PROCEEDINGS OF THE 2011 SOUTHERN FOREST ECONOMICS WORKERS (SOFEW) ANNUAL MEETING

March 20-22, 2011

The Peabody Hotel

Little Rock, Arkansas

Editor:

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SOUTHERN FOREST ECONOMICS WORKERS (SOFEW)

2011 ANNUAL MEETING

March 20-22, 2011

The Peabody Hotel, Little Rock, AR

Sunday, March 20, 2011

6:00 PM: SOCIAL (PINNACLE ROOM)

6:00 – 7:30 PM: REGISTRATION (PINNACLE ROOM ENTRANCE)

Monday, March 21, 2011

7:30 – 8:00 PM: BREAKFAST (FOYER A)

7:45 – 12:00 PM: REGISTRATION (FOYER A)

8:00 – 9:30 AM: GENERAL SESSION I (SALON A)

8:00 AM: Welcome and Logistics – Sayeed Mehmood

8:15 AM: Dean's Welcome – Dr. Philip A. Tappe, Interim Dean, School of Forest Resources

8:25 AM: Keynote Speaker Introduction – Sayeed Mehmood

8:30 AM: Keynote Speech – Dr. Daowei Zhang; Professor, Auburn University – "The production process of generating competitive grants in forest economics research"

9:00 AM: SOFEW Presentation – Marcus K. Measells and Stephen C. Grado; Mississippi State University – "SOFEW Evaluations: Are We Providing Value?"

9:20 AM: Questions and Comments

9:30 – 10:00 AM: REFRESHMENT BREAK (FOYER A)

10:00 – 11:15 AM: GENERAL SESSION II (SALON A)

10:00 AM: Panel Discussion – “Forest Economics: Yesterday, Today, and Tomorrow”

Dr. John L. Greene, USDA Forest Service

Dr. Amin Sarkar, Dean, School of Business, Alabama A&M University

Dr. Francisco Aguilar, Assistant Professor, University of Missouri

11:20 – 12:00 PM: STUDENT POSTER PRESENTATIONS (FOYER A)

Assessing Preferences towards Urban Trees in Suburban Communities: Bin Zheng and Yaoqi Zhang; Auburn University.

The Effect of Carbon Sequestration Credits on the Uneven-aged Forest Management of Loblolly-Shortleaf Pines in the Southern United States: Rajan Parajuli and Sun Joseph Chang; Louisiana State University.

Economic Estimate of Feral Hog Damage to Agriculture in Alabama: Wen Shi, Yaoqi Zhang, Bin Zheng, and Stephen Ditchkoff; Auburn University.

Using Discounted Cash Flow Analysis to Value the Benefits and Costs of Urban Trees: John E. Hatcher, Jr., Kristin S. Peterson, and Thomas J. Straka; Clemson University.

Evaluating Loblolly Pine Management Scenarios Considering Carbon Markets: Umesh Chaudhari and Matthew Pelkki; University of Arkansas at Monticello.

Residents’ WTP for Urban River Ecosystem Restoration: Yifei Zhang, Yaoqi Zhang, and Sheng Li; Auburn University

Climate Change and the Demand for Forest-Based Recreation: Adrienne M. Dorison, and Neelam C. Poudyal; University of Georgia

12:15 – 1:00 PM: LUNCHEON (SALON C)

1:30 – 3:00 PM: CONCURRENT SESSIONS I

CONCURRENT SESSION IA (HOFFMAN): FOREST PRODUCTS ECONOMICS

Moderator: Changyou Sun

Vertical price linkage between timber and forest products prices in the South: Zhuo Ning and Changyou Sun; Mississippi State University

Forest Valuation under the Generalized Faustmann Formula: Sun Joseph Chang; Louisiana State University

Estimation of Harvest Probabilities of Planted Pine at Plot Level with FIA Data: Navinderpal Singh, Robert C. Abt, Frederick W. Cubbage, Michael J. Roberts, and John Coulston; North Carolina State University

Linerboard production decisions under market uncertainty: Bin Mei, David Swinarski, and Mike Clutter; University of Georgia

CONCURRENT SESSION IB (MANNING): FINANCE AND INVESTMENT

Moderator: John L. Greene

Analysis of Timberland Returns: Is the Normality Assumption Justified?: Stanislav Petrasek; Hancock Timber Resource Group

Assessing the Inflation Hedging Ability of Timberland Assets in the United States: Yang Wan, Bin Mei, Mike Clutter, and Jacek Siry; University of Georgia

Analysis of the Timberland Discount Rate: Jacob Gorman, Larry Teeter, and Yaoqi Zhang; Auburn University

Willingness to Pay for Potential Standing Timber Insurance: Yiling Deng and Ian A. Munn; Mississippi State University

CONCURRENT SESSION IC (LAFAYETTE): EMERGING AND NON-TRADITIONAL MARKETS I

Moderator: Stephen C. Grado

Capitalization of Hunting Lease Income into Northern Mississippi Forestland Values: Anwar Hussain, Ian A. Munn, Jerry Brashier, W. Daryl Jones and Ryan Smith; Mississippi State University

Economic Impacts of Hunting, Fishing, and Wildlife-Associated Recreation on the Mississippi Economy: James E. Henderson, Stephen C. Grado, Ian A. Munn, and W. Daryl Jones; Mississippi State University

Compatibility of timber production, protection of biodiversity, carbon sequestration and recreation in forest stands: What can be learned from growth simulations?: Nicolas Robert and Anne Stenger; INRA-AgroParisTech, France

An Evaluation of Private Forest Landowners' Participation in Conservation Easements in West Virginia: Preliminary Results: Matthew Oliver and Kathryn G. Arano; University of West Virginia.

3:00 – 3:30 PM: REFRESHMENT BREAK (FOYER A)

3:30 – 5:00 PM: CONCURRENT SESSIONS II

CONCURRENT SESSION IIA (HOFFMAN): EMERGING AND NON-TRADITIONAL MARKETS II

Moderator: Francisco X. Aguilar

Meta-Analysis of Willingness to Pay Estimates for Certified Wood Products: Zhen Cai and Francisco X. Aguilar; University of Missouri

Estimating Wildlife Viewing Recreational Demand and Consumer Surplus: James Mingie and Changyou Sun; Mississippi State University

A Time-Series Approach to Understanding Demand for Recreational Visits in National Park: Neelam C. Poudyal, and Bamadev Paudel; University of Georgia and Wayne State University

Valuing Ecosystem Services from Private Forests: Rebecca L. Moore; University of Georgia

CONCURRENT SESSION IIB (MANNING): GLOBAL AND REGIONAL STUDIES

Moderator: Ian A. Munn

International trends in forest products consumption: Is there convergence?: Joseph Buongiorno; University of Wisconsin

Global Competitiveness of U.S. Forest Products Industries: A General Equilibrium Analysis: Anwar Hussain and Ian A. Munn; Mississippi State University

Long-range forest sector and timber market projections (2020-2060) based on USFPM/GFPM and alternative global scenarios: Peter J. Ince; USDA Forest Service

CONCURRENT SESSION IIC (LAFAYETTE): FOREST MANAGEMENT/DECISION ECONOMICS I

Moderator: Brett J. Butler

Welfare implications of tax driven industrial timberland ownership change on U.S. timber markets: Mohammad Mahfuzur Rahman, Ian A. Munn, and Changyou Sun; Mississippi State University

The Effects of Forest Taxation Policies on Family Forest Owners in the United States: Brett J. Butler (USDA Forest Service), Paul Catanzaro (University of Massachusetts-Amherst), John L. Greene (USDA Forest Service), Jaketon Hewes (Family Forest Research Center), Michael A. Kilgore (University of Minnesota), David B. Kittredge (University of Massachusetts-Amherst and Harvard Forest), Zhao Ma (Utah State University), and Mary Tyrrell (Yale School of Forestry and Environmental Studies)

Value of scientific information for managing landscape-level effects of a cumulative land use history: Ronald Raunikar, Richard Bernknopf, William Forney and Shruti Mishra; Western Geographic Science Center

Tuesday, March 22, 2011

8:00 – 8:30 AM: BREAKFAST (FOYER A)

7:30 – 8:30 AM: SOFEW Planning Committee Meeting (PECK BOARDROOM)

8:30 – 10:00 AM: CONCURRENT SESSIONS III

CONCURRENT SESSION IIIA (HOFFMAN): CLIMATE CHANGE AND CARBON SEQUESTRATION I

Moderator: Robert K. Grala

Potential impact of carbon dioxide mitigating policy on carbon accumulation in Mississippi's forests sector: Prakash Nepal, Robert K. Grala, and Donald L. Grebner; Mississippi State University

Economic analysis of Chinese fir Carbon Sequestration in Zhejiang Province: Wen Shi, Yueqin Shen, Zhen Zhu, and Yaoqi Zhang; Auburn University and A & F University (China)

The role of forests in the assessment of the potential for terrestrial carbon sequestration: Sijia Zhang; UW-Madison/US Geological Survey

CONCURRENT SESSION IIIB (MANNING): BIOMASS AND BIOENERGY

Moderator: Donald L. Grebner

Preliminary Study on Determinants of landowners' choice for preferred harvesting methods of supplying woody biomass in Mississippi: Omkar Joshi, Donald L. Grebner, Ian A. Munn, Steven Grado, Robert K Grala, Anwar Hussain; Mississippi State University

U.S. residential wood energy consumption, trend, drivers, and future: Nianfu Song, Francisco X. Aguilar, Stephen R. Shifley, and Michael E. Goerndt; University of Missouri

The impact of land value and jobs from woody biomass production in the U.S. South: Bin Zheng, Mathew Smidt, and Yaoqi Zhang; Auburn University

10:00 – 10:30 AM: REFRESHMENT BREAK (FOYER A)

10:00 – 10:30 AM: POSTER PRESENTATION BREAK DOWN (FOYER A)

10:30 – 12:00 PM: CONCURRENT SESSIONS IV

CONCURRENT SESSION IV (HOFFMAN): CLIMATE CHANGE, CARBON SEQUESTRATION AND FOREST MANAGEMENT

Moderator: Matthew H. Pelkki

The Future Distribution of the Forest Cover Types in the Southern U.S and Its Potential Carbon Consequences on the Environment: Li Meng and Daowei Zhang; Auburn University

Project Evaluation of Sustainable Upland Hardwood Management in the U.S. South with the Monetization of Carbon: Joe Grinnell; Duke University

Cost share payment and willingness to participate in Virginia's Pine Bark Beetle Prevention Program: Adam Watson and Jay Sullivan; Virginia Tech

Does Pre-suppression Efforts Reduce Wildland Fire Suppression Expenditures? A Case of Pay Now or Pay More Later; Joseph S. Godwin, Daowei Zhang, and Jeffrey P. Prestemon; Auburn University

FULL PAPERS

Do Pre-suppression Efforts Reduce Wildland Fire Suppression Expenditures?

Joseph S. Godwin, Auburn University[1]; Daowei Zhang, Auburn University and Jeffrey P. Prestemon, USDA Forest Service

Abstract: Using data from the USDA Forest Service we estimate the impacts of prescribed burning treatments and the average area burned with respect to fire suppression expenditures. This is accomplished by constructing an 11-year panel data set consisting of Forest Service regions using a 2-stage least squares (2SLS) fixed effect model that controls for the effects of weather, previous fire activity, and prescribed burning treatments on the current year's fire activity. This model provides an estimated elasticity between increasing the area treated with prescribed burning and the need to later spend resources fighting forest fires. The results indicate that the Forest Service could see substantial savings from increasing prescribed burning programs in the western United States.

Introduction

In recent years the USDA Forest Service has adopted a more holistic approach to wildland fire management. This shift has been prompted by escalating wildland fire suppression cost and the recognition of the important role fire plays as part of a healthy ecosystem. As part of this transition the Forest Service has increased the use of controlled burns and wildland use fires for fuel management purposes. This paper attempts to develop a national model to analyze the tradeoff between fuel removal through the use of fire and fire suppression expenditures. For the purposes of this paper controlled burns and wildland use fires are collectively referred to as prescribed burning.

The Forest Service has increased its use of prescribed burning programs while demanding that the programs are cost effective. While making cost effectiveness an important consideration, little work has been done in the understanding tradeoffs between the pre-suppression treatments (e.g.: prescribed burning, and mechanical fuel removal programs) and wildland fire suppression expenditures across a large spatial area. Without a clearer understanding of the benefits from prescribed burning it is difficult to properly determining cost effectiveness. In this paper we attempt to estimate this tradeoff by analyzing expenditure data from 8 Forest Service regions. While the data set, only covering 11-years, is not as extensive as desired it does provided enough information to begin analyzing this topic. This paper uses data from the continental United States to create a generalized national level model estimating the relationship between prescribed burning treatments and wildland fire suppression expenditures. These estimates provided the point elasticities that are then used to determine how much each Forest Service region would save from a marginal increase in prescribed burning programs.

History and Literature Review

Since the beginning of the Forest Service the question of how to best limit emergency expenditures due to large fires has been asked. In 1926, then head of the Forest Service, William Greely observed:

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> From a purely business standpoint it is obvious that we should do anything that can be done within reason to cut down these large emergency expenditures which are necessarily wasteful because they are made under emergency conditions that involve great haste and stress, and which, after all, simply represent the stopping of great destruction. They are not constructive expenditures (Pyne 1982).

Early efforts at controlling the cost of the emergency expenditures relied on the speed of attack as the primary means of reducing the severity of wildland fires (Pyne 1982). This effort lead to a policy environment that sought to limit wildland fire damage by extinguishing fires as quickly as possible, which also had the perverse effect of increasing fuel loads over time (Arno and Brown 1991, Busenberg 2004, Steelman and Burke 2007). Fuel loads are generally defined as the amount of vegetative material present above the soil on a given landscape (Pyne et al. 1996).

Until the 1970's the Forest Service had focused on controlling fires by 10 A.M., under the fittingly named the 10 A.M. policy. Beginning in the early 1970's the policy started to evolve slowly into the current multifaceted approach that weighs net losses, recognizing the beneficial nature of fire in certain settings, against cost (Pyne 1982). In 1995 the Federal Government revised Federal Wildland Fire Policy to minimize the danger of catastrophic wildland fire. The new policies were driven be 3 major objectives: 1) protecting human life, property and natural/cultural resources, 2) reintroducing fire back into ecosystems, and 3) giving greater inter- and intra-agency support for fire managers (Hesseln 2000). The 1995 Federal Wildland Fire Policy increased the importance of prescribed burning as a tool in overall fire management. However, this increase in importance had to make economic sense with the Forest Service requiring that their programs be cost-effective (Hesseln 2000).

The need to develop a multifaceted approach has also been driven by rising real cost of fighting fires. In 2005 the Forest Service spent $760 million on fire suppression expenditures up from $160 million in 1977, with both figures being in 2003 dollars (Mercer et al. 2000). A contributing cause to this real increase in cost can be attributed to the success of fire suppression practices that had the unintended consequence of increasing fuel loads (Busenberg 2004). In congressional testimony in August 2000, fire ecologists Dr. Loen Nueschwander said, "Fires will inevitably occur when we have ignitions in hot, dry, windy conditions… It is one of the great paradoxes of fire suppression that the more effective we are at fire suppression, the more fuels accumulate and the more intense the next fire will be." (USDA Forest Service 2000).

The local nature of fire makes generalizing results from specific landscapes difficult. Estimates of per acre cost for prescribed burning treatments can range greatly. For example Wood (1988) estimated a range of $2.78/ac to $33.65/ac in 1988 dollars for prescribed burning of Southwestern Ponderosa Pine, while Cleaves et. al. (2000) had a range of $7.67/ac to $344.46/ac in 1994 dollars for prescribed burns on National Forest land. A consistent finding in the research is that prescribed burning treatments exhibit economies of scale on the size of the treatment area (Jackson et al. 1982, Gonzalez-Caban and McKetta 1986, Wood 1988, Rideout and Omi 1995).

Most of the early research into prescribed burning looked at localized data for a short period of time. Jackson et al. (1982) looked at burns conducted in Forest Service region 1 for 1979 and 1980, Gonzalez-Caban and McKetta (1986) looked at single year's data for 2 national forests, Wood (1988) used survey data for 3 national forests. The results were very landscape specific and could not be easily generalized. Looking at the spatial nature of fire risk Knoshima et al. (2008) determined that fuel treatments can be utilized to form fire breaks that maximize the benefit of the treated area. This is accomplished by using fuel treatments to break up high risk areas and placing treated areas perpendicular to prevailing winds. Looking past the stand level Rideout and Omi (1995) developed a more generalized model by looking at 340 fuel treatments scheduled by the National Park Service. Additionally important work has been done on broad-scale wildland fires at the state level (Prestemon et al. 2002, Mercer et al. 2007). But little has been done in the way of examining fuel treatments and their tradeoffs with other fire suppression expenditures at the national level.

Theoretical and Empirical Framework

A prominent way of framing the wildland fire management problem is with the cost (C) plus net value change (NVC) framework. This framework is capable of addressing the challenges of optimizing pre-suppression and suppression efforts. The C+NVC is a minimization problem that has two distinct parts: the cost of the fire that includes suppression and pre-suppression expenditures and the net value change that is the sum of the damage caused by the fire minus the benefits received from the fire, the C+NVC function is (Rideout and Omi 1990):

$$MIN\!: C + NVC = W^p P + W^s S + NVC(P, S) \qquad (1)$$

Where P and S denote pre-suppression and suppression activities, and W^p and W^s are the unit cost of those activities, respectively.

Net value change (NVC) not only captures the damage that a fire causes, but also incorporates the positive benefits that fires (e.g.: restoring a fire dependent ecosystem or reducing fuel loads through wildland use fires) can provide to a landscape. While federal agencies have control over the amount of fuel removed from forests, it is not necessarily correct to think of suppression expenditures as a trade-off between spending resources on fuel removal or spending resources fighting fires. Year to year variation in fire activity is great with the average fire size and area burned fluctuating greatly. Other factors besides fuel loads, such as weather, influence the level of fire activity (e.g., Flannigan, et al. 2009; Meyn et al. 2010). Weather also influences when and how prescribe burning is conducted. However, a fuel treatment program targeted at high risk/high value areas can reduce the threat posed by fire, and possibly lower fire suppression expenditures. Even though fire is a spatial phenomenon, we believe using regional level data offers an opportunity to estimate the effects of fuel reduction programs on overall fire suppression expenditures and determine if the optimal amount of fuel treatments are being applied.

To control for the effects of weather and other variables a two-stage approach is used. This approach will first estimate fire intensity (equation 2) and pre-suppression activities (equation 3) using lagged data and weather. Not captured by equation 3 is the budgeting process that determines the Forest Service's budget constraint for prescribed burning activity. It is assumed the budget constraint is determined by a political process and then the Forest Service is maximizing treatments given that unobserved constraint. The second stage (equation 4) uses the estimated result from the first stage and data about the terrain in each region to complete the estimation of fire suppression expenditures.

First Stage Regressions:

$$\text{Logavgburn}_t = \beta_1 + \beta_2\text{Logbiomass}_t + \beta_3\text{Logavgburn}_{t-1} + \beta_4\text{Logprescribedburn}_{t-1} + \beta_5\text{Pdsirseph}_t + \beta_6\text{Pdsirseph}_{t-1} + \varepsilon_t \quad (2)$$

$$\text{Logprescribedburn}_t = \beta_1 + \beta_2\text{Logbiomass}_t + \beta_3\text{Logavgburn}_{t-1} + \beta_4\text{Logprescribedburn}_{t-1} + \beta_5\text{Pdsirseph}_t + \beta_6\text{Pdsirseph}_{t-1} + \varepsilon_t \quad (3)$$

Second Stage Regressions:

$$\text{LogEFSE}_t = \beta_1 + \beta_2\text{Logavgburn}_t + \beta_3\text{Logprescribedburn}_t + \beta_4\text{Logbiomass} + \varepsilon_t \quad (4)$$

Where:

LogEFSE is Natural Log of the Total Emergency Fire Suppression Expenditures
Logavgburn is Natural Log of Average Area Burned
Logbiomass is Natural Log of Biomass per Acre
Logprescribedburn is Natural Log of Area Treated with Prescribed Burning
Pdsirseph is September Measure of the Palmer Drought H Index

The regression is run using a double-log model. This allows the results from the regression to be read as elasticities where $B_i = \left(\frac{\partial y}{\partial x_i}\right)\left(\frac{x_i}{y}\right)$. This provides the elasticities for fire suppression expenditures for a given change in pre-suppression activities and fire intensity.

Data

The panel data is created by pooling observations for the Forest Service regions, with region 10, consisting solely of Alaska, being excluded from this data set. Pooling the 11 years (1998-2008) of data by the remaining 8 Forest Service regions produces an 88-observation data set. Table 1 list the summary statistics. Note that the use of lagged variables reduces the number of observations used in the models to 80. The dependent variable in the second stage regression (equation 4) is the natural log of emergency fire suppression expenditures. This data was provided by the Forest Service and is based on its accounting records. Emergency fire suppression expenditures represent money spent on large fires by the Forest Service. The GDP deflator is used to adjust for inflation, with a base year of 2004.

The independent variables are a mix of endogenous and exogenous variables. The endogenous variables are the natural log of the average area burned for the Forest Service and the natural log of the area treated with prescribed burns conducted by all agencies. The data for both of these variables were obtained from the National Interagency Coordination Center (NICC) and is available for 1998-2008.[2] The average area burned is the amount of acres burned divided

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2. The NICC geographic area coordination centers were paired with the Forest Service (FS) regions in the following way. FS Region 1 consisted of the NICC Northern Rockies region, FS Region 2 consisted of the NICC Rocky Mountain region, FS Region 3 consisted of the NICC Southwest region, FS Region 4 consisted of the NICC Great Basin West and Great Basin East, FS Region 5 consisted of the NICC Southern and Northern California Operation regions, FS

by the number of fires and the area treated by prescribed burnings includes both wildland use fires and controlled burning. Both of these variables are used as dependent variables in the first-stage regressions, equations (equation 2) and (equation 3) with their one-year lags being included as independent variables.

The first exogenous variable is the natural log of biomass. This variable was derived from a ratio between net volume of timber on timberland and the total acres of timberland and reserve forest in each region. This data was obtained from the Forest Service inventory survey for the years 1997, 2002, and 2007. The first step was to aggregate state and sub-regional level data to the Forest Service region level.[3] Estimation for the non-observed years is then calculated by taking the difference between the surveyed years and dividing by the number of years between. This average yearly change was then added to each year in order to create an estimated net volume of timber. The biomass ratio is then calculated by dividing the net volume of timber by the combined timberland and reserved forestland area in thousands of acres to get an approximate measure of the thousand cubic feet of biomass on each thousand acre of land. The one-year lag of the natural log of this value is included in the model as an independent variable in both the first and second-stage regressions.

The final variable is the September Palmer Drought Severity H Index, which has been used to forecast suppression cost in previous studies (Abt et al 2009). Several different climate or weather variables were tried; however, multicollinearity between restricts the number of variables that can be included in a single regression. The September Palmer index is selected as a proxy for weathers conditions in the 3rd quarter. All regions, expect Region 8, experience the most acres burned in the 3rd quarter. Region 8 has the most acres burned in the 2nd quarter, followed by the 3rd quarter.

The Palmer Index is weighted based on the amount of national forest land in each region and is also provided by the Forest Service. The Palmer Index uses precipitation and temperatures to create a long-term index for measuring droughts. A 0 reading for the Palmer Index indicates a normal measure with drought conditions receiving a negative value up to -4 and periods of above average rainfall a positive measure, up to 4 (NOAA 2010). The one-year lag of the Palmer Index is also included in both first-stage regressions.

Empirical Results

The random effect and fixed effect models are identical in the variables used expect for assumption about the distributions of the errors. The results from the fixed effects model results are included in Table 2 and 3. The results from both models were similar. With major difference being the biomass variable is statistically significant in the fixed effect model, and just outside the 10% cut-off in the random effects model. Since a Hausman test indicates the results from the

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Region 6 consisted of the NICC Northwest region, FS Region 8 consisted of the NICC Southern region, and FS Region 9 consisted of the NICC Eastern region.

3. Forest Service Regions 1, 2 and 4 required some states to be appropriated between them. Region 1 was determined by summing Montana, North Dakota, 50 percent of Idaho, and 5 percent of South Dakota. Region 2 included 66 percent of Wyoming, 95 percent of South Dakota, Nebraska, Kansas, and Colorado. Region 4 was made up of Nevada, Utah, 33 percent of Wyoming, and 50 percent of Idaho. The remaining states fell in whole under a Forest Service region. This method is admittedly ad hoc, but a more structured method could not be found.

random effects model might be spurious, we will focus our discussion on the results of the fixed effects model.

The first-stage of the fixed effect model is a pair of regressions that have the natural log of average area burned (equation 2) and the natural log of prescribed burns (equation 3) as the dependent variables. The independent variables are identical in both regressions and the results for both are listed in Table 2. The regressions independent variables consist of the current years September Palmer Index, the one-year lag of the September Palmer Index, the one-year lag for the natural log of average area burned, the one-year lag the natural log of prescribed burns, and the natural log of biomass.

For the regression using the natural log of average area burned as the dependent variable (equation 2) the current and 1 year lag September Palmer Index was statistically significant. The current years index is significant that the 1 percent level, while the previous year's index is significant at the 10 percent level. The current year's measure of the Palmer index has a coefficient of -0.242 indicating that more severe drought conditions leads to an increase in the average size of the area burned. The previous year's Palmer index has a significant positive coefficient of 0.134, an indication that when the previous year had above average rainfall the following year experienced larger fires. A possible interpretation for this is that a wet fall promotes above average growth of vegetation. When a region that experienced this above average growth has a dry fall the next year fuel loads are increased. In addition to the Palmer index variables, biomass is statistically significant at the 5% level with a coefficient of 7.709. This result is in-line with expectations of higher fuel loads resulting in large fires.

For the regression with the natural log of prescribed burns as the dependent variable (equation 3) the current year's Palmer index is significant at 5% level with a slightly positive sign of 0.064. Reflecting the importance of favorable weather conditions on the amount of prescribed burns conducted. If conditions are too wet or too dry the amount of prescribed burns used is lower compared to normal weather conditions. Biomass has a coefficient of 2.560 and is significant at the 5% level. The positive relationship between prescribed burning and biomass is a sign that in area with higher fuel loads more prescribed burning is being implemented. No other variables are statistically significant.

The results from the second-stage regression (equation 4) are presented in Table 3. The second-stage uses the natural log of emergency fire suppression expenditures as its dependent variable. The natural log of average area burned and the natural log of prescribed burns have been instrumented by the first-stage regressions. Both the average area burned and prescribed burns are significant, at the 10 and 5 percent level respectively. The coefficient for average area burned is 0.443, and -1.789 for prescribed burns. The signs are the expected directions with an increase in the average fire size leading to an increase in suppression expenditures. Specifically a 1 percent increase in average fire sizes leads to a 0.443% increases expenditures. For prescribed burns a 1% increase in the amount of burns conducted leads to an anticipated decrease in suppression expenditures by 1.789%. This is an important result since is shows the Forest Service could see a reduction in suppression expenditures by increasing their pre-suppression efforts. The natural log of biomass is not significant; however, *biomass* is significant in both first stage equations indicating the fuel loads have an effect on expenditure cost, but through fire size and prescribed burning programs.

Conclusions

Using Forest Service regions as the unit of observation we create a panel data set that is used to estimate the effects that the average fire size and the area treated with prescribe burns, measured in acres, has on wildland fire suppression expenditures. Using a 2SLS approach to control for weather we are able to obtain elasticity estimates for the Forest Service as a whole. These elasticities can now be used to estimate the savings to the Forest Service from a hypothetical 1% increase in area treated with prescribed fires. The results of our analysis shows the Forest Service is failing to fully maximize the benefits of a prescribed fire regime, specifically in the western United States. By increasing the acres treated the Forest Service has the possibility to lower emergence suppression expenditures, while reintroducing fire risk to western landscapes.

Using the elasticity for prescribed burns from Table 3, we estimate the hypothetical savings from a 1% increase in prescribed burning for Forest Service regions based off of each region's 11-year average expenditures and amount of land treated with prescribed burns. The results for these estimations are listed in Table 4 with the dollar figures in 2004 dollars. Forest Service region 8 and 9, which consist of the eastern United States, saw the smallest savings Region 5, consisting predominantly of California, had the largest estimated savings of $5,451.76 per acre. Regions 1, 4 and 6 had an estimated savings ranging from $1,147.27 to $1,912.14 per acre.

The relatively high estimated savings for regions 1, 4, 5, and 6 suggest the Forest Service might lower expenditures by increasing the amount of prescribed burning conduct in those regions. Updating the estimates from Cleave et al. (2000) to 2004 dollars provides for an average cost for prescribed burning treatments. Region 5 had the highest average cost for prescribed burning treatments at $423.39. This gives Region 5 a net savings of $5,028.37. These results are not to suggest that the Forest Service can treat any land and receive the estimated benefits. But, by extending prescribed burn treatments to land that is demeaned to have the highest fuel loads and most at risk of catastrophic wildland fire the Forest Service can expect to reduce expenditures overtime.

References

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Table 1: Summary Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
ESFE	95,344,846.11	10,789,4252.20	2,698,709.23	663,972,968.73
Biomass	1.90	0.63	1.17	3.30
Avgburn	234,040.40	336,737.10	2,281.50	168,6751.00
Prescribedburn	285,587.60	468,056.50	245,593.00	225,0793.00
Pdsirseph	-0.903	2.209	-5.126	5.325

Table 2: First-Stage Regression-Fixed Effects

Dependent Variable	Natural Log Average Area Burned		Natural Log of Prescribed Burns	
	(Coefficient)	(Standard Errors)	(Coefficient)	(Standard Errors)
Logbiomass	7.709**	3.558	2.560*	1.465
Logavgburn lag 1 year	0.089	0.119	0.051	0.049
Logprescribedburn lag 1 year	0.119	0.253	0.130	0.106
Pdsirseph	-0.242***	0.061	0.062**	0.027
Pdsirseph lag 1 year	0.134*	0.065	0.008	0.027
Constant	-1.730	2.883	8.813***	1.176
N	80		80	

Note: *** is 1%, ** is 5%, and * is 10% levels of statistical significance.

Table 3: Second-Stage Regression-Fixed Effects

Dependent Variable	Natural Log of Emergency Fire Suppression Expenditures (Coefficient)	(Standard Errors)
Logavgburn	0.443*	0.250
Logprescribedburn	-1.789**	0.774
Logbiomass	3.864	4.597
Constant	35.077***	8.054
Wald Chi		37781.81
R^2 within		N/A
R^2 between		0.41
R^2 overall		0.35
N		80

Note: *** is 1%, ** is 5%, and * is 10% levels of statistical significance.

Table 4: Estimated Savings in 2004 dollars of a 1% Increase in Area Treated with Prescribed Fires

Region	Additional Treated Area in Acres	Estimated Savings	Savings Per Acre	Average Prescribed Burning Cost[1]
1	1,166.62	$1,878,569.95	$1,611.17	$197.81
2	1,029.01	$676,009.90	$657.32	$64.46
3	2,080.53	$1,344,076.04	$646.39	$67.29
4	1,256.12	$1,440,308.65	$1,147.27	$112.74
5	887.14	$4,833,759.97	$5,451.76	$423.39
6	1,318.79	$2,520,291.12	$1,912.14	$231.44
8	13,552.35	$739,935.96	$54.63	$44.00
9	1,556.45	$205,175.19	$131.90	$67.19

1. The average cost for all types of prescribed burning from Cleaves et al. 2000 updated to 2004 dollars.

Specialized Discounted Cash Flow Analysis Formulas for Valuation of Benefits and Costs of Urban Trees and Forests

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Abstract

Discounted cash flow (DCF) analysis is a method of valuation often used in forests managed for timber production objectives to obtain the present value (PV) of cash flows, or the value in current day dollars considering interest (Bullard and Straka 1998). Several conventional forestry valuation software packages use DCF as a method for financial decision-making because it accounts for the time value of money and represents the dynamic financial nature of a timber stand. Early forest valuation models, such as Faustman's formula, rely on the principles of DCF analysis to determine important forestry investment financial criteria such as land expectation value (LEV) and financial optima like rotation length (Tietenberg and Lewis 2008). DCF analysis produces reliable monetary valuations for natural resources, including forests (Gollier et al. 2008). DCF is often used over long time spans with good results; however, its use to value long life assets, like trees, may produce issues like fairness to future generations and inflation estimates.

Despite its accepted use in forestry for timber production, DCF analysis, or the income approach generally, has not been frequently used in urban forestry and arboriculture. Cash flows for benefits and costs from single trees or urban forests are difficult to determine, and the mathematical structure of DCF analysis is somewhat complicated (Council of Tree and Landscape Appraisers 2000; Straka and Bullard 2006). Negative cash flows or expenditures (both capital and operating) are called "costs" in traditional forestry investment analysis, but they are more likely to be labeled as "expenses" in an appraisal income approach.

Conventional forestry valuation software packages (such as FORVAL) can be used for DCF calculations, but they require that cash flows be input in one of a few standard structures (single sum, terminating annuity, perpetual annuity, or perpetual periodic series) (Straka and Bullard 2002). These standard structures have rigid assumptions about the cash flow sequences; for example, a cash flow occurring each year and beginning at year 1 or a cash flow occurring periodically every x years and beginning at year x (Straka and Bullard 2002). Benefits (i.e., income) and costs in urban forest and tree valuation situations do not always occur in these structured patterns and standard DCF formulas do not handle irregular cash flows well. This is another primary reason the income approach is often difficult to apply in these situations (Bullard and Straka 2006).

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We identified a series of specialized discounting formulas that were well-suited for solving valuation problems that follow typical cash flow patterns occurring in the benefit and cost structures of urban tree and forest situations; that is, those that do not follow standard structured cash flow patterns and, thus, would be difficult to value using many conventional DCF formulas (McPherson and Simpson 2002; McPherson 2003; McPherson 2007). Using the standard DCF formulas common to forest valuation (Appraisal Institute 2008, Bullard and Straka 1998) as a foundation, we constructed a series of new or "special" DCF formulas that will allow these benefit and cost situations to be evaluated using conventional DCF valuation software packages. We also reviewed the basic standard DCF formulas as they are the basis of the "specialized" formulas. Most formulas could be utilized as part of a standard DCF valuation software models like FORVAL (Straka and Bullard 2006; Bullard et al. 2011).

Single-sum Discounting (SSD)

The basic formula used in DCF analysis is the formula for discounting a single sum. It discounts a cash flow to year zero on a cash flow time line. Year zero represents the current point in time or the beginning of year one or time period one. This formula is:

$$V_0 = \frac{V_n}{(1+i)^n}$$

Where V_0 is the value at year zero, V_n is the value at year n, i is the interest rate (expressed as a decimal), and n is the number of years being evaluated.

Present Value of a Terminating Annuity (TA)

Sometimes, cash flows of the same magnitude occur annually. The basic formula calculates the present value of a terminating annual series as:

$$V_0 = a\frac{(1+i)^n - 1}{i(1+i)^n}$$

Where a is the annual cash flow and the remaining variables are as defined previously.

Present Value of a Perpetual Annuity (PA)

In some urban forestry situations (such as the creation of a conservation easement that generates perpetual uniform benefits over time), the value of an annual cash flow occurs forever. The calculation of a perpetual annuity is simply:

$$V_0 = \frac{a}{i}$$

Where a is the annual cash flow and the remaining variables are as defined previously.

Present Value of a Terminating Periodic Series (TPS)

The prior valuation formulas were basic DCF analysis tools. Most valuation software packages include an automatic computation of these values. The TPS formula is not a basic DCF formula. Terminating periodic refers to a situation where benefits or costs have a regular, uniform magnitude, but occur on a periodic, not an annual basis. An example would be stormwater or flood mitigation every 20 years, starting at year 20 and ending at year 140. The formula could easily be adapted to time periods shorter than a year. The TPS formula is:

$$V_0 = a\frac{(1+i)^{nt}-1}{[(1+i)^t-1](1+i)^{nt}}$$

Where t is the length of each period in years, n is the number of compounding periods, and the remaining variables are as defined previously.

Present Value of a Fixed Rate Increasing Annuity (FRIA)

In other situations, the benefits or costs may occur annually, but have a magnitude that increases at an exponential rate. For example, a tree's ability to sequester carbon may increase a given rate per year. In this case, we can use a formula for the present value of a growing annuity. The calculation of the FRIA is:

$$V_0 = \frac{a}{(i-g)}[1-(\frac{1+g}{1+i})^n]$$

Where g is the percentage rate of growth of the annuity (expressed as a decimal) and the remaining variables are as defined previously.

Present Value of Minimum Size Delayed Annual Cash Flows (MSDACF)

In some urban trees, annual cash flows may not occur until the tree reaches a certain minimum size. For example, electricity savings in summer from tree shade or privacy benefits from a large tree do not begin until the tree reaches a certain size. Other examples might be privacy benefits, sound barrier benefits, air quality, health, and recreation benefits (Martin 1989; Novak et al. 2002; Wolf 2004). In fact, MSDACF valuation is common in urban forestry applications, as many urban forest benefits rely on a certain crown size or structure more than a particular age or diameter breast height (DBH). These crown assets only occur once the tree has reached a minimum age for developing a mature crown. The MSDACF formula is:

$$V_0 = a\frac{(1+i)^{n_a}-1}{i(1+i)^{n_a}(1+i)^{n_v}}$$

Where n_a is the number of years for which the annuity occurs and n_v is the number of years the annuity is delayed from the standard annuity. We note that this formula also applies to costs with similar financial scheduling, like periodic costs for pruning.

Present Value of Minimum Size Delayed Periodic Cash Flows (MSDPCF)

Similar to the MSDACF, the MSDPCF calculates the present value of benefits (or costs) incurred periodically that are contingent upon the tree reaching a certain “minimum size.” An example would be the “windbreak” ability of a tree in a windstorm. First, the tree would need to reach a minimum size to have windbreak ability and, second, the benefit would occur periodically, not every year. The MSDPCF formula is:

$$V_0 = a\frac{(1+i)^{n_a t}-1}{[(1+i)^t-1](1+i)^{n_a t}(1+i)^{n_v}}$$

Where $n_a t$ is the number of years for which the series occurs, t is the length of the time period, and n_v is the number of years in the future the series begins.

Present Value of Patterned Terminating Periodic Series (PTPS)

Urban trees may have several systematic, “stacked” cash flows, where one cash flow is “stacked” onto another. A cash flow of a smaller magnitude (i.e., the base series) may occur on a frequent basis, but necessitate a cash flow of a larger magnitude (i.e., the stacked series) on an infrequent basis. An example would be the soil enhancement benefit of trees. Fertilization might be reduced on an annual basis (the base series) and soil aeration might be reduced every 10 years (i.e., the stacked series). In this case, the larger cash flow is stacked onto the pattern of the smaller cash flow, and the following formula should be used:

$$V_0 = a_1\frac{(1+i)^{n_1 t_1}-1}{[(1+i)^{t_1}-1](1+i)^{n_1 t_1}} - (a_2 - a_1)\frac{(1+i)^{n_2 t_2}-1}{[(1+i)^{t_2}-1]((1+i)^{n_2 t_2}}$$

Where a_1 is the cash flow of the base series, a_2 is the cash flow of the stacked series, i is the interest rate, n_1 is number of years the base series occurs, t_1 is length of the time period for the base series, and n_2 is number of years the stacked series occurs, and t_2 is length of the time period for the stacked series.

Present Value of Minimum Size Delayed Patterned Terminating Cash Flows (MSDPTCF)

Like other benefits or costs that do not begin until a minimum tree size occurs, patterned terminating benefits or costs need be discounted back to year zero. A systematic pruning of a tree on two levels is an example of this calculation; for example, minor pruning every five years and major pruning every twenty years. If so, the following formula should be used:

$$V_0 = a_1\frac{(1+i)^{n_1 t_1}-1}{[(1+i)^{t_1}-1](1+i)^{n_1 t_1}(1+i)^{n_{v1}}} - (a_2 - a_1)\frac{(1+i)^{n_2 t_2}-1}{[(1+i)^{t_2}-1]((1+i)^{n_2 t_2}(1+i)^{n_{v2}}}$$

Where a_1 is the cash flow of the base series, a_2 is the cash flow of the stacked series, n_1 is number of years for which the base series occurs, t_1 is length of the time period for the base series, and n_2 is number of years the stacked series occurs, t_2 is length of the time period for the stacked series, n_{v1} is number of years the base annuity is away from year zero, and n_{v2} is number of years the stacked annuity is away from year zero.

Urban Tree Site Value (UTSV)

In the traditional forestry literature LEV or bare land value is calculated for land in permanent timber production (Klemperer 1996). This methodology can be used to calculate the PV of any perpetual cash flow-producing investment (Straka and Bullard 1996). This means a site value for an urban tree can also be calculated by compounding the PV of the tree's cash flows to the end of its "rotation" (defined as its viable life on the site) and assessing this over a perpetual time frame. The following formula accomplishes this:

$$UTSV = \frac{PV(1+i)^n}{(1+i)^n - 1}$$

UTSV is the urban tree site value with a perpetual time horizon, while *PV* is the present value of all benefits and costs of the tree for one "rotation," and *n* is the length of the "rotation."

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SOFEW Evaluations: Are We Providing Value?

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SOFEW Evaluations: Are We Providing Value?

Abstract:

The Southern Forest Economics Workshop (SOFEW) steering committee at Mississippi State University (MSU) has collected and analyzed SOFEW annual meeting evaluations since the 2006 annual meeting in Knoxville, Tennessee. Participants were asked to rank on a 5-point scale the host organization, meeting location, general and technical sessions, as well as provide their primary reason(s) for attending the meeting and topics they were interested in for upcoming meetings. Since the University of Tennessee hosted the 2006 SOFEW annual meeting, we have shared meeting responsibilities among academia, private industry, and the USDA Forest Service. Subsequent hosts were Texas A&M University, University of Georgia's Center for Forest Business, The Forestland Group, and the USDA Forest Service's Southern Research Station. Host organizations and meeting locations have received high rankings every year as well as have most general and technical sessions. However, some sessions lacked appeal to some participants for a variety of reasons. Primary motivations for attending annual meetings were to "present a paper" or "to network and experience fellowship with peers." Recently, one of the biggest concerns for participants and the SOFEW steering committee is dwindling meeting attendance. One suggestion for enhancing the value of SOFEW meetings is to offer an opportunity for refereed publications. For example, the majority of participants felt that a publication of select refereed manuscripts would be valuable and could possibly increase attendance. Evaluation information has been conveyed to each year's regional planning committee to ensure we continually improve and make annual meetings relevant to participating members and others. We look forward to improving benefits SOFEW members receive from annual meetings and hope to increase future attendance.

Key words: attendance, meeting evaluations, membership, SOFEW, value

Background:

Over the last several years, the biggest concern for the Southern Forest Economics Workshop (SOFEW) steering committee at Mississippi State University (MSU) and host organizations has been dwindling meeting attendance. With decreased meeting attendance, SOFEW annual meetings are becoming more difficult to plan and also maintain their profitability. Therefore, the SOFEW steering committee and the host organizations have collected and analyzed SOFEW annual meeting evaluations since the 2006 meeting in Knoxville, Tennessee. Since the University of Tennessee organized the 2006 SOFEW annual meeting, we have had a sharing of meeting host responsibilities on the part of academia, private industry, and the USDA Forest Service. Subsequent hosts were Texas A&M University (2007), University of Georgia's Center for Forest Business (2008), The Forestland Group (2009), and the USDA Forest Service's Southern Research Station (2010). Participants at each meeting were asked to rank on a 5-point scale the host organization, meeting location, general and technical sessions, as well as provide their primary reason(s) for attending and topics they were interested in for upcoming meetings. Evaluation information has been conveyed from the steering committee to each year's regional planning committee to ensure we continually improve and make annual meetings relevant to participating members and others.

Methods:

A 3-page evaluation instrument was developed by the MSU SOFEW steering committee. Each year the committee edits the evaluation instrument and sends it to the regional host planning committee to fill in detailed meeting information. Once the evaluation is acceptable, it is printed at the host meeting site and distributed at the registration table or within registration packets given to attendees. Evaluations are to be returned at the end of the meeting, or they can be mailed or e-mailed to the MSU SOFEW steering committee. The committee then tabulates the evaluation feedback and distributes it as needed to SOFEW members.

Results and Discussion:

SOFEW meeting evaluations serve to gather the meeting participants' basic attitudes concerning the current meeting and to use this information to serve as a guideline for future meetings. Attendance for the meetings from 2006 through 2010 has been 70, 59, 88, 108, and 72, respectively. Returned evaluations since 2006 have been 28, 30, 33, 19, and 24 which correlates to response rates of 40, 51, 38, 18, and 33 percent, respectively. Primary motivations for individuals to attend SOFEW meetings are to "present a paper" and to "network and experience fellowship with peers" (Table 1). Most general sessions and technical concurrent sessions received high rankings ("excellent" to "very good") every year. Of course there have been exceptions to this, but rarely has this been the case. Participants expressed their attitudes about having a student poster session at the annual meetings with the majority believing it would be valuable (Table 2). Although at the 2011 SOFEW annual meeting there was some discussion among members about changing the format for poster presentations. Participants were also asked to rate their ideas about having a publication of select refereed manuscripts along with the current practice of having online proceedings from meetings (Table 3). The majority felt it

Table 1: Southern Forest Economics Workshop (SOFEW) meeting participant reasons for attending annual meetings, 2006-2010.

Reason	**2006**	**2007**	**2008**	**2009**	**2010**
Desirable meeting location	0	0	1	1	0
Program content of sessions	6	3	11	5	4
To present a paper	9	16	6	5	10
To have graduate students present	1	2	1	2	1
To network and fellowship with peers	11	9	14	6	8
Other	1	0	0	0	1

Table 2: Southern Forest Economics Workshop (SOFEW) meeting participant feelings about including a student poster session at annual meetings, 2006-2010.

Year	**Extremely Valuable**	**Very Valuable**	**Somewhat Valuable**	**Little Value**	**Not Valuable**
2006	5	8	12	1	0
2007	3	13	13	1	0
2008	2	11	13	5	1
2009	4	5	8	1	0
2010	5	11	8	0	0

Table 3: Southern Forest Economics Workshop (SOFEW) meeting participant feelings about having a select publication of refereed manuscripts along with the current practice of having online proceedings derived from SOFEW meetings, 2006-2010.

Year	**Extremely Valuable**	**Very Valuable**	**Somewhat Valuable**	**Little Value**	**Not Valuable**
2006	9	13	4	1	1
2007	14	13	3	0	0
2008	15	10	5	1	1
2009	4	8	5	1	0
2010	8	10	4	2	0

would be very valuable to have a refereed publication from the SOFEW meetings. This was done recently at the 2007 SOFEW annual meeting hosted by Texas A&M University in San Antonio, Texas whereby a book was published with select refereed papers serving as individual chapters. Those who participated as editors, reviewers, and authors were extremely pleased with the outcome.

The MSU SOFEW steering committee also asked that meeting participants provide at least one suggestion for a specific topic or speaker for upcoming meetings. Participants provided a wide array of topics, but those most frequently mentioned included carbon sequestration, carbon credits, private landowner topics, globalization of the forest industry, ecosystem services, bioenergy, forest certification, and recreation. Overall, the majority of participants ranked SOFEW meetings as “very valuable” to “extremely valuable” when compared to other meetings they usually attend. In general, host organizations and meeting locations have received high rankings ("very good" to "excellent") every year (Table 4-5). There were several other questions covering varying topics. The majority of individuals did not report any problems with regard to the online registration process facilitated by MSU. As expected, most individuals were not willing to host a future SOFEW annual meeting. Most participants felt that the SOFEW Web site provided an adequate amount of information about SOFEW-related issues and activities. The overwhelming majority were in favor of a twice a year SOFEW e-newsletter; however, there were no offers to facilitate this process.

Individuals provided several comments about the annual SOFEW meetings. Some of the more frequent comments were to have more invited presentations or presenters. Also recommendations were to have more diversity with regards to presenters (i.e., more individuals from forest industry and government agencies). It was also recommended that we attract more "professionals" to the annual meetings. Again, this relates back to the diversity issue in regard to having more forest industry and government agency representatives along with an increased number of professors participating and presenting at the SOFEW meetings. Since there is always a significant portion of attendees who are graduate students, these responses were to be expected. Better communications and improved advertising for meetings and calls for abstracts were also recommended by many participants as ways to help alleviate many of the above issues.

Participants also provided feedback on ways to improve SOFEW in general, and ways that can enhance value to SOFEW members and meeting participants in the future. As previously mentioned, one suggestion for enhancing value was to offer an opportunity for refereed publications. For example, the majority of participants have felt that a select publication of refereed manuscripts would be valuable and could possibly increase attendance. Respondents also suggested increasing the forest industry and government agency participation, both as speakers and meeting attendees, to increase the diversity and therefore value of the annual

Table 4: Southern Forest Economics Workshop (SOFEW) meeting participant ratings of the host performance during annual meetings, 2006-2010.

Year	**Excellent**	**Very Good**	**Good**	**Fair**	**Poor**	**No Opinion**
2006	7	13	6	1	0	1
2007	10	16	3	0	0	1
2008	15	15	0	0	0	3
2009	8	6	2	1	0	1
2010	6	7	8	2	0	0

Table 5: Southern Forest Economics Workshop (SOFEW) meeting participant ratings of hotel facilities used for annual meetings, 2006-2010.

Year	**Excellent**	**Very Good**	**Good**	**Fair**	**Poor**	**No Opinion**
2006	7	11	5	2	2	1
2007	2	10	11	5	0	2
2008	11	14	6	0	0	2
2009	10	4	2	2	0	0
2010	11	6	5	1	0	1

meetings to all attendees. It was felt that one reason for poor attendance is that forest industry and government agency participants may not be as interested in graduate student research presentations, especially since much of this work is in a preliminary stage of development. Another suggestion was to have field tours available either before or immediately after SOFEW annual meetings as a way to show attendees different forest management alternatives in different locales in the South. Of course, this would extend the length of the meeting and, in these hard economic conditions, that may not be an option for some participants. However, field trips could always be made optional, with an extra charge placed on participants who want to engage in this type of activity.

As noted earlier, several individuals noted the decreased, poor attendance of the last few annual meetings and considered this an extremely important issue that needed to be addressed in the future; both by the MSU SOFEW steering committee and other active SOFEW members. When an overview of past meetings are looked at, it seems that SOFEW has moved past its original intent which, in part, was to serve as a chance to provide graduate students and newer professors a chance to network with professionals who work primarily in the area of natural resource economics and other related topics. It appears SOFEW is currently at a crossroads, suggesting that it needs to redefine itself and move forward in a new or rejuvenated direction, or it will not survive into the future.

Conclusions:

Are we providing value to SOFEW members and annual meeting participants? Based on the results of annual SOFEW meeting evaluations, we can show that we are indeed providing value to those attending the meetings. Are there ways to improve upon the value provided? Like any endeavor or meeting, there are ways to improve. As indicated earlier, providing a refereed manuscript outlet, increasing the number of forest industry and government agency speakers, and possibly compiling a SOFEW e-newsletter would be ways to improve member satisfaction and hence the value they associate with SOFEW. So, how do we get more industry and government agency participation? We must do a better job of promoting our annual meetings to these groups. We should also announce SOFEW meetings to other potentially interested groups such as the Association of Consulting Foresters, Society of American Foresters south-wide chapters, and other relevant forestry associations and organizations. Perhaps, as some have suggested, we should consider increasing the scope of SOFEW to other regions of the United States and possibly promote SOFEW internationally as well. Based on the SOFEW evaluations, the MSU SOFEW steering committee plans to work on these issues in the near future as a means toward improving benefits SOFEW members receive from annual meetings and in the hope of increasing future attendance. It appears SOFEW is currently at a crossroads, suggesting that it needs to redefine itself and move forward in a new or rejuvenated direction, or it will not survive into the future.

Estimating Wildlife Viewing Recreational Demand and Consumer Surplus

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Abstract

Motivated by the increasing popularity of wildlife viewing and a growing emphasis on management for nontimber outputs, wildlife viewing demand was assessed. Specific objectives included determining factors affecting participation and frequency of use, and furthermore, deriving 2006 nationwide wildlife viewing consumer surplus estimates. With the travel cost method as the theoretical basis, the empirical estimation method employed was a two-step sample selection model that included a probit first step and a negative binomial second step. Consumer surplus per trip estimates ranged from $215.23 to $739.07 while aggregate national estimates ranged from $44.5 billion to $185.1 billion. Results reveal that age, race, and urban residence affect participation and frequency similarly. This research can help policymakers in particular better understand determinants of wildlife viewing participation and frequency. The value of wildlife viewing access can be used to justify funding initiatives aimed at protecting or managing for this use.

Key words: consumer surplus, sample selection, travel cost method, wildlife viewing

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Introduction

America's forests are utilized for a variety of uses by numerous individuals with often different needs and wants. Similar to other forms of non-consumptive and non-rival recreation such as hiking and bicycling, wildlife viewing has increased in popularity in recent decades. From 1996 to 2006, the number of wildlife viewing participants increased from 62.8 million to 71.1 million (USDI 2006). In comparison, during this same period, the number of hunters and fishermen decreased from 39.6 million to 33.9 million (USDI 2006). When compared especially to consumptive forms of recreation such as hunting and fishing, wildlife viewing appears to be growing in popularity.

As identified by the US Fish and Wildlife Service's 2006 Fishing, Hunting, and Wildlife Associated Recreation survey, wildlife associated recreation generated approximately 122 billion dollars worth of expenditures in 2006. This amount was roughly one percent of the nation's gross domestic product (USDI 2006). In 2006, wildlife viewing expenditures totaled roughly 45.6 billion dollars with nearly 28 percent of this amount being related to trip expenditures and 21 percent directed to the purchase of wildlife viewing equipment (USDI 2006). Undoubtedly, wildlife viewing is an important economic component of the uses of the nation's natural resources.

Goods and services provided by natural resources can be classified as either market or non-market goods. To evaluate demand for non-market goods, methods such as contingent valuation (CV) and the travel cost method have been utilized by many researchers. In contrast to CV studies which are based on an individual's stated preferences, the travel cost method is a revealed preferences approach that relies on the actual behavior of recreationists (Zawacki et al. 2000). In theory, the travel costs incurred by recreationists to a site can be used to determine a proxy price for access that they would be willing to pay (Pearse and Holmes 1993). As demonstrated by previous researchers, the outcomes from travel cost demand analyses can be utilized to derive consumer surplus estimates (Zawacki et al. 2000).

Despite its popularity, few studies have explicitly examined wildlife viewing demand. Recent studies such as Zawacki et al. (2000) and Marsinko et al. (2002) focused solely on wildlife viewing trip frequency. As a result, factors affecting an individual's decision to become a wildlife viewing participant were not examined. Since only trip takers were considered as part of the relevant population in the truncated datasets of these studies (Zawacki et al. 2000, Marsinko et al. 2002), selection bias concerns arose since everyone is not a potential wildlife viewing trip taker in reality. Rockel and Kealy (1991) studied wildlife viewing participation and trip frequency but utilized a sample selection approach that did not take into account the count data nature of the trip frequency variable. In addition, survey data utilized by previous studies has become outdated. For instance, Rockel and Kealy (1991) utilized 1980 survey data while Zawacki et al. (2000) and Marsinko et al. (2002) utilized data from 1991.

In order to fill a knowledge gap left by previous studies, the objective of this study was to determine recreational demand and consumer surplus associated with nationwide wildlife viewing for the year 2006 using a sample selection model. The first component involved determining factors that influence an individual's decision to become a wildlife viewing participant. Similar to Rockel and Kealy (1991), Zawacki et al. (2000), and Marsinko et al. (2002), the second component of the study involved determining factors affecting the number of trips a wildlife viewing participant takes. Using the demand models created from the study's second component, consumer surplus estimates were obtained.

Potential implications involving policymakers exist as a result of better understanding recreational wildlife viewing demand. Policymakers and managers of parks and refuges could potentially introduce measures such as entrance fees to better take into account the value of uses such as wildlife viewing (USDA 2007). These revenue creating measures can potentially be used to protect the wildlife resources of the park and manage for recreational uses such as wildlife viewing. A better understanding of determinants of wildlife viewing participation and trip frequency can be particular useful in light of recent trends affecting natural resources. Such trends include increased pressure on resources due to population growth, increased urbanization, and increased forest conversion into urban and developed uses (USDA 2007).

Methods

Data source

Data from the 2006 National Survey of Fishing, Hunting, and Wildlife Associated Recreation (FHWAR) was utilized. Carried out consistently every five years since 1955, the FHWAR is a very detailed assessment of the following three major areas of wildlife recreation: hunting, fishing, and wildlife watching (USDI 2006). The 2006 FHWAR contains a wide variety of thorough information relating to wildlife recreation participation, trip expenditures, equipment expenditures, and demographics. Consisting of three major datasets, the 2006 FHWAR comprises of a screening file containing 144,509 records, a sportsperson file containing 21,942 records, and a wildlife watching file containing 11,285 records.

Empirical model

Two empirical models were established. First, in order to identify wildlife viewing participants and to avoid potential selection bias concerns, the following model was constructed:

$$X_i = f(D_i, S_{ij}) \quad (1)$$

where X_i is the individual's decision to participates in a wildlife viewing trip, D_i is a set of demographics, and S_{ij} are potential substitute or complementary variables and their associated prices. Hunting and fishing were the potential substitutes or complements of consideration.

In order to estimate demand for wildlife viewing trips, the following model similar to the one created by Zawacki et al. (2000) was adopted:

$$Y_{ij} = f(C_{ij}, S_{ij}, D_i) \quad (2)$$

where Y_{ij} is the number of wildlife viewing trips a participant takes to a state, C_{ij} is the individual's trip costs to the state, S_{ij} are potential substitute or complementary variables (hunting and fishing) and their associated prices, and D_i is a set of demographics.

Estimation technique

In order to estimate wildlife viewing participation and demand, a sample selection estimation technique was utilized. The basic logic of sample selection estimation is that an outcome variable is observed only when a certain criterion of the selection variable is met (Greene 2008, pp. 882-887). For this research, the selection component was wildlife viewing participation while the outcome component was wildlife viewing trip frequency. Since the selection variable was binary and the outcome variable was a count, the first stage was estimated using a probit regression model and the second stage was measured using a count-data model (Sun et al. 2008).

Borrowing the framework from the previous study by Sun et al. (2008), the participation decision can be modeled by the following:

$$z_i^* = g(w_i);\ z_i = 1 \text{ if } z_i^* > 0 \qquad (3)$$

where z_i is the realization of an unobserved variable (z_i^*) indicating participation and w_i is a set of explanatory variables used to predict participation. This binary dependent variable indicates whether or not an individual at least 16 years old has taken a trip of at least one mile away from his or her home for the purpose of viewing wildlife.

The second stage, or frequency of participation, can be expressed by the following model:

$$y_i = f(x_i);\ y_i \text{ is only observed when } z_i = 1 \qquad (4)$$

where y_i is trip frequency contingent on participation and x_i is a set of explanatory variables predicting frequency (Sun et al. 2008). With Poisson regression, the essential assumption is that the conditional mean and conditional variance of the distribution are equal (Greene 2008, pp. 906-911). When overdispersion does exist, the use of a negative binomial regression model is favored (Greene 2008, pp. 906-911).

With two-step sample selection estimation techniques, the selection and outcome components must be estimated jointly. As demonstrated by Sun et al. (2008), estimating the components jointly can be approached using techniques such as full information maximum likelihood (FIML) and Greene's two-step method. For this study, the FIML approach was utilized. With FIML estimation, the distributions of the first and second step equations are defined jointly (Greene 2008, pp. 383-384). Unlike Greene's two step non-least squares approach, the correction associated with the FIML approach is performed internally rather than through the use of an inverse mills ratio. In addition, the significance of the parameter rho (ρ) can be used to ascertain whether the use of a sample selection model was appropriate.

Consumer surplus

Using the demand equation, individual per trip and aggregate consumer surplus estimates were obtained. Consumer surplus is essentially the difference between a consumer's willingness to pay for a product and the actual amount the consumer has to pay to obtain the product (Mendes and Proenca 2007). In the count-data regression model, a point estimate of an individual's consumer surplus can be obtained by calculating the negative reciprocal of the cost coefficient (Yen and Adamowicz 1993). Aggregate consumer surplus estimates were obtaining by multiplying individual consumer surplus estimates by the number of wildlife viewing trips (232 million) that took place in the year 2006 (USDI 2006).

Construction of cost variables

Similar to previous literature (Zawacki et al. 2000, Rockel and Kealy 1991), reduced and full versions of wildlife viewing trip costs were created. A reduced version of the wildlife viewing trip costs variable included transportation costs (private vehicle, public transportation, and air) and fees (guide, public access, and private access). The full trip cost version contained the categories associated with the reduced version and added the categories of lodging and food.

Similar to previous literature (Zawacki et al. 2000, Marsinko et al. 2002), an individual's hunting and fishing trip costs were represented in this study as the statewide average of hunting and fishing costs where the wildlife viewing trip took place. For wildlife viewing non-participants, an individual's hunting and fishing trip costs were represented as the statewide average of the individual's state of residence since it is assumed that, if a non-participant decided to take a wildlife viewing trip, it would take place in his or her state of residence (Zawacki et al. 2000). Similar to wildlife viewing, reduced and full versions of hunting and fishing trip costs were created. In contrast to wildlife viewing and hunting, reduced trip costs for fishing contained the categories of transportation, fees, bait and ice, and essential boating costs such as launching, mooring, and fuel. Interaction terms were created to avoid forcing hunting and fishing costs on individuals who do not hunt or fish.

A provision for the opportunity cost of time was included in each of the cost variables. Following Zawacki et al. (2002), individual per trip opportunity cost of time estimates were calculated by multiplying trip time by a fraction of the wage rate. Wage rate estimates were obtained by dividing household income by the total hours of a full work year. Similar to Zawacki et al. (2002), this study used the wage rate multipliers 0.25 and 0.50.

Sample construction

After variable transformations were made, a sample of the data was constructed in order to carry out data analysis. After removing records with missing observations, records associated with the top five percent of trip costs observations were removed in accordance with a procedure used by previous researchers (Zawacki et al. 2000, Rockel and Kealy 1991). Of the remaining observations, a random sample of 25% of the remaining records was used for the analysis of this study. 25% of the remaining usable data produced a sample size of 23,111. Since ten percent of the relevant population took a wildlife viewing trip away from home in 2006 (USDI 2006), the sample was constructed to coincide with this finding. As a result, out of the total sample of 23,111 individuals, ten percent or 2,311 took a wildlife viewing trip away from home.

Empirical Results

Information related to demographics, hunting and fishing experience, wildlife viewing participation, and wildlife viewing trips took can be found in Table 1.

Table 1. Sample demographics, hunting and fishing experience, and dependent variables.

Variable	Explanation	Mean	Std. Dev.
Demographic Variables			
Age	In years	46.24	17.53
Age squared	In years	2445.58	1736.51
Sex	1if male; 0 if female	0.48	–
Married	1 if currently married; 0 otherwise	0.62	–
Household income	In thousands of dollars	58.27	28.94
Some college to BA/BS	1 if education is up to 4 year degree; 0 otherwise	0.43	–
Graduate degree	1 if education is graduate degree; 0 otherwise	0.12	–
White	1 if white; 0 otherwise	0.85	–
Urban residence	1 if urban residence; 0 if rural	0.67	–
Employment	1 if employed; 0 otherwise	0.66	–
Fishing and Hunting Experience			
Ever hunted	1 if ever hunted in lifetime; 0 otherwise	0.23	–
Ever fished	1 if ever fished in lifetime; 0 otherwise	0.53	–
Dependent Variables			
Trip taker	1 if trip away from home is taken; 0 Otherwise	0.10	–
Trips to site	Number of trips to state	8.14	21.20

Trip costs associated with wildlife viewing, hunting, and fishing were organized by costs and wage rate specifications and are presented in Table 2. Overall, wildlife viewing had the lowest trip costs while hunting had the highest. Trip costs for wildlife viewing, hunting, and fishing followed expected patterns as full costs values were greater than reduced costs values and costs containing the half wage rate specification were greater than costs containing the quarter wage rate specification. The largest trip costs values contained the full costs and half wage rate specifications.

Table 2. Wildlife recreation trip costs organized by costs and wage rate specification.

Variable	Costs	Wage Rate	Mean ($)	Std. Deviation ($)
Wildlife viewing	Reduced	Quarter	57.59	79.22
	Reduced	Half	74.22	95.78
	Full	Quarter	140.54	280.36
	Full	Half	157.17	291.55
Hunting	Reduced	Quarter	148.73	244.50
	Reduced	Half	168.79	251.22
	Full	Quarter	226.55	327.06
	Full	Half	246.61	343.34
Fishing	Reduced	Quarter	100.34	96.53
	Reduced	Half	116.72	102.08
	Full	Quarter	173.81	169.97
	Full	Half	190.18	175.89

Model Selection

Four models were constructed to take into account trip costs and wage rate specifications. Issues concerning multicollinearity arose with regard to the variables sex and household income. The potential of multicollinearity and a lack of literature support to justify the inclusion of sex in the models led to the omission of this variable. The variable household income was positively correlated with such variables as marital status, graduate level education, and employment. Ultimately, the final model excluded the three variables since economic theory suggests that income should be a significant factor and variables such as employment and marital status have no relevant potential policy implication. The education variable signifying some college experience up to the completion of a bachelor's degree was found to be insignificant in preliminary analysis and was omitted from the second step due to a lack of literature support to justify its inclusion.

For the count data second step, the negative binomial overdispersion parameter theta was found to be significant in all four models (Table 4). Preliminary analysis involving the dispersion parameter alpha also indicated the presence of overdispersion. Essentially, the presence of overdispersion indicates that the dependent variable number of trips taken is positively skewed since the majority of participants took a few trips while a small number of participants took a large number of trips. Since the overdispersion parameter was significant, the use of a negative binomial regression model was appropriate for all of the sample selection models. The parameter rho (ρ) was significant in all models indicating the appropriate use of the sample selection model (Table 4).

Wildlife Viewing Participation

Results modeling an individual's decision to participate in a wildlife viewing trip can be found in Table 3. All models indicate that age positively impacted participation while age squared was negative. These combined results indicate a quadratic relationship and show that an individual's likelihood of participation increased with age but decreased once an individual reached a certain age. Education was found to be a positive and significant factor. Individuals possessing some college education up to the completion of a bachelor's degree were found to have a higher probability of participation. In addition, white individuals were more likely to participate than those of other ethnicities. Household income was found to be a positive and significant factor as well. As a result, an individual's likelihood of participation increased as household income increased. A significant demographic variable that negatively impacted participation was urban residence. As a result, individuals who lived in rural areas were found to have a higher probability of participating than individuals who lived in urban areas.

The impacts of other forms of wildlife recreation were considered in the participation model as well. According to results from all four models, an individual who had ever fished in his or her lifetime was less likely to participate in a wildlife viewing trip than an individual who had never fished. Costs associated with hunting and fishing were considered in the models as well. Hunting and fishing costs were found to be positive and significant in all four models indicating that as hunting and fishing costs increased, the likelihood of an individual choosing to participate in a wildlife viewing trip increased. As a result, increasd hunting and fishing costs for an individual led to an increased probability of an individual becoming a wildlife viewing participant.

Table 3. Determinants of wildlife viewing participation estimated by a probit regression model.

	Reduced 0.25	Full 0.25	Reduced 0.50	Full 0.50
Variable	Coefficient	Coefficient	Coefficient	Coefficient
Constant	-3.231[a]	-3.193[a]	-3.219[a]	-3.189[a]
Age	0.051[a]	0.049[a]	0.051[a]	0.049[a]
Age squared	-0.001[a]	-0.001[a]	-0.001[a]	-0.001[a]
Household income	0.002[a]	0.002[a]	0.002[a]	0.002[a]
BA/BS degree	0.107[a]	0.102[a]	0.108[a]	0.103[a]
Race	0.526[a]	0.522[a]	0.523[a]	0.521[a]
Urban residence	-0.146[a]	-0.151[a]	-0.148[a]	-0.152[a]
Ever hunted	0.029	0.070[c]	0.015	0.063
Ever fished	-0.450[a]	-0.469[a]	-0.550[a]	-0.530[a]
Int Hunting costs	0.003[a]	0.001[a]	0.002[a]	0.001[a]
Int Fishing costs	0.013[a]	0.008[a]	0.012[a]	0.008[a]
Log-likelihood	-6289.40	-6162.90	-6281.27	-6165.46
$\chi 2$	2446.75	2699.75	2463.01	2694.63

a and c indicate significance at the 1% and 10% level respectively; n = 23,111

Wildlife Viewing Demand

Results modeling the number of wildlife viewing trips of at least one mile away from the home an individual made in 2006 can be found in Table 4. Similar to participation, age was a positive factor while age squared was a negative factor. Race was found to be a significant and positive factor for all models as white individuals were likely to take more trips than individuals of other ethnicities. A significant demographic variable found to negatively impact the number of wildlife viewing trips taken by a participant was urban residence. Household income was found to be a negative and insignificant factor affecting trip frequency.

Similar to participation, the impacts of other forms of wildlife recreation were considered in the wildlife viewing frequency models as well. The variable ever hunted was found to be positive and significant for all four models. As a result, an individual who had ever hunted in his or her lifetime was likely to take more wildlife viewing trips than an individual who had never hunted. Hunting costs were found to be negative but insignificant in all four models indicating the possibility of a weak complementary relationship between wildlife viewing and hunting. Fishing costs were positive and insignificant. The insignificance yet positive signs of the fishing costs variables indicate that fishing and wildlife viewing potentially are weak substitutes.

Trip costs associated with wildlife viewing, hunting, and fishing were included in the wildlife viewing demand models as well. In agreement with assumptions related to the travel cost method, wildlife viewing trip costs was a negative and significant factor that influenced the number of trips a participant took. As a result, participants were likely to take fewer wildlife viewing trips as trip costs associated with wildlife viewing increased.

Table 4. Determinants of wildlife viewing demand estimated by a sample selection model.

	Reduced 0.25	Full 0.25	Reduced 0.50	Full 0.50
Variable	Coefficient	Coefficient	Coefficient	Coefficient
Constant	-0.623	-0.800[b]	-0.576	-0.789[b]
Age	0.043[a]	0.044[a]	0.043[a]	0.044[a]
Age squared	-4.589E-04[a]	-4.575E-04[a]	-4.470E-04[a]	-4.548E-04[a]
Household income	-0.001	-0.001	-2.020E-04	-0.001
Race	0.269[c]	0.280[b]	0.259[c]	0.279[b]
Urban residence	-0.132[b]	-0.124[b]	-0.135[b]	-0.125[b]
Ever hunted	0.343[a]	0.345[a]	0.334[a]	0.348[a]
Ever fished	0.114	0.185[a]	0.108	0.176[b]
Int Hunting costs	-2.142E-04	-2.615E-04	-2.443E-04	-2.699E-04
Int Fishing costs	6.380E-04	3.646E-04	5.603E-04	3.703E-05
Trip Costs	-4.646E-03[a]	-1.366E-03[a]	-3.969E-03[a]	-1.353E-03[a]
Overdispersion (θ)	0.087[a]	0.074[a]	0.089[a]	0.073[a]
ρ	0.491[a]	0.498[a]	0.482[a]	0.495[a]
Log-likelihood	-12763.46	-12640.41	-12751.97	-12638.87
$\chi 2$	29802.58	29704.30	29855.92	29631.85

a , b, and c indicate significance at the 1%, 5%, and 10% level respectively; n = 2,311

Consumer Surplus

Consumer surplus estimates organized by trip cost and wage rate specification can be found in Table 5. Overall, individual per trip consumer surplus estimates ranged from $215.23 to $739.07. As expected, the most conservative per-trip consumer surplus estimate was found using the reduced costs and quarter wage rate specification. The model specification containing the most robust individual consumer surplus estimate involved the full costs and half wage rate specifications. According to the results, models that contained the full cost versions of the trip costs variables produced much larger consumer surplus estimates than models that contained the reduced cost versions of the trip costs variables. Compared to trip cost specification, wage rate specification did not have as a significant impact on consumer surplus estimates. Aggregate consumer surplus estimates ranged from $44.5 billion to $185.1 billion and followed the same patterns demonstrated by the consumer surplus individual per trip estimates.

Table 5. Wildlife viewing individual per trip and aggregate consumer surplus estimates.

Costs Specification	Wage Rate	Point estimate ($)	Std. deviation ($)	Aggregate Range ($ billions)
Reduced	Quarter	215.23	23.57	44.5 - 55.4
Reduced	Half	251.95	27.66	52.0 - 64.9
Full	Quarter	732.33	59.07	156.2 - 183.6
Full	Half	739.07	58.69	157.8 - 185.1

Discussion

As in previous studies, consumer surplus estimates were highly sensitive to assumptions related to categories to include in the trip costs variables as well as wage rate specification. Comparing to previous studies, consumer surplus estimates obtained by this research were fairly similar and moderately higher. Aggregate consumer surplus estimates obtained for the year 2006 ranged from $44.5 to $185.1 billion based on modeling assumptions involving costs and wage rate specifications. Adjusting for inflation and reflecting its findings in 2006 dollars, Zawacki et al. (2000) found aggregate consumer surplus estimates to range from $8.5 to $97.7 billion. In addition, Rockel and Kealy (1991) found aggregate consumer surplus estimates to range from $18.9 to $400 billion while Boyle et al. (1994) calculated an aggregate consumer surplus estimate of $19.6 billion.

Overall, since the value of wildlife viewing access seems to be increasing, policymakers potentially have an impetus to introduce legislation aimed at increasing funding and access for wildlife viewing on public lands. The examples of previously enacted aid programs such as the Pittman-Robertson Act, Dingell-Johnson Act, and Migratory Bird Conservation Act can be useful in implementing a federal program that specifically targets wildlife viewers and the preservation and restoration of wildlife viewing habitat (McKinney et al. 2005). Since wildlife viewing equipment expenditures totaled $9.9 billion in 2006, policymakers could consider placing federal excise taxes on equipment such as binoculars, cameras, and bird feed that can be used to fund wildlife viewing habitat preservation and restoration efforts (USDI 2006). In addition, policymakers could also consider the sale of wildlife viewing or non-consumptive stamps that can give buyers free admission to federal refuges and national parks.

Determinants of participation and trip frequency have potential implications for policymakers as well. Even though one should be cautious of applying national results to specific local areas, results from this research highlight some potential important trends. In an effort to promote recreational wildlife viewing, policymakers could consider incentives as well as educational programs aimed at increasing wildlife viewing awareness among young people in particular. Also, considering nationwide demographic trends involving rising minority and, in particular, Hispanic populations and a general increased movement of individuals from rural to urban areas, policymakers may consider the use of incentives as well as outreach programs aimed at increasing wildlife viewing awareness among those in the Hispanic population and those living in urban areas. Regarding demand, household income was found to be negative and significant. Though not intuitive, this result is similar to findings from Zawacki et al. (2000) and Rockel and Kealy (1991) who found negative or insignificant income coefficients.

Even though this research did not find significance involving the hunting price variable, land managers in particular may be interested in exploring increasing either hunting or wildlife viewing opportunities found on their land. If hunting and wildlife viewing are indeed complementary activities, increasing opportunities for one of the recreational activities would likely increase both the number of hunting and wildlife viewing trips a participant takes. In contrast to both Zawacki et al. (2000) and Rockel and Kealy (1991), this study found fishing costs to be positive but insignificant for the demand equation. If, however, wildlife viewing and fishing were substitutes, managers attempting to promote wildlife viewing could emphasize the potential low cost nature of wildlife viewing trips in attracting wildlife viewing trip takers.

The current research provides greater insight concerning aspects of wildlife viewing participation and demand. By using a sample selection estimation technique, possible concerns involving selection bias were alleviated. Even though the research possessed methodological concerns such as the specification of the costs variables, the study identified determinants of wildlife viewing participation and demand and identified also the possibility of the increasing value of wildlife viewing access.

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Vertical price linkage between timber and forest products prices in the South

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Abstract

Timber market and forest product market are linked and integrated through prices of their own. In this study, the presence of price transmission asymmetry is investigated for wood products sector in southern United States. Threshold cointegration and an asymmetric error correction model are employed to analyze the price dynamics between prices of standing timber, delivered timber and also two representative lumber prices. Cointegration tests confirm the integration and efficiency of timber market in the South. The estimated results of error correction model reveal that the asymmetric price transmissions exist only when price of the lumber board is linked with upstream prices. While generally, cumulative effects are symmetric. Moreover, if there is any adjustment path asymmetry, adjustment from positive deviations always requires longer time than that from negative deviations when lumber prices are set as driving forces. But asymmetric transmission is not a prevalent phenomenon in southern timber market.

Keywords: Asymmetric price transmission; Timber market; Engle-Granger two-step approach, Threshold cointegration; Asymmetric error correction

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1. Introduction

Price is considered to be the principal mechanism connecting the different market stages. A study by Yin and Caulfield with timber prices shows that real prices in timber market have become more volatile after early 1990s (2002).The controversial harvesting restrictions in Pacific Northwest, lumber trade dispute with Canada, damage on timber production caused by Hurricane Hugo and Katrina, as well as the demand shock brought by debt crisis have thrown more concern on the volatility. No matter a supply or demand shock occurs in any stage along the linkage, it would be vertically transmitted to other stages upward or downward in some measure.

Traditionally, economic theory has assumed that prices adjust rapidly to equate demand and supply (Brännlund 1991). However, symmetric price transmission is not a natural result of market dynamics. Recent literature provides evidence of asymmetric price transmission (APT) in agriculture, gasoline, and financial markets (Meyer and Cramon-Taubadel 2004), with the phenomenon occurring when downstream prices react in a different manner to upstream price changes, depending on the characteristics of upstream prices or changes in those prices. It brings the consequence that that a group is not benefiting from a price reduction (buyers), or increase (sellers) that would under conditions of symmetry have taken place sooner and / or have been of greater magnitude than observed (Meyer and Cramon-Taubadel 2004). In spite of one among the most fundamental questions, whether it exists in timber market of southern U.S. is still indistinct so far. If it is the case, quite a lot of previous public programs need to be revised accordingly.

Depending on the issue and study purpose, APT has been classified and analyzed in several ways. One typical classification is positive versus negative APT. If one price (e.g., price of petrol) reacts more fully or rapidly to an increase in another price (e.g., price of crude oil) than to a decrease, then the price transmission is referred to as positive asymmetry (Meyer and von Cramon-Taubadel 2004). More generally, with positive APT, price movement that squeezes the margin is transmitted more rapidly or completely than the equivalent movement that stretches the margin. Conversely, APT is negative when price movements that stretch the margin are transmitted more rapidly or completely. However, it is self-evident that this classification of APT would become inverse if assumed causality between variables changes. According to the conclusion drawn from former research, positive APT is more widespread in natural resource market than the contrary situation. In addition, APT can also be classified as vertical or spatial. A typical example of vertical APT is that consumers often feel increases in farm prices are more fully and rapidly transmitted to retail levels than equivalent decreases (Kinnucan and Forker 1987). And a spatial ATP could be seen when price of central market transmits differently to peripheral markets. When this classification is associated to this study, vertical APT among stages in southern timber market would be our concern.

Various sources of APT have been discussed in the literature (Frey and Manera 2007), one among them widely approved is downstream traders' market power: giant retailers try to maintain their "normal" profit margin when prices rise, but they try to capture the larger margins that arise, at least temporarily, when upstream prices fall (Ben-Kaabia 2007). Another cause of spatial APT often cited is the asymmetric flow of information between central and peripheral markets (Abdulai 2000). Prices at a central market, by virtue of its size and the fact that it is at the center or a network of information, may tend to be less responsive to price changes in individual peripheral market than vice versa. Other causes of APT include political intervention, inventory management (Meyer and Cramon-Taubadel 2004) and inflation (Ball and Mankiw 1994). In spite of potential causes of asymmetric price transmission, empirical analyses of this phenomenon typically do not allow differentiation among the different possible causes (Capps and Sherwell 2007).

The assumed causality that refers to the direction of price movements along the supply chain is another issue should be cared about. According to price determination theory, producer price changes determine retail price changes; that is price transmission flows downward along the supply chain and the direction of causality runs from upstream to downstream. However, the empirical results of studies applied to different commodities in different countries regarding this issue are mixed (Saghaian 2007). For example, Tiffin and Dawson (2000), studying the UK lamb market, found that lamb prices were determined in the retail market and then passed upward along the supply chain; that is, the direction of causality is from retail to producer prices. However, Ben-Kaabia, Gill, and Boshnjaku (2002) found both supply and demand shocks were fully passed through the marketing linkage, i.e., they found complete price transmission. So previous assumption toward causality direction is not necessary; upstream and downstream prices would both be set as dependent variable to one another at first, and significance of the causality assumption would be tested by econometric models.

Price transmission dynamics has been the subject of several papers in forest products sector across different areas, but generally speaking, previous studies of linkage between forest product and factor markets are rare (Hanninen, Toppinen et al. 2007). Early works emphasized the determinants of southern pine stumpage prices (Guttenberg and Fasick, 1965; Anderson, 1969; Guttenberg, 1970). Among these early studies with the issue of price transmission between stumpage price and forest products prices, Haynes (1977) linked regional stumpage and national sawnwood markets using the derived demand approach. Regionally, Luppold and Baumgras (1996) and Luppold et al. (1998) analyzed how price margins between stumpage and national sawnwood changed in Ohio, concluding that the shrinking market margin is a result of competitive market forces, and although stumpage and sawnwood prices follow each other, short-term deviation is still possible due to insufficient market information. Most recently, Zhou and Buongiorno (2005) conduct a research with the issue of price transmission between products at different stages of manufacturing in forest industries in the South from 1977 to 2002. All prices are found to be nonstationary, and there is no evidence of cointegration between prices. When price transmission is significant, the full adjustment takes about two years. Considering achievements got in this field so far, clearly, fresh research is needed in this field.

And therefore, the overall objective is to examine dynamics between upstream and downstream prices among three stages in forestry sector in southern US, and furthermore, to provide an understanding of market information efficiency and welfare distribution between timber suppliers, processors and consumers. Under the objective, three questions are involved: firstly, whether this phenomenon exists in forestry sector in the South; secondly, if it exists, what's its magnitude and direction; and finally, whether the deviation would return to equilibrium, and if yes, how long would it be required.

2. Methodology

2.1. Linear cointegration analysis

Upstream prices and downstream prices' properties of nonstationarity and order of integration can be assessed using the Augmented Dickey-Fuller (ADF) Test (Dickey and Fuller 1979). The original test was extended by Perron (1989) to overcome the problems associated with which deterministic components should enter DF test, by requiring adding lagged terms of the dependent variable to the test equation. If both the price series appear to have a unit root, then it is appropriate to conduct cointegration analysis to evaluate their interaction. Following testing procedure (Pfaff 2008), the ADF equation would be tested without neither constant nor trend. The null hypothesis is that the series are nonstationary in their levels. The nonstationary series are I(1) with the first differences being I(0).

The Johansen approach is a multivariate generalization of the Dickey-Fuller test (Johansen 1988; Johansen and Juselius 1990). The test is a procedure for testing cointegration of several I(1) time series. According to Johansen and Juselius, any p-dimensional vector autoregression can be written in the following models:

$$X_t = \pi_1 X_{t-1} + \cdots + \pi_K X_{t-K} + \varepsilon_t \quad (1a)$$

$$\Delta X_t = \sum_{i=1}^{K-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-K} + \varepsilon_t \quad (1b)$$

where X_t is a vector of price series of one pair of downstream price and upstream price, with K as the number of lags, and ε_t as the error term. While the connection between equation 1a and equation 1b is $\Gamma_i = -I + \sum_{j=1}^{i} \pi_i$ and $= -I + \sum_{k=1}^{K} \pi_k$, with I as an identity matrix.

To do the cointegration test, Two specific models would be adopted, one with trend, the other with constant. Johansen proposes two different likelihood ratio tests of the significance of these canonical correlations and thereby the reduced rank of the coefficient matrix Π in each model: the trace test and maximum eigenvalue test. The trace one tests the null hypothesis of r cointegrating vectors against the alternative hypothesis of n cointegrating vectors; on the other hand, the maximum eigenvalue one, tests the null hypothesis of r cointegrating vectors against the alternative hypothesis of r +1 cointegrating vectors. Given that the time series studied are I(1), according to the results of the ADF test we can use Johansen test to examine whether there is a linear relation among the variables which are stationary.

Another linear cointegration test, the Engle-Granger two-stage approach, practices on the residuals from the long-term equilibrium relationship (Engel and Granger 1987). During the first stage, long-run relationship between prices series would be estimated, and the price of upstream price is chosen to be placed on the right side as the driving force, which could be expressed as:

$$D = \alpha_0 + \alpha_1 U + \xi_t$$

or $U = \alpha_0 + \alpha_1 D + \xi_t$ (2)

where U and D represent upstream prices and downstream prices separately, α_0 and α_1 are coefficients, ξ_t is error term. In the next step, an augmented Dickey-Fuller test is adopted to check the residuals to see whether the price series of each equation are cointegrated with a unit root test (Engel and Granger 1987). There would be no serial correlation in the regression residuals with lags involved; Akaike Information Criterion (AIC) or Bayesian Information Criterion (BIC) could be used as rule for selection. Equation for step 2 could be in form of:

$$\Delta\hat{\xi}_t = \rho\Delta\hat{\xi}_{t-1} + \sum_{i=1}^{L} \phi_i \Delta\hat{\xi}_{t-i} + \mu_t \quad (3)$$

where ρ and ϕ_i are coefficients, $\hat{\xi}_t$ is the estimated residuals, Δ indicates the first difference, μ_t is a white noise disturbance term, and L is the number of lags. Five pairs of prices would be analyzed through this model. If the null hypothesis of $\rho = 0$ is rejected, then the residual series from the long-term equilibrium is stationary and that pair of upstream price and downstream price would be cointegrated with each other.

2.2. Threshold cointegration analysis

Linear cointegration analysis potentially implies a symmetric transmission progress; Enders and Granger (1998) argue that the Dickey Fuller test and its extensions are mis-specified if adjustment is asymmetric. And therefore, Enders and Siklos (2001) propose a two-regime threshold cointegration approach to entail asymmetric adjustment in cointegration analysis, among which TAR and MTAR are the most popular models.

$$\Delta\hat{\xi}_t = \rho_1 I_t \hat{\xi}_{t-1} + \rho_2(1 - I_t)\hat{\xi}_{t-1} + \sum_{i=1}^{L} \phi_i \Delta\hat{\xi}_{t-i} + \mu_t \quad (4)$$

I_t=1 if $\hat{\xi}_{t-1} \geq \tau$, 0 otherwise; or (5a)

I_t=1 if $\Delta\hat{\xi}_{t-1} \geq \tau$, 0 otherwise (5b)

where I_t is the Heaviside indicator, P the number of lags, ρ_1, ρ_2 and φ_i the coefficients, and τ the threshold value. The lag P is specified to account serially correlated residuals and it can be selected using AIC or BIC.

The Heaviside indicator I_t can be specified with two alternative definitions of the threshold variable, either the lagged residual ($\hat{\xi}_{t-1}$) or the change of the lagged residual ($\Delta\hat{\xi}_{t-1}$). Equations (4) and (5a) together are referred to as the Threshold Autoregression (TAR) model, and Equations (4) and (5b) are named as the Momentum Threshold Autoregression (MTAR) model. The TAR model is designed to capture potential asymmetric deep movements in the residuals (Enders and Granger 1998; Enders and Siklos 2001). The MTAR model is useful to take into account steep variations in the residuals; it is especially valuable when the adjustment is believed to exhibit more "momentum" in one direction than the other.

The threshold value τ can be specified as zero, given the regression deals with the residual series. However, Chan (1993) proposes a search method for obtaining a consistent estimate of the threshold value, which could offer stronger power with an estimated threshold. Given A total of four models are entertained in this study. They are TAR Equation with τ = 0; consistent TAR Equation with τ estimated; MTAR Equation with τ = 0; and consistent MTAR Equation with τ estimated. Since there is generally no presumption on which specification is used, it is recommended to choose the appropriate adjustment mechanism via model selection criteria of AIC and BIC (Enders and Siklos 2001). A model with the lowest AIC and BIC will be used for further analysis.

Insights into the asymmetric adjustments in the context of a long-term cointegration relation can be obtained with two tests. First, it is determined whether downstream price and upstream price are cointegrated in the TAR and MTAR models: an *F*-test is employed to examine the null hypothesis H_0: $\rho_1 = \rho_2 = 0$ against the alternative of cointegration with either TAR or MTAR threshold adjustment. Secondly, the asymmetric adjustment is tested when the null hypothesis above is rejected: a standard *F*-test would be adopted to evaluate the null hypothesis of symmetric adjustment in the long-term equilibrium (H_0: $\rho_1 = \rho_2$). Rejection of the null hypothesis indicates the existence of an asymmetric adjustment process.

2.3. Error correction model with threshold cointegration

The Granger representation theorem (Engel and Granger 1987) states that an error correction model can be estimated when all the variables have been proved to be cointegrated. Two extensions on the standard specification in the error correction model have been made for analyzing asymmetric price transmission. Granger and Lee (1989) first extend the specification to the case of asymmetric adjustments. Error correction terms and first differences on the variables are decomposed into positive and negative components. This allows detailed examinations on whether positive and negative price differences have asymmetric effects on the dynamic behavior of prices. The second extension follows the development of threshold cointegration (Engel and Granger 1987; Balke and Fomby 1997). When the presence of threshold cointegration is validated, the error correction terms are modified further.

The error correction models with threshold employed in this study could be expressed as:

$$\Delta D = \theta_D + \delta_D^+ E_{t-1}^+ + \delta_D^- E_{t-1}^- + \sum_{j=1}^{J} \alpha_{Dj}^+ \Delta D_{t-j}^+ + \sum_{j=1}^{J} \alpha_{Dj}^- \Delta D_{t-j}^- + \sum_{j=1}^{J} \beta_{Dj}^+ \Delta U_{t-j}^+ + \sum_{j=1}^{J} \beta_{Dj}^- \Delta U_{t-j}^- + \vartheta_{Dt} \quad (6a)$$

$$\Delta U = \theta_U + \delta_U^+ E_{t-1}^+ + \delta_U^- E_{t-1}^- + \sum_{j=1}^{J} \alpha_{Uj}^+ \Delta U_{t-j}^+ + \sum_{j=1}^{J} \alpha_{Uj}^- \Delta U_{t-j}^- + \sum_{j=1}^{J} \beta_{Uj}^+ \Delta D_{t-j}^+ + \sum_{j=1}^{J} \beta_{Uj}^- \Delta D_{t-j}^- + \vartheta_{Ut} \quad (6b)$$

where *ΔU* and *ΔD* are the upstream prices and downstream prices in first difference, *E* error correction terms, *θ, δ, α* and *β* coefficients, and ϑ error terms. The subscript $_U$ and $_D$ differentiate the coefficients by stages, *t* denotes time, and *j* represents lags. All the lagged price variables in the first difference are split into positive and negative components, as indicated by the superscripts $^+$ and $^-$. The maximum lag *J* is chosen with the AIC statistic so the residuals have no serial correlation. The two error correction terms are defined as $E_{t-1}^{+} = I_t\hat{\xi}_{t-1}$ and $E_{t-1}^{-} = (1 - I_t)\hat{\xi}_{t-1}$, which in turn are constructed from the threshold cointegration regressions in Equations (4) and (5).

Possible presence of asymmetric price behavior could be examined with simple inspection on the coefficients as a first insight. The signs for the driving variables should be positive; while the signs for price-takers are expected to be negative. Furthermore, three types of several single or joint hypotheses (Frey and Manera 2007) could be formed as following. The first type hypothesis would be two the Granger causality tests by employing F-tests: H_{01}: $\alpha_i^+ = \alpha_i^- = 0$ and H_{02}: $\beta_i^+ = \beta_i^- = 0$ for all lags i at the same time, so that the stage of price driver could be judged. The second type of hypothesis would be the cumulative symmetric effect as H_{03}: $\sum_{i=1}^{j}\alpha_i^+ = \sum_{i=1}^{j}\alpha_i^-$ and H_{04}: $\sum_{i=1}^{j}\beta_i^+ = \sum_{i=1}^{j}\beta_i^-$, which is a relatively long run test for asymmetry. And finally, the equilibrium adjustment path asymmetry would be tested with null hypothesis of H_{05}: $\delta^+ = \delta^-$, to examine whether it is possible to get back to equilibrium after a shock, and if it is the case, how long it will take.

3. Data and variables

In the upstream stage, stumpage and delivered timber prices are collected from Timber-Mart South from 1977 to 2009 by states. Because reporting frequency has changed from month to quarter since January 1988, the mean of each quarter before 1988 is used as quarterly observation, and therefore, the upstream prices are collected quarterly. Prices in 11 southern states are averaged to match data range of downstream prices. The prices of lumbers, lumber boards of Southern pine 1×4#3 (LA) and selects of Southern pine1×4 (LB), are obtained as downstream prices, from the Forest Products Market Price and Statistics Yearbook published by Rand Lengths during the same period. Although monthly data is available with Rand Lengths Yearbook, only mid-month data of each quarter are reported to gain consistency with stumpage and delivered timber prices. To summarize, the data frequency of this study is quarterly with all 11 states in the South as a whole.

4. Empirical results

4.1. Descriptive statistics and unit root test

The descriptive statistics of the four variables involved in this study are reported in Table 1. With upstream prices, delivered timber price is higher than stumpage price on each observation, and the gap between them is relatively stable. On the other hand, downstream prices, due to diverse sizes and qualities of different products, are not proper for direct comparison. The trend and fluctuation during the period of study could be observed in Figure 1; roughly speaking, the group of prices seems to change synchronously, with a generally upward tendency and an unstable development during the most two recent decades. Furthermore, covariances between variables have partly approved the initial thought: the one between stumpage price and delivered timber price is as high as 0.99; and covariances between upstream prices and price of LB are higher than those connecting with LA. Additionally, that between the two lumbers is 0.87.

Table 1 Descriptive statistics and unit root test results for the prices

Name	LA	LB	PD	PS
Definition	Lumber boards of Southern pine 1×4#3	Lumber selects of Southern pine1×6	Average delivered price of Southern pine sawtimber	Average standing price of Southern pine sawtimber
Mean	235.4	735.6	273.9	201.4
Std. Dev.	64.1	231.6	94.2	73.1
Minimum	134	342	120	80
Maximum	408	1147	439	344
ADF test	0.26 [6]	0.11 [9]	0.20 [11]	-0.37 [11]
1^{ST} Diff(Δ)	-5.22*** [6]	-3.48*** [9]	-2.24** [11]	-2.17** [11]

Notes: The critical values are 2.58 -1.95 -1.62 for ADF test at the 1%, 5%, and 10% levels, respectively (Enders, 2004). ** and *** denote significance at the 5% and 1% level, respectively. The numbers in the bracket are lags used in the test.

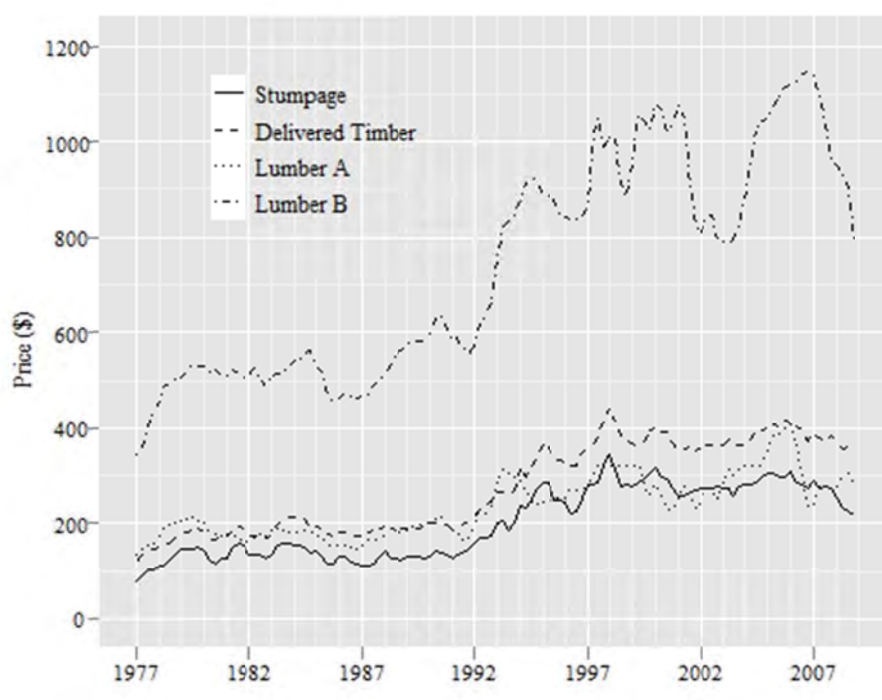

Fig. 1. Quarterly prices of timber and forest products in the South (1q. 1977 – 4q. 2009).

As mentioned above, the ADF test is employed to examine nonstationarity of the four prices. The lag length for ADF test is determined by the AIC statistic and Ljung-Box Q test. The procedures proposed by Enders (2004) are followed to perform the regression. As reported in Table 1, the statistics reveal that unit roots cannot be rejected at the 10% level for all the four prices but all can be rejected at the 1% level for the first difference form. Thus, it could be concluded that stumpage price, delivered timber price and the two selected lumber prices in southern timber market are integrated of order one.

4.2. Results of linear cointegration analysis

Cointegration could be investigated among each pair of upstream and downstream variables; moreover, although delivered timber price is an upstream price when it is matched with lumber prices, it turns to be a downstream price when it is compared with stumpage price. So finally, five pairs of prices (LA~PD, LB~PD, LA~PS, LB~PS, PD~PS) would be under price transmission analysis in this study. To begin with, the linear cointegration between the five pairs of prices could be conducted by both Johansen test and Engle-Granger two-step approach.

Firstly, cointegration between pairs of prices would be determined by Johansen test. Two specific models with two tests respectively would be involved as mentioned in methodology section. Lag length for all the four test types is three, based on lowest AIC and BIC. As reported in Table 2, conclusions drawn from each test are quite different from one another: although none of the null hypothesis of one cointegration could be rejected by either maximum eigenvalue or trace statistics, only one null hypothesis of on cointegration could be rejected at 10% significance level when there is a trend in the model, implying only stumpage price and delivered timber price out of the five pairs are cointegrated if only this model is taken into consideration. Nevertheless, both null hypotheses could be rejected when pairs of prices include the price of LA with the Johansen approach model with a constant. However, pairs of prices with LB could not be proved to be cointegrated with upstream prices with this test, maybe due to the price gap between LB and other wood products, and also to the linear and symmetric transmission hypothesis rooted in the model per se.

Table 2 Results of the Johansen cointegration tests on the prices

Pairs of Prices	Johansen λ_{max}				Johansen λ_{trace}			
	Trend		Constant		Trend		Constant	
LA~PD	r = 1	3.52	r = 1	3.32	r = 1	3.52	r = 1	3.32
	r = 0	15.77	r = 0	15.99**	r = 0	19.29	r = 0	19.31*
LB~PD	r = 1	2.93	r = 1	2.90	r = 1	2.93	r = 1	2.90
	r = 0	10.09	r = 0	9.33	r = 0	13.02	r = 0	12.24
LA~PS	r = 1	3.10	r = 1	3.09	r = 1	3.10	r = 1	3.09
	r = 0	16.71	r = 0	16.01**	r = 0	19.81	r = 0	19.10*
LB~PS	r = 1	3.04	r = 1	2.71	r = 1	3.04	r = 1	2.71
	r = 0	10.40	r = 0	10.31	r = 0	13.44	r = 0	13.02
PD~PS	r = 1	2.83	r = 1	2.98	r = 1	2.83	r = 1	2.98
	r = 0	26.01***	r = 0	9.44	r = 0	28.84**	r = 0	12.43

Note: r is the number of cointegrating vectors. *, **, and *** denote significance at the 10%, 5% and 1% level, respectively. The critical values are from Enders (2004).

As the second linear cointegration test, the implement of Engle-Granger approach involves two steps. The first step is a long-term relationship regression between upstream price and downstream price, with specification as Equation (2); without prior information of market drive, either upstream or downstream price could be independent variable. And the second step would be a unit root test conducted on the residual obtained from step one, as specified in Equation (3). Two to seven are proved to be the proper lag lengths for conducting the tests respectively indicated by AIC and Ljung-Box Q. The statistic results are described in Table 3, except the pair of stumpage price and delivered timber price, null hypotheses of no cointegration could all be rejected at least with 5% significance level.

4.3. Results of the threshold cointegration analysis

As explained in the methodology part, four threshold autoregression models, TAR, MTAR, and their consistent specifications are planned to conduct the nonlinear cointegration

Table 3 Results of the Engle-Granger tests

Pairs of Prices	ρ (t-value)		AIC	BIC	Q_{LB} (4)	Q_{LB} (8)	Q_{LB} (12)
LA~PD	-0.242***	(-4.962)	1005.322	1019.582	0.9931	0.9094	0.9312
PD~LA	-0.182***	(-4.096)	1087.792	1102.052	0.9963	0.8014	0.7429
LB~PD	-0.345***	(-4.861)	1199.430	1225.098	0.9893	0.999	0.9952
PD~LB	-0.215***	(-3.630)	1027.817	1042.077	0.9285	0.3243	0.2167
LA~PS	-0.262***	(-4.971)	1028.159	1042.419	0.6063	0.5054	0.605
PS~LA	-0.183**	(-3.276)	1034.589	1054.553	0.8523	0.7934	0.6905
LB~PS	-0.201**	(-3.044)	1256.774	1276.738	0.767	0.1618	0.1924
PS~LB	-0.192**	(-2.924)	978.4	998.3643	0.7644	0.1935	0.2915
PD~PS	-0.089	(-0.924)	907.5305	930.3467	0.968	0.9025	0.2779
PS~PD	-0.182*	(-2.327)	871.2878	882.6959	0.7645	0.78	0.1406

Note: ρ refers to ρ in Equation (3); *, ** and *** denote significance at the 10%, 5% and 1% level. The critical values are from Enders (2004).

analysis; procedure by Chan is followed to estimate the threshold. When appropriate lag length is being chosen to address the serial correction in residual series, AIC, BIC and Ljung-Box *Q* statistics are selected to perform as rules of thumb. Under first estimation of the four models, lower AIC and BIC could be acquired when the model are consistent, which is a symbol of better performance, so only statistics of consistent TAR and MTAR are reported in Table 4, with threshold τ, estimation of ρ_1 and ρ_2, as well as two null hypotheses. Furthermore, the consistent MTAR seem to be better performed than consistent TAR.

Table 4 Results of threshold cointegration tests

	Method	Threshold	ρ_1	ρ_2	Φ (H_0: $\rho_1 = \rho_2 = 0$)	F (H_0: $\rho_1 = \rho_2$)
LA~PD	TAR	-26.014	-0.191***	-0.387***	15.343***	5.205**
	MTAR	9	0.023	-0.302***	19.01***	11.29***
PD~LA	TAR	32.571	-0.209***	-0.155***	8.6***	0.495
	MTAR	-22.908	-0.238***	0.137	16.036***	13.542***
LB~PD	TAR	44.164	-0.404***	-0.277***	12.819***	1.832
	MTAR	3	-0.254***	0.463***	14.464***	4.548**
PD~LB	TAR	-16.655	-0.226***	-0.375***	9.754***	2.342
	MTAR	5.885	-0.362***	0.249***	9.12***	1.242
LA~PS	TAR	-25.087	-0.17**	-0.37***	7.415***	4.828**
	MTAR	10	0.002	-0.331***	13.063***	15.241***
PS~LA	TAR	-18.642	-0.174**	-0.111	3.518**	0.545
	MTAR	-12.916	-0.199***	0.132	8.783***	10.505***
LB~PS	TAR	33.501	-0.273***	-0.242***	7.407***	0.108
	MTAR	-31.022	-0.263***	-0.257***	7.347***	0.003
PS~LB	TAR	10.147	-0.185**	-0.268***	5.878***	0.755
	MTAR	10.803	-0.069	-0.262***	7.049***	2.889*
PD~PS	TAR	6.326	-0.146*	-0.265***	5.795***	0.907
	MTAR	2	-0.107	-0.325***	6.917***	3.055*
PS~PD	TAR	-5.475	-0.279***	-0.152*	6.303***	1.027
	MTAR	-1.7	-0.106	-0.207**	7.426***	3.188*

Note: *, **, and *** denote significance at the 10%, 5% and 1% level, respectively. The critical values are from Enders (2004).

When cointegrations are investigated with these nonlinear models, all relationships between upstream prices and downstream prices have been testified to be cointegrated at 5% level regardless of transmission direction. Even two pairs have not proved to be cointegrated very well with former tests are included, verifying the conclusion that Enders and Granger model with threshold fits data better, particularly when asymmetric transmission possibly exists.

Moreover, asymmetric price transmission has been proved to be the result at least on one lumber price with consistent MTAR model: from the statistics generated by F-test, most significant asymmetric transmission appear in the two pairs of prices including LA, especially upstream prices are set as driving force. Yet the asymmetry is not quite severe, if there is any, when the other three pairs without LA are taken into consideration. Specifically, point estimate have demonstrated that positive deviation converges more slowly from long-term equilibrium than negative deviations, when LA is a dependent variable in the model. For example, when price transmission is estimated by consistent TAR model from delivered timber price to LA price, positive deviations resulting from increases in the LA price or decreases in the delivered timber price are eliminated at 19.1% per quarter; negative deviations from the long-term equilibrium resulting from decrease in the LA price or increases in the delivered timber price are eliminated at a rate of 38.7% per quarter, twice as fast as that of the positive deviation. In other words, positive deviations take about more than fifteen months (1/19.1% = 5.24 quarters) to be fully digested while negative deviations take less than eight months only. Almost all other significant point estimates have shown positive asymmetry on price transmission when lumber prices are set as dependent variable.

4.4. Results of error correction model

Given the consistent MTAR model is the best among these from the threshold cointegration analyses, the error correction terms are constructed using Equations (4) and (5b). The asymmetric error correction model with threshold cointegration is estimated, with three to seven lags selected by AIC, BIC and Ljung-Box *Q* statistics with each model respectively. Key statistics are reported in Table 5, including null hypothesis of Granger causality tests, cumulative asymmetric effects, as well as symmetric momentum equilibrium adjustment path.

The hypotheses of Granger causality between the prices are assessed with *F*-tests. Generally speaking, causality interactions between stumpage prices, delivered timber prices and lumber prices are not as strong as that between stumpage price and delivered timber price. Specifically, although most prices have strong impact on themselves' evolution, only three out of five pairs of prices are proved to have brought price fluctuation to the corresponding price. Among the three pairs, causality between delivered timber price and price of LB, as well as between stumpage price and delivered timber price seem to be bidirectional, in other words, change of either price significantly causes change of the other one. But the causality between stumpage price and price of LA seem to exist only when downstream price is transmitted to upstream price. That is to say, the price of LA evolves more independently or it is driven by factors other than upstream prices; while the price of stumpage price has been dependent on price of LA.

Furthermore, the cumulative asymmetric effects are also examined. Little evidence of asymmetric cumulative effect has been found neither upward nor downward. Except that when the transmission is between stumpage price and delivered timber price: null hypothesis of symmetric cumulative effect could be rejected at 10% level when delivered timber price is transmitted to stumpage price, which is not extremely significant.

Table 5 Results of the asymmetric error correction model with threshold cointegration

Pairs of Prices		δ^+	δ^-	H_1	H_2	H_3	H_4	H_5
1	PD	-0.097	0.089*	1.811†	0.641	0.990	0.838	3.268*
	LA	0.085	-0.250***	0.495	13.151***	2.223†	0.269	8.223***
	LA	0.187***	-0.177**	9.034***	1.143	3.990**	1.091	15.726***
	PD	-0.113***	0.014	1.313	2.377**	2.477†	2.897*	2.591†
2	PD	0.007	0.047*	1.442	1.134	0.157	0.043	1.260
	LB	-0.224***	-0.127*	1.977*	14.372***	0.235	1.591	1.345
	LB	0.575***	0.588***	9.835***	1.714*	3.645*	0.342	0.003
	PD	-0.097	-0.093	1.981**	1.619*	0.000	0.251	0.001
3	PS	-0.023	0.140**	4.363***	0.429	2.745†	0.535	4.728**
	LA	-0.059	-0.335***	2.095**	7.505***	0	0.018	8.698***
	LA	0.189***	-0.102	6.200***	1.833*	1.914	1.594	7.607***
	PS	-0.154***	-0.033	0.549	5.072***	2.490†	6.424**	2.302†
4	PS	0.034	0.013	2.310**	1.071	0.154	1.198	0.414
	LB	-0.084†	-0.213***	1.450	12.779***	1.082	4.521**	3.220*
	LB	0.644**	0.368***	10.048***	1.153	4.451**	0.295	0.987
	PS	0.058	-0.097†	0.898	2.676***	0.049	0.980	1.650
5	PS	-0.093	0.070	3.247***	3.653***	2.909*	0.416	0.087
	PD	0.006	-0.098	1.792*	1.818**	3.308*	0.926	0.423
	PD	0.117	-0.012	1.823**	1.708*	0.905	3.163*	0.396
	PS	-0.137	0.118	3.659***	3.266***	0.384	3.015*	1.322

Note: §, *, **, and *** denote significance at the15%, 10%, 5% and 1% level, respectively. H_{01} and H_{02}, $\alpha_i^+ = \alpha_i^- =0$ and $\beta_i^+ = \beta_i^- =0$ for all lags respectively, which are Granger causality tests. H_{03} and H_{04} assess the cumulative asymmetric effect: $\sum_{i=1}^{J}\alpha_i^+ = \sum_{i=1}^{J}\alpha_i^-$ and $\sum_{i=1}^{J}\beta_i^+ = \sum_{i=1}^{J}\beta_i^-$. H_{05} is about equilibrium adjustment path asymmetric effect $\delta^+ = \delta^-$.

The final type of asymmetry examined is the momentum equilibrium adjustment path asymmetries. Two pairs with the price of LA have shown this type of asymmetric price transmission with consistent MTAR model, which is a similar conclusion drawn from nonlinear cointegration analysis. For instance, when the transmission from delivered timber price to lumber board's price is investigated, the point estimates of the coefficients for the error correction terms are -0.097 for positive error correction term and 0.089 for the negative one for delivered timber price: the first sign is wrong while it is not significantly different from zero; the second coefficient is only significant at 10% level. It implies that in the short term the delivered timber price has some different responding speed to positive and negative deviations but the difference is weak. However, for price of LA, coefficient from negative deviation is -0.25, which is significant at 1% level while the coefficient from positive deviation is not significant at all, demonstrating that the price of LA responds to shock bringing negative deviation much faster, which takes about one year to fully digest, than the one in opposite direction. On the other hand, when lumber price is set as the driving force, positive deviation seems to be digested more quickly; actually, this is the coin's other side of the last results. This is also what happens between stumpage price and price of LA. However, generally speaking, momentum equilibrium adjustment path asymmetry is not true when other three pairs are mentioned.

5. Conclusion

Pine timber market plays a significant role among industries in the South, and is also an essential component of national timber market. And therefore, its mechanism, especially price transmission dynamics, should be under thorough investigation, to make timberland investment less risky and more attractive. Thus, the present paper aims to survey integrity and causality between different stages of forest products and examine possible existence of asymmetry in vertical price transmission mechanism in southern timber market of the US.

Three main conclusions could be drawn from the analyses among stumpage price, delivered timber price as well as two lumber prices. Firstly, although Johansen test could not arrive at the conclusion of cointegration between prices of different stages, Engle-Granger two-step approach shows much higher significance on market cointegration particularly with a threshold in the model. The conclusion suggests that generally speaking, southern timber market is efficient and could achieve equilibrium among vertical stages in long term even after shocks. This conclusion is different from that drawn from Zhou and Buongiorno's paper (2005), which may be due to the fact that dimension of upstream price and downstream price in that paper are not chosen to be compatible.

Secondly, when Granger causality tests are employed to examine timber market in the South, causation does not appear to be a prevailing phenomenon among prices of different stages. Unidirectional causation only exists in one out of five pairs of prices: from price of LA upward to stumpage price; two pairs seem to be causes of price fluctuation to one another; nevertheless, price of the left two pairs tend to evolve independently. It implies that the power on price change is not solely downward, sometimes lumber prices have strong influence on the prices of upstream prices, confirming the assumption at the very beginning; while on the other hand, some prices of forest products are independent, or more reasonably, are more liable to be impacted by exogenous variables rather than upstream / downstream prices, such like forestry policy, forestry programs, international trade, etc. This is consistent with one of assumptions claiming "timber demand is subject to exogenous i.i.d. shocks" in a paper discussing dynamic behavior of efficient timber market (Mcgough, Plantinga et al. 2004). However, Mohanty et al. (1996) argued that Granger causality focuses on short run dynamics rather than long run equilibrium relationships, and when long period of forest cultivation is added, this conclusion should not be overstated.

Last but not least, both consistent threshold autoregression model and error correction model confirmed asymmetric price transmission when price of LA is set as dependent variable: adjustment from positive deviations, i.e., increases in the LA price or decreases in upstream prices, always requires longer time than that from negative deviations. That is also to say, prices of forest products among vertical linkage are more sensitive and act more swiftly when the price margin is squeezed than stretched, price of the selected board being mentioned. But it is not the case when other three transmission relationships are under examination. As a result, whether price transmission is symmetric or not depends on the specific products; while at least it is symmetric when price is transmitted between the first two stages: from stumpage price to delivered timber price and backward. And when asymmetry comes to existence, lumber manufacturers are the benefit takers. It is sensible to deduce that market power in this stage along the chain would be an explanation.

On one hand, with the probable expanding demand on lumber consumption in the long run and the relatively stable supply in timber market, international trade may play even a more important role in the approaching future. Vertical market linkage might be altered and lumber prices would be cointegrated with import prices instead of upstream prices. The conclusions drawn from this study may be a hint of this tendency. On the other hand, enormous lumber producers have power over small mills as well as small industry and private timberland owners. The power may influence not only on the margin between stages, but also on the change of margin when there are shocks in timber market, causing more economic loss to the price-takers.

It becomes to be a much more important issue when the recent debt crisis knocked housing market severely, and left loss distribution in timber market a big problem. And therefore, forestry policy and programs are required to improve welfare of small-mill and small-tract owners in this intensely competitive market, moreover, to maintain and even attract investors in forestry sector.

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Welfare implications of tax driven industrial timberland ownership change on U.S. timber markets

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Abstract

In the last two decades, many firms in the U.S. forest products industry have either divested their timberlands to timber investment management organizations (TIMOs) and conservation organizations or converted their corporate structures from C corporations to real estate investment trusts (REITs). All landowners sold smaller timberland tracts for nonforestry uses. Reduced timber supplies from conservation organizations and timberland loss to other nonforestry uses were believed to have consequences on the welfare (i.e. economic surplus) shares of producers and consumers in the U.S. timber markets. This issue has not been adequately addressed in existing literature. Equilibrium displacement models were employed to address welfare implications in U.S. timber markets attributed to timberland ownership changes. Due to the net reduction of timber supply, total social welfare decreased by $43 million in 2006. Compared to over $33 billion U.S. timber markets, this welfare reduction was quite small. This study thus helps justify timberland divestiture decisions of industrial timberland owners, and understand the shifts of welfare share among producers and consumers when timberlands change hands.

Keywords: Divestiture; EDM; REITs; surplus; TIMOs

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Introduction

Since the late 1980s and early 1990s, there has been an unprecedented change of industrial timberland ownership in the United States. Primary sellers were industrial corporate (IC) landowners (traditionally known as vertically integrated forest products firms) and the largest identifiable group of buyers was timber investment management organizations (TIMOs). Both buyers and sellers of timberlands had grounds for selling and buying timberlands. Primary factors for selling timberlands include poor shareholder returns, debt reduction through the sale of timberland assets, increased tax efficiency through the movement to more efficient tax structures such as real estate investment trusts (REITs), and decreased insurance values of internal timber supplies attributed to mature timber markets (Hickman 2007; Rogers and Munn 2003; Yin et al. 1998). The reasons for buying timberlands by TIMOs and other private organizations were favorable returns and low risk, and timberland values, apparent correlation with inflation thus providing a 'hedge' against inflation (Clutter et al. 2007). Since timberland investments were attractive to nonindustrial corporate (NIC) landowners (i.e., REITs, TIMOs), their investment in timberland increased considerably over this period. Investment in timberland by institutional investors in the U.S. has grown from just under \$1 billion in 1985 to \$4 billion in 1995, \$12 billion in 2003 (Li and Zhang 2007) and \$15 billion in 2005 (Clutter et al. 2007).

There is one major difference between IC timberland owners and TIMOs/REITs with regard to tax treatment of timberlands and timber. IC timberland owners are usually classified as Sub-chapter C corporations, and any profits obtained from timber sale are taxed twice – once at the corporate level (usually 35%), and once at the stockholder level when dividends are disbursed (usually 15%). The practical effect of this tax policy is that shareholders of IC landowners can recoup as little as 50% out of every dollar of profit made from a timber sale. In contrast, shareholders of NIC landowners can normally retain about 85% of the profit from timber sales with a 15% tax rate (Block and Sample 2001; Clutter et al. 2007; Hagan et al. 2005; Siegel 2004). As a result, income taxation law has become one of the major driving forces behind timberland sales since the late 1980s and early 1990s. Presumably, this shift in timberland ownership has considerable consequences on stakeholder welfare (i.e., producer and consumer surplus) in U.S. timber markets. Previously, one perceived benefit of owning timberland for a forest products firms was guaranteed timber supplies for their mills. Nonetheless, from the perspective of NIPF landowners, there has been wide concern that internal timber supplies by forest products firms may have negative impacts on timber markets and NIPF landowner welfare (Murray 1995).

Past studies analyzed various issues related to taxation laws (Daughtrey et al. 1987; Sun 2007). For example, Boyd and Daniels (1985a) applied a General Equilibrium Model (GEM) to examine income taxation in forestry. Welfare losses generated by preferential capital gains treatment of timber were much greater than previously imagined. Federal taxation laws applicable to IC timberland owners were one of the major forces pushing them to divest their timberlands. About 37 million acres of timberland was sold between 1981 and 2005. Of this, 15 million acres were sold to TIMOs, 10 million acres to conservation groups, 10 million acres to publicly traded REITs and master limited partnerships (MLPs), and 2 million acres to private forest product companies (Boyd 2006; Hickman 2007).

Large-scale timberland ownership change gave rise to a net reduction in the timber production base. Conservation groups purchased a considerable acreage of timberland and their main objective was environmental conservation rather than timber production. Reduced management intensity for timber production on these lands would reduce timber supply. Also, all timberland owners, including industrial owners and TIMOs, sold tracts that had higher values in other uses such as urban development. These tracts were converted to higher and better uses (HBUs) like house building or urban sprawling. Most lands used for rapidly increasing urban sprawl came from forest land (LaGro and DeGloria 1992). One of the major non-forestry conversions of timberland is real estate development which captured higher land prices (Zinkhan 1993). Thus, the U.S. timber markets suffered a two-way timber supply reduction: (1) reductions to the timberland base through conversion of timberland to HBUs and (2) a reduced supply from land acquired by conservation agencies. This study was designed to address the extent of timber market equilibrium displacement (i.e., displacement of timber price and quantity supplied) and to evaluate its subsequent impact on the welfare shares of producers and consumers in the U.S. timber markets.

Methods

To address the above research issues, an equilibrium displacement model (EDM) was used. EDMs have been widely used to estimate the displacement of market equilibrium caused by external shocks such as adoption of a new policy or imposition of environmental regulations on forest resource use. Displacements of price and quantity as measured by EDMs can be used to estimate the welfare changes for consumers and producers in the market. Thus, EDMs are hailed as a powerful methodology for welfare analysis. Several studies (Boyd and Daniels 1985b; Brown and Zhang 2005; Sun 2006; Sun and Kinnucan 2001) were carried out using EDMs to determine impacts of law and policy shocks on timber markets.

Conceptual Model

Following Brown and Zhang (2005), Sun and Kinnucn (2001), and Sun (2006), the total timber market has been modeled with the following system of equations:

[1]	Timber supply by IC owners	$Q_i = f(P, L_i)$
[2]	Timber supply by NIPF landowners	$Q_n = g(P, L_n)$
[3]	Timber supply by NIC and other owners	$Q_r = h(P, L_r)$
[4]	Aggregate timber supply	$Q_s = Q_i + Q_n + Q_r + Q_g$
[5]	Aggregate timber demand	$Q_d = k(P)$
[6]	Market clearance	$Q_d = Q_s$

where P is the timber price; L_i, L_r, L_n are respectively the acreage of timberland owned by IC timberland owners, NIC timberland owners and NIPF and other private landowners; and Q_g is the supply of timber by public ownership. The model has four exogenous variables L_i, L_n, L_r, and Q_g and six endogenous variables Q_i, Q_n, Q_r, Q_s, Q_d, and P.

The model is constructed based on following assumptions: (i) timber supply by public ownership is constant over the study period; (ii) timber supply shift is upward and parallel; (iii) supply shift is caused by two different factors - conversion of timberlands to HBUs, and less intensive timber management by conservation groups; (iv) timberlands converted to HBUs constitutes a small percentage of total timberland base; (v) timberland management regimes under corporate industrial owners and REIT and TIMO ownerships were similar; (vi) there is no demand shock over the study period; (vii) timber market is competitive and a common timber price prevails in a certain regional market; (viii) timber economy is closed, i.e., it does neither import nor export timber; and (ix) there is a direct linear relationship between the size of the landbase, and inventory and timber supply although this may only be true in the short run. Assumption (ix) enables using inventory elasticities in this study and deducing following relationship between timberland base (L) and corresponding timber inventory (I) for owners $m\,(=i,n,r,g)$.

$$L_m = tI_m$$

$$dL_m = tdI_m$$

The equation system [1] through [6] can be totally differentiated as follows.

[1a] $\tilde{Q}_i = \varepsilon_i \tilde{P} + \xi_i \tilde{L}_i$

[2a] $\tilde{Q}_n = \varepsilon_n \tilde{P} + \xi_n \tilde{L}_n$

[3a] $\tilde{Q}_r = \varepsilon_r \tilde{P} + \xi_r \tilde{L}_r$

[4a] $\tilde{Q}_s = \lambda_i \tilde{Q}_i + \lambda_n \tilde{Q}_n + \lambda_r \tilde{Q}_r + \lambda_g \tilde{Q}_g$

[5a] $\tilde{Q}_d = \eta \tilde{P}$

[6a] $\tilde{Q}_d = \tilde{Q}_s$

The variables with tildes indicate percentage changes in those variables. For example, $\tilde{L}_i$ equals the remaining industrial timberland acreage after divestiture minus the original timberland acreage before divestiture divided by the timberland before divestiture. The symbols ε's, ξ's, and η are supply, inventory and demand elasticities, respectively, and λ_m 's are timber supply shares for each owner compared to the total market supply.

There is an implicit relationship among owner landbases; total timberland is the sum of all timberland and the parcels that were converted by all owners to higher and better non-forestry uses (L_{HBU}). These parcels went out of timber production. Thus the relationship can be expressed as, $L = L_i + L_n + L_r + L_g + L_{HBU}$ which on total differentiation, gives,

$$\tilde{L} = \tilde{L}_i l_i + \tilde{L}_n l_n + \tilde{L}_r l_r + \tilde{L}_g l_g + \tilde{L}_{HBU} l_{HBU}$$

where, l_m 's are the land shares of each owners with reference to the total timberland of all owners. Compared to the total timberland in the U.S., L_{HBU} was small and it was assumed that $l_{HBU} = 0$. Even though substantial acreage changed ownership, the total timberland area remained almost constant over time which implied that, $\tilde{L} = 0$. According to Smith et al. (2010), the balance between public and private timberland has not changed since 1953. This suggests that private timberland ownership change remained confined within the purview of private owners and the public timberland base remained constant over this period, i.e. $\tilde{L}_g = 0$. Thus the above expression reduces to,

$$\tilde{L}_i l_i + \tilde{L}_n l_n + \tilde{L}_r l_r = 0$$

$$\tilde{L}_r = -\frac{\tilde{L}_i l_i + \tilde{L}_n l_n}{l_r}$$

Again, since timber supply from public forest land is not affected either by market forces or by the timber tax policy, $\tilde{Q}_g = 0$. Given these, and substituting equations [1a], [2a] and [3a] into [4a],

[7] $$\tilde{Q}_s = \lambda_i \varepsilon_i \tilde{P} + \lambda_i \xi_i \tilde{L}_i + \lambda_n \varepsilon_n \tilde{P} + \lambda_n \xi_n \tilde{L}_n + \lambda_r \varepsilon_r \tilde{P} + \lambda_r \xi_r \left(-\frac{\tilde{L}_i l_i + \tilde{L}_n l_n}{l_r} \right)$$

Substituting equations [7] and [5[a]] into [6[a]], and solving for $\tilde{P}$ yield equation [8].

[8] $$\tilde{P} = \frac{\lambda_i \xi_i \tilde{L}_i + \lambda_n \xi_n \tilde{L}_n - \lambda_r \xi_r \left(\frac{\tilde{L}_i l_i + \tilde{L}_n l_n}{l_r} \right)}{\eta - \lambda_i \varepsilon_i - \lambda_n \varepsilon_n - \lambda_r \varepsilon_r}$$

Substituting [8] into [5[a]] and solving for $\tilde{Q}$,

[9] $$\tilde{Q} = \eta \times \frac{\lambda_i \xi_i \tilde{L}_i + \lambda_n \xi_n \tilde{L}_n - \lambda_r \xi_r \left(\frac{\tilde{L}_i l_i + \tilde{L}_n l_n}{l_r} \right)}{\eta - \lambda_i \varepsilon_i - \lambda_n \varepsilon_n - \lambda_r \varepsilon_r}$$

Equations [8] and [9] are the reduced forms for percentage changes in timber price and equilibrium quantity in the market expressed in terms of elasticity parameters and timberland ownership changes.

To measure the welfare changes for landowners, vertical shift of price in supply is needed. Vertical shift of price in supply is equivalent to a percentage change in price holding the supply constant (i.e., $V_s = \tilde{P}\,|_{\tilde{Q}_s = 0}$). As measured by Sun and Kinnucn (2001), vertical shift in supply was calculated with equation [10].

[10] $$V_s = -\frac{\lambda_i \xi_i \tilde{L}_i + \lambda_n \xi_n \tilde{L}_n - \lambda_r \xi_r \left(\frac{\tilde{L}_i l_i + \tilde{L}_n l_n}{l_r} \right)}{\lambda_i \varepsilon_i + \lambda_n \varepsilon_n + \lambda_r \varepsilon_r}$$

Again, following Sun and Kinnucn (2001) and Brown and Zhang (2005), welfare changes due to supply shifts were calculated using equations [11] through [15].

[11] $$\Delta PS_i = P^0 Q_i^0 (1 + \frac{1}{2}\tilde{Q}_i)(\tilde{P} - V_s)$$

[12] $$\Delta PS_r = P^0 Q_r^0 (1 + \frac{1}{2}\tilde{Q}_r)(\tilde{P} + V_s)$$

[13] $$\Delta PS_n = P^0 Q_n^0 (1 + \frac{1}{2}\tilde{Q}_n)(\tilde{P} - V_s)$$ [Following equation 11]

[14] $$\Delta PS_G = (P^a - P^0) Q_G^0$$

[15] $$\Delta CS = -P^0 Q^0 \tilde{P} (1 + \frac{1}{2}\tilde{Q})$$

U.S. average timber prices and timber supplies in 2006 were used in this study. Displacements of timber prices in softwood and hardwood markets were calculated using equation [8]. Similarly, the overall displacements of equilibrium quantity of hardwood and softwood supply were calculated using equation [9]. Utilizing parameter values reported in Table 2 in equations [11], [12], [13], and [15], welfare changes (i.e., producer and consumer surplus changes) were calculated, respectively, for IC, NIC, NIPF landowners, government, and consumers in softwood and hardwood markets of the U.S. Welfare changes were estimated based on average annual and total size of timberland ownership change from 1987 through 2006.

Welfare changes were estimated based on annual and total ownership changes and are reported in Table 4.

Sensitivity analysis

Since elasticity parameters used in this study were calculated or assumed based on existing literature and timber prices used were not zone-specific, a sensitivity analysis for the elasticities and timber prices was necessary to examine the extents of possible welfare changes for landowners, consumers, and society. There are several ways to perform sensitivity analysis on stochastic parameters. Sun and Kinnucan (2001) carried out a stochastic simulation to place 95% confidence intervals around mean welfare loss borne by southern landowners due their conformity to environmental regulations. In a similar study, Brown and Zhang (2005) increased and decreased elasticity estimates by 50% and examined the changes in welfare range for forest industrial landowners due their conformity to SFI.

In this study, a stochastic simulation was carried out on elasticity estimates and timber prices. Each elasticity parameter was lowered by 25% of its estimated value to obtain its lower bound for a simulation process. Similarly, it was raised by 25% to get the upper bound. The upper and lower bounds of the parameter formed the stochastic range for the parameter to vary in the simulation process. For timber prices, the stochastic range was defined by minimum and maximum average timber prices across the U.S. Each parameter estimate of elasticity and price was simulated with 10,000 iterations. Since timberland divestiture and timber supply data were collected directly from 2006 real world markets, these were held constant while the sensitivity analysis was carried out.

Data and data sources

Total and annual average changes of timberland ownership over time

Approximately two thirds of the total forest land in the U.S. are timberland (Fiacco 2011). By 2006, U.S. timberland totaled 517 million acres. Since the late 1980s and early 1990s, there have been large-scale timberland transactions. Rinehart (2001) reported that about 20 million acres of timberlands were divested from 1989 to 2001. Of this, IC timberland owners divested 15.9 million acres accounting for 79.5% of the total acres sold during this period. Boyd (2006) reported that IC timberland owners held 68 million acres of timberland in the U.S. in 1981. By 2005, their holdings dropped just to 21 million acres, 69.1% reduction. In contrast, over the same period, the holdings of TIMOs and REITs grew from just zero to over 25 million acres. By 2006, IC timberland owners had divested nearly 80% of their timberland holdings. Most of this is now owned by NIC landowners (Smith et al. 2010).

As reported in Table 1, from 1987 through 2006, timberland ownership for IC landowners decreased by 68.73%, an average annual decrease of 3.44%. Similarly, the decrease of NIPF timberland ownership was 10.07% in total and 0.50% annually during the same period. Using this information and $\tilde{L}_r = -(\tilde{L}_i l_i + \tilde{L}_n l_n) / l_r$, total and annual values of $\tilde{L}_r$ were estimated to be 0.4802 and 0.0239, respectively.

Table 1. Chronological patterns of timberland ownership in millions of acres by IC landowners (IC), nonindustrial private forest landowners (NIPF) and the public ownership in the United States from 1952 to 2006 and total and annual percentage change rate of timberland ownership from 1987 to 2006.

Owners	Years						Total Change	Annual change
	1952[a]	1962[a]	1977[a]	1987[a]	1992[a]	2006[b]	1987-2006	1987-2006
IC	58.98	61.43	68.94	70.35	70.46	22.00	-68.73%	-3.44%
NIPF	304.44	307.53	285.25	283.56	287.61	255.00	-10.07%	-0.50%
Public	145.45	146.16	138.17	151.03	131.49	156.00	3.29%	0.16%
Total	508.87	515.12	492.36	504.94	489.56	433.00	-10.71%	-0.54%

[a] Powell et al. (1993); [b] Smith et al. (2010).

Timber prices

2006 quarterly prices for softwood and hardwood were collected from multiple online sources accessed through Logprice.com (2010) and USDAFS (2010). Price data were collected for 50% of the states (i.e., 25 states) randomly chosen from six different zones of the United States: Northeast (NE), North Central (NC), Southeast (SE), South Central (SC), Rocky Mountains (RM) and Pacific Coast (PC). Softwood prices for all four quarters of 2006 for a specific state were averaged to obtain the state simple average softwood price for that state. Obtained in this way, the 25 state average prices were further averaged to obtain the U.S. simple average softwood price. The same process was followed to obtain the U.S. simple average hardwood price.

Demand elasticities

Elasticity values were obtained from the literature. Where more than one value was available, elasticities were averaged to generate one elasticity measure for each owner and timber type. Table 2 depicts the values of all elasticities and other parameters used in this study. Demand elasticities for softwood and hardwood used in this study were -0.45 and -0.24, respectively (Buongiorno 1996).

Supply elasticities

Liao and Zhang (2008) estimated supply elasticities for industrial softwood sawtimber and industrial softwood pulpwood to be 0.70 and 0.90, respectively for U.S. South. Industrial pulpwood supply elasticities estimated by Prestemon and Wear (2000) was 0.66. Industrial softwood supply elasticity values as calculated by Adams and Haynes (1980) and were 0.26, 0.39, 0.47, 0.99, and 0.32, respectively, for the PSW, SC, SE, NC, and NE regions. Based on these values, mean supply elasticity of industrial softwood was calculated to be 0.58. Newman and Wear (1993) estimated supply elasticity for hardwood sawtimber and pulpwood to be 0.27 and 0.58, respectively, for the SE and their average value, 0.43, was taken for industrial hardwood supply elasticity. Private or NIPF softwood supply elasticity values were 0.12, 0.39, 0.30, and 0.31, respectively, for the PSW, SC, SE, and NC (Adams and Haynes 1980). Again, private softwood supply elasticity values as calculated for the regions WW, NOW, and SWO were 0.34, 0.18, and 0.15, respectively (Adams 1983). Prestemon and Wear (2000) calculated NIPF pulpwood elasticity for U.S. to be 0.12. In this study, the NIPF softwood supply elasticity was 0.24, an average of all of these elasticity values. Newman and Wear (1993) estimated NIPF hardwood sawtimber and pulpwood as 0.22 and 0.33, respectively, and this study used the average, 0.28, for NIPF hardwood supply elasticity (Table 2). Currently, there is no literature on supply elasticity of NIC landowner timber supply. Since the timber management intensity maintained by this ownership type was similar to industrial owners, their timber supply elasticity was assumed to be closer to that of industrial owners. Thus, the softwood and hardwood supply elasticities from NIC owners were assumed to be 0.55 and 0.40, respectively (Table 2).

Table 2. Estimated or assumed values of elasticity parameters, landbase change rates from 1987 to 2006, land acreage shares, and timber supply shares by timber types and landownership types in 2006 in the United States.

Parameter	Parameter descriptions	Timber types	
		Softwood	Hardwood
η	Demand elasticity of timber with respect to price	-0.45[a]	-0.24[a]
ε_i	Price elasticity of timber supply for IC [l] landowners	0.58[b]	0.43[c]
ε_r	Price elasticity of timber supply for NIC [m] landowners	0.55[d]	0.40[d]
ε_n	Price elasticity of timber supply for NIPF [n] landowners	0.24[e]	0.28[f]
ξ_i	Inventory elasticity of timber for IC landowners	0.70[g]	1.23[g]
ξ_r	Inventory elasticity of timber for NIC landowners	0.60[d]	1.00[d]
ξ_n	Inventory elasticity for NIPF landowners	0.75[h]	1.00[d]
l_i	Timberland share for IC landowners	0.04[i]	0.04[i]
l_r	Timberland share for NIC landowners	0.16[i]	0.16[i]
l_n	Timberland share for NIPF landowners	0.49[i]	0.49[i]
l_g	Timberland share for government	0.30[i]	0.30[i]
λ_i	Timber supply share for IC landowners	0.06[i]	0.06[i]
λ_r	Timber supply share for NIC landowners	0.21[i]	0.21[i]
λ_n	Timber supply share for NIPF landowners	0.64[i]	0.65[i]
λ_g	Timber supply share for government	0.09[i]	0.08[i]
$\tilde{L}_i$	Change rate of timberland base for IC landowners	-0.6873[j]	-0.6873[j]
		-0.0344[k]	-0.0344[k]
$\tilde{L}_n$	Change rate of timberland base for NIPF landowners	-0.1007[j]	-0.1007[j]
		-0.0050[k]	-0.0050[k]
$\tilde{L}_r$	Change rate of timberland base for NIC landowners	0.4802[j]	0.4802[j]
		0.0239[k]	0.0239[k]

[a](Buongiorno 1996); [b](Adams and Haynes 1980), (Liao and Zhang 2008), (Prestemon and Wear 2000); [c](Newman and Wear 1993); [d] assumed; [e](Adams and Haynes 1980), (Adams 1983), (Prestemon and Wear 2000); [f](Newman and Wear 1993); [g](Adams and Haynes 1980), (Nagubadi and Munn 2001); [h](Adams and Haynes 1980); [i] calculated from real world data; [j] total change rate of timberland ownership from 1987 to 2006; [k] Annual average change rate of timberland ownership in from 1987 to 2006; [l] IC = industrial corporate ; [m] NIC = nonindustrial corporate; [n] NIPF = nonindustrial Private Forest;

Inventory elasticities

Adams and Haynes (1980) obtained 1.00, 0.46, 1.00, 0.41, 0.49, 0.20, and 0.37 as industry softwood inventory elasticities for PNWW, PNWE, PSW, SC, SE, NC, and NE, respectively. Nagubadi and Munn (2001) estimated inventory elasticities for hardwood sawtimber and pulpwood to be 1.65 and 1.87 and for the SC region. Thus the mean elasticity values for industry softwood and hardwood inventories were 0.70 and 1.23, respectively (Table 2). Adams and Haynes (1980) also estimated NIPF softwood inventory elasticities of 1.00, 1.00, 1.00, 1.00, 0.66, 0.72, 0.35, and 0.28, respectively, for PNWW, PNWE, PSW, RM, SC, SE, NC, and NE regions. Thus the average NIPF softwood inventory elasticity was 0.75 (Table 2). Hardwood inventory elasticity value for NIPF, hardwood and softwood inventory elasticities of NIC owners were not readily available in any literature. As mentioned earlier, the timber management intensity maintained by NIC landowners was similar to industrial landowners and thus, their inventory elasticity was assumed to be close to that of IC landowners, 0.60. Although inventory elasticity varies based on stand composition, and substitution between pulpwood and sawtimber harvesting (Brown and Zhang 2005), the inventory elasticities were assumed *a priori* as approximately unitary (Hynes and Adams 1985). Using this piece of information, inventory elasticities for NIPF hardwood, NIC hardwood were assumed to be 1.00 (Table 2).

Timberland and timber supply shares for different landowners

Estimation of inventory elasticities to be used in the study was followed by estimation of timberland and timber supply shares for each owner. Timberland shares (l's) were calculated from acreage of timberland owned by different owners in 2006. Similarly, supply shares (λ's) were calculated from timber supplied by different timberland owners in 2006. All these share values are reported in Table 2.

Results

Displacement of timber market equilibrium

Softwood and hardwood price increases were 0.11% and 0.14%, respectively (Table 3). Initial and displaced quantities of softwood and hardwood timber supply from different landowners are also presented in Table 3. As expected, timber supply decreased from IC landowners and NIPF landowners and increased from NIC owners. For softwoods and hardwoods, IC timber supply declined by 2.34% and 4.17%, respectively, and NIPF supply declined by 0.40% and 0.53%, respectively, on average annual landownership change basis. On the contrary, NIC timber supply increased annually by 1.50% for softwood timber and 2.45% for hardwood timber based on average annual landownership change.

Table 3. Initial and landownership changes driven displaced timber prices (U.S. dollar per MMBF) and timber supply (thousand MMBF) by timber product types and landownership types in the United State in 2006. Price changes and supply changes are based on annual average timberland transactions from 1987 through 2006.

Markets	Price			Landowners	Timber supply		
	Initial [a]	Displaced	Change		Initial [b]	Displaced	change
Softwood	164.42	164.60	0.11%	Public	10,289	10,289	0.00%
				IC	6,583	6,429	-2.34%
				NIC	25,134	25,510	1.50%
				NIPF	76,300	76,034	-0.40%
				All owners [c]	118,306	118,247	-0.05%
Hardwood	201.53	201.82	0.14%	Public	5,525	5,525	0.00%
				IC	3,813	3,654	-4.17%
				NIC	14,559	14,916	2.45%
				NIPF	44,198	43,995	-0.53%
				All owners [c]	68,095	68,071	-0.03%

[a] Average U.S. timber prices available through Logprice.com (2010) and USDAFS (2010); [b] modified from Smith et al. (2010); IC=industrial-corporate owners; NIC=nonindustrial corporate owners; NIPF=nonindustrial private forest land owners; Price changes and supply changes are based on annual average timberland transactions from 1987 through 2006; [c] data may not add to total due to rounding.

Welfare analysis

Base scenario

Based on annual average timberland sale rate (3.44% of their total land), producer surplus for IC landowners decreased, by $1.75 million, $0.89 million, and $2.64 million, respectively, in softwood, hardwood markets, and both markets. Over 1987 to 2006, IC landowners sold off 68.73% of their total timberland. Given this landbase reduction, their producer surplus decreased by $27.18 million, $10.63 million, and $37.81 million, respectively, in the softwood, hardwood and combined timber markets (Table 4). Like industrial corporate landowners, NIPF landowner land base reduction contributed to their surplus loss. Among all timberland owners, NIPF landowners faced the largest welfare losses. Their surplus declined by $20.46 million and $10.54 million, respectively, in the softwood and hardwood markets. Their total surplus loss, when softwood and hardwood markets were combined, approximated $31 million. When their total timberland base reduction (10.07% of their total land) was considered, their welfare reductions were $396.93 million, $201.43 million, and $598.36 million, respectively, in the softwood, hardwood, and both markets (Table 4).

Table 4. Changes in producer, consumer, and total welfare (surplus) in U.S. timber markets based on total and annual average timberland ownership change rate from 1987 through 2006.

Landbase change	Markets	Surplus change (million U.S. dollars) [b]						
		Producer [a]					Consumer	Total [c]
		Public	IC	NIC	NIPF	Net		
Total	Softwood	37.46	-27.18	366.37	-396.93	-20.28	-428.61	-448.89
	Hardwood	32.10	-10.63	297.46	-201.43	117.50	-394.27	-276.77
	Both markets	69.56	-37.81	633.82	-598.36	97.22	-822.88	-725.67
Annual	Softwood	1.87	-1.75	15.99	-20.46	-4.35	-21.46	-25.81
	Hardwood	1.61	-0.89	12.09	-10.54	2.26	-19.79	-17.53
	Both markets	3.47	-2.64	28.08	-31.00	-2.09	-41.25	-43.34

[a] IC=IC landowners; NIC=NIC landowners; NIPF=nonindustrial private forest landowners; [b] all values are based on 2006 timber prices and supplies; [c] data may not add to total due to rounding.

Since NIC landowner timberland share increased annually by 2.39%, their producer surplus increased by $15.99 million and $12.09 million, respectively, in the softwood and hardwood markets. Their total gain in both markets was $28.08 million. When their total land increase rate (through purchase) from 1987 through 2006, 48.02%, was considered, their surplus increased by $366.37 million in the softwood market, $297.46 million in the hardwood market and $633.82 million in both markets (Table 4). Although timber supply from public timberland was assumed constant over time, the government benefitted from higher timber prices. For average annual timberland transactions among other producers, the government surplus increased by $1.87 million, $1.61 million, and $3.47 million, respectively, in softwood, hardwood and both markets. For total timberland transactions among other landowners, government surplus increased by $37.46 million in the softwood market, $32.10 million in the hardwood market and $69.56 million in both market (Table 4).

Unlike the government, consumers faced reduced consumer surplus in timber markets. Their welfare reduction was $21.46 million in the softwood markets, $19.79 million in the hardwood markets and $41.25 million in both markets based on annual average rate of timberland transactions among landowners. When total land transactions were considered, their consumer surplus decreased by $428.89 million, $394.27 million and $725.67 million, respectively, in softwood, hardwood, and combined markets (Table 4). Based on annual average timberland transaction rate, total social welfare reductions were $25.81 million, $17.53 million, and $43.34 million, respectively, in softwood, hardwood and both markets. When total land transactions among all landowners were considered, total social welfare decreased by $448.89 million in the softwood market, $276.77 million in the hardwood market, and $725.67 million in both markets (Table 4).

Sensitivity results

Results of the sensitivity analysis of welfare (i.e., surplus) estimates for producers and consumers are presented in Table 5. When stochastic parameters were simulated, the absolute mean values of producer (as a group) surplus, consumer surplus and total surplus increased by 43%, 26%, and 26%, respectively, compared to the original absolute surplus change in combined timber markets based on annual average land transactions. For total land transactions, the absolute mean for producer surplus increased by 15% and both consumer and producer surplus by 26%, when compared to the original absolute surplus changes.

Table 5. Sensitivity of changes in producer, consumer and total surplus in U.S. timber markets based on total and annual average timberland ownership change rates from 1987 through 2006.

Landbase Change	Markets	Surplus change (million U.S. dollars) [a]						
		Producer [b]					Consumer	Total [c]
		Public	IC	NIC	NIPF	Net		
Total	SW	48.62	-35.13	473.67	-514.26	-27.10	-555.58	-582.68
		(6, 106) [d]	(-78, -5)	(62, 1030)	(-1138, -67)	(-130, 43)	(-1210, -71)	(-1282, -75)
	HW	38.97	-12.70	357.81	-245.22	138.86	-477.41	-338.54
		(-16, 106)	(-34, 5)	(-148, 975)	(-678, 98)	(-59, 386)	(-1300, 193)	(-932, 133)
	Both	87.59	-47.83	831.48	-759.49	111.76	-1032.98	-921.22
		(14, 171)	(-94, -10)	(137, 1607)	(-1472, -160)	(-112, 369)	(-2019, -145)	(-1772, -175)
Annual	SW	2.43	-2.28	20.82	-26.67	-5.70	-27.92	-33.62
		(0.3, 5.4)	(-5.1, -0.3)	(2.8, 46.2)	(-59.4, -3.5)	(-14.4, -0.5)	(-61.8, -3.7)	(-74.9, -4.4)
	HW	1.94	-1.08	14.60	-12.75	2.71	-23.89	-21.18
		(-0.8, 5.4)	(-3.0, 0.4)	(-5.7, 40.6)	(-35.6, 5.0)	(-1.0, 8.8)	(-66.1, 9.3)	(-58.9, 8.2)
	Both	4.37	-3.36	35.41	-39.42	-2.99	-51.81	-54.80
		(0.7, 8.8)	(-6.7, -0.7)	(6.2, 70.9)	(-79.2, -8.4)	(-12.8, 5.4)	(-104.7, -7.8)	(-109.4, -10.3)

[a] All values are based on 2006 timber price and supply; [b] SW=Softwood market; HW=Hardwood market; IC=IC landowners; NIC=NIC landowners; NIPF=Nonindustrial private forest landowners; [c] Data may not add to total due to rounding; [d] Values in the parentheses are the 95% confidence intervals around respective means;

Based on annual average timberland transactions, surplus change for producers as a group, consumers, and society as a whole ranged between -$12.8 and $5.4 million, -$12.8 and $5.4 million, and -$109.4 and -$10.3 million, respectively. For total land transactions, surplus changes varied between -$112 and $369 million for the producer group, -$2019 and -$145 million for consumers, and -$1772 and -$175 million for society.

Discussion and conclusions

This study quantitatively examined the welfare consequences borne by timberland owners and consumers for changes in timberland ownership from 1987 through 2006. Producer surplus for NIC owners increased for two reasons: (1) their timberland base increased considerably through land purchases which increased their timber supply and, (2) increased timber prices due to net decrease of timber supply by all owners. Although timber supply from public ownership was assumed constant during the study period, government welfare share increased due to increased timber price. Although consumers were not any part of timberland ownership changes, they were adversely affected due to increased timber prices and they faced the largest consequences among all involved in the timber markets. Their surplus reduced by a large margin due to increased timber price increased. Although producer surplus increased for some landowners (NIC timberland owners and public ownership), decreased for some landowners (CI timberland owners, NIPF landowners), consumer surplus decreased, overall social welfare decreased due to net reduction in timber supply in U.S. timber markets. This reduction is attributed to reduction of timberland base through nonforestry uses of timberlands and a reduced timber supply held back from the markets by conservation groups since their primary objective of owning timberland is environmental conservation.

The overall impact of timberland ownership change was nominal on the U.S. timber market. The price increase over the 20 year divestiture period was $3.64 per MMBF (i.e., $0.18 per MMBF per year) for softwoods and $5.81 per MMBF (i.e., $0.29 per MMBF per year) for hardwoods. Based on total acreage of timberland transactions among landowners over the divestiture period, timberland ownership change did cost society about $726 million in total social surplus reduction. Based on the 2006 U.S. average for softwood and hardwood prices and timber supply data (Smith et al. 2010), the U.S. timber market size was estimated as $33.3 billion in 2006. And, estimated total social welfare reduction was about $43 million in the same year. Thus, the social welfare reduction was quite small compared to total timber market size.

This study explains the mechanism of welfare shifts among producers and consumers, and quantifies welfare changes for each of the landowners attributed to timberland ownership changes in the U.S. It also evaluates how consumers and society face consequences for timberland ownership changes. While government loses tax income for timberlands being owned by S corporations like TIMOs and REITs, it earns a positive producer surplus change due to higher timber price. However, this study has not investigated the balance between the two. It is a step forward to justify industrial timberland divestiture decisions. Although IC timberland owners divested timberland and faced reduction in producer surplus, the reduction is presumed to be trivial compared to the potential benefits from divesting industrial timberlands such as profits from timberland sales, avoidance of double taxation, increased capital, and debt reduction. However, these options were not investigated in this study. Further investigations may be carried out to include all of these factors to further resolve the issue of whether industrial timberland divestiture was at all a profitable option for IC timberland owners.

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Quantifying the value of scientific information for managing natural resources

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Abstract

The applied value of scientific information (VOI) has been and is under continuing investigation in analyses of potential and actual uses of US Department of the Interior (DOI) information products. The value of components of VOI have justified the costs of the scientific programs creating the information products, however total VOI is typically much more than the particular application exhaustively analyzed. A full accounting of total VOI must include all known uses of the information and, additionally, must estimate the future development of unknown uses of the information. Full VOI accounting requires a combined approach using studies of the most valuable known uses and a model of diffusion to unknown current and future uses. Estimates of the total VOI for each potential research program can be combined into an objective for optimizing constrained research budgets or for maximizing net return on research investment. Such an analysis is a long term objective given the limited VOI results currently available. In the shorter term VOI components quantification will remain quite useful for affirming the efficiency of research investment choices, developing understanding of the nature of VOI in DOI research programs and connecting information products to operational applications.

Keywords: value of information, geographic information, moderate-resolution land imagery, remote sensing, nonpoint source pollution.

I. Introduction

The research programs of the US Department of the Interior (DOI) generate valuable information for the purposes of federal governance, regulation and management and also for the uses of private concerns and other non-governmental organizations. A better understanding of the value of DOI information products is crucial for better direction of limited scientific research resources. Value of information (VOI) is defined as the expected value of an informed decision less the expected value of an uninformed decision (Magesan and Turner 2010). Here we describe how the USGS has applied the revealed preference method to quantify the value of DOI information products and discuss empirical results from cost-benefit studies that have quantified the value of some information products.

One example of valuable scientific information at DOI is the Geologic Program of the USGS that produces Earth science information to assist in evaluating resource potential, defining and mitigating risks associated with natural hazards, and characterizing the potential impact of natural geologic processes on human activity, health, the economy, and the environment (see section III for a description of more research). On type of information product of the Geologic Program is geological map information. As described below a value of $18 million was quantified for one use of a new higher resolution geological map. This value greatly exceeds the $2.2 million used to create the map information.

"Scientific knowledge," according to Nelson (1959), "has economic value when the results of research can be used to predict the results of trying one or another alternative solution to a practical problem." The basis of the VOI method used to analyze DOI research is the analysis of the use of information for practical applications. In this chapter, we explain the theoretical economic foundation for estimating VOI that are calculated by assessing how the improvements in implementing projects using a DOI information product compared to the value possible if that information were not available. Then we describe specific examples of the VOI calculation method in the next section.

II. Information as a market good

Scientific information has long been known to be most valuable when it is freely available both because duplicate efforts are avoided if information is known to be available and the applicability of the information can be freely assessed. On the surface this seems a paradox – scientific information is valuable, in fact it is most valuable when it is disseminated at a price of zero (Arrow 1962). How can something available at zero price have value? Actually, anything we buy has value above the sales price (Figure 1). The market for information (Figure 2) is a special case of the general market in Figure 1 because the cost of disseminating copies of the information can be very close to zero with modern electronic information technology. The supply curve in a free market is the cost of supplying one more unit of the good, which for the information market is the cost of one more copy of the information. Therefore the supply curve for the information market is very close to the horizontal axis. Because the free market price for easily disseminated information is zero, we might ask, "who has an incentive to create this easily

Figure 1. The general case of the free market for a good.

- Consumers derive value above the price (p_1) they pay for a market good (the shaded area labeled "consumer surplus").
- The cost of supplying each additional unit of the good (marginal cost) determines the nature of the supply side of the market (the shape and slope of Supply)
- Suppliers have an incentive to enter the market if they can get enough of the producer surplus to justify the sunk costs of entry.

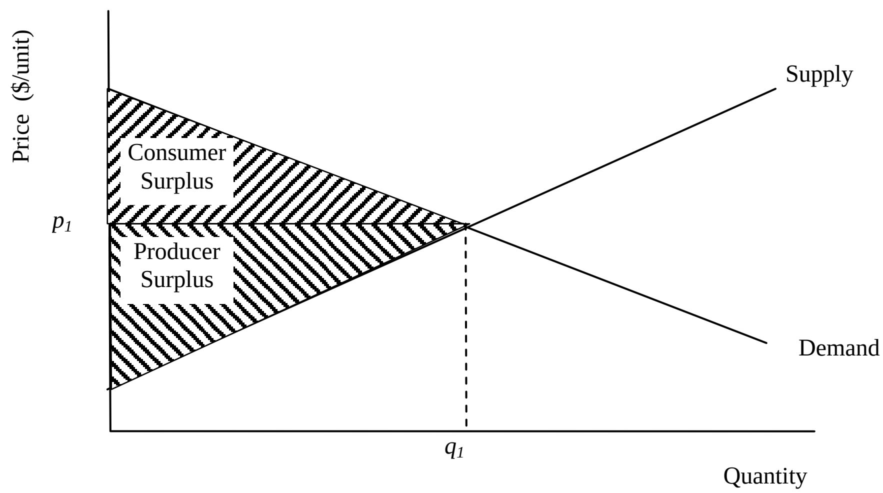
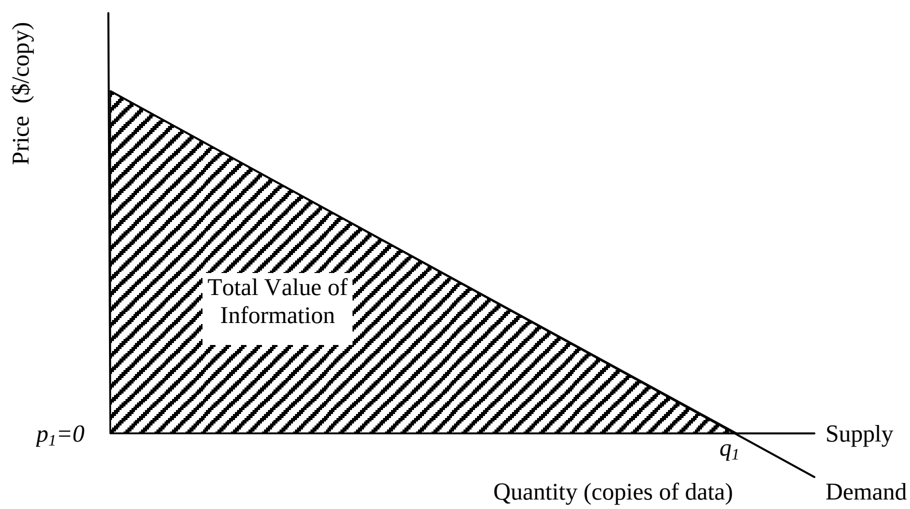


Figure 2. The market for information is a special case with the Supply curve very close to zero.

- The total value of information is the consumer surplus.
- The cost to disseminate one additional copy of the information is very low using modern information technology.
- Producer surplus is very low and can justify little investment for entering the market (creating information).
- If no one creates the information the market fails to come into existence.



disseminated product?" This is the crucial question that illustrates the importance of measuring the value of information (VOI).

Note that this information market analysis applies to any information, including, for example, news. With the advent of electronic media, the cost of supplying one more copy of the news has plummeted along with the ability to charge a price for access to the information, as the market model (Figure 2) predicts. This situation in the news market is the latest stage of a much longer historical process of decreasing prices for news as more efficient dissemination technology has developed. One consequence of this trend in news is that many providers go out of business. They calculate that the profit from selling copies of the news is not worth the investment in the investigative journalism needed to create news information. We characterize information created at the DOI as "scientific information," but the free market economic analysis of scientific information is not different from any other type of information.

Multiple strategies are used to promote the creation of scientific information despite the zero free market price outcomes. One common strategy is to convert the free market for information into a monopoly market by turning the information into a type of property called intellectual property (IP). A complex international framework of patent, copyright and trademark law is designed to give limited monopoly power to IP owners which provides incentive to create and disclose information. Enforcement of IP rights is an expensive and unwieldy process and in the end we do not have freely available information. Another strategy is voluntary creation by scientists contributing their time and by research in charitably funded institutions. But, a well known economic result for voluntary provision of public goods is that they will be underprovided (Samuelson 1954). A third strategy, publicly supported science, can be an important source of investment in the creation of scientific information because of the problems with the alternatives. When this third strategy is used to create scientific information many questions arise. How much should be spent on research? Which are the best research programs to fund? Is the information created by a research project valuable enough to justify the research budget? To answer these questions VOI must be well understood. Thus, VOI has direct application in informing government research funding policy. Better understanding and assessment of VOI can better guide governmental decisions about investment in scientific research.

III. USGS Scientific Information

"To improve understanding, the USGS produces scientific assessments and information on the quality and quantity of our Nation's water resources; collects, processes, integrates, archives, and provides access to geographic, geospatial and natural resource data; generates and distributes information needed in the conservation and management of the Nation's biological resources; and conducts multi-purpose natural science research to promote understanding of earth processes." (U.S. Geological Survey FY 2010 Budget Justification,
http://www.usgs.gov/budget/2010/greenbook/FY2010_USGS_Greenbook.pdf)

The USGS surveys, investigations and research contribute a variety of public scientific information that is used by a wide range of government agencies, academic institutions and private concerns. Programs in Geographic, Geologic, Hydrologic and Biologic

Sciences all contribute to the objective of providing unbiased scientific information to the public. Examples of USGS scientific information products are described below:
Geography integrates important environmental and societal processes to facilitate our understanding of how human well-being and environmental quality can be improved and maintained. Geography programs identify the spatial variation in these characteristics and qualities and facilitate a more "place-specific" solution to environmental problems, including reduction of risk and options for greater adaptation to an uncertain future, including those related to global climate change. Remote sensing of the Earth is used to monitor and analyze changes on the land, study connections between people and the land, and provide society with relevant science information to inform public decisions. Land cover on the Earth's surface—the pattern of natural vegetation, agriculture, and urban areas—is the product of both natural processes and human influences. Land cover represents an unbiased signature of environmental conditions. Improved understanding about the consequences of landscape change assists decision makers in the fields of land use planning, land management, and natural resource conservation. The Geographic Research, Investigations, and Remote Sensing provides information about land surface change including change due to wildfire, agricultural production, urbanization, forest logging, climate change and other factors operating at broad regional scales.
Geology provides Earth science information to assist in evaluating resource potential, defining and mitigating risks associated with natural hazards, and characterizing the potential impact of natural geologic processes on human activity, health, the economy, and the environment. The mission of Geology is to contribute to the provision of responsible resource protection and use and to serve communities by providing information that improves the understanding of national ecosystems and resources. The mission is, additionally, to improve the understanding of energy and mineral resources to promote responsible use and sustain the Nation's dynamic economy, and also to improve understanding, prediction, warning and monitoring of natural hazards to inform decisions by civil authorities and the public to plan for, manage, and mitigate the effects of hazard events on people and property. Products of the Earthquake Hazards Program include timely notifications of earthquake locations, size, and potential impacts; regional and national assessments of earthquake hazards; and public outreach to communicate advances in understanding earthquakes, their effects, and the degree to which they can be predicted. The Global Seismic Network Program provides high-quality seismic data to support earthquake alerting, tsunami warning, hazards assessments, national security (through nuclear test treaty monitoring), loss reduction, and research on earthquake sources and the structure and dynamics of the Earth. The Volcanic Hazards Program provides geoscience data and information needed to reduce the loss of life, property, and economic and societal impacts of hazards related to volcanoes. The Program provides information from a system of five observatories that continuously monitor seismic activity, surface deformation, gas emission, and satellite imagery of high-threat volcanoes. The Landslide Hazards Program gathers information, conducts research, responds to landslide disasters, and produces scientific information products that can be used by a broadly based user community, including Federal, State, and local governments and the private sector. Investigations focus on research to better understand, assess, and monitor the causes and mechanisms of ground failure. The National Cooperative Geologic Mapping Program provides multiple-purpose geologic maps that depict the

distribution of the Nation's sediment and rocks and the resources they provide. Geologic maps are vital for exploring, developing, and preserving mineral, energy, and water resources; evaluating and planning for land management and environmental protection; reducing losses from natural hazards, including earthquakes, volcanoes, landslides, and other ground failures; mitigating effects of coastal and stream erosion; siting of critical facilities; and planning for basic earth science research. The Coastal and Marine Geology Program provides information products on geologic conditions and processes critical to the management of the Nation's coastal and marine environments. These products are regional and national hazard, resource and environmental assessments of coastal and marine conditions, change and vulnerability to human and natural processes. The Mineral Resources Program provides current and reliable information about both domestic and international mineral resources and the consequences of their development. Planners and decision-makers at Federal, State, and local levels use this information to inform decisions that affect both supply and development of mineral commodities. The Energy Resources Program provides information about energy resources (oil, natural gas, coal, and others such as geothermal and gas hydrates) and the environmental and human health effects of energy resource occurrence and use. The Program assesses the energy resource potential of the Nation and the world (exclusive of U.S. Federal offshore waters). The Energy Independence and Security Act of 2007 calls for the USGS to assess the national potential for geologic carbon sequestration and assist the BLM in an evaluation of geologic carbon sequestration on public lands.

Hydrology Programs include: Groundwater Resources, National Water-Quality Assessment Program, Toxic Substances Hydrology, Hydrologic Research and Development, National Streamflow Information Program, and Hydrologic Networks and Analysis. Groundwater Resources provides information regarding groundwater availability in the Nation's major aquifer systems, evaluates this information over time, and characterizes the natural and human factors that control recharge, storage, and discharge in the Nation's major aquifer systems. The National Water-Quality Assessment Program provides information to improve our understanding of stream ecosystems and ecosystem change due to human and natural causes and the role of the water environment in human and ecosystem health. The Program also serves as the water-quality component of a water census for the United States. The Toxic Substances Hydrology program is a water quality research program that provides reliable scientific information and tools that explain the occurrence, behavior, and effects of toxic substances in the Nation's hydrologic environments. The results of those efforts provide a foundation for informed decision making by resource managers, regulators, industry, and the public. The National Streamflow Information Program provides information from a national streamgaging network. Hydrologic Networks and Analysis provides information about the chemical quality of rain and snowfall; streamflow and the water quality of streams to fulfill USGS obligations for specific river basin compacts and treaties; and the water quality and trends of selected major rivers.

Biology provides information needed in the conservation and management of the Nation's biological resources. Biological Research develops new methods and techniques to identify, monitor, and manage fish and wildlife, including invasive species, and their habitats. Scientists inventory populations of animals, plants, and their habitats; and monitor changes in abundance, distribution, and health of biological resources through time. Research and models relating to the impacts of contaminants, land use, climate and other factors help DOI land and resource managers maintain the health, diversity, and ecological balances of biological resources while meeting public needs, such as game harvests and use of public lands and waters. The Biological Research and Monitoring Programs develop information about how ecosystems are structured, function and provide "ecosystem services." This information is necessary to effectively manage and conserve biological resources. The Status and Trends of Biological Resources program provides information to advance research, facilitate resource management and stewardship, and promote public understanding and appreciation of the Nation's living resources, with emphasis on Federal lands. The Contaminant Biology Program provides information on the effects of environmental contaminants in the Nation's biotic resources with emphasis on resources managed by the DOI. The Terrestrial and Endangered Resources Program provide wildlife-related information for those managing the distribution, abundance, and condition of wildlife populations and communities. The Terrestrial, Freshwater, and Marine Ecosystems Program provide information needed to understand how management alternatives will affect ecosystems and the services they provide under a variety of climate, land use, and other change scenarios. The Invasive Species Program provides information needed to prevent, detect, control, and eradicate invasive species and to restore impaired ecosystems.

IV. VOI empirical studies in the Department of Interior

The USGS has taken the lead in developing VOI research for the Department of Interior with studies of the National Map, geological maps, moderate resolution land imagery, water quality information, earthquake hazard mapping, and other earth science information. The underlying method in this research is the analysis of the value of using the information compared to the situation without the information. The information has value two reasons either 1) better decisions with higher payoff and/or lower cost are possible compared to the situation without the situation or 2) the uncertainty in the outcome of a decision is reduced when the information is available so that less of a risk premium is attached to the decision. The VOI research program was kicked off in the early 1990s with a study of the USGS National Geological Mapping Program (USGS Circular 1111). In this early study the value of a new geological map for environmental decision making was analyzed in a case study of landfill siting and road construction in Loudoun County, Virginia. The new map provides information at a spatial resolution of 250 m compared to the best alternative information available at the 1 km scale. The new higher resolution map provided a benefit of $4.07 to $7.77 million[2] over the previous coarser map for the applications considered. This documented partial VOI of the map can be compared to the cost of mapping the county which was $1.94 million. Because the information can then be reproduced and distributed at little cost, the total benefit is much higher than for these applications.

Geological maps can also be used by private concerns. In a cooperative investigation with the Geologic Survey of Canada, the USGS has explored the value of bedrock geological maps to mining enterprises (USGS Professional Paper 1721) in both a mature mining region (the Flin Flon Belt) and a potential frontier mining region (Southern Baffin

[2] All prices are expressed at the 2010 price level.

Island). The bedrock maps are used to identify domains most likely to contain commercially valuable metal sulfide deposits. The coarser resolution map that was available before the newer mapping effort results in a noticeably different map (Figure 3) compared to the analysis of the new finer resolution map (Figure 4). By reducing uncertainty about the location of potential deposits, an expectation of positive return on mineral exploration investment is possible for more ventures. For example, in South Baffin Island the updated, finer resolutions map would stimulate $18.0 million more exploration activity than the previously existing, coarser resolution map while the cost for the new map was $2.2 million. The exploration investment is equivalent to the risk adjusted net present value of the extracted minerals.

In addition to geographic information, accurate environmental quality data can also be valuable. Rabinovici *et al.* (2004) analyzed the value of protecting swimmers from fecal pollution as indicated by *E. coli* level. Closing a beach to swimming when pollution is incorrectly assessed as excessive is a costly mistake. And, if the economic maximum contamination level is accurately determined then leaving the beach open when it is incorrectly assessed to be safe is also a costly mistake. This study finds that $148 to $546 per day would be saved at the Indiana Dunes State Park if accurate and timely *E.Coli* data were available. However, the information is much more valuable to formulation of policy since the policy of never closing beaches yields between $3,225 and $19,536 in daily benefits compared to existing policy, i.e. the probability of contracting illness is quite low so the expected costs of illness are small compared to the benefits of using the beach.

Much value of geographic information is in the ability to integrate it with other information to understand cumulative regional or landscape-level consequences of policy. For example, large earthquakes have widespread effects so the appropriate level of risk analysis is at the regional scale. Bernknopf *et al.* (2006) studied the expected earthquake losses in Watsonville, CA under a range of mitigation portfolio options. The geographic information provided a value between $59.7 and $67.4 million by documenting the net benefit of a mitigation policy targeted to the highest risk locations compared to the untargeted mitigation policy alternative.

In addition to the value of more efficiently responding to natural hazards when geographic information is available, this geographic information is useful for assessing the impacts of land use and management activities on environmental quality. Efficient prevention of ground-water contamination by nonpoint source insecticides and herbicides is a valuable use of information analyzed in a case study of agricultural land use in the Pearl Harbor Basin on the Island of Oahu, Hawaii (USGS Professional Paper 1645). The information provided a net present value of $319 million if the most efficient alternative identified is used to optimize benefits net of wellhead treatment costs.

Ground-water quality is also made vulnerable not only due to the application of synthetic agricultural chemicals, but also due to augmentation of naturally occurring soil nutrients at the profit maximizing rate of application. A study is currently underway to integrate Landsat moderate resolution land imagery with other information for Eastern Iowa to determine the value of that information to protect groundwater resources from nitrate pollution while minimizing any loss in agricultural production.

Each of the above VOI studies, exhaustively documents a use value for a type of information, but the total VOI will typically consist of many components. That total value includes unknown future uses and diffusion of use to new types of users and users in new locations. A study of the total value of the National Map was conducted by modeling diffusion of technological applications of the mapping information (USGS Circular 1271). The net present value of the total VOI of the National Map was found to be $2.9 billion for the stream of benefits over a 30 year time horizon. This VOI greatly exceeds the $417 million net present cost of developing and maintaining the National Map.

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Land-use Changes,
Forest Type Changes, and Related Environmental Concerns in the Southern U.S.

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Abstract

This study projects the future distribution of forest types in the South by examining the factors that directly or indirectly influence historical forest type changes using a two-stage discrete choice model, and explores the environmental consequences caused by forest type transition in terms of carbon sequestration on forest lands. Projection results indicate that the area of pine plantation will keep increasing, with a total increase rate of 58 percent during 1997-2047, and the areas of natural pine and hardwoods will decline. Comparing the projections of carbon stocks on forest lands with and without forest type transition, carbon storage from the dramatic change of increase of planted pine, and decline of other forest types are not significantly different from that without forest type transition.

Keywords:
Two-stage discrete choice model, land use change projection, forest type projection carbon sequestration

Introduction

Forests in the South account for 27 percent of all forest lands in the United States (Smith et al. 2009). A fairly constant 96 percent of these forest lands in the South is timberland over the past half century (Alig and Butler 2004). Between 1952 and 1997, planted pine area increased by more than 10.1 million hectares in the South, mainly caused by artificial regenerations of harvested natural pine, mixed-oak-pine, and hardwood stands or plantations on old agricultural lands. Naturally generated pine lost a total of 59 percent of its area, which is the largest change of forest type, followed by increases of planted pine and upland hardwood, and decrease of lowland hardwood (Alig and Butler 2004).

Trends might continue and perhaps be expected because regenerated plantations, the vast majority of which are composed of softwood species, could produce larger volumes of higher-value sawtimber in less time relative to hardwoods, and provide relatively larger returns for forest owners (Siry 2002). However, hardwood forests have higher annual wood production and higher carbon stocks than softwood forests (Brown et al. 1999, Brown and Schroeder 1999). On average, the carbon storage ability of planted pine is only from 46 percent to 70 percent of that of upland hardwood forests, depending on site quality (FIA 2003). The different growth rates and carbon sequestration capabilities of forest types could cause unclear consequences for the future

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availability of timber, wildlife habitat, forest carbon, and other forest ecosystem goods and services.

The purpose of this study is to project the future distribution of southern forest types, and to examine related carbon consequences. This study takes the advantages of discrete choice models by using available point level forest type data from the Forest Inventory and Analysis (FIA), and considers land use dynamics between forestry and non-forestry sectors as a simultaneous process on land use dynamics within forest sectors.

The next section introduces the method for projecting the future forest type changes and the data used in the study, followed by our model estimation results, and land use and forest type projections. Then we present the comparison results of carbon sequestrations with forest type changes and without. The final section summarizes and draws conclusions and policy implications based on our findings.

Methods and Data

This study follow Zhang and Polyakov (2010) ‘s conceptual scheme (Figure 1) of pine plantation simulation to project land use dynamics in the coming half century in the first stage, and then project forest type changes conditional on land use projection results in the second stage. Our main econometric models are discrete choice models, which are specified as

$$P_{n(t+1)j|i}(\boldsymbol{\beta}_n) = \frac{\exp(\alpha_{ij}+\boldsymbol{\beta}'\boldsymbol{X}_{ntj}+\boldsymbol{\gamma}_j'\boldsymbol{S}_{nt})}{\sum_{k=1}^{J}\exp(\alpha_{ik}+\boldsymbol{\beta}'\boldsymbol{X}_{ntk}+\boldsymbol{\gamma}_k'\boldsymbol{S}_{nt})} \quad (1)$$

where α_{ij} are the conversion-specific constants equal to 0 $\forall\ i=j, \boldsymbol{\beta}$ is a vector of coefficients of the attributes characterizing alternative land uses or alternative forest types, and γ_j is a vector of coefficients of the plot-specific attributes for land use or forest type j ($\gamma_J = 0$ to remove an indeterminacy in the model). The variation of $\boldsymbol{\beta}$ is determined by our model preference results.

Projection of Future Land Use Change Patterns

In the first step, we perform the econometric study of U.S. South land use and land use change, and project future land use patterns with the random parameter logit (RPL) model, The available latest ten-year interval U.S. South land use data that trace land use transitions are

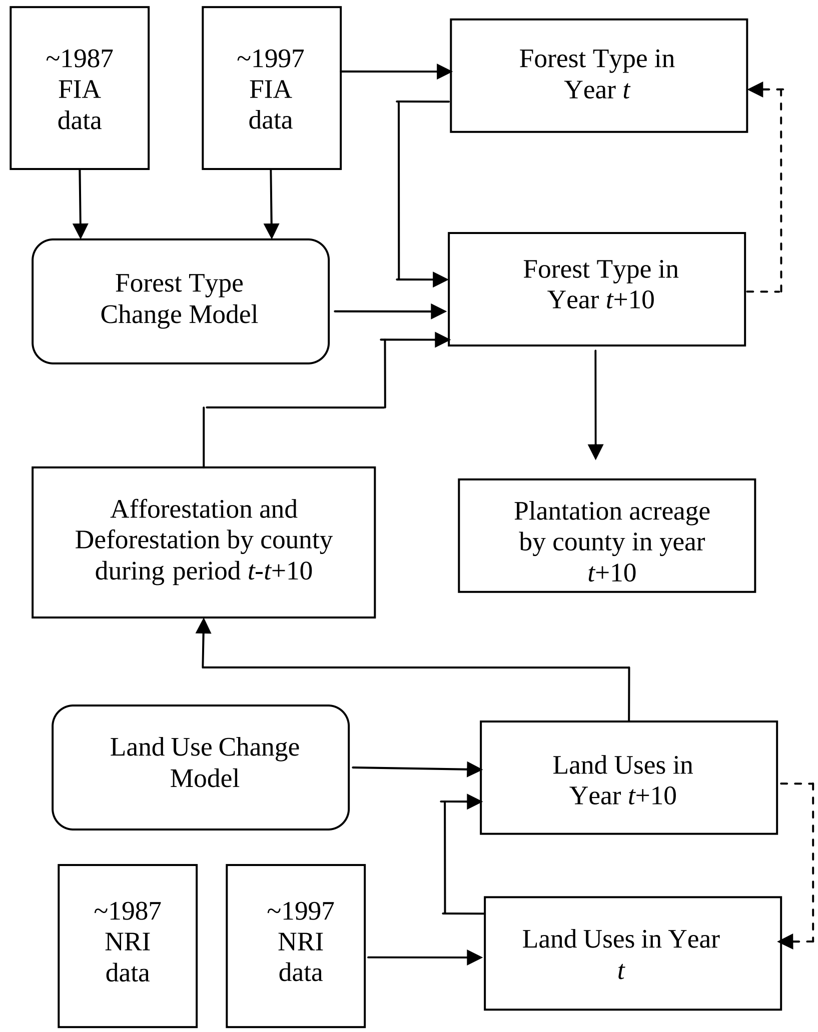

Figure 1. The structure of plantation development simulation.
Source: Zhang D, Polyakov M, 2010.

derived from National Resources Inventory (NRI) from 1987 to 1997. Plots in non-federal rural purposes are chosen with four initial uses *i* (crop, pasture, range and forest) and five final uses *j* (crop, pasture, range, forests, and developed lands). Our dependent variable in the RPL model is land use category in 1997. Explanatory variables in the model include socio-economic and bio-physical factors which could limit and influence the chance of a particular land parcel being converted to another use, with previous ten-year average real values for time-variant variables and fixed values for time-invariant variables. To be consistent with the forest type change projection in the second stage, we exclude non-forest counties which are mostly in western Texas in NRI according to Forest Inventory and Analysis (FIA) records.

In total, our land use change study covers 1,027 forest counties in the South, including 188,823 plots, representing 67 percent of the total non-federal rural lands. The key variables used in the model are economic returns for land use alternatives, dummy variable "Prime farmland" from NRI, population interaction index (PII) from the Census block group population data, and continuous variable of slope for each point from NRI. We also include three dummy variables, Piedmont, Mississippi Delta, Mountains and Plateau to capture land use transition patterns with respect to physical geographical features. Counties in coastal plain are set as the base. In terms of classic land theory, we assume that the higher the economic return of a kind of land use, the higher probability of lands remaining or converting to that certain use. Lands classified as “prime farmland” are more likely to stay in or convert to agricultural use due to high productivity of agricultural products (Polyakov and Zhang 2008, Zhang and Polyakov 2010). Slope of a site is assumed to negatively influence lands in agricultural use and developed use. The steeper the slope is, the less probability of land remaining in or converting to those uses.

Parameter estimates in the RPL model are used to project major land use areas in the coming half century. Keeping all time-invariant variables with the same values, we adjust county land rents for different land use types based on their historical growth rates from 1987 to 1997. The average annual growth rates of land rents for cropland, pasture, rangeland and forests are 2.22 percent, 4.68 percent, 0.48 percent, 3.49 percent, and 0.85 percent, respectively. PII adjustment is based on the annual growth rate of population projected by US Census Bureau.

Projection of Future Forest Type Patterns

In the second stage, the RPL model is used to explore dynamics of forest type changes among five major forest types: planted pine, natural pine, mixed pine, upland hardwood, and bottomland hardwood using the FIA remeasurement data. The FIA data are collected on an approximate 10-year cycle for sample plots located roughly in a 5 by 5 grid pattern. To match data collection time between NRI and FIA, we use inventory data between 1980 and 1990 as the initial point, and data between 1990 and 2000 as the final point. Remeasurementable plots in these two periods record the actual forest types in the two different time periods.

Explanatory variables for the analysis include socio-economic and bio-physical factors as well. The projection of forest type change is based on parameter estimates in the first stage, and the projection of forestlands in the second. We assume that the growth rates of economic returns for different cover types in future decades follow the same change trend in 1987-1997. Using the rates of forest loss and gain calculated from the land use change projection for each FIA unit in each state, we adjust area of each forest plot to make sure that the dynamics of forest loss and gain can be fully presented.

Estimation Results

With the assumption of log-normal distribution of the economic returns in each stage, we estimate the model with Conditional Logit (CL) and Random Parameters Logit (RPL) specifications, and test the model preference between CL and RPL in each stage. Then we report the estimation results for the preferred model. Tables 1 and Table 2 present our model estimates for the RPL model and CL model for the two steps, respectively. For both of the two stages, most parameters are highly significant at the 1% or 5% level with expected signs. Both the mean of economic returns for different land uses in the land use change model and the difference of economic earnings for different forest types in the forest types change model positively influence the probability of lands or forests remaining or converting to that kind activity. The standard deviation of economic returns in the first model is significant at the 1% level, indicating that economic returns vary among plots with a log-normal distribution.

Table 1. Plot-level RPL model estimation results for land use changes

Variables	Final Land Uses (choices)				
	Crop	Pasture	Range	Forest	Developed
Initial Crop	0	-2.1856***	-5.2509***	-2.1793***	-3.4005***
	---	(0.0349)	(0.1773)	(0.0355)	(0.0557)
Initial Pasture	-2.3079***	0	-3.5133***	-1.3274***	-3.1546***
	(0.0385)	---	(0.0975)	(0.0339)	(0.0572)
Initial Range	-3.2120***	-2.3547***	0	-2.2242***	-3.8102***
	(0.1117)	(0.0739)	---	(0.0772)	(0.1135)
Initial Forest	-5.6016***	-4.6611***	-7.4261***	0	-4.6249***
	(0.0500)	(0.0374)	(0.1071)	---	(0.0418)
PII	-0.0023***	-0.0038***	-0.0016***	-0.0025***	---
	(0.0002)	(0.0001)	(0.0002)	(0.0001)	---
Change of PII	-0.0054***	-0.0015***	-0.0027***	-0.0071***	---
	(0.0005)	(0.0005)	(0.0008)	(0.0003)	---
Prime land	1.3816***	1.0300	0.3144*	0.4807***	---
	(0.0530)	(0.0527)	(0.1633)	(0.0516)	---
Slope	0.1159***	0.1603***	-0.6014***	0.0398***	---
	(0.0070)	(0.0065)	(0.0352)	(0.0068)	---
Pie	-0.4312***	0.3289***	0.6659***	0.1489***	---
	(0.0489)	(0.0465)	(0.1132)	(0.0407)	---
Mountain	-0.0232	0.2053***	-0.1900	-0.0796	---
	(0.0584)	(0.0560)	(0.2278)	(0.0523)	---
Delta	1.5689***	0.7517***	-1.2986*	0.5966***	---
	(0.1256)	(0.1312)	(0.7234)	(0.1308)	---
Economic Return for All Land Use Alternatives	Mean of economic return	-9.6244***	Std. Dev. Of Return	1.2475***	
		(0.2532)		(0.1394)	
Number of observation	188,823				
Log-likelihood	-64915.68				
Preudo R^2	0.7864				

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level

Land Use and Forest Type Projections

Based on the estimation results and the method described above, we start our land use simulation from 1997 to 2047 in decades. We could not use land use data between 1997 and 2007 due to data unavailability of NRI. While the land use simulation results for 2007 with

Table 2. RPL model estimation results for forest type changes

Variables	Final Forest Types (choices)				
	Pine Plantation	Natural Pine	Mixed Pine	Upland Hardwood	Bottomland Hardwood
Initial Pine Plantation	0	-3.5650***	-2.6353***	-3.3690***	-3.2017***
	---	(0.2129)	(0.2258)	(0.5066)	(0.2327)
Initial Natural Pine	-1.5277***	0	-0.7903***	-1.6046***	-1.5480***
	(0.2040)	---	(0.2192)	(0.4571)	(0.1875)
Initial Mixed Pine	-1.5854***	-1.8691***	0	-1.2591***	-4.5938***
	(0.2491)	(0.2198)	---	(0.4684)	(0.4655)
Initial Upland Hardwood	-2.3058***	-4.1947***	-1.6123***	0	-0.9976**
	(0.2255)	(0.1974)	(0.2470)	---	(0.4503)
Initial Bottomland Hardwood	-4.5938***	-6.8684***	-3.9383***	-3.7817***	0
	(0.4655)	(0.4937)	(0.4674)	(0.4533)	---
Population Influence Index	-0.1859***	-0.0229**	-0.0325***	-0.0426***	---
	(0.0141)	(0.0106)	(0.0089)	(0.0142)	---
Change of Population Influence Index	0.0524*	0.0770***	0.0225	0.0369	---
	(0.0312)	(0.0238)	(0.0205)	(0.0297)	---
Slope	-0.0369***	-0.0186***	-0.0149***	-0.0512***	---
	(0.0034)	(0.0025)	(0.0019)	(0.0054)	---
Soil Hydricity	-0.2640	0.6008***	0.9255***	2.3828***	---
	(0.1721)	(0.1369)	(0.1168)	(0.0992)	---
Piedmont	-0.5691***	-0.2848***	-0.2755***	-0.1678**	---
	(0.0526)	(0.0492)	(0.0419)	(0.0726)	---
Mountains and Plateau	-1.6115***	-0.6300***	-0.6544***	-0.4658***	---
	(0.1047)	(0.0945)	(0.0680)	(0.1625)	---
Mississippi Delta	-0.3523**	0.4486**	0.0075	0.9537***	---
	(0.1580)	(0.1331)	(0.1259)	(0.1658)	---
Log(re-measurement period)	0.7862***	0.3778***	0.0972	-0.5450**	---
	(0.1130)	(0.0940)	(0.1213)	(0.2245)	---
Earning Profits	**Mean of Gross Return**	0.0002 (0.0001)			
Number of observation	40459				
Log-likelihood	-30576.95				
Preudo R^2	0.57				

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level

assumed change rates of economic return and population influence index indicates a 2.10 percent (3.71 million acres) decrease of forest lands from 1997 to 2007, which is 0.3 percentage overestimate of the decrease compared to FIA statistics (1.8 percentage decrease in FIA). For the ten-year interval simulation from 2007 to 2047, forests increase by 0.13 percent during 2007-2017, then presents an increasing decrease trend with rate of 0.42 percent, 0.77 percent, and 1.11 percent in every decade, where the total decrease of the study period is 4.24 percent.

Table 3 presents the region aggregate land area projected for each forest type after adjusted by projection of forest land areas in the first stage from 1997 to 2047. During this period, pine plantations increase by 57.77 percent, but natural pine, mixed pine-hardwood, bottomland hardwood, and upland hardwood decrease 30.30 percent, 22.74 percent, 17.63 percent and 5.20 percent, respectively.

Table 3. Projections of the areas of private timberland in the South by forest type between 1997 and 2047, million hectares

	1997	2007	2017	2027	2037	2047	Change (1997-2047)
Pine plantation	10.2	13.7	15.1	15.9	16.2	16.1	57.77%
Natural pine	10.8	10.2	9.1	8.5	8.0	7.6	-30.30%
Mixed-pine hardwood	10.1	9.1	9.1	8.8	8.3	7.8	-22.74%
Bottomland hardwood	10.4	9.2	8.9	8.7	8.5	8.6	-17.63%
Upland hardwood	24.0	22.1	22.1	22.2	22.5	22.7	-5.20%
Total forest	65.6	64.2	64.3	64.0	63.5	62.8	-4.21%

Carbon Consequences from Forest Inventory Projection

This section quantifies the approximate contribution of the forestry sector to the region's carbon balance. Our goal to compare the influence of forest type changes on carbon emission allows us to not to account for long-term effects of prior land-use changes on soil carbon, which means that soil carbon sequestrated by different land use categories other than forests in 1997 or by land-use changes from or to forest in the following decades is not considered. We first estimate the growing-stock volume of each forest cover type under the initial and the projected forest type distributions in each period, and then calculate the forest ecosystem and harvested carbon using the standard estimates for forest types from Smith et al. (2006). By comparing the differences of carbon sequestration under the scenario of the initial and the projected forest type distribution, we examine how forest type changes contribute to carbon emissions in forest sector.

Table 4 presents the cumulative carbon stock for the five cited forest types under the scenarios that the transitions among forest types exist or not. Panels A, B, and C present the projected forest areas for each forest type, the cumulative carbon stocks in forests only, and total carbon stocks in forests, forest products, and landfills, respectively. We adjust forestland areas for the one without transition based on land use projections in the first stage to make the total forestlands in each decade equal to the areas with transition. From Table 17, the carbon stock in forests only for scenario that no forests types transition exists but only within self-regeneration and self-harvest increases by 8.39 percent, from 11.3 Gg (1Gg $=10^{15}$g) to 12.2 Gg, while the carbon stock is projected to decline by 0.6 Gg (4.90 percent) over the 50-year period when forest type conversions are allowed. The associated 1.5 Gg ton reduction of carbon stock in forests is mainly caused by the loss of carbon stocks from natural pine and other hardwood species, and the conversion of these stocks to pine plantation. While this reduction can be made up by increases in total carbon stocks of forests and forest products. The conversion among forest types brings in a 0.5 Gg increases of total carbon stock including standing forests, forest products, and landfills.

We also project carbon emissions from energy recapture to estimate carbon fluxes in the forest within forest products. These emissions will reduce carbon stocks by releasing carbon to the atmosphere. On the other side, these emissions would offset emissions from using other sources of fuel to produce the same energy, and are used to measure how much fuel is needed to generate the same power. The last row in panel C presents cumulative carbon emission from using forest by-products in the energy stream in each decade. In general, energy emissions from forest type transition are higher than that from non-transition except two periods, 2017-2027, and

Table 4. Forest area inventories and carbon stocks (Billion tonnes carbon by the year given; 1 tonne=1 Mg=10^6 g; 1 Gg=10^9 Mg)

	Forest cover type without transition							Forest cover type with transition						
	1997	2007	2017	2027	2037	2047	Change 1997-2047	1997	2007	2017	2027	2037	2047	Change 1997-2047
Panel A: Forestland area (Million hectares)														
Pine plantation	10.2	10.0	10.0	10.0	9.9	9.8	-4.22%	10.2	13.7	15.1	15.9	16.2	16.1	57.77%
Natural pine	10.8	10.6	10.6	10.6	10.5	10.4	-4.22%	10.8	10.2	9.1	8.5	8.0	7.6	-30.30%
Mixed-pine hardwood	10.1	9.9	9.9	9.9	9.8	9.7	-4.22%	10.1	9.1	9.1	8.8	8.3	7.8	-22.74%
Bottomland hardwood	10.4	10.2	10.2	10.2	10.1	10.0	-4.22%	10.4	9.2	8.9	8.7	8.5	8.6	-17.63%
Upland hardwood	24.0	23.5	23.5	23.4	23.2	23.0	-4.22%	24.0	22.1	22.1	22.2	22.5	22.7	-5.20%
Total forest	65.6	64.2	64.3	64.0	63.5	62.8	-4.22%	65.6	64.2	64.3	64.0	63.5	62.8	-4.21%
Panel B: Carbon stocks in forest only (Gg carbon)														
Pine plantation	1.6	1.8	1.8	1.6	1.6	1.8	14.68%	1.58	2.38	2.37	2.36	2.38	2.74	73.23%
Natural pine	1.9	1.9	1.9	1.9	1.9	1.9	1.39%	1.86	1.76	1.57	1.44	1.34	1.26	-32.05%
Mixed-pine hardwood	1.7	1.8	1.8	1.9	1.9	1.9	11.64%	1.70	1.58	1.59	1.51	1.39	1.27	-25.07%
Bottomland hardwood	2.1	2.2	2.2	2.2	2.2	2.2	5.83%	2.12	1.85	1.80	1.76	1.74	1.76	-16.91%
Upland hardwood	4.0	4.1	4.2	4.3	4.3	4.4	9.12%	4.00	3.73	3.99	3.66	3.68	3.67	-8.29%
Total forest	11.3	11.8	12.0	11.8	11.9	12.2	8.39%	11.3	11.3	11.3	10.7	10.5	10.7	-4.90%
Panel C: Carbon stock in forests, forest products and landfills (Gg carbon)														
Pine plantation	1.6	2.0	2.2	3.1	3.2	3.1	93.09%	1.6	3.5	4.5	4.9	4.7	6.1	283.12%
Natural pine	1.9	2.8	2.6	2.5	2.6	2.4	31.62%	1.9	2.6	2.2	1.9	1.9	1.7	-9.27%
Mixed-pine hardwood	1.7	2.0	2.0	2.1	2.2	2.2	28.12%	1.7	1.8	1.8	1.7	1.6	1.5	-12.51%
Bottomland hardwood	2.1	2.4	2.4	2.4	2.4	2.4	13.05%	2.1	2.3	2.1	2.0	2.0	2.1	-2.51%
Upland hardwood	4.0	4.8	4.8	4.9	5.0	5.0	25.71%	4.0	4.4	4.5	4.2	4.3	4.3	7.65%
Total forest	11.3	14.0	14.1	15.0	15.3	15.1	34.14%	11.3	14.7	15.0	14.8	14.5	15.6	38.65%
Energy emission	--	1.4	1.8	3.5	3.9	2.3	64.29%	--	1.87	2.79	2.94	3.13	3.04	62.57%
Total carbon stock	11.3	12.7	12.3	11.5	11.5	12.8		11.3	12.8	12.2	11.9	11.4	12.6	

2027-2037. Total carbon stock from all cited factors indicates that there is not too much difference between these two kinds of forest type distributions for the environmental perspective.

Conclusions and Discussions

Land use, land use changes and forest type changes have environmental impacts. Policy analysts try to find appropriate policy to maximize social benefits and to balance landowners' economic goals. In this study, we project future forest type distribution under land use and land use change dynamics through a two-stage discrete choice model, and explore the influence of this change from the side of carbon sequestrations for the forest sector.

Our results indicate that the increasing trend of pine plantation adoption and decrease of other forest types will continue in the coming half century. Private pine plantations will increase by about 58 percent, from 10.2 million hectares in 1997 to 16.1 million hectares in 2047, and natural pine, mixed hardwoods, bottomland hardwoods, and upland hardwoods will decrease by 30 percent, 23 percent, 18 percent, and 5 percent, respectively, in the study period. Economic returns and population growth are highly correlated to the conversion. Assuming economic returns growing at their historical growth rates and population density changing as United States Census Bureau projected, the transition among forest types results in 1.23 Gg Carbon (C) decrease of carbon stocks in standing forests, and 0.5 Gg C increase of carbon stocks on both forests and forest products in 2047 than that without forest cover type change. Difference of total amounts of carbon storage including sequestrations in standing forests, forest products, landfills, and energy emission is 0.2 Gg Carbon (C). Thus, there is no obvious evidence to say that the expansion of pine plantations and shrinkage of other forest types could produce severe environmental problems caused by carbon emissions under these two proposed forest management strategies.

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Inventory and capacity of forest carbon sequestration mitigation activities: the state of the literature

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Abstract

Forests contain by far the largest terrestrial carbon pool with the most potential for changing land-based carbon sequestration. To identify forest land use and management changes that optimize carbon sequestration and minimize GHG emissions, this literature review summarizes field and model-based studies on the effect of forest land use change and forest management change on carbon sequestration in the United States. I also identify the economic cost of different mitigation activities and potential challenges of forest based carbon sequestration projects. I compile relevant national and regional scale data sets about current forest land based mitigation practices as well.

Key words: terrestrial carbon, afforestation, sequestration cost, literature review.

Introduction

Forest lands are the major carbon sink of the United States. Land use change and forestry (LUCF) are seen as mitigation options with potentially low opportunity costs and high ancillary benefits (IPCC 2000). The latest data for the United States indicate Land use, land-use change, and forestry (predominately forest) activities in 2009 resulted in a net C sequestration of 1015.1 Tg CO_2 Eq. (276.8 Tg C). This represents an offset of approximately 18.4 percent of total U.S. CO_2 emissions (U.S. EPA 2011). This paper is part of a larger study to synthesize field and model-based research on effects of land use change and land management on carbon sequestration and greenhouse gas (GHG) fluxes by region, ecosystem, and carbon. I mainly looked at research on forest-based mitigation activities and summarize general findings.

Forest based GHG mitigation activities

Afforestation

Afforestation from agriculture lands, mainly from croplands and rangelands is a land-use change practice that has been widely studied in different carbon sequestration scenarios. Alig, *et. al.* (2010) found that carbon payments, as the form of CO_2 pricing, have the largest overall impacts on carbon sequestration. Changes in deforestation caused by development or afforestation from

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agriculture can affect forest carbon sequestration, when combine with the carbon payments policy. The largest forest carbon gains or prevention of losses arise with the capability to afforest agricultural land when CO_2 prices are significant. Plantinga, *et. al.* (1999) estimated the marginal costs of carbon sequestration through afforestation in Maine, South Carolina, and Wisconsin. They found that afforestation appears to be a relatively low-cost approach to reducing CO_2 concentrations. A series of Winrock International studies of the states of Oregon and Washington (Dushku, *et. al.* 2008a, 2008b) concluded that the afforestation of rangelands is the largest terrestrial sequestration opportunity, both in terms of absolute quantity and costs. Another Winrock International study by Brown, *et. al.* (2006) also showed that significant amount of carbon can be sequestered in Shasta county, California through afforestation of rangelands at relatively modest cost. Lubowski, *et. al.* (2005) investigated the cost of forest-based carbon sequestration on a national level. They proposed a two-part policy involving a subsidy for the conversion of land to forest and a tax on the conversion of land out of forest. A second feature of the policy is a requirement that afforested lands remain in forest for a specified period of time. This policy provides incentives for afforestation, rather than for carbon sequestration directly. One constraint on afforestation is that the total acreage is limited.

Forest management changes
The managed forest has greater potential. Forests can be managed for mixed objectives and benefits. Besides reducing GHG buildup in the atmosphere, forests can also provide co-benefits such as clean air, recreation, biodiversity, wood products, esthetics, and high quality water.

Laiho, *et. al.* (2003) studied the effects of intensive stand management on site carbon pools. The management practices include different harvesting-disturbance regimes and herbicide treatments. They found that herbicide treatment decreased the C pool of hardwoods and understory, and increased that of planted pines. The response patterns of soil and forest floor C pools were different on their two study sites, which might be due to different drainage regimes on two sites. Goines and Nechodom (2009) assessed the carbon sequestration capabilities and costs of the national forests in California under different management scenarios and concluded that the region's forest carbon sink depends on the frequency and the extent of wildfire and the effectiveness of forest health management strategies. Maximum carbon sequestration is not always compatible with other resource objectives.

Hudiburg, *et. al.* (2009) investigated the potential for increased land-based carbon in Oregon and Northern California forests. The study suggests there is high potential for increased land-based carbon storage with increased rotation age or reduced harvest area. Dushku, *et. al.* (2008a, 2008b) found that lengthening the timber harvest rotation age beyond the economical rotation has limited potential both in terms of quantity and costs. Meanwhile, forest conservation, such as extending riparian buffers, is limited in scope and tends to be expensive. Depro, *et. al.* (2008) examined the potential of forest carbon sequestration on public timberlands at a national scale by comparing different timber harvest scenarios and estimated annual carbon stock changes associated with each. The analysis found that under a "no harvest" scenario eliminating harvests on public lands would result in an annual increase of 17-29 million metric tonnes of carbon (MMTC) per year between 2010 and 2050. In contrast, moving to a more intense harvesting policy would result in annual carbon loss of 27-35 MMTC per year between 2010 and 2050.

Nunery and Keeton (2010) described the impact of harvesting frequency and post-harvest structural retention on carbon storage in northern hardwood-conifer forests. The results suggested that passive management sequesters more C than active management. Management practices favoring lower harvesting frequencies and higher structural retention sequester more C than intensive forest practices.

The Winrock studies (Dushku, *et. al.* 2008a, 2008b) found that forest fire appears to be the most important management issue to address, and hazardous fuel removal has the potential to avoid substantial carbon dioxide emissions. In Brown, *et. al.* (2006), hazardous fuel reduction also appears to qualify as carbon offset projects. A landowner could gain from sale of the biomass removed from the forest and from sale of carbon credits gained from reducing fire severity. Dore, *et. al.* (2010) compared the impact of thinning on reducing wildfire in ponderosa pine forests in the southwestern United States and found that thinning is a desirable alternative to intensively burned forests to maintain carbon stocks and primary production. Reinhard and Holsinger (2010) simulated effects of mechanical fuel treatments and prescribed fire on stand-level forest carbon in the northern Rocky Mountains. The results do not support the use of fuel treatments solely to protect carbon stocks or reduce emissions since fuel treatments produced emissions and the untreated stands stored more carbon than the treated stands even after wildfire. Wiedinmyer and Hurteau (2010) estimated the potential reduction in fire emissions when prescribed burning is applied in dry, temperate forest systems in the western U.S. According to the study, wide-scale prescribed fire application can reduce fire emissions for the western U.S by 18-25%. The study suggested that prescribed burning is amenable only for western forests that historically has fairly frequent fire return intervals and low or mixed severity effects. It also suggested in systems where tree regrowth is fast, repeated prescribed burning may have a higher carbon cost than a one-time wildfire event.

Ruddell, *et. al.* (2009) emphasized the need to develop mandatory national standards that promote the registration and trading of forest carbon offset projects. They also proposed policy initiatives to sequester carbon through sustainable forest management.

Carbon tax/subsidy program or carbon offset market

Im, *et. al.* (2009) examined the potential changes in forest carbon sequestration from timber harvest shifts in federal land of western Oregon. The results indicated that substantial loss of carbon caused by increased federal harvest could be offset by relatively small reductions in private harvest. Therefore, a regional carbon flux target could be achieved by a carbon tax/subsidy program or a carbon offset market.

Forest-based biomass

A study by the Manomet Center for Conservation Sciences (Walker, *et. al.* 2010) compared the cumulative carbon emissions of biomass relative to continued burning of fossil fuels in the state of Massachusetts. They found that the greenhouse gas implications of burning forest biomass for energy vary depending on the characteristics of the bioenergy combustion technology, the fossil fuel technology it replaces, and the biophysical and forest management characteristics of the forests from which the biomass is harvested. Goines and Nechodom (2009) also emphasized the importance of reducing carbon emissions associated with bioenergy produced from forest biomass.

Fertilization and irrigation treatments
Sanchez, *et. al.* (2007) measured the soil carbon contents after harvest with fertilization and irrigation treatments. In their study, the post-harvest soil carbon dropped below pre-harvest levels after three years and tillage increase soil carbon content after three years. There was no significant effect of treatments on the soil carbon content. Oren, *et. al.* (2001) detected a large gain in forest carbon sequestration from higher atmosphere CO_2 and increased soil nutrients, in particular nitrogen.

Methods of studies

We characterized the study methods as model based research and field based research. Forest and Agriculture Sector Optimization Model with Greenhouse Gases (FASOMGHG) is a widely used optimization model for large scale and long time horizon policy analysis. Optimization models such as the FASOM-GHG modeling system simulate both economic and biophysical systems in the U.S. forestry and agricultural sectors. With a number of scenarios about carbon prices, rate of deforestation and afforestation, change of management regimen, the simulation provides information about the potential effectiveness of policies to address climate change in the U.S. and includes all states in the conterminous United States, major forest and agricultural products, land use change between forest and agricultural sector. Meanwhile, studies on effects of fertilization, fuel reduction, irrigation treatment are generally field based and employ statistical analysis.

Land ownership and mitigation activities

US land ownership patterns are complex. The potential for carbon sequestration critically depends on the land ownership and consequently land use decision making which is driven by a variety of economic, social and policy incentives. According to Vesterby and Krupa (2001), there are 420 million acres of private forest land, primarily in the South-Central, Corn Belt, and Southeast U.S. While less than one percent of owners hold 45% of the forestland, 19.6 % of the forestland is held by owners of less than 50 acres (Sampson and DeCoster, 1997). Much of the emphasis has been on incentives to expand carbon sinks on private lands in the U.S. On private lands, policy makers rely heavily on market incentives and change of management methods to encourage carbon sequestration. In the constant-price scenarios, GHG mitigation declines over time, as landowners react early to incentives. Declining rates of mitigation are the result of carbon saturation, harvests, and the conversion of forests back to agriculture. In the rising-price scenarios, GHG mitigation increases over time as landowners are assumed to fully recognize that prices will rise and therefore employ some mitigation actions later.

Table 1 compares results from constant carbon price scenario in Murray *et.al.* (2005), eight comparable U.S. studies reviewed by Richards and Stokes (2004), and results from Sedjo *et.al.* (2001). The results in the studies reviewed by Richards and Stokes (2004) vary widely, due to compounding factors such as the extent of ecosystem components included in the carbon calculations, the biophysical foundation for the carbon sequestration rates used, and the land costs included in cost calculations. The results from Sedjo *et.al*. (2001) are for all of North America. The FASOM-GHG model in Murray *et.al.* (2005) used a more detailed modeling of land opportunity costs in U.S. agriculture sector. This produces a more elastic afforestation response than Sedjo *et.al.* (2001), which relies on a single inelastic land-use supply function from agriculture.

Carbon sequestration (Tg CO_2 Eq. per Year)							
Activity	GHG Price Scenario ($/t CO_2 Eq.)						
	$5	$15	$30	$50	$1.36-$40.87	$13.62	$27.25
	Murray, *et. al.*(2005)				Richard and Stokes (2004)	Sedjo, *et.al.* (2001)	
Afforestation	2.3	137	435	823	147-2,349		
Forest management	105	219	314	385	404		
Total forest carbon	107	356	749	1208	551-2753	265	563

Table 1. Comparison of constant carbon price scenario on private lands.

There are 317 million acres public forest land (Vesterby and Krupa, 2001) in the United States, mainly in the Rockies, Southwest, and Pacific Coast. The top six states in order of public timberland area are Oregon, Idaho, Montana, California, and Colorado/Washington (tied). Studies of carbon sequestration on public land concentrate on changes of forest management methods and variation of harvest levels.

Depro *et al.* (2008) found that a ‘‘no timber harvest’’ scenario eliminating harvests on public lands completely would result in an annual increase of 17–29 million metric ton of carbon (MMTC) per year between 2010 and 2050—as much as a 43% increase over current sequestration levels on public timberlands and would offset up to 1.5% of total U.S. GHG emissions. Small reductions in private harvest could offset substantial losses of carbon flux on federal timberlands caused by increased federal harvest (Im, *et. al.* 2009). The more limited work regarding estimates of public lands’ contribution to the U.S. carbon sink pertains to the projection of the status quo or business-as-usual case or BAU (Turner *et. al.* 1995) or to regional contributions (e.g., Alig *et. al.* 2006).

Sequestration cost

Stavins and Richards (2005) synthesized major studies of carbon sequestration cost analysis and showed that for a marginal cost range of $25 - $75 per short ton of carbon, the U.S. could sequester nearly 300 million tons of carbon annually ($7.50 - $22.50 per metric ton of CO2-

equivalent). When increasing the range to $30 - $90 per ton, 500 million tons of carbon could be sequestered annually. Murray *et. al.* (2005) showed that carbon sequestered on a low productivity site are more costly than carbon sequestered on a high productivity site, and per-acre payment approach is less efficient than the per-tonne approach.

Barriers to synthesis:

Due to different units of measurement, geographic scope, time horizon, mitigation activities and methods, carbon sequestration studies are problematic to compare. In addition, carbon might be reported in annual averages, cumulative or annualized equivalent amounts and in either metric or English units. One way to make the studies comparable is to normalize the results into equivalent annual carbon flows over a fixed time horizons.

Acknowledgements:

I would like to thank Dr. Anne Wein of the Western Geographic Sciences Center for many valuable insights into identifying the most relevant literature and methods for abstracting and organizing relevant information. I thank the United States Geological Survey (USGS) for the opportunity to develop the ideas expressed here in the course of completing contract research assignments for them. Note that any mistakes or errors in this manuscript are my own and that this is not a USGS information product.

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POSTERS

Dorison, A. and N.C. Poudyal. Climate Change and the Demand for Forest-based Recreation.

Parajuli, R. and S.J. Chang. Carbon Sequestration and Uneven-aged Management of Loblolly Pine Stands in the Southern USA: A Joint Optimization Approach.

Climate Change and the Demand for Forest-Based Recreation

$OFEW

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Introduction

Increasing temperature, drought, and frequent storms are often linked with climate change. Climate change trends may put nature-based outdoor recreation activities such as hunting and wildlife viewing at risk. Recent surveys of recreation participation have determined that both the number of participants and participation days in both of these activities has steadily declined over the past 15 years. This corresponds to the period with a gradual increase in a number of climatic incidences such as drought, heat, storms, precipitation etc. Climate change is expected to affect outdoor recreation in a number of ways (Mendelsohn & Markowski, 1999).

- Climate change may affect the enjoyment of particular outdoor activities due to excessive heat, cold, rain, etc.
- Warming will expectedly shorten winter seasons and lengthen summer ones, altering recreation routines.
- Climate changes may alter the ecology of the ecosystem and in turn change the quality of benefits associated with recreating in a given area and reduce the consumer surplus.

The objective of this study is to explore the relationship between demand for forest based recreation and a number of different variables explaining the climate change in the *Southeastern United States.

Materials and Methods

State level data on demand for forest recreation activities were combined with the climatic data of corresponding years to investigate if states experiencing seasons of extreme climatic conditions observed any decline in demand. Demand was measured in terms of days of participation by residents and non-residents for two major forest-based activities, hunting and wildlife viewing. Similarly, climatic conditions were captured by using three different measures, average temperature, precipitation and drought index for the seasons relevant for the activity. Recreation days data was obtained from the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Activities from the years 1991, 1996, 2001, and 2006. The climatic data for same years was obtained from the National Climatic Data.

Exploring the relationship started with a simple scatter plot analysis. Since some of the states have larger demand simply because they are bigger in population, we expressed the demand in per capita terms. To evaluate the extent of association between demand and climatic variables, we fitted a regression line following Mendelsohn & Markowski (1999). As this is not a smooth time series dataset, this study assumes that all the observations are independent. Based on the R squared values, equations were selected to decide between a linear and non-linear relationship. Per capita demand for hunting and wildlife viewing was projected for the years 2050 and 2080 by plugging projected climate change data (A2 scenario) into the regression equation.

*Southeastern states include: AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA

Fig. 1: Hunting Days Per Capita Vs. Average Temperature

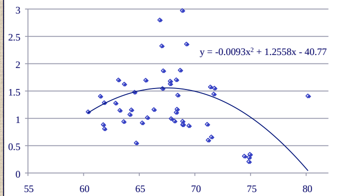


Fig. 4: Wildlife Viewing Per Capita Vs. Average Temperature

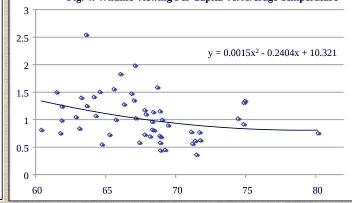


Fig. 2: Hunting Days Per Capita Vs. Average Precipitation

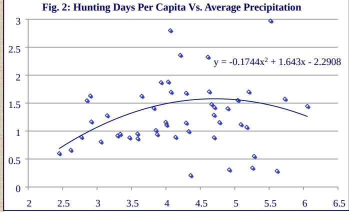


Fig. 5: Wildlife Viewing Per Capita Vs. Average Precipitation

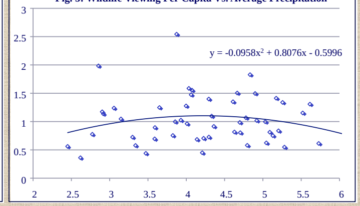


Fig. 3: Hunting Days Per Capita Vs. Average Drought Index

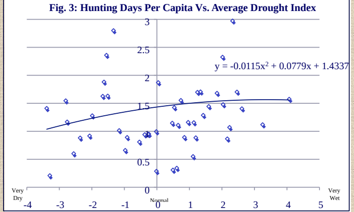
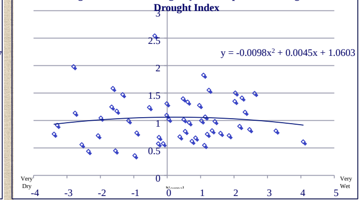


Fig. 6: Wildlife Viewing Days Per Capita Vs. Average Drought Index



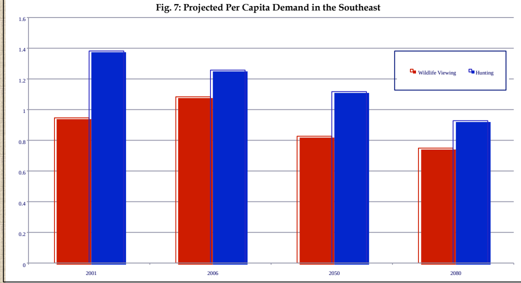
Results and Discussion

Results from the scatter plot graphs and fitted regression equations are shown in figures (1-3 for hunting, and 4-6 for wildlife viewing). In all cases, polynomial equations exhibited better fit over linear equations, indicating that the effects of these climatic variables on recreation demand are mostly non-linear.

Demand for hunting days increased with some initial increase in temperature and precipitation, but eventually declined with further increase in heat and precipitation. This indicates the slight increase in temperature and precipitation may increase the demand for forest-based recreation, but excessive heat and precipitation could hurt the demand. Demand for hunting days will decline during extreme drought and extremely wet seasons, but may increase during near normal seasons.

Similar to demand for hunting days, increases in precipitation had similar effects on demand for wildlife viewing days, but increases in temperature were negatively related with the demand. Further, per capita wildlife viewing days was maximized at the center of drought scale. Contrasting effect of temperature and drought on hunting and wildlife viewing could be attributed to the potential differences in sensitivity of hunters and wildlife viewers to these climatic conditions.

Fig. 7: Projected Per Capita Demand in the Southeast



A preliminary projection indicates that per capita demand of hunting and wildlife viewing days in the region may decline through 2080 (Figure 7). However, it will be interesting to see if rapid population growth will offset the negative effect of climate change. Forest managers and recreation planners could use this information to understand how the use of forests for these non-timber benefits and the associated economic impacts will be affected by expected climate change.

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Carbon Sequestration and Uneven-aged Management of Loblolly Pine Stands in the Southern USA: A Joint Optimization Approach

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Objective

- To assess management and financial impacts resulting from the integration of carbon sequestration benefits into uneven-aged stands of loblolly pine in the southern USA.

Introduction

Carbon sequestration is regarded as a viable and cost effective option for reducing global greenhouse gas emissions. Several studies(1,2,3) have analyzed joint management effects of carbon and timber under different even-aged forest management scenarios. However, research specifically focused on the inclusion of carbon sequestration benefits into uneven-aged management has received little attention among researchers.

Methods

Growth and carbon data

- USDA Forest Vegetation Simulator (FVS)-Southern Variant (SN).
- Q-ratio of 1.4 and site index of 85 feet (base age 50 years).

Optimization of uneven-aged stands

Generalized Faustmann Formula (4) for calculating land expectation values (LEVs).

$$LEV_1 = e^{-r_1 t_1}\left[V_1\{Q_1(t_1,g_1)\} + \int_0^{t_1} A_{1,j}\, e^{r_1(t_1-j)}\, dj + LEV_2\right] - v_1(g_1) - k_1$$

where,

$V_1\{Q_1(t_1,g_1)\}$ is the stumpage value at the time of harvest.
$A_{1,j}$ represents carbon benefits as an annual income source.
$v_1(g_1)$ is residual growing stock at the beginning of cycle 1.

- Existing stumpage prices in Louisiana: $257/MBF (Doyle) of pine sawtimber and $28/cord of pine pulpwood.
- Carbon prices assumed: $0, $5, $10, $20 and $40 per metric ton.
- We considered the principle of additionality while calculating the carbon sequestration benefits.

Sensitivity analyses

- Interest rates: 4%, 6% and 8%.
- Market stumpage prices of sawtimber and pulpwood (respectively): $257, $28; $350, $35 and $450, $45.

Results

Optimum management schedule (timber only)

We found the optimum cutting cycle of 18 years and residual basal area of 60 square feet with the maximum LEV of $1312.24.

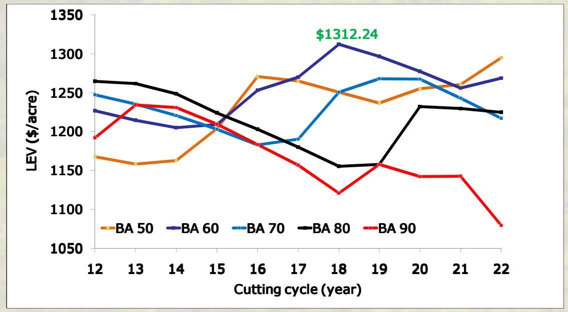

Figure 1. Generalized LEVs ($/acre) associated with various levels of residual basal area and cutting cycle at the current stumpage prices and 4% interest rate.

Changes in interest rate and stumpage prices altered optimum management regimes significantly

Table 1. Increase in stumpage prices of sawtimber and pulpwood increased maximum LEV, cutting cycle and residual BA. The stumpage prices had less impacts on optimum level of management schemes at higher interest rates.

Interest rate (%)	Stumpage price ($)	Maximum LEV ($/acre)	Cutting cycle (years)	Residual BA (sq.ft.)
4	256, 27*	1312.24	18	60
	350, 35	1872.32	26	60
	450, 45	2489.35	26	60
6	256, 27	911.49	5	60
	350, 35	1071.63	6	80
	450, 45	1408.72	12	85
8	256, 27	732.71	5	55
	350, 35	870.22	5	60
	450, 45	1022.78	5	60

*stumpage value of sawtimber ($/MBF) and pulpwood ($/cord) respectively.

Conclusions

- Inclusion of carbon benefits into uneven-aged loblolly pine stands not only increased LEV manifolds but also lengthened cutting cycle significantly.
- Interest rate and stumpage prices had opposite effects on optimum management regimes of uneven-aged loblolly pine stands.

Optimum joint management regimes of timber production and carbon sequestration

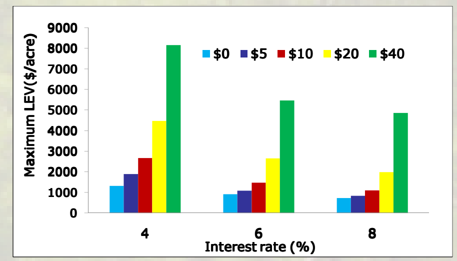

Figure 2. The joint maximum LEVs associated with different carbon prices and interest rates. Lower interest rates had higher LEVs at every level of carbon price.

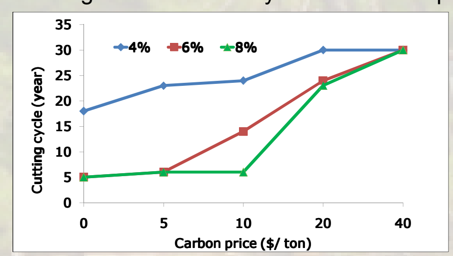

Figure 3. An increase in the carbon price significantly prolonged optimum cutting cycle regardless of the interest rate.

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PRESENTATION SLIDES

Grinnell, J. Project Evaluation of Sustainable Upland Hardwood Management in the U.S. South with the Monetization of Carbon.

PROJECT EVALUATION OF SUSTAINABLE UPLAND HARDWOOD MANAGEMENT IN THE U.S. SOUTH WITH THE MONETIZATION OF CARBON

Joseph Grinnell

Southern Forest Economics Workshop (SOFEW)
Little Rock, AR
March 20-22, 2011

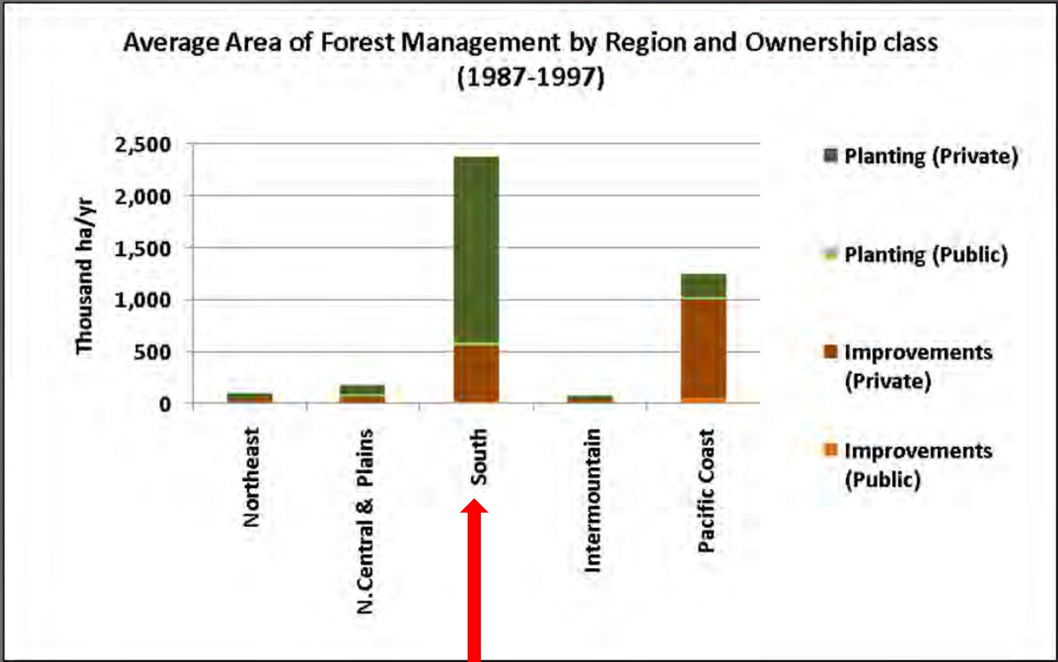
Improved Forest Mngt (IFM) Offsets

- Retaining post-harvest acceptable growing stock above business as usual (BAU) levels
- Slowing harvest cycles
- Minimizing timber harvest impacts
- Prohibition of timber harvesting on working forestland

Improved Forest Mngt Offsets

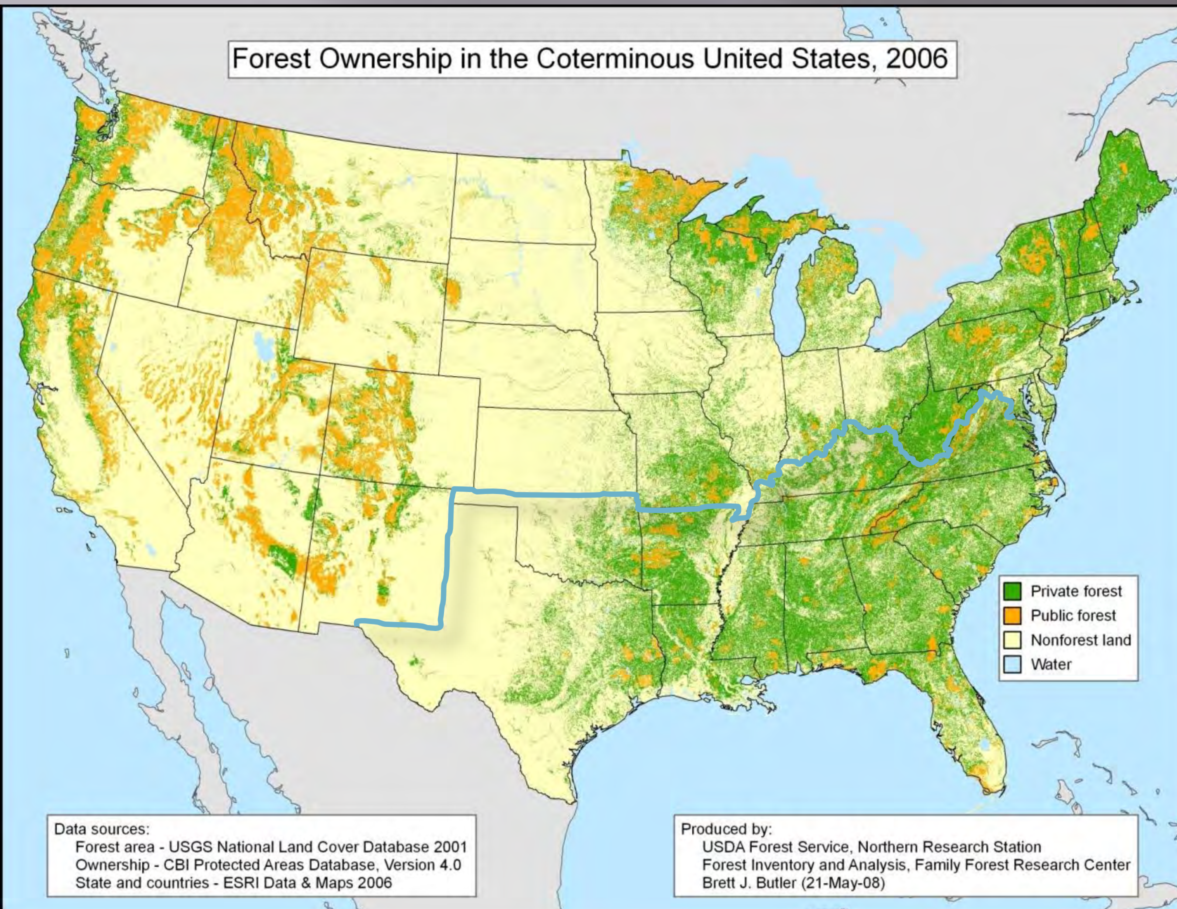
- Focus of many recent studies
  - Applied research on IFM opportunities in upland hardwood forests is exceptionally lacking
    - nearly all studies are focused on industrial plantation management and/or simplistic scenarios

- Case studies informing southern hardwood forest owners and managers of IFM opportunity are essential

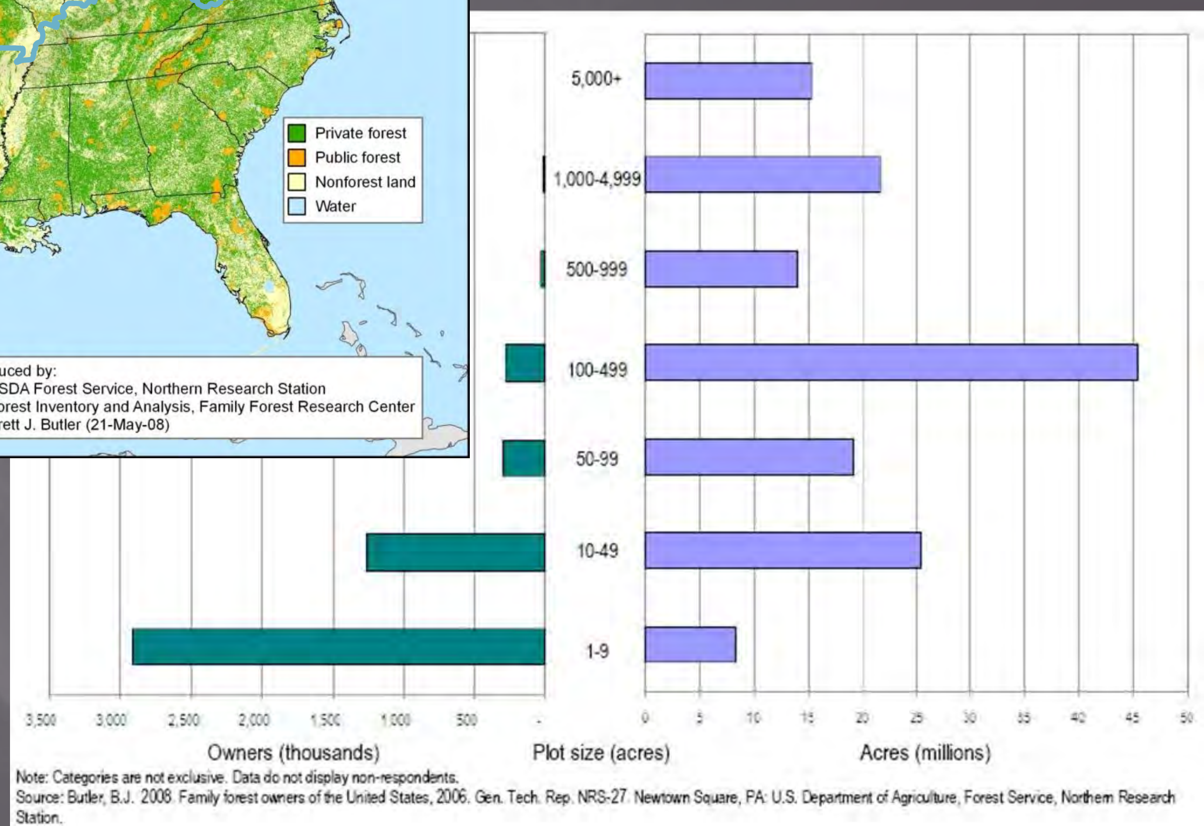


Forest Ownership

SOFEW 2011



- Nearly half of family owned forestland is comprised of 50-499 acre tract sizes and another quarter is comprised of larger tracts, held by 12.1 percent and 0.7 percent of owners respectively



- Past harvesting guided by written management plans occurred on only ~8% of 10+ acre family ownerships controlling 25% of family forestland

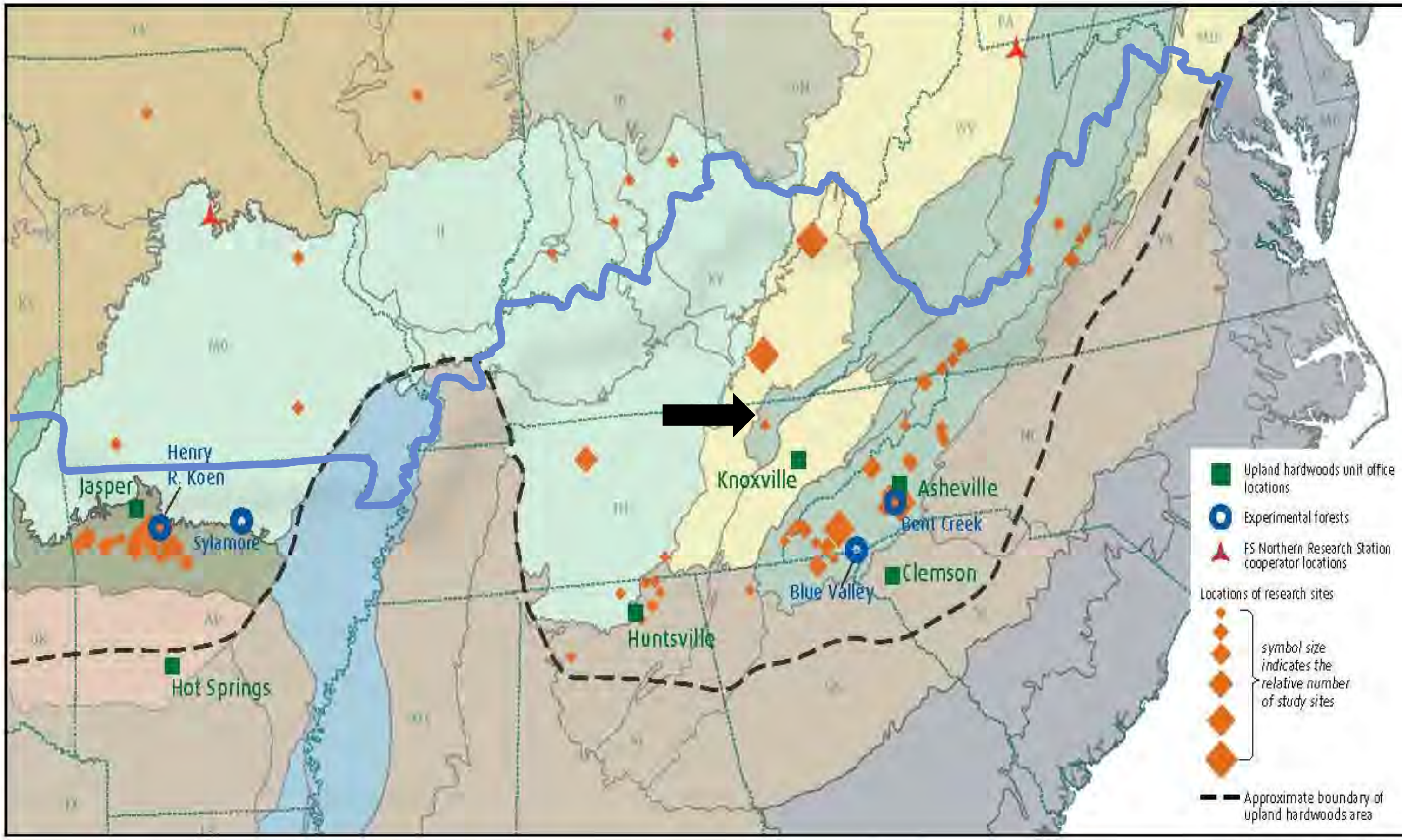
DISTRIBUTION OF UPLAND HARDWOOD FORESTS

Upland Hardwoods Ecology and Management Research Work Unit, SRS

Upland hardwoods unit researchers cooperate with land management agencies across North America to continue to build a comprehensive ecoregion approach to site classification. Ecoregions are defined based on similarities in plant and animal species, climate, soils, and the general topography of the landscape. This method starts with the very broad geographic ecoregions, then focuses on progressively smaller areas—subregions, landscapes, and finally land units. A definitive national ecoregion map was published in 1994. In 2005, a revised national map was produced of ecological subregions that includes digital databases for physical (temperature, precipitation, soils) and vegetation data for each subregion.

Upland Hardwoods Research Work Unit cooperators include:

- University of Kentucky
- Virginia Polytechnic Institute and State University
- Clemson University
- University of Tennessee
- University of Missouri at Columbia
- Alabama A&M University
- North Carolina State University
- University of the South (Sewanee)
- Mississippi State University
- North Carolina Wildlife Resources Commission
- Alabama Wildlife Resources Commission
- The American Chestnut Foundation
- The Nature Conservancy
- Missouri Ozark Forest Ecosystem Project
- Stevenson Land Company
- MeadWestvaco
- Daniel Boone National Forest
- Bankhead National Forest
- Pisgah National Forest
- Ozark-Ouachita National Forest
- Daniel Boone National Forest



Eastern Broadleaf Forest

Continental climate of cold winters and warm summers. Annual precipitation is greater during summer, water deficits infrequent. Topography is variable, ranging from plains to low hills along the Atlantic coast. Interior areas are high hills to semi-mountainous, parts of which were glaciated. Vegetation is characterized by tall, cold-deciduous broadleaf forests.

Midwest Broadleaf Forest

Continental climate with warm to hot summers. Frequent growing season water deficits. Flat to hilly terrain with features associated with former glaciation. Vegetation consists of cold-deciduous, hardwood-dominated forests with a high proportion of species able to tolerate mild, brief, periodic drought during the late summer.

Interior Broadleaf Forest

Continental climate with hot summers. Summer soil moisture deficits are common. Vegetation is broadleaf deciduous forests with a somewhat open canopy and greater density of species tolerant of drought.

Appalachian Broadleaf Forest

Temperate climate with cool summers and short, mild winters. Annual precipitation is plentiful and evenly distributed with short periods of water deficit. Landscapes are predominantly mountainous. Forest vegetation is characterized by a closed canopy of mainly oaks; broadleaf forests change to coniferous or shrub lands at higher elevations. Ice storms are an important broad scale disturbance. High-intensity rain storms are associated with remnants of occasional hurricanes; lightning-caused fires are uncommon.

Boston Mountains

Continental climate with cold winters and hot summers. Landscape is low mountains formed by dissection of sedimentary formations. Forest vegetation is predominately broadleaf deciduous species that can tolerate brief periods of drought.

Southeastern Mixed Forest

Generally uniform maritime climate with mild winters and hot, humid summers. Annual precipitation is evenly distributed, but a brief period of mid to late summer drought occurs in most years. Landscape is hilly with increasing relief farther inland. Forest vegetation is a mixture of deciduous hardwoods and conifers.

Ouachita Mixed Forest

Continental climate, with short, cool winters and long, hot summers. Precipitation occurs throughout year, but summers are dry. Vegetation consists of mixed needle leaf and cold-deciduous broadleaf forests.

Outer Coastal Plain Mixed Forest

Humid, maritime climate; winters are mild and summers are warm. Precipitation is abundant with rare periods of summer drought. Upland forest vegetation is dominated by conifers, with deciduous hardwoods along major floodplains.

Lower Mississippi Riverine Forest

Climate with warm winters and hot summers. Precipitation occurs throughout the year with minimum in fall. Much of this subregion is influenced by periodic flooding of the Mississippi River.

Prairie Parkland (Temperate)

Continental climate with cold winters and hot summers. Moderate amounts of precipitation that occurs mainly during growing season. Landform is mainly plains with areas of low hills. Vegetation was once herbaceous with woodland of scattered deciduous broadleaf trees along floodplains of major rivers; almost all has now been cleared for agriculture.

Prairie Parkland (Subtropical)

Modified maritime subtropical, humid climate of relatively warm winters and hot summers. Moderate amounts of precipitation occurring during summer. Landforms are plains with low hills. Vegetation is mainly herbaceous with areas of deciduous broadleaf woodland, particularly along floodplains.

Pervasive Mismanagement of Upland Hwds

- Diameter limit (DL) cutting is the most commonly employed harvesting practice in Appalachia and in hardwood forests generally
  - Rarely administered by foresters, and in turn, result in exploitation
    - on decent sites (Red Oak site index 65+), this reduces biodiversity similar to that resulting from single-tree selection harvests by allowing shade tolerant maples to dominate
    - Leaves the stand less capable of producing quality sawtimber from desirable species

Oak Decline

- If management and low intensity wildfire are absent…
  - biodiversity also regresses
  - red oak species become increasingly vulnerable to "Oak decline"
    - "Oak decline" is a natural disease complex that can only be forestalled by active mngt (recommended if >25% RO in stand)
  - Gypsy moth invasion from the North is an increasing threat because they prefer oak leaves and exacerbate the incidence and severity of "Oak decline"

Oak Decline

- The longest running experiment in hardwood silviculture portends the elimination of all oak seed sources and competitive advance regeneration with continued DL cuts
- Despite their dominance across the Appalachian landscape for the last 2000 years, upland oak forests now face a ominous future in the absence of recommended oak-sustaining silviculture
  - 80% of oak forests in the eastern U.S. are owned by non-industrial private forest owners so their conservation will rely on widespread adoption of oak-management on NIPF land
    - A marked decline of oaks will catalyze an unprecedented change in upland hardwood ecosystems

Potential Reinforcement of Perverse Incentives

- Hardwood markets incentivize high-grading and there may be an ensuing rise in such activity as timber prices recover with the economy
  - High-grading and absence of wildfire induces maple dominance
    - Maple dominance increases stand density
      - Higher stand density results in greater live tree carbon stocks
      - Abundance of shade tolerant species stimulates periodic annual growth approaching that of even-age mngt.
  - High-grading markedly reduces subsequent timber values
    - Lower timber value facilitates passive or no mngt.
    - Passive or no mngt. more favorable for carbon value

Study Objective and Area

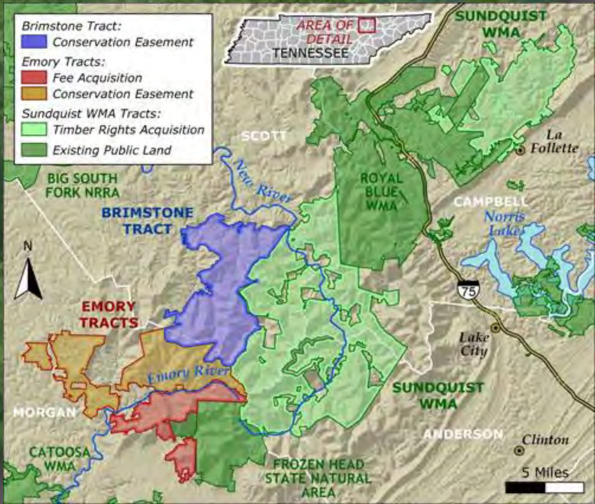
- Provide the first real world project-scale assessment of sustainable upland hardwood management under the new national Climate Action Reserve (CAR) Forestry Project Protocol (finalized Aug. 2010)

  - **Research Question**: For typically-managed FFO mature timberland, can the switch to a sustainable harvesting scenario employing oak silviculture generate a financially viable amount of CAR emission reductions?

  - Given that potential earnings from carbon sequestration are not likely to outweigh those of timber harvesting, the IFM management regime simulated was intended to still reflect timber-driven forest management

Study Area: Cumberland Mountains of TN

- Continuous forest inventory (CFI) data and separate regeneration sampling data provided by The Forestland Group, LLC (in yellow and red areas of map)



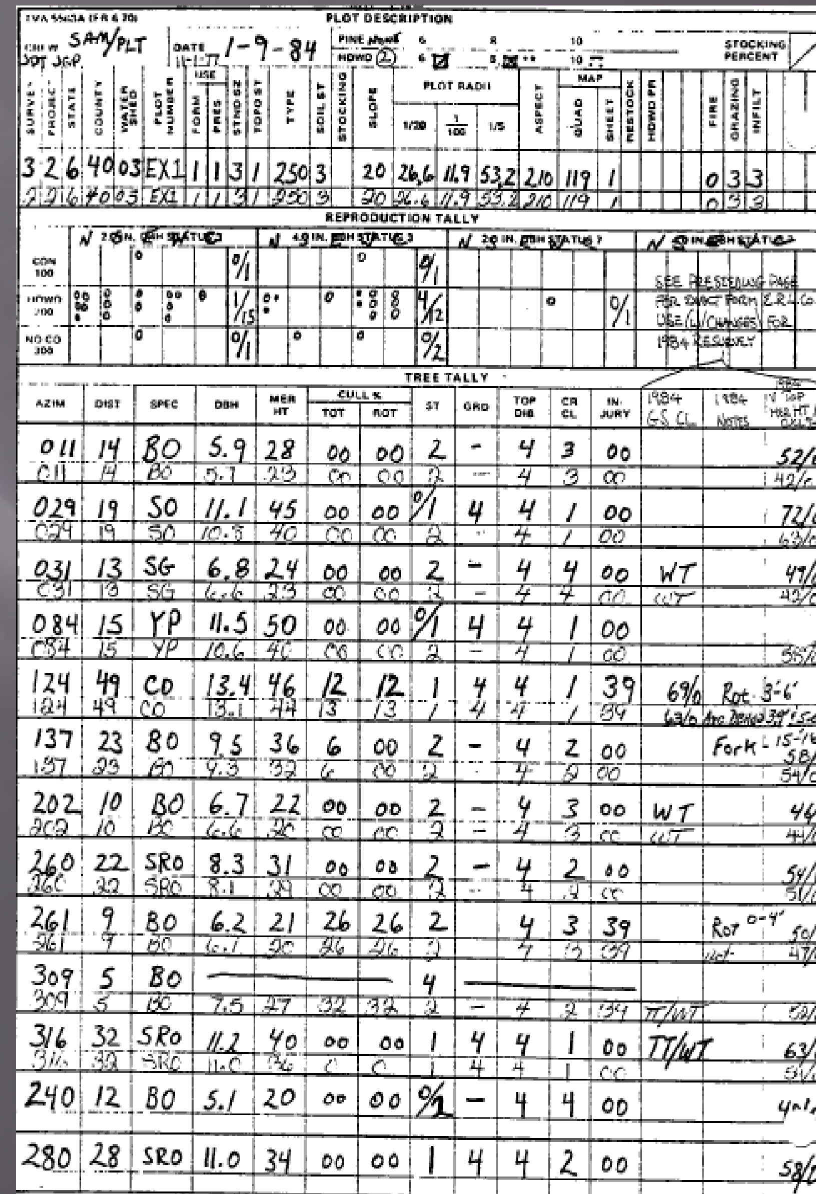
Key Assumptions

SOFEW 2011

- BAU knowledge/attitudes held by the hypothetical owner(s) and heir(s) result in short-term profit maximization with 4% real time value of money
- same operational BMPs applied in BAU and project scenario
- large natural disturbances and climatic changes are ignored
- timber prices start at 2007 lows and grow 1%/yr
- carbon price grew at zero or 1%/yr (i.e. assuming Hotelling rule is inapplicable)
- live tree and standing dead tree C pools only
- 15% Reversal Risk Rating (C credit discount)
- part of an aggregate of 24 IFM projects under 1 of the approved sustainability certification systems
- sustainability certification costs were ignored or assumed to be included in project development/implementation costs

Inventory Data

- Inventories done in 1984 and 1994
  - Stand characteristics indicated 60-69 and 70-79 yr age-classes respectfully
  - Conditions in each inventory represent those of ~1/5 of even-aged timberland in the region
  - 84' data was simulated b/c such a project would be less likely to earn credits at the outset for above-average carbon stocks



PLOT DESCRIPTION

SURVEY-PROJECT	STATE	COUNTY	WATERSHED	PLOT NUMBER	FORM	PRES	STND SZ	TOPO ST	TYPE	SOIL ST	STOCKING	SLOPE	PLOT RADII 1/20	1/100	1/5	ASPECT	QUAD	SHEET	RESTOCK	HDWD FR	FIRE	GRAZING	INFILT
3	2	6	40	03	EX1	1	1	3	1	250	3	20	26.6	11.9	53.2	210	119	1			0	3	3
3	2	6	40	03	EX1	1	1	3	1	250	3	20	26.6	11.9	53.2	210	119	1			0	3	3

REPRODUCTION TALLY

SEE PRECEDING PAGE FOR DIRECT FORM E.R.Co. USE (L) CHANGES FOR 1984 RESURVEY

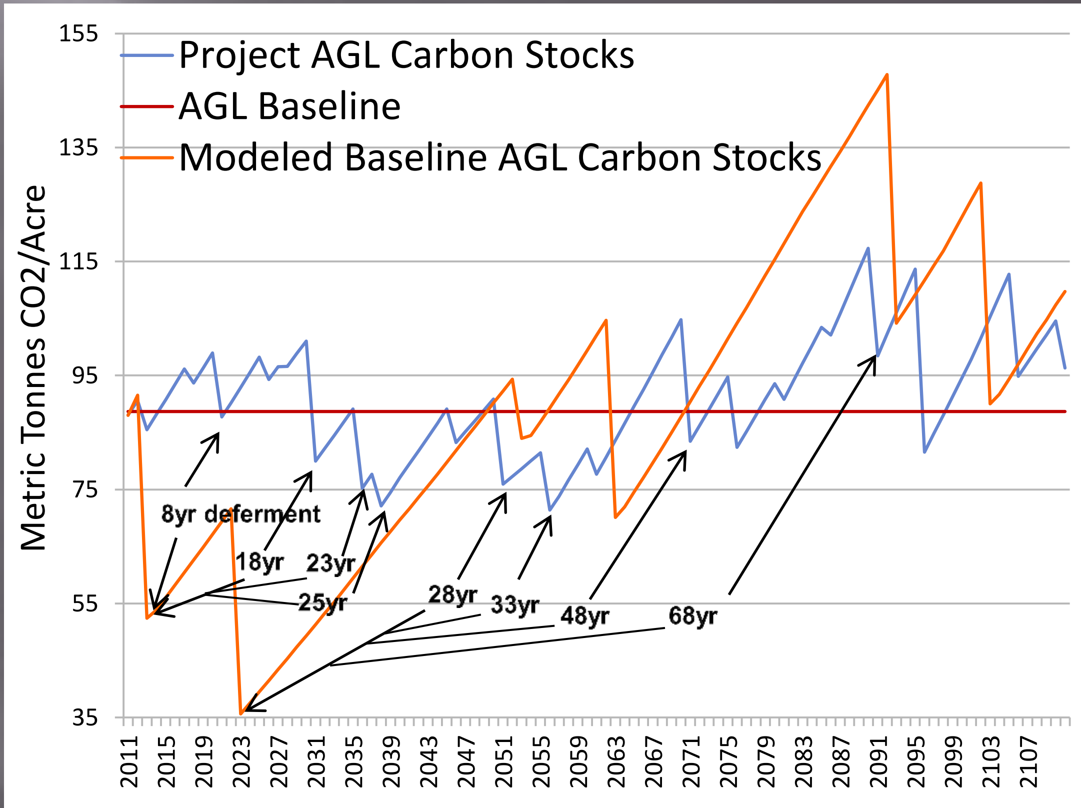
TREE TALLY

AZIM	DIST	SPEC	DBH	MER HT	CULL % TOT	CULL % ROT	ST	GRD	TOP DIB	CR CL	INJURY	1984 GS CL	1984 Notes	1984 TOP HGT
011	14	BO	5.9	28	00	00	2	-	4	3	00			52/0
011	14	BO	5.7	23	00	00	2	-	4	3	00			42/0
029	19	SO	11.1	45	00	00	0/1	4	4	1	00			72/0
029	19	SO	10.5	40	00	00	2		4	1	00			63/0
031	13	SG	6.8	24	00	00	2	-	4	4	00	WT		49/0
031	13	SG	6.6	23	00	00	2	-	4	4	00	WT		42/0
084	15	YP	11.5	50	00	00	0/1	4	4	1	00			?
084	15	YP	10.6	40	00	00	2	-	4	1	00			55/0
124	49	CO	13.4	46	12	12	1	4	4	1	39	6%	Rot 3'-6'	
124	49	CO	13.1	44	13	13	1	4	4	1	39	63/0	Arc Dead 39' 5.0'	
137	23	80	9.5	36	6	00	2	-	4	2	00		Fork 15'-16'	58/0
137	23	80	9.3	32	6	00	2		4	2	00			54/0
202	10	BO	6.7	22	00	00	2	-	4	3	00	WT		44/0
202	10	BO	6.6	20	00	00	2	-	4	3	00	WT		44/0
260	22	SRO	8.3	31	00	00	2	-	4	2	00			54/0
260	22	SRO	8.1	29	00	00	2		4	2	00			51/0
261	9	80	6.2	21	26	26	2		4	3	39		Rot 0-4'	50/0
261	9	80	6.1	20	26	26	2		4	3	39			47/0
309	5	BO					4							
309	5	BO	7.5	27	32	32	2	-	4	2	39	TT/WT		52/0
316	32	SRo	11.2	40	00	00	1	4	4	1	00	TT/WT		63/0
316	32	SRO	11.0	36	0	0	1	4	4	1	00			51/0
240	12	BO	5.1	20	00	00	0/1	-	4	4	00			40/0
280	28	SRO	11.0	34	00	00	1	4	4	2	00			58/0

Simulation Model (much more in paper)

SOFEW 2011

- Forest Vegetation Simulator (FVS) used to build 100yr models
  - Hypothetical 400 acre family forest given by the Reserve's 40ac even-age harvest limit and 10-stand simulation
    - BAU scenario with 12″dbh DL cuts
      - 200ac in year 2 / 200ac in year 12 and in 40 yr cycles thereafter
    - Project scenario with treatments scheduled to balance age-classes and carbon fluxes while regenerating competitive oaks and pursuing quality sawtimber production over long-run



Stand ID	ER24	ER152	ER3	ER25	ER4	ER33	ER1	ER26	ER34	ER35
FIA Type	Sugar Maple -Basswood	Yellow Poplar - White & Red oak	Yellow Poplar	White & Red oak - Yellow Poplar	Chestnut oak	Scarlet oak	Chestnut - Black - Scarlet oak	Chestnut - Black - Scarlet oak	White & Red oak - Yellow Poplar	Sugar Maple - Basswood
1976 Type	Beech-Birch-Maple	Yellow Poplar	Yellow Poplar	Oak-Hickory	Oak-Hickory	Oak-Hickory	Oak-Hickory	White Pine-Hardwoods	Yellow Poplar	Yellow Poplar
Topographic Position	Upper	Middle	Upper	Middle to Lower	Middle	Lower	Middle to Low	Middle	Lower (SMZ)	Middle (SMZ)
Slope percent	40	60	55	35	35	30	50	60	35	55
Aspect	W-NW	NW	NE	W-SW	S-SW	E-SE	W	S-SW	S-SW	N-NE
Site Index$_{50}$	70-Black oak	70-BO	80-YP	65-BO	60-BO	60-BO	65-BO	60-BO	70-BO	70-BO
Size Class*	ST	ST	ST	ST	PT	ST	PT	PT	ST	ST
Trees ac^{-1}	4,244	5,528	708	2,150	1,465	3,155	1,193	1,493	1,083	7,128
Basal area(ft^2 ac^{-1})	80	99	113	97	105	71	155	98	105	78
FIA Stocking Class	Moderate	Full	Moderate	Full	Full	Moderate	Over	Full	Full	Moderate
SILVAH Stocking**	51%	65%	46%	68%	89%	64%	117%	73%	67%	62%
Stand Density Index Stocking	69%	95%	68%	83%	89%	80%	105%	77%	77%	75%
Merchantable volume (ft^3 ac^{-1})	1,740	1,891	2,924	2,122	1,684	1,419	3,041	1,871	2,219	1,520
Sawtimber volume (ft^3 ac^{-1})	1,391	1,429	2,506	1,473	465	822	901	777	1,257	863
MDM(6+"DBH)**	17.8	17.7	16.5	16.6	15.0	13.1	9.2	13.1	13.1	13.9
Effective Age**	94.3	97.5	82.3	91.2	93.3	69.8	53.8	101.1	72.8	75.7
Years to Maturity** (year)	1.0 (2011)	1.9 (2012)	7.7 (2018)	8.0 (2018)	18.3 (2028)	25.8 (2036)	51.8 (2062)	29.7 (2040)	26.7 (2037)	22.4 (2032)
Harvest yr/MDM	2020/18.9	2030/18.8	2035/21.8	2037/24.2	2050/17.8	2055/23.8	2070/19.5	2090/25.6	NA	NA

*ST = Sawtimber; PT = Poletimber

**Metrics in SILVAH (Silviculture of Allegheny Hardwoods) decision support program; MDM = mean merchantable diameter

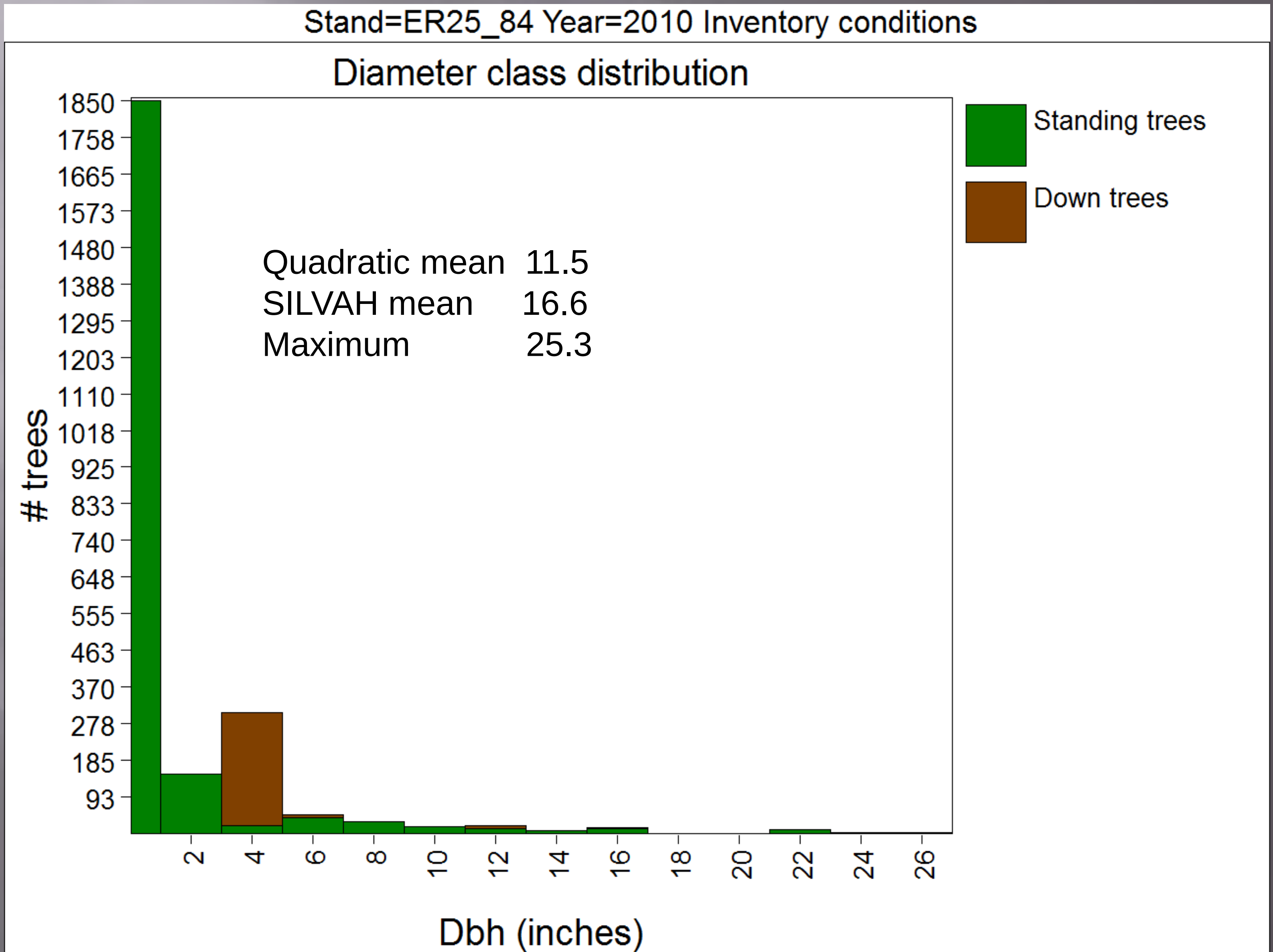
SOFEW 2011

Table 2. Project Treatment Schedule

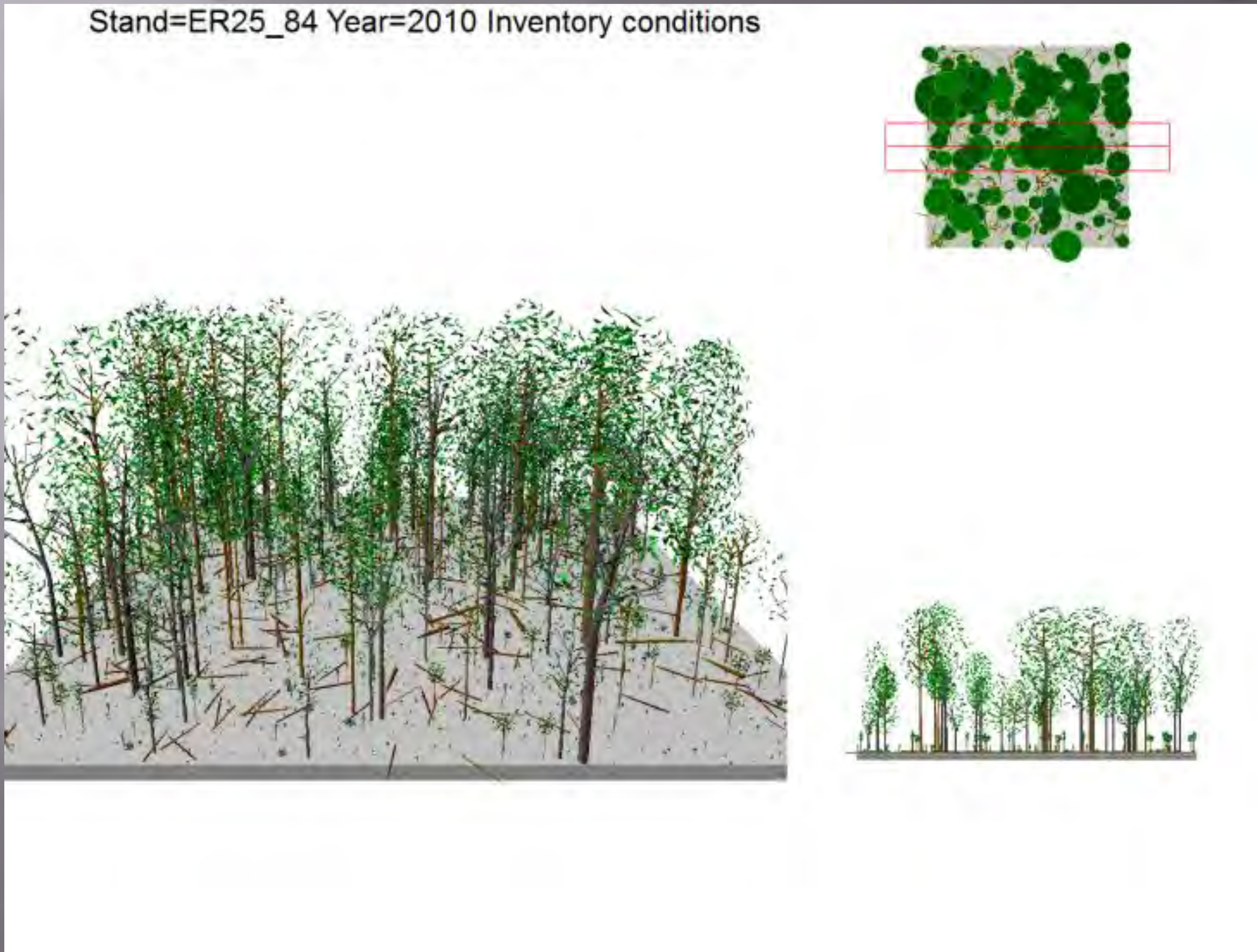
Key: Revenue = Green; Revenue & Cost = Yellow; Cost = Pink

Year	ER24	ER152	ER3	ER25	ER4	ER33	ER1	ER26	ER34	ER35
2013					CTR		CTR			
2018				CTR cut				CTR cut		
2021	Final Cut	prep spraying								SMZ
2026			prep cut		CTR cut					
2028				prep spraying						
2031	PCTR	Final Cut				CTR cut	CTR cut		SMZ	
2036			Final Cut					CTR cut		SMZ
2038				Final Cut						
2046		PCTR	PCTR			prep cut/ spraying				
2051	PCTR			PCTR	Final Cut					
2056						Final Cut			SMZ	SMZ
2061		PCTR/ reserve tree cut	PCTR/ reserve tree cut				prep spraying			
2071	CTR/ DoC			PCTR/DoC/ reserve tree cut			Final Cut		SMZ	
2076			CTR/ DoC/ reserve tree cut		PCTR/ reserve tree cut	PCTR/ reserve tree cut				
2081		CRT/ DoC/ reserve tree cut								
2091	CTR/ DoC							Final Cut	SMZ	SMZ
2096		CTR/DoC	CTR/ DoC	CRT/ DoC/ reserve tree cut	CTR/ reserve tree cut	CTR	PCTR/ reserve tree cut			
2106	Final Cut									
2111		CTR/DoC						PCTR/ reserve tree cut	SMZ	

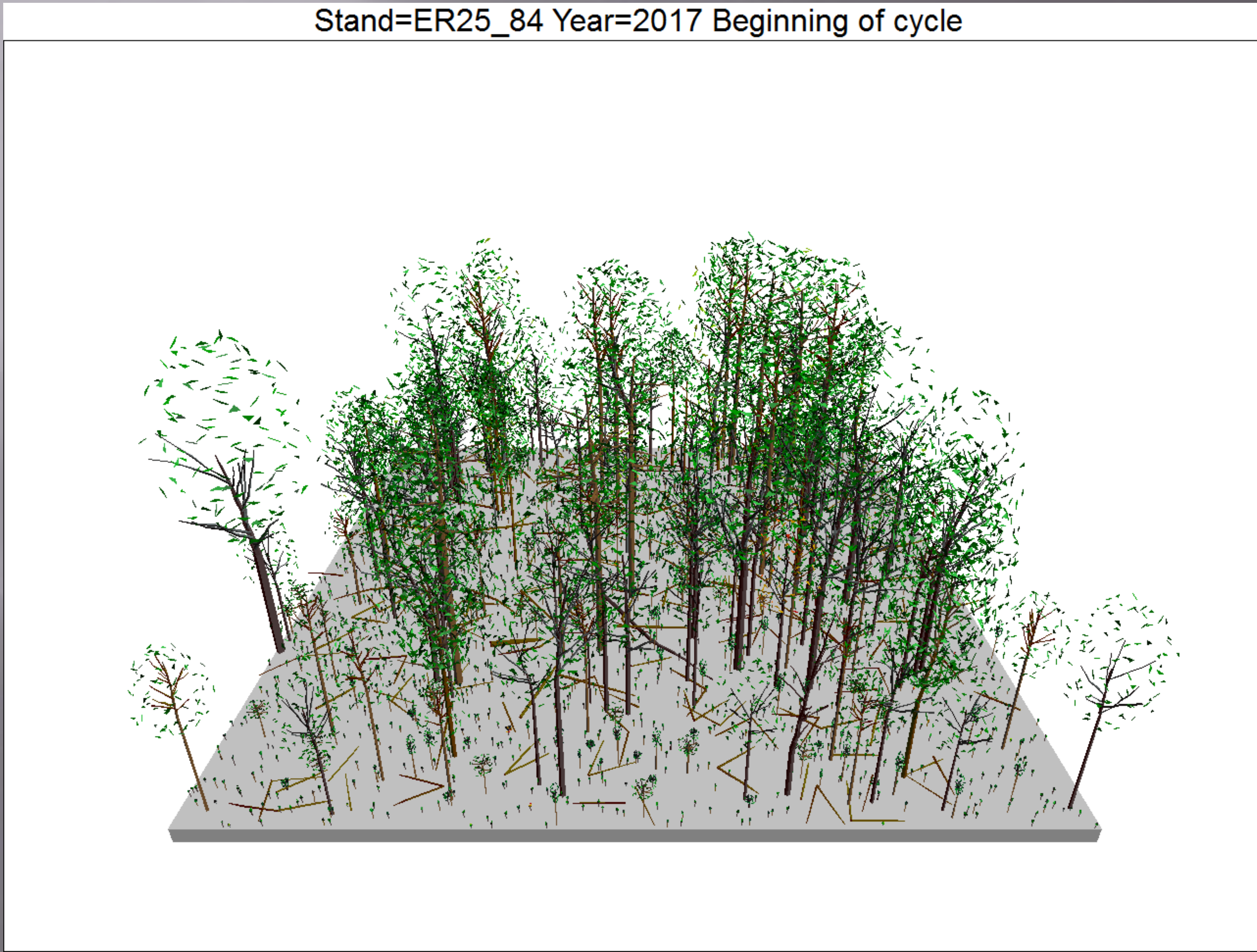
Example Simulation of Oak Mngt



Example Simulation of Oak Mngt

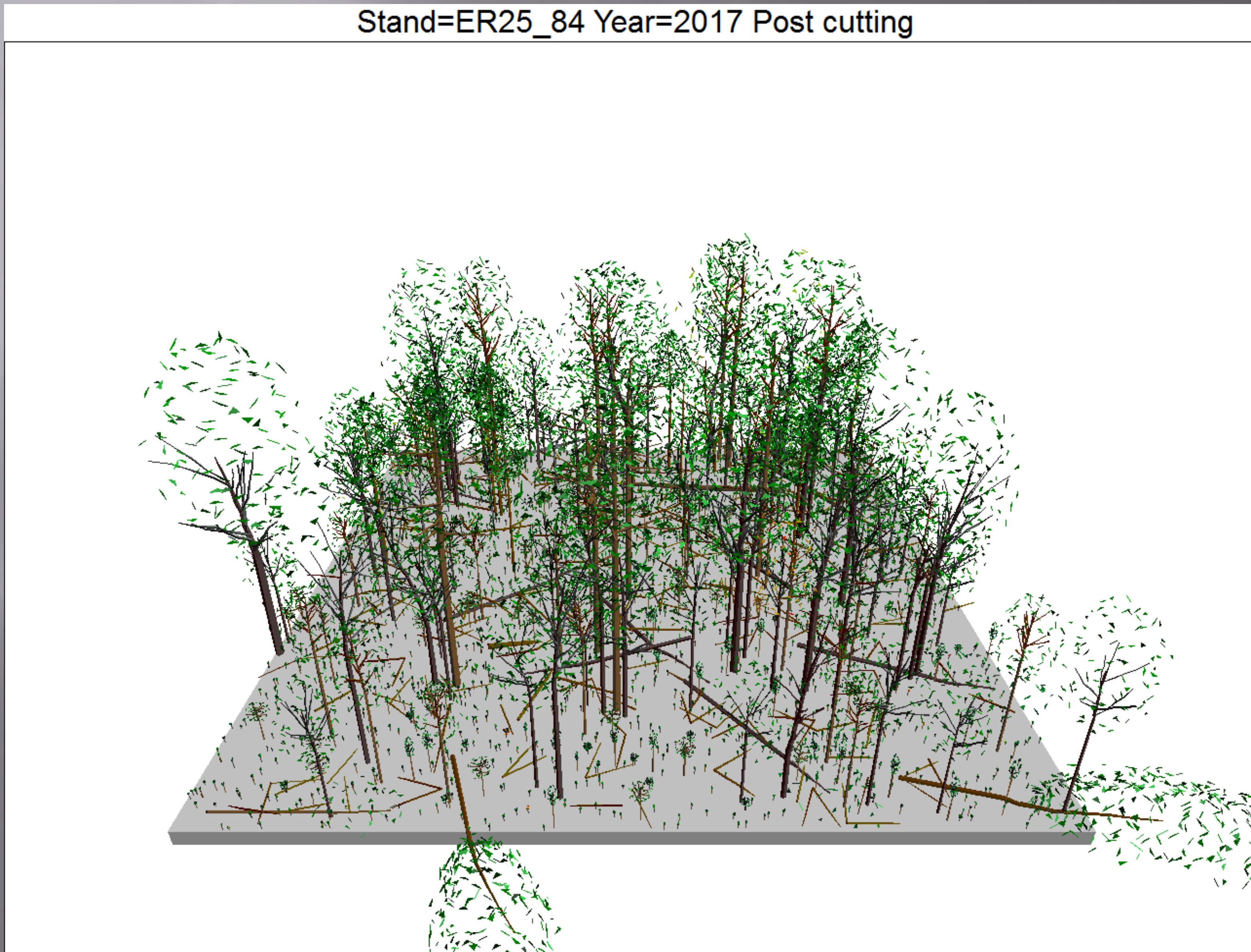


Example Simulation of Oak Mngt



Year	ER25
2012	
2017	CTR cut
2020	
2025	
2027	prep spraying
2030	
2035	
2037	Final Cut
2045	
2050	PCTR
2055	
2060	
2070	PCTR/DoC/ reserve tree cut
2075	
2080	
2090	
2095	CRT/ DoC/ reserve tree cut
2105	

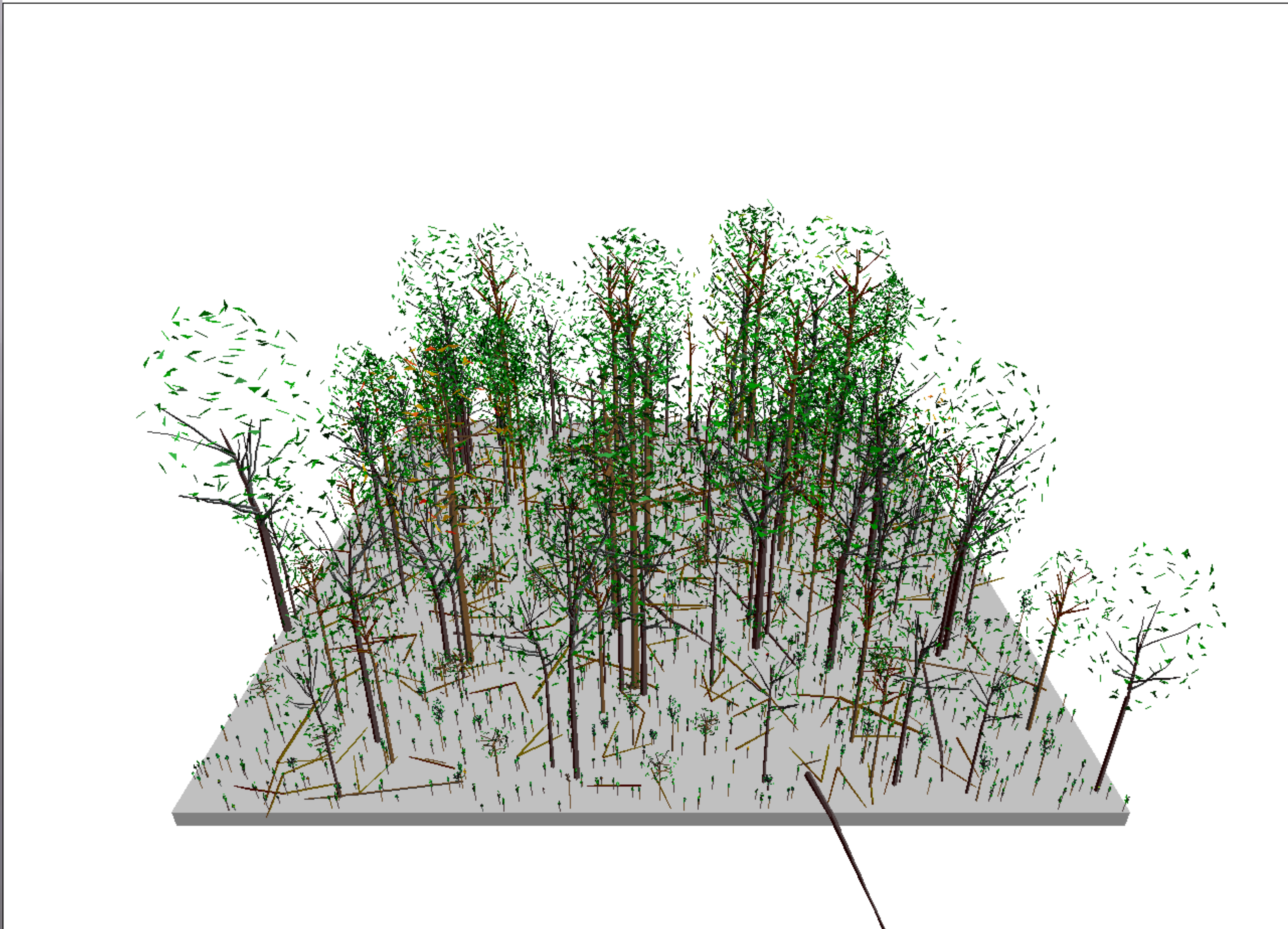
Example Simulation of Oak Mngt



Year	ER25
2012	
2017	CTR cut
2020	
2025	
2027	prep spraying
2030	
2035	
2037	Final Cut
2045	
2050	PCTR
2055	
2060	
2070	PCTR/DoC/ reserve tree cut
2075	
2080	
2090	
2095	CRT/ DoC/ reserve tree cut
2105	

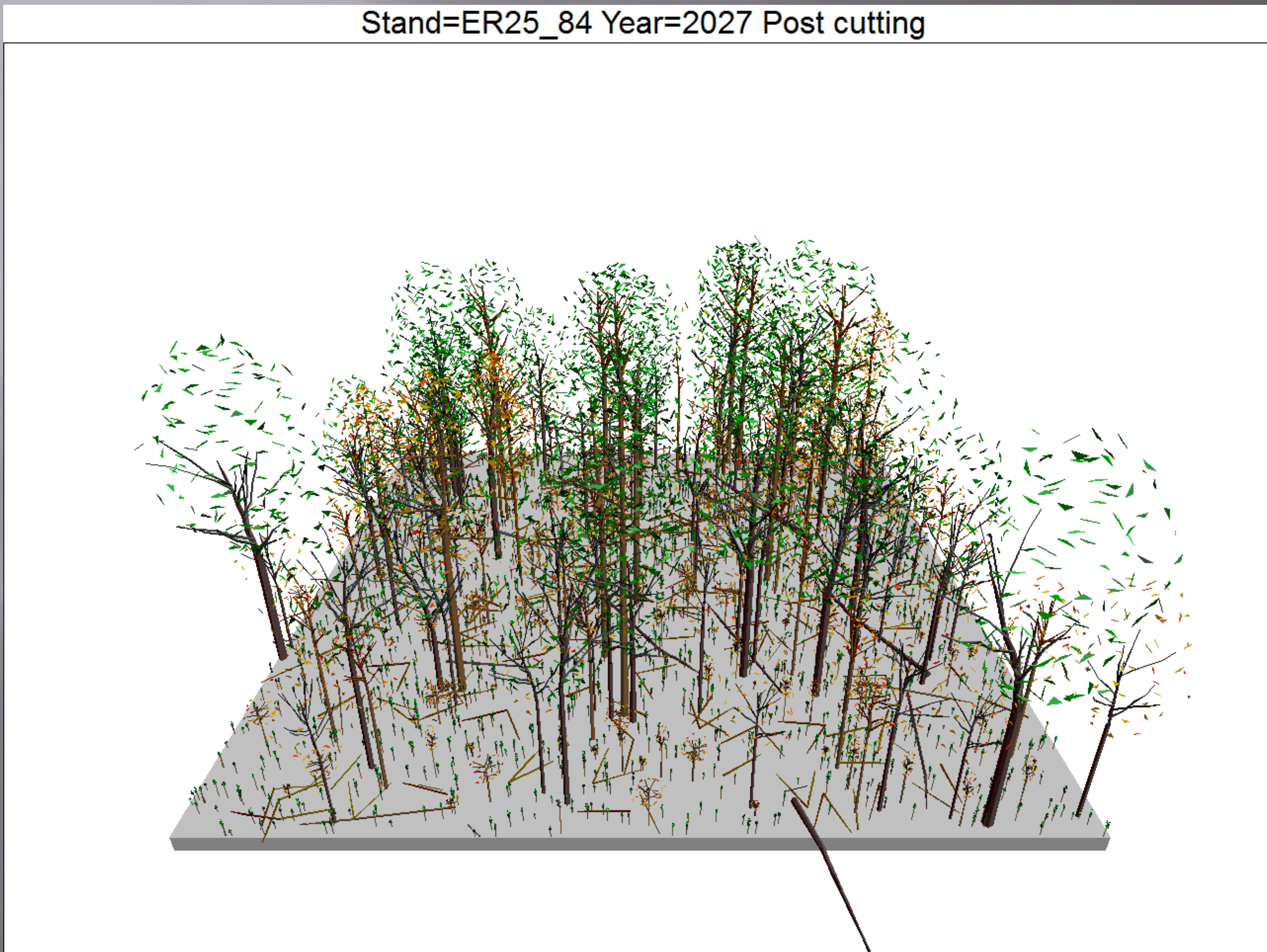
Example Simulation of Oak Mngt

Stand=ER25_84 Year=2027 Beginning of cycle



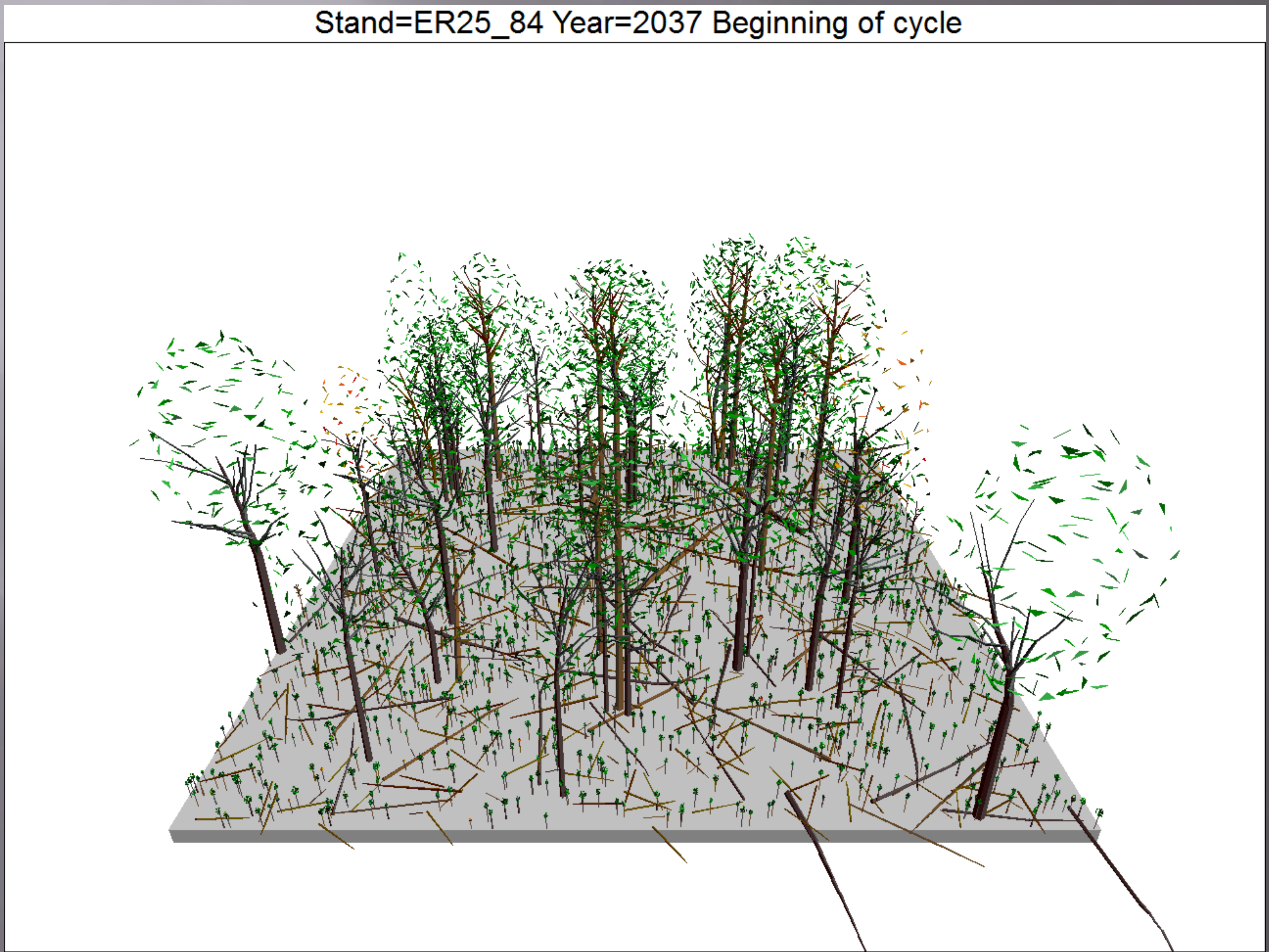
Year	ER25
2012	
2017	CTR cut
2020	
2025	
2027	prep spraying
2030	
2035	
2037	Final Cut
2045	
2050	PCTR
2055	
2060	
2070	PCTR/DoC/ reserve tree cut
2075	
2080	
2090	
2095	CRT/ DoC/ reserve tree cut
2105	

Example Simulation of Oak Mngt



Year	ER25
2012	
2017	CTR cut
2020	
2025	
2027	prep spraying
2030	
2035	
2037	Final Cut
2045	
2050	PCTR
2055	
2060	
2070	PCTR/DoC/ reserve tree cut
2075	
2080	
2090	
2095	CRT/ DoC/ reserve tree cut
2105	

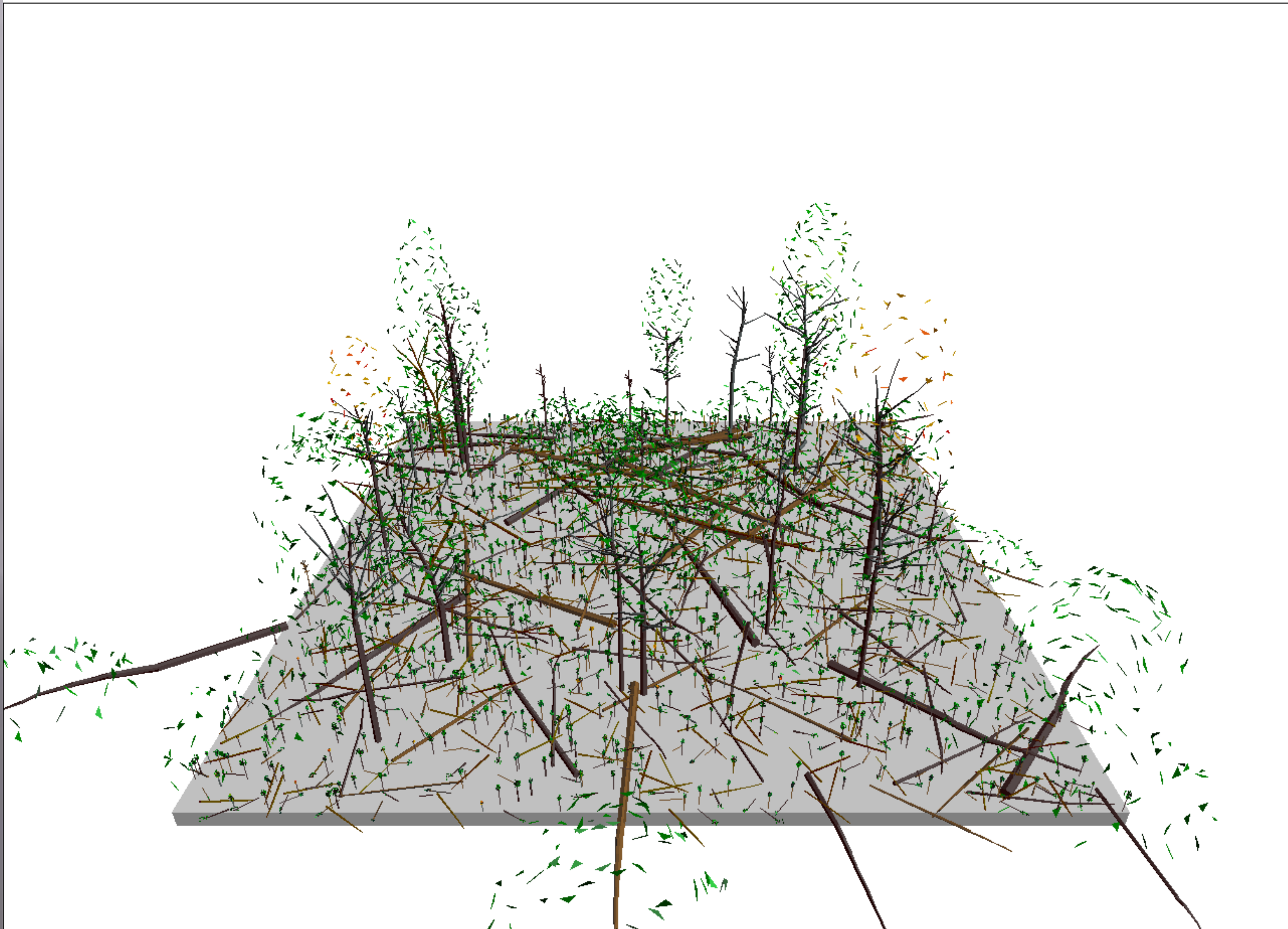
Example Simulation of Oak Mngt



Year	ER25
2012	
2017	CTR cut
2020	
2025	
2027	prep spraying
2030	
2035	
2037	Final Cut
2045	
2050	PCTR
2055	
2060	
2070	PCTR/DoC/ reserve tree cut
2075	
2080	
2090	
2095	CRT/ DoC/ reserve tree cut
2105	

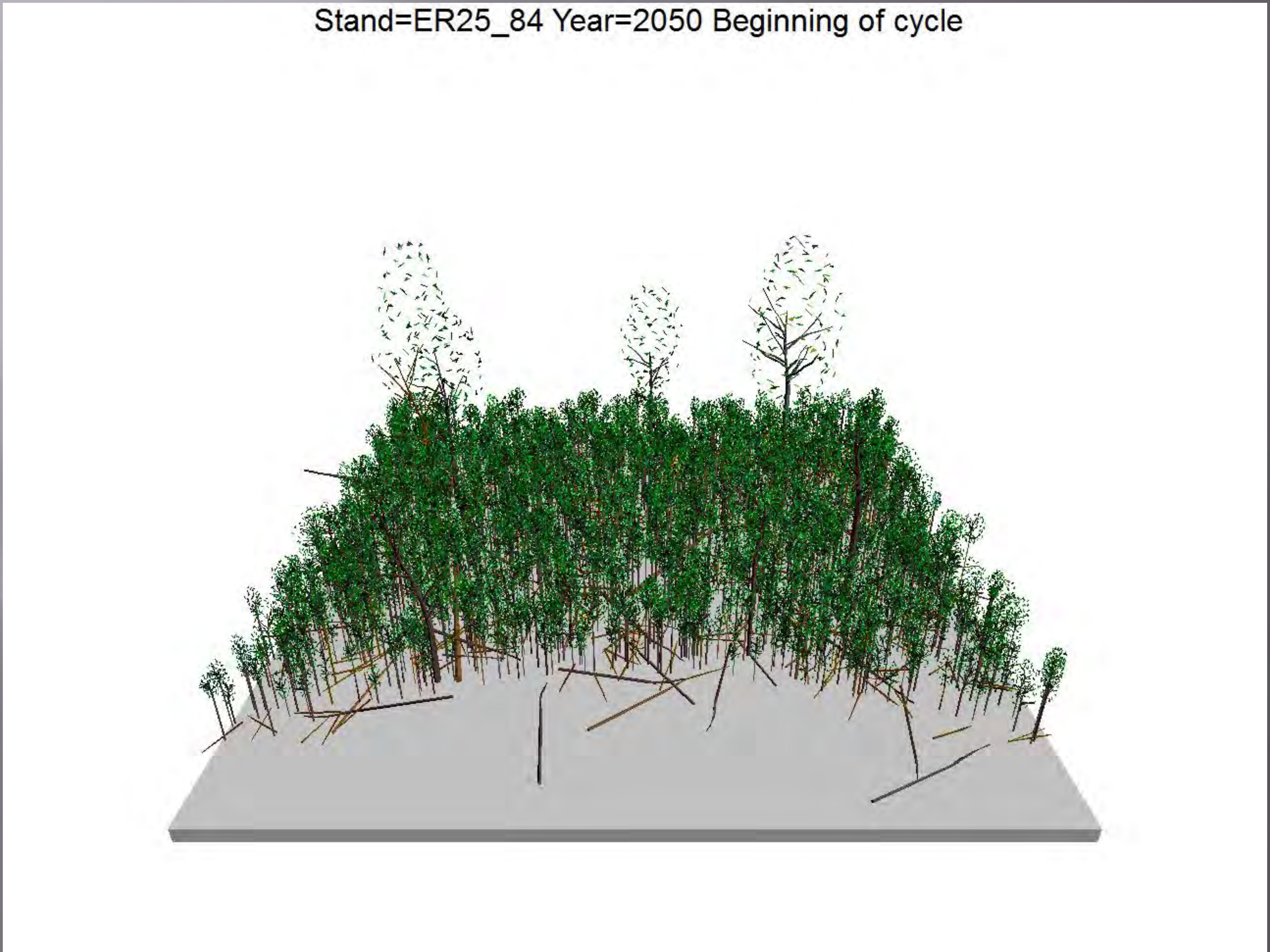
Example Simulation of Oak Mngt

Stand=ER25_84 Year=2037 Post cutting



Year	ER25
2012	
2017	CTR cut
2020	
2025	
2027	prep spraying
2030	
2035	
2037	Final Cut
2045	
2050	PCTR
2055	
2060	
2070	PCTR/DoC/ reserve tree cut
2075	
2080	
2090	
2095	CRT/ DoC/ reserve tree cut
2105	

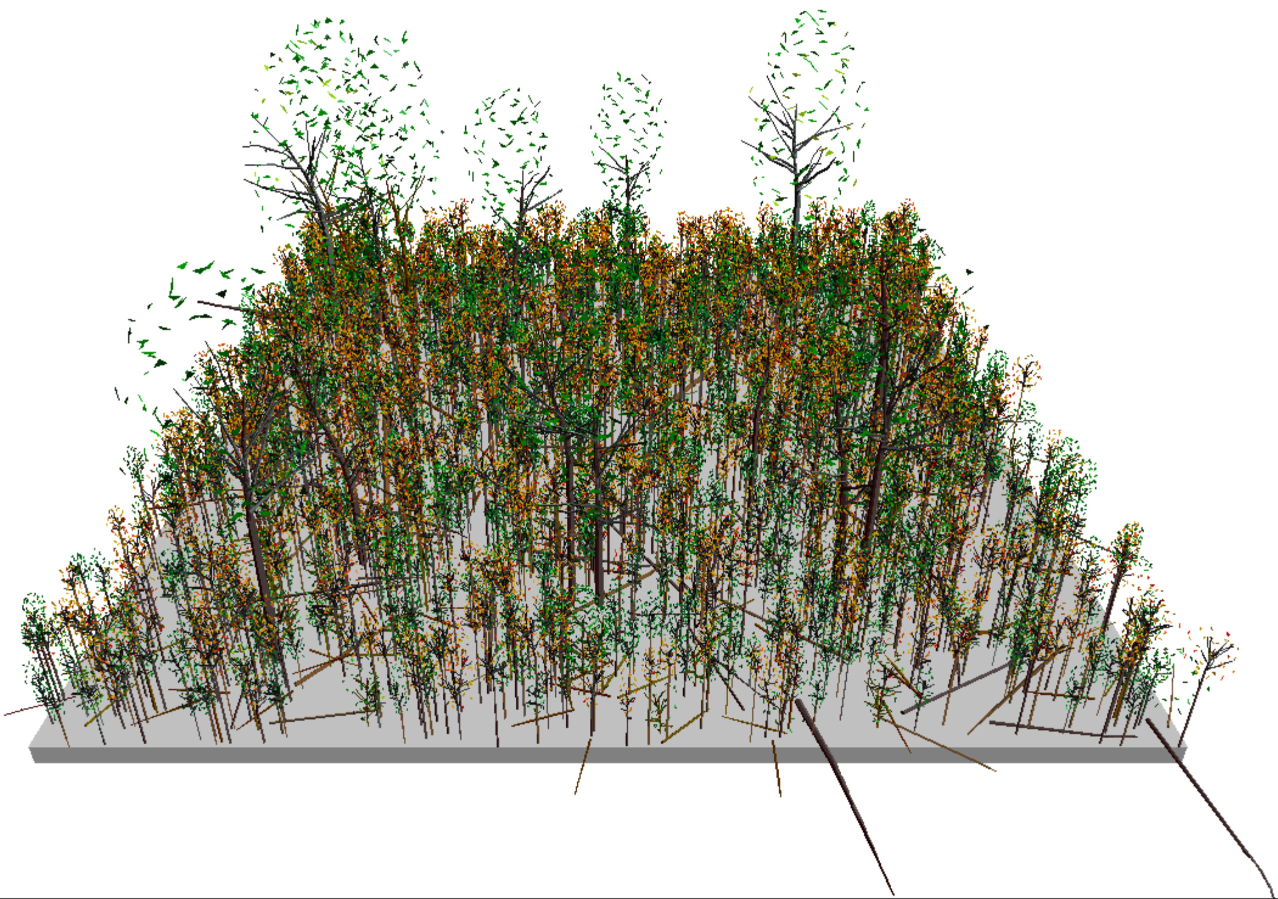
Example Simulation of Oak Mngt



Year	ER25
2012	
2017	CTR cut
2020	
2025	
2027	prep spraying
2030	
2035	
2037	Final Cut
2045	
2050	PCTR
2055	
2060	
2070	PCTR/DoC/ reserve tree cut
2075	
2080	
2090	
2095	CRT/ DoC/ reserve tree cut
2105	

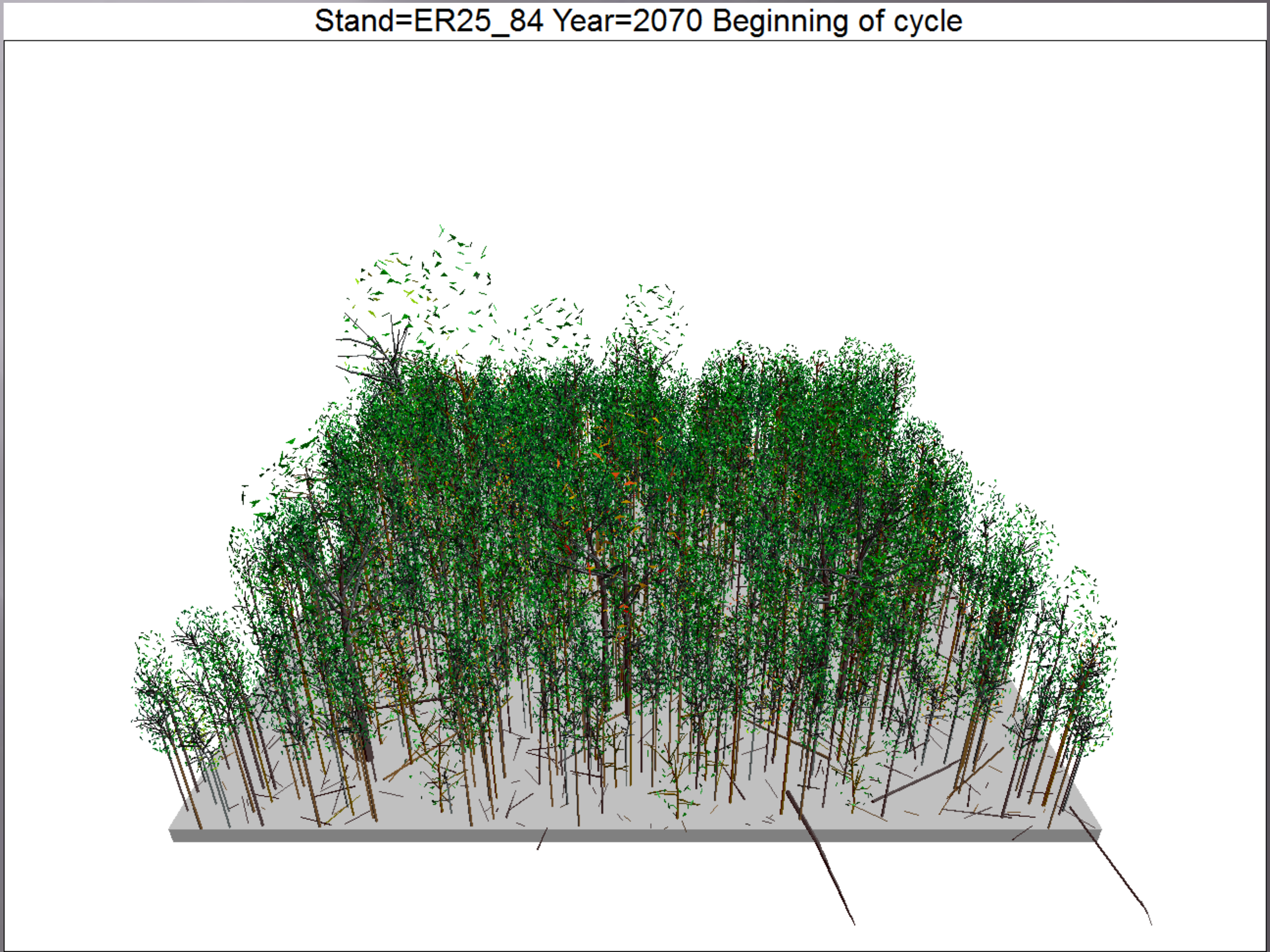
Example Simulation of Oak Mngt

Stand=ER25_84 Year=2050 Post cutting



Year	ER25
2012	
2017	CTR cut
2020	
2025	
2027	prep spraying
2030	
2035	
2037	Final Cut
2045	
2050	PCTR
2055	
2060	
2070	PCTR/DoC/ reserve tree cut
2075	
2080	
2090	
2095	CRT/ DoC/ reserve tree cut
2105	

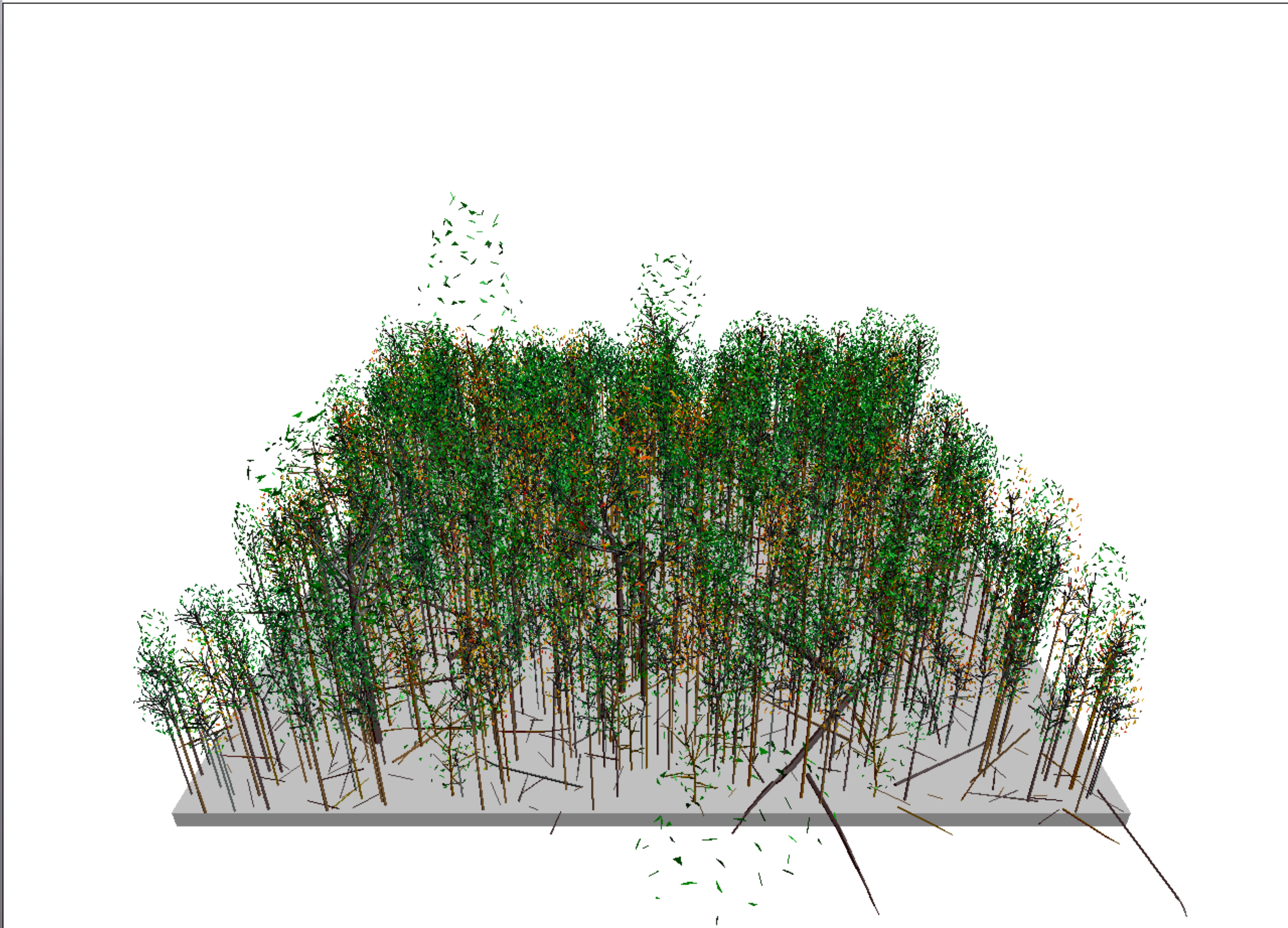
Example Simulation of Oak Mngt



Year	ER25
2012	
2017	CTR cut
2020	
2025	
2027	prep spraying
2030	
2035	
2037	Final Cut
2045	
2050	PCTR
2055	
2060	
2070	PCTR/DoC/ reserve tree cut
2075	
2080	
2090	
2095	CRT/ DoC/ reserve tree cut
2105	

Example Simulation of Oak Mngt

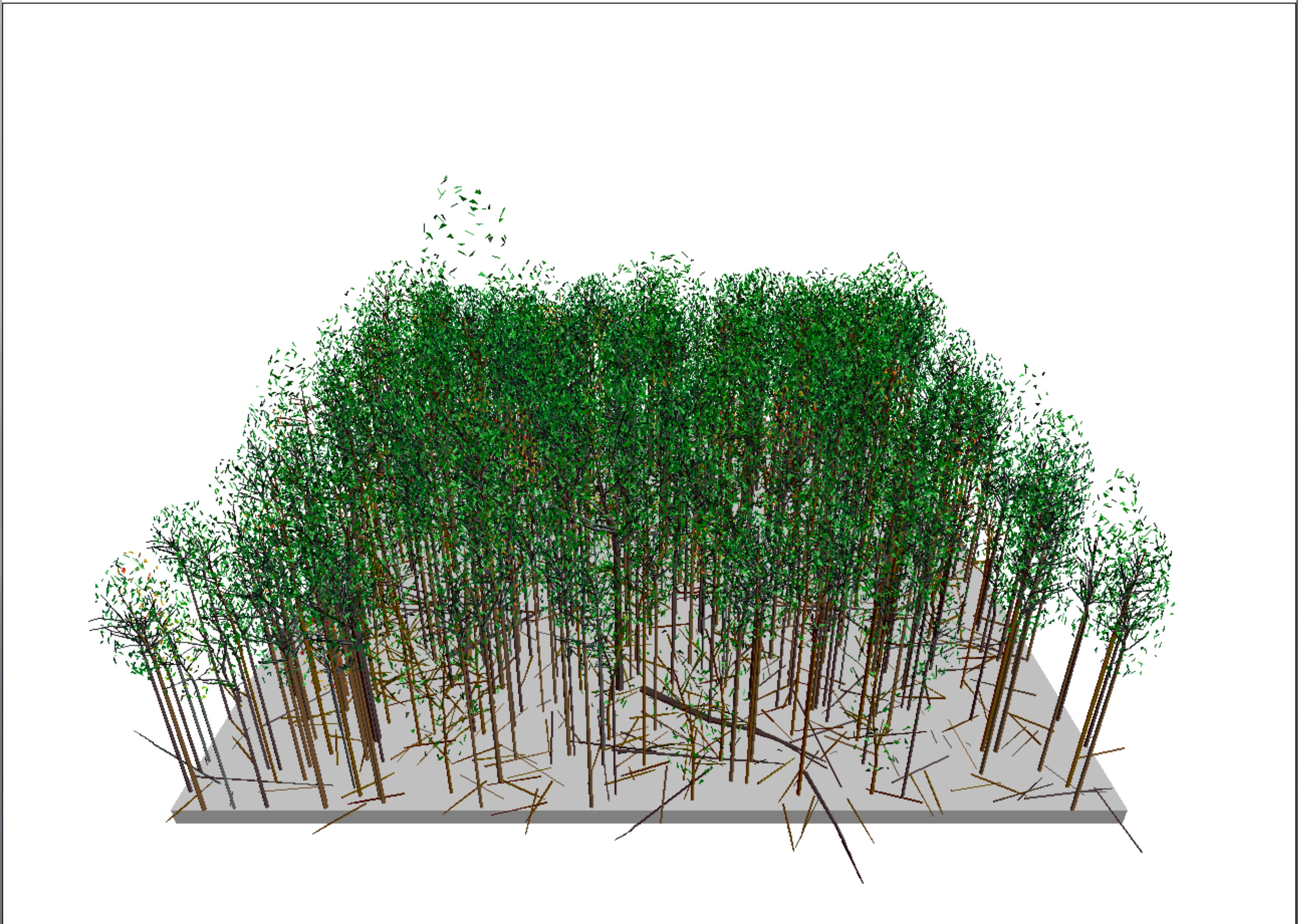
Stand=ER25_84 Year=2070 Post cutting



Year	ER25
2012	
2017	CTR cut
2020	
2025	
2027	prep spraying
2030	
2035	
2037	Final Cut
2045	
2050	PCTR
2055	
2060	
2070	PCTR/DoC/ reserve tree cut
2075	
2080	
2090	
2095	CRT/ DoC/ reserve tree cut
2105	

Example Simulation of Oak Mngt

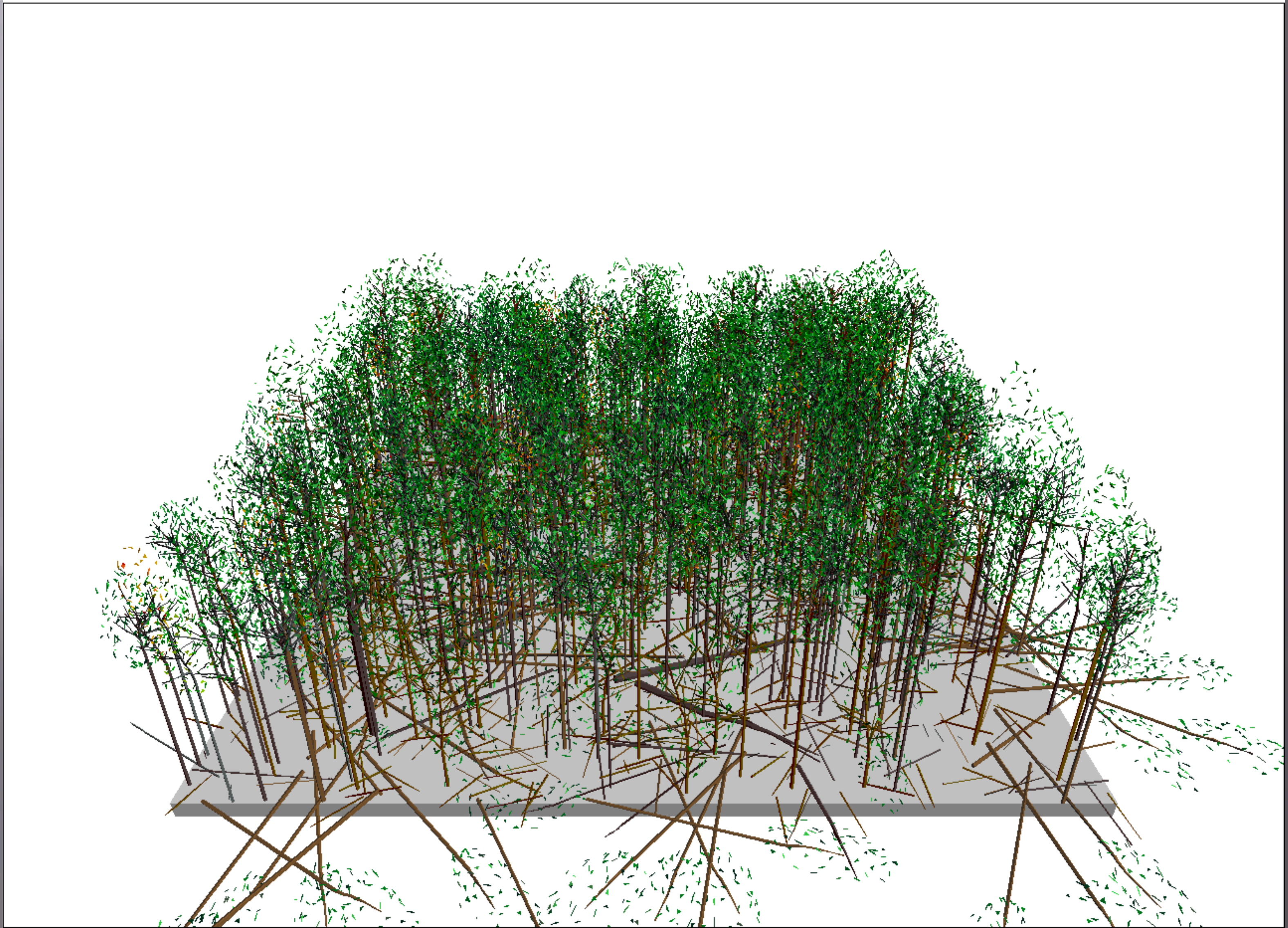
Stand=ER25_84 Year=2095 Beginning of cycle



Year	ER25
2012	
2017	CTR cut
2020	
2025	
2027	prep spraying
2030	
2035	
2037	Final Cut
2045	
2050	PCTR
2055	
2060	
2070	PCTR/DoC/ reserve tree cut
2075	
2080	
2090	
2095	CRT/ DoC/ reserve tree cut
2105	

Example Simulation of Oak Mngt

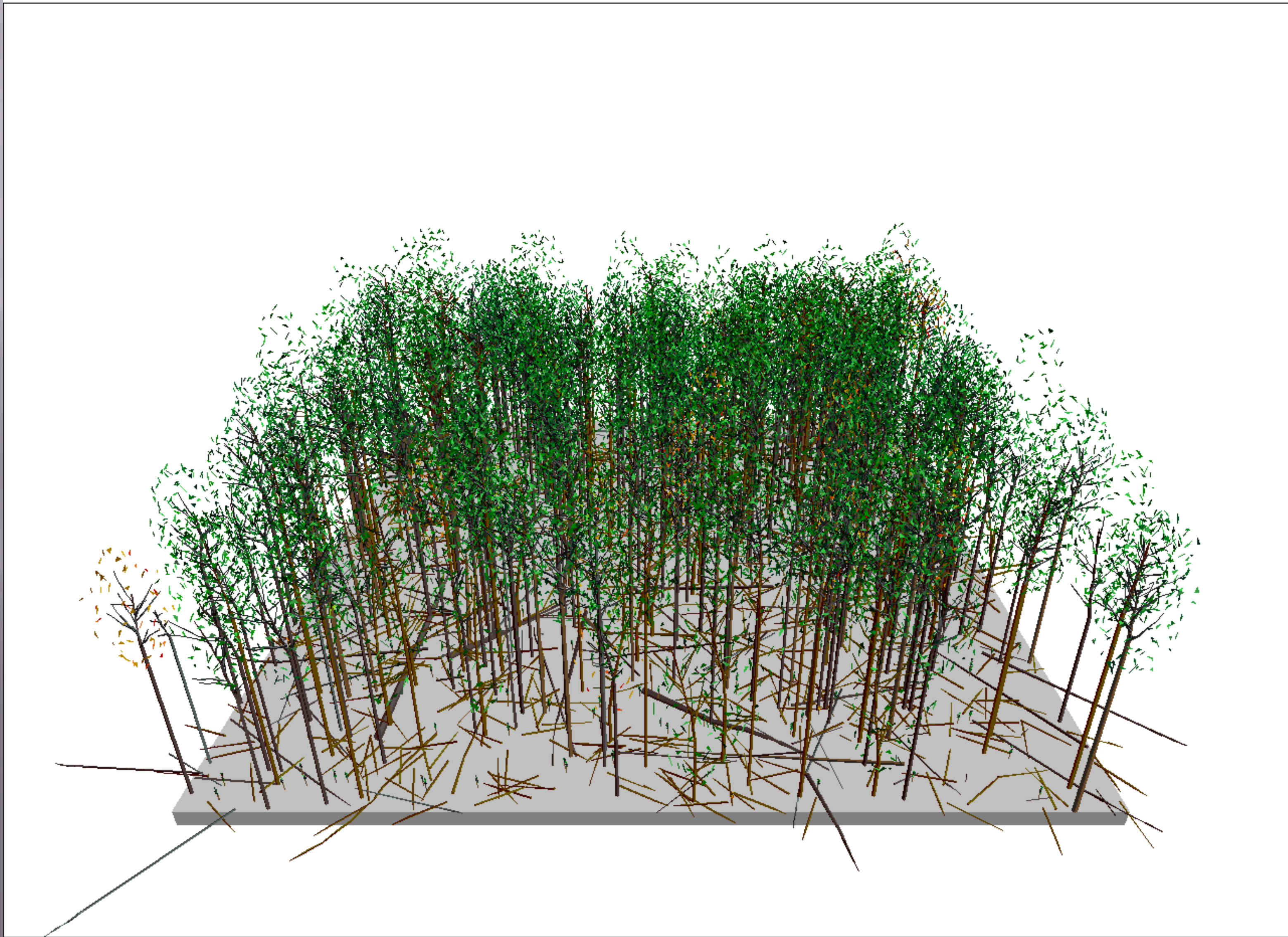
Stand=ER25_84 Year=2095 Post cutting



Year	ER25
2012	
2017	CTR cut
2020	
2025	
2027	prep spraying
2030	
2035	
2037	Final Cut
2045	
2050	PCTR
2055	
2060	
2070	PCTR/DoC/ reserve tree cut
2075	
2080	
2090	
2095	CRT/ DoC/ reserve tree cut
2105	

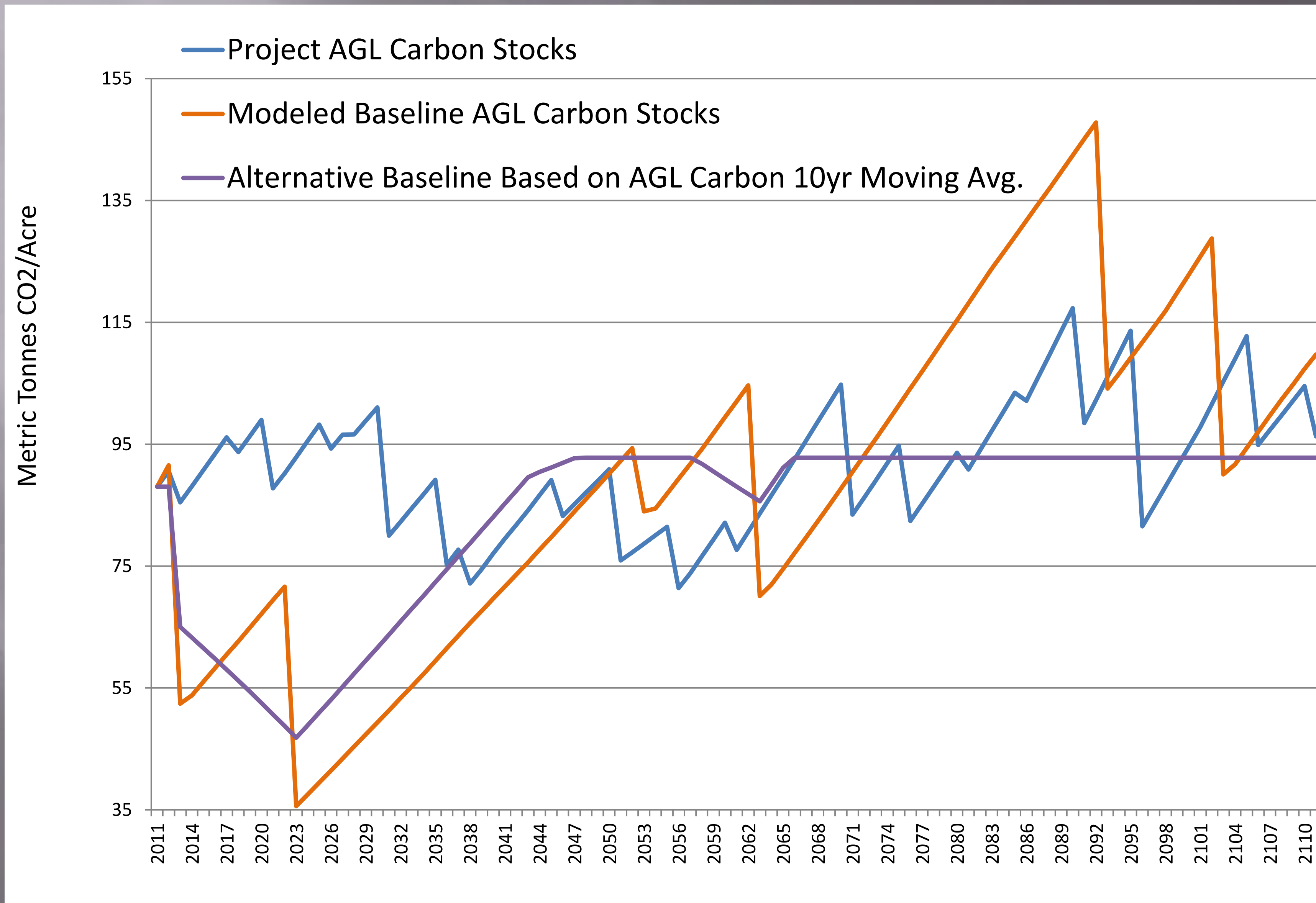
Example Simulation of Oak Mngt

Stand=ER25_84 Year=2110 End of projection

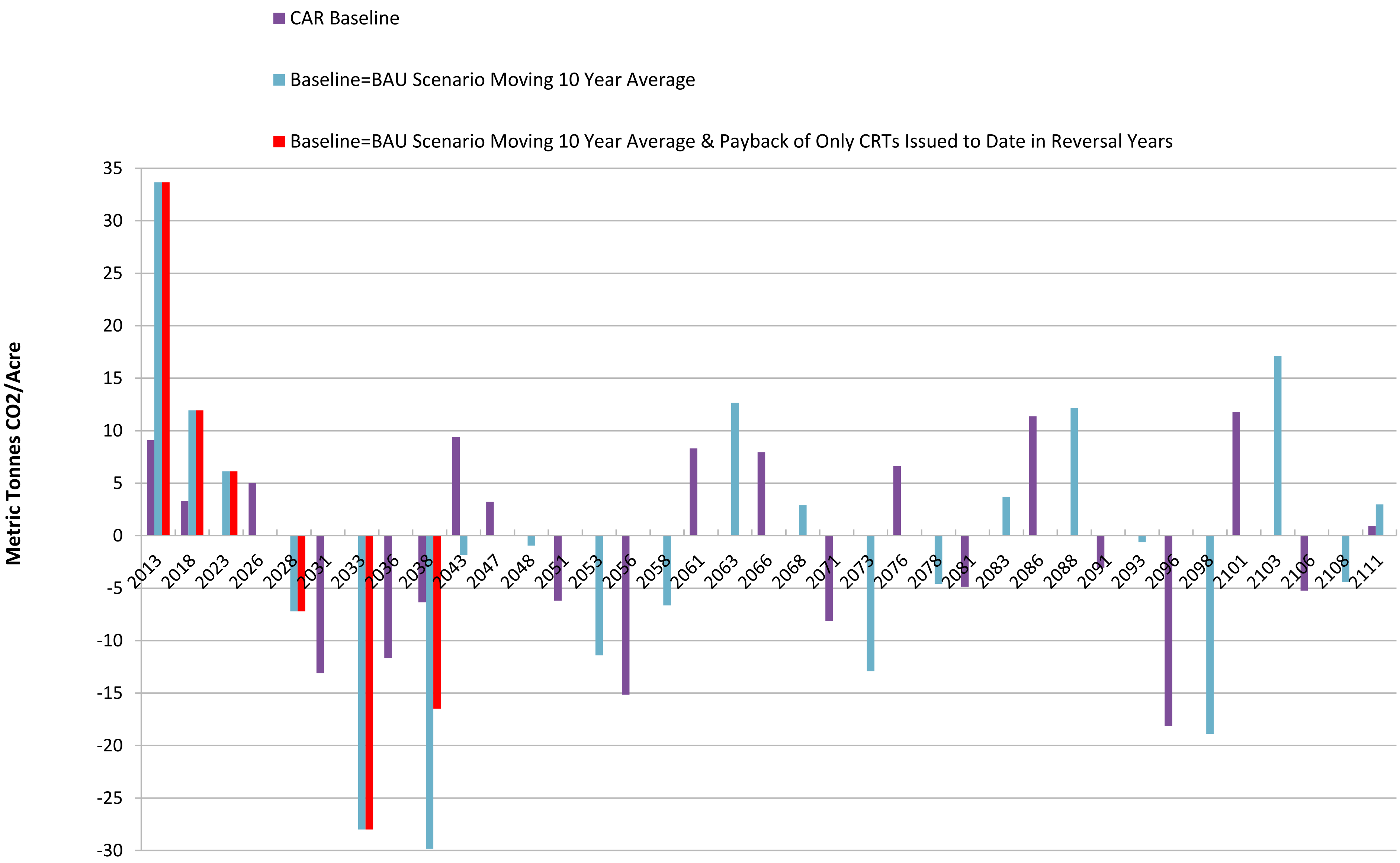


Year	ER25
2012	
2017	CTR cut
2020	
2025	
2027	prep spraying
2030	
2035	
2037	Final Cut
2045	
2050	PCTR
2055	
2060	
2070	PCTR/DoC/ reserve tree cut
2075	
2080	
2090	
2095	CRT/ DoC/ reserve tree cut
2105	

Alternative AGL carbon baseline = $\text{Max}\left(\left(\frac{(\sum_{t=yr}^{t+9} \text{AGL carbon}_t)/10}{\text{AGL carbon}_{t0}} \cdot \text{CP}\right), \text{CP}\right)$ (after BAU harvests begin)



Scenario Removals/Reversals



Key Findings

- Despite lower sawtimber production over 100yr horizon, net present value was highest for BAU scenario in all cases due to effect of time discounting
  - Carbon Reduction Tonnes issued gave no justification for IFM engagement under the given harvest regime and circumstances modeled
    - NPV was negatively correlated with carbon price b/c of unlimited liability imposed by CAR for negative carbon stock changes (or reversals)
- Reversal rules seem to be designed exclusively for avoided deforestation projects
  - Compensation and verifications required for reversals are prohibitively expensive

Key Findings

- Medium to small size, consistent-aged mature upland hardwood projects below the CAR common practice benchmark are at an inherent disadvantage due to opportunity cost and oak decline considerations
- Adopting alternative baseline w/moving 10yr average AGL carbon stock (instead of 100 yr average) and limiting reversal compensation to previously issued credits was only variation of the CAR protocol that was more cost-effective than the timber-only project scenario but not BAU, i.e. only case to have generated net carbon value
- CAR as written is not likely to incentivize sustainable management in southern forests to a significant extent unless timber production is a low priority management objective and low intensity high periodicity wildfire returns to the landscape to increase the competitiveness of oak recruits

Conclusions

- Current CAR rules seem to favor projects with young forests or those with balanced age-classes at project inception
- Additional CAR-IFM refinements are crucial to its deployment in mature Appalachian forests
- Other IFM offset methodologies emanating from project developers may be the only option for IFM projects in working hardwood forests

Thank You!

- Acknowledgements:
  - My Advisor Brian Murray, Nicholas School
  - Fred White, The Forestland Group
  - Danna Smith, Dogwood Alliance
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  - Greg Bailey, American Forest Management
  - Coleman Doggett, Nicholas School
  - Christopher Galik, Nicholas School
  - Chad Keyser, Don Vandendriesche, Lance David and other FVS lifesavers
  - John Nickerson, California Action Reserve
  - Connie Best, Pacific Forest Trust
  - Charles Grier, (Retired) US Forest Service Southern Region
  - Patrick Miles, US Forest Service Northern Research Station