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I am submitting herewith a thesis written by Jennifer M. Sexton entitled "Feasibility Study of Carbon Offsets as a Source of Revenue for a Land Trust using the Climate Action Reserve's Avoided Conversion Protocol." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Environmental Science.

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Feasibility Study of Carbon Offsets as a Source of Revenue for a Land Trust using the Climate Action Reserve's Avoided Conversion Protocol

A Thesis
Presented for the
Master of Science Degree
The University of Tennessee at Chattanooga

Jennifer Marie Sexton
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DEDICATION

This work is dedicated to all those who go back to school later in life in search of something better.

ACKNOWLEDGEMENTS

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NOMENCLATURE

cm	centimeter
ha	hectare
m	meter
Mt	metric ton, or tone
Mt CO_2e	metric tons of carbon dioxide equivalent
ppmv	parts per million by volume
Tg	teragrams

ABBREVIATIONS

ACP	Avoided Conversion Project
AGB	above-ground biomass
BGB	below-ground biomass
CAR	Climate Action Reserve
CP	Conversion Project
CRT	Climate Reserve Tonne
d.b.h.	diameter at breast height
FVS	Forest Vegetation Simulator
GHG	greenhouse gas
GWP	global warming potential
H.R.	House of Representatives
IR	infrared
LTA	Land Trust Alliance
spp.	species (general)
TRGT	Tennessee River Gorge Trust
USEPA	United States Environmental Protection Agency
USFS	United States Forestry Service

ABSTRACT

In 2008, 279 million hectares of forest land contained 45,337 teragrams (Tg) of carbon. Changes in land use and forestry practices in 2008 resulted in a net carbon sequestration of 940.3 Tg of carbon dioxide equivalent, or 13.5% of total U.S. greenhouse gas emissions in 2008, making forests a net sink for carbon. With increasing development pressures, organizations such as land trusts, that protect forest land and prevent deforestation, are positioned to become key players in climate change mitigation. There are 21 land trusts in Tennessee protecting over 165,000 acres of land. One such land trust, the Tennessee River Gorge Trust (TRGT), is located in Chattanooga, Tennessee. Since its inception in 1981, the TRGT has protected approximately 17,000 acres of the approximate 27,000 acres that comprise the Tennessee River Gorge, a 26 mile canyon carved through the Cumberland Plateau by the Tennessee River. The TRGT owns 6,140 acres of mostly forested land and was selected as the model organization for this study. The aim of the present project was to determine the financial potentiality of a land owner, specifically a land trust, registering a carbon offset project under the Climate Action Reserve's (CAR) Avoided Conversion Protocol. It was found that determining a carbon baseline did not require significant financial resources but did require specialized knowledge of tree species identification. It was also found that due to the inherent variability in identifying and measuring trees from year to year, it would be prudent, particularly for the inexperienced landowner, to map the layout of the trees in each plot. This process would allow for not only the accurate and precise accounting of year to year growth, but would also facilitate tracking and accounting of ingrowth and mortality within the plot. The study revealed that two significant challenges exist for those wanting to register a carbon offset project: 1) the acquisition and application of forest growth modeling data and 2) the ability to meet the legal and performance standards established in the protocol. It would be prudent for a landowner to investigate the various registries and the details of their protocols, including associated project registration fees, before investing in a project. Further, organizations exist now that will do all of the field work and paperwork and will cover all upfront costs associated with establishing a carbon offset project, with the exception of third party verification, for a percentage of the revenue. These organizations were not examined in this study, but they could be a mechanism whereby more landowners become involved in carbon offsetting. Finally, the study found that carbon offsets could be a significant source of revenue for landowners, particularly land trusts, but would depend on the demand for

and value of carbon offset credits in emerging markets influenced by the possibility of regulation.

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Chapter 1 Introduction

1.1 Climate Change

Greenhouse gases (GHG) in the atmosphere absorb and reflect or redirect radiation in the infrared (IR) region of the electromagnetic spectrum (Horvath, 1993). The greenhouse effect is the natural mechanism in which Earth absorbs visible light emitted from the Sun, converts it into IR radiation, and emits it to the troposphere where GHGs can absorb, reflect, or redirect it. Carbon dioxide (CO_2) and water vapor, both GHGs, absorb the majority of the emitted IR and radiate it in all directions. The amount of IR emitted back towards Earth, and consequently the temperature of Earth's surface, is partially controlled by the concentration of GHGs in the atmosphere (Crowley, 2000).

Greenhouse gases are standardized for comparison purposes using a measure called global warming potential (GWP) that is based on both IR absorption strength and atmospheric residence time, or how long a particular gas molecule remains in the atmosphere. Carbon dioxide is the most prevalent GHG, but there are others such as methane, ozone, nitrous oxide, hexafluoride, chlorofluorocarbons, hydrofluorocarbons, perfluorocarbons, and hydrochlorofluorocarbons with a greater ability to absorb IR and longer residence times in the troposphere. The GWP of all GHGs are measured against that of CO_2. For example, CO_2 has a GWP of 1. Methane has 21 times the GWP of CO_2. Accordingly, methane has a carbon dioxide equivalent value (CO_2e) of 21.

Carbon dioxide exists in a natural state of balance between the atmosphere and Earth. Natural processes such as plant respiration and decomposition, volcanic eruptions, and forest fires release CO_2, which are buffered naturally by the oceans and terrestrial ecosystems (Schimel et al., 1995). According to the International Panel for Climate Change Fourth Assessment

Report, from AD 1000 – 1750, atmospheric CO_2 concentrations ranged from 275 to 285 ppmv (parts per million by volume) (Forster et al., 2007).

However, the natural balance between Earth and atmosphere can be disrupted. In the last 250 years, CO_2 levels have increased 100 ppmv to 380 ppmv, an increase of 0.4 ppmv per year (Houghton, 2007). And the increases are becoming larger in magnitude, as the highest decadal growth rate of 19 ppmv measured since the 1950s occurred between 1995 and 2005 (Keeling & Whorf, 2004). According to the U.S. Environmental Protection Agency's (USEPA) 2010 report on Inventory of Greenhouse Gas Emissions and Sinks, total U.S. GHG emissions have increased 14 percent from 1990 to 2008. During that same time, CO_2 emissions have increased by 820.4 million metric tons, or teragrams carbon dioxide equivalents (Tg CO_2e). In summary, in 2008, carbon dioxide emissions (5,921.2 Tg CO_2e) accounted for approximately 85% of total U.S. GHG emissions (6,956.8 Tg CO_2e) (USEPA, 2010).

Fossil fuel emissions and alteration of plant and soil carbon reserves due to land use changes, such as the conversion of forests to agriculture or urban use, are primary sources of increased atmospheric CO_2 concentrations (Vitousek, 1994; Houghton, 2007). Other anthropogenic sources include but are not limited to cement production, coke production, gas flaring, and landfills (Subak et al., 1993).

1.2 Carbon

Forests remove CO_2 from the atmosphere and convert it to cellulose, the primary structural component of plant cell walls. Carbon, in the form of cellulose, moves between several categories of forest carbon pools: above-ground biomass (AGB), below-ground biomass (BGB), understory vegetation, standing and down dead wood, forest floor litter, soil carbon, harvested wood products, and harvested wood products in solid waste disposal sites (USFS, 2007; USEPA, 2010). In 2008, land use changes and forestry activities were responsible for a net sequestration of 940.3 Tg CO_2e, or 13.5%, of total U.S. GHG emissions, or 6,956.8 Tg CO_2e (USEPA, 2010). This includes forest land remaining forest land, cropland remaining cropland, land converted to cropland, grassland remaining grassland, land converted to grassland, settlements remaining settlements (urban forests), and landfilled yard trimmings and food scraps.

United States forest land contained approximately 45,337 Tg carbon in AGB, BGB, dead wood, litter, and soil organic carbon (calculated for 635 million acres of forest land and excludes Hawaii, U.S. territories, large portions of Alaska and west Texas) (USEPA, 2010). In 2008 net annual changes in carbon stocks in forest pools for the aforementioned area, where forest land remained forest land, was 703.9 Tg CO_2e/year, or 10.1% of total U.S. GHG emissions, an increase of 15% from 598.1 Tg CO_2e/year in 1990 (USEPA, 2010). This increase is due primarily to improved forest management practices that increase carbon density and total forest land such as combating soil erosion, regenerating previously cleared forest land, converting marginal cropland to forest, and improving timber management activities.

1.3 Land

The total area of the United States (including Alaska and Hawaii) is 2.43 billion acres (Central Intelligence Agency, 2009). In 2007, approximately 751 million acres (or 31 percent) of the total area of the United States, was considered by the U.S. Forestry Service (USFS) to be forest land, or land at least 120 feet wide, one acre in size, with at least 10 percent land cover (USFS, 2009). Of forest land, fifty-six percent (or 423 million acres) is privately held by corporations, groups, and individuals; the remaining 44 percent is publicly held. Non-corporate private owners, including individuals, estates, trusts, clubs, and nongovernmental organizations, hold 38 percent (or 285 million acres) of all forest land (USFS, 2009).

Land trusts are organizations that actively work to conserve land through purchasing property outright, accepting land donations, negotiating conservation easements, and stewarding conserved land in perpetuity (Land Trust Alliance [LTA], 2005). There are over 1,700 land trusts in the United States that collectively protect 37 million acres of land. As undisturbed forests function as carbon sinks, the prevention of deforestation is a logical way to offset increasing carbon emissions, and with ever-increasing development pressures, land trusts are well positioned to become key players in offsetting climate change.

There are 21 land trusts in Tennessee that protect 165,828 acres of land (LTA, 2005). One such land trust, the Tennessee River Gorge Trust (TRGT), is located in the heart of Chattanooga, Tennessee. Its mission is to protect the viewshed of the Tennessee River Gorge through direct purchase or donation, conservation easement donation, lease, and memorandums of understanding with the State of Tennessee and the Tennessee Valley Authority. Since its inception in 1981, the TRGT has protected approximately 17,000 acres of the approximate 27,000 acres that comprise the Tennessee River Gorge, a 26 mile canyon carved through the Cumberland Plateau by the Tennessee River. The TRGT owns 6,140 acres through direct purchase or donation.

1.4 Legislation

At the time the present study began, the U.S. Congress was considering legislation that would have helped combat climate change through market based mechanisms. On June 26, 2009, the House of Representatives in the 111th United States Congress passed H.R. 2454, The

American Clean Energy and Security Act of 2009 (H.R. 2454, 2009). Its goal, among other things, was to reduce global warming pollution by steadily reducing the carbon emissions of regulated entities to levels 3% below 2005 levels by 2012, 20% below 2005 levels by 2020, 32% below 2005 levels by 2030, and finally, 83% below 2005 levels by 2050. The bill was never voted on by the Senate and was cleared from the books with the convening of the 112th US Congress on January 3rd, 2011.

That bill would have established a system whereby beginning in 2012, entities that emit CO_2, CH_4, and N_2O, or other GHGs as defined by the Administrator of the bill, would be considered reporting entities, or capped sources, and would be issued GHG emissions "caps," or limits. Capped sources could include any electricity source, any stationary source that produces "petroleum-based or coal-based liquid fuel, petroleum coke, or natural gas liquid, the combustion of which would emit 25,000 tons or more of CO_2e," any stationary source involved in the direct production of cement, nitric acid, ammonia, soda ash, glass, iron and steel, etc. (H.R. 2454, 2009). Therefore, capped sources include, but are not limited to, power companies, cement production plants, oil and gas refineries, chemical production facilities, and pulp and paper mills.

According to the bill, emissions beyond the allowable capped level would have been prohibited but capped entities could purchase carbon offset credits to remain compliant. Up to a maximum total of two billion metric tons of annual emissions could be offset by capped sources collectively through the purchase of carbon offset credits. Offset projects that could be verified as having resulted in permanent reduction or avoidance of GHG emissions or sequestration of GHGs would qualify for offset credits. Under the guidelines of the Act, an offset project developer would be issued one offset credit for each metric ton of carbon dioxide equivalent (Mt CO_2e) that could be verified by a third party to have been reduced, avoided, or sequestered. The offset credits could then be sold, traded, or exchanged to a capped source, up to a certain percentage of the source's total emission allowance, to meet the source's compliance obligations.

Another potential source of legislation is the USEPA. On April 2, 2007, the Supreme Court found that GHGs are covered by the Clean Air Act. On December 7, 2009, the Administrator of the USEPA, under section 202(a) of the Clean Air Act, issued two findings: 1) current and projected concentrations of CO_2 and five other GHGs in the atmosphere "threaten the public health and welfare of current and future generations" and 2) combined emissions of said GHGs from motor vehicles contribute to GHG pollution (USEPA, 2009). However, on April 7, 2011, H.R. 901, The Energy Tax Prevention Act of 2011, passed the House of Representatives. This purpose of this bill is to amend the Clean Air Act to prohibit the Administrator of the USEPA from promulgating regulations concerning, taking action relating to, or taking into consideration the emission of a GHG to address climate change (H.R. 910, 2011).

1.5 Climate Action Reserve Registry

California's Climate Action Reserve (CAR) is a nonprofit entity that creates standards for the quantification and verification of GHG emission reduction projects, issues carbon offset credits in the form of Climate Reserve Tonnes (CRT) to those projects, serializes and tracks those offset credits over time as they are traded, bought, or sold (CAR, 2010). They have developed standardized carbon offset protocols that could be used as a foundation for a federal GHG reduction program. Through CAR's reduction protocols, one CRT is issued for every one Mt CO_2e reduction in GHG emissions. Once CRTs are retired they officially become carbon offsets. The CAR is not an exchange, but CRTs can be sold or retired on behalf of a third party purchaser in an "over-the-counter" fashion through the CAR's system at a price negotiated between the seller and the buyer. Sometimes offset buying or selling is managed through brokers who function to link the buyer and seller together and who help negotiate pricing between the two parties. These offset transfers still occur within the CAR's system but pricing information is not public information (P. Browning, personal communication, September 30, 2010).

The CAR has developed protocols for several types of GHG reduction projects, including but not limited to Nitric Acid Production, Landfill, Organic Waste Composting, Urban Forest, and Forest ("Protocols," n.d.). Within the Forest Project Protocol v3.2, CAR recognizes Reforestation Projects, Improved Forest Management Projects, and Avoided Conversion Projects (ACP), each with a separate list of criteria that must be met before a project can qualify for offset credits (CAR, 2010). Avoided Conversion Projects specifically involve preventing the conversion of forested land to a non-forest use, such as residential, commercial, or agricultural land uses, through establishing a conservation easement or transferring the land to public ownership.

For any forested land to qualify as an ACP, the landowner must demonstrate 1) a "significant threat of conversion" exists, 2) the proposed ACP will not employ broadcast fertilization, and 3) the proposed ACP area is not already part of a previously registered forest project (CAR, 2010). It is not necessary to show that a threat to conversion is eminent, but rather show that the proposed ACP area can 1) legally be converted, also known as the Legal Requirement Test, and 2) that conversion is likely in the near to long-term future, also known as the Performance Test (P. Browning, personal communication, October 20, 2010) (CAR, 2010).

The Legal Requirement Test requires the landowner to demonstrate that the proposed ACP will achieve GHG reductions above and beyond anything required through compliance with any existing federal, state, or local rule, regulation, ordinance, or law (CAR, 2010). To meet the Legal Requirement Test, the landowner must prove that the proposed ACP area could legally be converted, herein referred to as the Conversion Project (CP), and this proof can include, but isn't limited to, documented approval from the governing county to convert the proposed project area to the anticipated type of conversion, documented zoning/planning regulations permitting the type of anticipated conversion, and documentation indicating surrounding areas of similar forested land were able to be converted to the anticipated type of conversion.

The Performance Test requires the land owner to demonstrate that the proposed ACP will achieve GHG reductions above and beyond anything achieved through "business-as-usual" activities (CAR, 2010). To meet the Performance Test, the land owner must provide a real estate appraisal indicating that the anticipated type of conversion is both possible, based on the physical characteristics of the property, and financially advantageous. The latter requires that the anticipated type of conversion has a higher market value, at least 40% higher, than the current value of the project area.

The proposed project boundary for an ACP is defined as the parcel(s), designated by the appraisal, to have an anticipated converted value of 140% the existing value of the property. Once the proposed ACP area is established, the landowner must account for all of the GHG sources, sinks, and reservoirs within the project boundaries. Required carbon pools for a forest preservation project include AGB, BGB, and long term wood products such as lumber; optional carbon pools include above-ground non-tree biomass, forest floor litter, dead wood, and soil carbon (USFS, 2007).

1.6 Study Objectives

Carbon offset credits have potential as a source of revenue for landowners, particularly land trusts. Objective 1 was to establish a carbon baseline for the study site and walk through the steps involved with establishing an Avoided Conversion Project with the CAR. Objective 2 was to perform a cost benefit analysis of the processes associated with Objective 1, from establishing a carbon baseline through registering and selling the resultant carbon offsets

Chapter 2 Materials and Methods

2.1 Study Area

Pot Point, the study site, is located in the Tennessee River Gorge on the outskirts of Chattanooga, TN. The name is in reference to the property's location on a set of rapids known as the "Boiling Pot," before the Tennessee River was damned in the 1960s. It is bounded by the Tennessee River on one side and by mature, protected forest on the other three sides (Figure 2.1). The site is a 162.28 ha parcel owned fee simple by the TRGT, a land trust that has been operating in the Chattanooga area since 1981. Fee simple means absolute ownership as opposed to land conservation through other means such as conservation easements where the

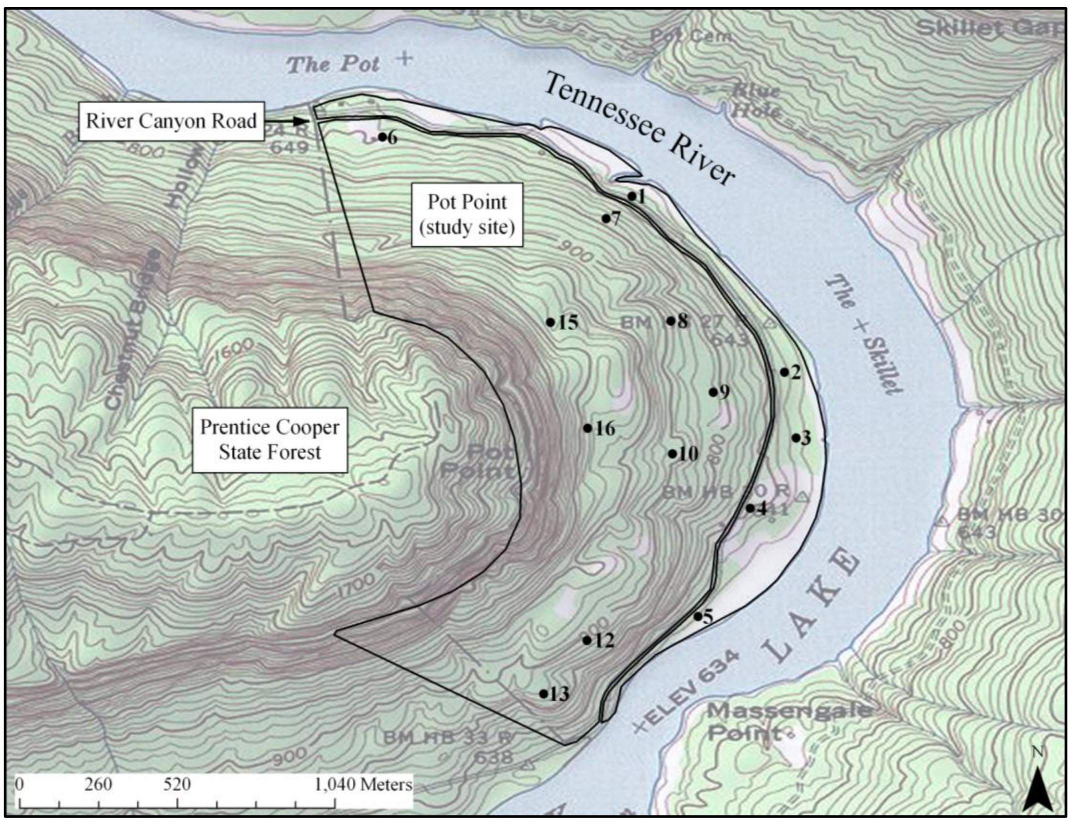

Figure 2.1. Map of the site of the proposed avoided conversion project and the 16 sampling plots to determine a carbon baseline for the 162 hectare property. River Canyon Road bisects the property that is bounded by the Tennessee River on one side and by mature protected forest on the other three sides.

development rights of a property might be purchased. River Canyon Road bisects the property into hydric and mesic forest communities. Most of the Pot Point property is mesic habitat that consists of mature forest dominated by oak and hickory with areas of upland pine; a small section of property that falls between the road and the river consists mostly of hydric habitat. Elevation change is approx 1,250 m from the river level to the top of the ridge. According to Jim Brown, one of the founders and the current Executive Director of the TRGT, 30 acres above the road were logged in the early 1950s and 20 acres below the road were once open field but now consist of young, ingrown forest (personal communication, September 4, 2009).

2.2 Carbon Baseline

2.2.1 Field Measurements

Permanent circular plots were established to estimate the above ground tree biomass and consequently establish a carbon baseline for 2008. The USFS's manual, "Measurement Guidelines for the Sequestration of Forest Carbon," was used as a guide for sampling procedures and estimating carbon stocks (USFS, 2007).

The Pot Point site was divided into three strata, lowland, midland, and upland, using River Canyon Road as a dividing line for the lowland stratum. The separation between midland and upland was established using a topographic line map and estimations of elevation change. Above 950 m was considered upland, between 700 and 950 m was considered midland, and below 700 m was considered lowland. The Tennessee River is at approximately 630 m elevation. Plot locations were evenly spaced across each stratum with five plots in the lowland, eight in the midland, and three in the upland stratum. Fewer plots were selected for the upland stratum due to difficulties in navigating the steeper terrain. In total, sixteen plots were established and surveyed.

Each plot had a radius of 17.84 m, encompassing approximately 1000 m^2, or 0.1 hectares. In total, one percent of the property was surveyed. Geographic coordinates were taken at the witness tree, located at the center of each plot, using a Trimble GEOXH equipped with an antennae and ArcPAD 7.0 that was borrowed from the University of Tennessee at Chattanooga. The antennae allowed for sub-meter accuracy (< 30 cm) with the heavy cover due to leaf-on conditions. The witness tree was marked both with a flag at its base and a piece of flagging tape placed beneath a rock near its base (Figure 2.2). Both flags were marked with the site number. A 100 m fabric field tape was used to measure the radius of each plot (Figure 2.2). One person stood by the witness tree and held the tape at 17.84 m while another person walked the tape straight from the center of the plot. This was repeated approximately nine times, essentially

Figure 2.2. Photos taken while measuring above-ground biomass (AGB). The leftmost photo shows the extent of the radius of a plot. The center photo shows Jim Brown using calipers to measure diameter at breast height (d.b.h). The rightmost photo shows a large rock and a flag at the base of a witness three. The rock has piece of flagging tape beneath it identifying the plot number.

breaking the plot up into eighths. A third person identified the species and measured the diameter at breast height (d.b.h.) of each tree greater than 2.5 cm d.b.h. that stood within the plot. Diameters were measured on the uphill side of the tree, at breast height, using 127 cm calipers. Sampling was done in the summer to allow for easier species identification and binoculars were used to assist with leaf identification.

Trees were usually identified to species. When a particular species could not be identified, only the genus was recorded. However, for the maple genus (*Acer spp.*), it was necessary to identify each individual species. Of the three species of maple found in the area, the red maple (*A. rubrum*) and the silver maple (*A. saccharinum*) fall into the soft maple/birch species classification for determining biomass. The third, sugar maple (*A. saccharum*), falls into the hard maple/oak/hickory/beech species classification. Other species, like oak (*Quercus spp.*), hickory (*Carya spp.*), and ash (*Fraxinus spp.*) that are indigenous to the area, each fall under the biomass species classification for hard maple/oak/hickory/beech, hard maple/oak/hickory/beech, and mixed hardwood respectively, so it was not necessary to identify those trees to species.

2.2.2 Carbon Baseline Calculations

Surveyed trees were classified into species groups according to allometric regression equations used to calculate AGB (Table 2.1) (Jenkins et al., 2004). Specifically, trees were classified as soft maple/birch (mb), mixed hardwood (mh), hard maple/oak/hickory/beech (mo), or pine (pi). In instances where the d.b.h. was beyond the maximum d.b.h. allowed for the aforementioned equations, the allometric regression equation for hardwoods was used to calculate AGB (Table 2.2) (Brown & Schroeder, 1999). Below-ground biomass was estimated from AGB using the equation for temperate forests (Cairns et al., 1997).

$$BGB = \exp(-1.0587 + 0.8836 \ln AGB + 0.2840) \qquad (1)$$

Where BGB = below-ground biomass density in tons/hectare (t/ha) and AGB = above-ground biomass density (t/ha).

Table 2.1. Above-ground biomass equation[a], constants, and d.b.h. limits for hardwood and softwood species by species group (modified from Jenkins et al., 2004).

Species Group	Abbreviation	Parameter β_0	Parameter β_1	Max d.b.h.[b] (cm)
	Hardwood			
Soft maple/birch	mb	-1.9123	2.3651	66
Mixed hardwood	mh	-2.4800	2.4835	56
Hard maple/oak/hickory/beech	mo	-2.0127	2.4342	73
	Softwood			
Pine	--	-2.5356	2.4349	180

[a]Biomass equation:

$$y = \exp(\beta_0 + \beta_1 \ln x) \qquad (2)$$

Where

y = total above-ground biomass (kg) for trees 2.5 cm and greater in d.b.h.,

x = d.b.h. (cm),

exp = "e" to the power of,

ln = natural log base "e" (2.718282).

[b]Maximum d.b.h. of trees measured in published equations.

Table 2.2. Above-ground biomass equation[a], constants, and d.b.h. limit for southern hardwood species by species class (modified from Brown & Schroeder, 1999).

Species Class	Parameter β_0	Parameter β_1	Parameter β_2	Parameter β_3	Max d.b.h.[b] (cm)
Hardwood	0.5	25000	2.5	246872	85.1

[a]Biomass equation:

$$y = \beta_0 + \frac{\quad}{\quad} \qquad (3)$$

Where

y = above-ground biomass (kg),

x = d.b.h. (cm).

[b]Maximum d.b.h. of trees measured in published equation.

The AGB and BGB totals for each site were used to calculate total carbon using the assumption that carbon content is approximately half of the biomass content (USFS, 1979).

2.3 Forest Growth Rate

2.3.1 Plot Resampling

The sixteen plots were revisited and remeasured in July, 2010, exactly two years following the initial baseline measurements for the Pot Point property for the purposes of calculating a growth rate for the property. Again, both the species, and genera where species could not be identified, and d.b.h. were recorded for every tree greater than 2.5 cm d.b.h. that stood within the 17.84 m circumference of the plot.

2.3.2 Year Two Carbon Calculations

Each tree was classified into a particular species group as mentioned previously and as defined by the allometric regression equations presented in Jenkins et al. (2004). Where the d.b.h. was outside of the accepted ranges for the aforementioned equations, the allometric regression equation for hardwoods was used (Brown & Schroeder, 1999). The equation for temperate forests was used to calculate BGB from AGB (Cairns et al., 1997).

2.3.3 Forest Inventory and Analysis (FIA) DataMart

For validation purposes, the USFS's FIA DataMart was used to estimate an average growth rate for the eastern Tennessee area (USFS, 2010).

2.3.4 Statistics

Total counts ($\alpha = 0.05$) and AGB ($\alpha = 0.05$) for all plots for 2008 and 2010 were compared using a two-tailed related-samples t-test. Average AGB for each stratum ($\alpha = 0.05$) were compared for 2008 and 2010 using a two-tailed related-samples t-test. Average AGB for each stratum was compared for the 2008 sampling year using a single-factor ANOVA ($\alpha = 0.05$). All calculations were done using Microsoft Excel. An alpha value of 0.05 was used to minimize the potential for both Type I errors, the probability of rejecting a true null hypothesis, and Type II errors, the possibility of failing to reject a false null hypothesis.

2.4 Cost Analysis

2.4.1 Initial Set-up Costs

Expenses associated with establishing a carbon baseline, including equipment costs and effort for both field work and data analysis, were estimated. Direct costs associated with initially registering a carbon offset project with the CAR were determined, which include project registration and third party verification fees.

2.4.2 Carbon Offset Credits and Projected Revenue

Revenue is based on the number of carbon offset credits the ACP is expected to generate above and beyond that of CP scenario. For the ACP scenario, the 2008 baseline data was projected out for 100 years assuming an annual growth rate of 2.2 percent. The CP scenario assumed the same growth rate with a 9.0% loss due to conversion for the first ten years. Total and relative increase in biomass was used to estimate the relative increase in carbon. A range of CRT prices were used to estimate potential CRT revenue, after which all overhead costs were subtracted.

2.4.3 Projected Revenue Less Recurring Costs

Recurring costs include annual property taxes and an annual account maintenance fee with the CAR. Both were projected out to 100 years, the lifetime of an ACP with CAR. Annual property taxes were based on taxes paid in 2009 with an estimated annual increase of 0.25% and 0.5%.

Chapter 3 Results

3.1 Count Characteristics

A total of one percent of the 162 hectare property was surveyed and a total of 902 trees were identified and measured across the sixteen plots in 2008 (Table A.1, Appendix) and 946 in 2010 (Table A.2, Appendix). For both years, the most frequently identified species was the sweetgum (*Liquidambar styraciflua*).

Of the 16 plots, only one plot (plot 9) had the same number of trees sampled in both years (Figure 3.1). Plots 1 through 8, and plot 10, had higher 2010 counts than the 2008 counts whereas plots 11 through 16 had 2010 counts lower than 2008 counts. Overall, 44, or 4.9%, more trees were sampled in 2010, resulting in an average increase of 2.75 trees per plot. However, there was no statistical difference seen in total tree counts between sampling years for individual plots (t (16) = -0.83, $p > 0.05$) (Table A.3, Appendix).

Furthermore, the species identified from 2008 to 2010 also varied (Table A.1, Table A.2, Appendix). Data from plot 1 are presented in figures 3.1 through 3.3 for the purpose of demonstrating common trends. For example, 17 green ash (*Fraxinus pennsylvanica*) were identified in 2008, but only 11 were identified in 2010 for plot 1 (Figure 3.2). Three blackgum (black tupelo, *Nyssa sylvatica*) were identified in 2010 whereas none were identified in 2008 and two hickory (*Carya spp.*) were identified in 2008 whereas none were identified in 2010. Overall, six additional trees were identified for plot 1 in 2010.

In addition, the species classifications for plot 1 also differed from 2008 to 2010 (Figure 3.3). Specifically, 37 mixed hardwoods, five hard maple/oak/hickory/beech, and four soft maple/birch were identified in 2008. Conversely, 41 mixed hardwoods, two hard maple/oak/hickory/beech, and nine soft maple/birch were identified in 2010.

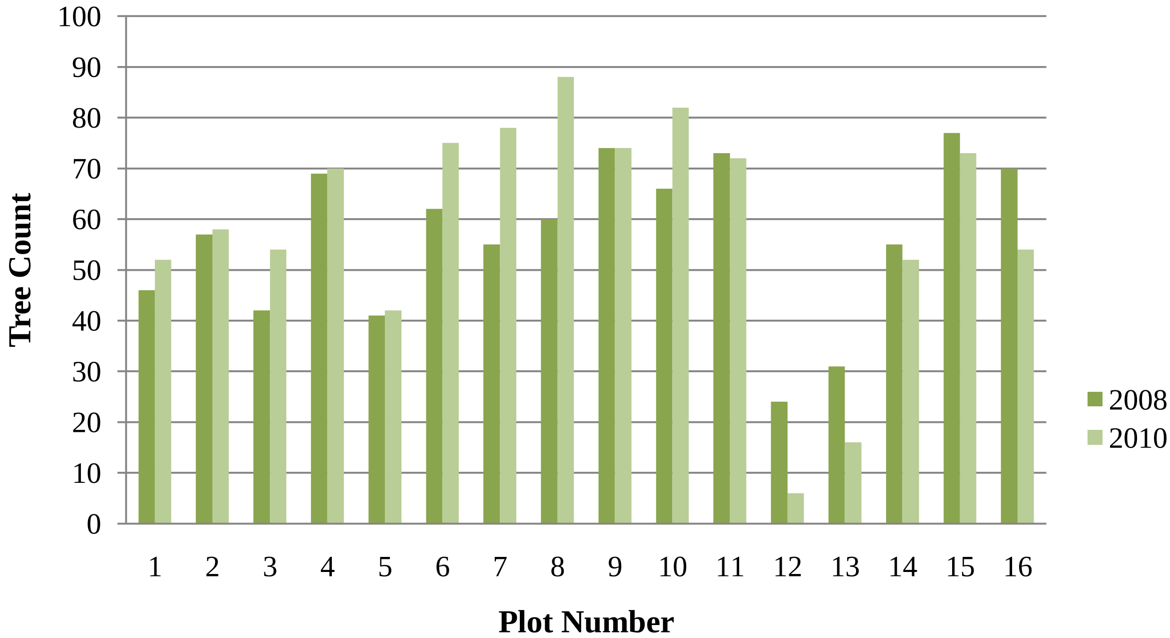

Figure 3.1. Total tree counts by plot number for sampling years 2008 and 2010 at the proposed site of the ACP. In 2008, 902 trees were identified and measured; 946 trees were identified and measured in 2010.

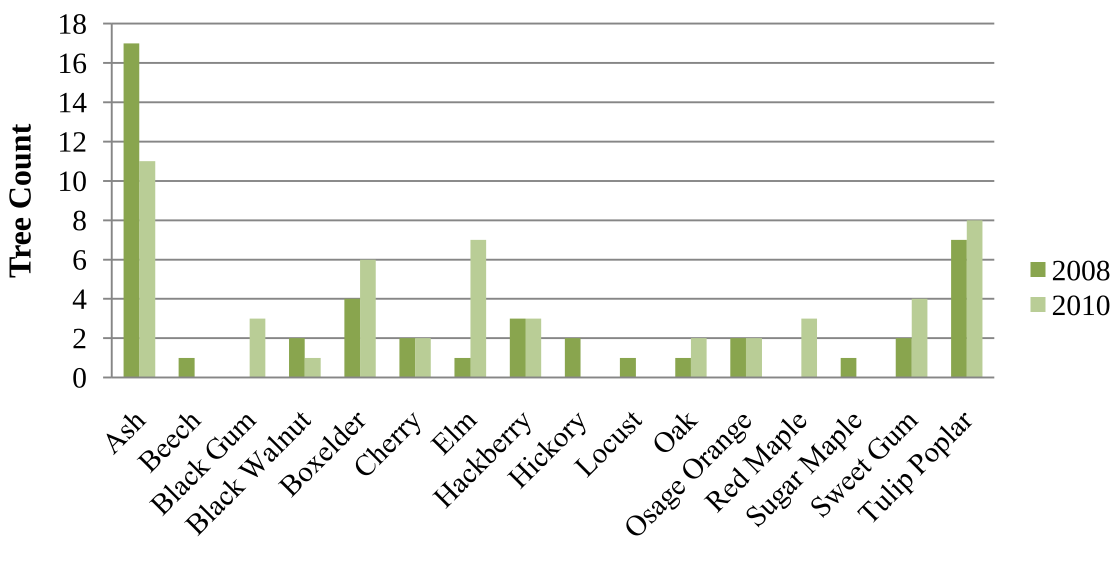

Figure 3.2. Tree counts for plot 1, one of the 16 permanent plots set up at the site of the proposed ACP. Tree counts are organized by the species/genera identified for sampling years 2008 and 2010.

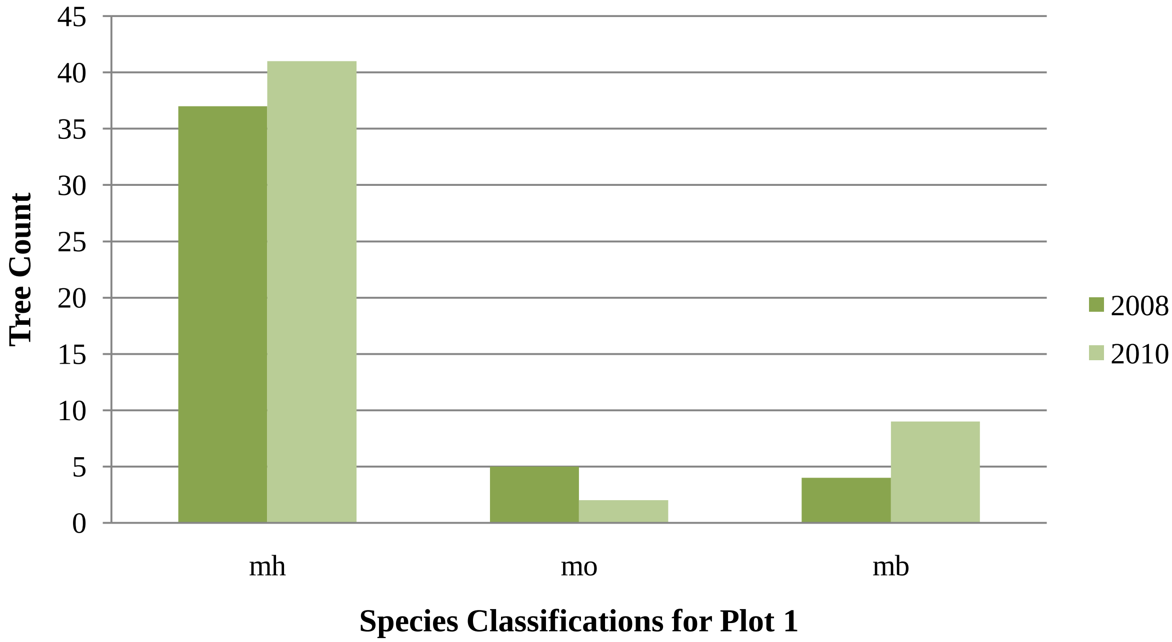

Figure 3.3. Tree counts for plot 1, one of the 16 permanent plots set up at the proposed site of the ACP. Tree counts are organized by species classification, as defined by the allometric regression equations used to calculate biomass, for sampling years 2008 and 2010. Classification categories include mixed hardwood (mh), hard maple/oak/hickory/beech (mo), soft maple/birch (mb), and pine (pi) (not shown).

Differences in count, species/genera identified, and/or species classification were seen for all sixteen plots. However, even though the counts and/or species identified were not identical, the same six species/genera occupied the top 68.7 and 65.0 percent of the total number of trees identified in 2008 and 2010, indicated by the shaded cells in Table 3.1. These six species/genera were sweetgum (*Liquidambar styraciflua*), various species of oak (*Quercus alba*, *Q. bicolor*, *Q. coccinea*, *Q. falcate*, *Q. michauxii*, *Q. prinus*, *Q. rubra*, *Q. shumardii*, *Q. stellata*, and *Q. velutina)*, tulip poplar (*Liriodendron tulipifera*), dogwood (*Cornus florida*), various species of hickory (*Carya glabra*, *C. ovata*, *C. texana*, and *C. tomentosa*), and American beech (*Fagus grandifolia*).

Table 3.1. Total species/genera counts for all 16 plots for 2008 and 2010 sorted by most frequently identified. Beech, Dogwood, Hickory, Sweet Gum, and Tulip Poplar are the top six species/genera identified both years.

2008		2010	
Species/Genera	Count	Count	Species/Genera
Sweet Gum	172	160	Sweet Gum
Oak	119	110	Beech
Tulip Poplar	107	108	Oak
Dogwood	82	87	Tulip Poplar
Hickory	77	79	Dogwood
Beech	63	71	Hickory
Ash	35	64	Elm
Sourwood	35	47	Red Maple
Elm	27	32	Ash
Pine	26	24	Pine
Red Maple	24	23	Sourwood
Ironwood	18	20	Black Gum
Cherry	16	19	Ironwood
Hackberry	16	19	Sugar Maple
Boxelder	15	16	Hackberry
Silver Maple	15	15	Cherry
Sassafrass	9	12	Boxelder
Black Gum	8	12	Silver Maple
Hophornbeam	8	9	Sassafrass
Locust	7	5	Mulberry
Mulberry	6	3	Black Walnut
Sugar Maple	6	3	Hophornbeam
Black Walnut	5	2	Locust
Osage Orange	3	2	Osage Orange
Hawthorne	1	2	Paw Paw
Persimmon	1	1	Hawthorne
Sycamore	1	1	Sycamore
Paw Paw	--	--	Persimmon
Total	902	946	Total

Table 3.2. Total AGB per plot for 2008 and 2010 with percent differences in AGB and total tree count. A positive percent difference indicates an increase from 2008 to 2010; a negative value indicates a decrease.

Plot	2008 AGB (Mt)	2010 AGB (Mt)	Difference in AGB (%)	2008 Tree Count	2010 Tree Count	Difference in Count (%)
1	12.09	13.47	11.3	46	52	13.0
2	18.58	17.93	-3.5	57	58	1.8
3	10.00	11.68	16.8	42	54	28.6
4	19.17	19.21	0.2	69	70	1.4
5	12.66	12.32	-2.6	41	42	2.4
6	20.90	25.44	21.7	62	75	21.0
7	19.98	21.71	8.7	55	78	41.8
8	25.81	24.20	-6.2	60	88	46.7
9	28.77	25.56	-11.2	74	74	0.0
10	21.82	17.84	-18.2	66	82	24.2
11	15.15	13.54	-10.6	73	72	-1.4
12	7.62	4.50	-40.9	24	6	-75.0
13	9.15	5.40	-41.0	31	16	-48.4
14	24.30	19.30	-20.6	55	52	-5.5
15	20.45	16.22	-20.7	77	73	-5.2
16	26.63	22.06	-17.2	70	54	-22.9
Average	18.32	16.90	--	56.38	59.13	--
Total	293.06	270.37	-7.7	902	946	4.9

3.2 AGB, BGB, and Carbon Calculations

3.2.1 2008 and 2010 Compared

In 2008, there was 293.06 tons of AGB. In 2010, there was 273.37 tons of AGB, a 7.7% decrease in biomass (Table 3.2). However, 4.9% more trees were identified and measured in 2010 versus 2008. For example, AGB increased 11.3% from 2008 to 2010 for plot 1, with a corresponding increase in total tree count for that plot from 46 to 52 trees, or 13%. Conversely, for plot 9, AGB decreased from 28.77 Mt to 25.56 Mt, or 11.2%, while tree the count was the same. Strangely, AGB decreased 18.2% for plot 10 but tree count went up from 66 to 88 total trees identified, a 24.2% increase. Total AGB for each plots for both sampling years was compared using a paired two-tailed t-test ($\alpha = 0.05$). There was a statistically significant

Table 3.3. Average AGB by stratum and the weighted average AGB for the three strata for 2008 and 2010. A positive percent difference indicates an increase from 2008 to 2010; a negative value indicates a decrease.

Stratum	2008 Average AGB (Mt/ha)	2010 Average AGB (Mt/ha)	Difference (%)
Lowland	155.65	166.76	7.1
Midland	183.27	161.07	-12.1
Upland	237.92	191.91	-19.3
Weighted Average of the three Strata[a]	192.28	173.24	-9.9

[a]The average of the average AGB for each of the three strata.

difference in total AGB for individual plots for 2008 and 2010 (t (15) = 2.04, $p < 0.05$) (Table A.4, Appendix).

Lowland AGB increased 7.1% to 166.76 Mt/ha. Both midland and upland AGB decreased 12.1 and 19.3% respectively (Table 3.3). Overall, the average of the average AGB for each of the three strata, the weighted AGB, was 192.28 Mt/ha in 2008 and 173.24 Mt/ha in 2010, a 9.9% decrease in AGB per hectare. There was no statistically significant difference between the average AGB for the three strata for 2008 and 2010 (t (3) = 1.15, $p > 0.05$) (Table A.5, Appendix).

Due to the variability seen in the biomass calculations for 2008 and 2010, a positive growth rate for the study site could not be calculated. As such, FIA data from the USFS was used to estimate an average growth rate for the eastern Tennessee area and was applied to the baseline data collected in 2008.

3.2.2 2008 Baseline

In 2008, there was 293,057 kg (293.06 Mt) of AGB standing within the 16 study plots (Table 3.4). The lowland sites, which consisted of plots 1 through 6, had 93.39 Mt of AGB with an average of 15.57 Mt/plot. The midland sites, sites 7 through 13, had 128.29 Mt of AGB with an average of 18.33 Mt/plot. Sites 14 through 16, classified as the upland sites, had a total of 71.376 Mt of AGB with an average of 23.79 Mt/plot. The plots, on average, contained 18.316 Mt of AGB.

The lowland sites averaged 155.655 Mt of AGB per hectare (Table 3.5). The midland sites averaged 183.268 Mt AGB per hectare and the upland sites averaged 237.922 Mt AGB per hectare. The weighted average, or the average of the average AGB for each stratum, was 192.282 Mt AGB per hectare. The analysis of variance revealed that elevation had no effect on total AGB for the three strata ($F(2, 13) = 1.724$, $p > 0.05$) (Table A.6).

Similarly, BGB averaged 38.422 Mt/ha, 44.139 Mt/ha, and 56.072 Mt/ha for the lowland, midland, and upland sites respectively. The weighted average, or the average of the average BGB for each stratum, was 46.2114 Mt BGB per hectare.

The total weighted average for AGB and BGB was 238.49 Mt/ha (Table 3.6). The total weighted average for above-ground and below-ground carbon was 119.25 Mt/ha. There was 31,203.24 Mt of AGB containing 15,601.62 Mt or carbon and there was 7,499.14 Mt of BGB containing 3,749.57 Mt of carbon. There was a total of 38,702.38 Mt of AGB and BGB and a total of 19,351.19 Mt of carbon contained within the AGB and BGB at the site of the proposed ACP.

Table 3.4. Above-ground biomass totals and averages for the 16 plots sampled in 2008.

Plot	Total AGB (kg)	Total AGB (Mt)	Total AGB by Stratum (Mt)	Average AGB by Stratum (Mt)
1	12,094.81	12.09		
2	18,575.10	18.56		
3	9,999.15	9.99	93.39	15.57
4	19,170.32	19.17		
5	12,655.85	12.66		
6	20,897.63	20.89		
7	19,977.16	19.98		
8	25,806.51	25.81		
9	28,771.67	28.77		
10	21,815.97	21.82	128.29	18.33
11	15,146.64	15.15		
12	7,621.57	7.62		
13	9,148.20	9.15		
14	24,296.95	24.29		
15	20,452.16	20.45	71.37	23.79
16	26,627.39	26.63		
Total	293,057.07	293.06	--	--

Table 3.5. Total AGB and BGB per hectare per plot for 2008; average AGB and BGB by stratum.

Plot	AGB (Mt/ha)	BGB (Mt/ha)	Average AGB by Stratum (Mt/ha)	Average BGB by Stratum (Mt/ha)
1	120.95	30.86		
2	185.75	45.08		
3	99.99	26.08	155.66	38.42
4	191.70	46.36		
5	126.56	32.12		
6	208.98	50.03		
7	199.77	48.08		
8	258.07	60.28		
9	287.72	66.36		
10	218.16	51.97	183.27	44.14
11	151.47	37.65		
12	76.22	20.52		
13	91.48	24.11		
14	242.97	57.16		
15	204.52	49.09	237.92	56.07
16	266.27	61.97		
Weighted Average	--	--	192.28	46.21

Table 3.6. Biomass and carbon totals for the proposed ACP area.

Biomass	Biomass Weighted Average (Mt/ha)	Total Biomass (Mt)	Carbon Weighted Average (Mt/ha)	Total Carbon (Mt)
2008 AGB	192.28	31,203.24	96.14	15,601.62
2008 BGB	46.21	7,499.14	23.11	3,749.57
Total	238.49	38,702.38	119.25	19,351.19

3.3 Growth Rate

Total AGB was found to be 7.7% less in 2010 than 2008 even though total tree count for 2010 increased 4.9% (Table 3.2). Due to the variability in the data collected during the two sampling years, it was necessary to determine an average growth rate for the area, rather than calculate a specific growth rate for the property.

The site of the proposed ACP is located in Marion County, Tennessee, which falls within the USFS's eastern Tennessee unit boundary. The USFS's FIA data for 2004 through 2007 yielded an average forest growth rate for the eastern Tennessee area of 2.2%, with a range from 2.0% to 2.5% (Table 3.7) (USFS, 2010).

Table 3.7. Gowth rate percentages and averages for all of the unit boundaries for Tennessee taken from the USFS's FIA data.

Year	West	West Central	Central	Plateau	East[a]
2007	3.7%	3.4%	3.2%	2.4%	2.0%
2006	3.8%	3.5%	3.2%	2.2%	2.1%
2005	3.8%	3.4%	3.6%	2.1%	2.2%
2004	4.2%	3.2%	3.7%	2.3%	2.5%
Average	3.88%	3.38%	3.43%	2.25%	2.2%

[a]The site of the proposed ACP is located in Marion County, which falls within the eastern Tennessee unit boundary.

3.4 Cost Analysis

3.4.1 Initial Set-up Costs

Total equipment costs associated with establishing a carbon baseline for the study site in 2008 were estimated to be $983.04 (Table 3.8). The GPS unit actually used in this study, a Trimble GEOXH with an antenna and ArcPAD 7.0 software, was borrowed from the University of Tennessee at Chattanooga. This unit and software together cost about $10,000 and would be cost prohibitive, so a different unit was priced for the purposes of keeping the study realistic. The field crew consisted of an expert in tree identification, a technician, an intern, and a volunteer. Data collection took a total of 4 days at 8 hours a day (Table 3.9). In total, field work hours cost $1,707.20, or $53.35 an hour. Data analysis took a technician and an intern 56 hours at a cost of $605.60, or $18.35 an hour. The total for data collection and analysis, including equipment costs, was $3,295.84.

The costs associated with registering a project with CAR are fixed costs and include an account set-up fee and a project submittal fee (Table 3.10). These one-time fees totaled $1,000.00. The CAR's avoided conversion protocol requires that the proposed project area be appraised. An appraisal was estimated to be $1,500.00.

Table 3.8. Equipment and associated costs needed for determining a carbon baseline for the proposed ACP in 2008.

Equipment:	Cost per Unit	Total Cost
GPS Unit (Garmin eTREX Vista HCx)	$349.99	$349.99
Binoculars (Bushnell Legend 10x42)	$325.00	$325.00
300'/100 m fiberglass open reel field tape	$74.25	$74.25
127 cm calipers	$231.00	$231.00
Vinyl stake wire flags	$0.05	$0.86
Vinyl flagging tape	$1.94	$1.94
Total	--	$983.04

Table 3.9. Total field and data analysis hours and costs associated with determining a carbon baseline for the proposed ACP in 2008.

Field Hours[a]:	Total Hours	Total Cost
Expert ($35.00/hr)	32	$1,120.00
Technician ($13.00/hr)	32	$416.00
Intern ($5.35/hr)	32	$171.20
Volunteer	32	$0.00
Data Analysis Hours:	Total Hours	Total Cost
Technician ($13.00/hr)	40	$520.00
Intern ($5.35/hr)	16	$85.60
Total	184	$2,312.80

[a]Hourly wages estimated from what TRGT was paying those individuals at the time of the study (J. Brown, personal communication, February 10, 2010).

Table 3.10. Initial fees associated with establishing an account with CAR, registering an ACP, and having the ACP verified through a third party[a].

CAR Fees:	Total Cost
Account Set-up	$500.00
Project Submittal	$500.00
Appraisal Fee	$1,500.00
Third Party Verification Fees[a] ($1,200.00/day):	Total Cost
Documentation Review/Paperwork (3 days)	$3,600.00
Meeting with Registrant/Field Work (3 days)	$3,600.00
Report Generation/Submission (1 day)	$1,200.00
Total	$10,900.00

[a]Estimated (S. Sager, personal communication, October 5, 2010).

Third party verification costs were estimated to be $1,200.00 per day (S. Sager, personal communication, October 5, 2010). It was determined that third party verification could take as many as seven days, including three days of project and paperwork review, three days of on-site meetings and field work, and finally, one day to write and submit the final report to CAR, for a grand total of $8,400.00 for third party verification. Total cost associated with establishing a carbon baseline, having the proposed ACP verified through a third party, and then registering the project with CAR was $14,195.84.

3.4.2 Carbon Offset Credits and Projected Revenue

The number of offset credits the proposed ACP is eligible for is based on the annual incremental difference between the two scenarios, the ACP and the CP, or the amount of GHG emissions reduction gained with the ACP over that which would be lost with the CP. Annual forest growth was assumed to be 2.2% for both scenarios (USFS, 2010). However, the two scenarios differ in that a 90% loss of forest due to anticipated conversion is assumed for the CP scenario over the first ten years, equivalent to a 9.0% loss per year (Table 3.11) (CAR, 2010). For the first ten years of the ACP, 29,375.96 Mt of biomass were projected to be protected from conversion over that of the CP scenario resulting in 14,687.98 Mt of carbon eligible for offset credits. After the first ten years, growth was assumed to be 2.2% for the remaining 90 years of the CP. During the project lifetime of the ACP, 208,244.06 Mt of biomass equivalent to 104,122.03 Mt of carbon were projected to be protected from conversion (Table 3.12). One metric ton of carbon is equivalent to one metric ton of CO_2 equivalent, which is equivalent to one carbon offset credit, or one CRT through the CAR.

Table 3.11. Biomass projections for the proposed ACP and the CP; change in biomass, relative change in biomass, and relative change in carbon between the ACP and the CP for the first ten years.

Year		Projected Project Biomass[a]		ΔBiomass[c] (Mt)	Relative ΔBiomass[d] (Mt)	Relative ΔCarbon[e] (Mt)
		ACP (Mt)	CP[b] (Mt)			
2008	1	39,553.84	35,993.99	3,559.85	3,559.85	1,779.92
2009	2	40,424.02	33,475.13	6,948.89	3,389.04	1,694.52
2010	3	41,313.35	31,132.54	10,180.81	3,231.92	1,615.96
2011	4	42,222.24	28,953.89	13,268.36	3,087.55	1,543.77
2012	5	43,151.13	26,927.69	16,223.44	2,955.08	1,477.54
2013	6	44,100.46	25,043.29	19,057.16	2,833.72	1,416.86
2014	7	45,070.67	23,290.76	21,779.90	2,722.74	1,361.37
2015	8	46,062.22	21,660.88	24,401.35	2,621.44	1,310.72
2016	9	47,075.59	20,145.05	26,930.54	2,529.20	1,264.60
2017	10	48,111.25	18,735.30	29,375.96	2,445.41	1,222.71
Total		--	--	--	29,375.96	14,687.98

[a]Biomass projections are based on 2.2% annual growth rate and include AGB and BGB.
[b]CP scenario assumes 9.0% conversion, or loss in biomass, for the first 10 years.
[c]The annual difference in biomass between the two scenarios.
[d]The change in biomass for year one subtracted from the change in biomass for year two, and so on, to avoid double-counting.
[e]Carbon content is half of the biomass content (USFS, 1979). One Mt of carbon is equivalent to one Mt CO^2e, or one CRT.

Over the Avoided Conversion Project's lifetime of 100 years, the 401 acre site of the proposed ACP was estimated to be eligible for 104,122.03 carbon offset credits, or CRTs, with the CAR. Based on estimates of what CRTs were trading for in 2010, the aforementioned CRTs were projected to be worth between $208,000 and $728,000 (Table 3.12, Table A.7). However, once initial set-up costs and $49,500 in annual account maintenance fees were accounted for, the CRTs were estimated to be worth between $144,000 and $665,000.

Table 3.12. Relative change in biomass and carbon between the proposed ACP and the CP for the lifetime of the project, 100 years; revenue potential based on three CRT pricing schemes less overhead and account maintenance fees.

Year	Relative ΔBiomass[a] (Mt)	Relative ΔCarbon[b] (Mt)	$2.00/CRT	$4.00/CRT	$7.00/CRT
1	3,559.85	1,779.92	$3,559.85	$7,119.69	$12,459.46
2	3,389.04	1,694.52	$3,389.04	$6,778.09	$11,861.65
3	3,231.92	1,615.96	$3,231.92	$6,463.84	$11,311.71
4	3,087.55	1,543.77	$3,087.55	$6,175.10	$10,806.42
5	2,955.08	1,477.54	$2,955.08	$5,910.16	$10,342.79
6	2,833.72	1,416.86	$2,833.72	$5,667.45	$9,918.04
7	2,722.74	1,361.37	$2,722.74	$5,445.48	$9,529.59
8	2,621.44	1,310.72	$2,621.44	$5,242.88	$9,175.05
9	2,529.20	1,264.60	$2,529.20	$5,058.39	$8,852.19
10	2,445.41	1,222.71	$2,445.41	$4,890.83	$8,558.95
1-10	29,375.96	14,687.98	$29,375.96	$58,751.91	$102,815.85
11-100	178,868.11	89,434.05	$178,868.11	$357,736.22	$626,038.38
1-100	208,244.06	104,122.03	$208,244.06	$416,488.13	$728,854.23
Less Set-up Costs[c]	--	--	$194,048.22	$402,292.29	$714,658.39
Less Account Fees[d]	--	--	$144,548.22	$352,792.29	$665,158.39

[a]The change in biomass for year one subtracted from the change in biomass for year two, and so on, to avoid double-counting.
[b]Carbon content is half of the biomass content (USFS, 1979). One Mt of carbon is equivalent to one Mt CO^2e, or one CRT.
[c]Overhead costs were estimated to be $14,195.84.
[d]Based on annual account maintenance fee of $500 over a period of 99 years, or $49,500.

Table 3.13. Potential revenue based on three CRT pricing scenarios less property taxes for the lifetime of the project assuming an annual increase in property taxes of either 0.25% or 0.5%[b].

Projected Project Revenue before Property Taxes	Revenue Less Total Property Taxes[a]	
	$272,279.89 (0.25% annual increase)	$310,400.88 (0.5% annual increase)
$144,548.22 ($2.00/CRT)	-$127,731.67	-$165,852.65
$352,792.29 ($4.00/CRT)	$80,512.40	$42,391.41
$665,158.39 ($7.00/CRT)	$392,878.49	$354,757.51

[a]Total property tax liability calculated for 100 years based on year one property tax estimate of $6.00 an acre (J. Beach, personal communication, November 1, 2010).
[b]Based on an estimated annual property taxes increase of 0.25 or 0.5% (J. Brown, personal communication, November 18, 2010).

Finally, annual property taxes were also accounted for over the project lifetime. Based on an annual increase of 0.25% or 0.5%, property taxes for the 401 acre study site were projected to total either $272,279.89 or $310,400.88 (Table 3.13). At $2.00/CRT and after all fees and property taxes were deducted, the ACP was estimated to be in the negative between $127,000 and $165,000 over the 100 year period. At $4.00/CRT, the CRTs generated by the proposed ACP were projected to be worth, after all fees and property taxes were subtracted, between $42,400 and $80,500 over the 100 year period. Finally, at $7.00/CRT, the proposed ACP was determined to generate between $354,000 and $392,000 over the 100 year period. In summary, at $2.00 a CRT, a landowner stands to lose approximately $1,200 to $1,700 a year for 100 years. On the other hand, at $4.00 to $7.00 a CRT, a land owner stands to gain approximately $800 to $4,000 a year.

Chapter 4 Discussion

Carbon offset credits have potential as a new source of revenue for property owners, particularly land trusts. The present study set out to determine what steps were involved in calculating carbon offset credits, what costs were associated with the process, and what potential financial gains could be had from selling offset credits.

Multiple carbon registries were researched, and California's Climate Action Reserve (CAR) was chosen as the registry for this study primarily because CAR had a protocol for avoided conversion, whereas most registries did not at the time. A land trust in Chattanooga, Tennessee, the Tennessee River Gorge Trust (TRGT), was used as the model organization and one of their more easily accessible properties, Pot Point, was selected as the site of the proposed avoided conversion project (ACP).

Permanent plots were equally spaced among three strata, lowland (5 plots), midland (8 plots), and upland (3 plots), in an effort to increase the accuracy of the biomass calculations (USFS, 2007). An analysis of variance revealed no statistically significant difference in average above-ground biomass (AGB) between the three strata. A total of one percent of the property was sampled; sampling a greater percentage of the property could increase precision and accuracy of measurements and long-term monitoring.

Equipment costs associated with the field work were minimal, and only required a GPS unit for recording the center of each plot and a set of calipers for measuring d.b.h. Calipers made for quicker measurements of tree diameters, but were slightly more costly than a diameter tape and could have been less accurate. Accuracy could theoretically increase with a d-tape, particularly when measuring irregularly shaped trees. However, two measurements taken at right angles to each other could be averaged when using calipers in an effort to increase accuracy for irregular trunks while minimizing time spent in the field. Only one measurement, taken from the uphill side of the tree, was recorded for the diameters used in this study.

The majority of the initial expense associated with establishing a carbon baseline came from paid time spent in the field and on data analysis. The field work required a minimum of three people who for this study were being paid at their usual rate as employees of the TRGT. The field work could have been done with two people, although this would have increased the amount of time spent in the field. Further, paid time spent on data analysis was also costly, but could have been accomplished by one person. Neither the field work nor the data analysis required specialized skills beyond the ability to read a caliper, use a spreadsheet program to analyze data, and identify trees.

Identifying trees accurately was essential to getting a true assessment of the amount of biomass and consequently the amount of carbon on the study site. In this study, the expert at tree identification was Jim Brown, the Executive Director of the TRGT and a trained forester. Having revisited the plots two years after the initial data collection in 2008, it became clear that differences in both tree count and identification were causing variability in the biomass calculations. Even though Jim Brown measured and identified all of the trees in the plots both years, trees were still misidentified and measured differently, illustrating the inherent difficulty and variability in surveying trees in a species rich areas such as the mixed mesophytic forests of the southeastern United States.

One way to possibly control for variability would be to map out each tree in every plot, including snags and those less than the d.b.h. cutoff. The U.S. Forestry Service's (USFS) manual, "Measurement Guidelines for the Sequestration of Forest Carbon," describes a process for mapping out permanent plots to more precisely and accurately track growth of standing trees, mortality, and ingrowth of new trees (USFS, 2007). This option was considered for the present study, but not undertaken due to time constraints.

Due to the variability in the biomass calculations between the two sampling years, a specific growth rate for the study site could not be calculated. Even though total AGB for each plot between sampling years was found to be statistically different, the total biomass for 2010 was less than that for 2008, which would have resulted in a negative growth rate. Instead, an average growth rate for the eastern Tennessee area was estimated from the USFS's Forest Inventory and Analysis (FIA) data (USFS, 2010). Ideally, forest growth and yield simulators, like the USFS's Forest Vegetation Simulator (FVS), would have been utilized to forecast growth from the 2008 data, and are required by CAR's ACP, but models like these call for inputs such as live height, height to top kill, crown ratio code, and tree damage and severity codes, among others. The inputs required to run the FVS model in particular were beyond the expertise of the field team and would have added to the time spent in the field.

For this study, it was sufficient to estimate growth using an average growth rate for the area. The CAR, however, does require growth and yield simulators be used to supplement direct measurements and project future growth. A list of approved models is listed in Appendix B of the Forest Project Protocol v3.2 (CAR, 2010). Unfortunately, typical landowners are not equipped with the expertise needed to acquire the necessary data to run the aforementioned growth models and the cost to hire a consultant with such expertise would likely be cost prohibitive.

The final section of the present study was the cost-benefit analysis (Tables 3-9 through 3-14). Establishing a carbon baseline was found to be costly, mostly due to paid time in the field and paid time spent on data analysis, but not cost prohibitive. However, projecting future forest growth, as it stands now, is not as simple as using an average growth rate from USFS data as was done in the present study. Using growth and yield models will likely require outside sourcing that would certainly come at a cost to the landowner.

Equipment costs and registration fees were found to be minimal. Other overhead including third party verification, CAR's annual account maintenance fee, and annual property taxes were more substantial. Fees associated with verification are subject to a lot of variability and depend on the verifying body and the size of the project to be verified. Property taxes are also highly variable and will depend on the state and county in which the proposed ACP is located. In terms of land trusts, Tennessee in particular only allows nonprofit organizations a property tax exemption up to 100 acres per county (Tennesee Code Annotated, § 67-5-212). Property taxes become a significant cost for land trusts such as the TRGT that own thousands of acres in only a few counties.

Ultimately, an ACP's revenue potential is determined by how many carbon offset credits, or CRTs, the ACP can generate. An ACP generates offsets on the relative difference between how much biomass, and consequently carbon, is projected to accumulate over 100 years beyond that of how much carbon would accumulate in the event of the anticipated conversion in the absence of the ACP. In the absence of actual figures on the type and amount of potential conversion, conversion is estimated by the protocol based on the most likely type of conversion to occur in the vicinity of the site of the proposed ACP. For this particular study, it was assumed that the most likely type of conversion that could occur, in the absence of an ACP, was conversion to agricultural use.

Other types of possible conversion could have been selected, including conversion to residential or commercial use. Conversion to commercial assumes a 95% total forest conversion over 10 years. Residential conversion considers the number of possible parcels the property is expected to be divided up into and each parcel is estimated to deforest three acres. The anticipated type of conversion and the associated default rates of conversion can increase or decrease the amount of CRTs the proposed ACP is expected to generate. The relative difference between the ACP and the CP is greater when the total anticipated conversion of the CP is greater.

It was found for this study that 104,122 CRTs would be generated by the proposed ACP. Due to the anticipated conversion, the ACP was expected to generate 1,468 CRTs per year for the first 10 years. The remaining 90 years, where conversion is no longer anticipated, the ACP was found to generate 993 CRTs per year. An average of 1,041 CRTs were projected to be generated per year by the proposed ACP. However, not only do the number of CRTs generated by the proposed ACP dictate total potential revenue, but also the price that the CRTs are expected to sell for.

A range of CRT prices were used for this study. Unfortunately, the proposed ACP lost money when CRT pricing was lowest. The project was found to make money at CRT pricing at the mid to high range.

4.1 Data Gaps and Uncertainties

First and foremost, several assumptions were made regarding the eligibility of the project site for an avoided conversion project with CAR. As this property is already owned by the TRGT, a land trust whose mission is to protect the property in perpetuity, the project area does not meet the Performance Test requirement that the proposed project site be at risk for development nor does it meet the Legal Requirement Test that the proposed project site be legally developable.

Next, for the purposes of this study, it was sufficient to use the USFS's FIA data to calculate an average growth rate for the geographic region. However, this approach would not meet CAR's avoided conversion protocol standards as the protocol requires an approved forest growth and yield model be used to project hypothetical forest conversion and subsequent growth for 100 years for the CP at the start of the project from the measured carbon baseline.

Finally, CRT pricing is based on 2010 estimates. These prices are subject to supply and demand in a market which is currently driven by those who purchase offsets in anticipation of future legal requirements and those who purchase offsets voluntarily.

Chapter 5 Conclusions

The purpose of this study was to determine if a landowner, particularly a land trust, could sell carbon offset credits as a source of revenue. As carbon markets in the U.S. are still in their infancy, there is a lot of disjointed information. The idea was to pull this information together in a useful form to give a landowner some sense of the processes and costs associated with determining a carbon baseline and registering an offset project with a registry.

Setting up the plots and determining biomass from d.b.h. was relatively easy. The main challenge could be acquiring and applying the necessary data for the forest growth modeling software such as the USFS's FVS. Any carbon verifier would have experience running these models, so a landowner could seek out assistance or advice there. Further, the USFS provides a week long FVS training course open to the public.

Meeting the legal requirements for a carbon offset project could be another stumbling block, so a landowner should thoroughly investigate the particular protocol under consideration. Not all registries are the same, so a landowner should also investigate registry requirements and approved protocols to find the one best suited to the offset project. Again, carbon verifiers could serve as a source of information for the best registry and protocol for a particular project.

Carbon offset credits could be a substantial source of revenue for landowners provided those credits have value in emerging carbon markets. Land trusts in particular, whose sole mission is land conservation, could benefit greatly from the regular stream of revenue which could then be applied towards new conservation projects. Unfortunately, land that is already protected through conservation easements or is publically owned is not eligible as an avoided conversion project as it does not meet the Performance Test or the Legal Requirement Test outlined in CAR's protocol.

Landowners can benefit financially from selling carbon offsets. However, the concept is so new and the information so scattered, that landowners would likely shy away from it altogether. Only the determined landowner would consider carbon offsets an attractive source of revenue at this point. Further, there are organizations out there that will do all of the field and paperwork and cover all upfront costs associated with establishing a carbon offset project, with the exception of third party verification, for a percentage of the revenue. While these organizations were not examined in this study, they could serve as a mechanism whereby the less determined landowner gets involved in carbon offsetting and deserve consideration.

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Appendices

Table A.1. Species and genera identified at the 16 permanent plots established to determine a carbon baseline for the proposed ACP in 2008.

Species/Genera	Plot Number							
Identified	1	2	3	4	5	6	7	8
Ash	17	4		1	6	4		
Beech	1					16	5	7
Black Gum								
Black Walnut	2				1	1		
Boxelder	4				8	3		
Cherry	2	3	3	3				
Dogwood		4	2	2		2	11	14
Elm	1		5	9	1	4	2	
Hackberry	3	2	5	2	4			
Hawthorne				1				
Hickory	2	2		6		9	1	8
Hophornbeam		5				2		
Ironwood		15	1					
Locust	1			3				3
Mulberry			1	2		3		
Oak	1	2		7		8		8
Osage Orange	2			1				
Paw Paw								
Pine				1			3	
Persimmon		1						
Red Maple		1				4		1
Sassafrass						2	4	
Silver Maple					15			
Sourwood			1				1	
Sugar Maple	1						3	
Sweet Gum	2	13	22	31	5	3	15	7
Sycamore					1			
Tulip Poplar	7	5	2			1	10	12
Total:	46	57	42	69	41	62	55	60

Table A.1. (continued)

Species/Genera Identified	Plot Number 9	10	11	12	13	14	15	16
Ash	1		2					
Beech	17	6					11	
Black Gum		2			3			3
Black Walnut			1					
Boxelder								
Cherry			3			1	1	
Dogwood	3	6	5	4	5	11	6	7
Elm	2	2	1					
Hackberry								
Hawthorne								
Hickory	3	3	9	3	4	11	4	12
Hophornbeam							1	
Ironwood							2	
Locust								
Mulberry								
Oak	13	6	10	12	4	22	13	13
Osage Orange								
Paw Paw								
Pine	2	8	4				7	1
Persimmon								
Red Maple	4	5	2			5		2
Sassafrass	1			1	1			
Silver Maple								
Sourwood	2	9	6	1	6	1	4	4
Sugar Maple						1		1
Sweet Gum	5	16	27	3	6	1	14	2
Sycamore								
Tulip Poplar	21	3	3		2	2	14	25
Total:	74	66	73	24	31	55	77	70

Table A.2. Species and genera identified at the 16 permanent plots for the proposed ACP in 2010.

Species/Genera	Plot Number							
Identified	1	2	3	4	5	6	7	8
Ash	11	7	2	1	9	1		
Beech		4				22	22	17
Black Gum	3						1	1
Black Walnut	1				1			
Boxelder	6				5	1		
Cherry	2	3	2	2				
Dogwood		2	4	2		1	9	26
Elm	7	1	19	15	2	8	2	1
Hackberry	3	2	4	4	3			
Hawthorne								
Hickory				6	1	10	4	7
Hophornbeam						3		
Ironwood		14	1			3		
Locust				2				
Mulberry			1	3			1	
Oak	2	4	1	10		6		11
Osage Orange	2							
Paw Paw				2				
Pine							3	
Persimmon								
Red Maple	3	1			3	7	2	2
Sassafrass						2	3	
Silver Maple					11			
Sourwood								1
Sugar Maple				1		9	5	
Sweet Gum	4	16	20	22	6	1	14	11
Sycamore					1			
Tulip Poplar	8	4				1	12	11
Total:	52	58	54	70	42	75	78	88

Table A.2. (continued)

Species/Genera	Plot Number							
Identified	9	10	11	12	13	14	15	16
Ash			1					
Beech	21	11	1			1	11	
Black Gum		7	5				1	2
Black Walnut			1					
Boxelder								
Cherry		1	2			2	1	
Dogwood	2	6	5		1	9	7	5
Elm		3	5			1		
Hackberry								
Hawthorne		1						
Hickory	6	3	8	2	3	7	5	9
Hophornbeam								
Ironwood							1	
Locust								
Mulberry								
Oak	12	4	9	3	3	20	11	12
Osage Orange								
Paw Paw								
Pine	5	7	3				5	1
Persimmon								
Red Maple	6	9	3			8		3
Sassafrass	1	1	1			1		
Silver Maple		1						
Sourwood	3	7	4		5		2	1
Sugar Maple						3	1	
Sweet Gum	3	20	22	1	2		17	1
Sycamore								
Tulip Poplar	15	1	2		2		11	20
Total:	74	82	72	6	16	52	73	54

Table A.3. Paired Two-Sample for Means t-Test Results (α = 0.05): Comparison of Total Tree Counts by Plot for 2008 and 2010.

	2008 Count	2010 Count
Mean	56.375	59.125
Variance	249.45	519.58
Observations	16	16
Hypothesized Mean Difference	0	--
df	15	--
t Stat	-0.830573156	--
P (T<=t) two-tail	0.419239008	--
T Critical two-tail	2.131449536	--

Note. Compares the total tree count for individual plots for 2008 and 2010 with statistics ($p > 0.05$).

Table A.4. Paired Two Sample for Means t-Test Results (α = 0.05): Comparison of Total AGB (Mt/ha) by Plot for 2008 and 2010.

	2008 AGB	2010 AGB
Mean	183.161	168.984
Variance	4304.591	4144.476
Observations	16	16
Hypothesized Mean Difference	0	--
df	15	--
t Stat	2.042762244	--
P (T<=t) two-tail	0.029530024	--
T Critical two-tail	2.131449536	--

Note. Compares the total AGB for individual plots for 2008 and 2010 with statistics ($p < 0.05$).

Table A.5. Paired Two Sample for Means t-Test Results (α = 0.05): Comparison of Average AGB (Mt/ha) by Stratum for 2008 and 2010.

	2008 Average AGB	2010 Average AGB
Mean	192.282	17.245
Variance	1752.891	296.455
Observations	3	3
Hypothesized Mean Difference	0	--
df	2	--
t Stat	1.149424863	--
P (T<=t) two-tail	0.369282992	--
T Critical two-tail	4.30265273	--

Note. Compares the average AGB for each of the three strata, lowland, midland, and upland, for both sampling years 2008 and 2010 with statistics ($p > 0.05$). The lowland includes plots 1 through 6; midland includes plots 7 through 13; and upland includes plots 14 though 16.

Table A.6. One-way Analysis of Variance Results for Average AGB for each Stratum for 2008 (α = 0.05).

Source of Variation	SS	df	MS	F statistic	p value	F critical
Between Groups	13535.82519	2	6767.912594	1.724037336	0.21671244	3.805565253
Within Groups	51033.0385	13	3925.618346			
Total	64568.86369	15				

Note. Compares the average AGB for each stratum for the 2008 sampling year with statistics ($p > 0.05$). The lowland stratum includes plots 1 through 6; midland includes plots 7 through 13; and upland includes plots 14 though 16.

Table A.7. Biomass projections for the lifetime of the proposed ACP and CP; change in biomass, relative change in biomass, and relative change in carbon between the ACP and CP.

Year		Projected Biomass		ΔBiomass = ACP – CP (Mt)	Relative ΔBiomass (Mt)	Relative ΔCarbon (Mt)
		ACP (Mt)	CP (Mt)			
0	2008	38,702.38	38,702.38	0.00		
1	2009	39,553.84	35,993.99	3,559.85	3,559.85	1,779.92
2	2010	40,424.02	33,475.13	6,948.89	3,389.04	1,694.52
3	2011	41,313.35	31,132.54	10,180.81	3,231.92	1,615.96
4	2012	42,222.24	28,953.89	13,268.36	3,087.55	1,543.77
5	2013	43,151.13	26,927.69	16,223.44	2,955.08	1,477.54
6	2014	44,100.46	25,043.29	19,057.16	2,833.72	1,416.86
7	2015	45,070.67	23,290.76	21,779.90	2,722.74	1,361.37
8	2016	46,062.22	21,660.88	24,401.35	2,621.44	1,310.72
9	2017	47,075.59	20,145.05	26,930.54	2,529.20	1,264.60
10	2018	48,111.25	18,735.30	29,375.96	2,445.41	1,222.71
11	2019	49,169.70	19,147.47	30,022.23	646.27	323.14
12	2020	50,251.43	19,568.72	30,682.72	660.49	330.24
13	2021	51,356.97	19,999.23	31,357.74	675.02	337.51
14	2022	52,486.82	20,439.21	32,047.61	689.87	344.94
15	2023	53,641.53	20,888.88	32,752.65	705.05	352.52
16	2024	54,821.64	21,348.43	33,473.21	720.56	360.28
17	2025	56,027.72	21,818.10	34,209.62	736.41	368.21
18	2026	57,260.33	22,298.10	34,962.23	752.61	376.31
19	2027	58,520.06	22,788.65	35,731.40	769.17	384.58
20	2028	59,807.50	23,290.00	36,517.49	786.09	393.05
21	2029	61,123.26	23,802.38	37,320.88	803.38	401.69
22	2030	62,467.97	24,326.04	38,141.94	821.06	410.53
23	2031	63,842.27	24,861.21	38,981.06	839.12	419.56
24	2032	65,246.80	25,408.16	39,838.64	857.58	428.79
25	2033	66,682.23	25,967.13	40,715.09	876.45	438.23
26	2034	68,149.24	26,538.41	41,610.83	895.73	447.87
27	2035	69,648.52	27,122.26	42,526.26	915.44	457.72
28	2036	71,180.79	27,718.95	43,461.84	935.58	467.79
29	2037	72,746.77	28,328.76	44,418.00	956.16	478.08
30	2038	74,347.20	28,952.00	45,395.20	977.20	488.60
31	2039	75,982.83	29,588.94	46,393.89	998.69	499.35
32	2040	77,654.46	30,239.90	47,414.56	1,020.67	510.33
33	2041	79,362.85	30,905.17	48,457.68	1,043.12	521.56
34	2042	81,108.84	31,585.09	49,523.75	1,066.07	533.03
35	2043	82,893.23	32,279.96	50,613.27	1,089.52	544.76
36	2044	84,716.88	32,990.12	51,726.76	1,113.49	556.75
37	2045	86,580.65	33,715.90	52,864.75	1,137.99	568.99

Table A.7. (continued)

	Year	Projected Biomass ACP Scenario (Mt)	Projected Biomass CP Scenario (Mt)	ΔBiomass = ACP – CP (Mt)	Relative ΔBiomass (Mt)	Relative ΔCarbon (Mt)
38	2046	88,485.43	34,457.65	54,027.78	1,163.02	581.51
39	2047	90,432.11	35,215.72	55,216.39	1,188.61	594.31
40	2048	92,421.61	35,990.47	56,431.15	1,214.76	607.38
41	2049	94,454.89	36,782.26	57,672.63	1,241.49	620.74
42	2050	96,532.90	37,591.47	58,941.43	1,268.80	634.40
43	2051	98,656.62	38,418.48	60,238.14	1,296.71	648.36
44	2052	100,827.07	39,263.68	61,563.38	1,325.24	662.62
45	2053	103,045.26	40,127.49	62,917.78	1,354.39	677.20
46	2054	105,312.26	41,010.29	64,301.97	1,384.19	692.10
47	2055	107,629.13	41,912.52	65,716.61	1,414.64	707.32
48	2056	109,996.97	42,834.59	67,162.38	1,445.77	722.88
49	2057	112,416.90	43,776.95	68,639.95	1,477.57	738.79
50	2058	114,890.07	44,740.05	70,150.03	1,510.08	755.04
51	2059	117,417.65	45,724.33	71,693.33	1,543.30	771.65
52	2060	120,000.84	46,730.26	73,270.58	1,577.25	788.63
53	2061	122,640.86	47,758.33	74,882.53	1,611.95	805.98
54	2062	125,338.96	48,809.01	76,529.95	1,647.42	823.71
55	2063	128,096.42	49,882.81	78,213.61	1,683.66	841.83
56	2064	130,914.54	50,980.23	79,934.31	1,720.70	860.35
57	2065	133,794.66	52,101.80	81,692.86	1,758.55	879.28
58	2066	136,738.14	53,248.04	83,490.11	1,797.24	898.62
59	2067	139,746.38	54,419.49	85,326.89	1,836.78	918.39
60	2068	142,820.80	55,616.72	87,204.08	1,877.19	938.60
61	2069	145,962.86	56,840.29	89,122.57	1,918.49	959.24
62	2070	149,174.04	58,090.78	91,083.27	1,960.70	980.35
63	2071	152,455.87	59,368.77	93,087.10	2,003.83	1,001.92
64	2072	155,809.90	60,674.89	95,135.01	2,047.92	1,023.96
65	2073	159,237.72	62,009.73	97,227.98	2,092.97	1,046.49
66	2074	162,740.95	63,373.95	99,367.00	2,139.02	1,069.51
67	2075	166,321.25	64,768.17	101,553.07	2,186.07	1,093.04
68	2076	169,980.32	66,193.07	103,787.24	2,234.17	1,117.08
69	2077	173,719.88	67,649.32	106,070.56	2,283.32	1,141.66
70	2078	177,541.72	69,137.61	108,404.11	2,333.55	1,166.78
71	2079	181,447.64	70,658.63	110,789.00	2,384.89	1,192.45
72	2080	185,439.49	72,213.12	113,226.36	2,437.36	1,218.68
73	2081	189,519.15	73,801.81	115,717.34	2,490.98	1,245.49
74	2082	193,688.58	75,425.45	118,263.12	2,545.78	1,272.89
75	2083	197,949.72	77,084.81	120,864.91	2,601.79	1,300.89

Table A.7. (continued)

Year		Projected Biomass ACP Scenario (Mt)	CP Scenario (Mt)	ΔBiomass = ACP – CP (Mt)	Relative ΔBiomass (Mt)	Relative ΔCarbon (Mt)
76	2084	202,304.62	78,780.68	123,523.94	2,659.03	1,329.51
77	2085	206,755.32	80,513.85	126,241.47	2,717.53	1,358.76
78	2086	211,303.94	82,285.16	129,018.78	2,777.31	1,388.66
79	2087	215,952.62	84,095.43	131,857.19	2,838.41	1,419.21
80	2088	220,703.58	85,945.53	134,758.05	2,900.86	1,450.43
81	2089	225,559.06	87,836.33	137,722.73	2,964.68	1,482.34
82	2090	230,521.36	89,768.73	140,752.63	3,029.90	1,514.95
83	2091	235,592.83	91,743.64	143,849.18	3,096.56	1,548.28
84	2092	240,775.87	93,762.01	147,013.87	3,164.68	1,582.34
85	2093	246,072.94	95,824.77	150,248.17	3,234.31	1,617.15
86	2094	251,486.55	97,932.91	153,553.63	3,305.46	1,652.73
87	2095	257,019.25	100,087.44	156,931.81	3,378.18	1,689.09
88	2096	262,673.67	102,289.36	160,384.31	3,452.50	1,726.25
89	2097	268,452.49	104,539.73	163,912.77	3,528.45	1,764.23
90	2098	274,358.45	106,839.60	167,518.85	3,606.08	1,803.04
91	2099	280,394.33	109,190.07	171,204.26	3,685.41	1,842.71
92	2100	286,563.01	111,592.25	174,970.75	3,766.49	1,883.25
93	2101	292,867.40	114,047.28	178,820.11	3,849.36	1,924.68
94	2102	299,310.48	116,556.32	182,754.15	3,934.04	1,967.02
95	2103	305,895.31	119,120.56	186,774.75	4,020.59	2,010.30
96	2104	312,625.01	121,741.22	190,883.79	4,109.04	2,054.52
97	2105	319,502.76	124,419.52	195,083.23	4,199.44	2,099.72
98	2106	326,531.82	127,156.75	199,375.06	4,291.83	2,145.92
99	2107	333,715.52	129,954.20	203,761.32	4,386.25	2,193.13
100	2108	341,057.26	132,813.19	208,244.06	4,482.75	2,241.37
Totals:		14,045,758.23	5,564,795.31	8,480,962.91	208,244.06	104,122.03

VITA

Jennifer Marie Sexton grew up in Floyds Knobs, Indiana, and attended Purdue University where she was awarded a Bachelor of Science in Biology in 1997. Following, she worked in the Department of Microbiology at the University of Alabama at Birmingham where she researched Human Immunodeficiency Virus and P22 phage. In 2005, she entered the graduate program at the University of Tennessee at Chattanooga in the Biological and Environmental Sciences Department. She served three semesters as a teaching assistant for Introduction to Biology Lab and worked as an Intern at the Tennessee River Gorge Trust. She received her Master of Science in Environmental Science in May 2011 and currently resides in Birmingham, Alabama, with her husband and works as a Geospatial Analyst.