Successive Land Surveys as Indicators of Vegetation Change in an Agricultural Landscape

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ABSTRACT

A series of anthropogenic disturbance conditions have altered the vegetation of the southern Appalachians during the past 200-years. The objective of this research was to identify the nature and timing of these vegetation changes in order to better understand the underlying causes. A total of 304 land surveys were collected for a small agricultural watershed from early settlement in 1787 through to the present day. Witness corners recorded tree species, shrubs, stumps, snags and non-vegetative markers. Types of witness corners were tallied and tested for shifts in frequency across time periods. Tree species were also classified by silvical characteristics including sprouting capability, shade tolerance, and seed type and these groupings were tested for shifts in frequency across time periods. Landform bias of the witness corners was tested using references contained in the surveys. Results showed significant shifts in white oak (*Quercus alba* L.), chestnut (*Castanea dentate* Marsh. Borkh.), chestnut oak (*Quercus prinus* Wild.), black oak (*Quercus velutina* Lam.), red oak (*Quercus rubra* L.), black locust (*Robinia pseudoacacia* L.), yellow poplar (*Liriodendron tulipifera* L.), and scarlet oak (Quercus coccinea Muenchh.). The central change was a steady decline in white oak, probably due to the absence of fire and changes in soil properties. Chestnut replaced white oak as the dominant species, but was removed by chestnut blight in the 1930's. Sprouting capability appeared to be the most important silvical characteristic across all species.

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I. INTRODUCTION

History contributes to the development of ecosystems. Past events and present conditions alter ecosystem composition and structure. Changes in species composition, soil physical and chemical properties, and resource availability can persist for centuries (Kalisz 1986, Foster and others 1992, Bratton and Miller 1994, Richter and others 1994, Compton and others 1998). Land use history can be the primary source of variation in site conditions. Therefore, in order to understand variations in ecological processes across a landscape, it important to consider the pattern of land-use legacies. In addition, an understanding of historical disturbance regimes can help guide the management of ecosystems, with the aim of maintaining past ecosystem structure and protecting vulnerable species (Cissel and others 1999, Swetnam and others 1999, Motzkin and Foster 2002).

Witness tree studies in North America have documented changes in species composition from pre-settlement to present day (Abrams and Ruffner 1995, Burgi and others 2000, Whitney and Decant 2003). In eastern deciduous forest these studies have noted a decline in white oak (*Quercus alba* L.), American beech (*Fagus grandifolia* Ehrh.), and eastern hemlock (*Tsuga canadensis* L. Carr.)(Foster and others 1998, Rentch and Hicks 2005). However, the studies have not been able to clearly identify the causes of these changes because they only describe pre-settlement forest composition and current forest composition (Abrams 2003).

During the 200-300 year period since European settlement in the southern Appalachians there have been a series of major shifts in disturbance conditions. Much of the original forest was cleared for agricultural production or timber extraction (Clarkson 1964, Whitney 1994). The role of fire in the eastern forest has been altered. Introduced pathogens such as the chestnut blight have removed entire species from the forest (McCormick and Platt 1980). Finally, human land use patterns have shifted due to the American Civil War, land abandonment following the depression of the 1930's, and increasing sub-urbanization (Salstrom 1994, Gragson and Bolstadt 2006). Each of these events influenced the composition of Appalachian forests at different times during the past 200 years. The use of successive land surveys allows us to identify the time periods of shifts in species composition and as a result, more accurately identify the causes of change.

Thus objective of my research is to use land surveys from Clover Hollow Watershed to characterize shifts in tree species composition from early settlement in 1780 through time to the present. The witness tree record provides a sample of the vegetation throughout this period of shifting disturbance conditions.

II. LITERATURE REVIEW

Use of Primary Historical Documents

Historical records can be an important source of ecological information. Historical documents such as land surveys, censuses, maps, photographs, and personal accounts contain information that can be used to characterize past vegetation and human/environment interactions. Most historical surveys record tree species at property corners, and many also record fields, roads, streams, landforms, vegetation community types, and large disturbances. Numerous researchers have used witness trees in land surveys to characterize pre-settlement forests in North America (Kenoyer 1930, Leitner and Jackson 1981, Russell 1981, Abrams and Ruffner 1995, Black and Abrams 2001b) Historical maps and photographs are another source of ecological information. They often provide the locations of vegetative communities, human populations, and other landscape features. Both sources exist at a wide range of scales. Censuses record the extent of human populations and their activities in a landscape. Specifically, agricultural censuses record land use types and intensity. Finally, personal records provide individual impressions of a landscape. Each of these document types is subject to bias and limitations. However, they provide important information about the condition of past landscapes and help explain the processes that influence landscapes today.

Census Data

There are several types of censuses that have been carried out in the United States. Population censuses characterize human populations and households. The 1850 population census in Virginia recorded the age, sex, and occupation of all members in a household. Industrial censuses record the extent of industrial production. They record the names, location, and productivity of various industries such as blacksmiths, grist mills, and tanneries. Agricultural censuses record the extent of agricultural production and land use types. Agricultural censuses were carried out at the start of each decade from 1850-1890. They recorded some of the following information: landowner’s name, acreage, value of farm, value of farm equipment, crop production, and livestock counts. Agricultural censuses have been used in several types of studies. They have been used to examine how agricultural practices influence laws (Sanchez and Nugent 2000), how cultivation techniques have increased net primary productivity (Bradford and others 2005), how census values compare to value of real estate sales (Johnson 1933), the productivity of different agricultural systems (Bender 2001), and to contrast differences in land use intensity across space and time (Moore and Whitman 1996).

Several studies have examined the accuracy and limitations of agricultural censuses. Problems include the difficulty of obtaining accurate livestock counts (Hurley 1957), estimation of market values (Powers 1911), and the exclusion of small farming units (Jessen 1949). An agricultural census records the state of a farm at a single moment in time. Livestock numbers, crops in the ground, and surplus fluctuate by the season or even by the day. Therefore, an agricultural census must be viewed as an estimation of agricultural production on a specific day of the year.

Land Surveys

Historical land surveys commonly recorded tree species, or witness trees, at deed corners. These species tallies can be viewed as a sample of the forest composition at the time of the survey. Witness tree studies have used species tallies to reconstruct pre-settlement forest composition and extent (Leitner and Jackson 1981, Russell 1981, Black and others 2002). Witness trees have also been used to examine species-site relationships in pre-settlement forests (Barrett and others 1995, Black and Abrams 2001b) and to evaluate disturbance regimes and fire return intervals (Leitner and others 1991, Schulte and Mladenoff 2005). Finally, witness trees have been compared to current forest composition in order to assess vegetation changes over time (Abrams and Ruffner 1995, Burgi and Russell 2000, Rentch and Hicks 2005).

Although survey trees do not provide an unbiased data set, they are the best data that we have from the time period. Potential biases of the data set include: inconsistency of survey instructions, species bias, size bias, topographic bias, and surveyor fraud (Bourdo 1956, McCune and Menges 1986, Black and Abrams 2001a). Instructions for surveyors have also changed through time. Witness tree studies have primarily focused on areas that were surveyed under the General Land Office System, Public Land Survey (PLS). This system divided new lands into square townships that resulted in a stratified sampling method. Ecological application of PLS data has included: maps of pre-settlement vegetation, densities of tree types, size distributions, and association of tree types with site characteristics (Leitner and others 1991, Batek and others 1999, Manies and Mladenoff 2000).

Much of the eastern United States was surveyed with the metes and bounds system. This system lacked the grid pattern of the PLS. As a result, surveyors were able to mark property lines as they deemed fit. This has been demonstrated to result in uneven sampling of topographic features (Black and Abrams 2001a). Surveyors also tended to favor large individuals, commercial species, and unusual species that would be easier to mark and locate in the future (Bourdo 1956, McCune and Menges 1986). Land survey records are certainly flawed, but they provide valuable information that is not available in other forms and they may provide a better source of historical vegetation composition than other survey records. For example, Burgi and Russell (2000) found strong correlations between species composition of early proprietor surveys and growing degree days; however, the same correlations did not exist for historical road surveys. Analysis of historical survey records requires an examination of survey type, context, execution and recognition of inherent bias.

Photographs

Photographs can be an excellent source of ecological data. They can provide a visual record of the location, extent and types of vegetation. Repeat photography of an area can be used to measure vegetation change over time. Aerial photography is the most common type of photography used in ecology because aerial photos are regional in scale, capturing large portions of the landscape. They also provide a standard, birds-eye perspective that can be compared across photographs. In addition, extensive records exist from the early part of the 20th century. Aerial photographs have been used to record both the conversion of natural habitats to agriculture (Black and others 1998) and the re-growth of forests on abandoned agricultural land (Brown 2003, Medley and others 2003). Brown (2003) correlated changes in land use and forest cover in the Upper Midwest using aerial photographs. He found that a change in the region from an extractive economy (logging/agriculture) to a recreation based service economy has led to increases in forest cover. Medley and others (2003) found similar trends in Ohio. However, additional census data allowed them to conclude that increased turnover in ownership was negatively correlated with forest cover and forest patch sizes. Several studies have used aerial photographs to characterize spatial changes of forest patches (Hessburg and others 1999, Orio and others 2005, Kennedy and Spies 2005). Orio and others (2005) documented a 24% decline in area occupied by aspen (*Populus tremuloides* Michaux) and an increase in fragmentation of patches from 1946 to 1994 in the South Warner Mountains, California. Kennedy and Spies (2005) found that fire suppression and intensive management have fragmented and reduced the size of early to mid-successional hardwood patches in Coastal Oregon. These hardwood patches are now limited to lower elevations, near streams. Repeat aerial photography is an excellent tool for assessing landscape-scale changes in vegetation patterns over time.

In recent years, local-scale repeat photography has been used to assess ecological change. Historical photographs of the forest understory and forest clearings have been used to assess changes in forest structure. Generally, these studies locate a historical photograph and then take a current photograph from the same location and perspective. This provides a comparison of vegetation at two points in time. Hastings and Turner (1965) were pioneers of this technique, noting that vegetation in the southwest appeared to be receding along a xeric to mesic gradient. They hypothesized that this was the combined result of changes in climate and heavy livestock grazing. Recently, repeat photography has been used to assess landscape level changes in vegetative communities. Manier and Laven (2002) found that during the last century forest cover has increased on the western slope of the Rocky Mountains, Colorado. The expansion of forest has led to a reduction in non-forested rangelands. Tape and others (2006) assessed the density of shrub vegetation in the arctic, finding that over the past 50 years alder (*Alnus* spp. Mill.), willow (*Salix* spp. L.), and dwarf birch (*Betula glandulosa* Michx.) have been increasing in density along hill slopes and valley bottoms. Historical photographs have also been used to characterize reference ecosystems and inform restoration efforts by land managers. Hessberg and others (1999) used historical aerial photographs to establish reference conditions and a historic range of variability for spatial patterns in forest of the Interior Northwest. Repeat photography has also been used to demonstrate fundamental changes in ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) forest undergrowth and spacing due to fire suppression and grazing. Historical photographs demonstrate the open nature of Ponderosa Pine forests when the area was first settled by Europeans (Swetnam and others 1999).

Travel Accounts

Travel accounts can be a valuable source of information. However, by nature, they are more qualitative and subject to bias than other sources of historical information (Cronon 1983, Whitney 1994, Russell 1997). These accounts are often the earliest descriptions of North American flora and fauna. Early settlers described the extent of forests, the game, and edible plants that they encountered. These accounts provide an impression of the landscape, but they were recorded by untrained, idealistic individuals that were committed to settling in the wilderness of North America. Promotional literature was often intentionally biased, with the intent of encouraging settlers to buy land. These descriptions emphasized the fertility of the soil, the abundance of game, and the ease with which the land could be converted into productive fields. Despite their inherent bias, first hand accounts can contribute to our understanding of past landscapes. They often add details to the more quantitative government records. They describe the details of early settlement life, the types of land use, and the products that were manufactured out of natural resources.

Some of the most valuable travel accounts were recorded by naturalists. Andre Michaux was a French naturalist that traveled extensively through North America during the 18th century. He traveled in three-fourths of the states east of the Mississippi, the Canadian province of Quebec, and the Bahama Islands (Williams 2004). He was a trained naturalist, noting species and community assemblages during his travels. His major works included *The Oaks of North America* (1801) and *The Flora of North America* (1803). During his travels in North Carolina he recorded the unknown species *Magnolia macrophylla* (Michx.) and *Rhododendron Catawbiense* (Michx.). The writings of these early naturalists record the distribution of plant species in a landscape undisturbed by European settlement.

Land Use History Case Studies

Recent studies have demonstrated that former land uses have long ranging impacts on ecosystem structure and function. Changes in species composition, soil physical and chemical properties, and resource availability can persist for a century or more (Kalisz 1986, Foster and others 1992, Bratton and Miller 1994, Richter and others 1994). As a result, it is important to understand the spatial distribution of former land uses and their continuing influence on current vegetative communities (Foster 1992, Lafon and others 2000, Bellemare and others 2002, Bender and others 2005). Research at the Harvard Forest, the Coweeta Hydrologic Laboratory, and the Duke Forest are examples of research sites that have benefited from the insights of land use history.

Harvard Forest – Petersham, MA

The Harvard Forest is a 1,200 ha research site with a transitional hardwood-white pine-hemlock forest type (www.lternet.edu/sites/hfr). It is located in central New England, 70 miles west of Boston. New England's history of disturbance and recovery make it an ideal setting for land use history studies. During the last four-hundred years the forests of New England have experienced change from a semi-natural/Native American disturbance regime, to an agriculturally intensive European settlement period, to a period of forest succession and recovery. The region also has an extensive written historical record following European settlement.

Land use history studies at the Harvard Forest have focused on forest disturbance and recovery. The primary source of disturbance has been agricultural land use, but researchers have also examined the effects of hurricanes, insect outbreaks, and climate change. Foster (1992) traced the land use history of a hemlock woodlot on the Harvard Forest from pre-settlement to today. The woodlot consisted of a presettlement forest of northern hardwoods, hemlock, and eastern white pine (*Pinus strobus* L.). Successive cutting created a chestnut (*Castanea dentata* Marsh. Borkh.) sprout forest which was eventually killed off by the chestnut blight and replaced by a stand of hemlock. The stand appears to be a stable, late successional forest, however it is a product of a unique series of anthropogenic disturbance. They study underlines the importance of past land use in creating the forests of today.

Several studies have reconstructed the forest composition of New England prior to European settlement (Foster and others 1998, Burgi and others 2000, Cogbill and others 2002, Foster and others 2002, Gerhardt and Foster 2002, Hall and others 2002). These studies use historical data such as land surveys, tax records, and first-person accounts to reconstruct pre-settlement forests. These reconstructions demonstrate that forests types were primarily distributed along climatic gradients prior to the disturbance of European settlement. Oaks (*Quercus* spp.), hickories (*Carya* spp.), and chestnuts were dominant in the southern region, while beech, hemlock, spruce (*Picea* spp.), birch (*Betula* spp.), and maples (*Acer* spp.) were typical of the northern regions (Cogbill and others 2002). Results have shown that on the same sites, current forest compositions are fundamentally different than pre-settlement forests. Foster and others (1998) demonstrated a disruption in species-environment relationships and potential homogenization of forest communities. There is less differentiation of forest types along the climatic gradients of latitude and elevation. There has been an increase in shade intolerant and moderately tolerant taxa such as birch, red maple (*Acer rubrum* L.), oak and pine (*Pinus* spp.). There has been a decrease in the occurrence of shade tolerant, long-lived taxa such as hemlock and beech. Gerhardt and Foster (2002) sampled the composition of modern forests and correlated this with physiographic and historical variables ranking them with the following importance: landform > agricultural history > elevation > hurricane = fire = logging. These studies indicate that land uses have long ranging impacts on the successional trajectory of an ecosystem.

Researchers have also examined the effects of different types of land use. These studies establish that a change has occurred and begin to identify the individual mechanisms at work such as soil changes and time since abandonment (Foster and others 1992, Motzkin and others 1996, Compton and others 1998, Motzkin and others 1999). Motzkin and others (1996) found that in the pitch pine-scrub oak vegetation community, pitch pine (*Pinus rigida* Mill.) was highly correlated (97%) with formerly plowed sites and scrub oak (*Quercus ilicifolia* Wangenh.) stands were correlated (89%) with unplowed sites. Several species such as wintergreen (*Gaultheria procumbens* L.), huckleberry

(*Gaylusaccia baccatta* (Wangenh.) K. Koch.), chinquapin oak (*Quercus prinoides* Willd.) and scrub oak have been unable to re-colonize sites that have been plowed. Compton and others (1998) analyzed the soil properties of these sites and found that agricultural use resulted in higher bulk density, lower loss on ignition and C:N ratios, and slightly lower C concentrations in the surface mineral soil.

The effects of these biotic and abiotic changes may not be apparent for many years. Successional patterns at the Harvard Forest appear to be divergent rather than convergent. Species composition in 1937 was dominated by similar early successional species. However, in 1992 a mosaic of later successsional forest types reflected different historical land uses (Motzkin and others 1999). Research at the Harvard Forest emphasizes the long term effects of land use on ecosystem structure and composition.

Coweeta Long Term Ecological Research Station – Coweeta, NC

The Coweeta Hydrologic Laboratory is a 2,185 ha research site with a mix of northern hardwood, cove hardwood, oak-chestnut, and oak-pine forest type (www.lternet.edu/sites/cwt). It is located in the southern Appalachian Mountains along the Tennessee-North Carolina border. The Coweeta research site was initially established to monitor watershed hydrology. Stream weirs were built in the 1930s and have been recording stream levels alongside vegetation inventories. This baseline historical record provides an opportunity to examine the effects of land use change on watershed hydrology and vegetation patterns.

Several studies at Coweeta have examined the effects of timber harvests. Leopold and Parker (1985) examined the effects of successive clearcuts on vegetative patterns from 1939 to 1984. In the final year of the study, basal area had increased by 80% with an increase in mesic species, such as yellow poplar (*Liriodendron tulipifera* L.) and sweet birch (*Betula lenta* L.), and a decrease in the less mesic oaks. Swank and others (2001) recorded a catchment's hydrology and water quality for 20 years following a clearcut and cable logging. Flow increased by 28% in the first year, but returned to baseline levels by the fifth year. Small increases in nutrient losses were recorded, while large increases in sediment yield occurred as a result of road building and heavy storms. High sediment yields continued for 15 years following the logging, demonstrating the lag between sediment inputs to a stream and the movement of sediment through a stream system. Knoepp and Swank (1997) recorded changes in soil cation concentrations in the same watershed during the same period. Ca, Mg, and K increased in the upper soil layer for the first 3 years. After 17 years, Mg and K levels were still higher than a reference watershed.

Researchers at Coweeta have also examined the effects of multiple land uses. Fraterrigo and others (2005) examined the heterogeneity of soil nutrients in hardwood stands 60 years after abandonment of pasture or timber harvesting. They found that averaged values showed little effect from land use, however at a finer scale, land use affected the spatial distribution and variance of nutrients. Intensive land use appeared to increase variance in P, K, and Mg while decreasing variance in C, N, and Ca. Elliot and others (1999) studied changes in vegetation structure and diversity after a watershed was clearcut, left with grass cover for five years, then treated with herbicide, and finally abandoned for 28 years. Regeneration was initially dominated by black locust (*Robinia pseudoacacia* L.) root sprouts, with yellow poplar increasing in density and basal area over time through seedling establishment. Regeneration of large seeded oaks, northern red oak (*Quercus rubra* L.), scarlet oak (*Quercus coccinea* Muenchh.), chestnut oak (*Quercus prinus* Wild.), and black oak (*Quercus velutina* Lam.) was generally poor. Disturbance increased the abundance of early successional woody species and herbaceous genera such as fireweed (*Erechtites hieraciifolia* (L.) Raf.), pokeweed (*Phytolacca americana* L.), and daisy (*Erigeron* spp.). The 28-year old, disturbed forest had much lower species richness and triple the density compared to the adjacent reference watershed.

The Coweeta Long Term Ecological Research project has also encouraged interdisciplinary research, combining social science with traditional ecosystem science. Gragson and Bolstad (2006) reviewed historical land use at Coweeta, and examine its effect on structure and function of ecosystems. The authors highlight the accelerating land use impacts from 1850-1900, with the number of farms increasing 275% and the average farm size decreasing by 66%. The number of cattle and hogs increased as the farm sizes decreased. The increase in animals per unit area increased soil compaction, leading to higher rates of runoff and soil loss. The heavy grazing also slowed rates of reforestation.

The land use history research at Coweeta focuses on the past 150 years. The timeline is shorter than the Harvard Forest, however the historical data is much denser. Both hydrology and vegetation data have been recorded alongside specific management prescriptions. The result has been a better understanding of the spatial heterogeneity of land use effects which are often lost when data are averaged across a large area (Fraterrigo and others 2005). Research at Coweeta has underlined the importance and complexity of past land uses effects on ecosystems today.

The Duke Forest – Durham, NC

The Duke forest is 2,853 ha located on the eastern edge of the North Carolina Piedmont Plateau. It ranges in elevation from 90-230 m and has a moderate climate, with an average daily minimum temperature of 0° C in January and an average daily maximum temperature of 31° C in July (www.nicholas.duke.edu/forest). It is primarily composed of agricultural land that was abandoned during the early part of this century and has since returned to forest. The purchase of this land soon after abandonment has allowed researchers to monitor the progression of forest succession over the past century. Oosting (1942) compiled a thorough inventory of the forest communities that were established within these old fields. He noted the general dominance of crabgrass (*Digitaria sanguinalis* (L.) Scop.) and horse weed (*Conyza canadensis* (L.) Cronq.) in first-year abandoned fields, squarrose white aster (*Aster ericoides* L.) and ragweed (*Ambrosia artemisifolia* L.) in second-year abandoned fields, and broomsedge (*Andropogon virginicus* L.) in third-year abandoned fields. Pines are generally established within five years of abandonment and grow into an even aged stand by the tenth year. Loblolly pine (*Pinus taeda* L.) is the most common species but Virginia pine (*Pinus virginiana* Mill.) and shortleaf pine (*Pinus echinata* Mill.) are also found depending on seed sources and site quality. This pine forest then matures and persists for decades with shade tolerant hardwoods growing in the under-story. Hardwoods eventually replace the pines after a century or more. These successional stages are typical of old-fields in the North Carolina Piedmont.

In the following years, research at the Duke Forest focused on explaining the underlying mechanisms that drive old-field succession. Keever (1950) examined the causes of the horseweed/ragweed/broomsedge herbaceous sequence, concluding that timing of germination and lifecycle were the primary factors. Oosting and Humphreys (1940) tested the viability of seeds in forest soils of varying successional age. They found that herbaceous, early successional invaders could germinate after long periods of burial, while later successional woody plants rarely germinated from buried seeds. The study helped explain the persistence of opportunistic old-field invaders that are short lived and dependent on sporadic, canopy disrupting disturbance. McQuilkin (1940) examined the establishment of pines in the successional sequence, highlighting the importance of seed source distance and geographic location. Bormann (1953) further explained the dominance of loblolly pine over sweet gum (*Liquidambar styraciflua* L.) in abandoned fields through its higher drought tolerance in first-year seedlings and its seed production at a younger age.

Recent research has utilized long term observations at the Duke Forest to test conclusions spanning all stages of succession. Peet and Christensen (1980) used 50 years of permanent plot data to explain succession as a population process. They identified the stages of early establishment, middle years when competition is high for limited resources, a resulting increase in mortality, and finally an uneven aged stand that is characterized by individual mortality, the scattered opening of resources and establishment of new individuals. Their work challenged earlier theories of succession as a series of community replacement sequences. Research has also examined the transition from pine to hardwood in old-field pine stands. Presence of herbaceous vegetation, vertebrate seed predation, seed sizes, and timing of droughts were all found to influence the species composition of emergent hardwood stands (DeSteven 1991, Peroni 1994a, Peroni 1994b).

Witness Tree Case Studies

Southern Michigan – General Land Office, Public Land Surveys

Southwestern Michigan was the study site of several early witness tree reconstructions of pre-European settlement forests. The region was surveyed from 1826 to 1832, prior to significant European settlement (Kenoyer 1930, Brewer and others 1984). The survey records provide a sampling of vegetation distribution before the majority of the region was disturbed by forest clearance and tillage of the soil. These records are important because the original forest communities have been almost entirely removed. Throughout the entire Lake States region, only 1.1% of the primary forest remains intact (Frelich 1995).

The region was surveyed under the General Land Office System, Public Land Survey (PLS). This system divided new lands into rectangular, six mile by six mile townships that resulted in a stratified sampling method. Townships were further divided into 36 one mile square sections. Surveyors were instructed to blaze two witness trees at each section corner and quarter section corner. The species, diameter, distance, and bearing from the corner were noted for each witness tree. Two additional trees on the line between section and quarter section corners were recorded with species, diameter and distance from the section corner (Zhang and others 2000). The detailed and systematic nature of the PLS makes it well suited for vegetation reconstruction.

Kenoyer (1930, 1933, 1940, 1942) established tree distributions and species associations in Barry, Calhoun, Branch, Ottawa, and Kalamazoo Counties. The square quarter sections were used to plot bearing trees on the county maps. Six plant associations were identified: beech-maple forest, oak-hickory forest, swamp forest, oak-pine forest, bur oak (*Quercus macrocarpa* Michx.) forest, and prairie. The oak-hickory forest was the dominant community. The beech-maple forest occupied sites with better soil quality and therefore has been cleared most extensively. The most abundant species, in decreasing order were: white oak, beech, bur oak, yellow oak (*Quercus muehlenbegii* Engelm.), tamarack (*Larix laricinia* Du Roi, K. Koch), elm (*Ulmus* spp. L.), sugar maple (*Acer saccharum* Marsh.), black ash (*Fraxinus nigra* Marsh.), hickory, and white ash (*Fraxinus americana* L.). There was also a slight bias towards the selection of beech as a witness tree. The bias was tested by calculating the average distance from the corner and the average diameter of recorded beech trees compared to other species. Additional studies of adjacent counties have identified similar species compositions and associations with soil types (Dick 1937, Hartsveldt 1951).

Brewer and others (1984) compiled a map of pre-settlement vegetation across southwestern Michigan. Their map was primarily compiled from Kenoyer's previous work, however the new map was more detailed with 22 different vegetation associations. The major difference was a separation of the dominant oak-hickory association into oak savannah and oak forest. They also identified eight separate swamp forest associations, differentiated between five other wetland types, and more accurately identified the locations of prairies. The authors identified the boundaries of each of these additional community types. Donnelly and Murphy (1987) compared the composition of a relatively undisturbed beech-maple forest in Berrien County with the pre-settlement forests of the same area. The current forest was sampled to calculate values for density, dominance (basal area), species frequencies, and importance values. Maps from Brewer and others (1984) were used to identify beech-maple forests within the General Land Office survey of Berrien County. Relative values for density, dominance (basal area), species frequency and importance values were calculated for the pre-settlement beech-maple stands. The results showed a similar composition of the two forests. Beech and maple dominated both stands, with beech having the highest frequency and greatest average basal area. The importance value of beech was lower in the relict stand (142 compared to 151), however the authors argued that this was probably due to the inclusion of smaller stems in the survey of the current stand. Beech might also have been over-represented in early survey records because of its easily blazed smooth bark (Bourdo 1956). Overall, the study concluded that the remnant beech-maple forest was a good representation of the pre-settlement forest composition and demonstrated the value of using PLS data to reconstruct early-European settlement forests.

Pennsylvania – Metes and Bounds Surveys

Pennsylvania was surveyed under the metes and bounds system. Metes and bounds was the survey system used across most of the northeastern United States, before implementation of the Public Land Survey. This system lacked the rectangular layout of townships and sections, with surveyors setting irregular boundaries according to topography, quality of land and adjacent surveys. Metes and bounds surveys are subject to surveyor bias (Black and Abrams 2001a), however they contain valuable data on pre-settlement Eastern deciduous forests and have been used for several studies in Pennsylvania.

Lutz (1930) tabulated almost 6,000 witness trees from a survey of northwestern Pennsylvania recorded by Samuel Dale from 1814 to 1815. Samuel Dale's survey was useful because it was collected in a remote area before settlement and his notes were unusually detailed. Lutz (1930) calculated that beech, hemlock, maple, birch, white pine, and chestnut accounted for 88% of the individual trees recorded. He also noted that species composition in the historical surveys was very similar to the species composition of Heart's Content, a nearby remnant old-growth forest. Whitney (1990) located the same survey records within the regions topographic positions to produce a more detailed picture of pre-settlement forests. He also compared his witness tree findings with current forest inventories to track the changes in the hemlock hardwood forests of Pennsylvania's Allegheny Plateau. Whitney (1990) departed from Lutz's (1930) technique by only counting the witness corners when calculating percentage composition. Lutz (1930) had included all species references in his abundance values, including references to the dominant species encountered along the survey lines. Whitney (1990) used the survey line descriptions of dominant species to create a dissimilarity matrix of species assemblages, instead of including them in composition tallies. He identified two major assemblages. Hemlock and beech dominated the first community type, accompanied by sugar maple, American sycamore (*Platinus occidentalis* L.), birch, and ash (*Fraxinus* spp. L.) The second community type was a northern extension of the southern Appalachian oak forest. It was dominated by chestnut and oaks, and included red maple, white pine, mountain laurel (*Kalmia latifolia* L.), sassafras (*Sassafras albidum* Nutt. Nees), and hickory. Whitney (1990) also used standard contingency table analysis procedures to examine the relationship of species distributions to parent material and topography. Within topography, slopes > 8% were divided into nose, upper side slope, lower side slope, and hollow. Slopes < 8% were divided into plateau top or terraces/floodplains. In this region, hemlock and beech were dominant across all parent materials and topography. Sugar maple was associated with the well drained, sandstone soils on top of the plateau, birch with moist, colluvial soils of the footslopes, and oaks with upper slope positions and stonier soils. The survey notes also recorded ‘windfalls’ and Whitney (1990) calculated a return time of 1,000-2,000 years for wind disturbance events.

Abrams and Ruffner (1995) performed physiographic analysis on witness trees in the Allegheny High Plateau and Allegheny Front physiographic regions of north central Pennsylvania. They included aspect in their landform divisions with plateau tops, south coves, north coves, and stream valleys. The results concluded that in the pre-settlement forests of the northern Allegheny High Plateau hemlock dominated (40-47%) mountain coves and stream valleys, while beech dominated (45%) the plateau tops. The central Allegheny Mountains and Allegheny Front were a mix of oak, maple, chestnut, hickory, and pine. White pine was found on the more mesic sites, while pitch pine (*Pinus rigida* Mill.) was found on the more xeric ridges. The study also found a much lower frequency of white pine (<4%), than had been reported in earlier studies of pre-settlement forests in the region. Comparison with current forest inventories found a great reduction in hemlock and beech in the High Plateau region. Maple, northern red oak, black cherry (*Prunus serotina* Ehrh.), and birch increased in frequency. In the central Allegheny Mountains chestnut appears to have been replaced with chestnut oak and northern red oak. Red maple and black cherry appear to have increased in frequency, perhaps due to fire exclusion.

Whitney and DeCant (2003) entered witness trees from four counties in northwestern Pennsylvania into a GIS. This enabled them to overlay witness tree locations with topographic position, aspect, soil drainage, and parent material. Beech and sugar maple were associated with the richer, finer-textured soils of the northern glaciated Appalachian Plateau. Oaks and chestnut were associated with the leached, nutrient poor soils of the southern unglaciated Appalachian Plateau. Current forest inventories showed a decline or absence of the four indicator species: beech, sugar maple, oak, and chestnut. They conclude that clearance for farming in the north and selective logging in the south have led to a homogenization of forest communities and the loss of a distinct north/south division between the beech-sugar maple and oak-chestnut forest types.

Black and Abrams (2001a, 2001b) examined anthropogenic influence on early land surveys in southeastern Pennsylvania. Both of these studies used surveys from the metes and bounds system. Black and Abrams (2001b) established species site relationships according to parent material, soil drainage, and soil surface texture. They reported that black oak and hickory were associated with limestone parent materials and well drained loamy sites. Black oak was also associated with acid shale and sandstone parent materials and well drained, upland soils. White oak was found in stream valleys and coves. Chestnut oak and chestnut were associated with well-drained, rocky sites on quartzite parent materials. For temporal analysis they grouped witness trees by parent material classes, to avoid the bias of early settlement on productive bottomlands. They found that mean survey dates for northern red oak, white oak, and hickory were much earlier than scarlet oak, black gum (*Nyssa sylvatica* Marsh.), and other early successional species. They speculated that this shift might have been the result of agricultural clearance on bottomland sites and selective logging in the uplands. Black and Abrams (2001a) also evaluated the influences of Native Americans and surveyor bias on metes and bounds witness tree distributions. The study found that metes and bounds surveys preferentially followed lines of low topographic relief and unequally sampled across landform classes. They compensated for this bias by separating the study area into physiographic sections and landform classes. Their results found that the dominant species of pre-European settlement forests were white oak and black oak. Hickory was more common in areas of low topographic relief, while chestnut was more common in areas of high topographic relief. Finally, the study compared catchments with known Native American villages to similar catchments that lacked Native American settlements. The catchments with Native American villages had increased frequencies of hickory, walnut (*Juglans* spp.), and black locust and decreased frequencies of white oak.

Land Use in Appalachia

The southern Appalachian Mountains have experienced a varied pattern of land use. The most significant land use impacts have been during the last 200-300 years of

European settlement. These impacts include heavy grazing of livestock, clearance of forests for agriculture, clearance of forests for timber, and introduction of pathogens and exotic species.

Native American Influences

Archaeological evidence indicates that peoples influenced by the Mississippian culture were established in the Southern Appalachian Mountains by A.D. 900 (Hudson 1976). The Mississippians built settlements along the fertile bottomlands of meandering rivers. Their land use was probably intensive, but limited to the areas directly surrounding their villages (Davis 2000). Their impacts included the clearance of large areas of forest for cultivation of corn, beans and squash. They cut river cane for use in building structures, tools, and baskets. Fire was used regularly to clear underbrush, attract game, and encourage the growth of berries. Native Americans also cultivated fruit and nut bearing trees by reducing forest competition through burning and cutting of undesirable species. The influence of Native Americans is still visible in eastern forest, with higher densities of tree species used by Native Americans around historical village sites (Black and Abrams 2001a).

European Settlement – Agriculture

The Spanish were the first Europeans to enter the Appalachians during Hernando De Soto’s expedition in 1540. Contact with Europeans introduced metal tools, guns, new crops and livestock, and most importantly disease. In the following decades epidemics of disease wiped out much of the native population in the eastern United States. The period between 1550 and 1750 allowed previously impacted areas to recover and mask the direct evidence of Native American land use (Davis 2000). Native American cultures and settlements re-formed during this period. However, the Appalachian Mountains of Virginia were north of Cherokee territory and east of the Shawnee territory (Hudson 1976). As a result, this area was mostly uninhabited when European settlers entered the region.

The Appalachians in southwestern Virginia were first settled by Europeans during the second half of the 18th century (Giles County Deedbook A, 1787). The first residents settled in large valleys, farming bottomlands with flat fertile soils and then moved to less accessible gaps and hollows, and then finally to isolated coves and upper ridges (Wilhelm 1978, Salstrom 1994). They cleared land and established subsistence level farms. Land was often cleared using the Native American technique of burning the underbrush and then girdling trees and planting crops among the dead stems (Salstrom 1994). Trees would be felled in the following years and used for building material and firewood.

Farm types and land-ownership varied according to the productivity of land and the background of settlers (Mann 1995). The central characteristic of these farms was a diversity of agricultural production (Inscoe 1989). They tended to pursue a wide range of agricultural practices including the cultivation of row crops and maintenance of livestock such as cattle, sheep, and swine. They also practiced land rotation: clearing an area and planting it in row crops for several years until it was no longer productive, then allowing livestock to graze it, and finally allowing the field to lie fallow and often revert to forest (Hart 1977).

Appalachia's major export prior to the Civil War was livestock. Cattle and swine were raised in the mountains and then driven east to the crop producing regions of the Piedmont and Coastal Plain (Gray 1941). Appalachia continued to provide the majority of livestock for the southern states until the passage of the Homestead Bill of 1852. The passage of the bill led to rapid settlement of lands in the mid-west. The opening of more productive lands to the west and the expansion of railroads that could transport agricultural produce and livestock to eastern markets kept agricultural prices low (Salstrom 1994). As a result, the less productive lands of the Appalachians were relegated to subsistence agriculture.

European Settlement – Logging

Three patterns have dominated the clearance of forests in the United States (Clark 1984, Lewis 1998). Initially, prime agricultural land was cleared for farming as settlers spread out from the eastern seaboard. Patches were cleared as plantations or homesteads were established. Trees were girdled or felled and fields were often burned in preparation for planting. Once fields had been established, settlers usually harvested single trees for fuel and building material. Aggressively sprouting species such as chestnut were harvested from woodlots and undeveloped, less productive lands. Large scale industrial logging primarily occurred in areas that were unsuited for agriculture in a series of regional waves. Industrial logging began in the northeast, followed by the Lake States, and then the Appalachian region. Most commercial logging in the Appalachians occurred during the late 1800's and early 1900's. Much of the Appalachian forests were cut-over during this logging boom (Clarkson 1964). The timber industry took little consideration of soil erosion and ecological consequences. As a result, erosion rates were much higher than what occurs today. Once forests had grown back through succession they were often selectively cut over for the next 100 years.

Conclusion

Historical documents provide considerable information about the composition and structure of North American ecosystems through time. This information can be used to assess the impact that our land use decisions have had on natural ecosystems, indicate reference conditions for ecological restoration, and help us understand the processes that underlie ecosystem structure and composition. During the past three decades ecological research has put a greater emphasis on land use as a fundamental ecological force. The network of Long Term Ecological Research Sites have led the field in supporting interdisciplinary research that includes land use and the expertise of historians in explaining ecosystem structure and function today. Natural scientists have begun to explore the available historical data, establishing methods for analysis of early land surveys. However the field is still relatively new and there is an abundance of historical data that is yet to be explored. This is particularly true in the southeast, where the irregular land surveys present unique challenges.

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IV. MANUSCRIPT

200 Years of Vegetation Change in an Agricultural Watershed

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Abstract

A series of anthropogenic disturbance conditions have altered the vegetation of the southern Appalachians during the past 200-years. The objective of this research was to identify the nature and timing of these vegetation changes in order to better understand the underlying causes. A total of 304 land surveys were collected for a small agricultural watershed from early settlement in 1787 through to the present day. Witness corners recorded tree species, shrubs, stumps, snags and non-vegetative markers. Types of witness corners were tallied and tested for shifts in frequency across time periods. Tree species were also classified by silvical characteristics including sprouting capability, shade tolerance, and seed type and shifts in frequency across these groupings were tested. Landform bias of the witness corners was tested using references contained in the surveys. Results showed significant shifts in white oak (*Quercus alba* L.), chestnut (*Castanea dentata* Marsh. Borkh.), chestnut oak (*Quercus prinus* Wild.), black oak (*Quercus velutina* Lam.), red oak (*Quercus rubra* L.), black locust (*Robinia pseudoacacia* L.), yellow poplar (*Liriodendron tulipifera* L.), and scarlet oak (Quercus coccinea Muenchh.). The central change was a steady decline in white oak, probably due to the absence of fire and changes in soil properties. Chestnut replaced white oak as the

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dominant species, but was removed by chestnut blight in the 1930's. Sprouting capability appeared to be the most important silvical characteristic across all species.

Index terms: Witness trees, metes and bounds, historical ecology, land surveys, chestnut, white oak, southern Appalachians, Southwestern Virginia.

Introduction

The vegetation of the eastern United States has experienced an intensive and varied pattern of disturbance during the past 300 years (Whitney 1994, Russell 1997). Most of the forests were cleared at least once for agriculture or timber. Much of the cleared agricultural land was tilled and planted with crops, often leading to erosion of the surface layers and depletion of nutrients. Livestock were grazed on both forested and cleared land, disturbing undergrowth and inhibiting regeneration. Forests that were not cleared were selectively harvested for desirable species. Finally, introduced pathogens such as chestnut blight (McCormick and Platt 1980), Dutch elm disease (MacDonald 2003), and the hemlock woolly adelgid (Orwig and Foster 1998) have removed entire species from the forest. It is certain that nearly all forests in the eastern United States have been influenced to varying degrees by human activities. In the southern Appalachians, direct human disturbance including farming, logging, mining, and road construction have impacted 98% of the landscape (Gragson and Bolstadt 2006).

Recent studies have demonstrated that human land uses have long-term impacts on ecosystem structure and composition (Motzkin and others 1996, Foster and others 1998, Bellemare and others 2002). Species with limited seed dispersal, such as beech (*Fagus grandifolia* Ehrh.) and hemlock (*Tsuga canadensis* L. Carr.) are slow to return to areas that were formerly cleared (Foster and others 1998). Tillage, grazing or logging can alter soil physical properties and distribution of nutrients (Compton and others 1998, Fraterrigo and others 2005). These abiotic changes can persist for centuries, excluding species that were present before disturbance. In New England. scrub oak communities are nearly absent from areas that were plowed during the early settlement of the 18th century (Motzkin and others 1996).

Several studies have used early land survey records to demonstrate differences between pre-settlement forest composition and current forest composition (Foster and others 1998, Burgi and others 2000, Dyer 2001, Rentch and Hicks 2005). Witness trees have demonstrated a decrease in abundance of long-lived, late-successional species such as beech and hemlock in New England (Foster and others 1998, Burgi and others 2000), and white oak (*Quercus alba* L.) in the central Appalachians (Rentch and Hicks 2005). However, little research has addressed the vegetation that persisted during the middle years of heavy agricultural disturbance (Hall and others 2002, Whitney and DeCant 2003). As forests were cleared for agriculture, vegetation remained in fence-rows, fields, and property boundary lines and was recorded in new surveys. An examination of change in tree species recorded in surveys over time provides a sample of species that persisted in the agricultural environment. It is important to understand the vegetation of this middle-period of agricultural disturbance because it helps identify the processes that created the forests of today.

Although few studies have used witness trees to ascertain the structure and composition of the agricultural period, we do know quite a bit about land that is impacted by agriculture because we can study current landscapes. Certain species are more successful in this highly disturbed environment (Johnson 1988, Ruremonde and Kalkhoven 1991, McLaughlin and Mineau 1995). Tree species with high fecundity and wind dispersed seeds (*Acer, Betula, and Liriodendron*) tend to be more successful in establishment than larger seeded species that depend on animals for dispersion (*Quercus, Carya, Cornus, Nyssa*) (Clark and others 1998). Trees in fencerows and on field boundaries provide habitat corridors for wildlife and plant species; they alter resource availability, and provide seed sources (Fritz and Merriam 1996, Corbit and others 1999, Freemark and others 2002, Goheen and others 2003, Donald and Evans 2006). Although these studies tell us about the way agricultural land exists today, they don't provide us with information about the composition of the past landscape. Witness trees offer a unique dataset, allowing us to examine historical agricultural landscapes.

The objective of my research is to use land surveys from Clover Hollow Watershed to characterize shifts in tree species composition from early settlement in 1780 through time to the present. The witness tree record provides a sample of the vegetation throughout this period of agricultural disturbance.

Study Area

Clover Hollow is a small agricultural watershed in Giles County, VA. The study site was chosen because it is a clearly delineated watershed that has experienced 200 years of agriculture following European settlement. The watershed is 2,595 ha and bounded on three sides by John's Creek Mountain and Clover Hollow Mountain. Clover Hollow is within the Southern Appalachian Ridge and Valley physiographic province. The bedrock is generally limestone valleys between sandstone and shale ridges. Soils have primarily formed from limestone and shale residuum mixed with sandstone and shale colluvium (Swecker and others 1981). Common soils in the valley are fine loamy, mixed, mesic Typic Hapludults. Soils on the sloping ridges are loamy-skeletal, mixed, mesic Typic Dystrochrepts. The watershed is drained by Clover Hollow Stream, a first order perennial stream that empties into Sinking Creek.

Currently, adjacent forests are characterized by: (1) northern red oak (*Quercus rubra* L.)-white oak at ridge-top sites, (2) chestnut oak (*Quercus prinus* Wild.) at mid-slope positions, and (3) red maple (*Acer rubrum* L.)-mixed oak at lower slope positions (Adams and Stephenson 1983). The earliest Clover Hollow land grant was recorded in 1787 and a majority of the area was settled within the next 60 years. The current land use is a mix of agriculture and residential areas. Corn, alfalfa, and hay are grown on flat to mildly sloping bottomlands and livestock is grazed on the steeper hillsides with interspersed patches of forest in the early stages of old field succession. The agricultural land is surrounded by an outer ring of forest on the steep slopes of the ridge-tops. Residential development has been increasing in Clover Hollow during the past 20 years with new housing mainly built on the lower slopes of the surrounding ridges.

Methods

Land Survey Records

Vegetation data were collected from land surveys contained in property deeds. Land surveys commonly species of witness trees at deed corners. These species tallies can be viewed as a sample of the landscape's vegetation at the time of the survey. Much of North America was surveyed prior to or just after European settlement. Ecological applications of pre-settlement land survey data include: maps of pre-settlement vegetation, densities of tree types, disturbance regimes, size distributions, and association of tree types with site characteristics (Leitner and Jackson 1981, Russell 1981, Barret and others 1995, Batek and others 1999, Manies and Mladenoff 2000, Black and others 2002, Schulte and Mladenoff 2005).

For this study, witness corners were collected from surveys attached to property deeds in the Giles County Courthouse, Pearisburg, Virginia and online through the Library of Virginia. The Clover Hollow watershed boundaries were delineated using ArcMap and the flow accumulation feature. Current property owners within the watershed were identified using the 2005 Giles County tax map. Parcels were then traced back through successive owners using Deed Books and Will Books in the Giles County Courthouse. The earliest courthouse deeds were matched with Commonwealth of Virginia land grants obtained through the Library of Virginia. Surveys were transcribed and plotted in Deed Plotter. Parcels were then connected to form parcel maps for 20 year periods. The parcel maps were used to eliminate deeds that were not within the watershed. All deeds that were partially within the watershed were included. Parcels of similar acreage were compared to eliminate any duplication of surveys. Surveys were assigned a date of the earliest deed they were associated with, since actual survey dates were seldom recorded. A total of 304 different surveys were identified for Clover Hollow between the years of 1787-2000. Witness corners were tallied by decade for each original survey producing a total of 4,947 witness corners.

Data Analysis

Chi-squared contingency table analysis was performed on types of witness corners; e.g. white oak, chestnut (*Castanea dentate* Marsh. Borkh.), stumps, or posts. To increase sample sizes for statistical analysis, witness corners were grouped into three time periods: early settlement (1780-1849), middle settlement (1850-1919), and late settlement (1920-2000). Non-tree points were classified as non-vegetative, stumps, dead trees (fallen and standing), and shrubs. Less common species were grouped together as minor hardwoods and under-story trees to meet the requirements of the test. All witness point groupings had a greater than 5 expected value in chi-squared contingency table analysis. In addition, all tree species were classified according to shade tolerance, sprouting ability, and seed type (Appendix A, B, Burns and Honkala 1990). Chi-squared contingency analysis was performed to test the significance of shifts in frequencies of species and class values across time periods. Topographic bias was a concern in examining the irregular metes and bounds surveys (Black and Abrams 2001). Increased sampling of the upper ridges or bottomland during different time periods could be mistaken for species shifts. Topographic bias was assessed by tallying the references to landforms that were frequently recorded in surveys. References to mountain tops, the sides of the mountain, ridge tops, and the sides of ridges were grouped as upland topography. References to hills, hollows, branches, flats, and bottoms were grouped as lowland topography (Appendix C). Topographic references were gathered for each time period and compared for shifts in sampling bias.

Results

Land surveys recorded a total of 4,947 witness corners in Clover Hollow from 1780-2000. The witness corners were 3,774 (76.3%) trees, 32 (0.6%) shrubs, and 1,141 (23.1%) non vegetative markers, including stumps and snags. The percentage of trees recorded as witness corners steadily decreased through time while non-vegetative markers increased (Figure 1). A total of 37 different tree and shrub species were recorded as witness corners (Table 1). The most common tree species over the entire period were white oak (15.5%), chestnut (13.7%), chestnut oak (12.2%), black oak (*Quercus velutina* Lam.) (6.1%) and hickory (*Carya* spp.) (4.1%) (Hickories were not differentiated by species in surveys).

White oak was the most common species during the early settlement period. White oak was twice as abundant as chestnut, the second most common species. Chestnut oak, black oak, northern red oak, and hickory were also frequently recorded. Chi-squared contingency table analysis identified highly significant shifts ($\alpha = 0.01$) in tree species frequencies through the three time periods for white oak, chestnut, chestnut oak, black oak, red oak, locust (*Robinia pseudoacacia* L.), yellow poplar (*Liriodendron tulipifera* L.), and scarlet oak (*Quercus coccinea* Muenchh.). Tree species that did not show significant shifts in frequency over time were hickory, dogwood (*Cornus florida* L.), gum (*Nyssa sylvatica* Marshall.), black walnut (*Juglans nigra* L.), basswood (*Tilia americana* L.), ash (*Fraxinus* spp.), red maple, and sugar maple (*Acer saccharinum* L.). The surveys recorded a significant increase in frequency of vigorously sprouting tree species from 46.4% to 69.7% of witness trees (Table 2). The shade tolerance and seed type groupings showed minor changes in frequency (Table 3, 4). Topographic analysis revealed a higher sampling of lowland topography than upland topography (Table 5). This bias remained consistent across the three time periods (60/40, 56.5/43.5, 72.7/27.2). Chi-squared contingency table analysis established that topographic bias did not significantly shift across time periods ($\alpha = 0.05$). The consistent bias across time periods suggests that shifts in species frequency were not the result of shifts in topographic sampling.

Discussion

Silvical characteristics of persistent species

Successful sprouting appears to be the most important silvical characteristic in determining tree species persistence in the agricultural landscape. Seed type and shade tolerance were less important. The most significant shift in frequency of silvical characteristics occurred among vigorous sprouting hardwoods and less vigorous sprouting hardwoods (Table 2). Vigorous sprouting hardwoods increased from 46.4% to 69.7% of recorded witness trees across the three time periods. Trees that sprouted quickly from stumps and roots would have had a competitive advantage following agricultural clearance and logging. Woodlots and fencerows were continually picked over for fuel, fences, and other local farm uses. Species such as chestnut and chestnut oak were able to continually re-sprout after cutting and dominated these late settlement stands.

This trend ran contrary to our expectation that agricultural clearance would result in an increase in early successional, shade intolerant species such as yellow poplar, black locust, sassafrass (*Sassafras albidum* (Nutt.) Nees.), and black cherry (*Prunus serotina* Ehrh.). The shade intolerant species did increase slightly during the middle settlement period (Table 3). It was during the middle settlement period that the watershed experienced its highest levels of agricultural clearance (Virginia Agricultural Census, 1850, 1860, 1870, 1880). Fast growing, shade intolerant species are able to exploit the open environment of fields and meadows. However, shade tolerant species also increased in frequency during the middle settlement period. During the late settlement period, shade tolerant species increased greatly, while shade intolerant species decreased. This suggests that shade tolerance played a role in the early decades of agricultural disturbance, but other factors were more important in determining the species composition following the initial phase of agricultural clearance.

Tree species with different seed types showed some minor changes in frequency over time (Table 4). Species with wind borne seeds increased significantly, while species with larger seeded nuts decreased. This same trend has been demonstrated in studies of seed dispersal and regeneration in agricultural and forested environments (Matlack 1994, Clark and others 1998).

White Oak

The most dramatic change recorded in the survey data is the decline of white oak. White oak is the dominant species during the early settlement period, accounting for 30.1% of the recorded witness trees. During the late settlement period, white oak accounts for 4.8% of the witness trees. A decline in white oak has been noted in witness tree research in southwestern Virginia and throughout the eastern United States (McCormick and Platt 1980, Abrams and McCay 1996, Abrams 2003). White oak is an opportunistic, fire tolerant species (Burns and Honkala 1990, Abrams 1992). Thick bark and an ability to compartmentalize injury from fire scars enabled white oak to flourish under the disturbance of low intensity ground fires prior to European settlement.

European settlement brought a change in disturbance regime, including widespread clearance, selective cutting of white oak for lumber, tannins, and local building materials, and the eventual suppression of all fire (Whitney 1994).

Change in soil physical and chemical properties, due to heavy agricultural land use, provide another explanation for white oak decline. Soil erosion from agricultural clearance, tillage, and grazing has been shown to reduce soil moisture and nutrient availability (Compton and others 1998, Fraterrigo and others 2005). These widespread changes in soil quality would have shifted site characteristics throughout the watershed, favoring the regeneration of chestnut oak over white oak. White oak is generally out-competed by chestnut oak on xeric, nutrient poor sites (Monk and others 1990, Barnes 1991).

The record of witness trees through time shows a steady decline in the prevalence of white oak from 30% to 16% to 5% (Table 1). The steady decline indicates that the condition responsible for white oak decline has been constant throughout the period since European settlement. This suggests that the cause is a long term change such as fire disturbance or soil degradation, and not the result of a specific event such as initial forest clearance or a wave of insect attack (Castello and others 1995, Orwig 2002). The long-lived nature of white oaks allowed them to remain on the landscape over time in the absence of regeneration. White oak has steadily declined in frequency as mature individuals have died. Opportunistic species such as chestnut, chestnut oak and hickory (vigorous sprouters) or red maple, sugar maple, and ash (wind-borne seeds) have replaced white oak under the post-European settlement disturbance regime.

American Chestnut

American chestnut and chestnut oak were the most persistent species through the agricultural disturbance of the past 200 years. Both species are vigorous sprouters, providing a competitive advantage following agricultural clearance and selective cutting of fencerows. Both species also produce large mast which might have encouraged landowners to leave individuals in fencerows and forests for improved grazing. Chestnuts could also be collected for human consumption. Recent studies have noted the abundance of chestnut sprouts along forest edges, in fencerows, woodlots, and old fields (Russell

1987, Paillet 1988, Paillet 2002). Second growth, coppice stands of chestnut were noted throughout New England during the 19th century (Cronon 1983, Whitney 1994). It appears that chestnut is particularly well adapted to agricultural disturbance.

The role of chestnut is especially interesting in light of its demise during the latter part of the 20th century. Chestnut constituted a quarter (27%) of the witness trees during the late settlement period. Most of these chestnuts were recorded from 1920-1940. Chestnuts accounted for 34% of the witness trees recorded during this 20-year period. A comparison of pre-settlement and present forest composition does not adequately record the boom and bust of the chestnut population. Chestnut was an important component of pre-European settlement forests in southwestern Virginia. However, its frequency was amplified by the disturbance regime following settlement. White oak was clearly the dominant species in pre-settlement forests with chestnut, black oak, and chestnut oak playing a supporting role. The high frequency of chestnut within agricultural landscapes during the early part of this century has resulted in an over estimation of its role in the pre-settlement eastern deciduous forest. McEwan and others (2005) used early settlement land surveys to examine the distribution of chestnut and possibly inform re-establishment efforts. However, caution should be taken in drawing conclusions from surveys that were conducted after significant settlement, considering the increase in chestnut abundance due to human land use.

Clearance

The increase over time of non-vegetative markers recorded as witness corners suggests increasing levels of clearance along property boundaries (Figure 1). This conclusion is reinforced by the increase in stumps recorded as witness corners until 1900 (Figure 2). The number of stumps recorded then decreases until 1960-1979 when there is a dramatic increase. It is possible that this is the result of landowners removing chestnut snags killed by the chestnut blight in the preceding decades (Frothingham 1924, Vandermast and Van Lear 2002). It is important to note that percentage of vegetative witness corners is not necessarily an indicator of overall forest cover within the watershed. Current aerial photographs indicate that the watershed is 50% forested today. However, the majority of this cleared land is on lowland topography where, according to the landform bias test, the highest percentage of witness corners was recorded throughout all three time periods. The witness corners also do not record vegetation change in the interior of parcels. This probably explains the lack of an increase in frequency of black locust and tulip poplar, noted old-field pioneer species in the region (Lafon 2004).

Testing Landform Bias

The test used in this study for landform bias could be applied to many areas in the southeast. The majority of witness tree studies have been conducted using GLO surveys in the mid-west or the scattered rectangular surveys that were recorded in the northeast. The mid-Atlantic and southern states have been avoided due to the prevalence of irregular metes and bounds surveys. Studies that have been carried out using metes and bounds surveys have generally relied on county plats that pieced these surveys together (Black and Abrams 2001). However, plats are not available for most areas and the time required to produce them is inhibitive. Without the ability to place witness corners on the landscape, researchers have been hesitant to draw conclusion on species composition because of an inability to test whether surveys were an accurate sample of the landscape.

The advantage of the test for landform bias used in this study is that it does not require the surveys to be pieced together and plotted on the map. The test can be performed with the data contained in the surveys. It is particularly well suited for surveys of mountainous regions, where landform references are common due to the rough terrain. The 304 surveys examined in this study recorded 754 landform references (Table 5). There was one landform reference for every 6.5 witness corners. The landform references provided a fairly dense sampling of the terrain. This technique could be applied to early land surveys throughout the Appalachians. The majority of public forest land in the eastern United States is within the Appalachian Mountains. These lands are increasingly being viewed as important reserves of rare plant and animal species. Witness tree studies could provide information on the pre-European settlement species composition of forest in this region. This information would be valuable in guiding forest management and ecological restoration.

Conclusion

Successive land surveys in Clover Hollow Watershed show the decline of white oak, the loss of chestnut, and the value of using successive witness tree records to track vegetation change. The decline of white oak is likely a result of reduction in fire frequency and loss of soil quality caused by agricultural soil erosion. This decline represents a major loss of an important food source for many wildlife populations including white tailed deer, turkey, and grey squirrel and the decline of an economically-important timber species. Chestnut increased in density following European settlement because the disturbance regime of frequent cutting favored vigorous sprouting species; however after the chestnut blight entered this area in the 1930s, chestnut was eliminated from the forest overstory. This represents a loss of an important wildlife and commercial species. The use of witness tree data from successive land surveys has the potential to develop into an important tool for land managers in the southeastern United States. The data set provides an understanding of the historical range of variability for a forest type and thus serves as a valuable guide in forest management and ecological restoration.

Aknowledgements

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Table Captions

Table 1. Witness trees species counts and percentages recorded in property deeds for Clover Hollow, VA. Although non-tree witness corners were recorded they were not included in this data set. Asterisks denotes species with frequency shifts that were significant at $\alpha = 0.01$.

Table 2. Vigorous sprouting hardwoods and less vigorous sprouting hardwoods recorded as witness trees in property deeds for Clover Hollow, VA.

Table 3. Shade tolerance of species recorded as witness trees in property deeds for Clover Hollow, VA.

Table 4. Seed types of species recorded as witness trees in property deeds for Clover Hollow, VA. Asterisks denotes frequency shifts that were significant at $\alpha = 0.01$.

Table 5. References to upland topography and lowland topography recorded in property deeds of Clover Hollow, VA. Chi-squared contingency table analysis of shifts in topographic references were not significant ($P = 0.102$).

Witness Tree	Scientific name	1780-1849	1850-1919	1920-2000
White oak*	*Quercus alba*	426 (30.1%)	329 (15.7%)	12 (4.8%)
Chestnut*	*Castenea dentate*	209 (14.7%)	405 (19.4%)	66 (26.6%)
Black oak*	*Quercus velutina*	173 (12.2%)	124 (5.9%)	6 (2.4%)
Chestnut oak*	*Quercus prinus*	169 (11.9%)	381 (18.2%)	54 (21.8%)
Northern red oak*	*Quercus rubra*	72 (5.1%)	79 (3.8%)	1 (0.4%)
Hickory	*Carya spp.*	60 (4.2%)	122 (5.8%)	21 (8.5%)
Yellow poplar*	*Lirodendron tulipifera*	48 (3.4%)	53 (2.5%)	2 (0.8%)
Scarlet oak*	*Quercus coccinea*	40 (2.8%)	24 (1.1%)	3 (1.2%)
Dogwood	*Cornus florida*	39 (2.8%)	69 (3.3%)	7 (2.8%)
Basswood	*Tilia americana*	36 (2.5%)	44 (2.1%)	9 (3.6%)
Black gum	*Nyssa sylvatica*	32 (2.3%)	53 (2.5%)	5 (2.0%)
Black walnut	*Juglans nigra*	30 (2.1%)	54 (2.6%)	6 (2.4%)
Black locust*	*Robinia pseudoacacia*	16 (1.1%)	97 (4.6%)	12 (4.8%)
Red maple	*Acer rubrum*	13 (0.9%)	22 (1.1%)	10 (4.0%)
Ash	*Fraxinus spp.*	11 (0.8%)	28 (1.3%)	9 (3.6%)
Sugar maple	*Acer saccharinum*	11 (0.8%)	29 (1.4%)	4 (1.6%)
Pine*	*Pinus spp., Juniperus virginiana*	4 (0.3%)	47 (2.2%)	3 (1.2%)
Minor Hardwoods	*Aesculus octandra, Ulmus spp., Fagus grandifolia, Prunus serotina, Oxydendrum arboreum, Betula spp., Sassafras albidum, Juglans cinerea*	19 (1.3%)	59 (2.8%)	13 (5.2%)
Understory Trees*	*Celtis occidentalis, Ostrya virginiana, Morus rubra, Malus sylvestris, Amelanchier arborea, Prunus cerasus, Magnolia acuminate*	5 (0.4%)	48 (2.3%)	4 (1.6%)
Shrubs*	*Crataegus spp., Prunus Americana, Hamamelis virginiana, Lindera benzoin, Viburnum prunifolium*	4 (0.3%)	22 (1.1%)	1 (0.4%)
Total		1417 (100%)	2089 (100%)	248 (100%)

Table 1

Witness Trees	**1780-1849**	**1850-1919**	**1920-2000**
Vigorous sprouting hardwoods*	654 (46.4%)	1138 (56.3%)	170 (69.7%)
Less vigorous sprouting hardwoods*	755 (53.6%)	882 (43.6%)	74 (30.3%)
Total	1409 (100%)	2020 (100%)	244 (100%)

Table 2

Witness Trees	**1780-1849**	**1850-1919**	**1920-2000**
Shade tolerant species*	146 (10.3%)	249 (12.4%)	43 (17.6%)
Intermediate species*	1166 (82.5%)	1520 (75.8%)	176 (71.8%)
Shade intolerant species*	101 (7.1%)	235 (11.7%)	26 (10.6%)
Total	1413 (100%)	2004 (100%)	245 (100%)

Table 3

Witness Trees Seed Type	1780-1849	1850-1919	1920-2000
Nut*	1175 (83.2%)	1548 (74.9%)	176 (71.3%)
Drupe	84 (5.9%)	155 (7.5%)	20 (8.1%)
Wind Borne*	121 (8.6%)	201 (9.7%)	35 (14.2%)
Other*	33 (2.3%)	163 (7.9%)	16 (6.5%)
Total	1413 (100%)	2067 (100%)	247 (100%)

Table 4

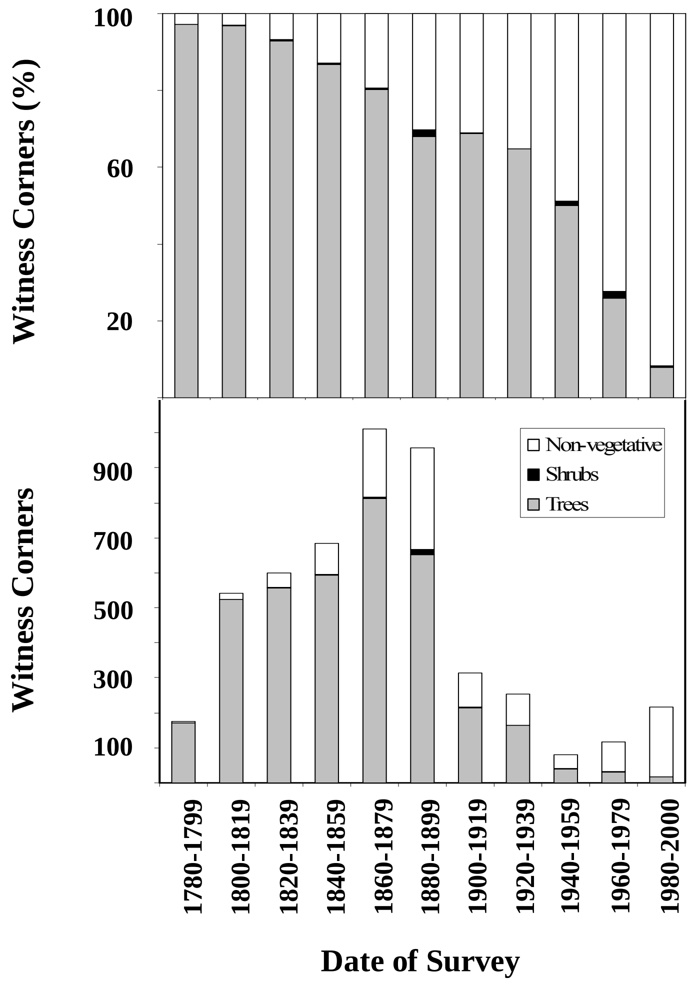
Topographic References	1780-1849	1850-1919	1920-2000
Upland Topography	122 (40%)	176 (43.5%)	12 (27.2%)
Lowland Topogaphy	183 (60%)	229 (56.5%)	32 (72.7%)
Total	305 (100%)	405 (100%)	44 (100%)

Table 5

Figure Captions

Figure 1. Types of witness corners recorded through time in surveys of Clover Hollow VA.

Figure 2. Percentage of stumps recorded as witness corners through time in surveys of Clover Hollow.



Witness Corners (%)
100
60
20
Witness Corners
900
700
500
300
100
Non-vegetative
Shrubs
Trees
1780-1799
1800-1819
1820-1839
1840-1859
1860-1879
1880-1899
1900-1919
1920-1939
1940-1959
1960-1979
1980-2000
Date of Survey

Figure 1

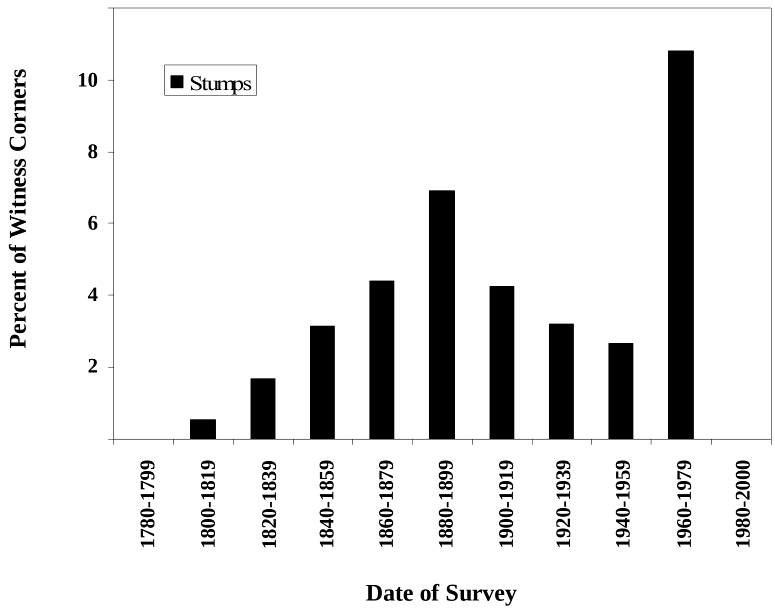

Percent of Witness Corners
10
8
6
4
2
Stumps
1780-1799
1800-1819
1820-1839
1840-1859
1860-1879
1880-1899
1900-1919
1920-1939
1940-1959
1960-1979
1980-2000
Date of Survey

Figure 2

V. APPENDICES

Appendix A. Sprouting classes for witness tree species

Vigorous Sprouters	Less Vigorous Sprouters
Scarlet oak	White oak
Chestnut oak	Black oak
Chestnut	Cucumber magnolia
Hickory	Black locust
Red maple	Ash
Yellow poplar	Black cherry
Northern red oak	Ironwood
Basswood	Dogwood
Sourwood	Sugar maple
Sassafrass	Black walnut
Mulberry	Beech
	Birch
	White Walnut
	Elm
	Hackberry
	Black gum
	Pine
	Eastern red cedar

Appendix B. Shade tolerance classes for witness tree species

Tolerant	Intermediate	Intolerant
Beech	Ash	Birch
Buckeye	Black oak	Eastern red cedar
Dogwood	Chestnut oak	Black locust
Black gum	Cucumber magnolia	Yellow poplar
Ironwood	Elm	Sassafrass
Basswood	Hackberry	Black walnut
Red maple	Hickory	White walnut
Mulberry	Red oak	Black cherry
Sourwood	Scarlet oak	
Sugar maple	White oak	
	Chestnut	

Appendix C. Landform references used for testing topographic bias

Upland Topography	Lowland Topography
"On mountain"	"Branch"
"Top of mountain"	"Hollow"
"Side of mountain"	"Flat"
"Gap of mountain"	"Bottom"
"Spur of mountain"	"On hill"
"Point of mountain"	"Top of hill"
"On ridge"	"Side of hill"
"Top of ridge"	
"Side of ridge"	
"Point of ridge"	

VITA

William T. Flatley was born May 4, 1977 in Wilton, Connecticut to Katharine P. Flatley and William F. Flatley. He has an older sister Edith Morgan Flatley in Chicago, Illinois. He has a younger sister Katharine P. Flatley in Antigua, Guatemala. Will spent the majority of his childhood in Connecticut, Tennessee, Ohio, New Hampshire, Wyoming, and Virginia. He was educated at Dartmouth College, The University of Barcelona, The University of the South, The University of Tennessee Chattanooga, and Virginia Polytechnic Institute and State University. He graduated with a Batchelor of Arts in History. After two years in the hospitality industry, Will fell in love with environmental history and has been pursuing his dream ever since. In August of 2004, he started work on his Master's of Science degree in Forestry (Forest Ecology) under Dr. Carolyn A. Copenheaver.