Forest Policy and Economics 46 (2014) 39–46

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

# Cost-share program participation and family forest owners' past and intended future management practices☆

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ARTICLE INFO

*Article history:*
Received 20 September 2013
Received in revised form 30 May 2014
Accepted 1 June 2014
Available online 26 June 2014

*Keywords:*
Cost-share programs
Family forest owners
Propensity score matching
National Woodland Owner Survey

ABSTRACT

Cost-share programs are commonly-used policy tools designed to influence management on privately-owned lands. Widely popular on agricultural lands, these programs and their association with landowner behavior have not been as thoroughly studied on forested lands. Based on a dataset of over 3500 observations and using propensity score matching to reduce possible selection bias, this study found that family forest owners in the U.S. Northern region enrolled in cost-share programs were more actively engaged in both silvicultural and conservation management activities than non-participants. These findings point to the capacity of cost-share public programs to promote better forest management. This study found that cost-share participation varied across size of forest holdings, owners' demographic characteristics, ownership objectives and forest location. Owners of smaller sized forestlands had a lower participation rate and might be a prime target group of future cost-share programs to widen forest and wildlife habitat management.



## 1. Introduction

Cost-share programs are part of a collection of natural resource policy tools aimed at influencing private land management based on the provision of financial incentives (Cubbage et al., 1993). Numerous federal and state cost-share programs have been established since the 1930s in the U.S. to promote conservation, productivity, and long-term sustainability of forests (Greene et al., 2004; USDA Forest Service Southern Research Station, 2011). Cost-share programs involve the use of financial incentives to support private landowners' initiatives in adopting land conservation practices and sustainable management (Claassen et al., 2008). Increasing amounts of funding have been spent in U.S. cost-share programs in recent years, and federal funding for conservation programs had been 5.5 billion in 2010 (Osteen et al., 2012; USDA Economic Research Service, 1997).

In the particular case of forests, cost-share payment programs have been established by mainly government agencies to promote conversion of non-forest land into forest, maintain forest cover, protect watersheds and wildlife habitat, foster better forest stewardship, and ensure long-term timber supplies (Bullard and Straka, 1988; Jacobson et al., 2009; Siikamäki and Layton, 2007). The Conservation Reserve Program (CRP), Environmental Quality Incentive Program (EQIP), Forest Legacy Program (FLP), Landowner Incentive Program (LIP), Wildlife Habitat Incentives Program (WHIP), and Wetland Reserve Program (WRP) are major federal cost-share programs private forest landowners may be eligible to participate. There are also dozens of state-run cost-share programs, a majority of which were established in the early 1970s (Bullard and Straka, 1988; Jacobson et al., 2009).

While some studies report significant impact of cost-share programs (Drummond and Loveland, 2010; Kilgore and Blinn, 2004; Lee et al., 1992; Mehmood and Zhang, 2002), others have shown that some forest landowners would have adopted conservation or production practices without program participation (Sun, 2007). Furthermore, the reported impact of this type of public support program has been questioned due to the potential bias when the non-random participation of enrollment fails to be accounted for (Bliss and Martin, 1990; Boyd, 1984; Kluender et al., 1999; Zhang and Flick, 2001). Econometrically, it has been argued that estimated effects of program participation using exogenous binary variables are biased (Heckman, 1978, 1990; Heckman et al., 1998a; Rubin, 1974, 1980). This bias is rooted in the fact that cost-share programs are chosen by eligible participants rather than assigned randomly, making participation a non-random treatment and the variable describing participation endogenous. However, the endogenous variable for a public program participation was often treated as exogenous variables in past land owners studies using Ordinary Least Squares (e.g. Brooks, 1985; Hardie and Parks, 1991; Kline et al., 2002; Kula and McKillo, 1988; Lee et al., 1992; Zhang and Flick, 2001), Seemingly Unrelated Equations (e.g. Alig, 1986), Logistic (e.g. Hyberg and Holthausen, 1989; Nagubadi and Zhang, 2005; Royer and Moulton, 1987; Valdivia and Poulos, 2009), and Probit (e.g. Loyland et al., 1995; Nagubadi et al., 1996) models. All of them assumed that participation

☆ This research was partly funded by the Northern Research Station under U.S. Forest Service Agreement 09-PA-11242305-143.

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http://dx.doi.org/10.1016/j.forpol.2014.06.003
1389-9341/

variable was random and independent of other variables (Beach et al., 2005).

The motivation of this study was to examine the association between enrollment in cost-share programs and management of family-owned forests using unbiased estimation methods. We concentrate on family forest owners, defined as individuals, families, trusts, estates, family partnership, and other unincorporated groups (Butler et al., 2005, 2007; Butler, 2008). These family forest owners are the target group of most cost-share programs. Specifically, this study aimed to identify major reasons for family forest owners' participation in cost-share programs and to evaluate their association with forest land management practices for conservation and timber production. Forest land management practices evaluated in this study included (a) stated past forest management operations on existing forest land and (b) intended future forest land changes. Data from the National Woodland Owner Survey (NWOS) for the U.S. Northern region were used in the empirical estimation. The U.S. Northern region as defined by the USDA Forest Service encompasses the 20-state quadrant bounded by Maine, Maryland, Minnesota, and Missouri (Smith et al., 2009). Families account for 94% of the number of private forest owners and own about 73% of all private forest land in this region (Butler, 2008).

The rest of the paper is structured as follows. After a review of the recent literature, a theoretical framework for the application of Propensity Score Matching (PSM) as a tool to reduce non-random induced bias and an empirical model are introduced. The justification for the inclusion of variables of a Probit model is discussed before an explanation of the dataset, econometric estimation and presentation of results. Variables significantly affecting the participation in cost-share programs and associated cost-share effects on past and future forest management practices are then discussed. We conclude with implications of our findings and recommendations for future studies.

## 2. Review of studies on cost-share programs and forest lands

Numerous studies (e.g. Amacher et al., 2003; Beach et al., 2005) have explored the impact of cost-share programs as tools to promote timber production and the attainment of environmental and natural resource conservation objectives. Flick and Horton (1981) estimated the benefit–cost ratio of Virginia's Reforestation of Timberland Program to be as high as 3.5 for the first six years of its adoption, implying that program benefits substantially exceeded its costs. Cost-share programs in the U.S. South have been reported to have positively affected reforestation (Royer and Moulton, 1987) and increased timber supply (Lee et al., 1992; de Steiguer, 1984). Hardie and Parks (1991) estimated that the Forest Incentive Program, a federal cost-share program that supported silvicultural activities until 2002, might have encouraged about 70% of investments in forest regeneration in the U.S. South from 1971 to 1981 and been an effective instrument in increasing the acreage of pine monocultures. Kilgore and Blinn (2004) suggested cost-share programs to be one of the most effective policy tools for encouraging sustainable timber harvesting practices based on a survey of forest management organizations and state foresters in the U.S. and Canada. Using remote sensing data, Drummond and Loveland (2010) concluded that the CRP had promoted afforestation in the Eastern U.S. in the 20th century. The impact of public cost-share programs has also been evaluated in Europe with positive and statistically significant effects on forest management (Ovaskainen et al., 2006; Siikamäki and Layton, 2007).

Nevertheless, Bastos and Lichtenberg (2001) questioned the claimed success and broader impact of cost-share programs in addressing environmental concerns, and argued that, for instance, cost-share funding in Maryland was mainly used for land productivity and profitability instead of conservation over the 1994–1996 period. Valdivia and Poulos (2009) suggested that CRP payments do not have a statistically significant effect on landowners' attitudes toward adopting riparian buffers, strips of forests or grass land between agricultural land and water sources to reduce agricultural run-off.

## 3. Analytical framework

PSM has been developed as a methodological approach to correct for bias introduced during treatment selection or program participation process (Heckman et al., 1997a, b; Rosenbaum and Rubin, 1983, 1985). This method uses a quasi-experimental technique to mimic a randomization process through re-sampling (Apel and Sweeten, 2009; Liu and Lynch, 2011). A propensity score corresponds to the estimated probability for a given participant (forest owner) to take part in a treatment (cost-share program participation). The propensity score values are then used to match program participants and non-participants and exclude unmatched ones from the estimation of participation effects (Dehejia and Wahba, 1999). This method has been demonstrated to be an improvement in estimating treatment effects over methods without data re-sampling (LaLonde, 1986; Dehejia and Wahba, 1999, 2002).

In a PSM model, participation in a program refers to a treatment that may influence a vector of output variables $Y$. In this study the treatment was participation in cost-share programs, and output variables corresponded to stated past forest management operations and intended future forest land changes. Let the value of $Y$ be $Y_1$ after treatment and $Y_0$ before treatment, $D$ be a cost-share participation indicator ($D = 1$ for cost-share participation, 0 otherwise), and $X$ be a vector of observable variables affecting both participation of a forest landowner in a cost-share program and $Y$.

A binary model can estimate the propensity score (Heckman et al., 1998b; Imbens, 2000; Rosenbaum and Rubin, 1985). A probit model for computing propensity scores can be expressed as in Eq. (1).

$$\begin{aligned} D^* &= X'\beta + \varepsilon \\ D &= 1 \text{ if } D^* > 0, \text{ otherwise } D = 0, \end{aligned} \tag{1}$$

where $D^*$ is a latent variable, $\beta$ is a coefficient vector, and $\varepsilon$ is a random error with a normal distribution and mean zero. The propensity score is given by $p(X) = \Phi(X'\beta)$, which denotes a cumulative density function of the normal distribution. The probit model assumes $\varepsilon = D^* - X'\beta$ has a standard normal distribution, and thus $\beta$ can be estimated by maximum likelihood (Greene, 2002). The marginal effect of $X$ on the propensity score is $\mathrm{d}p(X)/dX = \beta'\phi(X'\beta)$, where $\phi(X'\beta)$ is the normal distribution density with argument $X'\beta$.

By PSM, a value of propensity score $p(X)$ was used to match a cost-share program participant with a nonparticipant. One-to-one nearest neighboring matching without replacement has been proposed for estimation with a large sample (Austin, 2007; Dehejia and Wahba, 2002) and was used in this study. Each treated observation was matched with one untreated observation, and the matched untreated observation was only used for one treated observation. Following Dehejia and Wahba (2002), observations were randomly ordered before matching to eliminate order effect, and the first participant were matched with the non-participant whose propensity score is closest to that of the first participant. Both the matched participant and non-participant were excluded from subsequent matches. Such a matching cycle was repeated until all participants were matched. The matched participants and non-participants were then used in the treatment effect estimation. The average treatment effect on a participating landowner is given by:

$$T = \frac{1}{n}\sum_{i=1}^{n}\{[Y_{1i}|p(X_{1i}),\ D=1]-[Y_{0i}|p(X_{0i}), D=0]\}, \tag{2}$$

where $n$ is the number of family forest owners participating in a cost-share program, $Y_{1i}$ is the observed $Y$ of the $i$th participant with an explanatory variable vector $X_{1i}$, and $Y_{0i}$ is the observed $Y$ of the $i$th matched non-participant with an explanatory variable vector $X_{0i}$.

To ensure the similarity of matched forest landowners, common support and covariate balance is essential for the PSM. Common support requires each participant to have a positive probability to be a non-participant. Excluding treated observations with propensity scores outside the range of scores for the untreated observation is an effective method to achieve common support (Caliendo and Kopeinig, 2008). In this study, two-sample *t*-tests explored the matching balance between the two groups for each individual covariate in *X* and ensured equivalent distributions of each covariate for the participants and nonparticipants. Likelihood ratio tests checked the overall covariate equivalence of the two groups of matched family forest landowners (Caliendo and Kopeinig, 2008). It is worth noting that when the number of variables in *X* is large, some statistically insignificant variables shall be dropped from the model to avoid over-parameterization (Caliendo and Kopeinig, 2008). Following Caliendo and Kopeinig (2008), Akaike Information Criterion (AIC) with a default critical value 9.4% of an automatic model selection command for the software STATA was used to reduce noise from redundant variables and enhance the balance of covariates in the matched sample.

Forest management activities (*Y*) from the NWOS were codified as binary values. This brings an empirical estimation challenge because there are no reliable estimates for the variances of values of *T* (Eq. (2)) for binary dependent variables. Hence, the McNemar test recommended by Austin (2011) was used in this study. To ensure the robustness of our results from one-to-one matching method, alternative matching methods such as multiple matching and local linear regression matching were applied to the original dataset, and their results were compared to those from the one-to-one nearest neighboring matching.

As with any other empirical applications this research is not free of practical limitations. This study was only capable of exploring the association between forest management and cost-share participation in general. Original data prevented us from investigating individual cost-share programs. In this regard, our findings are generalizable to the use of cost-share programs as a public policy tool to influence land management and cannot be used to evaluate particular federal or state programs. It is also worth mentioning the caveat of relying on self-reported answers from the NWOS. Adoption of past and intend to engage in future management practices was not observed directly but assumed to be as reported by respondents. This study was also limited by our inability to include natural resource descriptors for the forest ownership of a particular respondent. For instance, stand composition, terrain, soil characteristics and other biophysical variables can be important considerations in a landowner's decision to enroll in a cost-share program. Data availability and protection for the anonymity of responses in the NWOS prevented us from adding more detailed information about specific forest ownerships.

## 4. Variables and data

Family forest owners were assumed to make decisions regarding forest land management and cost-share participation to maximize utility derived from forest ownership. Variables for forest land management practices (*Y*) and participation in cost-share programs (*D*) were deemed endogenous to the forest management optimization process. A total of 13 land management variables representing past and intended management activities were investigated in our model (Table 1).

Stated past and intended future land management practices (*Y*) were modeled as a function of explanatory variables (*X*) including: (a) landowner demographics, (b) forest area and location, (c) acquisition of forest land, and (d) ownership objectives (Beach et al., 2005). All data used in this study came from the most recent NWOS for the U.S. Northern region (2002–2006 survey cycle). The NWOS is a national survey of forest landowners with one or more acres of forest in the U.S. The NWOS is part of the Forest Inventory and Analysis National Program coordinated by the U.S. Forest Service and samples forest owners using a stratified random technique (Butler et al., 2005; USDA Forest Service, 2011).

Demographic information including age, gender, race, education, and annual income described owners who made management decisions on behalf of the family (Esseks et al., 1992; Kline et al., 2000; Nagubadi and Zhang, 2005). The owner age values available in the NWOS data corresponded to mid-values of 10-year intervals used in the original survey and were set at 20 for owners under 25 and 80 for those older than 75. Likewise, household income values were mid-values of income intervals used in the NWOS. Forest area and location of forest captured forest land characteristics reported to influence land management practices (Kauneckis and York, 2009; Valdivia and Poulos, 2009). In this study, sub-region and distance to forest land from primary and secondary homes controlled for geographical differences.[1] The forest area used in this study corresponded to the total number (i.e. contiguous and non-contiguous plots) of forest acres held within a state by a family forest owner. The logarithm of forest acres was used to capture differences arising from land holding areas in our model because it has been shown to be linearly correlated with the probability of forest management (Butler and Leatherberry, 2004). Forest lands in our study have been acquired through purchase, gift, and/or inheritance. These variables were included in the model as it has been reported that the process of forest land acquisition may affect its management (Butler, 2008). Because the number of years of ownership is closely associated with the level of forest management experience, it was included as an explanatory variable. Forest lands are owned for multiple reasons including: timber, investment, aesthetic, biodiversity, privacy, legacy, firewood gathering, hunting, and recreation. Ownership reasons influence how forests have and will be managed in the future (Kline et al., 2000). Ownership reasons in the NWOS were self-reported using a 7-point rating scale (1 = Very important; 7 = Not important). In this analysis these values were re-coded to 1 to denote importance (i.e. original rate value <4) or 0 otherwise.

Following the suggestion of Larson (2004), family forest owners were categorized into groups based on number of acres of land in addition to including the logarithm of forest acreage to control for the effect of land holdings. Our trial estimations (not included in this manuscript) showed that the estimated coefficients of a PSM for landowner with at least 1000 acres were similar to those for owners with at least 100 cares but quite different from those for landowners with less than 100 acres. So, separate models for two groups of landowners were estimated. Group 1 or 'small owners' included owners of 10–99 acres of forest and Group 2 or 'medium to large forest owners' encompassed owners of at least 100 acres of forests. Owners with larger land holdings have greater incentives to manage forest intensively and could behave differently from owners with smaller forest parcels (Straka et al., 1984). The same propensity model was estimated for the two groups separately. It is worth mentioning that family forest owners with less than 10 acres of forest land were excluded from the analysis (Table 2) because of the extremely small proportion 0.1% of them participating in cost-share programs (compared to over 9% in the other two groups) and the challenge of conducting commercial forest management at such small scale (Butler and Leatherberry, 2004; Row, 1978).

All 13 management variables, 21 of the 25 explanatory variables, and the cost-share participation variable were binary. Table 2 presents mean values and ranges for variables included in the empirical estimation. The mean of a binary variable represents the proportion of observations with value 1 for the variable. Observations with missing values were excluded from estimations as suggested by Heiberger and Holland (2004). The number of years of forest ownership (*N_YR*) was calculated by subtracting the survey year from the year when the person acquired the land (Butler, 2008). We assumed that the length of ownership by only a current owner would affect forest management and values for *N_YR* were set to 70 when it was larger than 70 (Butler, 2008). Less than 1% of forest owners were affected by such a transformation. Mean values show differences between family forest owner groups.

[1] State-specific binary variables were proved not to be helpful in predicting cost-share participation in our preliminary analysis and were not included in the model.

**Table 1**
Types, names and definitions of variables used in the analysis of cost-share enrollment and forest management in the U.S. Northern region.

| Types of Variables | Names | Definitions |
|---|---|---|
| Treatment | *COST_SHARE* | Enrolled in a state or federal cost-share program = 1, otherwise = 0 |
| Demographics | *AGE* | Age, step-wise values for every 10 years from 20 to 80 |
| Demographics | *MALE* | Owner is male = 1, otherwise = 0 |
| Demographics | *NONWHITE* | Owner is non-white = 1, white = 0 |
| Demographics | *BACH_DGR* | B.S. is owner's highest education degree = 1, otherwise = 0[a] |
| Demographics | *ADV_DGR* | Master or Ph.D. is owner's highest education degree = 1, otherwise = 0[a] |
| Demographics | *INCOM* | Annual household income in U.S. thousand dollars, step-wise values |
| Forests area | *LFOREST_ACRE* | Logarithm of total forest land (in acres) |
| Forest location | *NORTHEAST* | Connecticut, Massachusetts, Maine, New Hampshire, Vermont or Rhode Island = 1, otherwise = 0[b] |
| Forest location | *MIDATLANTIC* | Delaware, Maryland, New Jersey, New York, Pennsylvania, or West Virginia = 1, otherwise = 0[b] |
| Forest location | *LAKESTATES* | Michigan, Minnesota or Wisconsin = 1, otherwise = 0[b]. |
| Forest location | *PRIM_HOME* | Forest is within 1 mile of owner's primary home = 1, otherwise = 0 |
| Forest location | *SECOND_HOME* | Forest is within 1 mile of owner's secondary home = 1, otherwise = 0 |
| Acquisition of forestland | *BOUGHT* | Forest was bought = 1, otherwise = 0 |
| Acquisition of forestland | *GIFTED* | Forest was a gift = 1, otherwise = 0 |
| Acquisition of forestland | *INHERITED* | Forest was inherited = 1, otherwise = 0 |
| Years of ownership | *N_YR* | Number of years of forest ownership |
| Ownership reason | *OBJ_TIMB* | Timber is an important ownership reason = 1, otherwise = 0 |
| Ownership reason | *OBJ_INVST* | Investment is an important ownership reason = 1, otherwise = 0 |
| Ownership reason | *OBJ_AESTH* | Aesthetics is an important ownership reason = 1, otherwise = 0 |
| Ownership reason | *OBJ_BIODIV* | Biodiversity is an important ownership reason = 1, otherwise = 0 |
| Ownership reason | *OBJ_PRIVACY* | Privacy is an important ownership reason = 1, otherwise = 0 |
| Ownership reason | *OBJ_LEGACY* | Legacy is an important ownership reason = 1, otherwise = 0 |
| Ownership reason | *OBJ_FIREWD* | Firewood is an important ownership reason = 1, otherwise = 0 |
| Ownership reason | *OBJ_HUNT* | Hunting is an important ownership reason = 1, otherwise = 0 |
| Ownership reason | *OBJ_RECR* | Recreation is an important reason for the ownership 1, otherwise 0 |
| Future management | *F_BUY* | Will buy forest land = 1, otherwise = 0 |
| Future management | *F_AFFO* | Will convert non-forest land into forest land = 1, otherwise = 0 |
| Future management | *F_DEFFO* | Will convert forest land into non-forest land= 1, otherwise = 0 |
| Future management | *F_SELL* | Will sell forest land = 1, otherwise = 0 |
| Future management | *F_SUBDIV* | Will subdivide forest land into small tracts = 1, otherwise = 0 |
| Past management | *TIMB_HVST* | Harvested timber = 1, otherwise = 0 |
| Past management | *MANAG_PLAN* | Had written forest management plan = 1, otherwise = 0 |
| Past management | *TREE_PLANT* | Planted trees = 1, otherwise = 0 |
| Past management | *SITE_PREP* | Did site preparation = 1, otherwise = 0 |
| Past management | *FIRE_REDU* | Practiced fire hazard reduction = 1, otherwise = 0 |
| Past management | *ROAD_MAINT* | Conducted road maintenance = 1, otherwise = 0 |
| Past management | *HABITAT_IMP* | Improved wildlife habitat = 1, otherwise = 0 |
| Past management | *CHM_APPL* | Applied chemical = 1, otherwise = 0 |

[a] : No-degree is the baseline for educational categories.
[b] : Midwest (U.S. States of Iowa, Illinois, Indiana, Missouri, and Ohio) is the baseline for regional variables.

Compared to other landowners, those in a group 1 (10–99 acres) had a lower average level of education, lower income and fewer number of years of forest ownership, and adopted fewer management practices with the exception of fire reduction (10% adoption by both groups). About 9% of small landowners in group 1 have participated in cost-share programs while this ratio is 19% for large landowners in group 2.

## 5. Results

### 5.1. Cost-share program participation

The estimation of the probit model for cost-share participation started with all 25 explanatory variables in Table 1 plus an intercept. Models with the least AIC were used for analyses (Burnham and Anderson, 2002). After the AIC variable selection, the model for group 1 had 9 explanatory variables and that for group 2 had 12 (Table 3). The exclusion of some variables suggested that they were unlikely to be correlated with cost-share program participation. The significance level of the Likelihood Ratio tests for both probit models was less than 0.01, and the cost-share participation statuses of at least 82% of observations were predicted correctly by the models. Of the 16 explanatory variables included in the estimation, only 5 were common to both forest owner group models, suggesting noticeable management differences associated with area of forest ownership. Marginal effects of variables on the propensity score were calculated at corresponding means. In the case of binary variables the marginal effect captured effect of the discrete change from 0 to 1 on the participation propensity.

The coefficient of *NONWHITE* in the model for group 2 was significant at the 5% Type-I error level, and the marginal effect of this variable suggested that the propensity for a non-white owner in group 2 was on average 0.15 greater than that for a white owner. However, such difference was not found to be statistically significant among small forest owners in group 1. The coefficient of advanced degrees (*ADV_DGR*) of a family forest owner in group 1 was significant and exhibited the largest positive marginal effect (0.06) among all variables in the model for this group. The estimated marginal effect for this variable was the second largest (0.10) in group 2. These findings suggest that family forest owners with advanced degrees exhibited a much higher probability of cost-share program participation. *Ceteris paribus*, the significantly positive coefficient of *LFOREST_ACRES* for group 1 means that owners with larger forest area within group 1 were more likely to enroll in cost-share programs. However, forest acreage did not make significant differences in the propensity to participate in cost-share programs by large family forest owners.

The significantly negative coefficients for *MIDLANTIC* indicate that both large and small landowners in Mid-Atlantic sub-regions were less likely to participate in cost-share programs than those in Midwest, else constant. However, only small landowners in the Northeast sub-region, as denoted by the coefficient of *NORTHEAST,* were significantly less likely to participate in cost-share programs than those in the Midwest. *Ceteris paribus*, having forest within 1 mile of owner's secondary

**Table 2**
Mean values of variables used in the PSM estimation for two groups of family forest owners with different forest ownership sizes.

| Variables | Group 1 10 to 99 Acres | Group 2 ≥100 Acres | Range of Values |
|---|---|---|---|
| *COST_SHARE* | 0.09 | 0.19 | 0, 1 |
| *MALE* | 0.87 | 0.91 | 0, 1 |
| *NONWHITE* | 0.02 | 0.03 | 0, 1 |
| *ADV_DGR* | 0.13 | 0.17 | 0, 1 |
| *LFOREST_ACRE* | 3.63 | 5.51 | 2.30–4.60 for group 1<br>4.61–12.64 for group 2 |
| *NORTHEAST* | 0.07 | 0.11 | 0, 1 |
| *MIDATLANTIC* | 0.19 | 0.20 | 0, 1 |
| *PRIM_HOME* | 0.66 | 0.58 | 0, 1 |
| *SECOND_HOME* | 0.19 | 0.34 | 0, 1 |
| *BOUGHT* | 0.87 | 0.86 | 0, 1 |
| *N_YR* | 22.76 | 26.66 | 0–70 |
| *OBJ_TIMB* | 5.14 | 4.10 | 1–7 |
| *OBJ_AESTH* | 2.04 | 2.08 | 1–7 |
| *OBJ_BIODIV* | 2.58 | 2.60 | 1–7 |
| *OBJ_PRIVACY* | 2.57 | 2.61 | 1–7 |
| *OBJ_FIREWD* | 4.82 | 4.64 | 1–7 |
| *OBJ_RECR* | 3.55 | 3.13 | 1–7 |
| *F_BUY* | 0.10 | 0.20 | 0, 1 |
| *F_AFFO* | 0.03 | 0.04 | 0, 1 |
| *F_DEFFO* | 0.02 | 0.05 | 0, 1 |
| *F_SELL* | 0.06 | 0.10 | 0, 1 |
| *F_SUBDIV* | 0.01 | 0.02 | 0, 1 |
| *TIMB_HVST* | 0.59 | 0.78 | 0, 1 |
| *MANAG_PLAN* | 0.09 | 0.25 | 0, 1 |
| *TREE_PLANT* | 0.25 | 0.30 | 0, 1 |
| *SITE_PREP* | 0.09 | 0.13 | 0, 1 |
| *FIRE_REDU* | 0.10 | 0.10 | 0, 1 |
| *ROAD_MAINT* | 0.30 | 0.49 | 0, 1 |
| *HABITAT_IMP* | 0.14 | 0.27 | 0, 1 |
| *CHM_APPL* | 0.09 | 0.14 | 0, 1 |
| Number of observations used in estimation | 2564 | 1044 | |

home (*SECOND_HOME*) and acquiring the forest land by purchasing (*BOUGHT*) increased the probability to participate in cost-share programs in group 2 by 0.08 and 0.09, respectively. The marginal effect of years of ownership on the probability to participate in cost-share programs was estimated to be 0.001 per year or 0.01 per 10 years for small land owners (group 1).

Results also show that owners with timber production as an important objective (*OBJ_TIMB*) in both groups were less likely to participate in cost-share programs. This could be a result of the fact that enrollment in cost-share programs often restricts forest harvest. It is not clear however why owners with strong biodiversity objectives (*OBJ_BIODIV*) in both groups showed a lower likelihood to participate in cost-share

**Table 3**
Probit model coefficients, $p$-values and marginal effects for family forest owner participation in cost-share programs in the U.S. Northern region.

| Dependent Variable *COST_SHARE* | Group 1 Forest Ownership: 10 to 99 Acres ($n = 2594$) | | | Group 2 Forest Ownership: ≥100 Acres ($n = 1044$) | | |
|---|---|---|---|---|---|---|
| Explanatory Variables | Coefficient | $p$-value | Marginal Effect on $p(X)$ | Coefficient | $p$-value | Marginal Effect on $p(X)$ |
| *Landowner demographics* | | | | | | |
| *MALE* | 0.096 | 0.41 | 0.01 | | | |
| *NONWHITE* | | | | 0.496 | 0.05 | 0.15 |
| *ADV_DGR* | 0.382 | <0.01 | 0.06 | 0.370 | <0.01 | 0.10 |
| *Forest area and location* | | | | | | |
| *LFOREST_ACRE* | 0.271 | <0.01 | 0.04 | | | |
| *NORTHEAST* | −0.399 | 0.02 | −0.04 | −0.162 | 0.31 | −0.04 |
| *MIDATLANTIC* | −0.286 | 0.01 | −0.04 | −0.345 | 0.01 | −0.08 |
| *PRIM_HOME* | 0.116 | 0.15 | 0.02 | | | |
| *SECOND_HOME* | | | | 0.300 | <0.01 | 0.08 |
| *Acquisition of forest land* | | | | | | |
| *BOUGHT* | | | | 0.412 | 0.01 | 0.09 |
| *Ownership: Years and objectives* | | | | | | |
| *N_YR* | 0.010 | <0.01 | 0.001 | | | |
| *OBJ_TIMB* | −0.095 | <0.01 | −0.01 | −0.137 | <0.01 | −0.03 |
| *OBJ_AESTHET* | | | | 0.061 | 0.18 | 0.01 |
| *OBJ_BIODIV* | −0.094 | <0.01 | −0.01 | −0.111 | <0.01 | −0.03 |
| *OBJ_PRIVACY* | | | | 0.061 | 0.02 | 0.02 |
| *OBJ_FIREWD* | | | | 0.095 | <0.01 | 0.02 |
| *OBJ_RECR* | | | | −0.049 | 0.06 | −0.01 |
| *CONSTANT* | −2.059 | <0.01 | | −1.153 | <0.01 | |
| *Percent predicted correctly (%)* | 91 | | | 82 | | |
| *Log-likelihood ratio test p-value* | | <0.01 | | | <0.01 | |

programs than other owners. Large owners who identified privacy (*OBJ_PRIVACY*) and firewood (*OBJ_FIREWD*) as important reasons for forest ownership were more likely to participate in cost-share programs, possibly because these owners were less prone to harvest their forest for timber production. The estimated effects of other variables were either statistically insignificant at the 5% Type-I error level or had been excluded from the model.

### 5.2. Propensity score matching and cost-share program effects

The association between cost-share participation and each of the 13 stated past and intended future management variables was estimated separately using Eq. (2). The number of owners enrolled in cost-share programs in groups 1 and 2 were respectively 229 and 193, while the number of landowners in these categories totaled 2594 and 1044, respectively (Table 4). All cost-share participants in group 1 were matched with non-participants. The propensity score of 3 participants in group 2 were out of the range of those of non-participants in the same group and therefore were not matched. The two-sample *t*-tests (one sample of participants and one sample of nonparticipants) for all the 16 explanatory variables included in the probit models indicated that the distribution of these variables were not significantly different at the 5% Type-I error level, suggesting that the matched groups of forest land owners had equivalent distribution for each covariates. The likelihood ratio test result for the overall covariate balance failed to reject the null hypothesis (Type-I error = 0.38) that the distributions of the covariates were the same, supporting the results of the two-sample *t*-tests. Hence PSM was deemed valid.

Table 4 shows estimated differences of proportions of cost-share participant and non-participant family forest owners with "1" values for each of the management variables. Results with alternative 1-to-3, 1-to-5, and local linear regressing matching methods included in the Appendix A show strong congruence among matching methods and the insensitivity of matching methods. The estimated differences represent cost-share program participation effects on land management variables. Because all management variables were binary, an estimated average effect after PSM conceptually implies an estimated change in proportions of owners who adopted (or would in the future) forest land management practices as a result of cost-share program participation.

According to differences (Δ) in Table 4, changes in the proportion of forest owners associated with cost-share participation were very different between small and large forest owner groups. The estimated values for four management variables (written management plan, tree planting, site preparation and chemical application) were statistically significant for both groups of family forest owners. However, there were three forest management practices (forest subdivision, road maintenance, wildlife habitat improvement) for which estimated changes were significant for one group of forest owners but not for the other. All statistically significant differences in forest management activities were positively associated with cost-share participation. For group 1 of family forest owners (smaller acreage), cost-share participation had a significantly positive effect at 5% Type-I error level on adoption of forest management plan, tree planting, site preparation, habitat improvement, and chemical application. Cost-share participants in group 1 are 76% more likely to adopt wildlife habitat improvement practices (from 0.17 for non-participants to 0.30 for cost-share participants) and 283% more likely to engage in site preparation (from 0.06 for non-participants 0.23 for cost-share-participants) than their counterpart nonparticipation in the same group. Group 1 landowners enrolled in a cost-share program were 133% more likely to have conducted tree planting compared to non-participants.

For family owners of larger forest acreage (group 2), cost-share participation was estimated to have significantly positive impacts at the 5% Type-I error level on stated future forest subdivision, forest management plan, tree planting, site preparation, road maintenance and chemical application. These results suggest increases in the proportion of large family owners by 19% for road maintenance (from 0.52 for non-cost-share-participants to 0.62 for cost-share-participants), 300% for future forest division (from 0.01 to 0.04), and about 222% of site preparation (from 0.09 to 0.29).

Cost-share program participation was estimated to have no statistically significant association with stated future activities except future forest subdivision by owners in the large family forest land group. Results also suggest that timber production and fire hazard reduction management by both owner groups, road maintenance by the small land owner group, and habitat improvement by the large group were not significantly linked with cost-share program participation.

## 6. Implications and discussion

Major differences in rates of cost-share participation were found between small and large family forest land owners and across geographical sub-regions. Family forest land owners in the larger acreage group showed a much greater level of enrollment than small forest land owners. The coefficients of sub-region variables in the propensity score estimation model suggest that family forest owners in the Northeast and Mid-Atlantic states had significantly lower levels of participation than those in the Midwest after other factors were controlled for. Although our model could not confirm what specific regional circumstances resulted in this lower level of participation, this finding suggest that states in the Northeast and Mid-Atlantic regions could potentially increase their level of cost-share program participation.

**Table 4**
Proportions of family forest owners performing certain forest management and proportional differences between cost-share participants and PSM matched nonparticipants in the U.S. Northern region by two owner groups.[a]

| Owner Groups by Forest Acres | Group 1 Forest Ownership: 10 to 99 Acres ($n$ = 2594) | | | Group 2 Forest Ownership: ≥100 Acres ($n$ = 1044) | | |
|---|---|---|---|---|---|---|
| Management Variable | Cost-share Participant (229) | Non-Participant (2365) | Δ | Cost-share Participant (193) | Non-Participant (848) | Δ |
| *F_BUY* | 0.10 | 0.12 | −0.01 | 0.30 | 0.22 | 0.08 |
| *F_AFFO* | 0.07 | 0.03 | 0.03 | 0.09 | 0.05 | 0.04 |
| *F_DEFFO* | 0.01 | 0.02 | <0.01 | 0.04 | 0.03 | 0.01 |
| *F_SELL* | 0.07 | 0.06 | 0.01 | 0.11 | 0.13 | −0.02 |
| *F_SUBDIV* | 0.01 | 0.02 | −0.01 | 0.04 | 0.01 | 0.03 |
| *TIMB_HVST* | 0.74 | 0.71 | 0.03 | 0.85 | 0.82 | 0.03 |
| *MANAG_PLAN* | 0.35 | 0.12 | 0.23 | 0.64 | 0.20 | 0.44 |
| *TREE_PLANT* | 0.42 | 0.18 | 0.24 | 0.45 | 0.34 | 0.11 |
| *SITE_PREP* | 0.23 | 0.06 | 0.17 | 0.29 | 0.09 | 0.20 |
| *FIRE_REDU* | 0.10 | 0.09 | 0.01 | 0.12 | 0.12 | 0.00 |
| *ROAD_MAINT* | 0.38 | 0.33 | 0.05 | 0.62 | 0.52 | 0.10 |
| *HABITAT_IMP* | 0.30 | 0.17 | 0.13 | 0.34 | 0.30 | 0.04 |
| *CHM_APPL* | 0.18 | 0.09 | 0.09 | 0.23 | 0.12 | 0.11 |
| *Unmatched participants* | | 0 | | | 3 | |

[a] : Underlined numbers indicate differences statistically significant from zero at 5% Type-I error level by McNemar test. Numbers in some cases may not match because of rounding.

The statistically significant coefficients in Table 4 imply that cost-share programs were positively associated with various forest management practices. For example, the promotion of silvicultural management such as tree planting, site preparation, road maintenance and chemical application activities are significantly and positively associated with cost-share participation in one or both groups of forest landowners. The significant coefficients for the forest management plan variable *MANAG_PLAN* were expected, because these are required by cost-share programs such as WHIP and FLP. These forest management plans can potentially help maintain or increase existing forest area, improve forest health and wildlife habitats, and protect water source and soil.

The magnitudes of the association of cost-share participation and forest management showed a discrepancy between the two family forest owner groups. Under the objective of greater adoption of cost-share programs among family forest owners, different policy strategies should be adopted. For example, 17% of nonparticipants in group 1 implemented habitat improvement practices, but this level of such implementation significantly increased to 30% when forest land owners participated in a cost-share program, indicating 13% change in the ratio of land owners practicing habitat improvement. The change in this ratio as result of cost-share participation in group 2 was estimated to be small (4%) and insignificant, from 30% for nonparticipants and 34% for participants. Hence, promoting such practices by land owners with less than 100 acres could be potentially more effective these owners hold about 40% of the total family forest land in the U.S. Cost-share participation was associated with a greater change in proportion (24%) of small owners who plant trees while such change was much smaller (11%) for large owners. The positive effect of cost-share participation on tree planting is consistent with previous studies (e.g. Bullard and Straka, 1988; Flick and Horton, 1981; Royer and Moulton, 1987). While Lee et al. (1992) and de Steiguer (1984) reported a positive effect of cost-share participation on timber harvest in the U.S. South, this study using more recent data did not find a significant effect of cost-share on timber production in the North although the coefficients were positive too.

Out of the five owner-stated future management activities only future subdivision of forest land by family forest land owners with at least 100 acres was significantly and positively associated with cost-share participation. Further research is needed to explain why cost-share participation was positively linked with stated future forest land subdivision by large forest owners. The estimated impact of cost-share participation on future subdivision by small land owners in group 1 was negative but statistically insignificant.

## 7. Conclusion

This study used binary models to investigate cost-share program participation by family forest owners in the U.S. Northern region. Thirteen out of 25 explanatory variables capturing information about family forest owners' demographics, forest area and location, acquisition of forest land, and ownership reasons were shown to be significantly associated with family forest owners' cost-share participation. It was found that family owners with at least 100 acres of forest were more likely to enroll in cost-share programs. Reasons to participate in cost-share programs were quite different between family owners in different acreage categories.

The association of cost-share participation on both silvicultural and conservation practices was generally positive. Results suggest that cost-share programs targeting family owners of smaller sized forests could be more effective in achieving these conservation objectives. Cost-share program participation showed stronger association with tree planting among this group of family forest owners than those with at least 100 acres of forest in the U.S. Northern region. However, a greater proportion of large forest owners could enhance other silvicultural management (site preparation, road maintenance, and chemical application) as a result of cost-share participation compared with family owners of smaller sized forests. Family owners of smaller sized forests had a lower level of cost-share participation than large owners, highlighting the potential for greater enrollment. Moreover, cost-share participation rates in the Northeast and Mid-Atlantic sub-regions would be lower than that in the Midwestern if other variables were equal. Further efforts to promote conservation through cost-share programs in these sub-regions might be needed. Also important, this study did not find statistically significant evidence of an inverse association between cost-share program enrollment and past timber supply.

## Appendix A

Differences in the proportion of forest management activities practiced by forest cost-share participants and nonparticipants [1 to 3, 1 to 5, and llr represent 1-to-3 matching, 1-to-5 matching and local linear regressive matching PSM methods, respectively].

| Owner groups by forest acres | Group 1 10 to 99 acres | | | Group 2 100 to 999 acres | | |
|---|---|---|---|---|---|---|
| Management variable | 1 to 3 | 1 to 5 | llr | 1 to 3 | 1 to 5 | llr |
| *F_BUY* | 0.01 | 0.01 | 0.01 | 0.06 | 0.07 | 0.07 |
| *F_AFFO* | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 |
| *F_DEFFO* | −0.01 | −0.01 | −0.01 | −0.02 | −0.01 | −0.01 |
| *F_SELL* | 0.02 | 0.03 | 0.03 | −0.02 | −0.01 | −0.01 |
| *F_SUBDIV* | −0.01 | −0.01 | −0.01 | 0.04 | 0.03 | 0.02 |
| *TIMB_HVST* | 0.06 | 0.06 | 0.08 | 0.03 | 0.04 | 0.05 |
| *MANAG_PLAN* | 0.26 | 0.26 | 0.27 | 0.43 | 0.43 | 0.42 |
| *TREE_PLANT* | 0.21 | 0.20 | 0.18 | 0.13 | 0.14 | 0.15 |
| *SITE_PREP* | 0.15 | 0.14 | 0.14 | 0.18 | 0.17 | 0.17 |
| *FIRE_REDU* | −0.02 | −0.02 | −0.01 | 0.01 | 0.01 | 0.01 |
| *ROAD_MAINT* | 0.09 | 0.07 | 0.07 | 0.11 | 0.12 | 0.10 |
| *HABITAT_IMP* | 0.13 | 0.13 | 0.14 | 0.03 | 0.03 | 0.05 |
| *CHM_APPL* | 0.09 | 0.09 | 0.09 | 0.09 | 0.10 | 0.10 |

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