THE IMPACT OF CARBON SEQUESTRATION POLICIES ON LAND USE AND THE ENVIRONMENT IN GEORGIA

by

SHANNA DAMKEN

(Under the Direction of Andrew Keeler)

ABSTRACT

In recent decades interest in the effects greenhouse gases have on the environment has increased, but not until recently have governments and policy makers even discussed policies for their mitigation. Agriculture and forestry sectors have received attention for their ability to sequester large amounts of carbon. For this study, the effects on land use change in Georgia stimulated by the introduction of different carbon permit prices are estimated. The resulting environmental benefits are estimated by using research from the Conservation Reserve Program. The results provide insight on the impacts a carbon incentive would have on land use change. This analysis reveals that potential benefits of sequestration incentives are substantial. Considering the multiple benefits of carbon sequestration is essential to creating informed and effective policies.

INDEX WORDS: land use change, carbon sequestration, multiple benefits

THE IMPACT OF CARBON SEQUESTRATION POLICIES ON LAND USE AND THE ENVIRONMENT IN GEORGIA

by

SHANNA DAMKEN

B.S., The University of Georgia, 2002

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2004

THE IMPACT OF CARBON SEQUESTRATION POLICIES ON LAND USE AND THE ENVIRONMENT IN GEORGIA

by

SHANNA DAMKEN

Major Professor:	Andrew Keeler
Committee:	Jeff Mullen David Newman

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
May 2004

ACKNOWLEDGEMENTS

I would like to thank my committee, Andrew Keeler, Jeff Mullen, and David Newman, for their assistance and support. Special thanks go to Andrew Keeler for his guidance and expertise. Jeff Mullen was always willing to help and provide insight. David Newman's expertise of the forestry sector in Georgia was instrumental. My family has provided immense support throughout my graduate studies, without their support this accomplishment would not have been possible. I would also like to thank my fiancé, Chad Davis, for always providing encouragement and being there for me. I would also like to thank my roommate and great friend, Quinn Kelley, for her kindness.

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

CHAPTER 1

INTRODUCTION

Background Information

Over the past several years, there has been increasing interest in the effects that greenhouse gases have on the environment. The increasing amount of carbon dioxide in the atmosphere is causing an accelerated effect on the warming of the earth, which can ultimately cause unprecedented effects on the environment and the global economy (Totten 1999). According to the National Academy of Sciences, the global mean temperature has increased one-degree farenheight over the last century and accelerated warming has occurred in the past 20 years (Environmental Protection Agency 2000). Climate research groups estimate that increased levels of greenhouse gases will raise U.S. temperatures by five to ten degrees by the end of this century (Soil and Water Conservation Society 2000). In particular, the past two decades have seen a rise in carbon dioxide emissions of over 25%. Also, the increased amount of carbon dioxide since 1750, the industrial age, and onwards is believed to be the reason for 60% of all greenhouse gas induced warming (Malhi et al. 2002). Besides an increase in the temperature of the earth, it is projected that precipitation will increase, sea levels will rise and biodiversity will be affected (Nordhaus 1993). Based upon these facts, it is clear that there is the likelihood of future problems. Solving these problems requires that mitigation of greenhouse gases, mainly carbon dioxide, must occur in the near future.

The increasing amount of greenhouse gases in the atmosphere has been a concern for many decades, but not until recently have governments and policy makers even discussed for their mitigation. There are several different ways to limit the amount of greenhouse gases in the atmosphere. These include but are not limited to: lowering dependence on fossil fuels, increasing use of carbon free and low carbon technologies such as solar power, wind power etc., and part of the solution includes carbon sequestration.. Through carbon sequestration the major greenhouse gas, carbon dioxide, can be offset with what many have deemed a relatively low cost approach to mitigating carbon dioxide.

Carbon Sequestration: An Introduction

One way to combat the increasing amount of greenhouse gases is through carbon sequestration. Carbon sequestration is defined as the storing of carbon in the soil, biomass, and in oceanic ecosystems for an extended amount of time. Carbon storage reduces or slows the buildup of atmospheric carbon dioxide (Soil and Water Conservation Society 2000). Carbon is stored in forests when plants alter carbon dioxide into carbon through photosynthesis (Plantinga et al. 1999). Carbon in forests is stored in many different areas such as soil, trees, plants and litter. A tree is made up of 50% carbon and the total volume of carbon in one tree increases until maturity is reached. Afterward, forest carbon is in equilibrium as old trees die and create a gap in the canopy allowing for younger trees to grow (Plantinga et al. 1999). U.S. community forests currently store 800 million tons of carbon and a single tree stores on average 13 pounds of carbon annually, approximately 2.6 tons per acre (Coder 1996). In agriculture, crops and other plants remove carbon dioxide from the atmosphere. As they are harvested the carbon in their roots is placed in the soil where it may potentially stay for long periods of time. Worldwide, soils are the main storage unit for carbon, holding over 75%. Of this 75%, forests account for 47% and wooded grasslands and savannas account for 25% (Malhi 2002).

Recently, substantial attention has been given to agriculture and forestry for their role in reducing the amount of greenhouse gases in the atmosphere through carbon sequestration. Many studies have determined that the sequestration of carbon, through forestry and agriculture, can potentially play a significant role in decreasing the amount of carbon dioxide at a relatively low cost compared to alternative means. There are three primary methods in which carbon can be sequestered by these sectors. They are reforestation, afforestation, and conservation tillage. An example of afforestation can be seen in the study by Plantinga, Mauldin and Miller (1999). They estimate that an afforestation policy in Maine, South Carolina, and Wisconsin could sequester substantial amounts of carbon dioxide at lower costs compared to alternative mitigation estimates given by the U.S. Office of Technology and Assessment and the National Academy of the Sciences. Moulton and Richards (1990) also estimate that planting permanent stands on cropland and pastureland could sequester 2.57 tons per acre of carbon annually in the United States (Stavins 1999). The example of conservation tillage is examined by Kurkalova et al. (2003). It is shown that the adoption of conservation tillage from conventional tillage in Iowa could potentially sequester 169,460 tons of carbon with a 10 million-dollar budget. From these studies alone, it is apparent that carbon sequestration is a relevant means to reduce global atmospheric carbon.

According to the Intergovernmental Panel on Climate Change (IPCC), the potential for global carbon sequestration and conservation between 1995 and 2050 can be partitioned between alternative uses. The estimates are 43% for plantations and agroforestry, 33% for tropical forest regeneration, and 24% for slowed tropical deforestation, which combine to 12-15% of the "business as usual" fossil fuel emissions (IPCC 2001).

Although agriculture and forestry can be seen as an alternative method of reducing GHG buildup, both of these sectors contribute a significant amount of greenhouse gases into the environment. These gases are emitted through land use conversions, fuel consumption, cultivation and fertilization of soils, livestock and management of the manure of livestock. Agriculture consumes over 50% of land and 75% of water removals in the continental 48 states (Feather et al. 1999). Agriculture is an intensive practice and has great effects on the environment. One example of these effects is the impact on surface water quality. The primary source of pollutants in waterways is nutrients from agriculture. These pollutants are the leading cause of waterway impairment in lakes and estuaries and the third leading cause in rivers (Feather et al. 1999). Agriculture also affects groundwater quality, air quality, and wildlife habitat (Feather et al. 1999).

Potential Co-Benefits

Many different studies have been conducted on the costs and the benefits (decreased carbon dioxide) of carbon sequestration, but few have considered the environmental benefits of a carbon sequestration program, beyond mitigating carbon dioxide buildup. Most studies identify the opportunity costs of agricultural production where benefits are seen as the specific amount of carbon removed from the atmosphere (Plantinga et al. 2003). Many studies have shown that the costs of carbon sequestration programs are comparable to or lower than alternative methods of removing greenhouse gases. Parks and Hardie show the cost per ton of carbon for the establishment of new forests on pastureland, compare favorably with technologies that reduce sources of emissions (Parks and Hardie 1995). Although the costs of carbon sequestration programs are potentially lower than alternative methods, the co-benefits of a carbon sequestration program are not analyzed to the same extent. Such co-benefits include decreases in soil erosion, nitrogen and phosphorus pollution and improvements in biodiversity, water quality, and watersheds. It is essential that climate change polices recognize the multiple benefits of a carbon sequestration policy. When the extent to which co-benefits affect the environment is ascertained, a carbon sequestration policy can be more accurately designed to consider multiple benefits.

Valuation methods and representative models can be used to determine the extent to which co-benefits affect and enhance the environment. Valuation is the process of quantifying the value of natural resources in monetary terms. Applicable methods include defensive expenditures, recreation participation models, and representative trip models. Each of these valuation methods along with modeling applications is used in different analyses to monetarily value and estimate the amount of benefits generated from the Conservation Reserve Program (CRP).

The CRP is the largest land retirement program in the United States (Feather et al. 1999). The CRP was established in 1985 to remove highly erodable cropland from agriculture. Since its beginnings, the goals of the CRP have changed to include a broader array of environmental indicators. These include improving water quality and improving fish and wildlife habitat (Feather et al. 1999). The CRP offers incentives to landowners for enrolling land in the program. Over the contract period, to offset lost income from not growing crops on the land, participants receive half the cost of establishing permanent cover crops and yearly rental payments (Ribaudo et al. 1990). The CRP offers financial, educational, and technical assistance to landowners that practice conservation techniques. The CRP has been very successful in enrolling acres. In 2002, approximately 34 million acres were under contract with the CRP (USDA).

Feather et al. (1999), Ribaudo (1989), and Ribaudo et al. (1990) have conducted major analyses of the CRP. Each analysis determines the value in monetary terms of the different co-benefits. These analyses also endeavor to estimate, for example, the amount of soil erosion reduced by the CRP program. Plantinga and Wu (2002) concluded that a carbon sequestration policy in Wisconsin could produce co-benefits of the same magnitude as the costs of the program using the results from valuation of the CRP. Valuation analyses along with estimates of co-benefits can help researchers and policy makers determine the effectiveness of different programs by conducting a benefit-cost analysis in which co-benefits are included.

Limited research is available concerning multiple benefits of carbon sequestration policies. It is necessary that policies concerning carbon sequestration recognize and assess these multiple benefits (co-benefits). For this study, land use change in Georgia and the resulting environmental effects are estimated.

Objectives

Carbon sequestration has enormous potential in the agriculture and forestry sectors with respect to combating greenhouse gas emissions. With carbon sequestration, nations can reduce carbon dioxide at a relatively low cost. It is essential that policies consider all relevant costs, benefits, and co-benefits. Many different areas of carbon sequestration, such as costs, are currently being analyzed. This study is a subset of a much broader economic and technical analysis being conducted on carbon sequestration.

The study region for this analysis is 52 important forestry counties in Georgia. Important forestry counties include areas that have greater than 50,000 acres in combined industrial and private timberland. These counties will allow agriculture landowners easier access into the sector since forestry is abundant in these counties. Georgia has an abundance of both agriculture and forestry and both of these sectors play a large role in the economy of the state. Forestland covers 65% of the state with over 24 million acres, while agriculture land use is 18%. Urban and other land uses consist of the remaining 17% of land in Georgia (Dangerfield and Hubbard 1998). These numbers demonstrate that the agriculture and forestry sectors are prevalent, implying that Georgia is an appropriate state for this analysis.

The main purpose of this study is to determine land use change, for the forestry sector, stimulated by the introduction of a carbon sequestration incentive program. The program analyzes the impacts of three different carbon permit prices ($10, $20, and $30 per ton of carbon) on the forestry sector. In this analysis the increase in carbon sequestered on agricultural lands is achieved by afforestation.

A carbon permit price is used for this simulation under the assumption that a carbon market has been implemented. Land use change will be determined using an econometric model for estimating land use allocation. The carbon sequestration incentive program is achieved by increasing net returns to forestry.

The increase in the net returns to forestry results in the conversion of agricultural acres to forestry. Once the conversion is accomplished, the resulting effects of the permit prices on environmental quality will be determined using existing research on valuation of the CRP. Specific objectives of the analysis include:

1) Assembly and construction of a data set detailing population density, land capability classes, and net returns to agriculture and forestry. This data set will contain the most current level of knowledge existing on land allocation.
2) Based on this current knowledge, an econometric model of land allocation is developed. This model is used to simulate a carbon sequestration incentive program

to private landowners for converting agriculture land to forest. The carbon sequestration program simulation will be estimated with two different assumptions for the permit price. The simulation will provide evidence about the potential impact that a carbon sequestration program would have on the net carbon sequestered.

3) Finally, the multiple benefits of a carbon sequestration policy will be estimated. These benefits will be determined using past valuation estimates from the CRP. Multiple benefits that will be considered are nitrogen and phosphorus pollution and soil erosion reduction, and water quality, freshwater based recreation and wildlife habitat improvements. The particular pollutants are chosen because they are the main environmental variables affected by the conversion of land to forestry.

This analysis will estimate the amount of land that would be converted from agriculture to forestry due to the introduction of a carbon sequestration program. The benefits in terms of sequestered carbon, and multiple benefits, will then be determined. The results from this study could potentially further the development of policy and programs involving carbon sequestration in Georgia.

CHAPTER 2

POLICIES AND PROGRAMS

In 1992, at the Framework Convention of Climate Change (FCCC), nations gathered together to begin discussions concerning incentives for greenhouse emission abatement. It was determined that there was a need to set worldwide target levels of greenhouse gas emissions. With this colossal decision, the process of setting, and more importantly, meeting emission goals to ultimately reduce and slow the effects of climate change began. In December of 1997, firm targets were set for developed and developing countries and approximately 160 nations signed the Kyoto Protocol of which 38 are developed countries (the United States withdrew in 2001). This protocol is the first international agreement to set specific targets for reducing greenhouse gas emissions of developed and developing nations. These targets require developed countries to reduce the amount of carbon dioxide and other greenhouse gases an average of 5% of their 1990 levels by 2008-2012 (Bettelheim and d'Origny 2002).

There are many different methods discussed in the protocol for which greenhouse gases can be reduced. Specifically, the protocol states that flexibility mechanisms can be used which include, ". . .removals by sinks resulting from human-induced land-use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990 shall be used to meet. . ." the Annex 1 countries' commitments (Bettelheim and d'Origny 2002). From the inclusion of forestry and land use changes in the Protocol, it is becoming widely accepted that forestry and agriculture can provide long term and sustainable sinks for carbon.

On March 28, 2001, the United States pulled out of the Kyoto Protocol because the government did not agree with the treaty. This decision was a disappointment to many; the U.S. government needs to make plans to offset greenhouse gases emissions. In an effort to revive the presence of climate change policies in Congress, Senator Brownback of Kansas has made three proposals concerning carbon sequestration. The Carbon Conservation Incentive Act was introduced April 26, 2001. The act establishes a carbon sequestration program to permit owners of eligible land to enroll in contracts of a minimum of 10 years. Another bill that concerns carbon sequestration was also introduced: Carbon Sequestration and Reporting Act. This bill encourages carbon sequestration practices in the United States. Also introduced was a bill to amend the Internal Revenue Code of 1986 to include a carbon sequestration investment tax credit for eligible tax payers (Brownback). Each of these bills recognizes the need for the United States to make plans to offset GHG emissions, which include carbon sequestration along with other mitigation techniques.

Other programs have been established that provide incentives for carbon sequestration. The Montana Legislature helped create the Montana Carbon Offset Coalition, a quasi-public entity. Landowners who enter a contract of over 100 years receive complete cost sharing to plant trees on land that is not naturally regenerating to trees and in return, receive payments to store carbon on the land. The general idea is to benefit corporations that generate carbon emissions through purchasing the carbon offsets associated with the recently forested land (Carbon Sequestration on Idaho Agriculture and Forestlands).

By the end of 2001, approximately 20 voluntary carbon offset trades had taken place that involved carbon sequestration on U.S. forest and agriculture land. Most of these trades concerned energy companies paying landowners and land management companies to embark on reforestation, afforestation, and soil conservation projects in return for future carbon credits. It is the hope of these companies that a carbon emission credit program will become a reality (King 2002). Although a carbon market is not yet established, the United States has in the past had experience and success with such markets. In 1990, a cap and trade program for sulfur dioxide emissions was instituted. This gave individual utility companies flexibility in determining the most efficient approach for reducing the amount of sulfur dioxide. The utility companies could reduce pollution at their own plants or they could purchase emissions credits from other plants that met the limits more cost-effectively and efficiently (Bonnie 2001). This program has been very successful and sulfur dioxide emissions have been reduced more than 20% below the levels the law mandates (Bonnie 2001).

According to Butt and McCarl, “Carbon markets are one popularly discussed way of promoting GHG emission mitigation where those desiring to exceed a set of imposed emission caps may enter into the market to buy emission rights” (p.2). Similar to the sulfur dioxide market, a carbon cap and trade program would place a cap on industrial sources of carbon dioxide. Under a cap and trade system individual emitters of carbon dioxide may emit a unit of emissions that is associated with a permit (Bonnie et al. 2002). Participants in a carbon market would include: (1) purchasers who face emission caps and desire to buy carbon permits to offset their emission levels (2) sellers who generate emission offsets by altering their practices and (3) middlemen who facilitate the transaction of emission offsets by connecting the sellers with the purchasers (Butt and McCarl, p.3). Included in the sellers’ category are farmers and forest owners who increase the amount of carbon sequestered in soils and trees. This increase could be achieved by altering their land management practices, which includes afforestation. Farmers and forestland owners may also purchase permits for the release of carbon sequestered, for example through harvesting. The inclusion of carbon sequestration in a carbon market could provide an alternative method of offsetting carbon dioxide that is cost competitive (Butt and McCarl, p.2).

CHAPTER 3

REVIEW OF LITERATURE

There is now scientific consensus that the nature of the atmosphere is changing due to the unprecedented amount of greenhouse gases present. The components of the atmosphere are adversely affected by industrialization and, as a result, the atmosphere will negatively affect nations' environmental quality. Climate change policies are recognized as a necessity by almost every nation and the beginnings of an international agreement has been initiated through the UNFCCC process. Although the United States withdrew from the Kyoto Protocol, the U.S. government recognizes the need to implement a policy that will arrest the affects of greenhouse gases.

The forestry and agriculture sectors have received a large amount of attention due to their ability to sequester carbon. Many different studies have shown that these sectors can offset a substantial amount of carbon dioxide through reforestation, afforestation, and conservation techniques at a relatively low cost compared to alternative methods. By the end of 2001, there were approximately 20 voluntary carbon programs that involved carbon sequestration on U.S. forest and agriculture land. Most of these projects involve energy companies paying landowners and land management companies to embark on reforestation, afforestation, and soil conservation projects in return for carbon credits. It is the hope of these companies that a carbon emission credit program will become a reality (King 2002).

The United States recognizes the importance of reducing greenhouse gases by conservation of forestlands and agriculture. In the upcoming years, the U.S. will likely invest a substantial amount of money into this conservation. The collaboration between the government, farmers and forest owners would help increase the carbon sink and also improve other facets of environmental quality. The increase in the carbon sink is estimated to reduce greenhouse gases approximately 12 million tons by 2012. It is essential that the U. S. government make plans to offset greenhouse gas emissions (U. S. Department of State Fact Sheet June 6, 2003). Mitigation techniques could include carbon sequestration as well as other methods.

Many different analyses have been conducted on carbon sequestration. Most of the studies concern the costs of sequestering carbon and rarely consider co-benefits. Studies usually consider the foregone benefits of agricultural production and the benefit is the amount of carbon sequestered (Plantinga et al. 2003). The cost of sequestering carbon has been shown to be comparable to or lower than alternative methods of removing greenhouse gases. The National Academy of the Sciences finds the average cost of substitution of alternative fuels for coal to be \$100-\$900 per ton of carbon and the Office of Technology Assessment finds the average cost estimates for increased residential energy efficiency and switching fuel range to be \$200 - \$2000 per ton of carbon (Plantinga et al. 1999). In Plantinga et al. (1999), the costs of an afforestation program were determined for three different states. To successfully sequester two million tons of carbon, costs ranged from approximately \$70/tonC in Maine to \$5/ton C in South Carolina and Wisconsin. Clearly, carbon sequestration is potentially a lower cost method than alternative techniques of mitigating carbon. Although the costs of carbon sequestration programs are lower than alternative methods, the co-benefits of a carbon sequestration program have not been analyzed to the same extent.

Until 1999, studies did not include the multiple benefits that a carbon sequestration policy should entail. Such co-benefits include reduced soil erosion, reduced nitrogen and phosphorus pollution, increased wildlife habitats and an improvement in water quality. Mathews et al. (2002) took the first step in the analysis of co-benefits. To determine the impacts on biodiversity, the effects of an afforestation policy on farmland and forestland birds in three different states, South Carolina, Maine, and southern Wisconsin, were analyzed. The study found that an afforestation policy in each state would result in a net loss of birds. According to Mathews et al., “The loss is due to the coincidence of centers of high farmland bird richness and low forest bird richness with areas economically suited to conversion” (p. 71). This study provides the first analysis of the impacts a carbon sequestration policy can have on biodiversity.

Pattanayak et al. (2002) considers the co-benefits of water quality on a national basis achieved by greenhouse gas mitigation strategies. This study links a national level water quality model (NWPCAM) to an agricultural sector model (ASMGHG) and estimates the impacts on water quality stimulated by the introduction of a GHG price. This study provides first order co-benefits and water quality improvements due to a GHG mitigation policy. It was found that in the southeast, carbon dioxide would decrease by 0.83 million metric tons of carbon equivalent per year and total suspended sediment would decrease by 44.59 million tons based on $50/tonne carbon equivalent. Overall, this study reveals that carbon policies could improve the status of the nations’ waters from below swimmable to approximately swimmable. Again this study shows that recognizing co-benefits, such as water quality, is essential in the development of GHG mitigation policies.

Plantinga and Wu (2003) estimated the effects that an afforestation policy in Wisconsin had on environmental quality. First, reductions in soil erosion, nitrogen and atrazine pollution were estimated, then past valuation techniques were applied to the resulting estimates. They estimated that conversion of 25% of agricultural land to forest would sequester 4.11 million tons of carbon per year, soil erosion would decrease by 9.48 million tons per year, nitrogen pollution would decrease by 10.97 million pounds per year, and atrazine pollution would decrease by 1.48 million pounds per year. Valuation techniques were then applied to monetarily determine the benefits from soil erosion reduction, hunting and enhanced wildlife habitats. The benefits summed to $103 million per year at the 25% conversion scenario. Under the same conversion scenario the costs ranged from $101 to $132 million per year. This implied that the benefits could outweigh the costs especially since the benefits from reduction in nitrogen and atrazine pollution, soil wind erosion, and other environmental benefits such as biodiversity and water quality were not included in the study. This study demonstrated that it is essential for environmental benefits to be considered in climate change policies for efficient implementation.

To accomplish the analysis of the articles above, two distinctly different approaches can be used. The first concerns established models at a national level, such as ASMGHG and FASOM, and the second concerns econometric models of land use.

Analysis of land use decisions made by landowners is not a new topic. However, recent studies have been using econometric techniques to perform the analyses of modeling future forest area (Ahn et al. 2000). These studies estimate the future allocation of land between alternative (mainly agriculture and forestry) uses based on variables that affect the landowner's decision (Ahn et al. 2000).

The beginnings of econometric analysis on land use did not include land quality. It was determined by many different studies that the omission of land quality resulted in incorrect estimates. Litchtenberg (1989) and Stavins and Jaffe (1990) showed that aggregate land use decisions are dependent on the different characteristics of land within a county. Hardie and Parks (1997) also showed that assuming homogeneous land quality in aggregate data models might lead to specification error and bias parameter estimates (Ahn et al. 2000). Hence, not including land quality in the model regression adversely affects econometric land use models.

A decade later, studies began to include heterogeneous land quality data in econometric land use models and are therefore, more reliable (Ahn et al. 2000). Studies usually incorporate aggregate data, specifically county information, because individual choices of land use are either too expensive to gather or not available. Modeling land use at the county levels can be seen as beneficial. Many different programs and policies, such as the CRP, are implemented at the county level and the effects on local land in each county can be used to cater a specific program to each county's different needs (Miller and Plantinga 1999).

Land use models based on aggregate data are an efficient means of determining land use decisions by landowners. Landowners base their decision on the opportunity cost of the land and the expected land rents in forestry and agriculture. Once the landowner's decision has been made, it is important to determine the value of natural resources that will be conserved by the conversion of agriculture land to forestry. Valuation methods and representative models can be used to determine the extent to which co-benefits affect and enhance the environment. Methods include defensive expenditures, recreation participation models, and representative trip models. Each of these valuation techniques is used in different analyses to monetarily value and estimate benefits generated from the CRP. Feather et al. (1999), Ribaudo (1989), and Ribaudo et al. (1990) have conducted major analyses of the CRP. These analyses also endeavor to estimate the amount of, for example, soil erosion, reduced by the CRP program. Valuation analyses along with estimates of co-benefits can help researchers and policy makers determine the effectiveness of different programs by conducting a benefit-cost analysis in which co-benefits are included.

This study utilizes an econometric land use model following Ahn et al. (1999) to determine the amount of land that will convert from agriculture to forestry based on the landowner's decision of profitability. To accomplish this, a simulation of a carbon sequestration program is introduced. The valuation results from the CRP as established by Feather et al. (1999), Ribaudo (1989), and Ribaudo et al. (1990) are also analyzed to determine the magnitude of co- benefits from an afforestation policy in Georgia.

CHAPTER 4

PLAN OF STUDY AND THEORETICAL APPLICATION

Methodology

The analysis uses data collected by the U.S Census Bureau, the Natural Resource Inventory division of the Natural Resource Conservation Service and the Georgia Department of Revenue.

The year 1997 is chosen for my analysis because it contains the most recent series of inventories on land use conducted every five years by the Natural Resources Inventory. Data on population density are collected from the U.S. Bureau of Census decade reports and are extrapolated to determine population density in 1997. The Natural Resources Inventory (NRI) data includes aggregate information from 159 counties in Georgia on land capability classes and land use for agriculture, forestland and urban land. The value of land in forestry and agriculture serves as a proxy for the net returns to each sector. The procedure for determining the net returns to forestry and agriculture includes:

Step 1 Collect data concerning the amount of land in each LCC for agriculture and forestry e.g. the amount of land in LCCI for agriculture. LCC represent the productivity of the land, where a value of I represents high quality land and a value of VIII represents low quality land. Next, Conservation Use Valuation Areas (CUVA) are needed. These estimates describe the value of the land.

Step 2 The net returns to forestry are calculated by using the following technique

$W^f = [(\text{forestland in } LCC_I \times CUVA_I)+...+(\text{forestland in } LCCV_{III} \times$

$\text{CUVA}_{\text{VIII}})] / (\text{forestland in LCC}_{\text{I}} + ... + \text{forestland in LCCV}_{\text{III}})$.

The net returns to agriculture are determined using the same procedure. The CUVA values from 1996 are provided by the Georgia Department of Revenue and it is assumed that the 1997 CUVA values are three percent greater than those of the preceding year.

After examination of the NRI data, counties in Georgia are selected for the analysis based on the degree of the forestry sector in each county. An econometric model of land use is then constructed and current land use in Georgia is estimated. The simulation of a carbon sequestration incentive program then leads to an estimate of land use change. The simulation is accomplished by increasing the net returns to forestry. The increase is achieved by using a permit price (ranging from \$10-\$30 per ton of carbon) in conjunction with Birdsey's regional forest carbon estimates. Regional forest carbon estimates for previous cropland and previous pastureland are calculated over a 60-year time period. This determines the present value of carbon sequestered.

The permits are allotted to agriculture and forestland owners for sequestering carbon. These permits could then be purchased by industrial sources of carbon dioxide to offset their emissions. Landowners who enter into the program must also purchase permits for releasing the sequestered carbon into the atmosphere. Two different methods for the calculation of permit prices are assumed. The first includes a constant real price for permits and the second assumes the permit price follows a Hotelling price path. The sole difference between the two scenarios is the assumption of how the permit price rises over time (Smith and Bernstein 2004). A constant real value for the permit price would follow the logic that each ton of carbon emissions reduction poses an equal amount of benefits and is not constrained by time. However a rising value of permits, reflecting a Hotelling price path, assumes that the "..Earth's atmosphere has a fixed assimilative capacity that is used up in equal amounts by each additional ton of emissions. Viewed as a depletable resource, the right rate of depletion would involve a Hotelling rate of increase in the price of emitting, which would be the rate of interest" (Smith and Bernsetin 2004 p.11). In the constant price scenario, the permit price remains fixed. Alternatively, for the rising permit scenario the permit price rises at the real rate of interest (4%).

Specifically the procedure to determine the present value of carbon sequestered includes:

Step 1 To determine the increase in the amount of carbon sequestered, the net amount of carbon sequestered per year is calculated.

Step 2 The permit price of carbon ($10, $20, and $30 per ton of carbon) is discounted at a 4% rate for the first scenario of a constant real price of carbon. For the second scenario of permits, the permit price rises at the assumed real rate of interest (4%).

Step 3 Each specified permit price for both specifications is then multiplied by the net amount of carbon sequestered per acre per year. This results in the annual present value of carbon sequestered. These values are then summed over a 60-year period.

To account for different regional forest carbon estimates for cropland and pastureland proportional estimates of the amount of cropland and pastureland for the 52 counties in the analysis are taken and applied to the present value of carbon sequestered.

The simulation of the carbon sequestration program induced by increasing the net returns to forestry results in land use change. The owner of the agricultural land must determine if it is more profitable to keep the land in agriculture or to convert to forestry i.e. the expected land rents in forestry and agriculture will determine the farmers' decision. The land that converts to forestry is marginal agriculture land because the owner of the land has decided that it would be more profitable to enter into the carbon sequestration program. In the simulation urban land is restricted to baseline values because it is believed that net returns to forestry have minimal affects on this land base. The procedure for determining land use change in Georgia stimulated by the introduction of a carbon sequestration program is as follows:

Step 1 An increase in the net returns to forestry is achieved by adding the present value of sequestered carbon to the baseline value of the net returns to forestry.

Step 2 Shares of forestry, agriculture, and urban land are estimated. The shares of forestry and agriculture are determined by modifying baseline values with the increase from the addition of the present value of carbon sequestered.

Step 3 The change in acreage is calculated by taking the difference between the share of forestry with the increase in the net returns to forestry and the share of forestry at baseline values. This difference equals the change in the share of forestry. Similarly for the share of agriculture, the difference between the share of agriculture with an increase in the net returns to forestry and the share of agriculture at baseline values is calculated.

Step 4 The resulting changes in the share of forestry and agriculture are then multiplied by total land in each county and then are summed over the 52 counties. These results show the amount of land conversion from agriculture to forestry.

Birdsey's regional estimates of forest carbon, used to determine the present value of sequestered carbon, are found in Sampson and Hair, 1996. These estimates include forest carbon for loblolly pine plantations with periodic thinnings throughout a 120-year time period. The regional forest carbon estimates were estimated using growth and yield studies. Volume yields were derived for newly afforested areas (previous cropland and previous pastureland). The estimates include periodic thinnings and clearcut harvest at the end of the rotation followed by regeneration in later rotations (Sampson and Hair, 1996). A 60-year time period is chosen for this analysis because this time frame will allow for one full harvest rotation followed by regeneration.

The increase in the net returns to forestry provides farmers with an incentive to adopt an alternative method of land use. The owner of the land must determine if it is more profitable to keep the land in agriculture or if it would be more profitable to convert to forestry. The landowners' decision determines the number of acres that are converted to forestry from agriculture in each county for a specified carbon price.

The Framework for the Landowner's Allocation

The land-manager's decision to convert to agriculture or forestry is based on the opportunity cost of the land, i.e. the expected land rents in forestry and agriculture will determine the landowner's decision. The following two sections are based on theory derived by Ahn et al. (2000). Following Ahn et al. (2000), which draws on earlier work from Plantinga (1996) and Miller and Plantinga (1999), it is assumed that the landowner is price-taking, risk-neutral, and maximizes discounted expected net returns by allocating one acre units of land to alternative uses (agriculture or forestry). The land in each county is assumed to be of homogeneous quality and the trees are even-aged. The landowner thus maximizes the present discounted value of expected net benefits as

$$(1)\ \max_{\{u_t\},\{v_t\}} \sum_{t=0}^{T} \delta^t \left[R^f_t (a_t)v_t + R^a_t (1-u_t)v_t \right] + \delta^{T+1}V_{T+1}(a_{T+1})$$

subject to

$u_t = \{0,1\}; v_t = \{0,1\}; a_{t+1} = a_t u_t(1-v_t) + u_t; a_t \geq 0; R^f_t(0) = 0$

where a_t = the age of the stand at the start of period t and a_0 is given

$v_t = 0$ continue to grow an existing stand

$v_t = 1$ harvest an existing stand

$u_t = 0$ allocate unit of land to agriculture

$u_t = 1$ allocate unit of land to forestry

$R^f_t (a_t)$ = expected net returns from harvesting a stand of age a_t

$R^a_t (a_t)$ = expected net returns to agriculture in period t

δ = constant discount factor

$V_{T+1}(a_{T+1})$= expected salvage value

t = 1,. . .,T

At the start of each period, the landowner must decide to harvest or to continue to grow an established stand and also to allot the land to agriculture or forest so that net returns are recognized. At the start of period v_t=1, trees must be cleared from the land to allow agriculture crops to grow. Assumed in the net return variable is the cost of converting land to agriculture. Bellman’s equation provides a solution to (1)

$$(2)\ V_t (a_t) = \max_{ut,vt} [R^f_t (a_t)v_t + R^a_t (1-u_t)v_t + \delta V_{t+1}(a_{t+1})]$$

for t = 1, . . . , T

$V_t (a_t)$ = value of the optimally managed unit of land

The right hand side of the equation above is linear in u_t. By design, the solution involves the choice of agriculture or forestry each period. The allocation of land in period t depends on W^f_t and W^a_t where

$$(3)\ W^f_t = R^f_t (a_t)v_t^* + \delta V_{t+1} [(a_t)(1-v_t^*) + 1]$$

$$(4)\ W^a_t = R^f_t (a_t) + R^a_t + \delta V_{t+1} (0)$$

and

W^f_t = expected value of optimally managed parcel of land conditional on the choice of forestry in time t

W^a_t = expected value of optimally managed parcel of land conditional on the choice of agriculture in time t

v_t^* = optimal harvesting decision

$V_t(0)$ = bareland value of a unit of land

The land-manager will choose forestry if $W^f_t \geq W^a_t$ and agriculture if $W^a_t \geq W^f_t$ in time period t.

It is shown by Plantinga (1996) that the time t allocation decision by the land manager is based on a comparison of discounted infinite streams of returns to agriculture and forestry if the land manager has static expectations, an infinite time horizon, and bare land. Thus equations (3) and (4) above become

$$(5)\ W^f(t) = [\delta^{a^*} / (1 - \delta^{a^*})]\ R^f (t,a^*)$$

$$(6)\ W^a(t) = [1 / (1 - \delta)]\ R^a(t)$$

where

a^* = the optimal rotation age given the net returns from harvesting a stand of age a_t

Equation (5) is the maximized value of bareland allotted to forest and equation (6) is the maximized value of bareland allotted to agriculture.

Since aggregate (county-level) data corresponding to net benefits across differing land managers and parcels of differing land quality is widely available, the above solution to the landowner’s allocation problem is used. The model is now extended to include heterogeneous land quality because land quality influences the net returns to forestry and agriculture and thus must be accounted for. To accomplish this, an index j (j = 1,. . ., J) is introduced to the net returns measures in equations (5) and (6) where J is the number of land capability classes (eight). To account for land-owners having different skills and knowledge levels which will ultimately affect net returns, another index n_i ($n_i = 1, \ldots, N_i$), for landowners, is introduced, where N_i is the number of landowners in county i and I is the number of counties. Therefore (5) becomes (7) and (6) becomes (8)

$$(7)\ W^f_j(t,n_i) = [\delta_a^* / (1 - \delta_a^*)]\ R^f(t,n_i,a^*)$$

$$(8)\ W^a_j(t,n_i) = [1/(1 - \delta)]\ R^a(t,n_i)$$

The net returns of the profit maximizing landowner can be further expressed as

$$W_j(t,n_i) = \max\{ W^f_j(t,n_i,a^*), W^a_j(t,n_i,a^*)\}.$$

Suppose that $H_j(t,n_i)$ acres of j quality land is held by landowner n_i in time t. Since the landowner goal is to maximize total profits, the landowner selects area of the land $h_{jk}(t,n_i) \geq 0$ to assign to forestry (k=1) and agriculture (k=2) in period t to maximize

$$(9)\ \sum_k W_j(t,n_i) h_{jk}(t,n_i)$$

subject to

$$\sum_k h_{jk}(t,n_i) = H_j(t,n_i)$$

The Kuhn-Tucker solution to (9) is the optimal allocation

$$h_{jk}^*(W_j(t,n_i), n_i) = \{0, H_j(t,n_i)\}$$

this specifies that all land of quality j is assigned to either forestry or agriculture. The optimal share of the total land of the landowner is expressed as

$$H(t,n_i) = \sum_{j=1}^{J} H_j(t,n_i)$$

allocated to use k is then expressed as

$$(10)\ f_k(X(t,n_i), n_i) = [1/(\ H(t,n_i)]\sum_{j=1}^{J} h_{jk}^{*}\ (W_j\ (t,n_i), n_i)$$

The optimal shares of land are restricted to the unit interval and are determined implicitly by the land quality factors, which are included in the net return functions. Hence $X(t,n_i)$ is defined as a vector of decision making variables, which include $W_j(t,n_i)$ and multiple measures of land quality.

An Econometric Model of Land Use

Data on land use shares typically consider aggregate (county) data since observations of individual landowner's allocation decisions are unavailable or too expensive to collect. Therefore the optimal land use shares, as described above, for landowners must be collected at the county level to be consistent with available data. Optimal land use shares will differ from actual land use shares due to "...exogenous shocks that occur after the land use decision is made" (Ahn et al. p.366). Thus the actual share of land allocate to use k by owner n_i is

$$(11)\ s_k\ (t,n_i), = f_k(X(t,n_i), n_i) + \gamma_k(t,n_i)$$

where

$$\gamma_k(t,n_i) = \text{mean zero disturbances}$$

and assuming that actual and optimal shares sum to one implies,

$$\sum_{k} \gamma_k(t,n_i) = 0.$$

Since shocks that may occur after the landowner's land use decision has been made are outside the model, it is assumed that they are uncorrelated with the decision variables:

$$E[X_h(t,n_i)\ \gamma_k(t,n_i)] = 0 \text{ for all } t,\ n_i,\ h, \text{ and } k.$$

The observed share of land allocated to use k in county i, $0 \leq\ y_k(t,n_i) \leq\ 1$, may be gathered as

$$(12)\ y_k(t,i) = \sum_{n_i=0}^{N_i} w(t,n_i)\,[s_k(t,n_i) + \nu_k(t,n_i)] + \nu hat_k(t)$$

$$= p_k(t,i) + \varepsilon_k(t,n_i)$$

If the data are based on a sample population and not based on the entire population,

$w(t,n_i)$ = sample weight allocated to each individual landowner n_i,

$\nu_k(t,n_i)$ = possible sampling error associated with each observation,

$\nu hat_k(t)$ = aggregate sampling error

Alternatively, if the data are a complete inventory of the entire population then,

$w(t,n_i)$ = relative share of land held by landowner n_i in county i,

$\nu_k(t,n_i)$ = potential sampling error for each observation

and

$p_k(t,i)$ = expected share of land in county i, allocated to use k, in time t

$\varepsilon_k(t,n_i)$ = composite error terms with mean variance structure similar to $\gamma_k(t,n_i)$ and are uncorrelated with the aggregated errors in the observed county-level land use shares

Substituting equation (11) into equation (12) one can see that the entire set of decision variables are included in the expected shares i.e. $X(t,n_i)$ includes all necessary variables for all individual landowners. Similarly to the land share data, data on individual landowner's decisions are either not available or too costly to collect, therefore aggregate county data is typically applied (Plantinga 1999). X(t,i) represents the county aggregate data and also include proxy variables for the land quality characteristics of county i. Since land in each county will have alternative uses besides agriculture and forestry, such as urban, a third category is defined as p_3 (t,i) = 1- p_1

(t,i) - p_2 (t,i) and represents all land that is not classified as forestry or agriculture. To consider variables that explain the allocation of land shares, $X(t,n_i)$ is thus enhanced.

The expected shares are usually estimated by specifying that $p_k(t,i)$ is proportional to $\beta_k{}' X(t,i)$ and limiting the linear form to the unit interval by an opportune transformation. Following many authors (Hardie and Parks, Plantinga and Wu) the logistic transformation

$$(13)\ p_k(t,i) = [\exp(\beta_k{}' X(t,i)] / \sum_k X(t,i)$$

is adopted. The logarithm of the expected shares

$$(14)\ \ln(y_k(t,i) / y_1(t,i)) = \beta_k{}' X(t,i) - \beta_1{}' X(t,i)$$

is linear in parameters and the model is identified when the parameters are normalized by setting β_1=0.

An Econometric Model of Land Use in Georgia

Using data on land use for 52 counties in Georgia, equation (13) is expressed as

$$S_k(t,i) = \exp(\beta_k{}' X(t,i)) / \sum_k X(t,i) + \varepsilon_{it}^k$$

where

$S_k(t,i)$ = the share of land in use k (k=forestry, agriculture, urban), in county i (i=1…I), in time period t (t=1 since one year is used for estimation)

$X(t,i)$ = exogenous variables describing land use in Georgia

β_k = vector of unobserved parameters

ε_{it}^k = mean zero error terms

The model above is estimated with 1997 land use data. The particular counties are chosen because the forestry sector is already well established in these counties and it is assumed that converting to forestry would be easier for agricultural landowners. Five counties, specifically Camden, Liberty, Charlton, Echols and Stewart, are excluded from the analysis due to land use and land quality constraints.

The share of land in agriculture, $S_a(i)$ is defined as the amount of land in cultivated cropland, non-cultivated cropland and pastureland for each county. The share of land in forestry, $S_f(i)$, includes all forested acres in Georgia for each county. The share of land in urban, $S_u(i)$, includes all other uses besides forestry and agriculture, such as urban and suburban areas.

The exogenous variables include a stream of net returns to forestry and agriculture denoted W^f_i and W^a_i. To account for high quality land in each county the variable HQ_i, is included and denotes the share of high quality land in each county. This variable represents the share of land for each county in LCC I and II. Medium land quality, MQ_i, is also included which consists of the share of medium quality land in LCC III and IV in each county. To account for land redirected to urban uses, a measure of population density (the total county population divided by the total county land area) is included denoted PD_i.

To estimate equation (13)

$$S_k(i) = \exp(\beta_k' X(i)) / \sum_k X(i) + \varepsilon_i^k$$

we follow previous works and apply the linear transformation discussed above and estimate

$$\ln[S_f(i) / S_u(i)] = \beta_f X(i) - \beta_u X(i)$$

$$\ln[S_a(i) / S_u(t,i)] = \beta_a X(i) - \beta_u X(i).$$

These models are identified when β_u is normalized to zero and a system linear in β_f and β_a is generated. Since the two equations contain the same set of regressors, estimating by seemingly unrelated regression is the same as estimating each equation separately, therefore each equation is estimated separately and ordinary least squares is applied.

Specifically

$$(15)\ \ln[S_f(t,i) / S_u(t,i)] = \beta_0 + \beta_1 W^a_i + \beta_2 W^f_i + \beta_3 PD_i + \beta_5 HQ_i + \beta_6 MQ_i \text{ (LCC IV) and}$$

$$\ln[S_a(t,i) / S_u(t,i)] = \beta_0 + \beta_1 W^a_i + \beta_2 W^f_i + \beta_3 PD_i + \beta_5 HQ_i + \beta_6 MQ_i \text{ (LCC IV)}$$

are estimated, which generates an equation linear in β_f and β_a and is recognized when β_u is normalized to zero.

The logarithmic transformation used to estimate equation (13) is known to induce heteroskedasticity and since county size and other factors in the variables are different across counties heteroskedasticity may be a problem (Wu and Segerson, 1995). Heteroskedasticity causes the variance of the parameter estimates to be biased and as a result the t-values for the estimated coefficients cannot be trusted.

Expected Signs

Ahn et al. notes, “Total differentiation of [15] indicates that the estimated coefficients measure the percentage change in the share ratios for one-unit changes in the independent variables” (p.369). Plantinga and Wu (2003) estimate a similar specification of the model and this analysis is expected to have similar findings. For the first equation of (15) the net returns to agriculture is expected to have a negative effect on S_f/S_u, however the net returns to forestry is expected to have a positive effect. Population density is expected to have a negative effect on S_f/S_u. High quality land is typically allocated to agricultural uses therefore high quality is expected to have a negative effect on S_f/S_u. Medium quality land is also typically allocated to agriculture uses therefore medium quality land is expected to have a negative effect on S_f/S_u.

For the second equation of (15), net returns to agriculture is expected to have a positive effect on S_a/S_u, however the net returns to forestry is expected to have a negative effect. Population density is expected to have a negative effect on S_a/S_u. High quality land is typically allocated to agricultural uses therefore high quality is expected to have a positive effect on S_a/S_u. Medium quality land is also typically allocated to agriculture uses therefore medium quality land is expected to have a positive effect on S_a/S_u.

CHAPTER 5

ESTIMATION RESULTS

Data Summary

Table 4.1 shows a summary of the data in the analysis.

Table 4.1 Data Analysis

Variable	Mean	Standard Deviation	Minimum	Maximum
Net Returns to Forestry	325.63	41.20	283.05	469.21
Net Returns to Agriculture	444.03	87.72	320.28	726.74
Population Density	58.96	68.83	8.22	292.37
High Quality Land	0.29	0.18	0	0.72
Medium Quality Land	0.39	0.13	0.10	0.67

Econometric Land Use Results

Because the logistic transformation is known to induce heteroskedasticity, White's test is applied under the null hypothesis of homoskedasticity. I fail to reject the null hypothesis at the 5% level for both equations in (15).

Table 4.2 and Table 4.3 list the estimated coefficients and standard errors for the ordinary least squares model. Partials and elasticities calculated at the mean values are also listed. Total differentiation of (15) verifies that the estimated coefficients measure the percentage change in the share ratios for a one-unit change in the independent variables (Ahn et al. 2000). Key parameter estimates have the expected signs although few are significantly different than zero at the 5% level. Table 4.2 shows the results for the ln(S_f/ S_u). For ln(S_f/ S_u), a one-unit change in the net returns to forestry increases the ratio of forest to urban land by 0.0091% and is significantly different from zero at the 5% level. Higher forest rents increase the share of forestry, which increases the ratio of forest to agriculture land. Population density is also significantly different from zero and decreases the share forest to urban land. An increase in high quality land tends to increase the ratio of forest to urban land and is also significantly different from zero. Although this positive relationship does not conform to prior expectations, it suggests that high quality land is also used in the forestry sector in Georgia. The measures of net returns to agriculture and medium quality land are not significantly different from zero.

Since the dependent variable depends on the ratio of two shares, "The effects of the regressors on individual land-use shares cannot be determined directly from the estimated equations…" (Plantinga 1999). However calculating the partials and elasticities shows the effects individual land use share have on the regressors. The elasticities estimated for the ln(S_f / S_u) indicate that the net returns to forestry, high and medium quality land all have a positive effect on the share of forestry and net returns to agriculture and population density have a negative effect on the share of forestry.

The results for the ln(S_a / S_u) show that the measures of all independent variables are significant except for the net returns to agriculture. A one-unit change in the net returns to forestry increases the ratio of agriculture to urban land by 0.0084%. Although, this result does not conform to prior expectations, the association between the net returns to forestry and urban land may cause this result. Counties with higher values of the net returns measure also have smaller amounts of urban land. This association between the net returns to forestry and the ratio of agriculture land to urban land could have caused this result. An increase in population density tends to decrease the ratio of agriculture land to urban as expected. An increase in the high quality and medium quality land tends to increase the ratio of agriculture to urban land. This is also as expected since higher quality land is typically allocated to agriculture uses. The elasticities estimated for the $\ln(S_a / S_u)$ indicate that all independent variables, except population density, have a positive effect on the share of agriculture.

Table 4.2. Regression Results for ln(Share of forestland/Share of urban land)

Variable	Parameter Estimates	Standard Errors	T-Values	Partials	Elasticities
Intercept	0.0664	0.9330	0.07		
Net Returns to Agriculture	-1.21E-5	0.0016	-0.01	-1.4542E-5	-0.0086
Net Returns to Forestry	0.0091*	0.0031	2.98	0.0014	0.6033
Population Density	-0.0130*	0.0016	-7.91	-0.0020	-0.1568
High Quality Land	1.3373*	0.6460	2.07	0.1767	0.0684
Medium Quality Land	1.1523	0.9393	1.23	0.1698	0.0883
R-Squared	Adj R-Sq	F-Stat	Obs		
0.68	0.64	19.40	52		

Note: * Indicates significance at the 5% level.
Partials and elasticities are calculated at the mean value of the variables

Table 4.3. Regression Results for ln(Share of agriculture land/Share of urban land)

Variable	Parameter Estimates	Standard Errors	T-Values	Partials	Elasticities
Intercept	-4.1722*	1.0991	-3.80		
Net Returns to Agriculture	0.0021	0.0018	1.17	0.0003	0.6734
Net Returns to Forestry	0.0084*	0.0036	2.33	0.0009	1.4834
Population Density	-0.0114*	0.0019	-5.90	-0.0012	-0.3601
High Quality Land	6.0718*	0.7609	7.98	0.7842	1.1923
Medium Quality Land	2.2645*	1.1065	2.05	0.2734	0.5584
R-Squared	Adj R-Sq	F-Stat	Obs		
0.71	0.68	22.31	52		

Note: * Indicates significance at the 5% level.
Partials and elasticities are calculated at the mean value of the variables.

Introduction of a Carbon Sequestration Program

A carbon sequestration program is simulated and the resulting land use change (agriculture to forest) is estimated using the econometric model of land use for Georgia developed in the preceding section. The simulation of the carbon sequestration incentive program and the resulting effect on land use change is achieved by the introduction of three different permit prices ($10, $20, and $30 per ton carbon). This is plausible since the establishment of a carbon market would include agricultural landowners that generate emission offsets by altering their land use practices, removing marginal agricultural land and planting trees on the land. This approach, afforestation, would increase the carbon sink. Farmers and forestland owners who participate would also purchase permits for the release of carbon sequestered through harvesting. Urban land is restricted to baseline values since it is believed that net returns to forestry have negligible affects on urban land given current conditions in Georgia. As previously mentioned, two different policy scenarios for permits are assumed. The only difference between the two scenarios concerns the assumption of how the price for permits rises over time. The first includes a constant real price for permits (CP) and the second assumes the permit price follows a Hotelling price path, rising value of permits (RP).

Table 4.4 shows the present values of carbon sequestered over the 60-year time period for both specifications of permit prices. The counties contain 66% cropland and 34% pastureland and proportions relative to the percentages are calculated. The rising price of permit scenario results in a greater amount of carbon sequestered at each carbon price.

Table 4.4. Present Value (PV) of Carbon Sequestered

Permit Price	CP	RP
$10/tonC	252.98	411.10
$20/tonC	505.95	822.21
$30/tonC	758.93	1233.31

Table 4.5 and 4.6 reveal the resulting land use change for the share of agriculture and forestry. For the CP scenario, a $10 permit price increases the forest area by 315,000 acres. At the greatest permit price of $30, the change in forestry acreage increases to 859,000 acres. However for the RP scenario, the results are even greater. The $10 permit price increases forest area by almost 500,000 acres. For the greatest permit price, forestry acreage increases by 38% to 1.27 million acres. For both scenarios of permits, as the permit price increases the forest acreage change increases but at a decreasing rate.

Table 4.5. Land Use Change from Increase in Net Returns to Forestry – CP

Permit Price	Change in Forest (acres)	Change in Agriculture (acres)
$10/tonC	315,604	-315,604
$20/tonC	601,910	-601,910
$30/tonC	859,661	-859,661

Table 4.6. Land Use Change from Increase in Net Returns to Forestry – RP

Permit Price	Change in Forest (acres)	Change in Agriculture (acres)
$10/tonC	497,953	- 497,953
$20/tonC	919,807	- 919,807
$30/tonC	1,270,531	-1,270,531

Environmental Quality Benefits

An increase in forestry acreage initiated by the carbon sequestration program has the potential to sequester large amounts of carbon and offset the effect of greenhouse gas emissions. Besides increases in the carbon sink, many multiple benefits such as reduction in phosphorus, nitrogen and soil erosion, will occur. These reductions result in improved soil productivity; water quality, freshwater recreation, and wildlife viewing.

The increase in the carbon sink was estimated using Birdsey's regional estimates of forest carbon for loblolly pine over a 60-year time period. To account for land that was previously crop or pasture, proportions were taken from the individual county data. The average annual amount of carbon sequestered is estimated to be 0.994 tons per acre. Using this value, results are shown in Table 4.7. For the CP scenario, at the $30 permit price, 854,000 tons of carbon is sequestered. However for the RP scenario, the average annual increase in the carbon sink is even greater at the highest permit price showing an increase of 1.26 million tons of carbon. The greatest amount of carbon emissions from Georgia is through fossil fuel combustion. For 1996, this source emitted 43,896,225 tons of carbon into the atmosphere (Georgia Department of Natural Resources 1999). The introduction of the carbon sequestration program can help offset these effects.

Table 4.7. Average Annual Increase in the Carbon Sink in tons

Permit Price	CP	RP
$10/tonC	313,710.38	464,965.28
$20/tonC	598,298.54	914,288.16
$30/tonC	854,503.03	1,262,907.80

Similar to the carbon sequestration program simulated in this analysis, the CRP removed marginal cropland from production and replaced the land with trees or pasture. The goals of the CRP have expanded to include a broader arrangement of environmental indicators. These include improving water quality and fish and wildlife habitat (Feather et al. 1999).

Many different analyses have been conducted on the impact of the CRP on environmental quality. In this study, I use estimates of the environmental benefits from the CRP to approximate the co-benefits of increased forestland. The estimates that follow should be used with caution and only as a rough guide.

Ribaudo (1989) estimated the amount of nitrogen and phosphorus pollution reduction due to CRP enrollment. Using Ribaudo's estimates for nitrogen of 0.016 and phosphorus of 0.0018 tons per acre per year, Tables 4.8 and 4.9 shows the reduction of nitrogen and phosphorus at each permit price for both permit scenarios. For the CP scenario, the highest permit price shows a decrease of 13,754 tons of nitrogen and 1,547 tons of phosphorus. In the RP case, at the greatest permit price 20,328 tons of nitrogen and 2,286 tons of phosphorus are reduced. These pollutants impair downstream users and reductions cause subsequent effects, such as improvements in water quality and freshwater-based recreation. These are maximum annual reductions for pollutants. It is clear that there are substantial reductions in nitrogen and phosphorus due to the carbon sequestration program in Georgia.

Table 4.8. Annual Reductions in Nitrogen and Phosphorus in tons – CP

Permit Price	Nitrogen	Phosphorus
$10/tonC	5,049.66	568.09
$20/tonC	9,630.56	1,083.44
$30/tonC	13,754.58	1,547.39

Table 4.9. Annual Reductions in Nitrogen and Phosphorus in tons – RP

Permit Price	Nitrogen	Phosphorus
$10/tonC	7,967.25	896.32
$20/tonC	14,716.91	1,655.65
$30/tonC	20,328.50	2,286.96

Ribaudo et al. (1990) estimates reduction in soil erosion, economic benefits of improved soil productivity, surface water quality, and wildlife habitat. Three different scenarios are used for the pattern of increase from 23 million acres (1987) to 45 million acres (1990). The scenario that is applicable for this analysis is the forestry scenario in the southeast where the enrollment pattern is altered to increase tree-planting coverage on enrolled land.

To calculate the CRP's effect on soil erosion, net acres removed were analyzed instead of the amount of land enrolled. Although farmers are adding land to the CRP other landowners are beginning production on their land due to the changes induced by the CRP. Removing marginal land from production can greatly reduce the amount of soil erosion. Sheet, rill, and wind erosion were the source of three billion tons of erosion from farmland in 1982 and reductions in erosion for Georgia are primarily due to sheet and rill erosion (Ribaudo et al. 1990).

Using Ribaudo's estimate of 12 tons per acre per year, Table 4.10 shows the average annual reduction in erosion per acre for both permit scenarios. In the CP scenario, reduction in soil erosion ranges from 3.7 million tons to 10.3 million tons reduced. Alternatively, for the RP scenario, reduction in soil erosion ranges from almost 6 million to 15.2 million tons. It is clear that this amount of soil saving has the potential to substantially benefit the state.

Table 4.10. Annual Reductions in Soil Erosion in tons

Permit Price	CP	RP
$10/tonC	3,787,248	5,975,436
$20/tonC	7,222,920	11,037,684
$30/tonC	10,315,932	15,246,372

Next, the economic benefits of reductions in soil erosion were estimated. If erosion continues at 1982 levels, the yield potential of cropland in the United States is expected to decrease by 2-4% and will cause a loss in profit (Ribaudo et al. 1990). Ribaudo's estimates of benefits induced by increases in soil productivity were calculated using the Erosion Productivity Impact Calculator soil loss model. The per-ton changes in yield and fertilizer use were multiplied by the prices of crops and fertilizers. These values were aggregated, which resulted in weighted regional damage per ton. Benefits caused by enrollment in the CRP of improved soil productivity were determined by multiplying regional damage per ton by net savings in soil.

Using Ribaudo's benefit estimate for improved soil productivity of $2.82 per acre per year, Table 4.11 shows annual results for the simulated carbon sequestration program. For the

CP scenario, a permit price of $30 results in benefits of $2.4 million per year. Benefits for the RP scenario are even greater. The highest permit price results in benefits of $3.5 million. These numbers indicate that improved soil productivity could greatly benefit the well-being of the state.

Table 4.11. Annual Benefits of Improved Soil Productivity (Thousand Dollars)

Permit Price	CP	RP
$10/tonC	$ 890	$1,404
$20/tonC	$1,697	$2,594
$30/tonC	$2,424	$3,583

Note: Benefits estimates are in 1997 Dollars

A decrease in the amount of soil erosion has a direct impact on the improvement of water quality. Removing marginal agricultural land from production reduces the amount of sediment and nutrients in waterways resulting in cleaner water and benefits to agriculture land and land downstream. Agriculture areas are the most prevalent cause of water-quality problems from nonpoint sources. Agricultural nonpoint source pollution impairs over two-thirds of the nations' river basins and it is estimated that the impairments cause more problems away from the farm (Ribaudo et al. 1990).

The CRP's effect on water quality was based on damage from soil erosion and flooding caused by soil erosion to different water uses including recreational fishing, navigation, water storage, irrigation ditches, roadside ditches, water treatment, municipal and industrial water use, and steam cooling. Each of these categories were estimated using different techniques that recognized the physical, chemical, hydrological, and economic links between soil movement and chemicals on the land and the resulting effects on water users downstream (Ribaudo et al. 1990).

The estimated benefit for recreational fishing was removed from the water quality estimate since later calculations include all types of freshwater based recreation.

Using Ribaudo's benefit estimate for improved water quality of $19.01 per acre per year, Table 4.12 shows the results for the simulated carbon sequestration program. Results for the CP scenario show improvement in water quality ranging from $6 million for the $10 permit price to $16.3 million at the greatest permit price. The results for the RP scenario show improvement in water quality ranging from $9.4 million to $24.1 million. These benefits will be seen on and off the farm thus improving water quality for all downstream users.

Table 4.12. Annual Benefits of Improved Water Quality (Thousand Dollars)

Permit Price	CP	RP
$10/tonC	$ 6,000	$ 9,466
$20/tonC	$11,442	$17,486
$30/tonC	$16,342	$24,153

Note: Benefits estimates are in 1997 Dollars

As mentioned above, improvements in water quality have effects on almost all uses of water. Feather et al. (1999) estimate benefits of all freshwater-based recreation (unlike Ribaudo who only estimates fishing) and benefits of wildlife viewing based on 1992 enrollment in the CRP. As noted above, a reduction in the amount of soil erosion has several effects including a decrease in nutrients, pesticides, and sediments. These decreases benefit fish populations and improve the appearance of water for recreation. The improvements in the appearance of water have a positive effect on all water users (Feather et al. 1999).

The data used by Feather et al. to determine the improvement of freshwater-based recreation due to enrollment in the CRP included information on land use, land cover from the NRI and behavioral data from the National Survey of Recreation and the Environment (NSRE). A representative trip model was used and sites were determined as feasible locations that recreationists might visit and are depicted by average soil erosion and other data included in the NRI. The regional data were then expanded using benefits transfer techniques to the entire United States to determine consumer surplus estimates.

Using the benefit estimate for improved freshwater-based recreation of $3.08 per acre per year, Table 4.13 shows the results for the simulated carbon sequestration program. The annual consumer surplus attributable to the carbon sequestration program ranges from $973,000 to $2.6 million for the CP scenario. Alternatively for RP, benefits range from $1.5 million to $3.9 million. These values indicate large increases in consumer surplus for the converted acres.

Table 4.13. Annual Benefits of Improved Freshwater Based Recreation (Thousand Dollars)

Permit Price	CP	RP
$10/tonC	$ 973	$1,536
$20/tonC	$1,856	$2,837
$30/tonC	$2,651	$3,919

Note: Benefits estimates are in 1997 Dollars

The CRP also increases wildlife habitat by moving acreage from marginal agriculture land to grassland or forestry. The increase of land in grassland and forestry improves habitats for animals, which leads to increased populations due to the improvement of habitat and water quality. The growth of animal populations increases hunting and viewing activities due to a reduction in effort (Feather et al. 1999). Feather et al. estimate benefits of wildlife viewing using data from the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (FHWAR) and the NRI. A representative trip model was used that estimates the total number of trips taken to all locations as a function of indicators of the characteristics of the land. These indicators serve as a proxy for the size and health of wildlife populations at recreational sites that may be available to individuals. Benefits-transfer was used to estimate welfare impacts. Specifically, the number of trips predicted was multiplied by a per trip value. The change in consumer surplus due to the CRP was determined using the population-weighing information provided by the FHWAR survey.

Using the benefit estimate for improved wildlife viewing of $1.40 per acre per year, Table 4.14 shows annual consumer surplus values of improved wildlife viewing for both permit scenarios. In the CP case, the increase in consumer surplus due to the introduction of the carbon sequestration program ranges from $442,000 to $1.2 million at the greatest permit price. For the RP scenario, benefits are slightly higher ranging from almost $697,000 to $1.7 million.

Table 4.14. Annual Benefits of Improved Wildlife Viewing (Thousand Dollars)

Permit Price	CP	RP
$10/tonC	$ 442	$ 697
$20/tonC	$ 843	$1,288
$30/tonC	$1,204	$1,779

Note: Benefits estimates are in 1997 Dollars

Total values of improved soil productivity, water quality, freshwater recreation, and wildlife viewing are shown in Table 4.15. Total benefits range from $8.3 million to $22.6 million for the CP scenario. However, the RP scenario results in greater total annual benefits ranging from $13.1 million to $33.4 million. The multiple benefits induced by the introduction of the carbon sequestration program are substantial and have the potential to significantly impact the well-being of Georgia.

Table 4.15. Total Annual Benefits (Thousand Dollars)

Permit Price	CP	RP
$10/tonC	$ 8,305	$13,103
$20/tonC	$15,839	$24,204
$30/tonC	$22,621	$33,433

Note: Benefits estimates are in 1997 Dollars

CHAPTER 6

CONCLUSION

Summary

There is a growing concern about the rising amount of greenhouse gases in the atmosphere. Recently, agriculture and forestry sectors have received increased attention for their role in reducing the amount of greenhouse gases in the atmosphere through carbon sequestration. This sequestering of carbon can potentially play a significant role in decreasing the amount of carbon dioxide in our atmosphere. Improvements in the size of the carbon sink caused by the agriculture and forest sectors are available at low costs.

Many different policies designed to offset the amount of greenhouse gases in the atmosphere are becoming more prevalent in the United States and worldwide. The Kyoto Protocol is the first international agreement with the potential to initiate greenhouse gas abatement. Forestry and land use changes are included in the protocol as a means for developed nations to reduce greenhouse gas emissions. In the United States by the end of 2001, there were approximately 20 voluntary carbon programs that involved carbon sequestration on U.S. forest and agriculture land. In anticipation of a future carbon market, some energy companies are paying landowners and land management companies to alter their current land use practices to include reforestation, afforestation, and soil conservation (King 2002).

In the past, the United States has had success with a cap and trade program for reducing sulfur dioxide emissions. In addition to abatement of this compound, the U.S. has gained valuable experience with such markets. The carbon sequestration program simulated in this analysis provides agricultural landowners flexibility in determining the most cost-effective and efficient crop to grow. The program provides agriculture landowners with permits for converting their land to forest over a 60-year period. Yearly permits are allotted for the amount of carbon sequestered on the land and permits also need to be purchased for the release of carbon sequestered. Two different scenarios concerning permits are considered in the study to examine alternative policy techniques.

The RP scenario results in a greater present value of carbon sequestered and thus results in greater total annual benefits. The results of the CP scenario show over 859,000 acres of marginal agriculture land converting to forestry at the highest permit price. For the RP scenario land use change is greater showing 1.27 million acres converting to forestry. For the highest permit price, 854,000 tons of carbon is sequestered in the CP scenario and for the RP scenario 1.26 million tons of carbon is sequestered annually.

Both approaches for calculating the permit price over time demonstrate that the movement of marginal agriculture land to forestry will not only help offset greenhouse gases but it will also have significant effects on environmental quality. The multiple benefits of a carbon sequestration policy need to be recognized and considered in policies regarding GHG abatement. In this analysis, total annual benefits for the constant real permit price and greatest permit price range from $8.3 million to $22.6 million for the CP scenario. Alternatively, the results for the RP scenario are greater. Specifically, at the greatest permit price total annual benefits range from $13.1 million to $33.4 million. Clearly, these figures indicate large benefits in addition to carbon sequestration.

Policy Implications

Even though a carbon market has not yet been established, a wide variety of people and institutions advocate such a market. With the success of the sulfur dioxide cap and trade program, the United States has the experience to establish a carbon market. This study indicates that there is a direct link between an increase in the net returns to forestry, by the introduction of a permit price presented as the discounted value of carbon sequestered per acre, and the amount of marginal agriculture land converting to forestry. The establishment of a carbon market in the United States and abroad is an efficient and necessary means to offset the amount of greenhouse gases in the atmosphere.

Besides reducing the amount of carbon dioxide in the atmosphere, such a program would also affect other aspects of environmental quality. I estimate that the carbon sequestration program has the most impact on water quality, followed by freshwater recreation, soil productivity, and wildlife. Total annual benefits for the greatest carbon price are substantial and indicate large benefits to farmers and the environment.

For a policy to successfully reduce carbon, other co-benefits need to be taken into consideration. Carbon sequestration can provide countries with more time until a more cost-effective method to reduce greenhouse gases is discovered. Carbon sequestration alone is not the answer. Dependence on fossil fuels needs to be minimized and the use of alternative technology needs to be more broadly implemented. Solely depending on carbon sequestrations is not practical, but by combining this approach with alternative technology and current means it is possible to cost effectively limit the risks that stem from increasing amounts of carbon.

This study shows that potential benefits of sequestration incentives are substantial. Forests and agriculture, specifically land use change, play a significant role in the release of carbon dioxide emissions. In the future when a carbon market is established, it is essential that conservation practices from agriculture and forestry are included. The implementation of a carbon market that includes these sectors requires standards, such as additionality, permanence, conservation benefits, annual credit/debit accounting, and third party certification. Additionality means only crediting increases in the carbon sink above “business as usual” activities. This addition of carbon dioxide will ensure that buyers of permits are receiving real reductions in carbon dioxide (Wayburn and Passero). The additional amount of carbon that is sequestered above the baseline needs to be stored for long periods of time to ensure long-term reductions in carbon dioxide as well as improvements in environmental quality. Conservation benefits such as the co-benefits discussed in this study should be encouraged in the carbon market (Wayburn and Passero). Also, careful consideration of the land that will be allowed to sequester additional amounts of carbon should be given therefore discouraging the destruction of native forests or wetlands. Annual credit/debit accounting of carbon sequestered should be included to make certain that only net gains of carbon are credited. Lastly, there should be a third party present (regulator) to guarantee the credibility of the transactions that are made (Wayburn and Passero).

These rules will increase the effectiveness of a carbon market that includes agriculture and forestry conservation measures. This analysis provides evidence that, given monetary incentives, agriculture landowners will convert marginal land to forest. The conversion of land from agriculture to forestry has substantial benefits for environmental quality. As shown by the analyses in the paper, not considering the co-benefits limits the scope of overall policy benefits. A complete carbon sequestration policy must recognize and consider all the potential gains including those from environmental benefits.

REFERENCES

Ahn, SoEun, Andrew Plantinga, and Ralph Alig. "Predicting Future Forestland Area: A Comparison of Econometric Approaches." *Forest Science*, vol.46, is.3, 2000, 363-376.

Bettelheim, Eric, and Gilonne d'Origny. "Carbon sinks and emissions trading under the Kyoto Protocol: a legal analysis." Capturing Carbon and Conserving Biodivesity. Eds. Swingland, Ian. Sterling, VA, 2003.

Birdsey Richard and L. Heath. "Carbon Changes in U.S. Forests." Forests and Global Change,Vol 2. Eds. Sampson, R.N.; Hair,D. Washington DC. 56-68 and Appendices.

Brownback, Sam. http://brownback.senate.gov/LICarbonFarm.htm

Butt, Tanveer, and Bruce McCarl. "Can Farmer Sell All the Carbon They Sequester?" http://ageco.tamu.edu/faculty/mccarl/discounts_outreach.pdf

Bonnie, Robert, Melissa Carey, and Annie Petsonk. "Protecting terrestrial ecosystems and the climate through a global carbon market." Capturing Carbon and Conserving Biodiversity. Eds. Swingland, Ian. Sterling, VA, 2003.

Bonnie Robert. "Carbon Sequestration and Emissions Trading: Confronting Climate Change While Creating Incentives for Improved Land Management." Testimony before the United States Senate Subcommittee on Science, Technology, and Space of the Senate Committee on Commerce Science and Transprotation. (May 2001).

Carbon Sequestration Markets. Carbon Sequestration on Idaho Agriculture and Forest Lands (2003). http://www.scc.state.id.us/PDF/Carbon%20Sequestration/Carbon%20Sequestration%20Markets.pdf

Coder, Kim. “Identified Benefits of Community Trees and Forests.” Warnell School of Forest Resources. http://www.forestry.uga.edu/warnell/service/library/for96-039/

Dangerfield and Hubbard. “Forestry Situation and Outlook with Implications for Agriculture, 1998.” Warnell School of Forest Resources. October 29, 1998. http://www.forestry.uga.edu/warnell/service/library/index.php3?docID=181

Environmental Protection Agency. http://yosemite.epa.gov/oar/globalwarming.nsf/content/Climate.html

Feather, Peter, Daniel Hellerstein and LeRoy Hansen. “Economic Valuation of Environmental Benefits and the Targeting of Conservation Programs: The Case of the CRP.” Economic Research Service. Agricultural Economic Report No. 778. April 1999.

The Georgia Department of Natural Resources. Environmental Protection Division Air Protection Branch. “Development of A Greenhouse Gas Emission Inventory For The State of Georgia.” Revised Final Report for Phase I of the United States Environmental Protection Agency’s State and Local Climate Change Program. January 12, 1999.

Hardie Ian and Peter Parks. “Land Use with Heterogeneous Land Quality: An Application of an Area Base Model.” *American Journal of Agricultural Economics*, vol. 79, May 1997, 299-310.

Intergovernmenal Panel on Climate Change. Third Assessment Report, Climate Change 2001: Impacts, Adaptation and Vulnerabiltiy. 2001.

King, Dennis. “Anatomy of ‘Early’ Carbon Sequestration Trading: Common Sense Can Prevent Costly and Embarrassing Mistakes.” *Journal of the Forum for Environmental Law, Science, Engineering, and Finance*, Summer 2002.

Kurkalova, Lyubov, Catherine King, and Jinhua Zhao. “Multiple Benefits of Carbon-Friendly Agricultural Practices: Empirical Assessment of Conservation Tillage.” Working Paper 03-WP 326. February 2003.

Lichtenberg Erik. "Land Quality, Irrigation Development, and Cropping Patterns in the Northern High Plains." *American Journal of Agricultural Economics,* February 1989, 187-194.

Malhi, Yadvinder, Patrick Meir, and Sandra Brown. "Forests, carbon and global climate." Capturing Carbon and Conserving Biodiversity. Eds. Swingland, Ian. Sterling, VA, 2003.

Mathews, Stephen, Raymond O'Connor, and Andrew Plantinga. "Quantifying the impacts on biodiversity of policies for carbon sequestration in forests." *Ecological Economics*, vol. 40, 2002, 71-87.

Miller, Douglas and Andrew Plantinga. "Modeling Land Use Decisions with Aggregate Data." *American Journal of Agricultural Economics*, vol. 81, February 1999, 180-194.

Nordhaus, William. "Reflections on the Economics of Climate Change." *Journal of Economic Perspectives*, vol. 31, is. 4, Autumn 1993, 11-25.

Pattanayak, Subhrendu, Allan Sommer, Brian Murray, Timothy Bondelid, Bruce McCaral and Dhazn Gillig. "Water Quality Co-Benefits of Greenhouse Gas Reduction Incentives in U.S. Agriculture: Final Report." September 4, 2002.

Plantinga, Andrew, Thomas Mauldin and Douglas Miller. "An Econometric Analysis of the Costs of Sequestering Carbon in Forests." *American Journal of Agricultural Economics*, vol.81, November 1999, 812-824.

Plantinga Andrew and JunJie Wu. "Co-Benefits from Carbon Sequestration in Forests: Evaluating Reductions in Agricultural Externalities from an Afforestation Policy in Wisconsin." *Land Economics*, vol. 79, is.1, February 2003, 74-85.

Plantinga, Andrew. "The Effect of Agricultural Policies on Land Use and Environmental Quality." *American Journal of Agricultural Economics*, vol. 78, November 1996, 1082-1091.

Ribaudo, Mark. "Water Quality Benefits from the Conservation Reserve Program." Economic Research Service. Agricultural Report No. 606. February 1989.

Ribaudo, Mark, Daniel Colacicco, Linda Langer, Steven Piper, and Glenn Schaible. "Natural Resources and Users Benefit from the Conservation Reserve Program." Economic Research Service. Agricultural Economic Report No. 627. January 1990.

Smith and Bernstein. "Impacts of Implementing a Carbon Cap with a Safety Valve on Allowance Prices." The Climate Change Policy Center. January 15, 2004.

Soil and Water Conservation Society Fact Sheet. "Storing Carbon Through Soil Conservation." http://www.swcs.org/docs/FactSheet.carbon.pdf

Stavins, Robert. "The Costs of Carbon Sequestration: A Revealed-Preference Approach." *The American Economic Review*, vol. 89, is.4, September 1999, 994-1099.

Stavins, Robert and Adam Jaffe. "Unintended Impacts of Public Investments on Private Decisions: The Depletion of Forested Wetlands." *The American Economic Review*, vol. 80, is. 3, June 1990, 337-352.

Totten, Michael. "Getting It Right: Emerging Markets for Storing Carbon in Forests." World Resources Institute. Forest Trends. 1999.

U. S. Department of State Fact Sheet. June 6, 2003.

U.S.D.A. Farm Service Agency. Conservation Reserve Program. Fiscal Year 2002 Summary. http://www.fsa.usda.gov/dafp/cepd/stats/FY2002.pdf]

Warnell School of Forest Resources. http://www.forestry.uga.edu/warnell/service/library/frn74/node2.html and http://www.forestry.uga.edu/warnell/service/library/for96-039/

Wayburn, Laurie and Michelle Passero. "The Use of Conservation Easements to Secure the Role of Private Forests in an Emerging Carbon Market." http://www.cfr.washington.edu/Outreach/carbon/Wayburn_Passero.pdf

Wu, JunJie, and Kathleen Segerson. "The Impact of Policies and Land Characteristics on Potential Groundwater Pollution in Wisconsin." *American Journal of Agricultural Economics,* vol. 77, November 1995, 1033-1047.