. (≥)	Range for LN_ACRES Max. (<)	Intercept coefficient Value	Intercept coefficient Standard error	LN_ACRES coefficient Value	LN_ACRES coefficient Standard error	p-value**	R^2***
HOME_1	Logistic	--	3.69	1.63	0.13	-0.35	0.04	<0.001	0.019
HOME_2	Logistic	3.69	--	1.06	0.11	-0.19	0.02	<0.001	0.012
OBJ_TIMBER_1	Logistic	--	5.63	-3.72	0.13	0.64	0.03	<0.001	0.076
OBJ_TIMBER_2	Logistic	5.63	--	-0.70	0.26	0.10	0.04	0.006	0.002
OBJ_WILDLIFE_1	Logistic	--	4.20	0.53	0.10	0.20	0.03	<0.001	0.008
OBJ_WILDLIFE_2	Logistic	4.20	--	1.54	0.15	-0.04	0.02	0.118	<0.001
HARVEST_1	Logistic	--	6.09	-3.96	0.13	0.61	0.03	<0.001	0.078
HARVEST_2	Logistic	6.09	--	-1.26	0.34	0.17	0.05	<0.001	0.005
PLAN_1	Logistic	--	4.87	-4.46	0.20	0.70	0.05	<0.001	0.060
PLAN_2	Logistic	4.87	--	-2.36	0.18	0.27	0.03	<0.001	0.017
ADVICE_1	Logistic	--	--	-2.91	0.08	0.43	0.01	<0.001	0.095
CERTIFIED_1	Logistic	--	6.27	-6.05	0.31	0.59	0.06	<0.001	0.051
CERTIFIED_2	Logistic	6.27	--	-3.80	0.57	0.23	0.07	0.002	0.007
TAX_PROGRAM_1	Logistic	--	4.10	-3.60	0.20	0.61	0.06	<0.001	0.042
TAX_PROGRAM_2	Logistic	4.10	--	-1.65	0.13	0.14	0.02	<0.001	0.006
COST_SHARE_1	Logistic	--	7.46	-5.56	0.17	0.65	0.03	<0.001	0.105
COST_SHARE_2	Logistic	7.46	--	-0.08	0.90	-0.08	0.11	0.460	<0.001
TENURE_1	OLS	--	--	21.23	0.52	0.85	0.09	<0.001	0.009
REC_1	Logistic	--	4.96	0.20	0.10	0.6	0.03	<0.001	0.082
REC_2	Logistic	4.96	--	2.62	0.49	0.11	0.08	0.162	0.002
CNC_TAXES_1	Logistic	--	4.45	1.14	0.11	0	0.03	0.944	<0.001
CNC_TAXES_1	Logistic	4.45	--	0.54	0.18	0.14	0.03	<0.001	0.005
CNC_HEIRS_1	Logistic	--	--	0.58	0.06	0.15	0.01	<0.001	0.012
TRANSFER_1	OLS	--	7.44	-2.00	0.09	0.08	0.02	<0.001	0.002
TRANSFER_2	OLS	7.44	--	-3.95	0.92	0.34	0.11	0.003	0.012
AGE_1	OLS	--	4.44	60.8	0.54	1.17	0.16	<0.001	0.012
AGE_2	OLS	4.44	8.67	65.88	0.92	0.09	0.15	0.560	<0.001
AGE_3	Logistic	8.67	--	97.36	14.94	-3.53	1.61	0.029	0.003
INCOME_1	OLS	4.72	--	-0.17	0.21	0.36	0.06	<0.001	0.007
INCOME_2	OLS	--	4.72	-14.68	2.26	3.45	0.41	<0.001	0.024
INCOME_3	OLS	4.72	--	-37.57	5.20	6.95	0.68	<0.001	0.063

* OLS = ordinary least squares

** p-values are for the coefficient of the variable of interest in each model.

** For logistic models, the McFadden's pseudo-R^2 values are reported. For OLS models, the standard R^2 values are reported.