

Do property tax benefits for forest landowners work? A review of effectiveness at retaining and promoting active management of private forests

Gregory E. Frey

U.S. Department of Agriculture, Forest Service, Southern Research Station, P.O. Box 12254, Research Triangle Park, NC 27709, USA

HIGHLIGHTS

- Past research explored effectiveness of preferential forest property tax programs.
- Moderate evidence of a weak impact on retaining forestland.
- Little evidence of any impact on increasing active forest management.
- Conserving forestland and increasing management may require different policies.
- Past research has potential biases.

ARTICLE INFO

Keywords:

Policy effectiveness
Preferential forest property tax programs
Family forest owners

ABSTRACT

Over the past several decades, concern about loss of forest-based ecosystem services has caused all fifty states to adopt programs to lower property taxes on enrolled private forestland. Although there has been a moderate amount of research on the effectiveness of these preferential forest property tax programs (PFPTPs), most studies only assess individual states, explore perceptions without an empirical basis, or present seemingly contradictory findings. This manuscript presents a systematic review of literature to determine the strength of evidence supporting PFPTPs' effectiveness at retaining and also promoting active management of private forests. There is moderate evidence that PFPTPs reduce forest land-use change, parcelization, or sales, although the effect apparently is relatively weak. There is very little evidence that PFPTPs encourage more active forest management. To design a PFPTP that does more to retain forests, studies indicate that a PFPTP may need fewer requirements and rules, whereas to encourage active management a PFPTP may need more. Thus, greater clarity of policy goals will help determine which approach is merited.

1. Introduction

Forests provide numerous beneficial ecosystem services for society, including regulation of air and water quality, provision of timber and non-timber products, sequestration and storage of carbon, and provision of habitat for wildlife (Millennium Ecosystem Assessment, 2005). Since most forests in the United States are privately-owned (Oswalt et al., 2019; Sass et al., 2020), losses of private forests to other, more profitable, land uses can markedly impact the level of these ecosystem services. Beyond this, within private forests that continue to exist, an overall lack of active management and investment limits benefits such as timber, carbon sequestration, etc. (Adams et al., 1982; Malmshheimer et al., 2008). Thus, U.S. institutions have dedicated substantial research,

resources, and policy debate to the twin tasks of retaining private forests and incentivizing active management (Best, 2002; Straka, 2011).

In the United States, direct public payments to incentivize private landowners to provide forest-based ecosystem services have declined by almost 25 % in real terms over the last decade (Frey et al., 2021), and despite the emergence of ecosystem service markets, existing payment mechanisms do not fully compensate most landowners for the societal benefits the forests they own provide. Thus, a major method to incentivize and indirectly compensate forest landowners has emerged through federal and state tax law. In particular, all fifty states offer reduced property taxes to forestlands that enroll in a preferential forest property tax program (PFPTP) (Kilgore et al., 2018a, b). While laws and regulations often do not clearly state the specific objectives of these

E-mail address: gregory.e.frey@usda.gov.

<https://doi.org/10.1016/j.landurbplan.2022.104647>

Received 5 April 2022; Received in revised form 8 November 2022; Accepted 20 November 2022

0169-2046/Published by Elsevier B.V.

PFPTPs, stated justifications frequently include the promotion of various ecosystem services such as provision of timber, maintenance of scenic values, habitat for fish and wildlife, and recreation (Kilgore et al., 2018a).

A moderate amount of literature has emerged assessing the effectiveness of PFPTPs in retaining forestlands and incentivizing active forest management the U.S.; however, these studies often address single states, utilize disparate methodologies, and sometimes present seemingly contradictory results. Understanding the implications of this body of work is elusive. I reviewed and synthesized this past work to generate lessons to aid future research and policy development.

1.1. Objectives

The objectives of this research involved understanding how preferential forest property tax programs (PFPTPs) impact private forest land and landowners. Specifically, I hoped to address the following research questions, based on existing, peer-reviewed, scientific literature:

- (1) Does enrollment in a PFPTP make retention of private forest parcels in the United States more likely (effectiveness at the extensive margin)?
- (2) Does enrollment in a PFPTP make private forest landowners in the United States more likely to undertake more active forest management activities than they would otherwise (effectiveness at the intensive margin)?

I define “retention” of private forestland in Objective 1 broadly as forestland continuing as forest land use under the same ownership. This implies the avoidance of conversion (e.g., development), sale, and parcelization. In reality all three of these processes are distinct, and one does not necessarily lead to another. However, researchers and policy-makers generally view parcelization and sale to be highly linked to each other and to be frequent precursors of conversion, which increase the likelihood of forest loss (see, e.g., Gobster and Rickenbach, 2004; Kilgore, 2014; Ko and He, 2011; Mundell et al., 2010; Stone and Tyrrell, 2012).

I define “active forest management” in Objective 2 as any activity conducted in the forest to modify forest structure or ecology, or to facilitate such modification, including planting or cutting trees, mechanical or chemical control of plants or animals, prescribed fire, infrastructure development, etc.

2. Background

2.1. Private forest owners in the United States

Since government-owned lands, including land held in trust (e.g., for tribes) do not pay property taxes, privately-owned forests are the relevant focus of this inquiry. Private forest ownerships constitute 58 % of forestland in the United States, although the distribution is not even, with private ownership covering 81 % of eastern but only 30 % of western U.S. forests (Oswalt et al., 2019). Among private categories, families own approximately 65 %, corporations 25 %, timber investment management organizations (TIMOs) and real estate investment trusts (REITs) 8 %, and other groups (such as conservation organizations, associations, and private land owned by tribes) 2 % (Sass et al. 2020).

Family forest owners (in the past, this term has overlapped significantly with “non-industrial private forest” (NIPF) owners) are the largest single forest landowning group in the U.S., and a particularly heterogeneous one, so the literature dedicates significant attention to them. A broad overview of family forest issues and research is beyond the scope here, but some key reviews and summaries of the family forest literature include Aguilar and Kelly (2019), Floress et al. (2019), Mayer (2019), and Straka (2011). Family forest owners vary widely in area owned, reasons for owning, activities pursued on their land, as well as concerns

and motivations for the future (Butler et al., 2021a; Finley and Kittredge, 2006). In general, however, concern about taxes, participation in a PFPTP, more active management, and harvest of timber are positively correlated with larger land area owned (Butler et al., 2021b). Still, for most family forest owners, financial issues are simply one among many motivations and concerns (Koontz, 2001).

2.2. Voluntary financial incentive programs for forest owners

Because family forests and other private ownerships in the U.S. are responsible for generating such a large portion of the nation’s ecosystem services, governmental and non-governmental organizations have developed a large number of voluntary financial incentive programs to move them towards retaining those lands and more actively managing them. These generally can be grouped into two types: direct payments and tax incentives. Direct payments to private forest landowners have averaged about \$3.3 billion (2015 dollars) per year (Frey et al., 2021) and include public government programs (such as “cost-sharing” programs that pay a portion of the cost of conducting some activity), compliance transactions (such as credits or offsets bought and sold through a market created by a law or regulation), and voluntary markets. Tax incentives include income tax incentives and property tax incentives, the latter of which is the focus of this inquiry. Although the magnitude of income tax incentives is unknown, Kilgore et al. (2018a) estimated that PFPTPs lower participants’ cumulative property taxes owed by \$1.6 billion (2014 dollars) in 2014, to landholdings totaling 85 million ha. This area of land participating in PFPTPs is multiple orders of magnitude larger than that participating in direct government payments (Frey et al., 2021).

Participation in voluntary financial incentive programs for forest owners is generally low nationwide (Aguilar and Kelly, 2019), although there are important differences by region and state (Frey et al., 2019). In general, one of the strongest correlates of participation in these programs is level of knowledge or awareness of the program itself, although this might be a case of at least partial reverse causation (participation in a program leads one to be more aware of it) (Aguilar and Kelly, 2019; Floress et al., 2019; Frey et al., 2019). Education and age also are landowner characteristics frequently linked to participation (Floress et al., 2019; Frey et al., 2019). However, land parcel and program characteristics may be more important drivers of enrollment (Frey et al., 2019).

2.3. Forest property tax history and research

Taxation has historically been a topic of great interest, passion, and at times controversy within the forestry community, and between the forestry community and other sectors of society in the United States. Historically, property tax applied to both the value of the land itself, as well as the value of the standing timber on it (Colligan, 2000; Shaw, 1907). Proponents of forest management believed the taxation of standing timber as real property to be a disincentive to owning and investing in forests, because of the long investment period in timber, haphazard appraisal rules, and the fact that agricultural crops were not taxed (Fairchild, 1908). Evidence of this disincentive included observations of destructive timber cutting, lack of replanting, underinvestment, eroded watersheds, and land forfeiture (Fairchild, 1908; Shaw, 1908).

Researchers explored theoretically numerous forms of forest taxation, work which continues to the present, seeking tax systems in which forests would pay their fair share but not be unfairly disincentivized, as well as not encourage changes away from sound management (e.g., Amacher, 1997; Chang, 1982, 2018a; Koskela and Ollikainen, 2001). Spurred by the work of Fairchild (1935), a consensus emerged in the first half of the 20th century that annual taxation of bare land would be neutral in the sense that it would not change the optimal management for the land, and annual taxation of timber would be replaced with a

yield or severance tax, applied when timber was cut. Despite relatively slow adoption of site value plus severance/yield tax by state legislatures (Haines, 1995; Williams, 1961), this view of the optimal taxation regime for forests remained common among foresters and forest landowners through at least the 1980s (Bare, 1990).

At the same time, the reality on the ground was already shifting (Colligan, 2000). The mass production of automobiles and post-war movement to suburban and exurban communities put new development pressure on forests. While previous generations of foresters feared denuded, barren landscapes and eroded soils (Fairchild, 1908), the new reality was subdivisions, strip malls, and parking lots. While previous generations believed annual taxation of timber disincentivized forestland because it imposed annual costs without annual income (Fairchild, 1935), the new reality was that taxation of land at the “highest and best” fair market value imposed strong financial disincentives on owning forestlands, when that “highest and best” use was for urban development (Colligan, 2000; Koontz, 2001; Sampson and DeCoster, 2000). At the same time, the growing environmental movement also highlighted how human society depended on ecosystem services (Millennium Ecosystem Assessment, 2005).

Taxes in general reduce financial returns to forestry significantly, and property taxes can be the highest single tax (Cushing and Newman, 2018). Forest landowners and their advocates have suggested that high bills might force them to sell or parcelize (Butler et al., 2010; Olson, 1979; Stone and Tyrrell, 2012). Threatened by the potential loss of forest-based ecosystem services (Kernan, 1999), all fifty states eventually created PFPTs to lower property taxes for forests (Kilgore et al., 2018a). All these laws provide some form of justification based on provision of ecosystem services, most common of which is timber provision (Kilgore et al., 2018a).

Currently, PFPTs take various forms, which scholars classify as either exemptions, flat taxes, or modified taxes, the latter of which can be based on a modified rate or modified assessment (Hickman, 1989; Kilgore et al., 2018b). The most common of these at present is the modified assessment approach, in particular the “current use valuation” method (Kilgore et al., 2018b). Indeed, modified tax programs have increased over time to include 43 states in 2014, up from 35 in 1977 whereas exemption and flat tax programs combined for only 13 states in 2014 (Jacobson and McDill, 2003; Kilgore et al., 2018b). At the same time, the number of states with a yield or severance tax has apparently decreased from a high of 30 or more states (Hibbard et al., 2003) to about 20 or fewer (Greaves, 2009; Timber Tax, n.d.). Thus, it can be said that the new emerging consensus form of forest property taxation in practice, in response to the threat of development, is to tax forestland at low assessed values, usually based on the value of land for timber production and not the “highest and best” fair market value, and exempt timber from property taxation. This emerging consensus perhaps lacks the rigorous theoretical support that was present in the previous consensus. Further, the methods, rules, and valuation approaches employed are highly variable (Colligan, 2000; Kilgore et al., 2018b; Li, 2019).

3. Methods

3.1. Systematic review

This research used the approach as described by the Preferred Reporting Items for Systematic Reviews and meta-Analyses (PRISMA) Statement (Liberati et al., 2009; Moher et al., 2009), where applicable. The PRISMA Statement essentially is a list of items to include when reporting a systematic review. It was originally written with medical science in mind, so some items do not apply, but most of its principles and approaches are broadly applicable. The original protocol for this research was described in Study Plan SRS-4804-2-12 which can be obtained from the author.

Rephrasing the research questions stated in the Objective section

above in the language of systematic reviews (Moher et al., 2009), the participants, interventions, comparators, and outcomes (PICOs) are:

- Participants – private tax parcels with forest land use, or the owners of such parcels
- Interventions – enrollment in a PFPTP
- Comparators – non-enrollment in a PFPTP
- Outcomes – twofold: (1) intervention group on average has a higher percentage that remains in forest land use, is not sold, or not parcelized than comparator group; and (2) intervention group on average has more active forest management than comparator group.

Importantly, this study focuses on changes in behavior at the individual landowner level caused by enrollment in a PFPTP. It does not comprehensively review at the related and important question of what factors cause landowners to enroll.

3.2. Literature search

In November 2021, I performed searches in the databases Google Scholar and Web of Science (core collection). I used search terms to identify literature focusing on property taxes as they relate to forests or timber. Table 1 presents the search terms used in each database. I aimed to include literature exploring the research questions described in the Objectives section, to understand the PICOs described above. To be considered relevant for this systematic review, a manuscript must be about the PICOs described, within the U.S., from 1990 to present. The start year was somewhat arbitrary, but approximately aligns with the time period by which most states had established current-use value taxation or similar programs for forests (Eckhoff et al., 2007; England, 2002; Fortney and Arano, 2010; Newman et al., 2000). I included research published in refereed, scientific journals, as well as scientific theses and dissertations, proceedings papers, and technical reports when they reported results that were not otherwise published in refereed journals. I preliminarily reviewed titles in each of the search results to eliminate those that were clearly not relevant. I combined the search lists and removed duplicates. Within the relevant manuscripts, during the full-text assessments described below, I iteratively identified cited references that seemed to provide relevant information and added these records to my list. From these sources, I conducted two types of syntheses: qualitative and quantitative.

3.3. Quantitative synthesis

To be included in the quantitative synthesis, a study had to present some way of testing a hypothesis in an applied context, relevant to the research questions and PICOs. These included simulations, capital budgeting, and numerical models (hereafter “models”); stated preference, perception, or intention studies (hereafter “perception studies”); and observational or empirical studies (hereafter “empirical studies”). I included strictly theoretical formulations in the qualitative synthesis, but not the quantitative. Within the quantitative assessment, I placed

Table 1
Search terms used in the systematic review.

Search	Database	Search terms	# of results ^a
1	Google scholar	intitle:forest intitle:taxation “property”	178
2	Google scholar	intitle:forest intitle:tax “property”	212
3	Google scholar	intitle:timber intitle:taxation “property”	43
4	Google scholar	intitle:timber intitle:tax “property”	64
5	Web of science	forest* “property tax**”	115
6	Web of science	timber “property tax**”	22
	Other sources		34

^a Total number of results with no time-period restriction, prior to any screening or removal of duplicates.

more emphasis on the results of empirical research, as these are less dependent on the researchers' modeling assumptions or respondents' biases, and generally are considered to be the principal avenue by which the hypotheses formulated based on models or perception studies can be confirmed or rejected.

For research question/outcome 1, I identified and recorded research findings related to comparing land-use conversion, sale, or parcelization between enrolled and non-enrolled lands. For research question/outcome 2, I identified and recorded findings related to increased number, frequency, intensity, or overall conduct of forest management activities, between enrolled and non-enrolled lands. To merit inclusion in the quantitative synthesis, these findings had to be concrete results of the study in question, not the authors' discussion or speculation. For both questions, these findings took many different forms, and some interpretation was necessary. In addition, I recorded information about data sources, model type, and unit of analysis.

I conducted two types of vote-count methods on the combined results from outcomes described above. First, I used the "conventional" vote-counting procedure following [Light and Smith \(1971\)](#), as described in [Bushman and Wang \(2009\)](#). I determined if the research finding in each study was statistically significant at a 0.05 alpha-level ($p\text{-value} < 0.05$). If not, I noted the finding as not significant. If so, I noted the sign of the effect. In some cases, statistical significance was not a relevant measure – for example in studies using deterministic numerical models. In these cases, I relied on the authors' discussion of the results and my own judgment to determine if the magnitude of the impact was substantial enough to merit inclusion as a positive or negative effect; otherwise, I noted as "no substantial change." When a study tested the hypothesis in multiple ways, I counted each individual finding separately. Then, I counted the number of findings in each category (positive, negative, not significant), with the category containing the most findings being the "winner" ([Light and Smith, 1971](#)). This method has the benefit of simplicity and family forest researchers have used it previously (e.g., [Floress et al., 2019](#)). However, other scholars have criticized it because the power of the procedure is very small and is asymptotically zero when the statistical power of individual studies is small (i.e., when effect sizes and sample sizes of individual studies are small) ([Bushman and Wang, 2009](#); [Hedges and Olkin, 1980](#)).

Second, I conducted a vote count with "sign test," which partially addresses the critique of the conventional method ([Bushman and Wang, 2009](#)). I utilized the sign of the result in each study, regardless of whether it was statistically significant, thereby bypassing the impact of statistical power. If the independent variable has no effect on the dependent, one expects a positive sign about 50 % of the time. I used a simple binomial table to determine if the number of positive results is more than would be expected in that case, at a 0.05 significance level ([Bushman and Wang, 2009](#)). I conducted the sign test on two sets of studies – all studies in the quantitative synthesis, and only those classified as empirical.

[Bushman and Wang \(2009\)](#) propose several other tests related to vote counting, and various other forms of quantitative synthesis can be conducted based on measurements of effect sizes. Unfortunately, the studies in this sample were too heterogeneous (as described above) to have comparable effect measurements. Therefore, I was limited to the two quantitative vote count approaches described above: conventional and sign test.

3.4. Qualitative synthesis

Because study designs, locations, and the details related to PFPTPs and participation varied substantially, the value of the quantitative synthesis is somewhat limited. Therefore, I also qualitatively described studies, results, and key implications, paying particular attention to consistencies and inconsistencies between studies. To be included in this qualitative synthesis, a study had to present some novel idea, theory, or evidence, relevant to answering or explaining one or more of the

research questions, i.e., understanding the effect of the intervention on the outcomes. This qualitative synthesis helps provide greater nuance and understanding of the issues and impacts. This qualitative synthesis results in a narrative, which I incorporated into both the Results and Discussion sections.

Given the diversity of data and model types used, it was impossible to combine quantitatively the results in any way to create a meta-measure of magnitude of the effects, as discussed above. Where possible, I qualitatively assessed the magnitude as none, weak, moderate, strong, or inconclusive. Generally, I based this on the responses of the various survey or focus group respondents, or in the case of empirical measurement of the effect, on the authors' presentation of the results or their discussion. In some cases, the authors used terms with precise definitions (e.g., "elasticity" - the percentage change in outcome induced by a one percent change in intervention); where possible I translated these into weak, moderate, or strong (e.g., "inelastic" or an elasticity less than one I interpreted as weak).

3.5. Assessing risk of bias in individual studies

For each study, I assessed the relative potential for various types of bias. Systematic reviews of literature on health interventions frequently assess risk of bias using scales, checklists, or individual components ([Higgins and Altman, 2008](#); [Liberati et al., 2009](#); [Moher et al., 2009](#)); however, the specific tools available in the literature to my knowledge are generally focused on clinical trial research, with narrow bias criteria and specific indicators relevant for that type of work. The literature on PFPTPs, on the other hand, while much more limited in number, has a much wider array of methodologies. I found no previous relevant risk-of-bias assessment frameworks in the literature. Given the wide range of approaches, it was necessary for me to create a framework that would include a wide range of possible biases.

After a preliminary assessment of all the literature from the search above, I identified six broad classes of potential bias within individual studies ([Table 2](#)). Many of these were linked to the type of methodological approach taken. For example, projections of future outcomes are inherently uncertain. However, steps can be taken to mitigate the impact of that uncertainty on the work. Therefore, I created a rubric with a three-point scale for each risk-of-bias class: low (1), medium (2), and high (3). Low represents little likelihood of that class of bias in that methodological approach. Medium represents modest potential for that class of bias in that type of research, or strong potential but steps taken to mitigate the bias. High represents strong potential for bias and few or no steps taken to mitigate bias.

Because particular biases may have greater or smaller negative impact than others, depending on specifics, I determined it was not appropriate to sum the scores across classes, or otherwise create a single "bias risk score." The risk assessment, therefore, remains categorical and qualitative in nature.

3.6. Limitations

Systematic literature reviews are inherently limited by the search protocols used. In particular, the databases and search terms may omit certain manuscripts. Also, the preliminary review of results may inadvertently eliminate certain studies that seem unrelated at first, but provide valuable results. I mitigated the limitations of the databases by utilizing two databases (Google Scholar and Web of Science) that have a different group of manuscripts and search methods. Because Google Scholar searches manuscript full texts, unrestricted searches for terms such as "forest tax" produce many results of limited or no relevance. Therefore, I chose to restrict searches for certain terms in Google Scholar to titles only. Web of Science searches titles and abstracts only, and a more restricted set of high-quality sources (i.e., refereed scientific literature). I further mitigated any gaps that might come from databases, search terms, or inadvertent exclusions by iteratively assessing the

Table 2
Potential sources of bias in research, and rubric to qualify likelihood of bias.

Potential bias	Description	Low (1)	Medium (2)	High (3)
1. Uncertainty	When modeling future events, do researchers account for uncertainty?	No modeling of future.	Models or simulations of future events that incorporate sensitivity analysis or range of inputs.	Models or simulations of future events without accounting for uncertainty.
2. Assumptions	Do researchers assume a treatment will have outcomes like other decision parameters? Do researchers model one variable and assume a link to another outcome variable? Do researchers assume some process or functional form?	Limited underlying assumptions that affect process.	Models or simulations derived from empirically-based equations. Researchers check for robustness	Models of one variable (e.g., financial returns) with assumed link to another variable (e.g., land use).
3. Sample/ Non-response	Are there factors that make one group of respondents more or less likely to be sampled? Is a group more or less likely to participate (non-response)?	No response required, or census conducted.	Researchers control/check for dissimilarities between sample or response/non-response groups.	Multiple uncontrolled sources of sample or non-response bias.
4. Response	Do respondents believe they have an incentive to respond one way (strategic)? Are they likely to give answer that they perceive is "socially correct" or desired by the researcher (acquiescence)? Are they asked about potential actions in unrealistic scenarios or those where they have little experience (hypothetical)? Are they asked to remember details from the past (recall)?	Observations of real-world behavior. Models not involving survey responses.	Perceptions of real-world behavior. Recall of occurrence of concrete, large-scale events in recent past (5 years or less).	Hypothetical questions about future possibilities or questions about preferences, level of agreement, or intentions. Recall of specific details of past events, or events in distant past (more than 5 years).
5. Level of analysis	Are observations undertaken at the same level as the treatment?	Observations are landowners, parcels, or plots.	Observations between county and parcel level, or some are landowners and other are at higher level.	Counties or larger.
6. Variables	Are there potentially confounding or endogenous explanatory variables? Are there multiple simultaneous treatment variables (policies, programs, etc.), the effects of which are difficult to disentangle?	No confounding variables. Single treatment.	Potential confounding variables with reasonable attempts to control/check robustness.	Uncontrolled confounders, or two or more concurrent treatments.

manuscripts and adding to the list of records any literature cited that seemed to provide valuable material.

4. Results

4.1. Results of literature search

Fig. 1 presents the number of records reviewed and documents included in this systematic review. In sum, out of 432 records screened, I selected 76 for the qualitative synthesis. Of these, 32 contain findings relevant to the quantitative analysis, of which 23 are relevant to retaining forestland (extensive margin) and 17 to active forest management (intensive margin) (eight have findings relevant to both questions).

4.2. Effectiveness of preferential forest property tax programs at retaining forestland (extensive margin)

I reviewed studies providing evidence as to whether the intervention of enrollment in a PFFTP is effective in the outcome of retaining forestland. Twenty-three manuscripts meet the criteria for inclusion in the quantitative analysis (Table 3) of which five are models, twelve are perception studies, and eight are empirical studies (two of the manuscripts present findings of two different types). Four perception manuscripts report results by region of one single large research study and are thus included as a single study here; similarly, two other manuscripts report results of a single study. Three of the empirical studies provide two different statistical tests on different metrics. Taken together, there are five model findings, eight perception findings, and eleven empirical findings, or 24 findings in total.

For the conventional vote count including substantial or statistical significance, twelve indicate a positive relationship, two a negative relationship, and ten no significant relationship. Among only empirical studies, five indicate a positive relationship, two negative, and four no significant relationship. For the sign test, 21 of 24 findings overall are positive; a result that large or higher would occur with probability 0.0001 if positive and negative results were equally likely. Looking only at the empirical studies, nine of eleven are positive, with a probability of 0.0322. In both cases I rejected the null hypothesis that positive and negative results are equally likely. Together, these vote-count meta-analyses suggest a positive relationship between PFPTPs and private forest land retention.

The five models are unanimous in their findings that lower taxes for forestland would be expected to increase the forest land area. This is consistent with standard economic theory (Anderson, 1993), and most likely therefore one of the core underlying assumptions of those models, that lowering taxes will increase relative profits to forestry and landowners will select the most profitable use of land.

Perception studies paint a more nuanced picture. These studies report perceptions of both state tax administrators and landowners. Although no studies report a perception that PFPTPs could decrease forest land area, only six of ten studies report a perception that PFPTPs assist in retaining forest land area that would otherwise be converted, sold, or parcelized. Qualitatively, authors report that administrators and landowners generally view the effectiveness as moderate at best (Butler et al., 2012; Greene et al., 2010; Jacobson et al., 2009a, 2009b; Kilgore et al., 2007; Ma et al., 2014).

Empirical studies mostly show a positive link between PFPTPs and forest land area. It is worth noting that the most appropriate level of analysis for these studies is the parcel or plot level, which is the level of the participant and intervention, at which a land retention decision would be made. Other studies report observations at the township, county, or state level. Of the three studies conducted at the parcel or plot level, all show a significant positive but weak effect. In addition to the empirical studies in the quantitative analysis (Table 3), two other studies report observational findings that are suggestive of no significant effect,

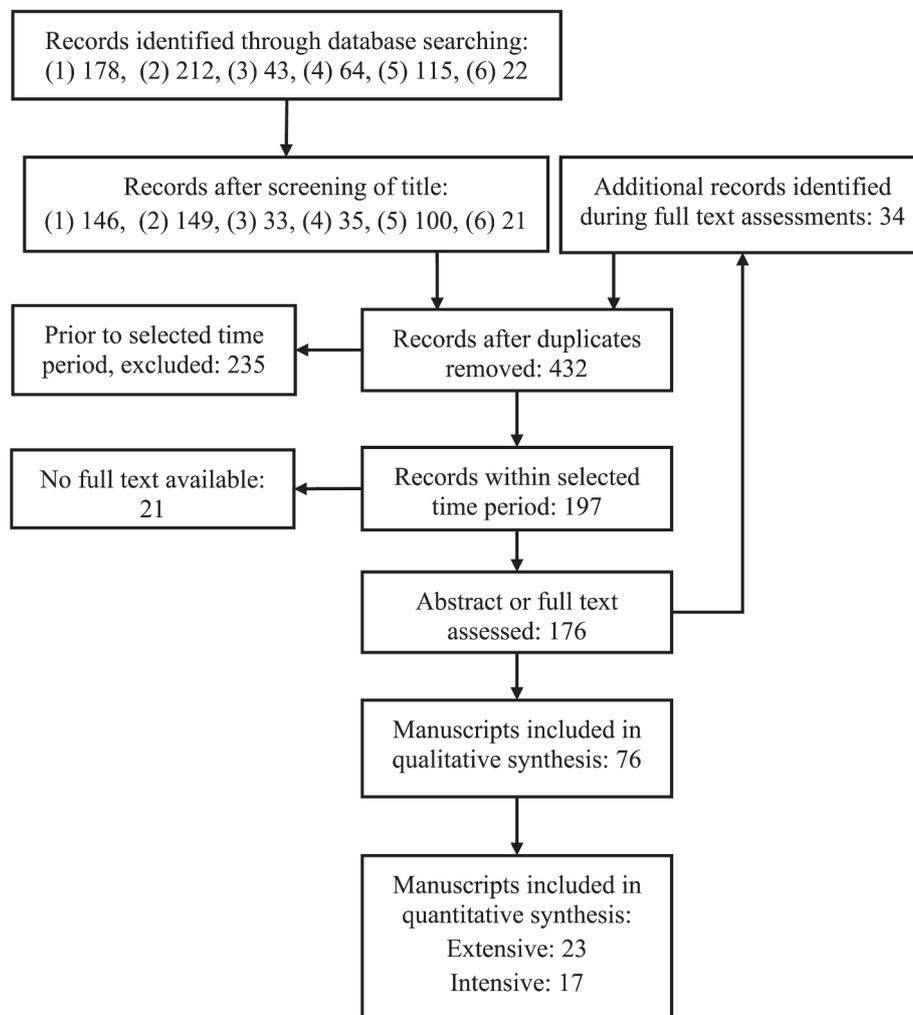


Fig. 1. Flow of documents included in the systematic review.

but not conducted in a manner consistent with reporting a correlation between a treatment (enrollment in a PFPTP) and an outcome (land-use conversion, sale, or parcelization). [Karl Wolfgang \(1998\)](#) finds that abandoned lands and lands in a PFPTP had different population means, suggesting enrolled lands are different from abandoned lands in ways other than just enrollment. [Ma et al. \(2014\)](#) finds no discernible differences in outcomes between states grouped by PFPTP characteristics and perceptions. These results slightly lessen the confidence in the outcome of the quantitative synthesis finding a positive link between PFPTP enrollment and retention of forestland, but overall, there is still moderately strong evidence of the link.

Every study reviewed in the quantitative synthesis has some risk of bias in at least one category ([Table 3](#)). Generally speaking, models project potential future outcomes based on a set of researcher assumptions and uncertain future conditions. Perception studies rely on sampling people's views, which may not match reality. These two categories are important for constructing theories and hypotheses, which must be tested empirically before they can be accepted or rejected. Empirical studies attempt to measure these real-life correlations, but are subject to other biases (i.e., correlation is not causation). Control for confounding (or endogenous) variables is an important measure before beginning to make inferences about causation. In my review, I identified only two empirical studies that take steps to control for confounding variables (although each had other potential biases): [Bagdon and Kilgore \(2013\)](#) and [Poudyal and Hodges \(2009\)](#). Notably, both show a significant positive, but weak, effect of PFPTPs on forest land retention.

Enrolled land may not be distributed randomly ([Locke and Rissman, 2012](#)), which could be correlated with forest land retention probability, as well. Some scholars propose a non-linear effect of the degree of urbanization, distance from urban center, or population on likelihood of enrollment, suggesting possible conflicting incentives ([Frey et al., 2019](#); [Hickman and Crowther, 1991](#)). This could be explained by the fact that there is little incentive to enroll forestland in highly rural areas because taxes are already low, and there is strong disincentive to enroll forestland in highly urban areas because the value of land in other uses is so high. Therefore, land in areas with moderate development pressure may be the most likely to enroll ([Frey et al., 2019](#)). In order to assess the actual impact of PFPTPs on forest land retention, researchers should control for these effects, which is frequently not done because of its difficulty.

With regards to relative effectiveness among PFPTPs nationwide, those with stricter standards/restrictions (e.g., construction on property not allowed) or more requirements (e.g., forest management plan required) to enroll or stay in the program are linked to lower enrollment ([Frey et al., 2019](#); [Stevens et al., 2002](#); [Williams et al., 2004](#)), and more forest loss/fragmentation ([Ma et al., 2014](#)). One study finds that larger tax reduction leads to higher enrollment ([Stevens et al., 2002](#)), whereas others find that the magnitude of tax reduction not linked to enrollment ([Dennis and Sendak, 1992](#); [Frey et al., 2019](#)). Theoretically, the basis for imposing the tax (site value or flat tax versus net forest productivity tax) can incentivize different land-use choices ([Chang, 2018b](#)), but this has not been tested empirically.

Table 3

Literature assessing impact of preferential forest property taxation on forest land area, by category of study, including five “models” (simulations, capital budgeting, and numerical models), twelve “perception” (stated preference, perception, or intention) studies, and eight “empirical” (empirical or observational) studies.

Study	State ^b	Data srce ^c	Methd ^d	Unit anal. ^e	Effect sign ^f	Signf. ^g	Qual. mag. ^h	Potential risk of bias ⁱ						Description/Notes
								1	2	3	4	5	6	
<i>Simulations, capital budgeting, and numerical models</i>														
Cho et al. (2017)	TN, KY	NLCD	LU	Plot	+	Sub	Weak	3	2	1	1	1	2	Waiving property taxes increases the share of forestland.
Brockett et al. (2003)	TN	Tax	CB	Parcel	+	Sub	Weak	3	3	1	1	1	2	Depending on reservation prices, property tax program might fully protect 4 % of parcels from development.
Daigneault et al. (2020)	Nat'l	FIA	PE	Plot	+	Sub	Mod.	3	2	1	1	1	2	Shifting from current use to fair market valuation reduces area by 3.4 % (5 million hectares).
D'Amato et al. (2010)	MA	Trans	CB	Parcel	+	NSub	Weak	3	3	1	1	1	2	Current use value tax program can make timber management profitable, but enrollment is low.
Nepal et al. (2015)	KY	Soil	CB	Plot	+	Sub	Strong	2	3	1	1	1	2	Eliminating property tax increases economically feasible area of biomass tree plantations eightfold.
<i>Stated preference, perception, or intention studies</i>														
Butler et al. (2012)	Nat'l	S/F	Likert	State/ LO	+	NSub	Mod.	1	1	3	2	2	1	Tax policies, in and of themselves, usually are not causing forest owners to take unplanned actions.
Brockett and Gebhard (1999); Brockett et al. (2003) ^a	TN	S	BC	LO	+	NS	None	1	1	3	3	1	3	No difference in plans to change land use.
Greene et al. (2010); Jacobson et al. (2009a, 2009b); Kilgore et al. (2007) ^a	Nat'l	S	Likert	State	+	Sub	Mod.	1	1	1	2	3	1	Program administrators ranked effectiveness at preventing conversion and parcelization as moderate.
Ma et al. (2014)	Nat'l	S	Likert	State	+	NSub	Mod.	1	1	1	2	3	1	53 % state program administrators view property tax programs effective at protecting forest resources.
Meier et al. (2019)	Nat'l	S	BC	LO	–	NS	None	1	1	2	2	1	3	Enrollees indicate no greater likelihood of divesting land.
Rushakoff (2021)	OR	S	L	LO	+	S	Mod.	1	2	2	3	1	1	A hypothetical increase in tax of \$5/acre/yr increases stated probability of selling land by 7.5 %
Williams et al. (2004)	TN	S	Likert	LO	+	NS	Mod.	2	1	2	3	1	1	19 % of owners self-report that the program is a major factor in keeping their land forested, additional 15 % reported some influence.
Stone and Tyrrell (2012)	NY	S	Likert	LO	+	Sub	Strong	1	1	2	3	1	1	Burden of property taxes was the number one stated reason for actual/potential parcelization (37 %/60 %).
<i>Empirical or observational studies</i>														
Bagdon and Kilgore (2013)	MN	Tax	L	Parcel	+	S	Weak	1	3	1	1	1	2	Relatively few landowners enrolled in program that would lower taxes substantially, but places greater restrictions on development.
Hickman and Crowther (1991)	TX	Tax	Corr.	Cnty	- / +	S / NS	Inc.	1	3	1	1	3	3	Participation negatively correlated with urbanization level, but withdrawal not correlated.
Kilgore (2014)	MN	Tax, Trans	Corr.	TS	- / +	S / NS	Inc.	1	1	1	1	3	3	Negative relationship found between forestland sale activity and forest land property tax burden in some cases, not significant for other measures.
Li and Izlar (2021)	GA	Tax, FIA	TT, OLS	Cnty groups	+	NS	None	1	1	1	1	3	3	Lack of change in temporal or spatial forest loss trends suggests no impact of program
Meng and Zhang (2013)	GA	NRI, Tax	L	Plot/ Cnty	+	S	Weak	1	2	1	1	2	3	Lower taxes on forestland supports maintaining or converting other uses to forest, but the effect is inelastic.
Polyakov and Zhang (2008)	LA	NRI, Tax	L	Plot/ Cnty	+	S	Weak	1	2	1	1	2	3	The probabilities of land-use transition or retention are relatively inelastic with respect to property taxes.
Poudyal and Hodges (2009)	TX	Trans, CoA	2SLS	Cnty	+	S	Weak	1	2	1	1	3	2	Property tax rates increased ownership fragmentation. However, the rate was relatively inelastic.
Wagner et al. (2002)	NY	Tax	BC	TS	+ / +	S / NS	Inc.	1	3	1	1	2	3	Much of land enrolled in tax program is already in a restrictive land-use zone.

^a Multiple manuscripts report findings of a single study.

^b States: Nat'l = National, GA = Georgia, KY = Kentucky, LA = Louisiana, MA = Massachusetts, MN = Minnesota, NY = New York, OR = Oregon, TN = Tennessee, TX = Texas.

^c Data source: CoA = USDA Census of Agriculture, Est. = author's estimate, F = focus group, FIA = USDA Forest Inventory and Analysis, I = interviews, NLCD = National Land Cover Database, NRI = Natural Resource Inventory, S = survey, Soil = soil survey, Tax = tax assessor data, Trans = real estate transactions.

^d Method: 2SLS = two-stage least squares regression, BC = bivariate comparison, CB = capital budgeting, Corr. = correlation statistic, Likert = Likert scale, LU = land-use model based on logistic regression, L = logistic regression, OLS = ordinary least squares regression, PE = partial equilibrium, T = *t*-test, TT = time trends analysis.

^e Unit of analysis: LO = landowner, TS = township, Cnty = county.

^f Effect sign: + = enrollment in program to lower property tax correlated with greater likelihood of forest retention (lower likelihood of land-use conversion, sale, or parcelization), - = enrollment in program to lower property tax correlated with lower likelihood of forest retention (greater likelihood of land-use conversion, sale, or parcelization). Effect sign is noted regardless of statistical significance.

^g Significance of effect: Sub/NSub = For models or other studies where statistical significance is not applicable or not reported, "Sub" represents a substantial effect, as interpreted by the study authors and/or the author of this manuscript (NSub = not substantial effect). S/NS = represent statistical significance (S) or no statistical significance (NS) at the 0.05 alpha-level.

^h Qualitative interpretation of the magnitude of the effect: magnitude qualitatively assessed as none, weak, moderate, strong, or inconclusive, as interpreted by the study authors and/or the author of this manuscript (see methods).

ⁱ Potential risk of study bias: see methods and table 2 for definitions.

In summary, there is moderately strong evidence of a positive, but weak link between tax reductions for forestland and retention of forests. There is little evidence that increasing the amount of the tax reduction increases enrollment in a PFFTP, but moderate evidence that reducing requirements and restrictions does so.

4.3. Effectiveness of preferential forest property tax programs at increasing active forest management (intensive margin)

Seventeen manuscripts report evidence related to a link between enrollment in PFFTPs and increased active forest management (Table 4). Four report findings from models, eleven from perception studies, and four from empirical studies. Two manuscripts report results of a single study, but these include both perceptions and empirical observations. Four perception manuscripts report results by region of one single large research study and I thus include as a single study here. One of the perception studies and two of the empirical studies report findings related to multiple metrics. Taken together, there are four model findings, eight perception findings, and six empirical findings, for eighteen total.

The conventional vote count resulted in ten positive results, three negative, and five not significant. Among only empirical studies, there are two positive, one negative, and three not significant. For the sign test vote count, fifteen of eighteen are positive, a result that large or larger would be expected only with probability 0.0038 if positive and negative results were equally likely. Among only empirical studies, four of five are positive, which has a probably 0.1886. This latter result fails to reject the null hypothesis that negative and positive results are equally likely among empirical findings; similarly, the modal category of empirical findings on the conventional vote count was "not significant." More empirical evidence is necessary to conclude with any certainty that PFFTPs increase active forest management.

Two of the three empirical studies are based on survey data, and thus subject to recall biases of respondents, but since the surveys asked about concrete past activities, I included them in the empirical section. All three report insignificant, mixed, ambiguous, or inconclusive results on forest management intensity in general. For example, Rathke and Baughman (1996) notes that enrollees were more likely to conduct timber harvest and timber-stand improvement, but were no more likely to plant trees, compared to non-enrollees. Brockett et al. (2003) finds a negative relationship with timber harvest and no relationship with other activities.

Numerous studies not included in the quantitative synthesis explore the theoretical impacts of various forms of tax on management of forests for timber production, or timber in combination with other ecosystem services (e.g., Alvarez and Koskela, 2007; Chang, 1996, 2018a; Costello et al., 1998; Englin and Klan, 1990; Gaffney, 2006; Gong and Susaeta, 2020; Karlwolkang, 1998; Koskela and Ollikainen, 1997, 2001; Ollikainen, 1990; Uusivuori and Kuuluvainen, 2008). The vast majority of

these are aimed at deriving the impact of taxes on the "optimal rotation," that is, the age at which forests should be harvested in order to maximize profits over the long run. One could view a shorter rotation as representing more intensive management, and a longer rotation representing less intensive management. The results of these theoretical studies can be contradictory depending on the model used and assumption made; however, the overarching message is that the basis for imposing the tax (e.g., flat tax, land value tax, site productivity tax, etc.) can have important consequences in terms of the intensity of management. In general, these papers do not directly explore the impact of a decrease in the overall amount of the property tax, which is likely to be the most important factor in PFFTPs.

Requirements for enrollment/enrollees such as having and following a forest management plan are among the ways that PFFTPs aim to drive enrollees to more active management. Oswald and Orr (2012) finds that most management plans do comply with the spirit, if not the letter, of the PFFTP regulations, thus it is plausible that enrollees may carry out better management. Schram et al. (2021) finds a relatively high level of management among enrollees. However, these studies are limited by the possibility that people who choose to enroll may simply be more active managers to begin with.

As in the previous section, all studies related to active forest management were subject to one or more source of bias (Table 4). Unlike that section, none of the empirical studies included adequate controls for confounding factors.

In summary, there is limited evidence that PFFTPs cause landowners to adopt more active forest management practices. Based on the existing (limited) evidence, those PFFTPs that do have an effect seem likely to be those with requirements for planning and implementing practices, and with relatively robust checks and enforcement.

5. Discussion and conclusions

5.1. Design of effective forest property tax policies

Overall, the general conclusion about modern PFFTPs that can be drawn from the empirical literature is one of relatively overall weak or inconclusive effectiveness at achieving their aims. This generally aligns with overall perceptions of the PFFTPs among program administrators and others (Hibbard et al., 2003; Jacobson and McDill, 2003; Kilgore et al., 2007).

The obvious next question is, how could policy-makers make PFFTPs more effective? The answer is challenged by the fact that reviews of PFFTPs show that many have mixed goals and objectives, which may not be clearly stated (Newman et al., 2000). Further, sometimes tax incentives are utilized because they are the policy tool that can pass state legislatures, rather than any analysis that shows they are more suitable than other tools. Researchers have stated that tax programs with clear goals and demonstrated advantage of utilizing tax policy over other

Table 4

Literature assessing impact of preferential forest property taxation on forest management, by category of study, including four “models” (simulations, capital budgeting, and numerical models), ten “perception” (stated preference, perception, or intention) studies, and three “empirical” (empirical or observational) studies.

Study	State ^b	Data source ^c	Method ^d	Unit anal. ^e	Effect sign ^f	Signf. ^g	Qual. mag. ^h	Potential risk of bias ⁱ						Description/Notes
								1	2	3	4	5	6	
<i>Simulations, capital budgeting, and numerical models</i>														
Chang (2018b)	N.A.	Est.	GF	Stand	-	Sub	Mod.	3	3	1	1	1	1	Unmodified tax has shorter rotation than no tax, but other tax forms have same rotation as no tax.
Daniels (1995)	TX		CB	Stand	+	NSub	None	3	3	1	1	1	1	Property tax incentives too low to induce changes except on the poorest sites.
Daigneault et al. (2020)	Nat'l	FIA	PE	Plot	+	Sub	Weak	3	2	1	1	1	2	Shifting from current use to fair market valuation reduces harvest by 0.3 % and carbon by 17 %.
Farrell (2012)	N.A.	Est.	CB	Stand	+	Sub	Strong	3	3	1	1	1	1	Lower taxes for management regime can lead to favorable returns for either syruing or managing for timber.
<i>Stated preference, perception, or intention studies</i>														
Brockett and Gebhard (1999); Brockett et al. (2003) ^a	TN	S	BC / R	LO	+	NS	None	1	1	3	3	1	3	Participation not correlated with plans for future timber harvest.
Galleguillos et al. (2018)	WI	I	Cnt.A.	LO	+	Sub	Strong	1	1	3	3	1	2	Tax reduction program incentivizes forest grazing; potentially conversion to silvopasture.
Jacobson (2001)	PA	S	Likert	LO	+	Sub	Mod.	1	1	3	3	1	1	Some landowners (less than half) state tax programs will affect their management behavior
Greene et al. (2010); Jacobson et al. (2009a, 2009b); Kilgore et al. (2007) ^a	Nat'l	S	Likert	State	+	Sub	Mod.	1	1	1	2	3	1	Program administrators ranked effectiveness at encouraging forest management as moderate
Klosowski et al. (2001)	MA	F	CA	LO	+	S	Weak	1	2	3	3	1	2	Increasing tax benefit from \$0 to \$2000 increase likelihood of adopting coordinated management from 0.6 to 5.6 %
Miller et al. (2014)	MI, MN, WI	F	Cnt.A.	LO	+	Sub	Strong	1	1	3	3	1	1	Most landowners were interested in tax relief in exchange for forest carbon management
Rushakoff (2021)	OR	S	L	LO	- / +	S / S	Inc.	1	2	2	3	1	1	Landowners more likely to clearcut and replant, but less likely to manage for wildlife in response to tax increase
<i>Empirical or observational studies</i>														
Brockett and Gebhard (1999); Brockett et al. (2003) ^a	TN	S	BC / R	LO	+ / -	NS / S	Inc.	1	1	3	3	1	3	Participation not correlated with silviculture activity; negatively correlated with past timber harvest.
Rathke and Baughman (1996)	MN	S	L	LO	+ / + / +	S / S / NS	Mod.	1	1	3	3	1	3	Enrollees were more likely to conduct timber harvest and timber-stand improvement; no more likely to plant trees.
Wagner et al. (2002)	NY	Tax	BC	Parcel/ TS	+	NS	None	1	3	1	1	2	3	Tax program requirements for management duplicated zoning restrictions.

^a Multiple manuscripts report findings of a single study.

^b States: Nat'l = National, MA = Massachusetts, MI = Michigan, MN = Minnesota, NY = New York, OR = Oregon, PA = Pennsylvania, TN = Tennessee, TX = Texas, WI = Wisconsin, N.A. = not applicable.

^c Data source: Est. = author's estimate, F = focus group, FIA = USDA Forest Inventory and Analysis, I = interviews, S = survey, Tax = tax assessor data.

^d Method: BC = bivariate comparison, CA = conjoint analysis, CB = capital budgeting, Cnt.A. = content analysis, GF = generalized Faustmann, Likert = Likert scale, PE = partial equilibrium, L = logistic regression, R = unspecified regression.

^e Unit of analysis: LO = landowner, TS = township.

^f Effect sign: + = enrollment in program to lower property tax correlated with more active forest management, - = enrollment in program to lower property tax correlated with less active forest management. Effect sign is noted regardless of statistical significance.

^g Significance of effect: Sub/NSub = For models or other studies where statistical significance is not applicable or not reported, “Sub” represents a substantial effect, as interpreted by the study authors and/or the author of this manuscript (NSub = not substantial effect). S/NS = represent statistical significance (S) or no statistical significance (NS) at the 0.05 alpha-level.

^h Qualitative interpretation of the magnitude of the effect: magnitude qualitatively assessed as none, weak, moderate, strong, or inconclusive, as interpreted by the study authors and/or the author of this manuscript (see methods).

ⁱ Potential risk of study bias: see methods and table 2 for definitions.

tools are more likely to be successful (Hibbard et al., 2003).

If the overarching goal of a particular PFPTP is to retain existing forestland, the evidence indicates that programs are likely to be more successful by focusing on enrolling and keeping enrolled as much land as possible. Past research suggests that the potential steps to achieve this include minimizing the number of requirements, rules, and reviews for enrolling as well as restrictions placed on enrolled land (Bagdon and Kilgore, 2013; Frey et al., 2019; Ma et al., 2014), simplifying procedural steps (Fortney and Arano, 2010), and including substantial penalties for withdrawal from the program (Chaini, 2006; England, 2002; England and Mohr, 2010; Frey et al., 2019). In addition, a high percentage of PFPTPs focus on timber production (Jacobson and McDill, 2003; Kilgore et al., 2018a), which does not necessarily match landowner uses and values (Finley and Kittredge, 2006; Fortney and Arano, 2010; Fortney et al., 2011; Kauneckis and York, 2009); therefore the research suggests that making PFPTPs more open to various potential forest uses or non-uses may engage more landowners (Fortney et al., 2011; Frey et al., 2019; Kauneckis and York, 2009). Disconnects between program goals and landowner values also sometimes lead to perverse incentives, whereby policies encourage destructive behavior (Galleguillos et al., 2018).

Notably, the literature is somewhat equivocal about the importance of the size of the tax benefit itself with some suggesting it is an important motivator (Fortney et al., 2011; Stevens et al., 2002) and others not (Dennis and Sendak, 1992; Frey et al., 2019). It may be that some minimum level of financial incentive is important, but beyond that is less necessary; in any case, the amount of the tax savings appear to be less important for generating higher enrollment than other factors mentioned above (Bagdon and Kilgore, 2013).

On the other hand, if the overarching goal is to promote active forest management, a PFPTP may be designed very differently. There is little evidence that PFPTPs have been very successful at this goal to date, but that which does suggests that including requirements such as forest management plans and conformance reports may work to promote management (Sendak and Huyler, 1994).

Thus, it appears that these two potential goals (forest retention or active forest management) may be at loggerheads – research suggests that effectiveness at retention needs fewer requirements, rules, reviews, and restrictions whereas effectiveness at promoting management may well need more. A single program may not be able to perform both goals well simultaneously, which brings us full circle to the discussion of clarity of goals and objectives.

There are a multitude of other policy challenges, of various degrees of nuance, which vary by state. As an example, most states group land for taxation into a finite number of categories such as forest and agriculture; however, such categories can create challenges and barriers for parcels with multiple or mixed uses (Chizmar et al., 2022; Kauneckis and York, 2009).

5.2. The role of outreach

Most landowners are not familiar with the PFPTP(s) in their state (Butler et al., 2012; Butler et al., 2010; Meier et al., 2019; Rathke and Baughman, 1996), and most non-enrollees indicate that lack of awareness is one of the main reasons they have not enrolled (Fortney et al., 2011). Research indicates that having a forest management plan and having received forestry advice (Brockett et al., 2003), as well as level of familiarity with a program (Frey et al., 2019; Williams et al., 2004) are key predictors of enrollment. While this is not a fully causal relationship (i.e., there likely is reverse causation) and no study to my knowledge has managed to conduct a randomized controlled trial on how outreach impacts enrollment, evidence suggests that engagement and technology transfer not only drives enrollment in PFPTPs, but may directly promote more active management (Aguilar and Kelly, 2019; Daniels et al., 2010; Wolde et al., 2016). Conversely, enrollment also generates opportunities for trusted sources of information directly to engage with landowners

(Rathke and Baughman, 1996; Sendak and Huyler, 1994; Snyder et al., 2020).

5.3. Research challenges, limitations, and risk of bias across studies

Research related to these questions is inherently challenging. As discussed above, the soundest research into the effect of enrollment on retention or management decisions is at the scale of the decision-making, i.e., the scale of the land parcel or landowner. Because of the voluntary and complex nature of these PFPTPs, it is extremely challenging to identify a causal relationship, even though strong correlation may exist. That is, endogeneity of retention and management decisions in the enrollment decision means that simply comparing the broad classes of enrollees with non-enrollees is insufficient.

Randomized controlled trials are quite challenging to devise in a practical way in the policy realm. The best studies seek to control for endogeneity and confounding factors. In this context, three options are likely to lead to the most accurate causal inference. First, researchers might seek to find instrumental variables that are correlated with enrollment, but not otherwise correlated with the outcome (retention or management decisions). These are challenging to identify. For example, one might suggest that forest land proximity to a cooperative extension center might make one more likely to know about, and thus enroll in, a PFPTP. However, since cooperative extension centers (and other sources of information) are usually located in the county seat or other urbanized area, that could suggest more development pressure on the land. Second, researchers might conduct a quasi-experimental statistical approach such as propensity score matching, which compares enrolled lands to non-enrolled lands with otherwise similar characteristics. It would be important in this case to look not only at the characteristics of the land, but also the landowner, who is making the decisions. Finally, a researcher might exploit a natural experiment. Differences in policy implementation across state or county lines are a form of natural experiment that can be useful, but still have limitations because various other policy, history, culture, and other variables are linked to administrative boundaries. A true natural experiment would require some subset of individual landowners arbitrarily enrolled in a PFPTP for reasons not linked to any of their other decision processes.

Given these challenges, every study identified in this body of literature has at least one inherent limitation, and there is a general risk of bias across studies. Overall, the largest potential source of research bias for empirically-based studies is that of self-selection into PFPTPs – those landowners who were likely to keep their land forested, or who were likely to be active managers anyway, are those who are also likely to enroll. Despite the limitations, the broad range of research approaches mitigates the risk.

5.4. Summary of results

In summary, there is moderate evidence that PFPTPs reduce forest land-use change, sale, or parcelization, although the effect is relatively weak. There is limited evidence that PFPTPs encourage more active forest management. To design a PFPTP that does more to retain forests may need fewer requirements and rules, whereas to encourage active management may need more, so greater clarity of policy goals will help determine which approach is merited. Future research can seek better to control for endogenous variables by carefully planned instrumental variables, propensity score matching, natural experiments, and to the extent possible, randomized controlled trials. Research may also seek to compare outcomes of PFPTPs with different characteristics within or between states to better understand the impacts of specific policy choices.

Declaration of Competing Interest

The author declares that he has no known competing financial

interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Acknowledgements

This study was funded by the U.S. Department of Agriculture, Forest Service, Southern Research Station. Thanks to Drs. Kathryn Gazal and Lloyd Irland for their comments on a previous draft of this manuscript. Any errors or omissions are those of the author.

Disclaimer

The findings and conclusions in this publication are those of the author and should not be construed to represent any official USDA or U.S. Government determination or policy.

References

- Adams, D. M., Haynes, R. W., Dutrow, G. F., Barber, R. L., & Vasievich, J. M. (1982). Private investment in forest management and the long-term supply of timber. *American Journal of Agricultural Economics*, 64(2), 232–241.
- Aguilar, F. X., & Kelly, M. C. (2019). US family forest management coupling natural and human systems: Role of markets and public policy instruments. *Landscape and Urban Planning*, 188, 43–53.
- Alvarez, L. H., & Koskela, E. (2007). Taxation and rotation age under stochastic forest stand value. *Journal of Environmental Economics and Management*, 54(1), 113–127.
- Amacher, G. S. (1997). The design of forest taxation: A synthesis with new directions. *Silva Fennica*, 31(1), 101–119.
- Anderson, J. E. (1993). Use-value property tax assessment: Effects on land development. *Land Economics*, 69(3), 263–269.
- Bagdon, B. A., & Kilgore, M. A. (2013). Observing forest property tax enrollment preferences in light of a multiyear restriction on development. *Northern Journal of Applied Forestry*, 30(2), 58–66.
- Bare, B. B. (1990). An analysis of forest property-tax burdens under a land and reforestation tax-system - a western Washington case-study. *Canadian Journal of Forest Research*, 20(5), 554–565. <https://doi.org/10.1139/x90-072>
- Best, C. (2002). America's private forests: Challenges for conservation. *Journal of Forestry*, 100(3), 14–17.
- Brockett, C. D., & Gebhard, L. (1999). NIPF tax incentives: Do they make a difference? *Journal of Forestry*, 97(4), 16–21.
- Brockett, C. D., Gottfried, R. R., & Evans, J. P. (2003). The use of state tax incentives to promote forest preservation on private lands in Tennessee: An evaluation of their equity and effectiveness impacts. *Politics and Policy*, 31(2), 252–281.
- Bushman, B. J., & Wang, M. C. (2009). Vote-counting procedures in meta-analysis. In H. Cooper, L. V. Hedges, & J. C. Valentine (Eds.), *Handbook of Research Synthesis and Meta-Analysis* (2nd ed.). New York: Russell Sage Foundation.
- Butler, B. J., Butler, S. M., Caputo, J., Dias, J., Robillard, A., Sass, E. M., 2021a, Family forest ownerships of the United States, 2018: results from the USDA Forest Service, National Woodland Owner Survey, *General Technical Report NRS-199*, U.S. Department of Agriculture, Forest Service, Northern Research Station, Madison, WI, 52 pp. doi - 10.2737/NRSGTR-199.
- Butler, B. J., Caputo, J., Robillard, A. L., Sass, E. M., & Sutherland, C. (2021b). One size does not fit all: Relationships between size of family forest holdings and owner attitudes and behaviors. *Journal of Forestry*, 199(1), 28–44.
- Butler, B. J., Catanzaro, P. F., Greene, J. L., Hewes, J. H., Kilgore, M. A., Kittredge, D. B., ... Tyrrell, M. L. (2012). Taxing family forest owners: Implications of federal and state policies in the United States. *Journal of Forestry*, 110(7), 371–380.
- Butler, B. J., Hewes, J. H., Catanzaro, P., Greene, J. L., Kilgore, M. A., Kittredge, D. B., ... Tyrrell, M. (2010). *Effects of federal, state, and local tax policies on family forest owners* (p. 76). Amherst, MA: Family Forest Research Center.
- Chaini, R. K. (2006). *Impact of tax policies on decision making behavior of non-industrial private forest owners of United States*. West Lafayette, IN: Purdue University. Ph.D. dissertation.
- Chang, S. J. (1982). An economic analysis of forest taxation's impact on optimal rotation age. *Land Economics*, 58(3), 310–323.
- Chang, S. J. (1996). US forest property taxation systems and their effects. In M. J. Baughman (Ed.), *Symposium on Nonindustrial Private Forests: Learning from the Past, Prospects for the Future*. MN: Minnesota Agricultural Experiment Station, St. Paul.
- Chang, S. J. (2018a). Forest property taxation under the generalized Faustmann formula. *Forest Policy and Economics*, 88, 38–45.
- Chang, S. J. (2018b). Forest valuation under the generalized Faustmann formula with taxation. *Forest Policy and Economics*, 88, 46–51.
- Chizmar, S., Parajuli, R., Frey, G., Bardou, R., Branau, A., MacFarland, K., ... Ameyaw, L. (2022). Challenges and opportunities for agroforestry practitioners to participate in state preferential property tax programs for agriculture and forestry. *Trees Forests and People*, 7, Article 100176. <https://doi.org/10.1016/j.tfp.2021.100176>
- Cho, S. H., Lee, J., Roberts, R. K., English, B. C., Yu, E. T., Kim, T., & Armsworth, P. R. (2017). Evaluating a tax-based subsidy approach for forest carbon sequestration. *Environmental Conservation*, 44(3), 234–243. <https://doi.org/10.1017/s0376892917000078>
- Colligan, D. J. (2000). Forest land taxation in the New Millennium: Stewardship incentivized. *Denver University Law Review*, 78, 413.
- Costello, S. T., Klemperer, W. D., Amacher, G. S., 1998, Efficiency and Equity of a Forest Site Value Tax, in: *Valuing Non-timber Forest Resources: Timber Primacy is Passé: the Proceedings of the 1997 Southern Forest Economics Workers Meeting: Little Rock, AR, March 19-21, 1997*, School of Forest Resources, University of Arkansas at Monticello, 177 pp.
- Cushing, T. L., & Newman, D. (2018). Analysis of relative tax burden on nonindustrial private forest landowners in the southeastern United States. *Journal of Forestry*, 116(3), 228–235.
- D'Amato, A. W., Catanzaro, P. F., Damery, D. T., Kittredge, D. B., & Ferrare, K. A. (2010). Are family forest owners facing a future in which forest management is not enough? *Journal of Forestry*, 108(1), 32–38.
- Daigneault, A. J., Sohngen, B. L., & Sedjo, R. (2020). Carbon and market effects of US forest taxation policy. *Ecological Economics*, 178, Article 106803.
- Daniels, J. M. (1995). *Economic analysis of property tax incentives for management of the red-cockaded woodpecker on private forest lands in Texas*. Stephen F: Austin State University, Nacogdoches, TX. M.S. thesis.
- Daniels, S. E., Kilgore, M. A., Jacobson, M. G., Greene, J. L., & Straka, T. J. (2010). Examining the compatibility between forestry incentive programs in the US and the practice of sustainable forest management. *Forests*, 1(1), 49–64.
- Dennis, D. F., & Sendak, P. E. (1992). An empirical study of enrollment in Vermont's use value appraisal property tax program. *Canadian Journal of Forest Research*, 22(9), 1209–1214.
- Eckhoff, M., Mackes, K., & Reader, T. (2007). Assessing state-sponsored tax incentive programs for nonindustrial private forest landowners in the western United States. *Western Journal of Applied Forestry*, 22(4), 253–260. <https://doi.org/10.1093/wjaf/22.4.253>
- England, R. W. (2002). *Current-use property assessment and land development: A theoretical and empirical review of development penalties*. Cambridge, MA: Lincoln Institute of Land Policy.
- England, R. W., Mohr, R. D., 2010, Land development and current use assessment, in: *Economics and Contemporary Land Use Policy* (Johnston, R. J., Swallow, S. K., eds), Routledge, pp. 196–208.
- Englin, J. E., & Klan, M. S. (1990). Optimal taxation: Timber and externalities. *Journal of Environmental Economics and Management*, 18(3), 263–275.
- Fairchild, F. R. (1908). The taxation of timber lands in the United States. *State and Local Taxation: International Conference under the Auspices of the International Tax Association: Addresses and Proceedings*, 69–82.
- Fairchild, F. R. (1935). *Forest taxation in the United States*. Washington, DC: US Government Printing Office.
- Farrell, M. L. (2012). The economics of managing maple trees for syrup or sawtimber production. *Northern Journal of Applied Forestry*, 29(4), 165–172.
- Finley, A. O., & Kittredge, D. B. (2006). Thoreau, Muir, and Jane Doe: Different types of private forest owners need different kinds of forest management. *Northern Journal of Applied Forestry*, 23(1), 27–34. <https://doi.org/10.1093/njaf/23.1.27>
- Floress, K., Huff, E. S., Snyder, S. A., Kosholek, A., Butler, S., & Allred, S. B. (2019). Factors associated with family forest owner actions: A vote-count meta-analysis. *Landscape and Urban Planning*, 188, 19–29.
- Fortney, J., & Arano, K. G. (2010). Property taxes and forests in West Virginia: A historical review. *Small-Scale Forestry*, 9(1), 67–80.
- Fortney, J., Arano, K. G., & Jacobson, M. (2011). An evaluation of West Virginia's managed timberland tax incentive program. *Forest Policy and Economics*, 13(1), 69–78.
- Frey, G. E., Kallayanamitra, C., Wilkens, P., & James, N. A. (2021). Payments for forest-based ecosystem services in the United States: Magnitudes and trends. *Ecosystem Services*, 52, Article 101377.
- Frey, G. E., Meier, J. T., Kilgore, M. A., Snyder, S. A., & Blinn, C. R. (2019). Factors associated with family forest landowner enrollment in state preferential forest property tax programs in the United States. *Land Use Policy*, 89, Article 104240.
- Gaffney, M. (2006). A simple general test for tax bias. *American Journal of Economics and Sociology*, 65(3), 733–749. <https://doi.org/10.1111/j.1536-7150.2006.00471.x>
- Galleguillos, N., Keeley, K., & Ventura, S. (2018). Assessment of woodland grazing in southwest Wisconsin. *Agriculture Ecosystems and Environment*, 260, 1–10. <https://doi.org/10.1016/j.agee.2018.03.012>
- Gobster, P. H., & Rickenbach, M. G. (2004). Private forestland parcelization and development in Wisconsin's Northwoods: Perceptions of resource-oriented stakeholders. *Landscape and Urban Planning*, 69, 165–182.
- Gong, P., & Susaeta, A. (2020). Impacts of forest tax under timber price uncertainty. *Forest Policy and Economics*, 111, Article 102030.
- Greaves, T. (2009). *States use gentle hand in taxing timberland*. Washington, DC: Tax Foundation.
- Greene, J. L., Daniels, S. E., Kilgore, M. A., Straka, T. J., & Jacobson, M. G. (2010). Effectiveness of financial incentive programs in promoting sustainable forestry in the West. *Western Journal of Applied Forestry*, 25(4), 186–193. <https://doi.org/10.1093/wjaf/25.4.186>
- Haines, T. K. (1995). *Current status and trends in timber severance tax legislation in the South*, U.S. Forest Service, Southern Forest Experiment Station, New Orleans, LA: Department of Agriculture.

- Hedges, L. V., & Olkin, I. (1980). Vote-counting methods in research synthesis. *Psychological Bulletin*, 88(2), 359–369.
- Hibbard, C. M., Kilgore, M. A., & Ellefson, P. V. (2003). Property taxation of private forests in the United States: A national review. *Journal of Forestry*, 101(3), 44–49.
- Hickman, C. A. (1989). *Inconsistent forest property-tax policies within selected southern states* (pp. 1–7). Southern Forest Experiment Station New Orleans, LA: USDA Forest Service.
- Hickman, C. A., & Crowther, K. D. (1991). *Economic impacts of current-use assessment of rural land in the East Texas pineywoods region*. Southern Forest Experiment Station, New Orleans, LA: US Department of Agriculture Forest Service.
- Higgins, J. P., & Altman, D. G. (2008). Assessing risk of bias in included studies. *Cochrane Handbook for Systematic Reviews of Interventions*:187–241.
- Jacobson, M., 2001, Taxes and laws: Do they change landowner behavior for the better? in: *International Union of Forest Research Organizations (IUFRO) Extension Working Party (S6.06-03) Symposium 2001*, The Regional Institute.
- Jacobson, M., & McDill, M. (2003). A historical review of forest property taxes in Pennsylvania: Implications for special forestland tax programs. *Northern Journal of Applied Forestry*, 20(2), 53–60.
- Jacobson, M. G., Greene, J. L., Straka, T. J., Daniels, S. E., & Kilgore, M. A. (2009a). Influence and effectiveness of financial incentive programs in promoting sustainable forestry in the South. *Southern Journal of Applied Forestry*, 33(1), 35–41.
- Jacobson, M. G., Straka, T. J., Greene, J. L., Kilgore, M. A., & Daniels, S. E. (2009b). Financial incentive programs' influence in promoting sustainable forestry in the northern region. *Northern Journal of Applied Forestry*, 26(2), 61–67. <https://doi.org/10.1093/njaf/26.2.61>
- Karlwofgang, A. (1998). *Alternative forest tax regimes and tax capitalization*. University of Arizona.
- Kauneckis, D., & York, A. M. (2009). An empirical evaluation of private landowner participation in voluntary forest conservation programs. *Environmental Management*, 44(3), 468–484.
- Kernan, H. S. (1999). Public values and tax valuation: Why tax a forest? *Journal of Forestry*, 97(4), 48.
- Kilgore, M. A. (2014). Do high property taxes influence family forest land tenure decisions? *Journal of Forest Economics*, 20(2), 161–173.
- Kilgore, M. A., Ellefson, P. V., Funk, T. J., & Frey, G. E. (2018a). Private forest owners and property tax incentive programs in the United States: A national review and analysis of ecosystem services promoted, landowner participation, forestland area enrolled, and magnitude of tax benefits provided. *Forest Policy and Economics*, 97, 33–40.
- Kilgore, M. A., Ellefson, P. V., Funk, T. J., & Frey, G. E. (2018b). State property tax programs promoting sustainable forests in the United States: A review of program structure and administration. *Journal of Forestry*, 116(3), 257–265.
- Kilgore, M. A., Greene, J. L., Jacobson, M. G., Straka, T. J., & Daniels, S. E. (2007). The influence of financial incentive programs in promoting sustainable forestry on the nation's family forests. *Journal of Forestry*, 105(4), 184–191.
- Klosowski, R., Stevens, T., Kittredge, D., & Dennis, D. (2001). Economic incentives for coordinated management of forest land: A case study of southern New England. *Forest Policy and Economics*, 2(1), 29–38. [https://doi.org/10.1016/S1389-9341\(00\)00035-6](https://doi.org/10.1016/S1389-9341(00)00035-6)
- Ko, D. W., & He, H. S. (2011). Characterizing the historical process of private forestland ownership parcelization and aggregation in the Missouri Ozarks, USA, from 1930 to 2000. *Landscape and Urban Planning*, 102, 262–270.
- Koontz, T. M. (2001). Money talks - But to whom? Financial versus nonmonetary motivations in land use decisions. *Society and Natural Resources*, 14(1), 51–65.
- Koskela, E., & Ollikainen, M. (1997). Optimal design of forest taxation with multiple-use characteristics of forest stands. *Environmental and Resource Economics*, 10(1), 41–62.
- Koskela, E., & Ollikainen, M. (2001). Forest taxation and rotation age under private amenity valuation: New results. *Journal of Environmental Economics and Management*, 42(3), 374–384.
- Li, Y. (2019). A comparative overview of current-use valuation of forests for property-tax purposes in the US South. *Journal of Forestry*, 117(1), 46–54.
- Li, Y., & Izlar, R. L. (2021). The Forest Land Protection Act program (FLPA) and conserving forestland in Georgia. *Forest Policy and Economics*, 124, Article 102399.
- Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., ... Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *Journal of Clinical Epidemiology*, 62(10), e1–e34.
- Light, R. J., & Smith, P. V. (1971). Accumulating evidence: Procedures for resolving contradictions among different research studies. *Harvard Educational Review*, 41(4), 429–471.
- Locke, C. M., & Rissman, A. R. (2012). Unexpected co-benefits: Forest connectivity and property tax incentives. *Landscape and Urban Planning*, 104(3–4), 418–425.
- Ma, Z., Butler, B. J., Catanzaro, P. F., Greene, J. L., Hewes, J. H., Kilgore, M. A., ... Tyrrell, M. (2014). The effectiveness of state preferential property tax programs in conserving forests: Comparisons, measurements, and challenges. *Land Use Policy*, 36, 492–499.
- Malmshheimer, R. W., Heffernan, P., Brink, S., Crandall, D., Deneke, F., Galik, C., ... Mortimer, M. (2008). Forest management solutions for mitigating climate change in the United States. *Journal of Forestry*, 106(3), 115–173.
- Mayer, A. L. (2019). Family forest owners and landscape-scale interactions: A review. *Landscape and Urban Planning*, 188, 4–18.
- Meier, J. T., Kilgore, M. A., Frey, G. E., Snyder, S. A., & Blinn, C. R. (2019). A comparison of participants and non-participants of state forest property tax programs in the United States. *Forest Policy and Economics*, 102, 10–16.
- Meng, L., & Zhang, D. (2013). Impacts of property tax on land use change decisions in Georgia. *Urban Ecosystems*, 16(1), 3–12.
- Millennium Ecosystem Assessment, 2005, *Ecosystems and human well-being: Synthesis*, in: *Millennium Ecosystem Assessment*, Island Press, Washington DC.
- Miller, K. A., Snyder, S. A., Kilgore, M. A., & Davenport, M. A. (2014). Family forest landowners' interest in forest carbon offset programs: Focus group findings from the Lake States, USA. *Environmental Management*, 54(6), 1399–1411.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine*, 6(7), e1000097.
- Mundell, J., Taft, S. J., Kilgore, M. A., & Snyder, S. A. (2010). Using real estate records to assess forest land parcelization and development: A Minnesota case study. *Landscape and Urban Planning*, 94(2), 71–76.
- Nepal, S., Contreras, M. A., Stainback, G. A., & Lhotka, J. M. (2015). Quantifying the effects of biomass market conditions and policy incentives on economically feasible sites to establish dedicated energy crops. *Forests*, 6(11), 4168–4190.
- Newman, D. H., Brooks, T. A., & Dangerfield, C. W., Jr (2000). Conservation use valuation and land protection in Georgia. *Forest Policy and Economics*, 1(3–4), 257–266.
- Ollikainen, M. (1990). Forest taxation and the timing of private nonindustrial forest harvests under interest rate uncertainty. *Canadian Journal of Forest Research*, 20(12), 1823–1829.
- Olson, D. D. (1979). Realities of nonindustrial private forest ownership in northern Michigan: An extension forester's opinion. *Journal of Forestry*, 77(1), 17–18.
- Oswald, J. R., & Orr, B. (2012). Non-financial tax compliance: Elements of management plans required by Michigan's Commercial Forest Act. *Journal of Horticulture and Forestry*, 4(9), 148–152.
- Oswalt, S. N., Smith, W. B., Miles, P. D., & Pugh, S. A. (2019). *Forest resources of the United States, 2017: A technical document supporting the Forest Service 2020 update of the RPA Assessment*. Department of Agriculture, Forest Service, Washington, DC: U.S.
- Polyakov, M., & Zhang, D. (2008). Property tax policy and land-use change. *Land Economics*, 84(3), 396–408.
- Poudyal, N. C., & Hodges, D. G. (2009). Property taxation and rural land values: Their effect on private forestland ownership structure in Texas. *Land Use Policy*, 26(4), 1100–1105.
- Rathke, D. M., & Baughman, M. J. (1996). Influencing nonindustrial private forest management through the property tax system. *Northern Journal of Applied Forestry*, 13(1), 30–36.
- Rushakoff, B. J. (2021). *An analysis of Oregon's preferential forest property tax programs in relation to non-industrial private forest landowners' tax program enrollment decisions and forest management behavior*. OR: Oregon State University, Corvallis. M.S. thesis.
- Sampson, N., & DeCoster, L. (2000). Forest fragmentation: Implications for sustainable private forests. *Journal of Forestry*, 98(3), 4–8.
- Sass, E. M., Butler, B. J., Markowski-Lindsay, M., 2020, Distribution of forest ownerships across the conterminous United States, 2017, *Research Map NRS-11*, U.S. Department of Agriculture, Forest Service, Northern Research Station, Madison, WI. doi -10.2737/NRS-RMAP-11.
- Schram, B., Potter-Witter, K., Huff, E., & Poudel, J. (2021). Family forest owner management decisions for participants enrolled in a forest property taxation program in Michigan. *Forests*, 12(1), 35.
- Sendak, P. E., & Huyler, N. K. (1994). *Timber management and use-value assessment*, Research Paper NE-691 (p. 8). Northeastern Forest Experiment Station, Radnor, PA: USDA Forest Service.
- Shaw, A. C., 1907, Forest taxation, in: *State and Local Taxation: National Conference under the Auspices of the National Tax Association*, National Tax Association, pp. 256–258.
- Shaw, A. C. (1908). Taxation of forest lands. *State and Local Taxation: International Conference under the Auspices of the International Tax Association*, 83–91.
- Snyder, S. A., Ma, Z., Floress, K., & Clarke, M. (2020). Relationships between absenteeism, conservation group membership, and land management among family forest owners. *Land Use Policy*, 91, Article 104407. <https://doi.org/10.1016/j.landusepol.2019.104407>
- Stevens, T. H., White, S., Kittredge, D. B., & Dennis, D. (2002). Factors affecting NIPF landowner participation in management programs: A Massachusetts case study. *Journal of Forest Economics*, 8(3), 169–184.
- Stone, R. S., & Tyrrell, M. L. (2012). Motivations for family forestland parcelization in the Catskill/Delaware watersheds of New York. *Journal of Forestry*, 110(5), 267–274.
- Straka, T. J. (2011). Taxonomic review of classical and current literature on the perennial American family forest problem. *Forests*, 2(3), 660–706.
- Timber Tax, n.d., Quick Reference: Forest Property Taxation Systems in the United States, *National Timber Tax Website*, U.S. Department of Agriculture, Forest Service; National Woodland Owners' Association; University of Georgia; and Southern Region Extension Forestry, Athens, GA.
- Uusivuori, J., & Kuuluvainen, J. (2008). Forest taxation in multiple-stand forestry with amenity preferences. *Canadian Journal of Forest Research*, 38(4), 806–820.
- Wagner, J. E., Davis, C. J., Roczen, D. E., & Herrington, L. P. (2002). Combining zoning regulations and property tax relief to retain forestland and promote forest management. *Northern Journal of Applied Forestry*, 19(2), 59–67.
- Williams, E. D., Gottfried, R. R., Brockett, C. D., & Evans, J. P. (2004). An integrated analysis of the effectiveness of Tennessee's Forest Greenbelt Program. *Landscape and Urban Planning*, 69(2–3), 287–297.
- Williams, E. T. (1961). Trends in forest taxation. *National Tax Journal*, 14(2), 113–144.
- Wolde, B., Lal, P., Gan, J., Alavalapati, J., Taylor, E., & Burl, P. (2016). Determinants of enrollment in public incentive programs for forest management and their effect on future programs for woody bioenergy: Evidence from Virginia and Texas. *Canadian Journal of Forest Research*, 46(6), 775–782.