Literature Review for

An Economic Analysis of Incentives for Carbon Sequestration on Non-Industrial Private Forests (NIPFs)

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Executive Summary

There is widespread recognition of the potential role forests can play in contributing to Green House Gas (GHG) reductions through carbon sequestration. Non-industrial private forests (NIPF) comprise a significant portion of forests in the U.S. (approximately 40%). Thus, it is crucial to assess the role that NIPF landowners can play in broader carbon sequestration efforts.

Management actions that could increase carbon sequestration on NIPF lands include afforestation of agricultural land, longer rotations, intensive management, changing stocking density, or choosing alternative tree species. Because the resulting carbon sequestration benefits are to a large extent external to individual landowners, incentives such as carbon sequestration subsidies and carbon release taxes, carbon rental fees, or cost-sharing agreements, may be necessary to induce them to adopt these management options. A key question is how effective these different policies can be in eliciting the desired management choices by NIPF owners.

In this report we assess the current state of knowledge about carbon sequestration in forests, including afforestation of agricultural land, sequestration in existing forests, and sequestration in NIPFs. We review the broader literature on the response of NIPF owners to incentives intended to promote specific forest management activities and to conserve habitat for endangered species, and discuss the literature on incentives for carbon sequestration in agriculture as well. We also discuss the issue of additionality in terrestrial carbon sequestration and briefly evaluate the suitability of the data available to study NIPF behavior in the context of sequestration.

The literature on carbon sequestration and incentives suggest that various types of incentives can effectively be used to promote afforestation and forest management practices to increase carbon sequestration. However, the literature on NIPFs suggests that the effectiveness of incentives programs depends on a variety of factors, including the objective of the policy and

landowner and property characteristics. Therefore, results from existing studies cannot necessarily be extrapolated to draw conclusions on the potential effectiveness of incentives for carbon sequestration on NIPFs. A separate study that focuses specifically on this topic would provide more reliable insights. Finally, our review suggests that the issue of additionality is relevant in this context, and that the design of any incentive scheme to elicit increased carbon sequestration needs to carefully consider how to minimize the costs caused by asymmetric information about landowner's baseline behavior.

1. Introduction

There is widespread recognition of the potential role forests can play in contributing to Green House Gas (GHG) reductions through carbon sequestration (Brand 1998; Metz et al. 2001; Lubowski et al. 2006). Non-industrial private forests (NIPF) comprise a significant portion of forests in the U.S. (approximately 40%). Thus, it is crucial to assess the role that NIPF landowners can play in broader carbon sequestration efforts.

Management actions by NIPF owners that could increase carbon sequestration on their lands include afforestation of land used for agriculture, increasing rotation length, intensive management (e.g. juvenile spacing, fire control, fertilization), changing stocking density, or choosing alternative tree species (Stainback and Alavalapati 2002; Sohngen and Mendelsohn 2003; Shaikh et al. 2007). Because the resulting carbon sequestration benefits are to a large extent external to individual landowners, incentives may be necessary to induce them to adopt these management options (Stainback and Alavalapati 2002). Specific incentives could include carbon sequestration subsidies and carbon release taxes, carbon rental fees, cost-sharing agreements, and agglomeration bonuses. A key question is how effective these different policies can be in eliciting the desired management choices by NIPF owners. This includes assessing and understanding: (i) Baseline behavior, i.e. NIPF landowner management choices and implications for carbon sequestration in the absence of any incentives; and (ii) Whether and how management choices could be modified by incentive-based policies, i.e., how landowners would respond to different types of incentives and the implications for carbon sequestration and incentive policy design.

Other factors to consider in assessing the potential of NIPFs for carbon sequestration include forest fragmentation and other spatial considerations, including the possibility of economies of scale for carbon sequestration (e.g., aggregators) and the potential role of agglomeration incentives; the impact of carbon markets on the value of forestland and the implications for transitions between forest and agriculture through increased afforestation or reduced deforestation; and other forest management objectives which may prevent landowners from undertaking carbon sequestration activities or reduce the extent to which they do so.

In this report we lay the foundation for research that will begin to address these questions. In section 2 we assess the current state of knowledge about carbon sequestration in forests, including afforestation of agricultural land, sequestration in existing forests, and sequestration in NIPFs. In section 3 we review the broader literature on the response of NIPF owners to incentives intended to promote specific forest management activities and to conserve habitat for endangered species. In section 4 we discuss the relevant literature on incentives for carbon sequestration in agriculture. In section 5 we discuss the issue of additionality in terrestrial carbon sequestration. In section 6 we briefly evaluate the suitability of the data available to study NIPF behavior in the context of sequestration. Finally, we summarize and provide concluding comments in section 7.

2. Carbon Sequestration in Forests

There is a large and growing literature that addresses the general topic of carbon sequestration in forests. Most of the attention to date has focused on issues related to the afforestation of agricultural land. A smaller body of work addresses carbon sequestration in existing forests, but does not necessarily focus on NIPFs. Only a relatively small number of studies deal specifically with the issue of carbon sequestration in NIPFs.

2.1 Afforestation of Agricultural Land

Much of the literature that examines afforestation of agricultural land has focused on estimating the costs of carbon sequestration. Parks and Hardie (1995) simulate the impacts of subsidies for sequestering carbon in new forests established on agricultural land. They derive a supply schedule for carbon sequestered in marginal agricultural land converted to forest and use this supply schedule to develop criteria for enrolling lands in a national carbon sequestration program. Plantinga et al. (1999), Stavins (1999), Newell and Stavins (2000), and Lubowski et al. (2006) use econometric models of land use to simulate the effects of a payment (subsidy) for forested agricultural land and a tax on deforested land. They find that sequestration increases with a subsidy or a combined subsidy/tax policy, but their main emphasis is on estimating marginal costs of sequestration. Plantinga et al. (1999) suggest that afforestation is a relatively low-cost way of reducing carbon concentrations. Stavins (1999) stresses that marginal costs of sequestration are not trivial, and that land heterogeneity leads to sharply increasing marginal costs as higher quality agricultural lands are converted to forest. Newell and Stavins (2000) find that costs of sequestration can be higher if trees are harvested periodically rather than permanently established, that marginal costs increase with discount rates, that higher agricultural prices lead to higher costs or less sequestration, and that delayed deforestation can sequester carbon at lower cost than increased forestation. Lubowski et al.'s (2006) estimated marginal costs of carbon sequestration are greater than those from previous engineering cost analyses and sectoral optimization models. They find that the estimated sequestration supply function is similar to the carbon abatement supply function from energy-based analyses, suggesting that forest-based carbon sequestration merits inclusion in a cost-effective portfolio of domestic U.S. climate change strategies.

Plantinga and Wu (2003) simulate the response by private landowners to subsidies for converting agricultural land (cropland and pasture) to forest in Wisconsin. They examine the environmental impacts of afforestation that go beyond carbon sequestration, such as modification of wildlife habitat and reductions in agricultural pollution, and find that the additional environmental benefits would be substantial, on the same order of magnitude as the costs of the subsidy program. Gillig et al. (2004) examine the effects of carbon payments in the form of a sequestration subsidy or an emission tax. They estimate response functions that depict the effects of carbon prices, energy prices, domestic agricultural demand, and foreign agricultural demand on GHG emission reductions and sequestration. Their results suggest that restricting carbon payments only to afforestation or deforestation or only to agricultural sequestration substantially reduces potential mitigation. Policies that include both sectors consistently yield the largest quantity of GHG offsets in their simulations.

Other papers have explicitly modeled the links between agricultural land, forest land, and timber markets, and examined the potential for offsetting changes in land use (from forest to agriculture) resulting from price feedbacks. Adams et al. (1993) address the link between forest and agricultural sectors to capture price feedbacks between forest, agricultural, and land markets. They find empirical evidence of a rise in agricultural prices, a fall in timber prices, and changes in stakeholder welfare that could result from large-scale afforestation programs. They argue that private landowners might need to be compensated to keep their land in forests. Otherwise, the price changes resulting from afforestation could provide an incentive for offsetting land use changes from forest to agriculture, creating carbon leakage. Alig et al. (1997) use a model of the U.S. forest and agriculture sectors in which land use choices and forest management decisions are endogenous. They examine the costs and land base adjustments from meeting a carbon sequestration target to minimize net social welfare costs. Their results suggest that policy-induced land use changes to forestry may induce compensating land use changes through their impact on markets. They argue that land use shifts to meet policy targets may not be permanent, and find that the main forms of adjustment to meet policy targets are to shift land use from agriculture to forest and to manage forests more intensively.

Finally, some papers have reported similar studies in other countries. For example, De Jong et al. (2000) examine the response of small (subsistence) farmers and communities in southern Mexico to incentives to switch from their current land use to forestry or adopt management measures to increase sequestration, such as agro forestry or improved forest management. They calculate the expected response to financial incentives in the form of carbon sequestration rents ranging from $0 to $40 per Megagram of C (MgC) sequestered. They find that the amount of carbon sequestered would rise rapidly from 1 million MgC to 38 million MgC when the incentive level increases from $5 to $15 per MgC, due mainly to natural forest management and fallow improvement.

Van Kooten et al. (2002) examine the institutions and incentives needed to encourage landowners in Canada to adopt tree planting on a large scale. They use data from a survey of landowners in western Canada to provide insights concerning transaction costs and the design of appropriate institutions and economic incentives for creating additional terrestrial carbon sinks at least cost. Their results suggest the transaction costs of getting landowners to convert their land from agriculture to plantation forests appear to be a significant obstacle, possibly increasing the costs of afforestation projects beyond what conventional economic analysis suggests. Over one quarter of their survey respondents indicated that they would be unwilling to enter into an afforestation program voluntarily, even if they are fully compensated for lost agricultural revenues and tree planting costs.

Zelek and Shively (2003) measure the costs of carbon sequestration on tropical farms in the Philippines. They empirically estimate the value of agricultural land and the opportunity cost of converting fallow and agricultural land to forest and agro forest. They also derive the rates of carbon sequestration for timber and agro forestry systems and compute incentive compatible compensating payment schedules for farmers who sequester carbon. To compute agricultural opportunity costs, they use a combination of data from household surveys conducted in the watershed and results from farm-level simulations. They find that agro forestry systems are a lower-cost alternative to pure forest conversion, providing carbon storage at a marginal cost that is up to 23% lower than the marginal cost of carbon storage through conversion to a pure tree stand.

Shaikh et al. (2007) examine the costs of planting trees on marginal agricultural land in western Canada and the compensation landowners would require for converting pasture and cropland to forestry. They conduct a contingent valuation survey of landowners to incorporate nonmarket values, risk attitudes, and unobservable transaction costs. They find that farmers are unwilling to plant trees on agricultural land without financial incentives, but that the necessary incentives would have to be less than net returns to agricultural activities on marginal agricultural land due to non-market benefits perceived by farmers from trees. Nevertheless, they find that average costs of carbon sequestration generated this way would exceed the projected value of the corresponding carbon credits under a carbon emissions trading program.

Ahn (2008) uses an econometric land use share model with province-level data to calculate the costs of carbon programs through afforestation in Korea. Estimation results show that an increase in forest returns causes landowners to convert agricultural land to forest, and suggest that carbon sequestration can be a cost-effective mitigation policy in Korea, although it is not necessarily the least cost option. The author argues that enhancing the management of timberland to increase of carbon stored per unit area is just as important as expanding afforestation. Rodriguez-Vicente and Marey-Perez (2009) analyze NIPF owners' management choices to transition between farming and forestry in Northern Spain. They use a survey of NIPF owners. They focus on past conversion of forest to meadow and marginal meadow to woodland. They examine the structural attributes of the forest holding and past changes and future land use intentions of NIPFs in the region for the 1999-2003 period. They find that the greatest forest management activity was associated with larger (productive) forest holdings, less divided forest land, and more time available to dedicate to forestry activities. Conversion of forestland into meadow responded to increasing demand for agricultural land and landowner's occupation as a farmer. Past transformation of marginal meadow to forest and future intentions to increase forest area depended on past experience with forestry and whether it had been profitable in the past, and on the occupation of the landowner (retired farmers and non-agricultural professionals). Intention to change forest species also depended on forest profitability.

This literature does not focus specifically on NIPFs or on studying the effectiveness of providing incentives for carbon sequestration. However, these studies rely on financial incentives, mostly tax/subsidy combinations, to measure the costs of afforestation programs. In doing so, they strongly suggest that financial incentives and changes in relative returns to land use affect land owner behavior and can be used to increase carbon sequestration in private forests.

2.2. Carbon Sequestration in Existing Forests

A number of papers focus more specifically on increasing carbon sequestration in existing forests. VanKooten and Sohngen (2007) provide a useful summary of this literature.

Plantinga and Birdsey (1993) develop a carbon budget model to examine the effects of forest management practices on carbon storage in private U.S. forests. The U.S. Forest Sector Model is used to project changes in forest resources under the assumption of market equilibrium for wood products. Changes in the forest carbon inventory result from tree growth and management activities, in particular harvesting. A base-run scenario projects increases in carbon storage in private timberlands by 2040; however, this increase is offset by carbon emissions resulting from harvesting. The study concludes that, if current trends in private timberland management continue, the effectiveness of these lands as a carbon sink may be limited. While carbon budget surpluses are expected in near decades, increasing deficits are projected in the future as harvests increase to meet higher demand for wood products.

Englin and Callaway (1993) investigate the impact of carbon payments on the optimal rotation age of Douglas fir. Using a range of carbon values from $10 to $200 per metric ton, they find that with carbon payments the rotation age was longer than the traditional Faustmann rotation age and was positively correlated with the price of carbon. Plantinga and Birdsey (1994) conduct a theoretical study to incorporate carbon payments into the forest rotation problem. They conclude that in most cases the optimal rotation is infinite when only carbon benefits are included in the analysis, whereas when both carbon and timber are included, the optimal rotation would be between the optimal carbon-only rotation and the optimal timber-only rotation. Huang et al. (2001) estimate the annual financial compensation that utility companies would have to pay private forest landowners to encourage sequestering additional carbon, and calculate the average cost to sequester a ton of carbon. They calculate the amounts needed to compensate forest landowners who apply economically sub-optimal rotations to sequester maximum carbon, or to motivate private landowners to convert unstocked lands into productive forest lands to sequester carbon. They find that the annual compensation values tend to increase as real interest rates increase: the minimum annual compensation is $0.84 per hectare (ha) using an interest rate of 2.5%, whereas the maximum annual compensation is $72.79 per ha using an interest rate of 12.5%.

Murray (2003) uses an analytical model of timber and carbon rotation and data from different forest settings to examine the effects of carbon sequestration incentives on the optimal management of an individual forest stand. He finds that the incentive modifies the optimal timing of harvest and the return to forest land use. Sohngen and Mendelsohn (2003) add carbon sequestration to an optimal control model of GHGs, and model an incentive for sequestration that takes the form of a carbon rental fee for each additional ton of carbon stored. They find that carbon rental payments increase the value of land used for forests, causing more land conversion to forest and increasing rotation lengths and management intensity (increasing stock density). However, they argue that changing management intensity is less effective and more costly at carbon storage than afforestation. Sohngen and Brown (2006) use a land use share model to examine the mix of upland hardwoods and softwoods in a three-state region of the South Central U.S. (Arkansas, Louisiana, and Mississippi). The land use share model is combined with a simulation model to examine the types of subsidies that could be used to maintain the stock of hardwoods in this region. The results suggest that subsidies of approximately $12–$27 per ha per year would maintain the area of hardwood forests and reduce carbon emissions over the next 30 years.

Guthrie and Kumareswaran (2009) use a theoretical model to examine the effectiveness of carbon credit payments in providing incentives for private forest owners to increase forest land and lengthen rotations. They focus on alternative payment systems that could be used to allocate carbon credits to forest owners, including allocation of credits depending on the amount of carbon actually sequestered at a point in time, and allocation according to the long-run carbon sequestration potential of land, where landowners receive payment as long as the land is planted with trees. They find that allocating carbon credits can significantly alter harvesting decisions by making forestry more profitable, lowering the timber price at which the landowner abandons forestry (i.e. switches land use) as well as the price at which it is optimal to harvest and replant. Their results suggest that payments based on actual carbon stock lead to longer rotation periods, while payments for long-run potential sequestration induce shorter rotation periods. Payments based on actual sequestration leads to greater benefits from sequestration at a lower cost.

In research focused on other countries, van Kooten et al. (1995) examine the implications of carbon subsidies and taxes for economically optimal harvest decisions and for carbon sequestration in forests in Western Canada. Subsidies are intended to encourage planting and management activities that promote tree growth, while taxes discourage harvest and the subsequent release of carbon. They find that (for the most likely range of parameters) rotation ages would increase by roughly 20% over the level where no carbon costs or benefits are considered. Van Kooten et al. (2002) examine the economic aspects of the institutions and incentives needed to encourage landowners in Canada to adopt tree planting on a large scale. They argue that there are transaction costs associated with plantation forests in developed countries that could make them more costly than originally anticipated. Unanticipated transaction costs could also thwart attempts by governments to implement afforestation on a large scale. For an empirical study, they obtain data from a mail-out survey of farmers in Canada's grain belt region. Their results suggest that the transaction costs of getting landowners to convert their land from agriculture to plantation forests appear to be a significant obstacle to afforestation, possibly increasing the costs of afforestation projects beyond what conventional economic analysis suggests. Even if they are fully compensated for lost agricultural revenues and tree planting costs, more than one-quarter of survey respondents (45 of 177) indicated that they would be unwilling to enter into an afforestation program voluntarily. The authors argue that a possible reason is that improving land by removing trees is considered costly, both financially and in terms of utility.

These papers examine carbon sequestration in forests, but do not focus specifically on NIPFs. Nevertheless, their results broadly agree with those from the literature that examines afforestation. In particular, they suggest that incentive programs including taxes or carbon payments or other types of subsidies can impact the management decisions of forest owners in ways that can lead to increased carbon sequestration.

2.3. Carbon Sequestration in NIPFs

There is a small literature that discusses carbon sequestration in the specific context of NIPFs. Stainback and Alavalapati (2002) suggest that forests being managed for commodity production could sequester additional carbon by lengthening the rotation and producing more products with a long product life, such as sawtimber, and fewer products with a shorter product life, such as pulpwood. They argue that, for private forests, incentives may be necessary to induce landowners to consider carbon sequestration benefits in their production decisions. They examine how internalizing carbon benefits onto private pine plantations in the southeast U.S. would impact forest management, specifically the optimal rotation age, the product mix produced, and the amount of carbon supplied in slash pine forests. They set up a model in which landowners are compensated for carbon sequestered as trees grow and carbon is stored in timber products (sawtimber and pulpwood) and are taxed for carbon emissions at harvest. They find that a carbon subsidy and tax policy would increase the amount of carbon sequestered in a forest stand in two ways: by lengthening the rotation age and increasing the amount of biomass produced in the stand, and by increasing the proportion of the biomass put into long-lived end products such as sawtimber. This incentive system would have a significant impact on the management decisions of private forestland owners. Positive values for carbon significantly increase forestland rents. This increase in private forestland rents induces landowners to use a larger portion of their land for timber production, thereby increasing timber supply at the extensive margin. The increase in forestland rents could also reduce forest conversion to other uses such as urban development. They also argue that the increase in land values has implications for the implementation of a carbon subsidy and tax policy, since the fact that landowners would gain substantially from such a policy indicates that it could be implemented on a voluntary basis similar to the way the Conservation Reserve Program is implemented.

Alig (2003) summarizes land use and land cover changes, identifies the drivers of deforestation, afforestation, reforestation, and timber harvest, and highlights the implications for carbon sequestration in forests, including NIPFs. He argues that U.S. landowners have responded significantly to past government programs for tree planting (afforestation), such as subsidized tree planting for environmental goals, and that projections indicate that U.S. private timberlands have considerable potential for additional wood production and more carbon sequestration under intensified management. However, he notes that NIPF owners' responses to incentives that try to affect harvest decisions, such as delaying harvest, are complicated by the fact that many owners do not have timber production as a primary goal and that some owners have multiple land management objectives.

Im et al. (2007) examine the welfare impacts and costs of a carbon tax and subsidy program for enhancing the sequestration of carbon on the existing private forest land base. Forest owners are subsidized for the carbon they accumulate and taxed for the carbon released by harvesting. They develop a theoretical model of a forest owner's response to the carbon tax and demonstrate how the forest owner will adjust harvest in various circumstances. They employ a model of the log market in Oregon to develop specific estimates of the impacts of the carbon tax on harvest and management actions and to examine the cost-effectiveness of the carbon tax as a mitigation option in the forestry sector. The simulated carbon tax leads to reduced harvest and increased carbon stock in standing trees and understory biomass. Changes in the level of silvicultural investments vary by owner, depending on the nature of their initial inventory. Average rotation age increases, varying in extent across ownerships and site qualities. Their estimates of the marginal cost of sequestering carbon in Oregon private forests are shown to be within the range of costs for projects considering afforestation alone in some eastern regions of the United States.

Fletcher et al. (2009) examine the willingness of NIPFs in Massachusetts to sell carbon credits in several hypothetical carbon sequestration programs. They use a pilot survey of 17 NIPFs in western Massachusetts, which contained a choice experiment for six alternative carbon credit programs with different eligibility requirements, time commitment, expected payment, and penalty for early withdrawal. They use regression models to examine the relationship between program ratings and attributes and socioeconomic characteristics of NIPFs, as well as their willingness to sell credits at various prices. They find that program rating increased with the expected payment and the length of commitment and decreased with the early withdrawal penalty. They also find that at current carbon credit prices, very few participants (less than 7%) would be willing to sell. However, the small sample size of this study suggests that these results should be interpreted with caution.

Our review of the literature on carbon sequestration in forests reveals that little attention has been paid to the potential effects of incentives for carbon sequestration in NIPFs. The broader literature on afforestation of agricultural land and carbon sequestration in forests suggests that incentives can be effective in changing land use and forest management decisions in ways that could increase the amount of carbon sequestered in forests. The extent to which these general results apply specifically to NIPFs, however, remains an open question given that, as Alig (2003) points out, their motivations for owning and managing forest land may differ from those of other forest owners and landowners. To gain additional insight into the behavior of NIPFs, next we review the broader literature on how they respond to incentive programs with alternative environmental goals, such as sustainable forestry practices or biodiversity conservation.

3. Incentives and NIPF Landowner Behavior

There is a large literature that explores NIPF landowner characteristics, objectives, and forest management decisions. This literature identifies a variety of policy tools that may influence the management decisions of NIPF owners, including education, technical assistance, regulation, and financial incentives. The most common financial incentives include cost sharing or grants for developing forest management plans or implementing forest management practices, including planting and stand improvement, and tax incentives through the federal income tax and state property tax systems (Jacobson et al. 2009a; 2009b). Summaries of this literature include

Amacher et al. (2003), Greene et al. (2005; 2006), Kilgore et al. (2007), and Joshi and Arano (2009).

Many of these papers focus on how landowner attributes and incentives shape forest management decisions or sustainable forestry practices. Several authors have reviewed the literature and conclude that NIPF owners are largely unaware of the existence of incentives or do not understand how they apply to them and that they would often carry out the supported practice even in the absence of incentives. They find that NIPF owners are largely unresponsive to property tax and capital gains provisions, and that forest property tax programs are only modestly successful in achieving their goals (Greene et al. 2005; 2006; Kilgore et al. 2007; Jacobson et al. 2009a; 2009b). They also identify approaches that have consistently been found to provide adequate incentives for NIPFs to practice sustainable forestry: technical and management planning assistance, cost sharing, and direct contact with a forester or natural resource specialist.

Jacobson et al. (2009a; 2009b) additionally use a survey of forestry agency officials who administer public incentive programs to examine whether, given changing forest ownership patterns and program emphases, financial incentives in the northern and southern regions are effective in promoting sustainable forestry practices, whether some programs are more effective than others, and the characteristics of effective programs. They evaluate eight federal incentive programs and three nonfederal programs. They find that forestry officials rated federal incentive programs as only adequate for NIPF owner awareness and appeal. They argue that one possible reason for the low appeal is a general weariness of participating in government programs for fear of loss of independence and fear of government control over management choices. Overall, forestry officials think that financial incentives are effective in promoting sustainable management practices. The results suggest that in general programs targeted specifically to forest owners are rated higher than programs targeted to ranchers and farmers in addition to forest owners.

Joshi and Arano (2009) agree that NIPF owners are largely unaware of incentive programs available to them, and thus argue that much remains to be done to encourage NIPF landowner investment in forestry activities. They suggest that existing programs have had limited success because they emphasize timber production, whereas landowners usually own forests for a variety of reasons, including recreation and wildlife or as a site for their home, and timber production may not be their main priority. They use data from a mail survey of 2,100 NIPF owners in West Virginia to evaluate the factors affecting their decisions to engage in timber harvest, silvicultural activities (e.g., planting, fertilization), property management (e.g., road maintenance, access control), and wildlife habitat management and recreation improvement. They find that age, education, profession, income, ownership size, length of ownership, distance to residence, objective of ownership, and development of a management plan were significant determinants of at least one of the categories of management activities.

Hardie and Parks (1996) examine how the level of cost-sharing might have affected the number and size of forest tracts enrolled in the reforestation cost component of the Forestry Incentive Program (FIP) in the southern pine region of the U.S. They report acreage enrollment predictions for government cost shares ranging from 0% to 100%. They also develop predictions that offer some insight into the potential effects of an education program aimed at informing NIPF landowners about the reforestation component of the FIP. The data used in the analysis are from an area-frame survey conducted by the National Agricultural Statistics Service. The results suggest that few acres would be planted after harvest if the cost-sharing programs did not exist.

The results also show that total acreage predictions decrease much more rapidly with decreases in the rate of cost-sharing when tract size is predicted to respond to the level of program support. The results also reveal that there is an effective trade-off between increasing the cost-sharing percentage and informing more NIPF owners about existing cost-sharing programs.

Nagubadi et al. (1996) examine factors influencing Indiana NIPF landowner participation in forestry assistance programs based on actual participation decisions. They use data collected by mail survey from NIPF landowners (789 respondents) in Indiana during the winter of 1994. They find that information and management factors are the most influential in predicting the probability of participation in forestry assistance programs. Landowners who are motivated by commercial interests and are involved in commercial forestry activities have a higher probability of participation in forestry programs. The results also suggest that the size of landholding is an important determinant of participation in forestry assistance programs in general, and classified forestry programs in particular.

Conway et al. (2003) argue that bequest motives, debt (or the propensity to save), and nontimber activities such as hunting, hiking, or wildlife observation could be important in determining NIPF landowners' harvest decisions. They use a survey of NIPF owners in the Southeastern U.S. to obtain data for a model addressing these motives. Their results suggest that there are significant differences between landowners holding large versus small forest properties, between absentee and resident owners, high versus low debt loads, and those that have and do not have bequest intentions. They find that absentee owners are less likely to harvest and engage in nontimber uses of their forest, hold higher debt relative to income, and are more likely to bequeath standing timber. They show that larger tracts are more likely to be harvested and used for nontimber activities and less likely to be bequeathed as standing timber. Finally, they conclude that landowners with high debt are more likely to engage in nonmarket activities on their land but also more likely to harvest and less likely to bequeath standing timber.

Nagubadi and Zhang (2005) develop a modified multinomial logit framework to model and predict land use changes by forest ownerships and forest types and apply it to forests in Alabama and Georgia. They find that land quality, federal incentive programs that promote tree planting, and better returns for forestry than for agriculture are the main factors driving the increase in timberland in the two states. Higher income levels and a higher proportion of good-quality land, on the other hand, decrease forestry land use. They find that higher forestry returns increase the amount of industrial private forests, and nontimber values increase acreage of NIPF ownership. Higher population density increases NIPF ownership, whereas a higher proportion of better quality land decreases NIPF ownership. They argue that pooling all types of timberland use into a single category can hide differences among heterogeneous ownerships and forest types and lead to incorrect predictions of land use change.

Ross-Davis et al. (2005) examine ownership characteristics and values of landowners in Indiana who had planted trees between 1997 and 2001 and their motivations for planting trees, and relate these ownership characteristics, values, and motivations to seedling survival during the critical establishment phase. They gather data through interviews of 151 individuals and field data collection from 87 sites. They find that landowners value their land for the privacy it provides, as a place of residence, and as a legacy for future generations. Landowners afforested primarily to provide for future generations, to supply food and habitat for wildlife, and to conserve the natural environment. Seedling survival was lowest on sites owned by individuals who did not value their land as a legacy for future generations. Raunikar and Buongiorno (2006) analyze the revealed willingness to pay of NIPF owners in the south central U.S. for the amenities of mixed age and mixed species forests (i.e. uneven-aged loblolly plantations). They estimate nontimber value (NTV) by the income that owners are willing to forego to maintain natural stands, instead of converting them to more profitable plantations. The results show that there are significant differences in the NTV of natural plots by ownership. The average NTV of natural plots was highest on public lands, second on NIPF lands, and least on industry lands. Specifically, they estimate that the average NIPF owner is willing to forego 60% of the timber profit for the NTV of their more natural stands compared to a less diverse industrially managed even-aged plantation.

Other papers focus on the effects of incentive programs to promote conservation of biodiversity and preservation of endangered species habitat on NIPFs. Kline et al. (2000) examine the reasons why NIPF owners own forest land and their willingness to adopt management actions, such as restricting harvest, to restore or protect riparian salmon habitat, in exchange for a financial incentive in the form of a federal income tax reduction. They use data from a survey of NIPF owners in western Oregon and Washington. They classify forest owners according to their timber and nontimber objectives and develop an empirical model of landowners' willingness to forego harvest in riparian areas for ten years as a function of the tax reduction, their socioeconomic characteristics, and forest ownership objectives. They find that a significant proportion of forest owners are motivated by objectives other than timber production and that for many habitat protection is consistent with their forest ownership objectives. They suggest that participation of some NIPFs could be enlisted through low cost programs that include technical assistance and education regarding management practices that benefit riparian species. They find that NIPF owners who have mainly timber objectives tend to own larger forests and a larger proportion of NIPF land, making their participation desirable. Financial incentives such as tax relief or cost sharing may be necessary to elicit their participation. They find that mean incentive payments necessary to induce participation vary by ownership objectives. Required payments to forego harvest are higher for owners who have primarily timber objectives than for owners with either timber and nontimber objectives or mainly recreation objectives.

Zhang and Flick (2001) examine the impact of financial incentives (cost-sharing and a tax incentive) and of potential regulatory land use restrictions imposed by the Endangered Species Act on NIPF landowner investment behavior. They conduct an econometric analysis of recorded reforestation activities under the incentives program and the regulatory threat, using data obtained through a survey of NIPF owners in North Carolina and South Carolina. The results show that incentives and regulatory threat influence NIPF reforestation behavior in opposite directions: incentives increase reforestation investment, while the threat of land use restrictions decreases it. The results imply that government financial assistance programs can be used to alleviate the disincentive provided by the Endangered Species Act in reforestation investment.

Langpap (2004; 2006) uses a survey to examine participation in incentive programs for endangered species conservation by NIPF owners in western Oregon and Washington and analyzes the likely effects of assurances, cost sharing, and compensation incentives on their forest management decisions. He identifies landowner and property characteristics that affect participation decisions for an incentive program designed to provide habitat for endangered species, and examines how these characteristics differ from those that determine participation in more general incentive programs. His results suggest that landowners who are younger, have acquired property more recently, own more woodland, and are interested in conservation and providing habitat are more likely to participate. He finds that compensation and assurances could have a significant effect on landowners' management decisions, but cost sharing may not. His results also suggest that more effective incentive programs would combine financial incentives with assurances about future regulation. Mayer and Tikka (2006) evaluate six voluntary economic incentive programs for biodiversity conservation from Europe and North America. They find that important factors contributing to program success include an allowance for some economic productivity in enrolled forests, a long period since the inception of the program, and little interference from other incentive programs.

Nelson et al. (2008) develop an integrated model that predicts private land use decisions as a function of existing market conditions and incentive-based conservation payments and predicts the impact of land use changes on ecosystem services and biodiversity conservation. They use data from Oregon to compare the provision of carbon sequestration and species conservation under five policies that offer payments for conservation. They compare the performance of targeted and untargeted land use conservation payment schemes relative to baseline land use patterns with no land use conservation policy as well as relative to the efficiency frontier for various levels of land use conservation program budgets. Their results suggest that incentives to restore land to natural cover increase both carbon sequestration and biodiversity conservation, but that there are tradeoffs between these two policy objectives. They show that policies aimed at increasing the provision of carbon sequestration do not necessarily increase species conservation and that highly targeted policies do not necessarily do as well as more general policies. Furthermore, they show that none of the conservation payment policies considered produce increases in carbon sequestration and species conservation that approach the maximum potential gains on the landscape.

Matta et al. (2009) examine the willingness of forest owners to adopt management practices designed to enhance biodiversity. They use data from a 2005 survey of NIPF owners in Florida to analyze how land, landowner, and program characteristics influence NIPF landowner participation in incentive programs designed to provide habitat beyond existing Best Management Practices. Their results indicate that mean willingness to accept for adoption of practices at their highest level of restriction would range between $37 and $151/ha/yr, suggesting that financial incentives would promote habitat conservation on NIPFs. The results also suggest that younger forest owners, with higher income, education, and more years of ownership are more willing to adopt the suggested practices. Distance from urban centers, residence on the property, and membership in forest or conservation organizations also increase the probability of participation.

Some papers have examined incentives for biodiversity conservation in other countries. For example, Siikamaki and Layton (2007) assess incentive payment programs relative to centralized, top-down approaches to biological conservation by comparing the cost and conservation outcomes of an incentive payment program and a top-down program applied to the protection of small-scale biodiversity hotspots in Finland. They estimate the opportunity cost of conservation from a survey of forest owners in Finland that asked them about enrolling land for species protection in return for a payment. They combine landowners' assessments of their forests with data on species habitat to derive estimates of the biological benefits of enrolling a site through a payment program or through a top-down mechanism, which are in turn used to examine the cost-effectiveness of achieving different biological targets through alternative approaches. They find that a fairly simple program that allows owners to enroll land can achieve conservation targets in a cost-effective manner. They also find that the incentive payment program performed better than a species-only site selection approach, and was nearly as cost-effective as the cost-effective (hypothetical) solution to the conservation program they use as a benchmark.

To summarize, a review of the literature on the effects of incentives on NIPF landowner behavior leads to sometimes conflicting conclusions. Most of the literature agrees that the response of NIPF owners to various incentives depends critically on the ownership motives of the landowner, as well as other landowner and property characteristics. However, there is much less agreement on the effectiveness of different types of incentives. If the goal is to promote forest management and/or sustainable forestry, then the consensus seems to be that financial incentives alone are largely ineffective in promoting the desired behavior. The noteworthy exception seems to be cost sharing incentives. In addition, given landowners' lack of knowledge about incentives, information and technical assistance may be effective as well. An additional noteworthy aspect of this literature is that surveys reveal that landowners may often carry out the desired management activities even in the absence of incentives. This highlights the issue of whether there is additionality in incentives programs, which will be discussed in Section 5.

If the goal is to promote biodiversity and habitat conservation, on the other hand, the existing evidence seems to suggest that financial incentives can be effective in promoting desirable management choices by NIPF owners. Furthermore, there is evidence that in this case cost sharing may again be the exception, with at least one study (Langpap 2006) finding that it may not be effective. There is also some evidence in this literature that landowners whose main ownership objective is not timber production may be willing to carry out some of the desired management activities at lower cost, which again raises the issue of additionality.

This divergence in results suggests that it is difficult to make generalizations about the impacts of incentives on NIPF owner behavior, and that their effectiveness may depend on the specific policy goal, and may vary across regions and over time, as well as with the characteristics of landowners. Thus, it might not be adequate to extrapolate from the existing literature to infer how NIPF owners may respond to incentives in the specific context of carbon sequestration.

4. Incentives for Carbon Sequestration in Agriculture

To complement our review of the literature on carbon sequestration in forests, in this section we provide a review of the recent economic literature on incentives for carbon sequestration in agriculture. Many of these papers examine how incentives affect agricultural landowners' decisions to adopt agricultural practices that increase carbon sequestration in agricultural soils.

Pautsch et al. (2001) examine different government and market-based instruments to increase soil carbon sequestration through increased adoption of conservation tillage. They use a model of the farmer's adoption decision and discuss the design of subsidy and market-based instruments, focusing on the institutions and practices surrounding agricultural policy. Then they use Natural Resources Inventory data (USDA Natural Resources Conservation Service) to estimate the probability that farmers adopt conservation tillage and combine the estimates with physical models of carbon sequestration to estimate and compare the costs of implementing a variety of subsidy and market-based schemes. They find that the lowest payment cost can be achieved using a price discriminating subsidy, although such an approach would not be politically viable. They find that a single subsidy is less efficient, but would have lower political and administrative costs. Their results indicate that payments associated with a price discriminating subsidy would be up to four times lower than a single price subsidy. They also find that costs would be much higher when payments have to be made to all farmers employing conservation tillage rather than just those adopting in response to the subsidy.

Feng et al. (2000) use a dynamic model that includes both emission reductions and sequestration as sources of GHG reductions to investigate the value of carbon sequestration in agriculture, and demonstrate that this value is only a fraction of the value of emission abatement unless the sequestration is permanent. They also show that to optimally reduce the carbon stock, sinks should be used as early as possible. They propose three instruments to efficiently implement sinks: a pay-as-you-go system, a variable-length-contract system, and a carbon annuity account. In a pay-as-you-go system, land owners sell and purchase emissions based on the permanent reduction of carbon. In a variable-length-contract system, independent brokers would buy permits from sequestration sources and sell them to carbon emitters, thus providing the service of generating “permanent” carbon reductions from a series of independent temporary reductions. In a carbon annuity account, a landowner who sequesters carbon is paid the full value of the permanent reduction in GHGs achieved, but the payment is put directly into an annuity account. The earnings, but not the principal, of the account can be accessed as long as the carbon remains sequestered. The principal is removed if the carbon is released. If the carbon is sequestered permanently, the landowner eventually earns all of the interest payments.

Antle et al. (2003) develop a method to investigate the efficiency of alternative types of policies or contracts for carbon sequestration in cropland soils, taking into account the spatial heterogeneity of agricultural production systems and the costs of implementing efficient contracts. They describe contracts being proposed for implementation in the U.S. and other countries that would pay farmers for adoption of specified practices (per-hectare contracts), as well as more efficient contracts that would pay farmers per ton of soil carbon sequestered, and show how to estimate the costs of implementing the more efficient contracts. They conduct a case study of a major agricultural region in the U.S. (the Northern Plains), which confirms that the relative inefficiency of per-hectare contracts varies spatially and increases with the degree of spatial heterogeneity. The results also show that per-hectare contracts are as much as five times more costly than per-ton contracts. Measurement costs to implement the per-ton contracts are found to be positively related to spatial heterogeneity but are estimated to be at least an order of magnitude smaller than the efficiency losses of the per-hectare contract for reasonable error levels. This finding implies that contracting parties could afford to bear a significant cost to implement per-ton contracts and achieve a lower total cost than would be possible with the less efficient per-hectare contracts.

Hartell (2004) asks what payments must be received by agricultural producers to induce them to supply certain quantities of beneficial nonfood outputs. In the empirical application, this study values carbon sequestration in agricultural soil through the adoption of no-till cultivation using mathematical programming to derive representative price schedules. The shadow price schedule for various levels of yearly carbon sequestration is derived by iteratively imposing minimum quantity constraints. The results and derived supply schedules show that the level of monetary incentive and total budgetary outlays required to induce multifunctional carbon sequestration might be lower than anticipated, but this depends importantly on assumptions about the level of producer risk aversion.

Pendell et al. (2007) study the carbon credit incentives needed to motivate adoption of no-tillage and/or manure applications to enhance soil carbon sequestration in corn production in

Kansas. They examine the net returns from continuous corn production using conventional and no-tillage with nitrogen fertilization from either ammonium nitrate or beef cattle manure for sequestering carbon with and without incentives. The results indicate that no-tillage and manure fertilization increase carbon sequestration. Carbon credits or government program incentives are not required to entice risk-averse managers to use no-tillage since no-till systems have the highest net returns and greatest sequestration rates, but are required to encourage manure use as a means of sequestering additional carbon even at historically high nitrogen prices.

Graff-Zivin and Lipper (2008) develop a farm-level model of the decision to adopt a technology that generates soil carbon sequestration co-benefits. They explore incentives of poor farmers to adopt production systems that increase soil carbon sequestration, focusing on the increased agricultural yield risk associated with the transition to a new farming system. They use a household dynamic optimization model of the decision to adopt conservation agriculture and supply soil carbon sequestration, where farmers optimize over expected utility of profits from agriculture and carbon sequestration. They considered two distinct impacts on agricultural productivity: the technological effects of the new system and the productivity effects of changes in soil carbon on agricultural output. Comparative static results indicate that increases in the soil carbon sequestration price and the discount rate have unambiguous impacts on equilibrium soil carbon levels, the former leading to higher and the latter to lower carbon sequestration levels. Increases in the price of agricultural output and risk aversion have ambiguous impacts, depending on the relative strength of the productivity and technology effects. The paper concludes with a discussion of designing soil carbon payment mechanisms to benefit low income farmers. The results suggest that pooling soil carbon sequestration payments and devising other group schemes to help farmers share risk offer the potential of providing an effective way of stimulating agricultural development and poverty reduction through climate change mitigation initiatives.

Finally, some papers report similar research in other countries. Antle and Diagana (2003) argue that incentive mechanisms for carbon sequestration in agricultural soils could contribute to alleviating rural poverty, enhancing agricultural sustainability, and mitigating GHG emissions. They assess the role that soil carbon sequestration could play in addressing soil degradation problems in developing countries. They conclude that emerging policies to mitigate GHG emissions, such as global carbon markets or the Kyoto Protocol's Clean Development Mechanism, and other international and national policies, could be used to create incentives for farmers in developing countries to adopt practices that benefit them and simultaneously help reduce GHG emissions. However, they caution that several significant challenges, such as lack of well-functioning legal and financial institutions or poorly defined property rights, would have to be overcome before poor farmers in developing countries are able to take advantage of these opportunities. They cite a carbon loan that provides financing for conservation investments to be paid back by generating carbon credits as an example of an institutional innovation that could help farmers overcome adoption barriers caused by imperfect capital markets.

Weersink et al. (2005) assess the extent to which agriculture can be part of meeting Canada's Kyoto commitments through direct means induced by a carbon market or indirectly through the voluntary adoption of GHG-reducing practices, such as reduced tillage. They consider three policy mechanisms that could affect the extent to which net GHG emissions are reduced: moral suasion, an offset market, and an inventory accounting system. They present a conceptual model of a supply curve for carbon credits and review the empirical evidence on the factors influencing this supply curve, including the potential price of carbon, the costs of a contract, and the opportunity cost of sequestration and emission reduction activities relative to their emission reduction potential. Based on the data, they argue that involvement by farmers in the offset market will be limited, but that there will be net GHG emission reductions from agriculture through voluntary adoption partially prompted by government extension efforts. They find that voluntary adoption of beneficial management practices will be the main way by which Canadian farmers will cut GHG emissions. Participation in the carbon-offset market will be limited due to relatively low prices offered by large emitters for carbon credits, discounts applied to those prices due to temporary sequestration, transaction costs and risk premiums associated with carbon contracts, and the low elasticity of supply of CO_2 abatement. Nevertheless, they argue that Canadian agriculture is likely to contribute significantly to reducing emissions through adoption of zero tillage and reduced fertilizer use, but that this contribution will respond mainly to personal economic objectives of farmers rather than to direct incentives through the offset program.

Antle and Stoorvogel (2008) explore the impacts of payments for agricultural soil carbon sequestration on poverty of farm households and the sustainability of agricultural systems. They use a theoretical model combined with case studies in Kenya, Peru, and Senegal. They find that carbon contracts are likely to increase rural incomes and reduce the rate of soil carbon loss. This suggests that carbon payments could have a positive impact on sustainability while also reducing poverty.

To summarize, these papers suggest that, as in the case of forest owners, incentives can be effective in eliciting management decisions that increase carbon sequestration from agricultural landowners. Some of these papers suggest that the issue of additionality may be relevant when implementing incentives programs in agriculture as well. We turn to a discussion of this issue in the next section.

5. Additionality

Within the framework of incentive programs for provision of ecosystem services, additionality generally refers to whether agents supplying ecosystem services in exchange for an incentive are being compensated for services they would not have provided in the absence of the incentive. The concern is whether the incentive actually elicits additional provision of the ecosystem service.

For instance, Murray et al. (2007) address how credits generated by agricultural soil carbon sequestration (ASCS) activities can be adjusted to account for the phenomena of permanence, leakage, and additionality (PLA). The underlying objective is to understand and quantify what the net carbon benefits of an ASCS project are once we account for the fact that (1) the sequestered carbon may be stored impermanently, (2) the project may displace emissions outside the project boundaries, and (3) the project's carbon sequestration may not be entirely additional to what would have occurred anyway under business-as-usual conditions. This article examines the conceptual and policy rationale for adjusting ASCS credits for PLA, describes methods for making these adjustments, and presents some evidence of the magnitude these effects could have on the economic returns. For the additionality of carbon sequestration, the authors introduce baseline estimation approaches and discuss data that could be used to develop baselines for the two main ASCS activities of interest and present an example of a calculation of additionality.

Ferraro (2008) discusses contract design issues in the context of payments for environmental services and argues that reducing informational rents (costs generated by private information) is important in this context in order to maximize the amount of services obtained from limited budgets. He adds that reducing informational rents also mitigates concerns about additionality. Wünscher et al. (2008) suggest a strategy to increase the additionality achieved by payments for environmental services (PES) by targeting benefit-cost ratios, incorporating multiple objectives, and explicitly considering the risk of environmental service loss as a spatial variable. They use data from Costa Rica to test the potential of the suggested targeting tool to boost the efficiency of that country's PES program in terms of additional environmental services per dollar spent. Their results suggest that the efficiency (benefit-to-cost ratio) of Costa Rica's PES program could be increased by using a targeting process that integrates spatial data rather than a targeting system based solely on priority areas.

More generally, the issue of additionality can be framed in the context of asymmetric information and contract design (see Salanié 2005 or Bolton and Dewatripont 2005 for comprehensive modern treatments). There are a number of recent applications in the context of provision of ecosystem services. Gren (2004) examines efficient contracts for converting arable land into pollution sinks. Crépin (2005) examines the use of incentives to create wetlands in an asymmetric information context. She uses a theoretical principal-agent model to show that contract choice can create welfare gains, and that the choice of contract depends on the distribution of the unobserved landowner type, the elasticity of costs and benefits to wetland size changes, and on the costs of acquiring information. Sheriff (2009) develops an empirical methodology to use available data to develop beliefs regarding the technology and distribution of types in a regulated sector characterized by hidden information. He uses the results to calibrate a second-best land conservation mechanism and evaluates its cost relative to simpler alternatives.

In the specific context of carbon sequestration in forests, the issue of additionality is mostly mentioned when discussing carbon offsets and the Clean Development Mechanism (CDM) of the Kyoto Protocol. Asuka and Takeuchi (2004) argue that non-additional certified emission reductions in excess of a certain number generated by relaxing the additionality criteria may eventually lead to economic losses for developing countries. Trexler et al. (2006) review a variety of suggested additionality tests based, for instance, on whether GHG emissions are reduced below regulatory requirements, if a project uses technology it otherwise would not, or if the rate of return on a project would be too low without sequestration incentives, among other criteria. They then discuss the potential for false positives and negatives in these tests, and how they can be implemented as part of an additionality policy that seeks to reduce type I and type II errors.

Van Kooten and Sohngen (2007) define additionality as getting credit only for carbon uptake above and beyond what occurs in the absence of carbon-uptake incentives. The additionality condition is satisfied if it can be demonstrated that a forest would be harvested and converted to another use in the absence of incentives. Carbon sequestered by incremental forest management actions, such as juvenile spacing, thinning, fire control, or fertilization would be eligible for carbon credits only if these activities would not otherwise have been undertaken. Afforestation projects satisfy additionality if they provide environmental benefits not captured by the landowner (e.g. water quality, wildlife habitat) and which would not be undertaken in the absence of economic incentives.

Schneider (2009) examines how the additionality of CDM projects has been assessed in practice by systematically evaluating 93 projects. He concludes that current tools used for evaluating additionality need improvement, as they can be subjective and difficult to validate, based on undocumented assumptions, and lacking credibility. Maness (2009) argues that any climate agreement will require clear and mutually acceptable methods for determining baseline levels of carbon sequestration, so that carbon offset credits for projects are given only for the additional carbon sequestered beyond what would have been sequestered in the absence of the project.

6. Data Availability

In this section we briefly outline the data available on carbon sequestration in forests and NIPFs to assess the viability of conducting empirical studies on the effectiveness of incentives for carbon sequestration in NIPFs.

The USDA Forest Service, as directed by the Resources Planning Act, conducts a comprehensive national assessment of renewable resources, including forests. The 2007 Forest Resources of the United States report includes, for example, data on forestland area, net volume of timber, annual growth, mortality, and removals, and average area planted and harvested by regions, subregions, states, productivity class, ownership group, and various other categories (USDA Forest Service 2008). It also includes estimated regional carbon storage and gross annual sequestration for the year 2000 and mean carbon per hectare by size-class and EPA Level II Ecological Region for the years 2001-2006. These data, however, are highly aggregated, and do not provide information at the individual forest owner level.

The Forest Inventory and Analysis (FIA)'s National Woodland Owner Survey, conducted by the USDA Forest Service, asks forest owners about characteristics of their woodland, ownership motives, woodland use and management, intended future uses, and concerns, and obtains demographic information as well. This database provides considerable information at the individual landowner level, including: age, gender, education level, and income of the forest owner; year, method, source of acquisition, and size of their holdings; harvesting and management activities conducted, conservation easements on the property, and participation in cost-sharing programs. However, it currently does not include any information on carbon, or carbon management and sequestration.

The National Resources Inventory (NRI) is a statistical survey of natural resource conditions and trends on nonfederal land in the United States, including privately owned lands, tribal and trust lands, and lands controlled by state and local governments, conducted by the USDA Natural Resources Conservation Service (NRCS) (2007). It provides nationally consistent statistical data on how these lands are used and on changes in land use patterns for the period 1982 - 2003. Land use categories analyzed include agriculture and forests.

In terms of data on incentives, Greene et al. (2009) have collected a database of all federal, state, and private incentives available to NIPF owners. However, this database only provides a listing of available programs, not actual data on their implementation or effectiveness.

7. Summary and Concluding Comments

In this report we have summarized the economics literature on incentives for carbon sequestration in forests, including afforestation of agricultural land and sequestration in existing forests and NIPFs, as well as the broader literature on effectiveness of incentives for forest management and biodiversity conservation on NIPFs and on carbon sequestration on agricultural land. We have also touched on the issue of additionality in the context of incentives for provision of ecosystem services and briefly reviewed relevant data sources.

There are large literatures on afforestation, carbon sequestration in forests, and incentives for NIPFs in general, but a very small literature on incentives for carbon sequestration on NIPFs. The broader literature on carbon sequestration and incentives suggest that various types of incentives can effectively be used to promote afforestation and forest management practices to increase carbon sequestration. However, the literature on NIPFs suggests that the effectiveness of incentives programs depends on a variety of factors, including the objective of the policy and landowner and property characteristics. Therefore, results from existing studies cannot necessarily be extrapolated to draw conclusions on the potential effectiveness of incentives for carbon sequestration on NIPFs. A separate study that focuses specifically on this topic would provide more reliable insights. Finally, our review suggests that the issue of additionality is relevant in this context, and that the design of any incentive scheme to elicit increased carbon sequestration needs to carefully consider how to minimize the costs caused by asymmetric information about landowner's baseline behavior.

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