**Evaluating Non-Industrial Private Forest Landowner Willingness to Manage for Forest
Carbon Sequestration in the Southern United States**

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Abstract

Forest carbon sequestration is considered one of the most efficient strategies for climate change mitigation, and forests provide significant carbon storage in the United States. Non-industrial private forest (NIPF) ownership is the dominant ownership group in the southern US, but little is understood about landowners' willingness to manage forests for carbon sequestration. This study examines NIPF landowner willingness to delay final timber harvest for additional carbon sequestration despite unknowns about positive or negative impacts to profitability that result from carbon price fluctuations. Survey data from 735 landowners in the southern United States were used to estimate a probit model analyzing their participation behavior. Landowner willingness to participate in carbon sequestration practices was 55%, 25%, and 16% when such practices were more profitable, revenue neutral or less profitable than timber management only, respectively. Although many landowners would require a significant monetary incentive to participate in carbon sequestration, others would participate with little or no incentive. Those having recreational goals for their property were the most likely group to participate in carbon sequestration. Management changes (i.e., management plan and verification requirements) and carbon revenue were the two most important determinants of their probability of participation. In

summary, this study provides a better understanding of the relationship between landowner participation and socioeconomic details, sequestration program attributes, attitudes, and behaviors. Designing education, incentive, and assistance programs that align with landowners' recreational goals would result in a low-cost carbon sequestration policy.

Key Words: Climate change, contingent rating, harvest delay, landowner decision making, carbon sequestration by forests

Introduction

Forest carbon sequestration is an efficient strategy for removing atmospheric carbon dioxide (CO₂), but the lack of national carbon-sequestration policy instruments and an emergent carbon market structure are contributing to uncertainty related to forest-based carbon-offset projects in the United States. If included in a national atmospheric greenhouse gas (GHG) reduction and climate change-mitigation strategy, forest-based carbon-sequestration strategies offer the most economical option for long-term storage (Malmsheimer et al. 2008). Multiple pieces of climate change legislation that considered forestry offsets as an integral part for climate change mitigation have been proposed in the United States Congress, but none has become law (Galik et al. 2013). Despite the lack of national carbon-sequestration policy instruments, two voluntary and compliance-based carbon offsets and registries, Chicago Climate Exchange (CCX) and California Compliance Offset Program, have provided or currently provide a forest carbon-trading opportunity for the private forest landowners in the United States. However, reasons such as lack of a consistent carbon price, higher transaction costs, and uncertainties related to longevity of the program are major obstacles to participation of private forest landowners (Kerchner and Keeton 2015). Recent involvement of the United States in global climate change

1 policy negotiations (Leggett 2011) indicate the potential of national climate change-mitigation
2 and carbon-sequestration policy instruments in the future.

3 In the southern US, non-industrial private forest (NIPF) landowners could make a
4 significant contribution toward climate change mitigation and carbon sequestration because they
5 own 58% of the total forestland (Butler and Wear 2013). However, NIPF landowners often own
6 their forestland for multiple reasons, including timber production, recreation, and biodiversity
7 conservation (Butler and Leatherberry 2006). In addition, landowners differ widely in terms of
8 forest management behavior, and their strategies range from passive to very active management.
9 To increase carbon storage, NIPF landowners may have to delay harvest or implement
10 alternative forest-management strategies (Galik et al. 2013). Despite their potential to increase
11 regional carbon storage, NIPF-landowner willingness to manage their forest for carbon
12 sequestration in the southern US is still unclear. Additionally, carbon market developments over
13 the last few years (Stanley and Yin 2013) have shown that carbon price might change
14 substantially, which can affect landowner revenues. It would be informative to know whether
15 NIPF landowners in the southern US would be willing to delay their final timber harvest for
16 carbon sequestration when the carbon revenue is not guaranteed. So far, there is limited
17 understanding related to the southern US landowner decision making and participation behavior
18 in climate change-mitigation and carbon-sequestration activities under an uncertain carbon-
19 revenue scenario.

20 This study analyzed the willingness of NIPF landowners in the southern United States to
21 manage a forest for carbon sequestration in hypothetical scenarios, in which landowner revenue
22 changes due to variations in carbon price. The specific goals of this study were to identify major
23 factors influencing NIPF landowner decisions to delay final harvest by 5 years for additional

carbon storage in the southern United States. The study is useful to policy makers working to establish effective carbon-sequestration policy instruments in the southern United States.

Background

Forests continue to play an important role in carbon sequestration and climate change mitigation in the United States. Major strategies for increasing carbon storage include increasing forest area (through afforestation or reforestation) or changing forest-management (through delayed harvest or reduced disturbance) strategies. Under a suitable carbon-sequestration policy, forest carbon stocks under private ownership are projected to increase in the southern United States (Murray et al. 2005). There is potential to increase carbon storage on NIPF lands in the southern United States through improved forest-management strategies (Galik et al. 2013). Forest carbon sequestration is financially feasible with an incentive for carbon storage (Huang and Kronard 2001, Alavalapati and Stainback 2005, Nepal et al. 2012). Huang and Kronrad (2001) simulated a financial analysis of carbon sequestration for NIPF lands in East Texas at different discount rates, site indices, thinning intensities, and rotation ages. Their cash flow analysis determined that land expectation values required to sequester carbon within living trees and wood products were financially feasible. Similarly, Nepal et al. (2012) analyzed the financial feasibility of managing NIPF lands for carbon sequestration in Mississippi and found that jointly managing for timber and carbon was a financially feasible option for landowners.

Existing literature on NIPF participation in forest carbon sequestration has mostly focused on market participation for carbon trading. Thompson and Hansen (2012) conducted an attitude study of NIPF landowners across the United States and found that only 37% of NIPF landowners held positive attitudes toward carbon trading. Fletcher et al. (2009) found that carbon-sequestration program requirements and payment influenced Massachusetts-landowner

1 willingness to sell carbon credits. Dickinson et al. (2012) found that forest area, owner
2 characteristics, and program features affected Massachusetts-landowner probability of
3 participation in carbon-sequestration programs. Similarly, forest area, harvesting practices,
4 owner characteristics, and credit-program characteristics were associated with landowner interest
5 in selling carbon credits in Michigan, Minnesota, and Wisconsin (Miller et al. 2012).
6 Landowners are motivated by factors other than just carbon price to participate in carbon
7 sequestration programs. Additionally, few landowners would participate with current market
8 requirements (which are similar to CCX requirements), so a different policy might be required to
9 encourage landowners to participate in carbon sequestration programs (Lindsay et al. 2011).

10 Additionally, several studies have suggested that financial and technical assistance
11 provided to landowners impact their behavior toward implementing alternative management
12 practices (Kline et al. 2000, Klosowski et al. 2001, Conway et al. 2003, Kendra and Hull 2005,
13 Kilgore et al. 2007, Kilgore et al. 2008, Lindhjem and Mitani 2012). Kline et al. (2000) analyzed
14 determinants of Oregonian NIPF landowners to defer harvest for timber and wildlife
15 management. This study found that landowner characteristics, forest area, and offer amount were
16 strong determinants of their decision to delay harvest and that their probability of participation
17 increased with the incentive amount. Furthermore, Kilgore et al. (2008) found that some NIPF
18 landowners in Minnesota expected payment for the enrollment in forest stewardship while others
19 were willing to pay for enrollment. Similar heterogeneity could be assumed to exist among
20 NIPF-landowner carbon-sequestration behavior in the southern United States. Likewise,
21 regarding carbon sequestration, landowners with strong environmental or ethical concerns could
22 be more willing to contribute for climate change-mitigation strategies.

1 Earlier studies have characterized NIPF landowners as a very heterogeneous group and
2 segmented them into different yet relatively homogenous groups largely based on reasons for
3 owning forestland (Kendra and Hull 2005, Ingemarson et al. 2006, Majumdar et al. 2007, Favada
4 et al. 2009, Urquhart and Courtney 2011, Hayrinen et al. 2014). The major reasons of owning
5 forestland included timber production or investment, recreation, non-timber benefits, and bequest
6 motive. Additionally, landowner interest toward managing their forest for conservation or
7 environmental reasons varied depending on their reasons for owning forestland. Gruchy et al.
8 (2012) found that landowners interested in habitat management were willing to harvest woody
9 biomass for bioenergy in Mississippi. In another study, landowner willingness to delay harvest to
10 enhance nontimber benefits was a function of their ownership objectives (Kline et al. 2000).

11 Building upon past studies, this study involved a contingent rating scenario to analyze
12 landowner response to a climate change-mitigation and carbon-sequestration program under
13 varying carbon-revenue situations. To analyze landowner behavior in a hypothetical policy or
14 market situation, contingent valuation is a suitable valuation option (Carson 2012). The
15 contingent valuation method (CVM) is one of the most widely used stated preference methods
16 for measuring the economic value of environmental programs. CVM has been considered a
17 suitable tool because it can be implemented using a survey instrument to identify and quantify
18 values people place on goods, services, and amenities when markets do not exist or the revealed
19 preference methods are not applicable (Carson 2012).

20 **Model**

21 Forest-management decisions by NIPF landowners can be modeled as utility
22 maximization behavior. Utility theory assumes that landowners aim to maximize their utility by

managing their forests for some combination of timber and non-timber outputs (Conway et al. 2003). For landowners, the cost of delaying harvest to sequester more carbon for climate change mitigation would involve opportunity costs associated with the delayed harvest. If landowners are offered an incentive to delay harvest for five years, their decision to participate or not would depend on the utility they expect to derive from the forestland over the five-year program. Because a landowner's reservation price depends on market expectation, time preference, and reason for owning forestland (Gregory et al. 2003), these factors would influence the opportunity cost of a five-year harvest delay for carbon sequestration. The probability of a landowner participating in a carbon-sequestration program would depend on whether the landowner values benefits other than timber from their forest. If landowners are offered a monetary incentive to delay harvest for five years, then landowners with a timber motive might require a higher incentive amount to forego harvest for five years as compared to landowners with non-timber goals. The delay-harvest strategy for carbon sequestration might enhance non-timber benefits from their forests, so a landowner valuing non-timber benefits has a reason to delay harvest with less incentive or even pay for it. The utility landowners derive from their forests would depend on their preference and forest-management objectives.

The utility index of an individual landowner can be determined from a set of observed factors related to each individual (Nagubadi et al. 1996, Joshi and Arano 2011). In a random utility framework, the utility model of a respondent j can be written as (Haab and McConnell 2003):

$$u_{ij} = u_i(y_j, z_j, \varepsilon_{ij}) \dots \dots \dots (i)$$

where $i = 1$ represents the carbon sequestration program in implementation and $i = 0$ stands for the status quo. The determinants of utility are y_j , the j^{th} respondent's income; z_j , a vector of landowner characteristics; and ε_{ij} , the random preference component related to the landowner. In terms of the environmental quality (e.g., increase in carbon storage) indicator q , the utility would be $u_i(y_j, z_j, q_i, \varepsilon_{ij})$ to indicate the change from status quo. The utility function is comprised of two components: observable component $v(y_j, z_j, q_1, \varepsilon_{1j})$, and unobservable random component, ε_{ij} . Based on this model, a rational landowner would say "yes" to an alternative if his or her new utility exceeds the status quo:

$$u_1(y_j + r_j, z_j, q_1, \varepsilon_{1j}) > u_0(y_j, z_j, q_0, \varepsilon_{0j}) \dots\dots\dots(\text{ii})$$

The landowner would accept the payment if and only if $u_1 \geq u_0$. The offer (r_j), or additional revenue from selling carbon, indicates additional monetary incentive available to the landowner from an alternative management strategy. In other words, when the landowner accepts the monetary offer (r_j):

$$v_1(y_j + r_j, z_j, q_1) - v_0(y_j, z_j, q_0) > \varepsilon_1 - \varepsilon_0 \dots\dots\dots(\text{iii})$$

where v_1 and v_0 indicate indirect utility functions. Additionally, some landowners might maximize their utility by managing their forest for joint production of timber and amenity services (Hartman 1976). The economic problem of such landowners would be to jointly maximize both net harvest revenue and amenity services from the forest (Amacher et al. 2009). In other words, environmentally oriented landowners might derive higher utility by jointly managing their forest for timber and public goods, such as carbon sequestration and climate change mitigation.

Method

Data

The data needed to accomplish the study objective were collected from a mailed survey of NIPF landowners with forestland in 11 selected states¹ in the southern United States. Within the selected states, counties without any pine forest type (*Pinus taeda*, *Pinus echinata*, *Pinus palustris*, or *Pinus elliottii*) in the USDA Forest Inventory and Analysis data were excluded from the survey. NIPF landowner database, including their corresponding addresses and the location of forest properties was purchased from ListGIANT², a private database vendor that compiles landowner lists based on county tax roll records. Thompson and Hansen (2012) also used the same vendor database for their NIPF forest carbon sequestration study.

The survey questionnaire included questions related to landowners' forestland characteristics, environmental preferences, and socio-economic details. The questionnaire requested that respondents provide information about their forest (i.e., size, ownership reason, forest type, management actions, and tenure), climate change attitudes (i.e., human activities that contribute to climate change), understanding of carbon sequestration topic, and socio-economic characteristics (i.e., age, income, and education).

The study used a contingent rating approach to identify factors affecting NIPF landowner willingness to sequester additional carbon. Specifically, landowners provided a rating response to three carbon sequestration scenarios that were compared with a baseline scenario representing

¹ Alabama, Arkansas, East Oklahoma, East Texas, Georgia, Florida, Louisiana, Mississippi, North Carolina, South Carolina, Virginia

² For more information, see www.listgiant.com

1 timber management only (Table 1). The baseline was a 35-year rotation for timber-only
2 management, whereas the alternative management scenarios required them to delay their final
3 harvest for five years. The baseline was compared with three scenarios of net present value
4 (NPV) from joint management for timber and carbon: a more profitable scenario (\$1,377,
5 \$1,744, \$2,333, \$2,922, and \$4,100) (Scenario 1), revenue-neutral scenario (\$1,361) (Scenario
6 2), and a less profitable scenario (\$1,230) (Scenario 3). Each landowner was offered one NPV
7 amount in the more profitable scenario, so there were five versions of the survey. These revenue
8 estimates were adopted from Nepal (2011).

9 The more profitable and revenue-neutral scenarios provided situations where carbon
10 revenue was greater than zero, unlike the less profitable scenario. The NPV estimates accounted
11 tree growth during the additional five years of delayed harvest and the additional carbon revenue
12 for the period. The NPV in the more profitable scenario included revenue with a carbon offset
13 payment for delaying the harvest by five years. The NPV under the revenue-neutral scenario was
14 set equal to the baseline case to provide an income-indifferent scenario to the respondent. The
15 NPV estimate for the less profitable scenario was based on a delayed harvest but without any
16 carbon revenue for the additional period. Because of the discounting for an additional five years
17 without any additional carbon revenue, the NPV was lower than the amount in the Baseline
18 Scenario. The rating scale in the questionnaire was 1 (Definitely Not Accept), 2 (Probably Not
19 Accept), 3 (Neutral), 4 (Probably Accept), 5 (Definitely Accept). Each respondent was asked to
20 rate individual scenarios in comparison to the Baseline Scenario.

21 The draft survey questionnaire was pretested in County Forestry Association meetings
22 (Jefferson Davis and Lee counties) in Mississippi and refined based on the feedback. The final
23 questionnaire included 32 questions within five pages. The survey was sent to 5,000 randomly

selected landowners in the fall of 2013 following the Dillman (2007) Tailored Design Method for conducting mail surveys. There were three mailings, and the time between successive mailings was approximately 3-4 weeks. Each mailing included a signed cover letter, a survey questionnaire, and a postage-paid return envelope. A reminder post card was sent to non-responding landowners between the first and second mailings.

Non-response bias

To test for a potential non-response bias, fifty non-responding landowners were randomly selected for telephone surveys and asked four key questions. Questions were related to their forest land (i.e., size of largest forested parcel), management behavior (i.e., availability of written forest management plan), climate change belief (i.e., whether human activities are contributing to climate change), and education. The respondents were given the choice of the question responses as shown in the survey instrument. Alternatively, a comparison was made between first and late responding (n=100) landowners using a t-test for the selected key questions. This approach has been adopted in previous studies (Filion 1975, Armstrong et al. 1977, Joshi et al. 2014).

Models estimation

An empirical binary model was estimated from landowner responses to the more profitable scenario. Landowner rating on the more profitable scenario was recorded into a binary format with ‘Definitely Yes’ and ‘Probably Yes’ versus other responses. This made the independent variable dichotomous where the respondent response was ‘Yes’ (Y=1) or ‘No’ (Y=0) during the survey period. Suppose x indicates a set of independent variables explaining landowner willingness to sequester carbon, and the set of parameters, β , represents the impact of changes in x on landowner probability of participation in a carbon-sequestration program. Then, landowner probability of participation in carbon program was:

$$\text{Prob}(Y=1|x) = F(x'\beta) \dots\dots\dots (iv)$$

$$\text{Prob}(Y=0|x) = 1 - F(x'\beta) \dots\dots\dots (v)$$

In a symmetric and normal cumulative normal distribution, the probit relationship between Y and x is (Greene 2012):

$$\text{Prob}(Y=1|x) = \int_{-\infty}^{x'\beta} \phi(t) dt = \Phi(x'\beta) \dots\dots\dots (vi)$$

The function $\phi(t)$ is a standard normal distribution. The probit model has two major advantages. First, unlike in a linear probability model, the predicted probability is bounded by 0 and 1 and thus avoids the problem of predicting values outside the probability range. The other important statistical advantage is that it forces disturbance terms to be homoskedastic (Nogubadi et al. 1996). In probability models, $E(y|x) = F(x'\beta)$, the parameters are not the marginal effects, so their interpretation requires computation of marginal effects. In a probit model, marginal effects are computed as:

$$\frac{\partial E(y|x)}{\partial x} = \phi(x'\beta)\beta \dots\dots\dots (vii)$$

where $\phi(.)$ is the standard normal density function. The marginal effects for dummy variables were computed as:

$$\text{Marginal effect} = \text{prob}[Y=1|\bar{x}_d, d=1] - \text{prob}[Y=1|\bar{x}_d, d=0] \dots\dots\dots (viii)$$

where $\bar{x}_d$ indicates means of all other variables in the model.

Table 2 presents the definition of the variables included in three empirical models. The landowner socio-economic variables were INCOME and AGE. The variable INCOME was a dummy variable representing annual household income greater than \$62,500. The dummy variable AGE indicated age greater than 65 years, which was the average age of the landowners.

Landowner forest resource and management related variables included ACRE, TIMBER, RECRETN, and HARVEST. The variable ACRE was the natural log of the total forest acreage owned by a landowners. The dummy variables TIMBER and RECRETN represented timber and recreation objectives of the landowner. The dummy variable HARVEST represented landowner plan to harvest forest in the future. Similarly, the variables NPV and MANAGE were included as sequestration program characteristics. The variable NPV was a continuous variable representing the natural log of the net present value realized by the landowner with program enrollment. MANAGE was a dummy variable representing landowners who consider the requirements of having a management plan and verification requirements as obstacles to enrollment. Landowner environmental attitude related dummy variables CLIMATE and CARBON represented their climate change attitude and carbon-sequestration understanding.

Result

Of 5,000 surveys sent to the randomly selected landowners, only 4,671 were valid addresses after discounting incorrect address, deceased individuals, and landowners who did not own forest. There were 735 completed responses received, resulting in a response rate of 15.8%. Thompson and Hansen (2012) also had a similar response rate (15.9%) on a nationwide study of NIPF landowner attitudes toward carbon sequestration and trading. A study on forest management decisions of NIPF landowners in West Virginia by Joshi and Arano (2009) received 20% usable response rate. One of the major reasons contributing for the lower response rate might be less familiarity with the carbon sequestration topic and complicated nature of the contingent rating scenario. The survey instrument also included items that required a substantial understanding about climate change and carbon sequestration as well as detailed information

1 about landowner forest management operations; some landowners may have lacked interest or
2 sufficient knowledge to complete the survey.

3 Non-response bias test results showed that there was no statistical difference ($P>0.10$)
4 between responding and non-responding landowners using a t-test in terms of forest land,
5 management behavior, climate change attitude and education, suggesting non-response bias was
6 not a concern. Alternatively, the comparison of late responding landowners as proxies for non-
7 respondents indicated no bias ($P>0.10$) from a t-test of the selected key questions. In addition,
8 our sample was comparable to National Woodland Owner Survey (NWOS) data (Butler and
9 Leatherberry 2006) in terms of average age, most frequently cited education and income
10 categories, and the proportion of male and female owners in the southern United States.

11 Table 2 presents a description of the variables included in the analysis and their summary
12 statistics. The respondents were relatively older with 49% of the respondents being older than 65
13 years. Among the respondents, 56% had an annual household income greater than \$62,500 per
14 year. Regarding their reasons of owning forestland, 45% of the respondents indicated that
15 recreation benefit was an important objective while 54% indicated that timber benefit was an
16 important objective. The average forest land size was 151.41 acres, but there was high variation
17 in the ownership size. Only 37% of the respondents in this study believed climate change was
18 scientifically proven. In terms of their knowledge regarding carbon sequestration, 40% indicated
19 having a good understanding of it. About 37% of the landowners indicated they have a plan to
20 harvest forest in the next five years.

Factors influencing participation in carbon sequestration scenario

Landowner willingness to delay harvest for additional carbon storage varied with the NPV amount offered. Table 3 presents percentage of landowners accepting or rejecting six different offer amounts to delay final harvest by five years for additional carbon storage. In the lowest-offer category, \$1,230/ac, the proportion of landowners accepting the amount was 16.71%, but the proportion increased with the offer amount, resulting in 66.67% acceptance for the offer category of \$4,100/ac, which indicates that landowner participation increased as revenue amount increased. In the revenue-neutral scenario of \$1,361/ac, the percentage of landowners willing to participate was 25.07%, and the participation rate increased to more than 42% with offer amounts of at least \$1,377/ac. The offer amount of \$4,100/ac was more than twice the amount in the Baseline Scenario; however, 33.33% landowners were still not interested in delaying final harvest for additional carbon storage. Additionally, the percentage of landowners willing to delay harvest by five years for climate change mitigation and carbon sequestration was 55.80% in the more profitable scenario while the proportions in revenue-neutral and less profitable scenarios were 25.07% and 16.71%, respectively.

Results for the profit model analyzing participation of NIPF landowners in a carbon-sequestration program are presented in Table 4. The model fitness statistics, log likelihood ratio, was statistically significant at the 1% significance level ($\chi^2 = 64.35$, $df=11$, $P<0.0001$), indicating the model properly described the data. The variables representing owner characteristics (INCOME, AGE), forest land and management attributes (ACRE, RECRETN), carbon sequestration knowledge (CARBON), and carbon sequestration program attributes (NPV, MANAGE) were statistically significant with at least $\alpha=0.10$ significance level. Among the NIPF landowner and ownership related variables, INCOME, AGE, ACRE and RECRETN had

marginal effect of 0.12, -0.09, 0.05, and 0.08, respectively. The variable CARBON was positively related, and was with marginal effect of 0.16. The positive coefficients for INCOME, ACRE, RECRETN, and CARBON indicated that landowners with higher income, larger acreage, non-timber ownership goals, and good understanding of carbon sequestration were more likely to delay harvest for carbon sequestration if it is more profitable to do so. Additionally, the probability of participation increased with greater carbon revenue (NPV). Conversely, additional management requirements (MANAGE) were negatively associated with their probability of participation. Higher marginal effects for NPV (0.20) and MANAGE (-0.22) indicated that sequestration-program attributes were stronger determinants for landowner participation in profit situations.

Discussion

NIPF landowners often manage their forests for multiple objectives, including timber, recreation, and bequest motives, and their forest-management decisions are based on individual utility-maximization behavior (Kline et al. 2000). In addition, these landowners have varied environmental and conservation preferences. Moreover, 58% of the forest land in the southern region is under their ownership (Butler and Wear 2013), so their participation is of utmost importance for a viable climate change-mitigation policy in the southern United States. This study estimated a probability model that established a relationship between the landowner's decision to delay timber harvest for additional carbon sequestration with the landowner's characteristics, forest land and management attributes, landowner's environmental attributes, and sequestration program attributes.

1 The ownership goal, RECRETN was positively and significantly associated with the
2 landowner participation behavior at the 10% significance level. All else being similar, NIPF
3 landowners with a recreational ownership goal were more willing to delay harvest for additional
4 carbon storage. Previous studies also found similar behavior among NIPF landowners in
5 Massachusetts regarding participation in carbon sequestration and trading (Lindsay et al. 2011,
6 Miller et al. 2012) or management programs (Stevens et al. 2002). This similarity suggests that
7 landowners with a recreational ownership goal can be the primary group potentially available to
8 implement climate change-mitigation strategies, so it is advisable to concentrate outreach
9 activities to these landowners in the southern United States. In a limited budget environment,
10 recreation-objective landowners would be the most likely group to approach for carbon
11 sequestration. Their willingness to manage for carbon sequestration could be attributed to the
12 compatibility of their recreation goals with carbon-sequestration strategies and their strong
13 environmental affinity.

14 Of particular importance is that 55.90% of the landowners were willing to participate in
15 the more profitable scenario but the proportion was 25.07% and 16.71% in revenue-neutral and
16 less profitable scenarios, respectively. Therefore, additional revenue is one of the major
17 motivations for NIPF landowners to participate in a carbon-sequestration program. The variable
18 NPV was positively and significantly associated with participation at a 1% significance level in
19 the probit model, which indicates that financial motives are one of the strongest reasons for why
20 landowners manage their forest for carbon sequestration. Furthermore, increase in the proportion
21 of landowners willing to participate in carbon sequestration with the increase in offer amount
22 indicates that financial motivation is an important reason for their decision to participate. It also
23 suggests that an increase in incentive amount would result in higher participation of NIPF

landowners in carbon sequestration programs. On the contrary, management requirements contributed to reduced landowner participation. The variable MANAGE was negatively and significantly associated at the 10% significance level in the probit model. The negative sign was as expected because a majority of landowners in the southern United States lack management plans (Butler and Leatherberry 2006) and they would be less willing to change their status quo without a large enough incentive provision. In other words, management changes might accrue additional costs and landowners might be reluctant to invest in these changes without a new payment provision (Lindsay et al. 2011, Dickinson et al. 2012, Miller et al. 2012, Kerchner and Keetom 2015). Additionally, some landowners might view such requirements as an intrusion into their privacy, freedom, and enjoyment (Fischer and Charnley 2010). Therefore, to engage NIPF landowners in forest carbon sequestration, an appropriate incentive, at least high enough to make the sequestration revenue neutral, should be associated with the desired management requirements. A similar finding was reported in the Lindsay et al. (2011) study which indicated that one of the major reasons for the lackluster response of NIPF landowners toward the former CCX and the current California carbon market could be due to their management requirements at relatively low carbon prices.

It is also important to note that landowners' carbon-sequestration understanding, CARBON, was positively and significantly associated with their probability of participation in the probit model at the 10% significance level. Therefore, improved understanding of carbon sequestration would increase landowner participation in sequestration programs. It is consistent with Kilgore et al. (2008) finding that landowner familiarity with the program is an important determinant of their probability of participation. However, only 40% of the landowners indicated having a good or very good understanding of carbon sequestration, which implies the need for

1 more climate change and carbon sequestration educational and outreach activities to involve a
2 higher percentage of landowners in carbon-sequestration activities in the southern United States.

3 The model also suggests that both owner-and ownership-related variables were
4 determinants of landowner participation in carbon sequestration. The variables ACRE and
5 INCOME were both positively and significantly associated with landowner-participation
6 behavior. Landowners with large acres would be more likely to delay harvest for carbon
7 sequestration in the higher profit situation. Landowners with large acreage might be more likely
8 to be active and investment-oriented managers (Nogubadi et al. 1996, Kline et al. 2000), so they
9 would likely participate in carbon sequestration to increase their revenue at higher carbon prices.
10 In addition, if they have property divided into multiple parcels, then an alternative management
11 strategy might be a preferred option for some parcels (Stevens et al. 2002). Similarly, change in
12 landowner household income increased their probability of participation in carbon sequestration.
13 However, the owner characteristic, AGE, was negatively and significantly associated at the 10%
14 significance level in the model. This result is similar to Lindsay et al. (2011) finding that
15 relatively older landowners were less willing to manage for carbon sequestration. Given that
16 almost 50% of NIPF landowners in the southern United States are 65 years of age and older,
17 outreach efforts should focus on educating this landowner group in terms of carbon sequestration
18 aspects and explaining if and how carbon sequestration can contribute to their forestland
19 ownership goals.

20 Contrary to expectation, a plan to harvest was not found to influence landowner decision
21 to delay harvest for carbon sequestration. Landowners with a plan to harvest trees from their
22 forest in the future were not more interested in the carbon-sequestration program as compared to
23 the other landowners without such plan during our survey. This result is counter to Lindsay et al.

(2011) finding that Massachusetts landowners with a plan to harvest in future were more interested in the carbon sequestration program. Our study involved delay harvest for only 5 years, which might have contributed for this difference. This short delay period might not be considered too constraining to landowners, especially if they considered delaying harvest anyway due to low timber prices.

Conclusion

This study analyzed NIPF landowner-participation behavior across the southern United States in a hypothetical carbon sequestration scenario, where landowner revenue may or may not increase because of the variation in carbon price. These results provide a better understanding of the relationship between NIPF landowner willingness to participate in carbon sequestration and their socio-economic characteristics, forest resource and management attributes, sequestration-program requirements and monetary incentive amount, climate change attitude, and carbon sequestration understanding. This understanding should help policy-makers, planners, landowner associations, and professionals to design and implement climate change-mitigation and adaptation strategies and to increase NIPF participation in these activities in the southern United States.

Considering the importance of involving NIPF landowners in climate change-mitigation activities in the southern United States and other regions, this study provides understanding on what groups of landowners are willing to participate in carbon sequestration. It is worth noting that some landowners are not interested in carbon sequestration even in high-profit situations while some other landowners will participate in climate change mitigation if given an appropriate monetary incentive. In addition, landowner goals, forest-carbon revenue, management requirements, and owner characteristics, including income, are a few strong

determinants of their probability to participate. This study concludes that a carbon-sequestration program that targets landowners with recreational-ownership goal along with climate change and carbon-sequestration educational information can more economically achieve their program goal of increasing participation of NIPF landowners. To involve southern NIPF landowners in climate change-mitigation programs, the planners need to be cognizant of these factors affecting landowners' decisions to participate in mitigation activities. More importantly, to minimize the impact on regional timber supply due to the delay-harvest strategy of NIPF landowners, policy-makers need to consider expected participation of the landowners at various incentive amounts for an effective and viable climate change-mitigation program in this region.

Landowners who expressed positive interest toward a carbon-sequestration program in this study, might not actually participate when the program is available to them, which can be attributed as one of the limitations of the hypothetical scenario studies. In this sense, landowner participation might be overestimated. Additionally, the scenarios involved only a five-year time span, which could be argued as too short, so different scenarios of longer duration with higher revenue amounts can be a possibility for a future research. To accurately predict landowner participation in a carbon-sequestration program with additional complex requirements, choice analysis of landowner preferences would provide more specific results. On a cautionary note, complex mail surveys may not receive enough responses from the landowners to produce precise estimates. Furthermore, this study focused only on forest landowner willingness to sequester carbon during a limited harvest delay period. However, while landowners control some parameters of timber grown on their properties, they have very limited to no impact on how raw timber will be utilized by primary and secondary forest products manufacturers. These manufacturers might produce both short- and long-life wood products and thus affect amount of

carbon accumulated during product lifespan. Thus, future research should also attempt to incorporate a life-cycle analysis to determine timber products, forest management strategies, and landowner program participation behavior will results in most beneficial carbon sequestration outcomes in the long term.

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6

Table 1: Comparison of attributes in the contingent rating scenario that was included in the survey of the nonindustrial private forest (NIPF) landowners in the Southern US. Each alternative scenario was rated in comparison to the base scenario only, which was not rated.

Attributes	Base scenario	More profitable scenario	Revenue-neutral scenario	Less profitable scenario
NPV	\$1,361	**	\$1,361	\$1,230
Rotation age	35	40	40	40
Timber	Yes	Yes	Yes	Yes
Carbon	No	Yes	Yes	Yes
Carbon revenue	No	Yes	Yes	No

** The net present value (NPV) options included \$1377, \$1744, \$2333, \$2922, and \$4100. Each landowner received only one of these amounts. There were 5 versions of the survey questionnaire.

1 Table 2: Variable definition, mean and standard deviation of the independent variables included
2 in the three models. Total sample size was 353 observations.

Variable	Definition	Mean	Std Dev
Owner characteristics			
INCOME	Dummy variable, 1 indicating landowner has greater than \$62,500 annual household income	0.56	0.49
AGE	Dummy variable, 1 indicating greater than 65 years age	0.49	0.50
Forest land and management attributes			
ACRE	Continuous variable, log value of total forest acreage	5.02	1.03
RECRETN	Dummy variable, 1 indicating recreation benefit is an important objective for the landowner	0.45	0.49
TIMBER	Dummy variable, 1 indicating timber benefit is an important objective for the landowner	0.54	0.44
HARVEST	Dummy variable, 1 indicating landowner has a plan to harvest forest	0.37	0.48
Owner environmental attributes			
CLIMATE	Dummy variable, 1 indicating belief that climate change is scientifically proven	0.37	0.48
CARBON	Dummy variable, 1 indicating respondent reported good or very good understanding of carbon sequestration	0.40	0.49
Sequestration program attributes			
NPV	Continuous variable, log of net revenue offered to the respondent	7.75	0.39
MANAGE	Dummy variable, 1 representing landowners who indicated management requirements (i.e., management plan, and frequent verification) are obstacles for participation	0.84	0.36

3

4

Table 3: Percentage of nonindustrial private forest (NIPF) landowners accepting or rejecting six different net present value (NPV) offers to delay final timber harvest for additional carbon sequestration in the southern US. The values in landowner column represent percentage out of 347 total respondents.

NPV amount offered (\$/ac)	Landowner response (%)	
	Yes	No
1230	16.71	83.29
1361	25.07	74.93
1377	42.86	57.14
1744	46.27	53.73
2333	65.28	34.72
4100	66.67	33.33

Notes: The NIPF landowners were asked to accept or reject the offer amount as compared to a baseline amount scenario, which offered \$1361/ac from standard timber management scenario. The offer amounts represent NPV offered to each landowner from joint management of timber and carbon scenarios.

Table 4: In the more profitable scenario, probit model estimates, standard errors, significance levels, and marginal effects for predicting participation of non-industrial private forest (NIPF) landowners in carbon sequestration in the southern United States.

Variable	Coefficient estimates	Std. error	P> z	Marginal effect
Intercept	-5.110	1.540	0.000	
NPV	0.599	0.188	0.001	0.202
CARBON	0.476	0.153	0.001	0.162
INCOME	0.367	0.152	0.016	0.125
MANAGE	-0.647	0.210	0.002	-0.220
TIMBER	-0.163	0.156	0.296	-0.055
RECRETN	0.251	0.145	0.084	0.085
AGE	-0.285	0.148	0.054	-0.097
ACRE	0.154	0.076	0.0424	0.052
CLIMATE	0.086	0.153	0.570	0.029
HARVEST	-0.088	0.153	0.563	-0.030

Notes: N= 353 observations (participation “Yes”= 197, “No”= 156). Marginal effects were calculated at the mean of the independent variables. For a dummy variable, marginal effect is the change in probability due to change in independent variable from 0 to 1. Model significance $\chi^2=64.35$, df=11, P<0.0001. Model fitness statistics adj. R square=0.22.

APPENDIX

Preference to forest carbon sequestration

Suppose you have a recently clear-cut 100 acres of forest land and are planning to replant loblolly pine. You could decide to establish a standard timber only management practice today and harvest it after 35 years in 2048 (**Baseline Scenario**). However, you have another option to manage the same forest land jointly for timber and carbon sequestration for 40 years until 2053. Such a joint management will be helpful in mitigating the build-up of greenhouse gases (i.e., mitigate climate change) as well as generating additional revenue from selling the stored carbon. By delaying harvest, you will be storing carbon for a longer period, thus having a greater climate change mitigation impact. Since the future is uncertain, any additional revenue from selling stored carbon will depend on the prevailing market conditions 40 years from now. Specifically, as compared to the base scenario, carbon prices may be high (**Scenario 1**), low (**Scenario 2**), or equal to zero (**Scenario 3**); and your net monetary return from the joint management might differ accordingly.

Baseline Scenario: This is a standard timber only management practice for 35 years. If you establish a new pine plantation today and harvest it after 35 years in 2048, your net monetary return will be equivalent to getting \$1,361 per acre today.

Indicate your preferences for scenarios 1, 2, and 3 as compared to the Baseline Scenario above by circling the number that best describes your preference. (**Instructions: 1= Definitely Not Accept, 2 = Probably Not Accept, 3 = Neutral, 4 = Probably Accept, 5 = Definitely Accept**). (Circle a number in each scenario below)

Scenario 1: This is a variation of the Baseline Scenario. If your net monetary return were equivalent to getting \$1,377 per acre today to jointly manage the same forest for timber and carbon for 40 years until 2053, then how likely are you to accept this choice as compared to the Baseline Scenario?

1	2	3	4	5
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Scenario 2: This is another variation of the Baseline Scenario. If your net monetary return were equivalent to getting \$1,361 per acre today to jointly manage the same forest for timber and carbon for 40 years until 2053, then how likely are you to accept this choice as compared to the Baseline Scenario?

1	2	3	4	5
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Scenario 3: This is the other variation of the Baseline Scenario. If your net monetary return were equivalent to getting \$1,230 per acre today to jointly manage the same forest for timber and carbon for 40 years until 2053, then how likely are you to accept this choice as compared to the Baseline Scenario?

1	2	3	4	5
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