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ORIGINAL RESEARCH

A Survival Analysis of Family Forest Owners in the USA: Estimating Life Expectancy and 5-Year Survivorship

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Abstract

Individuals, families, and trusts own a plurality of forest land in the United States, and the decisions made by these landowners have substantial impacts on the ecological, economic, and social benefits their lands provide. Some of the most impactful decisions include when and to whom to sell or leave their forested land, and whether or not to actively manage. Family forest landowners constitute an older population relative to the general population, and, the life expectancy of these landowners is a critical factor determining future land transitions, as well as patterns of management and land use. In this paper, we conduct a survival analysis using life tables and estimate that the average family forest landowner in the USA has a life expectancy of 21.0 additional years and an 89.3% chance of surviving the next five years. Five-year survivorship is a significant predictor of future plans to transfer land, as well as future intentions to actively manage. Additionally, at least in the Northeastern USA, survivorship significantly predicts filing wills and establishing trusts. These results suggest that landowners may be consciously or subconsciously aware of their declining life expectancy and may be taking it into account when making decisions regarding estate planning and land management.

Keywords Survival analysis · Life expectancy · Land transfer · National Woodland Owner Survey

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Introduction

Individuals, families, and family trusts (i.e. family forest ownerships or FFOs) represent the single largest forest ownership group in the USA, collectively owning 65 percent of private forestland and 39 percent of total forestland in the country (Butler et al. 2021). Consequently, what happens on and to *family* forest land has an outsized impact on the ecological systems and human values that rely in part or completely on forested land (Butler et al. 2022a, b; Caputo and Butler 2017). Unlike most corporate and public lands, however, which are characterized by a small number of decision makers (relative to acreage), many of whom have been exposed to formal training in forestry and/or land management, the substantial acreage represented by family forest land is owned by an equally large number of owners—9.6 million owners owning one or more acres[1] of forest land in 2018 (Butler et al. 2021)—each with diverse motives, intentions, and levels of knowledge and expertise. With so many acres depending on so many different owners, it makes sense that much effort and attention has been given to providing FFOs with resources, tools, and information to help them understand and manage their forests and woods, with the hope of keeping these critical resources intact and sustaining the wood products, habitat, carbon storage, and other human and natural values those forests provide (e.g. Baumgartner et al. 2003; Andrejczyk et al. 2016; Baker et al. 2019; Catanzaro and Hamunen 2019; Baranovskis et al. 2022; Butler et al. 2022a, b).

One area in which these multitudinous family forest lands are thought to be particularly vulnerable relates to land transfer. It is thought that the point at which family forest land is sold, given away or otherwise transferred to new owners is a particularly risky time in terms of keeping forest land intact and forested, with parcellation, development, clearing, and changes in land use being more likely at that time (Kittredge 2004; Stone and Tyrrell 2012). Long-term and intra-generational planning provides a general strategy for keeping land intact into the future (Catanzaro et al. 2014). In the USA, however, fewer than 6 percent of FFOs have a management plan and fewer than 3 percent have land enrolled in a formal conservation easement (Butler et al. 2021). At the same time, the median age of family forest landowners is 65 years old and—although only a minority consider it *likely* or *extremely likely* that they will sell their land in the short-term, defined as 5 years (Butler et al. 2021)—it is self-evident that much of their land will likely change hands in the relatively near term. Huff et al. (2019) found that the equivalent of 63 percent of U.S. family forest land had changed hands in the 12-year period between 2006 and 2018. As much as 18 percent of that had changed hands within the same family or ownership group, but that leaves 45 percent of the land having been transferred to a new ownership within a period only slightly longer than a decade. Granted, some of the transfer was undoubtedly elective and unrelated to issues of mortality, but much was likely to have been precipitated by the aging or death of the primary landowner(s).

[1] Butler et al. (2021) adopts a definition of forest land that requires a minimum of one acre. Consequently, all cited statistics from this publication refer to landowners owning at least one acre of forest land.

Mortality-driven land transfer has *indirect* implications for forest conservation and sustainability, if it increases the odds of land degradation or forest loss as a result, but it may also have *direct* implications for sustainability, if aging landowners manage their land differently from landowners with longer life expectancy. Given the current age of the average forest landowner, the low prevalence of formal planning instruments, and the high rate of forest land turnover, it behooves us to ask what role landowner survivorship and life expectancy might play in determining the timing, magnitude, and implications of forest land transfer in the short-term; as well as what the implications for forest stewardship and management might be.

It is common knowledge that a person's age is a significant, if not the *most* significant, predictor of how long they might expect to live. More than half of U.S. FFOs are 65 years of age or older and 17% are 75 years of age or older (Butler et al. 2021). This is almost twice the median age of the population at large (U.S. Census Bureau 2022). The literature shows that many forest management decisions and activities are correlated with landowners' age, with most of these decisions and activities becoming less likely among older landowners (e.g. Beach et al. 2005; Silver et al. 2015; Floress et al. 2019). These studies investigated activities such as timber harvesting, stand improvement, stewardship activities, and program participation, but *not* land transfer or estate planning. Using National Woodland Owner Survey (NWOS) data, Markowski-Lindsay et al. (2017a) found a significant and positive relationship between age and the odds of landowners' being *likely* or *extremely likely* to give away all or part of their land in the short term (i.e., 5 years). In a four-state region of the Northeastern USA, Markowski-Lindsay et al. (2017b) found that 66 percent of landowners had engaged in formal estate planning (i.e., having a will, trust, or other planning instrument), the majority of which were in a late stage of planning (Quartuch et al. 2021), and that age was a significant and positive predictor of engaging in estate planning. Bell et al. (2019) found that age significantly predicted having a will or setting up a trust, but did not significantly predict adoption of conservation easements in the same region (Catanzaro and Markowski-Lindsay 2021). Similarly, Markowski-Lindsay et al. (2018) found that older respondents were less likely to want to designate or control future land use. Taken together, these findings suggest that as landowners age, they are *less likely* in general to engage in timber harvesting, program participation, and other management activities, whereas they are *more likely* to consider transferring land, adopting wills, or setting up trusts (although not conservation easements or other instruments aimed at designating future land uses). These findings suggest strongly that landowners are aware of and responding to their declining life expectancy as they interact with and make decisions about their land.

Age alone, however, is only a partial predictor of how long a given individual is likely to live. Gender, race, ethnicity, location, occupation, physical condition, genetics, and a host of other factors also determine in part that individual's life expectancy. Although U.S. family forest landowners are notably non-diverse in terms of demographics (Butler et al. 2021), prior research has found significant effects of gender (Butler et al. 2017, Markowski-Lindsay et al. 2017a, 2020; Floress et al. 2019; Catanzaro and Markowski-Lindsay 2021), as well as race and ethnicity (Schelhas 2002, Gan et al. 2003, Gan et al. 2005, Schelhas et al. 2002, Goyke and Dwivedi 2021) on their behaviors, activities, and attributes. These effects tend in general to be smaller in magnitude and less likely to be significant than those associated with age, but taken together, demographics appear to be important in determining what landowners do with their forest land, as well as when and how they eventually transfer it.

Demographic life tables represent a common methodology for estimating an individual's life expectancy and/or survivorship from demographic variables and other characteristics. These tables are a standard tool for survival analysis, and used widely by census bureaus, public health agencies, insurance companies, and other organizations that need accurate, statistically-defensible representations of population-level life expectancy (Parkin and Hakulinen 1991). In this paper we use life tables from the National Center for Health Statistics (NCHS) and demographic data (age, race, ethnicity and gender) from the USDA Forest Service's National Woodland Owner Survey (NWOS), in order to explicitly quantify the life expectancy and short-term survivorship of family forest landowners in the USA. We believe this to be the first effort to explicitly quantify these attributes for family forest landowners in the USA or elsewhere. In addition, we fit statistical models to see whether short-term survivorship significantly predicts whether landowners believe they will transfer land or engage in future management activities. Finally, we replicate our approach using a supplementary dataset from the Northeastern USA to determine whether survivorship predicts a suite of estate planning behaviors. We hypothesize that: H1) five-year survivorship has a significant and positive effect on forest management activities, and H2) five-year survivorship has a significant and negative effect on land transfer and estate planning. In other words, we expect that landowners with a lower likelihood of living another five years will be *more likely* to sell or give land away, *more likely* to engage in end-of-life planning, and *less likely* to harvest timber or engage in other land management activities in the future, as compared to landowners with a higher survivorship.

Methods

The primary data for this paper comes from the National Woodland Owner Survey (NWOS), a product of the USDA Forest Service Forest Inventory and Analysis (FIA) program. The NWOS is USDA's official source of information on private forest ownerships in the United States and their objectives, goals, actions, and future intentions. The 2018 data cycle (used here) was completed in 2017–2018 and resulted in 9,524 complete surveys from family ownerships owning one or more acres of forest land, with an overall cooperation rate of 39.7% (Butler et al. 2021). The NWOS uses a spatially-explicit sample methodology, in which a hexagonal grid is established across the entire area of the USA and a single point is randomly located within each grid cell. The land use at each point is determined and, if found to be forested, the ownership of the land at that point is surveyed. The sampling intensity is determined for each state based on a target sample size of 250 responses per state (FFOs). Item non-response in the NWOS is addressed through a multiple imputation approach, in which five imputed values are derived for each missing variable on each survey. Across all variables in the NWOS, a mean of 3.7% of values

Table 1 Demographic categories used to classify NWOS respondents and the corresponding life tables from the National Center for Health Statistics. Table order represents respondent coding order

Demographic category	Definition	NCHS life table
Hispanic female (HF)	Hispanic and female	Table 12*
Hispanic male (HM)	Hispanic and male	Table 11*
Non-Hispanic black female (NHBF)	Not Hispanic and black and female	Table 18*
Non-Hispanic black male (NHBM)	Not Hispanic and black and male	Table 17*
Non-Hispanic white female (NHWF)	Not Hispanic and white and not black and female	Table 15*
Non-Hispanic white male (NHWM)	Not Hispanic and white and not black and male	Table 14*
Non-Hispanic female / general female (F)	Not Hispanic and not white and not black and female	Table 3*
Non-Hispanic male / general male (M)	Not Hispanic and not white and not black and male	Table 2*

*Arias et al. 2017

were imputed in the 2017–2018 cycle (Butler et al. 2021). For more information on the NWOS methodology, including sampling and non-response assessment, see Butler et al. (2021).

Along with questions on forest use and management, the NWOS includes a number of demographic questions. The sample unit of the NWOS is, strictly speaking, an *ownership*, which is comprised of one or more individual owners. The survey instructions state that the questionnaire should be completed by the owner who "makes most of the decisions" about the ownership's land (hereafter, synonymous with the *primary owner* or the *respondent*). It is this owner who has their demographics measured by the survey. We used four demographic variables from the NWOS-age, race, gender, and ethnicity-in conjunction with demographic life tables from the National Center for Health Statistics (NCHS) for 2017 (Arias et al. 2017) to predict life expectancy and survivorship for each of the NWOS respondents. First, using the gender, race, and ethnicity questions from the NWOS, we placed each survey respondent into one of eight demographic categories, each of which corresponded to a specific life table (Table 1). This was possible because the NWOS and NCHS life tables both use standard demographic language and definitions derived from the U.S. Census. Respondents were categorized using a sequential logic. Any respondent who identified as Hispanic was classified as Hispanic female (HF) or Hispanic male (HM). Any respondent who identified as non-Hispanic and black was classified as non-Hispanic black female (NHBF) or non-Hispanic black male (NHBM). Any respondent who identified as non-Hispanic and white was classified as non-Hispanic white female (NHWF) or non-Hispanic white male (NHWM).

Races other than black and white were not explicitly included in the NCHS life tables. Consequently, respondents who identified as non-Hispanic and *neither* black nor white were classified by gender only (i.e. the population-wide tables for the appropriate genders were used) as non-Hispanic female / general female (F) or non-Hispanic male / general male (M). The NWOS allows respondents to identify as more than race; respondents who identified as non-Hispanic and black *and* one or more than one additional races were identified as non-Hispanic black female (NHBF) or non-Hispanic black male (NHBF).[2] Following Census usage, gender was framed by NWOS and NCHS as a strict binary.

Once respondents were classified into one of the eight demographic categories, 5-year survivorship (i.e., the probability of surviving another five years) and life expectancy (i.e., expected number of years left to live) were calculated from the corresponding table based on age. A period of 5 years was adopted for the survivorship metric to complement the 5-year period of future activities and land transfer questions in the NWOS. NCHS life tables only went up to age 99, so ages older than this were truncated at age 99; thus, life expectancy and survivorship for respondents 100 years of age or older ($n = 4$) are marginally overestimated. Once life expectancy and 5-year survivorship were calculated for each NWOS respondent, summary population-level estimates such as mean survivorship, mean life expectancy, and total acreage by life expectancy were calculated using the survey weights and standard estimation procedures developed for the NWOS (Butler and Caputo 2021; Butler et al. 2021).

We fit several statistical models aimed at exploring the relationship between survivorship, life expectancy, and other attributes of FFOs and their land. These additional variables were also derived from NWOS survey items. First, we used Anova and Tukey's HSD to determine whether 5-year survivorship and life expectancy differed by region (North, South, West). Next, we fit two (unweighted) generalized linear models (GLMs) with the binomial distribution and logit link function (i.e., logistic regression models) in order to determine whether a respondent's 5-year survivorship predicts whether over the *same time period* (i.e., 5 years), that respondent is very likely to transfer (i.e., sell or give away) forest land (model 1), and planning to engage in one or more management actions (including timber harvest, collection of non-timber forest products, wildlife habitat improvements, stewardship treatments, grazing, road or trail construction, etc.) (model 2). Additional predictor variables for both models included region, forest acreage (i.e. size of forest holdings), whether a respondent has a strong emotional connection to the land (strong or very strong agreement), has engaged in no management activities in the previous 5 years, has transferred land in the previous 5 years, whether the likely future recipient of the land is part of the respondent's family, has a forest management plan, and has at least some college education. While the population-level estimates derived using the

[2] The authors acknowledge that this classification scheme simplifies the complexity inherent in race, particularly in mixed-race individuals. Given the methodological necessity to classify each respondent as only one of several, non-overlapping categories and the limited number of races included in the original tables, we were unable to do better.

standard NWOS methodology (see above) made use of all five imputation sets, the statistical models were fit using only a single imputed value for each null value (i.e., imputation set 1).

In addition to the primary dataset from the NWOS, we ran a parallel analysis using a secondary dataset derived from a survey to forest landowners in the Northeastern USA (hereafter the 'Northeastern Survey') aimed at developing a greater understanding regarding FFOs end-of-life, estate planning goals and activities. Importantly, this survey asked landowners whether they had engaged or were going to engage in a number of specific estate planning activities. This survey, as described in Markowski-Lindsay et al. (2017a), was conducted in 2015 and fielded in two watersheds in each of four Northeastern states; Maine, Massachusetts, Vermont, and New York (i.e. 8 watersheds total). The sample frame consisted of family forest landowners. Ownership data was derived from state and municipal government sources, and was sampled using a stratified random sampling approach in order to ensure that large and medium-sized ownerships were represented in the data. In total, 2,500 surveys were mailed out, evenly distributed across states and watersheds, and 789 were returned-for a 33% cooperation rate. In contrast to the primary dataset, missing values in this dataset had not been imputed; consequently, 26 surveys with incomplete demographic data were dropped, leaving a total sample size of 763 surveys for this analysis. More information on the implementation of the Northeastern Survey can be found in Markowski-Lindsay et al. (2017a).

In contrast to the primary NWOS data, the Northeastern Survey contained fewer demographic questions. Specifically, race and ethnicity were not collected, and so landowners' life expectancy and 5-year survivorship were calculated by age and gender only, using the generalized female and male life tables (equivalent to F and M in Table 1) using the same life tables as used for the NWOS. Survey weights had not been calculated for this dataset, so we did not calculate equivalent population-level estimates. Instead, four unweighted GLM models were fit (with the binomial distribution and logit link function) to determine the extent to which 5-year survivorship predicts whether respondents have done, are doing, or plan to do in the next year four estate planning activities: 1) discussing planning options with family, 2) making one or more firm decisions on planning options, 3) filing a will, and 4) setting up a trust. Additional predictor variables include size of forest holdings, whether respondents plan on passing all of their land to heirs, have at least some college education, and whether respondents positively intend on their land being kept undeveloped in the future. For all models in both datasets, Hosmer-Lemeshow goodness-of-fit, the Tjur statistic (2009), and VIF were assessed as model diagnostics. All analysis was done using R (R Core Team 2019). All code and outputs, as well as model coefficients, error terms, and goodness-of-fit statistics for statistical models has been included in Supplement 1.

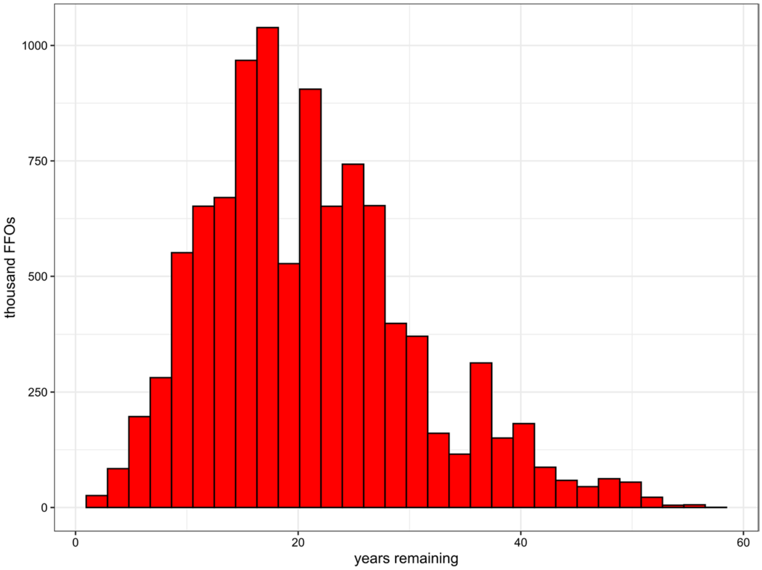

Fig. 1 Estimated population-level life expectancy among family forest landowners in the USA

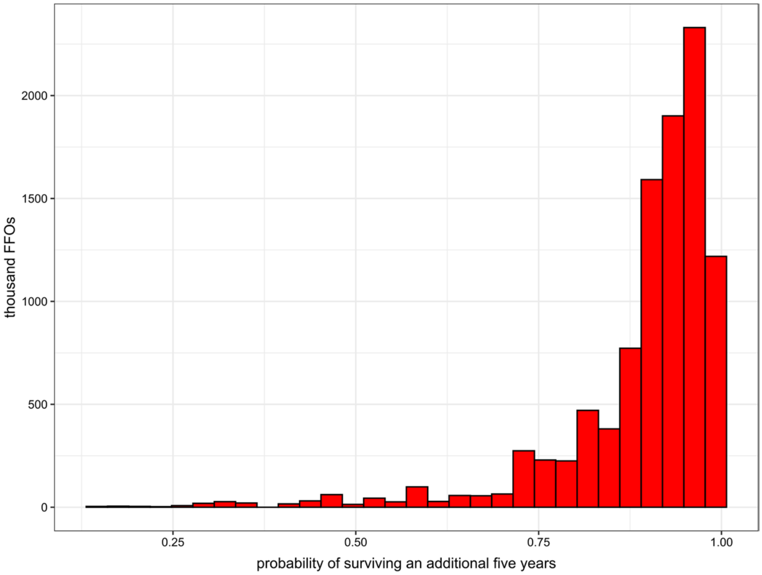

Fig. 2 Estimated population-level 5-year survivorship among family forest landowners in the USA

Results

The vast majority—greater than 76%—of NWOS respondents in 2018 were non-Hispanic white men. The majority of the remaining respondents were non-Hispanic

Table 2 Variables predicting whether family forest landowners are 'Extremely likely' to transfer land in the next 5 years, 2018, USA. Statistical model is a generalized linear model with a binomial distribution and logit link function. Predictor variables are: 5-year survivorship (SURV5), landowner has a strong emotional connection to the land (EMO_WOOD2), landowner has done no active management in the previous five years (ACT_NONE), landowner has transferred land in the previous five years (TRAN_RECENT2), landowner plans on transferring land to family in the future (TRAN_FAM), total size of forest holdings (AC_WOOD), region (REGIONSOUTH and REGIONWEST), landowner has a management plan (MAN_PLAN2), and landowner has some college education (OWN1_EDU2). Data are from the National Woodland Owner Survey (NWOS). Sample size = 9524; number of events = 595

	Estimate	Std. error	Odds ratio	z value	Pr(>|z|)
(Intercept)	0.190	0.266	1.210	0.715	0.475
SURV5	−2.577	0.270	0.076	−9.531	<0.001*
EMO_WOOD2	−0.380	0.095	0.684	−3.990	<0.001*
ACT_NONE	0.120	0.114	1.127	1.052	0.293
TRAN_RECENT2	1.150	0.110	3.158	10.444	<0.001*
TRAN_FAM	−1.253	0.092	0.286	−13.644	<0.001*
AC_WOOD	0.000	0.000	1.000	0.941	0.347
REGIONSOUTH	0.108	0.100	1.114	1.087	0.277
REGIONWEST	−0.030	0.122	0.970	−0.247	0.805
MAN_PLAN2	0.002	0.108	1.002	0.023	0.982
OWN1_EDU2	0.145	0.114	1.156	1.268	0.205

Hosmer and Lemeshow test, $p = 0.054$

Tjur statistic, 0.056

*Significant at the $\alpha = 0.05$ level

white females (20.3% of total). The mean truncated age across all respondents was 65.4 years, with a standard deviation of 11.7 years. Based on these inputs, the mean estimated population-level life expectancy of the primary owner of U.S. family forest ownerships in 2018 was 21.0 years (SE = 1.6 years) (Fig. 1). The mean estimated probability across the population of surviving an additional 5 years was 89.3% (standard error = 0.9%) (Fig. 2).

Most family forest acreage, 83.5% (SE = 1.8%) or 230.3 million acres (SE = 6.8 million acres), in 2018 was owned by people with a life expectancy of at least 10 years, with another 14.3% (SE = 1.9%) or 39.4 million acres (SE = 6.5 million acres), owned by people who can expect to live between 5 and 10 additional years. On the other hand, 2.2 percent of the land (SE = 0.2%) or 6.1 million acres (SE = 0.6 million acres) was owned by people expected to expire within the next five years.

Both response variables were homoscedastic within region (see Supplement 1) and, according to the ANOVA and TukeyHSD tests, there were significant differences at the $\alpha = 0.05$ level in both life expectancy ($p < 0.001$) and survivorship ($p < 0.001$) across the three regions. Specifically, landowners in the southern USA could expect to live 1.02 years less than landowners in the Northern USA ($p < 0.0001$) and 0.6 years less than landowners in the Western USA ($p = 0.044$). Similarly, 5-year survivorship was 1.3% higher in the North ($p < 0.001$) and 1.1%

Table 3 Variables predicting whether family forest landowners plan to engage in active management in the next 5 years, 2018, USA. Statistical model is a generalized linear model with a binomial distribution and logit link function. Predictor variables are: 5-year survivorship (SURV5), landowner has a strong emotional connection to the land (EMO_WOOD2), landowner has done no active management in the previous five years (ACT_NONE), landowner has transferred land in the previous five years (TRAN_RECENT2), landowner plans on transferring land to family in the future (TRAN_FAM), total size of forest holdings (AC_WOOD), region (REGIONSOUTH and REGIONWEST), landowner has a management plan (MAN_PLAN2), and landowner has some college education (OWN1_EDU2). Data are from the National Woodland Owner Survey (NWOS). Sample size = 9524; number of events = 7847

	Estimate	Std. error	Odds ratio	z value	Pr(>|z|)
(Intercept)	0.208	0.231	1.231	0.898	0.369
SURV5	1.246	0.238	3.477	5.245	<0.001*
EMO_WOOD2	0.474	0.074	1.606	6.403	<0.001*
ACT_NONE	−2.881	0.070	0.056	−41.225	<0.001*
TRAN_RECENT2	−0.148	0.128	0.862	−1.159	0.246
TRAN_FAM1	0.302	0.077	1.353	3.929	<0.001*
AC_WOOD	0.000	0.000	1.000	6.019	<0.001*
REGIONSOUTH	0.023	0.076	1.023	0.300	0.764
REGIONWEST	0.515	0.103	1.674	5.015	<0.001*
MAN_PLAN2	0.979	0.112	2.663	8.720	0.000*
OWN1_EDU2	0.260	0.078	1.297	3.326	0.001*

Hosmer and Lemeshow test, $p = 0.110$

Tjur statistic, 0.358

*Significant at the $\alpha = 0.05$ level

higher in the West ($p = 0.012$) relative to the South. There were no significant differences in either life expectancy or survivorship between the North and the West.

Five-year survivorship is a significant predictor of a landowner being 'extremely likely' to transfer land in the next five years, at the $\alpha = 0.05$ level (Table 2). For every 10% decrease in 5-year survivorship, a landowner is 1.3 times as likely to be consider themselves at the highest probability of transferring land. The odds of land transfer also significantly increase if the landowner 1) does not have a strong or very strong emotional connection to the land, 2) has transferred land in the past five years, or 3) is not planning on leaving the land to family. The magnitude of log odds estimates for these variables is not as high as for survivorship, however. These findings support H2.

Similarly, 5-year survivorship is also a significant predictor of a landowner engaging in active management in the next five years, at the $\alpha = 0.05$ level (Table 3). In this case, however, the relationship is positive; the odds of engaging in active management in the next 5 years increase by 1.13 times for every 10% increase in 5-year survivorship. Other variables that significantly increase the odds of active management (at the $\alpha = 0.05$ level) include, 1) having a strong emotional connection to the land, 2) planning on keeping the land in the family, 3) having greater acreage, 4) being in the West, 5) having a management plan, and 6) having some college education. The log odds estimates for these variables are lower in magnitude than for survivorship, however. The only variable that has a negative relationship with future

Table 4 Variables predicting whether family forest landowners have discussed estate planning options with their families, 2017, Northeastern USA. Statistical model is a generalized linear model with a binomial distribution and logit link function. Predictor variables are: 5-year survivorship (SURV5), landowner plans on passing all of their land to heirs (HEIRS2), landowner positively intends on forest land remaining undeveloped in the future (INT_FUT2), total size of forest holdings (AC_WOOD), and landowner has some college education (EDU2). Sample size = 763; number of events = 400

	Estimate	Std. error	Odds ratio	z value	Pr(>|z|)
(Intercept)	−0.318	0.586	0.727	−0.543	0.587
SURV5	−0.879	0.628	0.415	−1.400	0.162
HEIRS2	0.559	0.165	1.748	3.379	0.001*
INT_FUT2	0.820	0.184	2.272	4.464	<0.001*
AC_WOOD	0.004	0.001	1.004	2.824	0.005*
EDU2	0.606	0.178	1.832	3.409	0.001*

Hosmer and Lemeshow test, $p = 0.735$

Tjur statistic, 0.099

*Significant at the $\alpha = 0.05$ level

Table 5 Variables predicting whether family forest landowners have made decisions regarding estate planning, 2017, Northeastern USA. Statistical model is a generalized linear model with a binomial distribution and logit link function. Predictor variables are: 5-year survivorship (SURV5), landowner plans on passing all of their land to heirs (HEIRS2), landowner positively intends on forest land remaining undeveloped in the future (INT_FUT2), total size of forest holdings (AC_WOOD), and landowner has some college education (EDU2). Sample size = 763; number of events = 269

	Estimate	Std. error	Odds ratio	z value	Pr(>|z|)
(Intercept)	−1.099	0.594	0.333	−1.852	0.064
SURV5	−0.631	0.633	0.532	−0.997	0.319
HEIRS2	0.141	0.174	1.151	0.806	0.420
INT_FUT2	0.613	0.181	1.846	3.388	0.001*
AC_WOOD	0.003	0.001	1.003	2.910	0.004*
EDU2	0.769	0.195	2.158	3.954	<0.001*

Hosmer and Lemeshow test, $p = 0.688$

Tjur statistic, 0.061

*Significant at the $\alpha = 0.05$ level

management is *not* having done past management. Landowners who have engaged in active management in the past 5 years are almost 18 times as likely to engage in management in the next five years (i.e., the inverse of the odds ratio for ACT_NONE). These findings support H1. Both national models have non-significant Hosmer-Lemeshow statistics and variable inflation factors (VIF) below 2, suggesting adequate fit and the absence of problematic collinearity. The model predicting future land transfer has a Tjur statistic of 0.05, whereas the model predicting future active management has a Tjur statistic of 0.35. This second value is much higher because of the very strong relationship between past management and future management.

Table 6 Variables predicting whether family forest landowners have filed a will, 2017, Northeastern USA. Statistical model is a generalized linear model with a binomial distribution and logit link function. Predictor variables are: 5-year survivorship (SURV5), landowner plans on passing all of their land to heirs (HEIRS2), landowner positively intends on forest land remaining undeveloped in the future (INT_FUT2), total size of forest holdings (AC_WOOD), and landowner has some college education (EDU2). Sample size = 763; number of events = 533

	Estimate	Std. error	Odds ratio	z value	Pr(> |z|)
(Intercept)	1.980	0.755	7.245	2.622	0.009*
SURV5	−2.495	0.818	0.082	−3.051	0.002*
HEIRS2	0.560	0.179	1.750	3.134	0.002*
INT_FUT2	0.084	0.200	1.088	0.421	0.674
AC_WOOD	0.003	0.001	1.003	2.204	0.028*
EDU2	0.832	0.182	2.298	4.584	< 0.001*

Hosmer and Lemeshow test, $p = 0.042$

Tjur statistic, 0.069

*Significant at the $\alpha = 0.05$ level

Table 7 Variables predicting whether family forest landowners have established a trust, 2017, Northeastern USA. Statistical model is a generalized linear model with a binomial distribution and logit link function. Predictor variables are: 5-year survivorship (SURV5), landowner plans on passing all of their land to heirs (HEIRS2), landowner positively intends on forest land remaining undeveloped in the future (INT_FUT2), total size of forest holdings (AC_WOOD), and landowner has some college education (EDU2). Sample size = 763; number of events = 172

	Estimate	Std. error	Odds ratio	z value	Pr(> |z|)
(Intercept)	−0.211	0.612	0.809	−0.346	0.730
SURV5	−2.448	0.656	0.086	−3.733	< 0.001*
HEIRS2	0.636	0.203	1.889	3.135	0.002*
INT_FUT2	−0.102	0.207	0.903	−0.495	0.621
AC_WOOD	0.002	0.001	1.002	2.002	0.045*
EDU2	0.838	0.233	2.312	3.600	< 0.001*

Hosmer and Lemeshow test, $p = 0.626$

Tjur statistic, 0.060

*Significant at the $\alpha = 0.05$ level

The 763 responses in the Northeastern Survey dataset had a mean age of 63.3 years (standard deviation = 12.1 years). Seventy-one percent of the respondents were male. This is a slightly younger and slightly more female sample than the NWOS sample. We do not have survey weights for the Northeastern Survey, so we cannot calculate population-wide life expectancy and 5-year survivorship. The sample means for these variables are 20.7 years and 88.6%, both within one standard error of the population-level estimates calculated using the NWOS data. We conclude that both samples are from populations that are very similar in terms of age and gender characteristics; comparisons with race and ethnicity, which was not measured in the Northeastern Survey, are unknown.

In the Northeastern USA, 5-year survivorship *does not* significantly predict the likelihood of discussing future plans with family or deciding on those options, but it *does* predict the likelihood of filing a will or setting up a trust (Tables 4, 5, 6 and 7). For each 10% decrease in 5-year survivorship, the odds of taking these steps increase 1.28 times. This offers further support for H1. Additionally, landowners who have greater acreage and have at least some college education are significantly more likely to engage in all four planning options (where these variables are significant at the $\alpha = 0.05$ level). Landowners who plan on passing land to heirs are significantly more likely to discuss planning options, file a will, or set up a trust. Landowners who intend on keeping their land forested in the future are significantly more likely to discuss options and make final decisions. The model predicting whether landowners file a will has a marginally significant Hosmer-Lemeshow statistic ($p = 0.042$), suggesting the potential for some problems with the model fit. The VIF values for all variables in all four models are below 2. All four models have Tjur statistics below 0.10.

Discussion and Conclusions

In 2018, the average family forest landowner in the USA had a life expectancy of 21 additional years, with more than an 89% chance of living another 5 years. That being said, 2.2% of family forest land—more than 6 million acres—was owned by landowners who could expect to live no more than 5 additional years. This represents land that is potentially at a higher risk of being developed, sub-divided, exploitatively harvested, or otherwise degraded, as a result of end-of-life property transitions. Furthermore, these involuntary land transfers are additional to voluntary land transfers, where landowners sell land or give it away before they die-because they feel they are too old to care for it; or because they feel it is time to pass it on the younger generation; or for any of the manifold reasons people sell land, because they need the money, decide to relocate, or just don't want it anymore. We have every reason to believe that these elective land transfers represent the majority of land transfers in the USA. For example, in the current analysis we find that 16% of family forest acreage is owned by individuals with a life expectancy of less than ten years. Even if we assume that all of this land remains in current hands *until* the primary landowner expires, this is still substantially less than the 60% + of land that Huff et al. (2019) found had changed hands over a roughly equivalent period (12 years). This agrees with what we see in the NWOS, where-despite most landowners *expecting* (or *hoping*) to pass forest land onto their children-most landowners themselves first acquired their land by purchasing it from unrelated individuals (Butler et al. 2021).

Taken alone, a survival analysis can suggest future trajectories but ultimately cannot predict the future. A survival analysis *can*, however, contribute to investigating future trends in one of two broad ways. The first is through the incorporation of survival analysis techniques within a longitudinal research framework, i.e. a repeated measures analysis. The NWOS has been designed and implemented with a consistent sampling approach and standardized survey instruments with an eye towards longitudinal analysis (Butler et al. 2016; Huff et al. 2019). Average landowner age has been increasing marginally in the recent past, but it has been unclear to date whether these changes have been significant-or whether forest landowners, although undoubtedly *older* than the general population, retain a similar age distribution through time (Butler 2020). In other words, are forest landowners as a group "aging"-as it commonly maintained by forestry professionals-or are they merely consistently "older" (quite simply, perhaps, because older people are more likely to have the resources and rootedness to buy and own land)? Longitudinal analysis of NWOS data *does* suggest a significant increase in the percentage of landowners at least 65 years of age, across the three most recent survey cycles-2006, 2013, 2018 (Sass et al. 2023). At the same time, this analysis shows significant changes in ownership by women and individuals of color, each with corresponding differences in baseline life expectancy relative to age. The combined effect on total average landowner life expectancy is unknown and difficult to guess, particularly as life expectancy across the general population changes over time (Woolf and Schoomaker 2019). The best way to understand temporal trends in landowner life expectancy will be to repeat the current analysis—always using current and up-to-date life tables—within the larger program of longitudinal analysis for the NWOS.

The second broad way of using survival analysis to investigate future trends is through modeling. By including landowner life expectancy and short-term survivorship in social-ecological models of land use and land use change, we can strive to more accurately model the rate and magnitude of land ownership transitions, as well as-importantly-the ultimate implications of those transitions for land use and land cover change. Preliminary attempts at modeling land turnover using the current dataset show that half of family forest acreage could transition away from the current owners within 7 to 12 years (between 2025 and 2030), from a combination of mortality and elective sales/transfers-considerably sooner than we would expect to see from mortality alone (Caputo Unpublished data). This number certainly makes one pause, but without knowing who will receive these lands and what they will do with them-it remains difficult to estimate the ultimate ramifications in terms of the ecological and social benefits that forests provide. Research shows that US forest land is currently undergoing a net transition from family ownership to corporate ownership (Sass et al. 2021), although it is not clear to what extent this is due to families incorporating for more favorable tax and/or legal considerations without actual transfer of land. It is also not clear, again, what this might mean in terms of timber production, biodiversity, water quality, recreation access, and all of the other benefits that family forests currently provide. In the Southern USA, net loss of family-owned forest to corporate ownership has occurred in tandem with increased forest fragmentation and parcellation on the remaining family forest lands-with presumed implications for a number of benefits (Caputo et al. 2020). The situation is complex, with many interacting variables and factors at play, and social-ecological modeling is an established way to tease apart the complexity, in order to better understand the role that landowner mortality might play in determining the future fate of family forest lands.

The results of the regression models supported our research hypotheses. As 5-year survivorship declined, landowners were less likely to actively manage and more likely to plan on transferring land or to engage in formal estate planning actions, i.e. filing wills and establishing trusts. These findings support the idea that landowners are aware of and acknowledging their declining life expectancy, either implicitly or explicitly, in making decisions about their land. This is not surprising, but neither was it beyond doubt. Human beings approach end-of-life planning through a complex collage of emotions and rationalizations, neither blind to their mortality nor in complete rational acceptance of it; it is not uncommon for individuals to fail to file wills or otherwise prepare for death in time due to overestimation of their own life expectancy (Sheng et al. 2019).

Markowski-Lindsay et al. (2017b) found that less than two-thirds of landowners in the Northeastern USA had engaged in active estate planning. Given our current findings, we might assume that this percentage is even higher among those landowners with the lowest life expectancy. In other words, individuals with low life expectancy are more likely to have a will in place, whereas younger individuals with greater life expectancy may represent an outsized proportion of the landowners *without* wills/trusts; they may not have done any formal estate planning yet, but many will likely file wills or establish trusts as they age. This suggests a potential opportunity to target outreach and extension efforts related to estate planning. Instead of focusing efforts on the entire third of landowners without wills or other planning instruments, extension professionals could instead focus efforts on a target audience comprised of individuals, mostly older individuals, with reduced life expectancy. Further targeting could highlight individuals without family or close heirs. Such an approach could improve outreach efficiency by focusing efforts on those individuals for whom “nudges” and other interventions would have the greatest likelihood of mitigating risks due to landowners dying in the immediate term and land transitioning out of family ownership.

We believe this paper has demonstrated that survival analysis using demographic life tables is a useful technique for forest landowner researchers. This paper is just a start, however. Future research would be improved by having access to life tables split by a greater number of variables. For example, we found regional differences in life expectancy and survivorship, with both lower in the Southern US. Because we used the same national life tables for all respondents in our analysis, however, this finding is due-not to lower *inherent* life expectancy in this region or differences in health and environmental factors-but solely to demographic differences. Southern FFOs are marginally older and less white overall then their counterparts in the North and West, both of which contribute to lower life expectancy and reduced survivorship. Having separate sets of life tables for each region would allow greater precision in our estimates, by allowing for inherent regional differences in baseline life expectancy. Similarly, education is another demographic variable that is measured in the NWOS and could be used a split factor in a set of life tables, but which is not included in the current NCHS life tables.

One outstanding question is to what extent are life tables constructed for the general population suitable for the population of forest landowners? Landownership confers a number of benefits and opportunities, including access to outdoor spaces and recreational resources (Caputo and Butler 2017). It may be that, because of this, forest landowners have healthier lifestyles than the general population, and therefore have greater baseline life expectancy. On the other hand, forest landowners may incur accidents, or be subject to various risks and hazards at a greater rate that the general public (e.g. falling trees, wild animals, accidents in remote backcountry). Forest landowners may be wealthier or poorer on average than the general public, more or less likely to have spouses/partners and families, be more or less educated, or more or less inclined to unhealthy life habits, etc. The point being that the population of forest landowners in the USA may differ in non-random ways from the general population and the use of life tables calibrated for the general public may, therefore, be less accurate. An ideal solution to this problem would be a long-term study in which a cohort of forest landowners was followed from the time of land acquisition to the time of their death. Such a study would allow for survival probabilities to be calculated *specifically* for the forest landowner population, using custom actuarial (i.e. cohort-specific) life tables or alternative methods-such as the Kaplan-Meier method, commonly used in medical research (Parkin and Hakulinen 1991). In addition to improving our understanding of landowner life expectancy, a long-term cohort study would provide a number of valuable insights on many other facets of long-term forest ownership. That being said, it would be expensive, would take a long time to bear fruit, and would require significant institutional commitment and landowner participation (especially if tables were to split by other demographic variables, as with the NCHS tables used here). In the absence of such a long-term landowner study, life tables constructed for the general population are likely to be the most accurate available approach.

An important caveat to our work is that we were only able to calculate the life expectancy and survivorship of the survey *respondent*, who is assumed to be the primary owner and the only owner for which demographic data was collected in the 2018 NWOS. Thus, for example, the mean life expectancy of the *primary* owners of U.S. family forest ownerships in 2018 was 21 years. However, 68% of ownerships in 2018 had two or more owners (Butler et al. 2021), and we can say nothing about the demographics or life expectancy of these individuals. This does not impact our primary findings, to the extent that they refer to primary owners only, but it does temper the implications in regard to land transfer, in that, upon the death of the primary *owner*, forest parcels with additional owners may not necessarily transfer to a new legal *ownership*. The distinction is largely semantic, however, as the secondary (or tertiary) owners in the same ownership are just as much an unknown element as a new ownership would be. They may be just as likely or unlikely to sell or subdivide the land, high-grade the timber, or manage the forest, compared to the original primary owner. Additional research on multiple-owner and intergenerational decision-making for family forest ownerships is needed to better understand these dynamics.

At first glance, the life expectancies calculated here for family forest landowners may seem quite low, but 21 years represents more than a quarter of a lifetime for the average individual in the U.S. Additionally, it is almost exactly equivalent to the average family forest land tenure as of 2018, 21.3 years (Butler et al. 2021). For those landowners who choose to hang on to their land, a majority of them will be less than halfway through their period of stewardship. The average family forest landowner has an almost 90% chance of living an additional 5 years and more than 83% of family forest land is owned by people who can expect to live at least 10 years. Though understanding landowner mortality is key to understanding the future trajectory of private forest land in the USA, it is also equally important to continue thinking of family forest landowners as active, thriving land stewards. Family forest landowners, like family forests themselves, are alive and well.

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Declarations

Conflict of interest We have competing interests to declare.

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