Natural History of the Bitternut Hickory

(*Carya cordiformis*):

Its Occurrence Along a Small Stream

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ABSTRACT

In the winters from November 2007 through November 2013, I located 344 bitternut hickories (*Carya cordiformis*) along a small stream and ephemeral tributary. It was noticeable that they occurred in four size classes based on DBH: Population I (1/2 inch—3 3/4 inches DBH) 263 trees; Population II (4 inches—7 1/2 inches DBH) 60 trees; Population III (8 inches—13 1/2 inches DBH) 20 trees; Population IV (>16 inches DBH) 1 tree. I did not find any very large trees. I found that they are not particular to soil type—growing in well drained Nanford-Badin soil, as well as poorly drained Pittsboro-Iredell and Cid soils. They are growing in the Piedmont Alluvial Forest, Piedmont Bottomland Forest, Piedmont Mafic Cliff, Basic Mesic Forest, and Basic Oak-Hickory Forest plant communities in areas where water is available, but not in water or in places where water stands. The larger ones were growing in rocks or rock piles, which may hold water longer than unsheltered ground. I made a very rough estimate of their ages and possible years of germination: Population I (8 to 59 years) germinated 1953 to 2004; Population II (47 to 88 years) germinated 1924 to 1965; Population III (74 to 120 years) germinated 1892 to 1938; Population IV (110 years) germinated 1902. Land use (farming) and canopy-opening weather events, such as hurricanes and ice storms, have been the biggest influences on where they occur. They are growing at the *edges* of things: old fields, old roads, old drainage ditches, old fence lines, creeks, and flood plains. They are growing, for the most part, in areas unsuitable for agriculture: land that is too wet, too rocky, too steep, too clayey. They may like burned or disturbed soil. I believe that their nuts are distributed by rodents, birds, and flood waters. During the time of this study, the weather in the Study Area was dominated by a more-than-decade-long extreme drought, during which many of the small young trees died. The oldest trees would have survived another extreme drought in the late 1920s to 1930s. Bitternut hickories, while known as “water-loving,” must also have some tolerance to drought. The bitter compounds in their nuts protect the seeds from mold and fungi in the wet environments.

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Introduction

I was walking in the woods in late winter, down by a creek, when I saw, standing in front of me, a little tree with welcoming, out-stretched branches, and with unusual sulfur-yellow buds at the ends of its twigs. Tree-lover that I am, it was unusual for me not to know a tree around here, and I'd never seen this kind before. Maybe some kind of magnolia, I thought, I kept going back to this area to see what was going to emerge from these yellow buds. Finally, one day, they started unfurling into compound leaves, of all things! I couldn't believe it. What could this be? I searched in all the tree books I have, and there was no question about it. It had to be a Hickory, *Carya* spp. How could this be?

I thought I knew Hickories, living as I do on a rocky hillside surrounded by them--Southern Shagbark (*Carya carolinae-septentrionalis*), Mockernut (*C. tomentosa*), Pignut (*C. glabra*), and Red Hickory (*C. ovalis*). Bits of shells dropped by squirrels fall like rain, nuts on a tin roof like gunshots. On windy fall days, I need a hardhat.

On the other side of our hill, there is Shagbark Hickory (*C. ovata*), and I have seen Kingnut (*C. laciniosa*). So what was this Hickory that I didn't know?

I found it in Charlotte Hilton Green's Trees of the South, the Bitternut Hickory (*Hicoria* (sic) *cordiformis*). "'The hickory that is different,' children usually say in trying to describe this tree . . . . In winter this tree always has its calling cards prominently displayed--the buds, which are blunt, flattened, and bright yellow in color. Once familiar with these winter buds, no one could fail to recognize this tree."[1]

I wanted to know more. I didn't know I was going to find 344 of them along this creek and an ephemeral tributary.

Distribution of Hickories (*Carya* spp.)

The Southeastern United States is the center of biodiversity of Hickories (*Carya* spp.), with 12 (including Florida) of 18 species worldwide. North Carolina has ten species: *C. aquatica*, Water Hickory; *C. carolinae-septentrionalis*, Southern Shagbark

[1] Green, Charlotte Hilton, Trees of the South, Chapel Hill, 1939, p. 72.

Hickory; *C. cordiformis*, Bitternut Hickory; *C. glabra*, Pignut Hickory; *C. illinoinensis* (naturalized) Pecan; *C. laciniosa*, Big Shellbark (Kingnut) Hickory; *C. ovalis*, Red Hickory; *C. pallida*, Pale (Sand) Hickory; and *C. tomentosa (alba)*, Mockernut Hickory.

Hickories, family Juglandaceae, are classified into two sections: *Apocarya*, the "Pecan Hickories," with valvate bud scales, mostly seven to seventeen leaflets, and fruit husks winged at the sutures (in North Carolina, *C. aquatica*, *C. cordiformis*, and *C. illinoinensis*); and *Carya*, the "True Hickories," with six or more overlapping scales, five to seven leaflets, and husks unwinged or ribbed (in North Carolina, *C. carolinae-septentrionalis*, *C. glabra*, *C. laciniosa*, *C. ovalis*, *C. ovata*, *C. pallida*, and *C. tomentosa*).

Carya aquatica, *C. carolinae-septentrionalis*, *C. cordiformis*, *C. illinoinensis*, *C.laciniosa*, and *C. ovata* are diploids with N=16; *C. glabra*, *C. ovalis*, *C. pallida*, and *C. tomentosa* are tetraploids, with N=32.[2]

There is a lot of variation in Hickories, and they are hard to identify by bark, shape, and number of leaflets, and because the tall trees have few leaves, if any, at the eye level of the observer. In addition, they may be somewhat promiscuous, as there are many references to hybrids in the literature.[3]

Description of Bitternut Hickory, *Carya cordiformis*

Carya cordiformis is a medium to large tree, 40' to 100' tall, 1' to 3' in diameter at maturity, with stout, spreading branches, and long, clean trunk with little taper. It is a rapidly growing tree with deep and widespread roots.

Leaves are alternate, odd-pinnnately compound, 10" to 18" long, 10" wide, with 7 to 11 (mostly 9) sessile to nearly-sessile leaflets.

Leaflets are slender, long-tapering, and willow like, or broadly ovate, as in *C. cordiformis* var. *latifolia Sarg.*[4] (In my area there can be both forms, sometimes on the same tree.) Leaflets are finely toothed, bright green above and paler below. Terminal leaflets are larger than the basal. *See image below.*

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[2] Weakley, Alan. Flora of the Carolinas, Virginia and Georgia. University of North Carolina Herbarium, North Carolina Botanical Garden. Chapel Hill, N.C. 2010, p. 468.
[3] Sargent, Charles Sprague. Manual of the Trees of North America. Dover Publications, Inc., New York. 1965, p. 181; Weakley, ibid.
[4] Sargent, ibid.

Nuts (dehiscent drupes) are bitter, ovoid, thin-shelled, four-winged above the middle, about 1" long, distinctly beaked, and enclosed in a thin yellow-scaly husk, which splits about one-half the length. (They are fragrant, especially when green.)

Twigs are moderately stout, gray to greenish brown, hairy through early summer, and with pale, oblong lenticels. The pith is brownish-white and homogenous.

Buds are sulphur-yellow, ovoid, with scurfy valvate scales. Terminal buds are usually elongate, one-half inch long, four-angled, and oblique at the apex. Lateral buds are smaller and often angled away from the twig (especially near the apex).

Leaf scars are three-lobed-to-heart-shaped, with bundle scars in three groups, or scattered.

Bark is gray, thin and light colored, not shaggy, sometimes faintly tinged with yellow or red, generally smooth, except shallowly furrowed on large trunks. (On some older trees, the bark can be more similar to that of White Oak, *Quercus alba*, or White Ash, *Fraxinus americana*, than to Mockernut Hickory, *C. tomentosa*, or Red Hickory, *C. ovalis*. When there is a zigzag pattern, it is sparse and not intricately entwined, as in Pignut Hickory, *C. glabra*. The zigzag pattern in older *C. cordiformis* is reminiscent of the "Travelling Rib" pattern in Aran Islands knitting. The bark on

younger trees often resembles that of mature Redbuds, *Cercis canadensis* (in some places in my Study Area, they are growing side by side).

Bloom is in April in North Carolina, and fruit ripens in October.

Seed production begins at about 25 to 30 years, with maximum crops at 50 to 100 years. Large crops are produced every three to five years, with less in between. Nuts remain viable in the ground for at least a year.

The life span of *Carya cordiformis*, about 200 years, is not as long as other Hickories, and it grows to a lesser size--24" to 36" DBH and 100' tall.

Carya cordiformis readily sprouts from both stump and roots after injury and from the crown after removal by the Twig Girdler (*Oneideres cingulara*).

Carya cordiformis has the largest geographic range of any Hickory, being less susceptible to frost damage and occurring further north than other North American Hickories. It is found from Quebec to Florida in the East, and from Minnesota to Eastern Texas in the West. It is most abundant and reaches largest size in the Mississippi Valley.

It is the common Hickory of Iowa, Nebraska, and Kansas.

Carya cordiformis typically grows in rich or low, wet woods, and occurs throughout North Carolina. While it is known for being a "water loving" Hickory, it can be found on high ground away from water, but will ultimately reach a smaller size in such locations. (The ones I have found have been for the most part growing on slightly elevated areas within a floodplain of a small creek or on the north side of a hill.)

Carya cordiformis is a pioneer species, fast growing and shade intolerant. Unlike most Hickories, it can be transplanted, and has been used as a rootstock for other Hickories, and in fuel-wood plantations. It is considered the best Hickory for smoking meat.

The wood of *C. cordiformis* has been used for hoops, ox-yokes, tool handles, furniture, interior paneling, sporting goods, as well as fuel.

The fruit of *C. cordiformis*, although bitter tasting and inedible for humans, was (is?) ground for oil by Native Americans. The sap was (is?) collected in early spring to make a syrup.

Leaves of *Carya cordiformis* are high in calcium and are considered to be soil-improving.

Carya cordiformis readily hybridizes with the other "water-loving" Hickories (*Apocarya*), including *C. illinoinensis*; hybrids with *C. ovata*, *C. laciniosa*, and the tetraploids *C. glabra* and *C. ovalis* are known. (In my area, I think there has been some hybridization between *C. cordiformis* and the tetraploid *C. tomentosa*.)

Becoming Familiar with Bitternut--Nuts

I wanted to see how bitter *Carya cordiformis* nuts are so I tasted one. It was extremely bitter and astringent, like an unripe Persimmon, or the reddish, furry integument covering the edible part of a Pecan (in the same family). Why does a tree that may use animals to disperse and plant its fruit produce such astringent nuts?

I wanted to germinate some seeds; 2007 was a good year for Hickory nuts, even though we were in the middle of a drought. On January 15, 2008, I gathered some *C. glabra*, *C. carolinae-septrionalis*, and *C. cordiformis* nuts and put them in pond water. (There was no creek water at that time.) Half of the *C. glabra* and *C. carolinae-septrionalis* floated and the other half sank. All of the *C. cordiformis* fruits floated. Do all Bitternuts float or were these just duds?

I put them all, still in water, in the refrigerator for two weeks, and then planted them out on February 2, 2008.

I planted ten *C. cordiformis*, six *C. glabra*, and six *C. carolinae-septrionalis* in three three-litre olive oil cans with drainage holes and filled with a mixture of equal parts woods dirt, sand, and compost. (I had no way of knowing if any of these nuts were viable. They had already been picked over by squirrels. I discarded any that had weevil holes in them.)

I pushed the nuts down in the moist mixture, covered them with a layer of leaves, and left the cans out in the fenced garden where the deer could not get them. I did not water them again. (I also planted a "Mystery Nut," one that looked different, like an almond, separately in the ground nearby.) I ran out of time before covering the cans with hardware cloth.

Two days later I covered the cans with hardware cloth. A squirrel had already dug up the "Mystery Nut." Who would have thought that, with all the nuts lying around on the ground, a squirrel would bother to dig up one that I had planted?

By July 10, 2008, a few of the *Carya carolinae-septrionalis* and one *C. glabra* were coming up, none of *C. cordiformis*.

By October, there were no surviving seedlings from the nuts I planted. And there were no signs of any nuts remaining in the planting mixture.

In the meantime, some rodent had chewed a clean, chisel-cut hole into a cardboard box, in a plastic bag, on the back porch, and eaten most of the *C. cordiformis* nuts I had stored there, leaving the empty shells.

The germination experiment was too small a sample to show anything except that a squirrel had taken one of the nuts shortly after I planted it. It might be that they had also stolen ones from the cans in the two days between planting and covering with hardware cloth.

When I stored *C. cordiformis* nuts inside my house, they were all stolen by mice, presumably White-Footed or Golden (both of which have been observed in the house) until I learned to keep the nuts in a glass or metal container.

In any case, I have concluded that the smell of *C. cordiformis* nuts is extremely attractive to rodents and that the bitterness does not deter predation by squirrels or mice.

Becoming Familiar with Bitternut--Inner Bark

On March 8, 2008, after about four inches of rain in two days, a beaver appeared at our pond and began "sharpening" the trees. Beavers eat inner bark; beavers like wet areas; Bitternut grows in wet areas. Perhaps *Carya cordiformis* has bitter inner bark to protect itself from beavers.

Is the inner bark bitter? I cut some inner bark from a young *C. cordiformis* and hesitantly tasted it. I was pleasantly surprised that it actually tasted rather good!

I read that Native Americans tapped the "Swamp Bitternut" in early spring and used the sap in much the same way as Birch (*Betula* spp.) sap--for beverages, vinegar, syrups, sugars, and flavorings.[5]

On March 5, 2009, a warm day after five days of cold, I drilled a half-inch hole in the south side of two of the largest *C. cordiformis* I had found and tapped them

[5] Kavasch, E. Barrie. Native Harvests, American Indian Wild Foods and Recipes. New York, Dover, 2005, p. 26..

with quickly improvised equipment made from split bamboo, plastic bags, and duct tape.

On March 16, March 23, and March 27, I collected a total of about four cups of sap (probably diluted with the three and three-quarter inches of rain water that ran down the tree trunks during the period), and boiled it down to about one-quarter cup of flavorful, but not particularly sweet, brown liquid, which I have kept refrigerated and used as a flavoring in cooking.

As a result, I have concluded from this experiment that the bitterness produced by the tree would not deter mice, beavers, deer, bear, or anything else who may eat its bark.

I have also read that *C. cordiformis* nuts, although bitter and inedible for humans, were ground for oil by Native Americans and early European settlers.[6] I have not attempted that, but high oil content could be a reason that the bitter nuts are sought out by animals.

About the Land

The area I studied (the Study Area) is about 80 acres of privately owned Piedmont forest, formerly farm land, parts of three farms, fields and wood lots, abandoned in the 1930s because of drought and an infestation of the cotton boll weevil (*Anthonomus grandis*). There are still original farmhouses (some inhabited) and outbuildings nearby.

Most of the land was subsequently leased to hunting clubs who planted the non-native and highly invasive *Eleagnus umbellata* (Silverberry) (locally known as "Hackberry") to attract wildlife. Both have flourished.

Some areas were farmed on a small scale until the 1950s. Some portions were timbered in the 1950s and again in 2000, others in the 1960s.

There are now mixed Oak-Hickory-Eastern Red Cedar, or mixed Pine forests in the areas timbered in the 1960s, and mature Loblolly Pine (*Pinus taeda*) with early successional hardwoods in the abandoned fields.

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[6] Smith, H. Clay. "Bitternut Hickory," in Silvics of North America. Vol. 2, Hardwoods. U.S. Department of Agriculture, Forest Service, Agriculture Handbook 654. 1990, p. 36.

The land is rocky, hilly, and mostly north-facing. There are three creeks that flow northward between forested hills, through relatively flat floodplains. The total drop in the Study Area in elevation of the creeks is about 20 feet in approximately 1200 feet of run (1.6%).

In the floodplains of the creeks there is a dense shrub understory of *Aesculus sylvatica* (Painted Buckeye), *Asimina triloba* (Pawpaw), *Eleagnus umbellata* (Silverberry), and others.

I have lived in this vicinity since 1972 and walked the area for miles around, observing the native plants, animals, and geology. I have also talked to residents of an earlier generation, born in the area, and members of the Hunt Club, about events that occurred in the past that may be relevant to this study.

I participated in a water-table study for the Pittsboro Soil Series designation from 1997 to 2000 and also participated in several bird studies administered by the Cornell Laboratory of Ornithology, including Birds in Forested Landscapes and the long-running Project Feeder Watch.

I experienced the tornado of March 29, 1991, the ice storm of January 1996, Hurricane Fran (September 6, 1996), the "Carolina Crusher"[7] ice storm of January 2000, as well as ice storms of December 2002 and 2005, events that greatly impacted the trees in this area.

When I began this study, in the Fall of 2007, this area was in the midst of a more-than-decade-long drought, which began in the late 1990s and continued at least until 2013 and (I hope) has now ended. I have been collecting rainfall data for my garden since 2006. This would be the weather station nearest to the areas where I found the Bitternut Hickory (*Carya cordiformas*), a "water-loving Hickory."

Questions

I have many questions, things to find out about the Bitternut Hickory (*Carya cordiformas*). The ones I will attempt to answer, through field observation and library or internet research in this study are:

--Where do they occur in my area?

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[7] Fuhrmann, Christopher, Ross R. Connolly, and Charles Konrad II, "Winter Storm: An Overlooked Source of Death, Destruction and Inconvenience in the Carolina Piedmont Region." 60th Eastern Snow Conference, Niagara-on-the-Lake, ON, Canada, 2009, p. 1.

--What soils are they growing in?

--What plant communities do they share?

--Why do they grow where they are?

--How are the nuts dispersed?

--How old are these trees?

--Why would a tree make bitter fruit?

--Is there a connection between the bitterness of the nuts and the wetness of the habitats where the trees occur?

--What could be the evolutionary advantage, if any, for a tree which produces bitter fruit?

I have made maps of the size distribution of *Carya cordiformis* in the Study Area with respect to soil, topography, and plant communities. I will attempt to relate the current presence of *C. cordiformis* in the Study Area with previous land use as well as weather and predation-caused events that may have been factors in its spread.

Method

The Study Area

I chose an approximately 80-acre site of privately owned land in north-central Chatham County, North Carolina, as a Study Area, which includes the place where I first saw *Carya cordiformis*, as well as areas where I had never noticed any of these trees.

I wanted to determine the distribution and abundance of *C. cordiformis* within this Area and analyze their location with respect to soil, availability of water, plant communities, and anything else that might influence where they do and do not occur.

Marking the Trees

In November 2007 I began locating *Carya cordiformis* in my Study Area and marking them with orange flagging tape for relocating them the next year. (I could do this in winter only, after leaf fall, because of the dense shrub understory.)

I identified *C. cordiformis*, large and small, in winter, by buds only, because of the great variation in other physical characteristics in *Carya* spp. The distinctive scurfy, sulfur-yellow buds, often at eye level, are easy to see on the young trees.

I used 8 x 20 binoculars to see the buds of the large older trees where there were no low-level buds. The low morning sun in January illuminates the yellow buds on the tall trees. Sometimes I was lucky to find a small eye-level shoot.

I located *C. cordiformis* November 2007 through March 2008, October 2008 through March 2009, November 2009, October 2010 through February 2011, January 2012 through March 2012, November 2012 through February 2013, and November 2013.

In February 2012 I began marking the trees as "waypoints" with a Garmin 72H GPS Device which recorded the date, latitude and longitude of the trees, and gave each a number. I measured the circumference of the trees in inches, wrote it on green flagging tape tied around the trees, and recorded it in my field notebook. Back home, I converted circumference to DBH in inches, and recorded that in my field notebook.

I used the English system of measurement because both the USGS Bynum Quadrangle 7.5 minute series Topographic Map (1968),[8] and the Chatham County Soil Map Field Sheet (1993),[9] which I would use as base maps, are at the scale of 1" = 2000'.

Sometimes the Device misbehaved, skipping numbers, resulting in some gaps in the sequence. I came back later, and re-marked some trees where there had been a malfunction, making some numbers out of order. But, for the most part, it worked very well. (One malfunction happened when, all of a sudden, clouds parted, the winter sun lit up my blaze-orange hat, and honey bees came flying toward me out of a tree adjacent to the one I was working on--Tree #337.)

The Device also recorded elevation, but not at all accurately because of the heavy tree cover (many Red Cedars, *Juniperus virginiana*) and the hilly terrain. At best, the margin of error of the Device could be ±3-30 feet, depending on how many satellites were visible, cloud and tree cover, and experience (or lack of) of the operator. I am using the 1968 Bynum Quadrangle Topographic Map, and the 1993 Chatham County Soil Map Field Sheet, to estimate elevation and slope of the land.

After all the data were recorded, I removed the flagging tape from the trees. I also marked the corners of the Study Area as waypoints to be able to locate the Area as well as the *Carya cordiformis* on the various maps.

In order to calculate the growth rate of *C. cordiformis*, I measured the circumference/DBH of 22 selected trees again in December 2016, refiguring DBH to four decimal places by referring to the original circumferences.

Size Classes

I divided the *Carya cordiformis* into four populations based on their DBH:

Population I: 1/2" – 3 3/4" DBH (two fingers or one hand around)

Population II: 4" – 7 1/2" DBH (two to three hands around)

Population III: 8" – 13 1/2" DBH (three to four hands around

[8] United States Geological Survey. Bynum Quadrangle. 7.5 Minute Series (Topographic). 1968.
Chatham County, North Carolina. Soil Survey Field Sheet. U.S. Department of Agriculture. Natural Resources Conservation Service. 1993.

[9] Chatham County, North Carolina. Soil Survey Field Sheet. U.S. Department of Agriculture. Natural Resources Conservation Service. 1993.

Population IV: >16" DBH (six hands around).

Several trees are double. I have counted the total DBH of the two to determine to which population group they belong.

On the maps, I have given each population a different color: Population I--Blue; Population II--Pink; Population III--Orange; Population IV—Yellow/Green.

Dividing the Land into Areas

I divided the land where I found *Carya cordiformis* into six distinct Areas with regard to proximity to water, soil type, slope, aspect, plant community, and previous canopy-opening events. I used the plant community categories listed in The Classification of the Natural Communities of North Carolina, 3rd approximation. 1990.[10]

Area 1--Piedmont Alluvial Forest

Area 2--Piedmont Mafic Cliff

Area 3--Piedmont Bottomland Forest

Area 4--Basic Mesic Forest

Area 5--Basic Mesic Forest

Area 6--Basic Oak-Hickory Forest

I used the 1990 3rd approximation instead of the later (2012) 4th approximation[11] because its descriptions better fit the landscape and the winter season I was working in.

Naming the Creeks

There are three un-named creeks in my Study Area. To make the descriptions of the Areas clearer, I have named them:

1) "Bitternut Creek"--a northward-flowing, mostly perennial stream in the northern part of the Study area.

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[10] Schafale, Michael P., and Alan S. Weakley. Classification of the Natural Communities of North Carolina, 3rd approsimation. 1990. North Carolina Natural Heritage Program. Department of Environment and Natural Resources. Raleigh, NC.

[11] Schafale, Michael P. Guide to the Natural Communities of North Carolina. 4th approximation. North Carolina Natural Heritage Program. Department of Environment and Natural Resources. 2012.

2) "Little Bitternut Creek"--an intermittent tributary stream that carries a lot of water, and flows into "Bitternut Creek."

3) "Spring Creek"--the headwater of a perennial stream, in a different drainage, that flows outside of the Study Area.

Making the Maps

I transferred the "waypoints" from the GPS Device to the Garmin Base Camp computer program, taking "screen shots" of the four different populations of *Carya cordiformis* at scales of 1" = 500', 300', 200', 120', and 80', transferring them to a USB Flash Drive to be printed. I chose 1" = 500', 1" = 200', and 1" = 80' as the appropriate scales for this project: 1" = 500' and 1" = 200' (points only) for the USGS Topo Map[12] and Chatham County Soil Map[13] (both 1" = 2000'), and 1" = 80' to show all the points with their respective tree numbers.

Some *C. cordiformis* were only 6" apart; many were less than 3' apart. The Base Camp program was not designed for such close waypoints, often putting the number label for one tree on top of the points for neighboring trees, even at 1" = 80'. This, combined with the ±30' margin of error of the Device, may cause some trees and their labels to be shown on my final map, at 1" = 80', in a slightly different configuration than they actually are on the land.

I determined the soils where *C. cordiformis* occurs using the Chatham County Soil Survey Field Sheet (1993), combined with the "Soil Web" Smartphone App.,[14] and my observations of the soils visible in the bed and banks of "Bitternut Creek."

I used the USGS 7.5 minute Bynum Quadrangle Topographic Map, scale 1" = 2000' expanded to 1" = 500' and 1" = 200' as the base map for my soil and topo maps. I made tracings of the waypoints from Garmin Base Camp, and of portions of the expanded Topo and Soil maps, to assemble maps showing the location of *C. cordiformis* on the land.

I made rough estimates of the acreages of the different sections of the Study Area, and the watersheds of the creeks, by measuring on the 1" = 2000' USGS Topo

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[12] United States Geological Survey. Bynum Quadrangle. 7.5 Minute Series (Topographic). 1968.
[13] Chatham County, North Carolina. Soil Survey Field Sheet. U.S. Department of Agriculture. Natural Resources Conservation Service, 1993.
[14] California Soil Resource Lab. Soil Web. University of California Davis in collaboration with the USDA-NCRS.

Map and my 1" = 80' map of *Carya cordiformis*, and by using the "Measure Your Land" Smartphone App.[15]

There is a discrepancy in the position of "Bitternut Creek" between the USGS Topo Map and the Chatham County Soil Map Field Sheet, which I think arises from a confusion between the current channel of "Bitternut Creek," and the old, alternate, or overflow channel, still very visible, but carrying water only during floods. As a result, on my map I have moved the northern portion of the Soil Map southward so that the creek matches that on the Topo Map, and the soils better match those I observed in the creek bed and indicated by Soil Web.

I was hoping to count the number and DBH of *C. cordiformis* for each soil type, but the method I have used is not accurate enough for that. These maps I have made are the best estimation I can make of the occurrence of *C. cordiformis* on the land, given the discrepancy of the two maps and the ±30' margin of error of the GPS readings.

Observations and Other

Before beginning the main part of this study, in order to become familiar with *Carya cordiformis,* I tasted nuts and bark, and tapped two mature trees for sap, by drilling holes with a ½" drill, and using homemade split bamboo taps, plastic bags, and duct tape to collect the sap, which I boiled down to syrup. (See Introduction.)

Other than marking the trees and making the maps, my main method of study was field observation with naked eye, ears, nose, and with Nikon 8 x 20 binoculars, writing down what I noticed in my field notebooks.

I collected specimens of *C. cordiformis* leaves, bark, nuts, and the trunks of small trees that had died of drought during the study, and prepared cut sections to count their growth rings. To accurately count the rings on the cut sections, I photographed them with an iPhone5s camera, and then expanded the photographs to better show the rings on the small sections.

I looked for and found cached nuts under piles of leaves and bark on the ground in the vicinity of *C. cordiformis*. I found nuts on the ground partially eaten by flying squirrels, and in the dry creek beds.

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[15] Rublev, Ivan. Measure Your Land. Rostov-on-Don, Russia, 2013.

I observed and noted other woody vegetation growing with *Carya cordiformis* and photographed them, first with a Pentax PC 35 AF film camera (2007 - 2012), and then with an iPhone 5s camera (2013 - 2016). My husband also took photographs with a Canon S-100.

I scanned items to make digital photographs.

I researched weather and insect predation events that may have influenced the occurrence of *C. cordiformis* and collected rainfall data (within the Study Area) for the period 2006 - 2016 with a Davis Instruments Vantage Pro 2 Wireless Weather Station.

Results

Number of Trees

I found 344 *Carya cordiformis* of different ages, growing in an irregularly shaped but contiguous area of about 16 acres that includes a small, mostly perennial stream ("Bitternut Creek") and a smaller, intermittent tributary ("Little Bitternut Creek") . *See Figure 1.* These streamside habitats, as well as places cleared by blowdowns, are where I found *C. cordiformis*. My 80-acre Study Area also includes the headwater of another intermittent creek ("Spring Creek"), in a different drainage, with similar soil, where I found no *C. cordiformis*. *See Figures 2-3.*

While locating and marking *C. cordiformis* it became obvious that they occur as four distinct populations based on their DBH, with none in between, as if there were specific events that led to the dispersal and germination of these trees.

Table 1
Populations of *Carya cordeformis*

Population	**DBH**	**Number of Trees**
I	1/2″ – 3 3/4″	263
II	4″ -7 1/2″	60
III	8″ -13 1/2″	20
IV	>16″	1

The largest *C. cordiformis*, Populations II, III, and IV, are concentrated in or near the floodplains of "Bitternut Creek" and "Little Bitternut Creek." Smaller ones, Populations I and II, seem to be spreading gradually from north to south along "Little Bitternut Creek," with a Population II tree surrounded by several Population I trees.

There is a small concentration of some of the large (Population III) trees on the west side of the north-facing hill (slope 8% - 15%) south of "Bitternut Creek," along an old farm road next to a formerly open field (now forested) shown in a 1956 aerial

Figure 1. Distribution of Bitternut Hickory by Number and Population

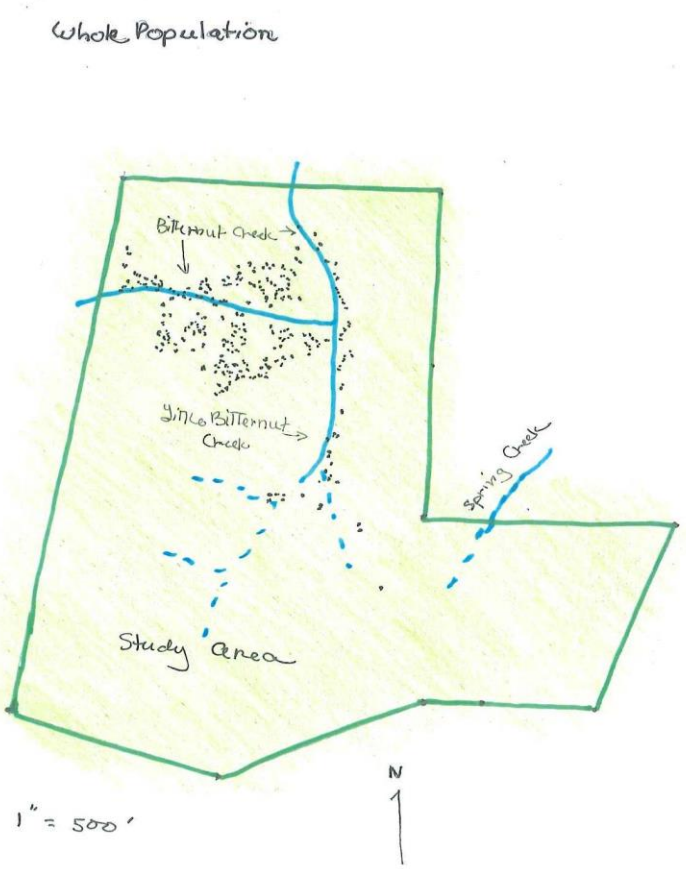

Figure 2. Whole Population in Study Area.

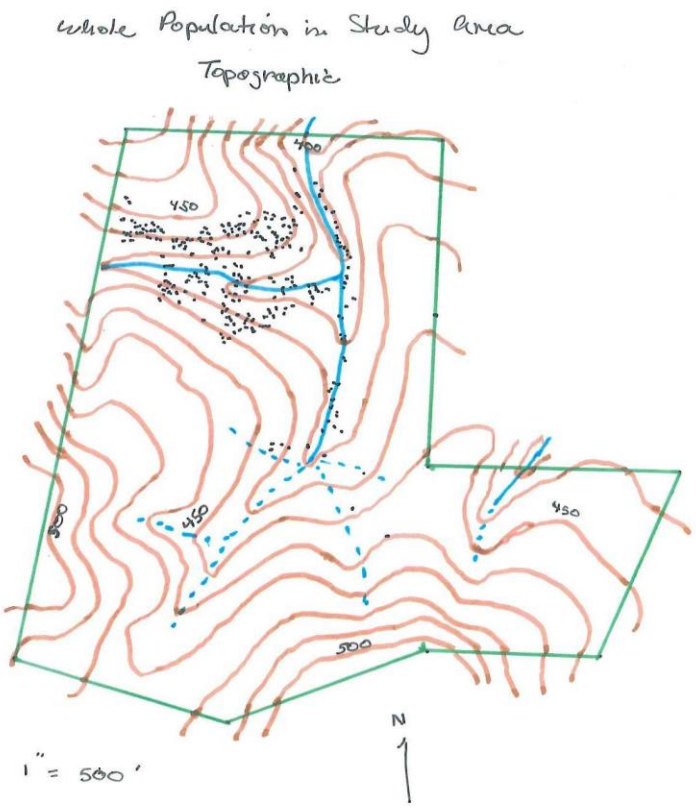

Figure 3. Whole Population in Study Area (Topographic).

photograph.[16] There is also a concentration of the smaller (Population I) trees on the east side of the same hill (slope 5%-8%), in an area formerly dominated by Shortleaf Pine(*Pinus echinata*) that suffered an attack of the Southern Pine Beetle (*Dendroctonus fontalis*) in the early 1990s, where many *P. echinata* died, leaving openings in the canopy.

Soils

There are four soil types in my Study Area: Cid, Georgeville, Nanford-Badin, and Pittsboro-Iredell.[17] These soils are weathered from Late Proterozoic (900-270 mya) fine-grained metavolcanic rocks, argillite, or metabasalt.[18],[19] *See Figures 4-5.*

Cid silt-loam formed in residuum weathered from argillite and other fine-grained metavolcanic rocks, is classed as strongly acidic (PH 3.5-5.5), forms a heavy, tight clay, and has a high (perched) water table in winter. This soil is considered one of the worst in our state for agriculture as well as septic tank absorption fields. Cid soil forms the floodplains on both both sides of "Bitternut Creek" in the west end of my Study Area.

Georgeville silt-loam formed in residuum weathered from fine-grained metavolcanics, is generally considered acidic (PH 4.5-7.3), and is a good well-drained (but eroded) agricultural soil. Georgeville soil occurs primarily on south-facing hills (slope 2%-10%) in my Study Area.

Nanford-Badin soils formed in residuum weathered from phyllites, slates, argillite, and other metasedimentary or metavolcanic rocks, is generally acidic (PH 5.5-6.5) and well drained. This soils borders "Little Bitternut Creek," "Bitternut Creek," and also occurs on the south-facing hill (slope 2%-15%) north of "Bitternut Creek."

Pittsboro-Iredell Complex soils formed in residuum weathered from basalt, greenstone, diabase, diorite, gabbro, and other dark colored mafic rocks, and tends

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[16] Chatham County, North Carolina. Soil Conservation Service. 1956. Personal possession.
[17] Chatham County, North Carolina. Soil Survey Field Sheet. 1993. Op. cit.
[18] U.S. Department of Agriculture. Natural Resources Conservation Service. Map Unit Descriptions. Chatham County, North Carolina. Tabular Data Version: 13. 07/02/2012.
[19] Bradley, Philip, Heather D. Hanna, Edward F. Stoddard, and Randy Bechtel. Geologic Map of the Bynum 7.5 Minute Quadrangle, Orange, Chatham and Alamance Counties, North Carolina. Department of Environment and Natural Resources, Division of Mineral and Land Resources, North Carolina Geological Survey 2013.

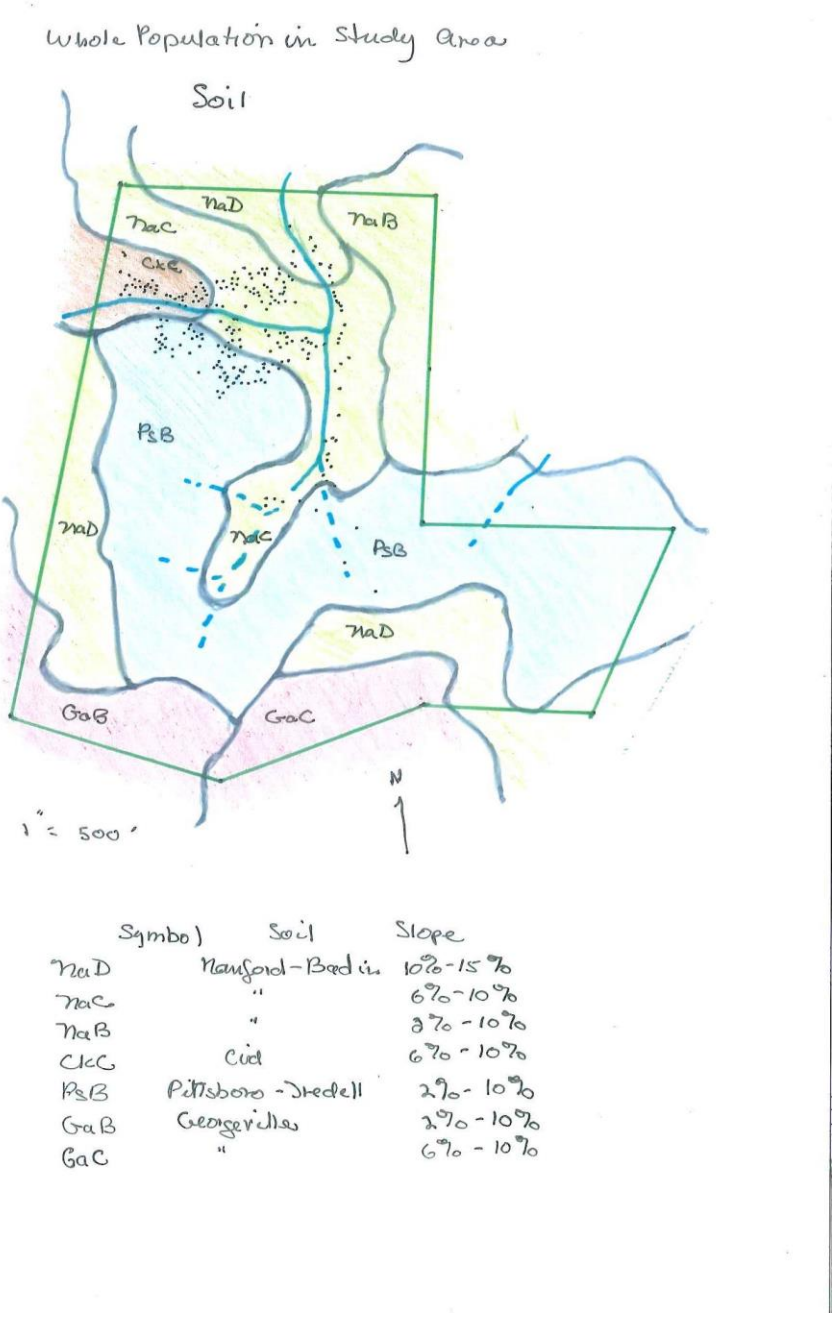

Figure 4. Whole Population in Study Area (Soils).

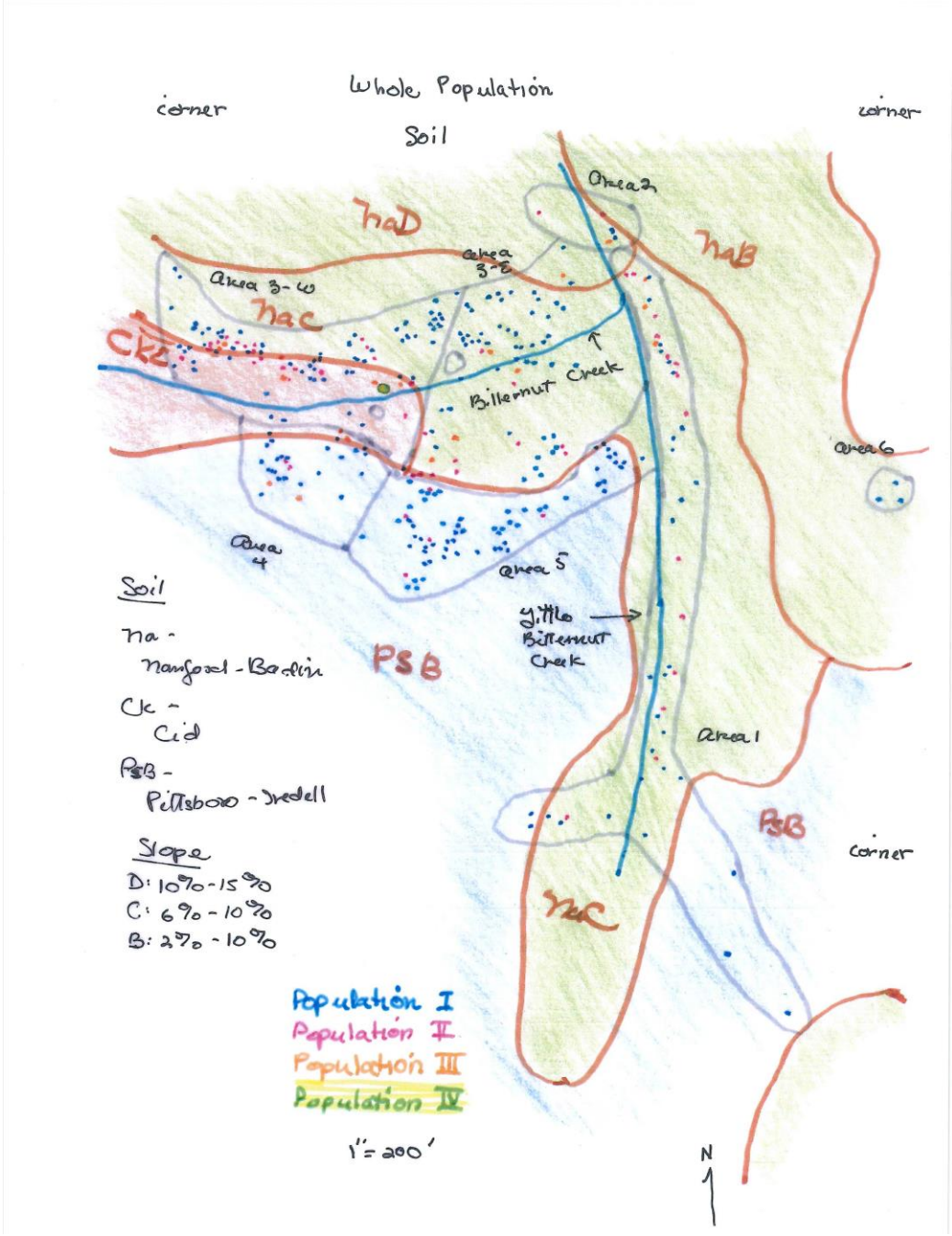

Figure 5. Detail of Whole Population (Soils).

to be circumneutral (PH 5.6-7.8). It is a fertile soil, but forms a heavy, tight clay, and has a high (perched) water table in winter. It is the stony soil of the north-facing hill (slope 2%-15%) south of "Bitternut Creek," and other north-facing hills in my Study Area.

Both Cid and Pittsboro-Iredell soils are heavy, tight clay soils that have a high (perched) water table in winter, and when dry become hard and will not accept water. Even though trees growing in these soils have to tolerate both wet and dry conditions, many species of trees in my Study Area have grown to a large size in these soils.

I found *Carya cordiformis* on the Cid, Nanford-Badin, and Pittsboro-Iredell soils, but none on the Georgeville. Many of the larger (Population III) trees occur in Nanford-Badin and Pittsboro-Iredell soils, but there is also a concentration of larger (Population III and IV) trees in the Cid soil.

Table 2

Soils in the Study Area

Soil Type	**PH**	**Parent Rock**	**Slope**	**Drainage**	***Carya cordiformis***
Cid	3.5-5.5	Argillite, other fine-grained metavolcanic rock	2%-10%	Poor	Present
Georgeville	4.5-7.3	Fine-grained metavolcanic rock	2%-10%	Well drained	Absent
Nanford-Badin	5.5-6.5	Phyllites, slates, argillite, metasedimentary or metavolcanic rocks	2%-15%	Well drained	Present
Pittsboro-Iredell	5.6-7.8	Basalt, greenstone, diabase, diorite, gabbro, other dark-colored mafic rocks	2%-15%	Poor	Present

A large part of the Georgeville soil area was timbered in 2000 and is on a south-facing slope (2%-6%), where *Carya cordiformis* may have been out-competed by other pioneer species, or where its seeds have not yet arrived. The remainder of the Georgeville areas are heavily forested (2%-10% slopes).

The Nanford-Badin and Cid soils where I found *C. cordiformis* are low lying lands bordering creeks. The Pittsboro soil area is higher, sloping (2%-8%), and north-facing. It retains water in winter, becomes impervious to water in summer, but benefits from the north-facing aspect and the moisture rising from "Bitternut Creek."

The better drained Nanford-Badin soils were used for agriculture and are criss-crossed with remnants of old farm roads which become conduits for water after rains. The old roads in the low lying creek floodplains also hold water during the wet season, creating essentially two creeks, with higher land in between. Most of the *C. cordiformis* I found in these floodplains were in raised areas, or on stream-side levees or terraces.

The Pittsboro soil area where I found some of the larger (Population III) *C. cordiformis* is higher, more steeply sloping (8%) and north facing. This area is also crossed with remnants of old farm roads, some used to carry rocks from adjacent fields or to dump trash (still visible). Most of the Population III *C. cordiformis* in this area are growing up through the middle of rock piles.

I have not been able to map the occurrence of *C. cordiformis* on the soils accurately enough to count their numbers on each type of soil. As it is, I can say that there are a number of trees in each Population growing in each of the soils that I found them in, with the exception of Population IV, of which I found only one individual.

My observations are consistent with those in the literature, which say that *C. cordiformis* is not particular to soil type.

Areas

I divided the land where *Carya cordiformis* occurs in my Study Area into six distinct Areas based on proximity to water, soil, slope, aspect, plant community, and

canopy-opening events. I named these areas using the The Classification of the Natural Communities of North Carolina, 3rd approximation.[20]

Area 1--Piedmont Alluvial Forest

Area 2--Piedmont Mafic Cliff

Area 3--Piedmont Bottomland Forest

Area 4--Basic Mesic Forest

Area 5--Basic Mesic Forest

Area 6--Basic Oak-Hickory Forest

Area 1 -- Piedmont Alluvial Forest

This Area of about three acres follows the northward drainage of "Little Bitternut Creek" (roughly 65 acres of watershed), about 1000 feet to its confluence with "Bitternut Creek." Trees #1-52. *See Figure 6.*

Trees #1-10 are located in the southernmost section of Area 1. Several drainages (slope 2% - 8%) and an old farm boundary ditch, combine from the southeast, south, and southwest to form north flowing "Little Bitternut Creek." The soil is Pittsboro 55%. Iredell 25%.

Population I trees #1-5 are relatively isolated from each other. Population I trees #7-10 are grouped around Population II tree #6—5 1/4" DBH, along with

Acer floridanum - Southern Sugar Maple

Carya carolinae septrionalis - Southern Shagbark Hickory

C. glabra _ Pignut Hickory

Eleagnus umbellata - Silverberry

Fraxinus americana - White Ash

F. pennsylvanica - Green Ash

Ilex opaca - American Holly

Juniperus virginiana - Eastern Red Cedar

Liquidambar styraciflua - Sweetgum

Quercus alba - White Oak

Q. nigra - Water Oak

and scattered others of varying sizes.

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[20] Schafely, op. cit.

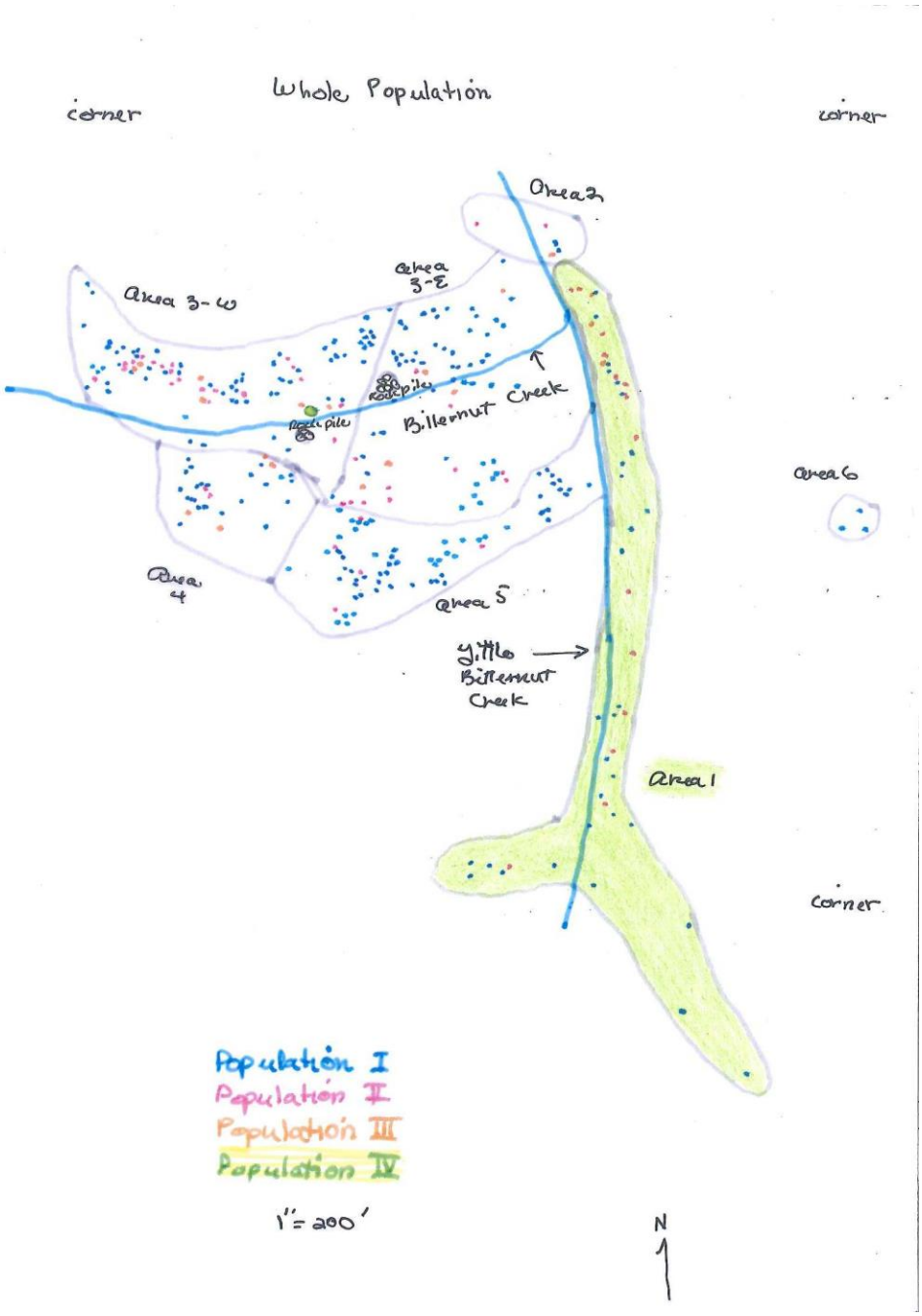


Figure 6. Area 1--Piedmont Alluvial Forest

Where all the different drainages come together the soil becomes Nanford (50%)-Badin (30%), and there is a proper floodplain on each side of "Little Bitternut Creek." On the west the floodplain is narrow (4'-10'); on the east it extends 50'-60'. Loblolly Pine (*Pinus taeda*), mixed with Shortleaf and Virginia Pine (*P. echinata* and *P. virginina*)-forested hills on east and west, extend to the edge of the floodplain on both sides of the creek.

On the east side of the creek the floodplain forms an approximately 1000' x 60' long stream-side corridor of deciduous trees, Eastern Red Cedar (*Juniperus virginiana*), Redbud (*Cercis canadensis*), Pawpaw (*Asimina triloba*), Silverberry (*Eleagnus umbellata*), and others.

Remnants of old farm roads run parallel to the creek in the eastern floodplain. They become multiple channels for water after rains. I found *Carya cordiformis* growing in slightly raised places within the floodplain--streamside levee or terraces--not in areas of flowing or standing water.

I often found a Population II *C. cordiformis* surrounded by several Population I trees, as if the older tree were the source of seed for the younger ones. They seem to be spreading slowly southward along “Little Bitternut Creek.” Some of the Population I trees are growing at the edge of the Pines.

About one-third of the way along this stream-side corridor, there was a large Black Walnut (*Juglans nigra*) that was uprooted in Hurricane Fran (September 6, 1996), but remained alive for ten years or so before succumbing to drought. The log is still visible and the surrounding area is still relatively open, showing the influence of juglone remaining in the soil.

The Hurricane (category 3) opened the canopy in several places, perhaps contributing to the growth of the young *C. cordiformis*.

Approximately one-half way down "Little Bitternut Creek" the remnants of old farm roads in the floodplain converge with the remnants of an old east-west farm road that forded the creek. North of this ford, and further downstream, trees of all kinds are larger and older, and were not so affected by the Hurricane. Fan Moss (*Forsstroemia trichomitria* [Hedw.] Lindb.) is growing on almost all the smooth-barked trees, including *C. cordiformis*, north of the ford in Area 1. *C. cordiformis* in this area (Trees #36-52), are larger, with many Population II and III trees.

Carya cordiformis along "Little Bitternut Creek" (Area 1):

Population I - 34

Population II - 15

Population III - 3

Table 3

Carya cordiformis in Area 1, Piedmont Alluvial Forest (Three Acres)

Popula-Tion	Tree #	DBH	Soil	Notes
I	1-5	1 1/2″-2 3/4″	Pittsboro 55% Iredell 35%	Relatively isolated from each other
II	6	5 1/4″	″	
I	7-10	2″-3″	″	Grouped around Tree #6
I	11-13	1 3/4″-2 1/4″	Nanford 50% Badin 30%	Southern part of "Little Bitternut Creek" flood-plain, where different drainages come to-gether.
II	14	6 3/8″	″	″
I	15-17	1 1/2″-3 1/2″	″	″
II	18	6 1/2"	“	Growing in a thicket of Paw Paws (*Asimina triloba*)
I	19-22	1 7/8”-2 3/8”	“	in Paw Paws
II	23	7 1/2”	“	paired with Sweet Gum (*Liquidambar styraciflua*)
I	24-25	1 1/4”-3 1/4”	“	Often the Population II
II	26	6 3/8”	“	trees are surrounded
II	27	4 1/2”	“	by several
I	28-33	1 1/2”-2 3/4”	“	Population I trees.
II	34	4 3/4”	“	“
II	35	6 3/4”	“	“
I	36	1”	“	North of ford, not affected by Hurricane Fran.
II	37	6 3/4”	“	“
I	38	2”	“	“
II	39	6 7/8”	“	“
I	40	1”	“	“

II	41	7”	“	“
I	42-43	1 1/2”-2 1/4”	Nanford 50% Badin 30%	“
III	44 (double)	8 3/4”	“	“
II	45	5 7/8”	“	“
II	46	4 1/8”	Nanford 40% Badin 35%	Area gets flooding from “Bitternut Creek” in heaviest rains.
III	47	8 7/8”	“	“
I	48	3 1/2”	“	“
III	49 (double)	8 3/4”	“	“
I	50	2 7/8”	“	“
II	51	6 1/4”	“	“
II	52	4 3/4”	“	“

Trees, Shrubs, and Vines Along "Little Bitternut Creek" (Area 1)

Trees

Acer floridanum - Southern Sugar Maple

A. rubrum - Red Maple

Betula nigra - River Birch

Carpinus carolininae - Ironwood

Carya cordiformis - Bitternut Hickory

C. ovalis - Red Hickory

C. ovata - Shagbark Hickory

C. tomentosa - Mockernut Hickory

Celtis laevigata - Hackberry

Cercis canadensis - Redbud

Cornus florida - Flowering Dogwood

Diospyros virginiana - American Persimmon

Fagus grandifolia - American Beech

Fraxinus americana - White Ash

F. pennsylvanica - Green Ash

Ilex opaca - American Holly

Juglans nigra - Black Walnut

Juniperus virginiana - Eastern Red Cedar

Liquidambar styraciflua - Sweetgum

Liriodendron tulipifera - Tulip Poplar

Morus rubra - Mulberry

Nyssa sylvatica - Black Gum

Platanus occidentalis - Sycamore

Pinus taeda - Loblolly Pine

Prunus umbellata - Hog Plum

Quercus alba - White Oak

Q. bicolor - Swamp White Oak

Q. falcata - Southern Red Oak

Q. michauxii - Swamp Chestnut Oak

Q. nigra - Water Oak

Q. pagoda - Cherrybark Oak

Q. phellos - Willow Oak

Q. rubra - Northern Red Oak

Q. shumardii - Shumard Oak

Ulmus alata - Winged Elm

U. americana - American Elm

U. rubra - Slippery Elm

Shrubs

Aesculus sylvatica - Painted Buckeye

Asimina triloba - Pawpaw

Eleagnus umbellata - Silverberry

Euonymus americana - Hearts-a-Bustin'

Ilex decidua - Deciduous Holly

Viburnum rafinesquinum - Downy Arrowwood

V. prunifolium - Black Haw

Vines

Bignonia capreolata - Cross Vine

Campsis radicans - Trumpet Creeper

Lonicera japonica - Japanese Honeysuckle

L. sempervirens - Trumpet Honeysuckle

Menispermum canadense - Canada Moonseed Vine

Parthenocissus quinquefolia - Virginia Creeper

Smilax spp. - Green Briar
Toxicodendrum radicans - Poison Ivy
Vitis labrusca - Fox Grape
V. rotundifolia - Muscadine Grape

Area 2 -- Piedmont Mafic Cliff

North of its confluence with "Little Bitternut Creek," "Bitternut Creek" cuts through a steep (15% slope), open, very rocky area of loose cobbles, boulders, and outcrops of weathered greenstone on east and west. There are a few *Carya cordiformis* growing up through the rocks. There are many Buckeyes (*Aesculus sylvatica*) in the narrow floodplains and at the base of the slopes. *See Figure 7.*

The two sides are very different. The west-facing east side is dry and rocky with very little, if any, soil showing between the rocks. There are few plants other than scattered trees growing there—a few Southern Shagbark Hickory (*C. carolinae-septrionalis*), Mockernut Hickory (*C. tomentosa*), Northern Red Oak (*Quercus rubra*), Post Oak (*Q. stellata*), Black Oak (*Q. velutina*), and others growing up through the rocks on this west-facing slope.

The east-facing west side is steeper, higher, more moist, has larger boulders, and slaty fragments, and a layer of soil that has been, in the past, covered with spring ephemerals. The large boulders in the outcrop at the base of the cliff near “Bitternut Creek” are covered with Christmas Fern (*Polystichum acrostichoides*), Resurrection Fern (*Pleopeltis polypodioides*), and various mosses.

Many of the trees that shaded the west side were blown down by Hurricane Fran and the area since has become drier. There are still a few large Red Oaks (*Quercus shumardii*) and Black Walnuts (*Juglans nigra*) shading the area, as well as large Redbuds (*Cercis canadensis*) and Spicebush (*Lindera benzoin*). Younger trees that have grown up are Ash (*Fraxinus* sp.), Red Maple (*Acer rubrum*), and Southern Sugar Maple (*A. floridanum*). The single *C. cordiformis* (Population II) is growing near the top of the cliff among the trunks and roots of trees downed by the Hurricane, along with White Oak (*Q. alba*), Mockernut Hickory (*C. tomentosa*), Sweet Gum (*Liquidambar styraciflua*), and Tulip Poplar (*Liriodendrum tulipifera*). A single Princess Tree (*Paulownia tomentosa*) has also grown up at the very top.

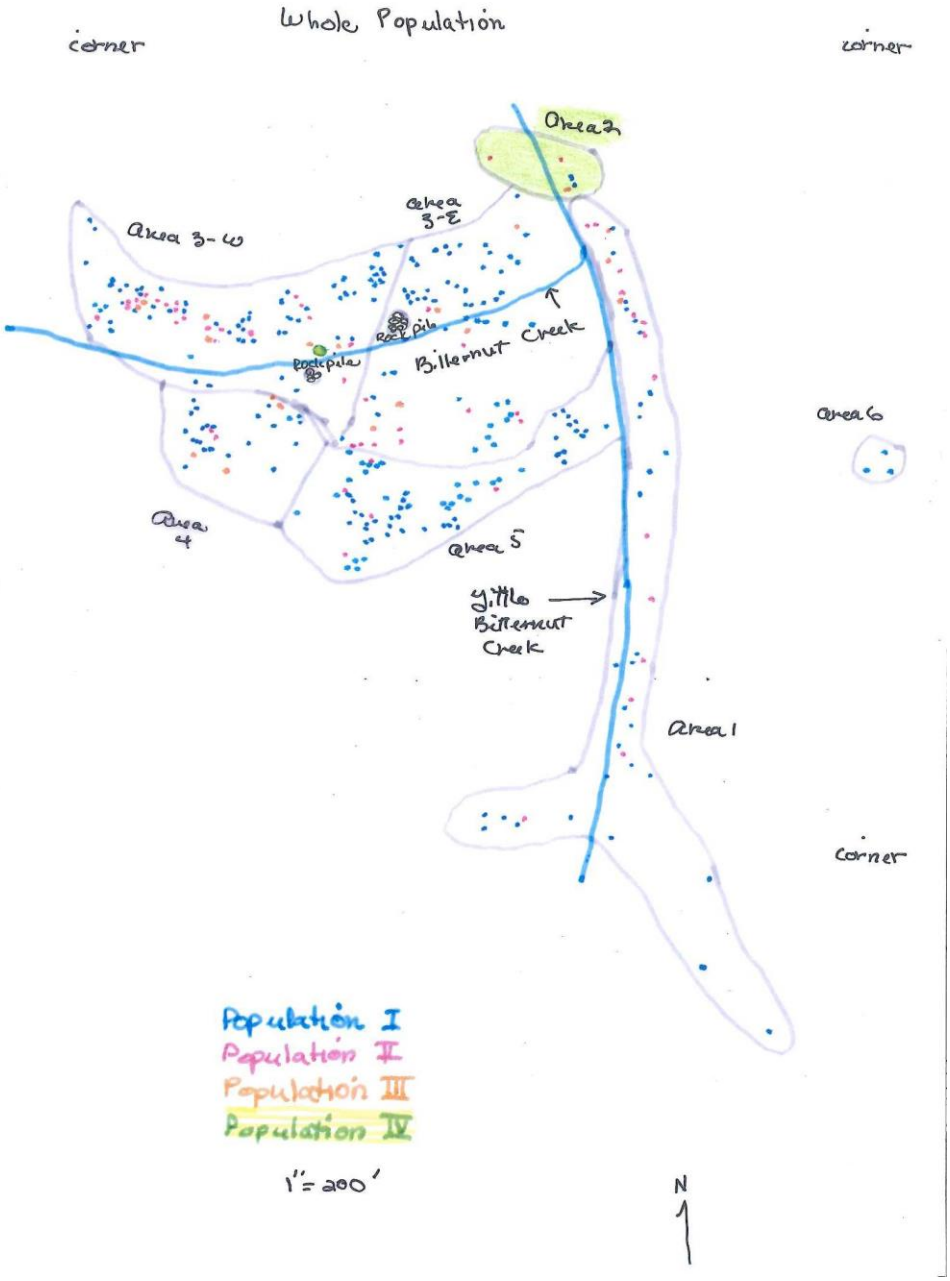


Figure 7. Area 2--Piedmont Mafic Cliff

There had been many large oaks (*Quercus* spp.) in this area on both sides of the creek that were downed by Hurricane Fran, opening up the canopy to the north and south.

Table 4

Carya cordiformis in Area 2, Piedmont Mafic Cliff (3/4 Acre)

Popula-tion	Tree #	DBH	Soil	Notes
III	53	8 1/2″	Nanford 40% Badin 35%	Growing in rocks in floodplain of “Bitternut Creek.”
I	54, 55	2″-2 3/4”	″	Growing in rocks, east side.
II	56	6 1/4″	″	“
II	361	7 3/8″	“	Growing in rocks, top of hill, west side.

Area 3 -- Floodplain of "Bitternut Creek"--
Piedmont Bottomland Forest

"Bitternut Creek" flows eastward about 870' through a wide (150'-300'), approximately six-acre floodplain (about 110 acres watershed), before turning northward near its confluence with "Little Bitternut Creek." This floodplain has some interesting features, as well as the largest concentration of Population III *Carya cordiformis* (12 trees) in my study, the only Population IV tree, 122 Population I, and 27 Population II trees.

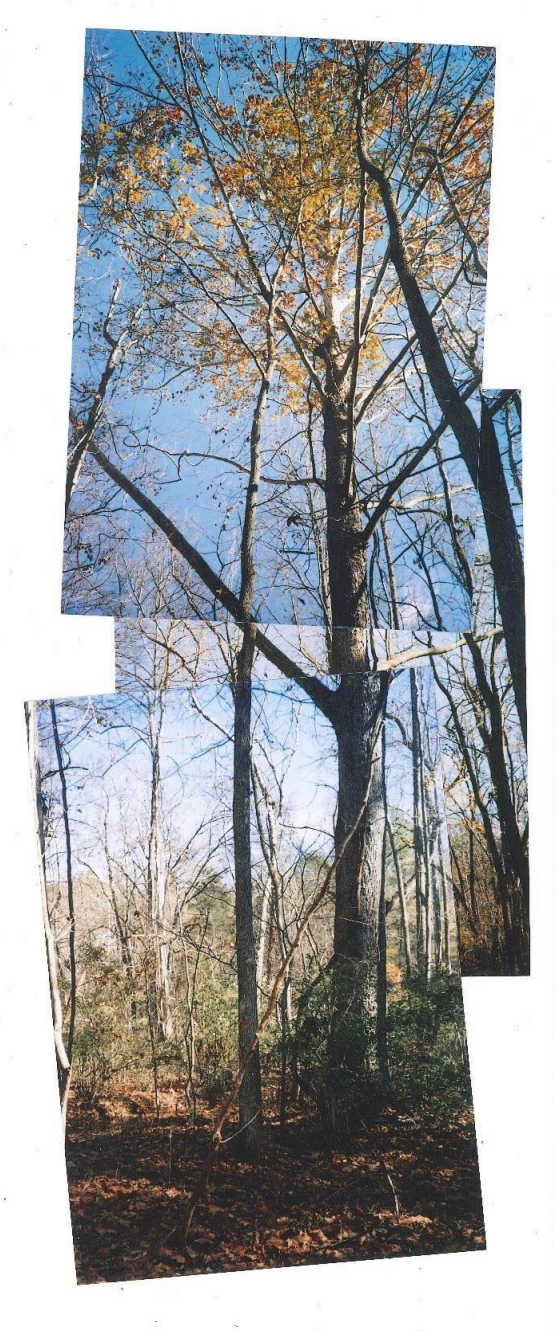
A downburst from Hurricane Fran (September 6, 1996) swept across the middle of this Area, downing large trees in its path, essentially dividing the floodplain into two parts, East and West, and opening up a large gap in the canopy to colonization by young *C. cordiformis*, *Aesculus sylvatica* (Flowering Buckeye), and *Eleagnus umbellata* (Silverberry).

There is a large Rock Pile on the north bank of the creek in the middle of this Hurricane corridor, where rocks apparently long ago were removed from the eastern part of the floodplain and piled on an existing outcrop. There are almost no visible

rocks in the eastern part of the floodplain. East of the Rock Pile, the soil is Nanford (50%)-Badin (30%); west of it the soil changes to Cid (70%).

Area 3—East

East of this Rock Pile on the north side of "Bitternut Creek" the floodplain is bisected by a deep, dry gully (or former channel) running southeast, which intersects "Bitternut Creek" near its confluence with "Little Bitternut Creek." Water flows in this gully only after the heaviest rains. *See Figure 8.*



This eastern part of the floodplain, not affected by Hurricane Fran, is a relatively open area of large trees and vines:

Betula nigra (River Birch) 15" DBH
Celtis laevigata (Hackberry) 18"-22" DBH
Juglans nigra (Black Walnut) 16"-23" DBH
Juniperus virginiana (Eastern Red Cedar), wind-downed, 11" DBH
Liquidambar styraciflua (Sweetgum) 20" DBH
Liriodendron tulipifera (Tulip Poplar) 16"-27" DBH (on raised area), one double-trunked, 38" total DBH
Pinus taeda (Loblolly Pine) 27" DBH (on raised area)
Platanus occidentalis (Sycamore) 35" DBH
as well as large *Cercis canadensis* (Redbud), *Fraxinus pennsylvanica* (Green Ash), and *Ulmus americana* (American Elm).

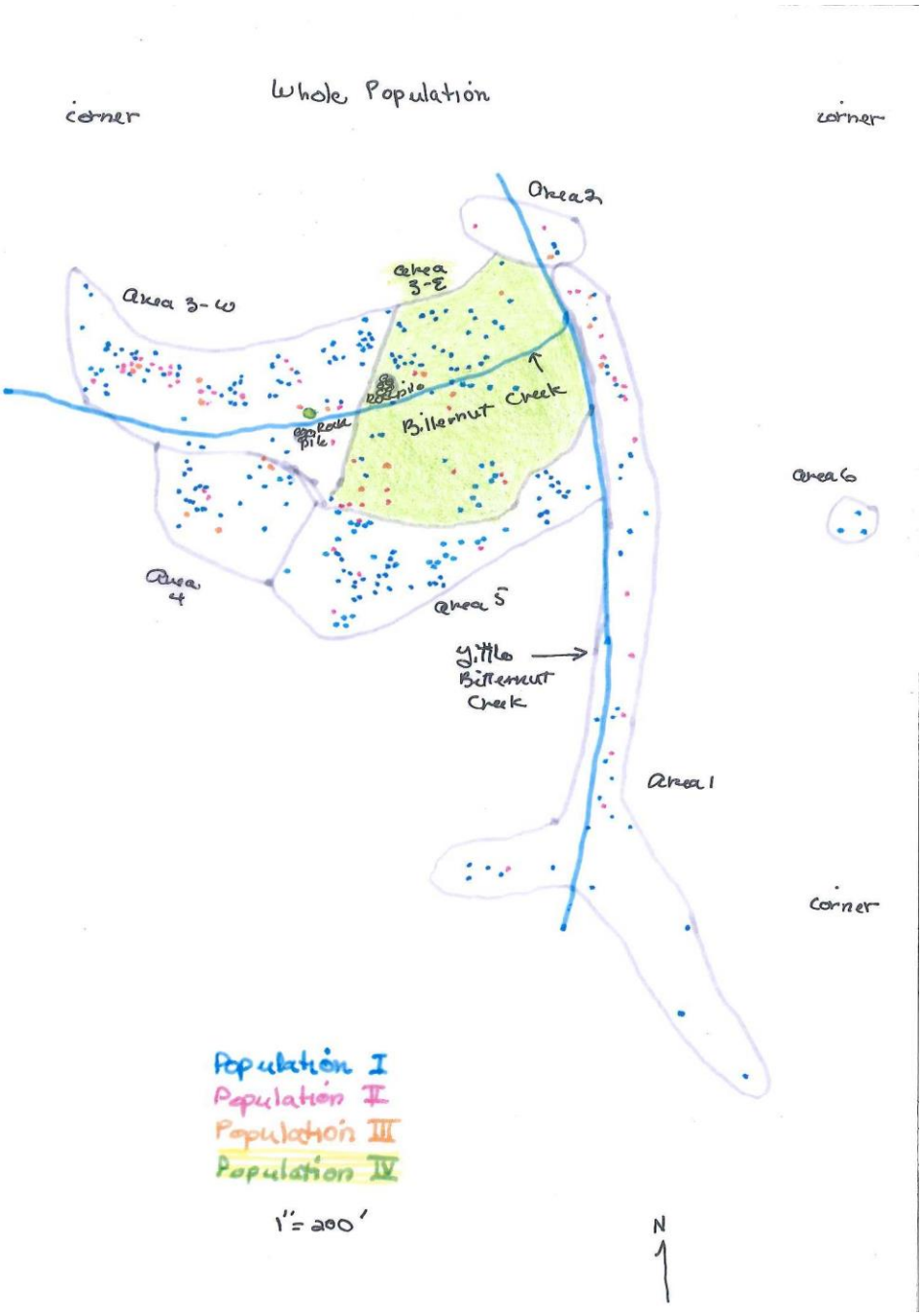


Figure 8. Area 3 East--Piedmont Bottomland Forest

as well as large *Cercis canadensis* (Redbud), *Fraxinus pennsylvanica* (Green Ash), and *Ulmus americana* (American Elm).

Some of the larger *Carya cordiformis* also occur in this area, near the creek on both sides, on the streamside levee of the dry channel (gully) and on the north and south edges of the floodplain, where the land rises slightly.

There are also 46 Population I trees, a few scattered in the floodplain itself, but mostly on the south-facing hill that rises from the floodplain to the north. On the northeast, the floodplain transitions into rubble from the western part of the Piedmont Mafic Cliff. A few *C. cordiformis* are growing in this transition area.

Table 5

Carya cordiformis in Area 3-East, Piedmont Floodplain Forest

(3 1/2 Acres)

Popula-tion	Tree #	DBH	Soil	Notes
I	Various, 46 trees	1/2”-3 3/4”	Nanford 50% Badin 30%	Scattered in the flood-plain, on bank of old streambed, most on the south-facing hill, rising from the floodplain to the north.
III	58	10 5/8″	″	45’-50’ tall, next to old streambed.
III	83	9 3/8″	″	Floodplain,
II	84	5 1/4″	“	“
III	241	8 5/8”	“	Near floodplain.
III	244	10”	“	Edge of floodplain.
III	249	9”	“	Nine’ from creek.
II	260	5 3/4”	“	In floodplain on higher ground.
II	341	4 1/2”	“	On slope, edge of floodplain.
II	343	4”	“	On slope.
II	357	7”	“	Floodplain.

Other woody plants in the Eastern part of the floodplain are:

Trees

Acer floridanum (Southern Sugar Maple)

A. rubrum (Red Maple)

Carpinus caroliniana (Ironwood)

Carya ovata (Shagbark Hickory)

Cornus florida (Flowering Dogwood)

Fagus grandiflora (American Beech) (higher up the slope to the south)

Ilex opaca (American Holly)

Quercus michauxii (Swamp Chestnut Oak)

Q. pagoda (Cherrybark Oak)

Ulmus alata (Winged Elm)

U. rubra (Slippery Elm)

Shrubs and Vines

Aesculus sylvatica (Painted Buckeye)

Bignonia capreolata (Crossvine)

Campsis radicans (Trumpet Creeper)

Euonymus americana (Hearts 'a Bustin')

Eleagnus umbellata (Silverberry)

Lonicera japonica (Japanese Honeysuckle)

L. sempervirens (Trumpet Honeysuckle)

Minispermum canadensis (Canada Moonseed Vine)

Parthenocissus quinquefolia (Virginia Creeper)

Smilax spp. (Greenbriar)

Toxicodendron radicans (Poison Ivy)

Vitis rotundifolia (Muscadine Grape)

V. spp. (Wild Grape)

Fan Moss (*Forsstroemia trichomitria*) is growing on almost all the smooth-barked trees, including *C. cordiformis* in Area 3, East and West.

Area 3--West

West of the Rock Pile, the soil changes from Nanford-Badin to Cid (70%), and the floodplain becomes rocky and narrower, especially on the south side (2'-5'), where the very rocky north-facing hill rises abruptly. There is a smaller but similar rock pile next to the creek on the south side. *See Figure 9.*

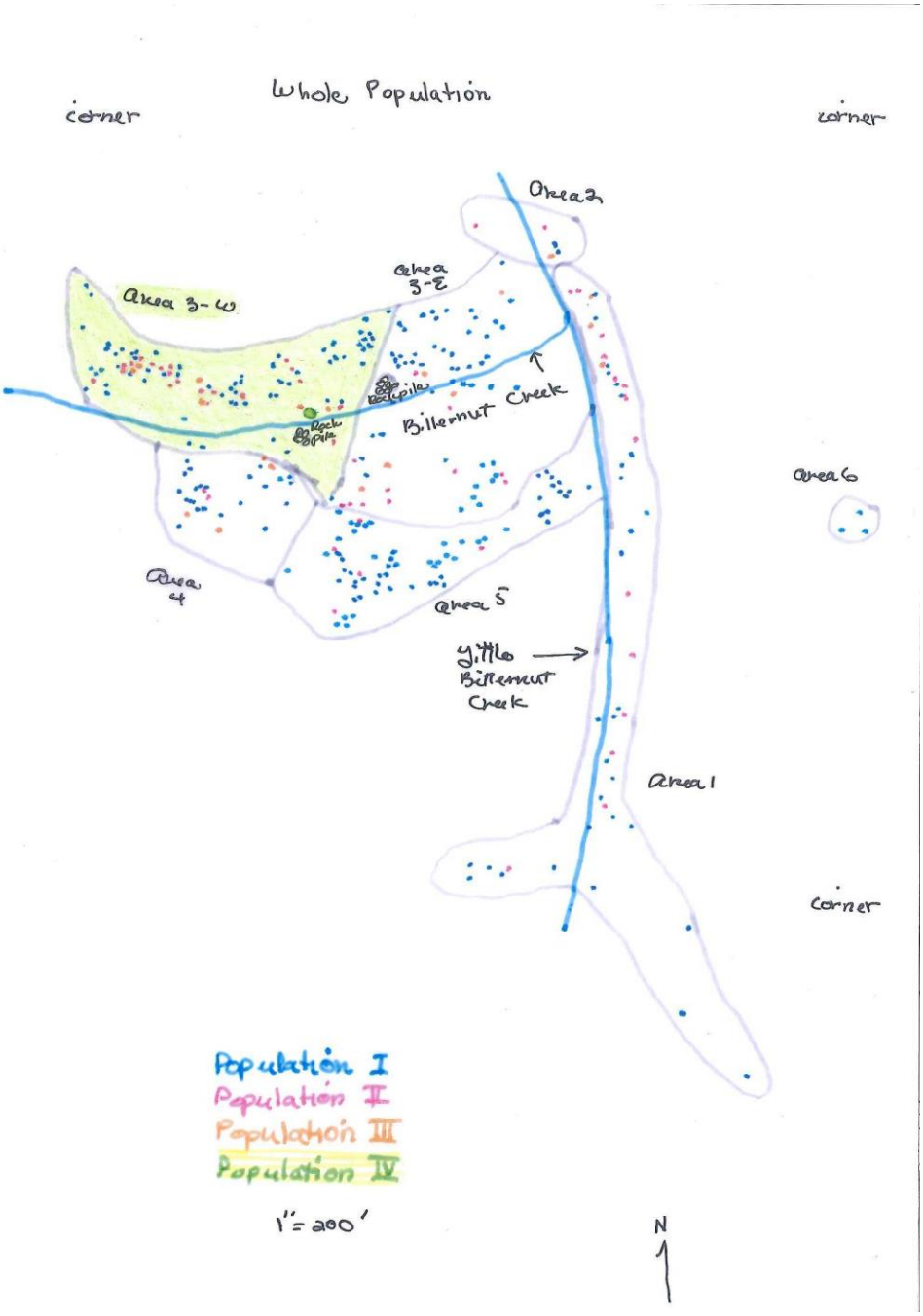


Figure 9. Area 3 West--Piedmont Bottomland Forest

A section of an old road runs parallel to the creek on the north side. It channels rain water into a gully, which empties into the creek upstream of the Rock Pile. In the narrow finger of land between this gully and “Bitternut Creek,” there is a concentration of the larger *Carya cordiformis*, Population III, and the largest one I found, Population IV. There are no *C. cordiformis* between the old road and the creek itself, even though there are Shagbark Hickory (*C. ovata*), and others growing there.

Tree #112 (Population IV) is growing in rocks at the western edge of the Hurricane corridor, in the middle of a thicket of *Eleagnus* ("Eleagnus Hell") along with Population I trees. Population II and III trees are also concentrated west of Tree #112, to the western edge of the Study Area, and up the south-facing hill north of "Bitternut Creek," along with *Fraxinus pennsylvanica* (Green Ash), *Ulmus americana* (American Elm), and others.

Table 6

Carya cordiformis in Area 3-West, Piedmont Floodplain Forest

(2 1/2 Acres)

Popula-tion	Tree #	DBH	Soil	Notes
I	Various, 76 trees	1/2″-3 7/8”	Cid 70%	Many on south-facing hill, on terraces, some on creek bank.
II	Various, 22 trees	4″-7”	″	On slope, on terraces, on edge of gully.
III	110	10 1/2″	″	On stream-side terrace.“
IV	112	16 7/8″	“	In rocks, between creek and gully.
III	113	11 1/2”	“	Between creek and gully.
III	148	8 7/8”	“	In rocky area.
III	165 (double)	12 “	“	Rocky, where land flattens.
III	166	13”	“	“
III	167 (double)	9 7/8”	“	Very close to #166.
III	170	10 1/8”	“	On slope.

Area 3--Barbed Wire Fence

Along the northern edge of the whole floodplain, slightly up the hill and running west to east, is an old, mid-20th century barbed wire fence. It is collapsed and partially buried under leaves at the southern edge of an area of about 50-year-old Loblolly Pine (*Pinus taeda*) on the south-facing hill (slope 6%-10%) above "Bitternut Creek." *Carya cordiformis* are growing along and south of this fence line, none above.

Along the southern edge of the floodplain, slightly up the north-facing hill (slope 8%) there is also a connecting barbed wire fence of the same era, but there seems to be no correlation between the line of the fence and the location of *C. cordiformis* on that side of the hill.

Area 4--Basic Mesic Forest

North-Facing Hill South of "Bitternut Creek" (Western Part) (About Two Acres)

This hill slopes downward (4%-8%) to the north below an overgrown agricultural field, the lower part of which has been colonized by *Juglans nigra* (Black Walnut). The forest at the edge of the field consists of large trees (14"-18" DBH):

Carya tomentosa (Mockernut Hickory)
Juglans nigra (Black Walnut)
Liquidambar styraciflua (Sweetgum)
Liriodendron tulipifera (Tulip Poplar)
Pinus echinata (Shortleaf Pine)
P. taeda (Loblolly Pine)
Quercus falcata (Southern Red Oak)—(27" DBH)

as well as large *Cercis canadensis* (Redbud) (8”-10” DBH) and large *Cornus florida* (Flowering Dogwood) (8”-10” DBH). There are large *Vitis* spp. (Wild Grape) vines, and *Eleagnus umbellata* (Silverberry), but no *Ilex opaca* (American Holly) or *Aesculus sylvatica* (Painted Buckeye). *See Figure 10.*

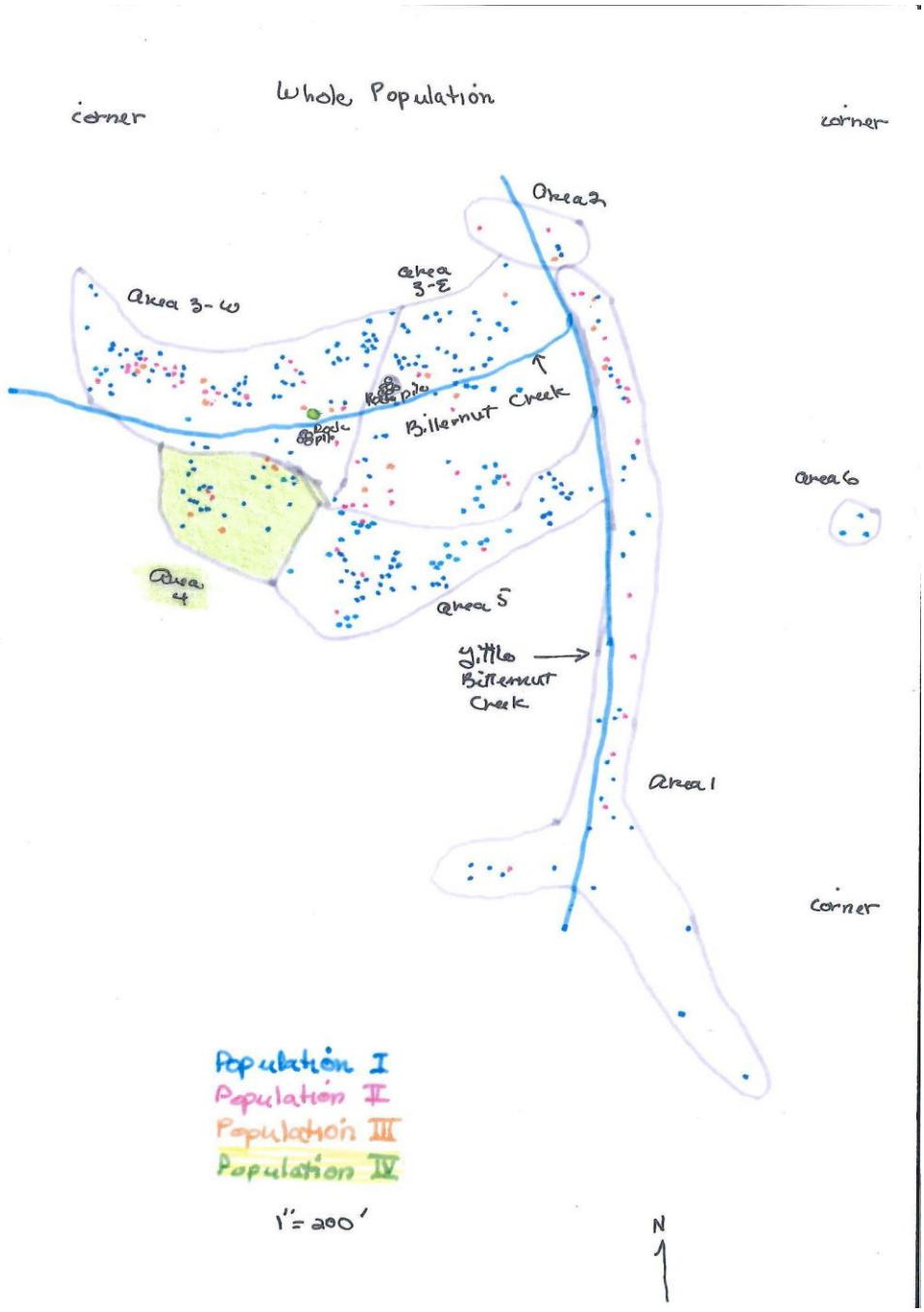


Figure 10. Area 4--Basic Mesic Forest

About half-way down the hill from the field, the slope becomes steeper (8%-16%) and *Aesculus sylvatica* (Painted Buckeye), *Ilex opaca* (American Holly), and *Carya cordiformis* appear. There was an old farm road that ran horizontally across the hill, probably for removing rocks from the field. This is a very rocky area (mostly basaltic), and two of the larger *C. cordiformis* (Population III) are growing up through rock piles in the old road bed. Two other Population III trees are growing lower down the hill at the edge of the floodplain of "Bitternut Creek." There are two Population II trees growing lower on the hill in rocks. *See images below.* The soil for this Area, as well as the field, is Pittsboro (55%)-Irdell (25%).

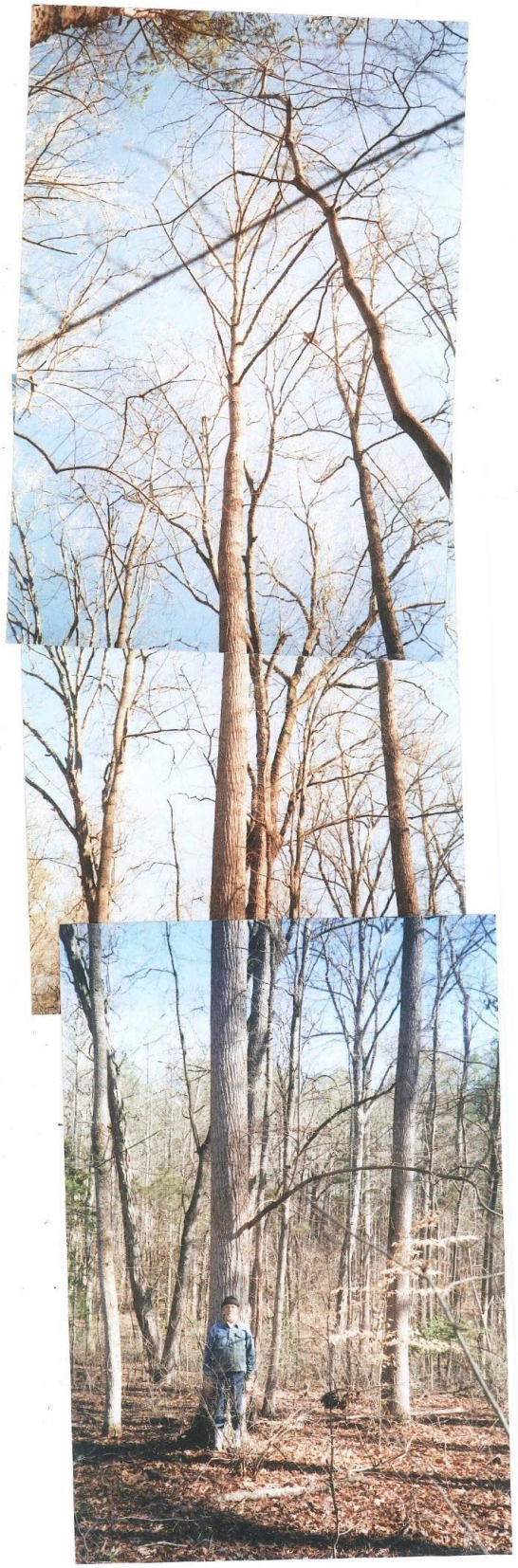
In addition to the *C. cordiformis* on the lower part of this hill, there are very large *C. ovata* (Shagbark Hickory) (31" DBH), *Juglans nigra* (Black Walnut), *Liriodendron tulipifera* (Tulip Poplar), *Liquidambar styraciflua* (Sweetgum), and many *Ilex opaca* (American Holly) and *Aesculus sylvatica* (Painted Buckeye).

This Area is west of a very wide spreading *Acer floridanum* (Southern Sugar Maple) that dominates the central part of the hill, and must have grown up when this area was more open than it is now.

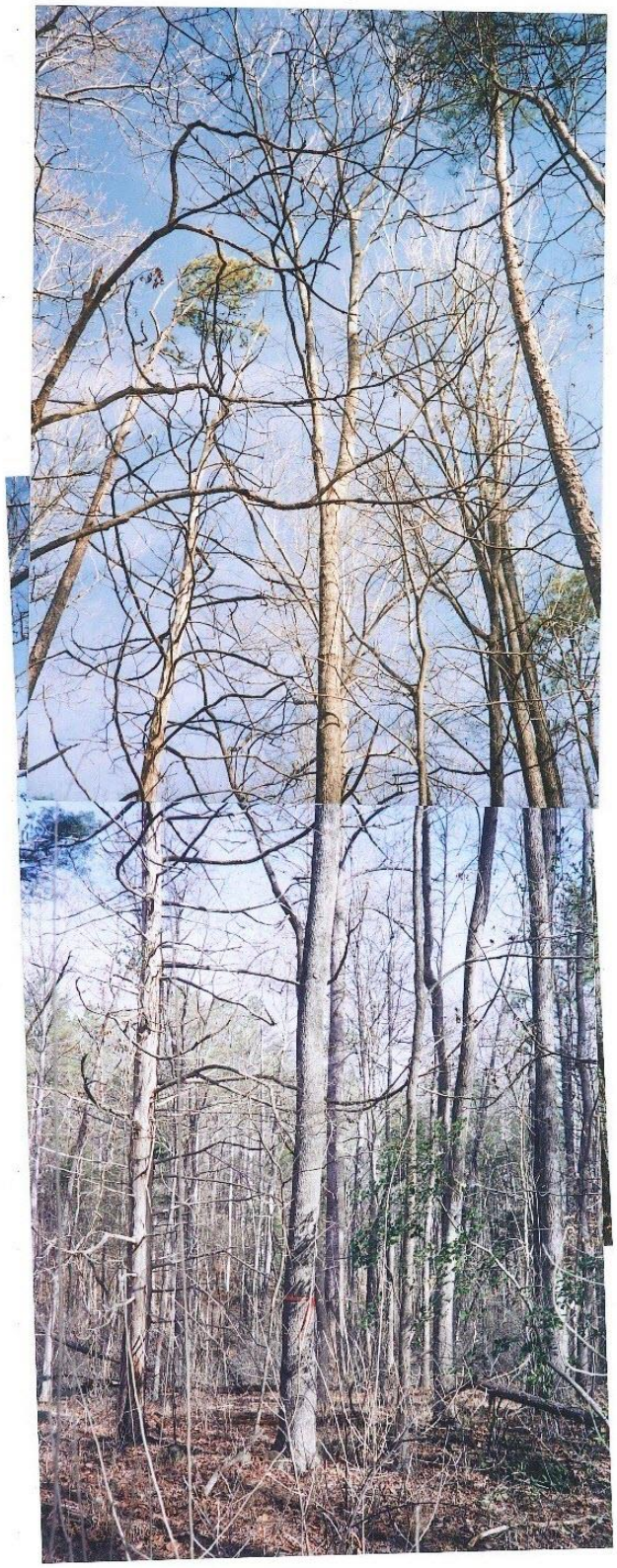
Table 7

Carya cordiformis in Area 4, Basic Mesic Forest (2 Acres)

Popula-tion	Tree #	DBH	Soil	Notes
I	Various, 26 trees	1"-3"	Pittsboro 55% Iredell 25%	Scattered on hill.
III	200	9 3/4"	"	Rocky.
III	209	13"	"	Bark looks like Ash, in rock pile, faint old road.
II	214	6 5/8"	"	Lower on hill, in rocks.
III	222	8"	"	Edge of floodplain.
III	223	8 5/8"	"	Slightly uphill from floodplain.



Tall Tulip Poplar in Area 4, Basic Mesic Forest



Population III Tree, No. 209

Area 5--Basic Mesic Forest

North-Facing Hill South of "Bitternut Creek" (Eastern Part) (About Four Acres)

This area is east of the Spreading Maple Tree (*Acer floridanum*) mentioned in the previous section. Most of the *Carya cordiformis* in this Area are Population I (78) or Population II (14), with one Population III tree. Most of the Population II trees and the one Population III tree are near the edge of the floodplain of "Bitternut Creek." *See Figure 11.*

Previously, this Area was dominated by *Pinus echinata* (Shortleaf Pine), until an infestation of the Southern Pine Beetle (*Dendroctonus fontalis*) in the early 1990s took out about 90% of the Shortleaf that were growing there. Now there are young trees of many kinds and a few mature Shortleaf scattered throughout. In addition to the approximately 80 Population I *C. cordiformis,* there are: *Acer floridanum* (Southern Sugar Maple), *A. rubrum* (Red Maple), *Celtis occidentalis* (Hackberry), *Cercis canadensis* (Redbud), *Cornus florida* (Flowering Dogwood), *Ilex opaca* (American Holly), *Liquidambar styraciflua* (Sweetgum), *Liriodendron tulipifera* (Tulip Poplar), and *Ulmus alata* (Winged Elm).

This Area is quite different from the previous Area even though it is on the same hill and has the same soil--Pittsboro (55%)-Iredell (25%). The hill slopes more gradually both to the north and east (3%-6%), except near the "Bitternut Creek" floodplain where it rises more steeply (8%). It is not as rocky, perhaps because the rocks may have been removed to the other Area. The presence of the Shortleaf (often called "Old Field Pine") suggests that this may have been an agricultural field. Part of this Area is shown as clear in the previously mentioned 1956 aerial photograph, as well as the 1968 topo map.

The hill also slopes to the east (6%) down to "Little Bitternut Creek" and the previously mentioned old road that forded the creek. This road marks the southern edge of this Area. There are many young *C. cordiformis* growing in the several old roadbeds from the ford almost to the top of the hill.

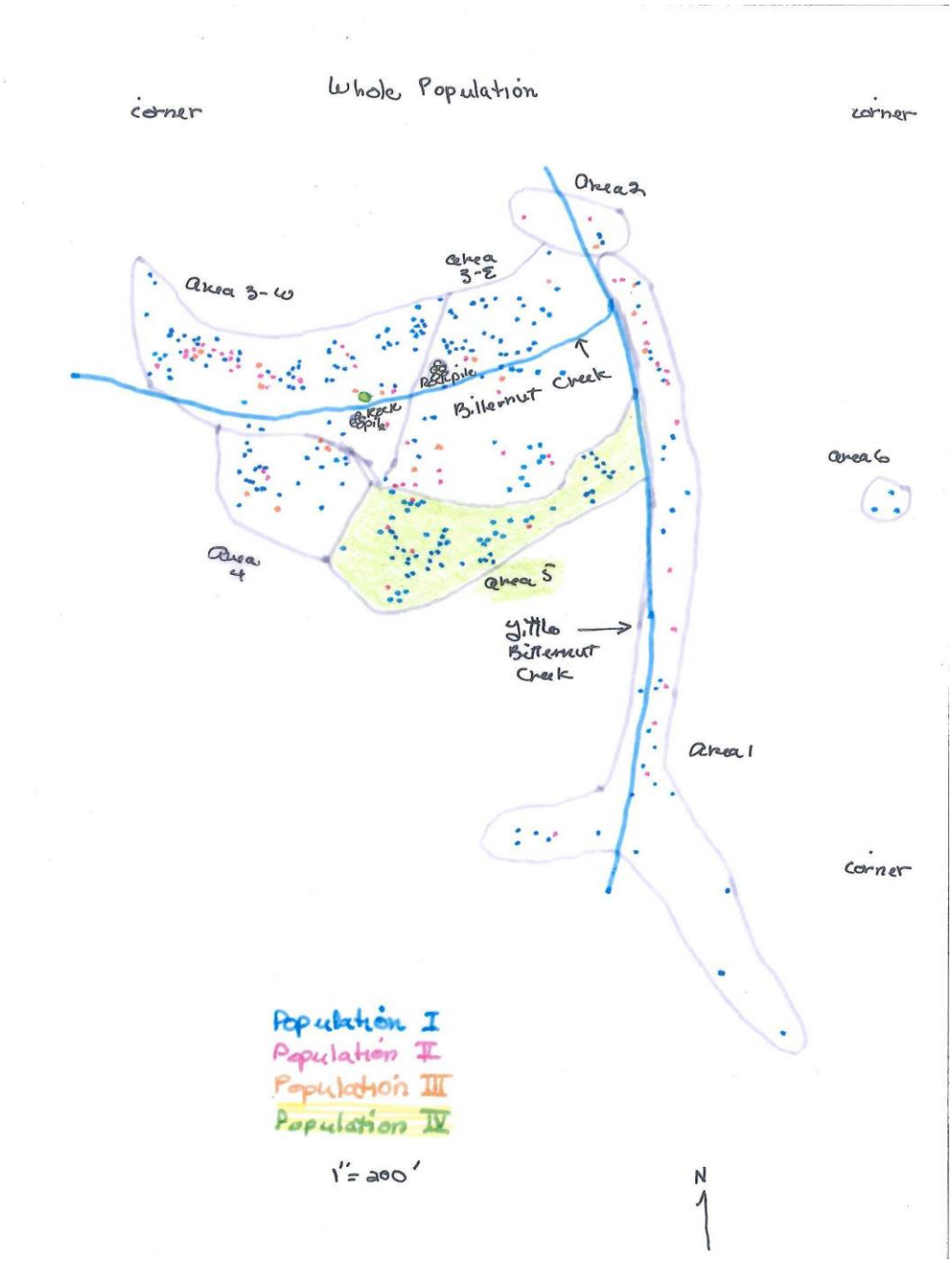


Figure 11. Area 5--Basic Mesic Forest

There are large old trees that mark the edge of the several former roadbeds: Ash (*Fraxinus* spp.), Tulip Poplar (*Liriodindron tulipifera*), Black Oak (*Quercus velutina*), large dead Cedar**,** Willow Oaks (*Q. phellos*), Elms (*Ulnus* spp.), Post Oak (*Q. stellata*), Southern Sugar Maple (*Acer floridanum*), Shagbark Hickory (*C. ovata*), Sweetgum (*Liquidambar styraciflua*). There are also large Hackberries (*Celtis occidentalis*) near the top of the hill, below the field. Some of the Ash have Resurrection Fern (*Pleopeltis polypodioides*) growing on their horizontal branches.

The land on the south side of the old roadbeds has grown up in Loblolly Pine (*Pinus taeda*), indicating that this area was also open sometime in the past.

Table 8

Carya cordiformis in Area 5, Basic Mesic Forest (4 Acres)

Popula-tion	Tree #	DBH	Soil	Notes
I	Various, 78 trees	1”-2 7/8″	Pittsboro 55% Iredell 25%	Scattered throughout the Area, many on or in old roadbeds.
II	239	5 3/8”	″	Down slope.
II	240	5 3/8″	″	“
III	241	8 5/8″	“	Near floodplain.
II	256	4 1/4”	“	Near garbage dump road.
III	258	8 3/8”	“	Down slope.
II	259	4 1/2”	“	Near floodplain.
II	262	4”	“	Up from floodplain.
II	269	4 5/8”	“	Down slope.
II	270	6”	“	Near floodplain, spring.
II	289	4 5/8”	“	In ford road.
II	317	4:	“	In hardwoods, rocks, near garbage dump.
II	322	5 1/2”	“	Near ford road.
II	336	5 1/4”	“	In hardwoods.
II	341	4 1/2”	“	Edge of floodplain.
II	343	4”	“	On slope.

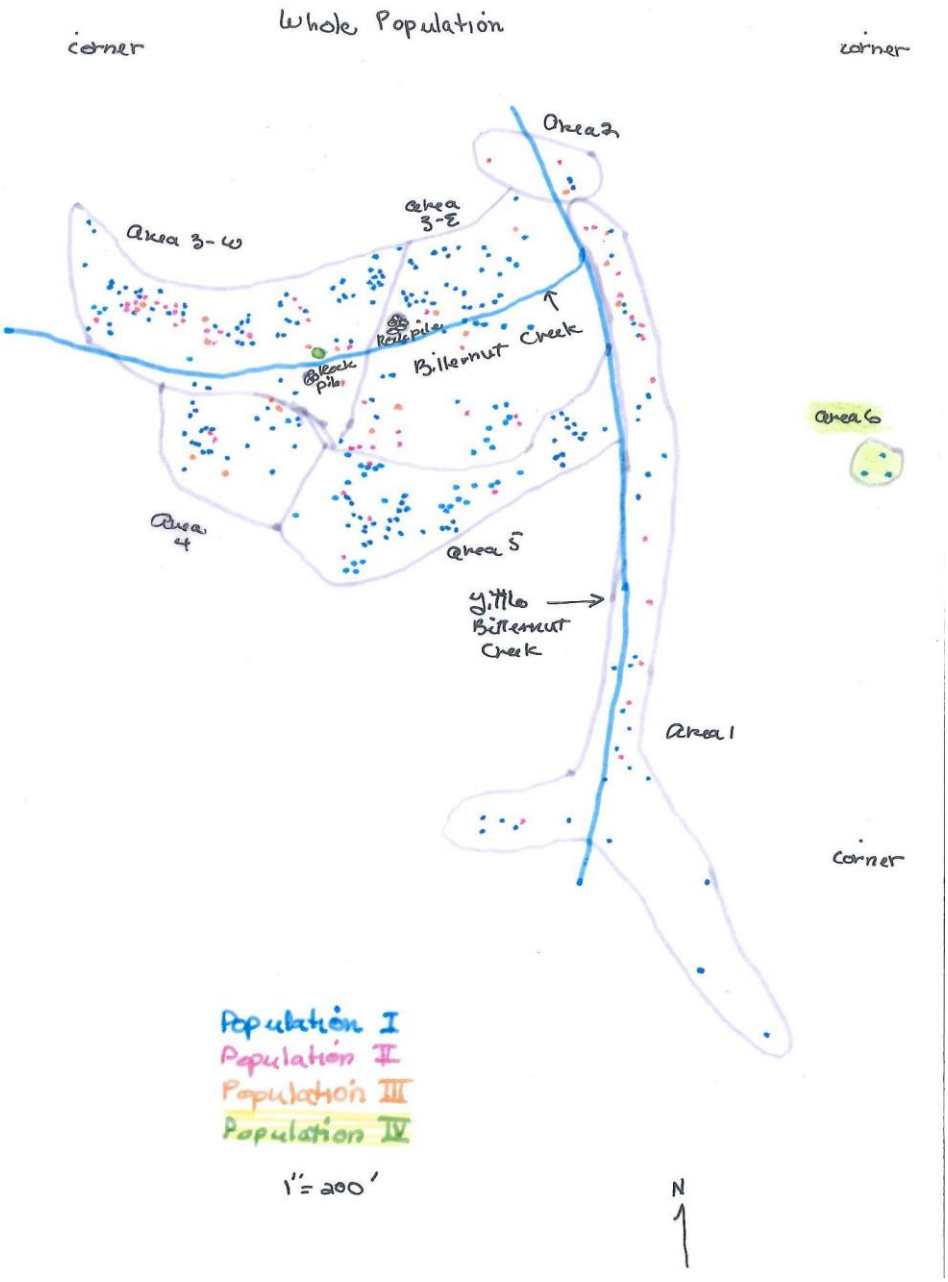


Figure 12. Area 6--Basic Oak-Hickory Forest

Area 6--Basic Oak-Hickory Forest (About 1/4 Acre)

There is an isolated group of at least three Population I *Carya cordiformis* at the top of a hill along the northeastern boundary of my Study Area, where the land is relatively level, but which slopes away to the west (6%) and east (7%). Tree #348. The soil is Nanford (36%)-Badin (33%). *See Figure 12.*

Some other trees in this Area are: *Carya carolinae-septrionalis* (Southern Shagbark Hickory), *C. tomentosa* (Mockernut Hickory), *Juniperus virginiana* (Eastern Red Cedar), *Pinus* spp. (Pines), *Quercus alba* (White Oak), *Q. stellata* (Post Oak), *Q. velutina* (Black Oak), *Ulmus alata* (Winged Elm), and *Viburnum prunifolium* (Black Haw).

Age of the Trees

I counted the rings on cross-sections of four Population I *Carya cordiformis* trees that were alive when I marked them in 2009, but subsequently died in 2011 or 2012 because of the more-than-decade-long extreme drought. I assume these trees died in 2011.

Table 9

Ages from Tree Rings

Tree #	DBH	Age	Germinated	Notes
---	7/8”	10 yrs.	2001-2002	
---	1 15/16”	19 yrs.	1992-1993	
189	2”	25-26 yrs.	1986-1987	In a clump of *C. cordi-formis* near the western border of Area 3-W
136	3”	29 yrs.	1982-1983	Near the fence in Area 3, this tree was 30’ tall.

Sometimes the outer rings had rotted off or were partially eaten away, so that it was difficult to count accurately, but it obvious that the dark winter rings are larger, often much larger, than the light summer rings in these trees that died.

In December 2016, using my map, field notes, and memory, I relocated and measured the circumference/DBH of 22 selected *Carya cordiformis* in the Study Area that I could find fairly easily. These trees were originally measured in February 2012, four years 10 months earlier.

Table 10

Increase in DBH of Selected *Carya cordiformis*,

February 2012 to December 2016

Popula-tion	Tree #	Area	DBH 2012	DBH 2016	Increase	DBH/yr.
I	1	1	2.2282”	2.3077”	0.0975”	0.0166”
I	2	1	1.8303”	2.0292”	0.1989”	0.0414”
I	3	1	1.7507”	1.7507”	No change	---
II	6	1	5.2521”	5.5704”	0.3183”	0.0663”
I	7	1	2.3873”	2.3873”	No change	---
I	9	1	1.9099”	1.9894”	0.0795”	0.0166”
I	13	1	1.7507”	1.8701”	0.1194”	0.2488”
II	18	1	6.5254”	6.9630”	0.4376”	0.0912”
II	23	1	7.4803”	7.5996”	0.1193”	0.0249”
II	26	1	6.3750”	7.5996”	1.2246”	0.2551”
II	41	1	7.0030”	7.9577”	0.9547”	0.1989”
I	43	1	1.5915”	2.1884”	0.5969”	0.1244”
III	47	1	8.9127”	9.8278”	0.9151”	0.1960”
III	53	2	8.4352”	9.1514”	0.7162”	0.1492”
II	56	2	6.2070”	6.2070”	No change	---
III	58	3-E	10.6634”	11.3000”	0.6366”	0.1326”
III	110	3-W	10.5042”	11.2204”	0.7162”	0.1492”
IV	112	3-W	16.8704”	18.2630”	1.3926”	0.2901”
III	113	3-W	11.4592”	11.8173”	0.3581”	0.0746”
III	166	3-W	13.0507”	14.1648”	1.1141”	0.2321”
III	200	4	9.7085”	9.9972”	0.2387”	0.0497”
III	209	4	13.0507”	14.2842”	1.2335”	0.2570”

Discussion

Introduction

In this discussion I will try to answer the questions I raised in the beginning of this paper:

Where does *Carya cordiformis* occur in my Study Area—in what habitats, what plant communities, what soils?

How are their nuts dispersed?

How have past predation and weather events and previous land use influenced where *C. cordiformis* occurs?

Why would a tree make bitter fruit, and is there a connection between the bitterness of the nuts and the wetland habitats of this tree?

How old are these trees?

In addition, I have made several observations about *C. cordiformis*: they seem more resilient to damage than other Hickories; they leaf out later and retain their leaves longer than other Hickories; they grow on raised areas within a wetland habitat; many of them, as well as other smooth-barked trees in the wet areas, have Fan Moss growing on them; there may be some hybridization between *C. cordiformis* and *C. tomentosa*.

Where Does *Carya cordiformis* Occur in My Study Area?

Most of the *C. cordiformis* I found are growing on raised areas, near but not in water—on slight rises, stream-side terraces and levees, or at the edges of floodplains. Many large trees are growing in rocks or rock piles.

Many young trees are growing up in areas cleared by blow-downs from Hurricane Fran, ice storms, and the Pine Beetle outbreak of the 1990s. The largest trees occur in Piedmont Bottomland Forest and Basic Mesic Forest plant communities. There are a few trees in Piedmont Mafic Cliff, one small tree in Basic Oak-Hickory Forest, and many in the Piedmont Alluvial Forest plant communities.

There may have been more large or larger *Carya cordiformis* near "Bitternut Creek" downed by Hurricane Fran.

Many *C. cordiformis* are growing along old fence lines and old roads. They are growing in both hilly and flat terrain, but not in places where water stands. Since *C. cordiformis* is known to be shade intolerant, these areas must have been more open in the past than they are now. They need water, they need light, and they may like disturbed soil.

I found *C. cordiformis* growing in Cid, Nanford-Badin, and Pittsboro-Iredell soils. There seems to be no preference for one over the others with both large and small trees growing in each. I have not found them in the Georgeville soil area, but that could be because the seed has not yet arrived there. The main determining factors for the location of these trees seem to be availability of water, past and present land use, and weather or predation-related canopy-opening events, that allow the shade-intolerant *C. cordiformis* to thrive.

The oldest and largest trees (Population IV and III) are growing near "Bitternut Creek" in Cid and Nanford-Badin soils as if they may be part of an original population. There are also some large trees (Population III) growing in Pittsboro-Iredell soil. There are Population II and I trees in the three soils.

The Cid and Nanford-Badin soils are classed as acidic, but I think that, in my Study Area, they may be at the high PH of their range, or circumneutral, given the mixed geology of the area, and the presence of basaltic and other mafic rocks at the surface. Soil disturbance seems to be more a factor than soil type in the location of *C. cordiformis*.

In the Georgeville soil areas I found trees which I believe to be hybrids between *C. cordiformis* and *C. tomentosa*--having bark and leaves like *cordiformis* but buds like *tomentosa*. I haven't yet looked for nuts from these trees. Their leaves are fragrant, like *tomentosa*.

How Are *Carya Cordiformis* Nuts Dispersed?

Many mammals and birds search for and eat Hickory nuts (*Carya* spp.). In my Study Area they could be eaten by Wood Duck, Bobwhite Quail (now uncommon), Wild Turkey, American Crow, Blue Jay, White-Breasted Nuthatch, Red Bellied

Woodpecker, Gray Fox, Eastern Cottontail, Eastern Chipmunk, Southern Flying Squirrel, Gray Squirrel, White-Footed Mouse, Golden Mouse, Raccoon, White-Tailed Deer, Black Bear, and Humans. In addition, many of these animals also feed on the flowers, bark, twigs, and/or foliage of Hickories.[21]

The sudden appearance of a hunter, the scream of a Red-Shouldered or Red-Tailed Hawk, the who-aw of a Barred Owl, or hoo-hoo of a Great Horned Owl could startle any of these animals and cause it to drop a *Carya cordiformis* nut on the ground in the Fall in a place where it could germinate and grow. The White-Breasted Nuthatch, Red-Bellied Woodpecker, and Southern Flying Squirrel who cache food in crevices or hollows in trees could find their stored nuts on the ground after a wind or ice storm. However, the animals that actively cache food on or near the ground are probably mostly responsible for the proliferation of *C. cordiformis* in my Study Area--Blue Jay, American Crow, Gray Squirrel, Southern Flying Squirrel, White-Footed Mouse, and Golden Mouse--all of which frequent the mature forest and low land habitats of this tree.

The astringency of *C. cordiformis* nuts may make them less palatable than those of other Hickories, but it does not deter animals from eating or caching them. In addition, *C. cordiformis* nuts are small compared to those of other Hickories; they are easily transported by small mammals and birds; the shells are thin and easily opened; and they may remain viable longer than others because of their bitter tannins. (Wood Ducks are the primary dispersers of the bitter nuts of the Water Hickory [*C. aquatica*],[22] which make up five to ten per cent of their diet.)[23]

One week in January 2008 I found many *C. cordiformis* nuts on the ground around Population III, Tree #53 (Area 2, Piedmont Mafic Cliff). (2007 was a good Hickory mast year.) When I came back to the tree the next week the nuts were gone, and the area around it cleared of leaves and nuts in the way that a flock of Wild Turkeys feeds. As this was a good Hickory nut year (even though we were in the middle of a drought), Turkeys took all the bitter nuts from around this tree when other, non-bitter nuts were available. A trail camera showed deer eating nuts from around this tree.

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[21] Martin, Alexander C., Herbert S. Zim, and Arnold L. Nelson. *American Wildlife and Plants: A Guide to Wildlife Food Habits*, Dover, New York, 1961.
[22] Bullard, A.J. Verbal communication, 2007.
[23] Martin, Alexander C.,, et al. Ibid.

I have found *Carya cordiformis* nuts cached under pieces of bark, and under leaves, on somewhat raised areas of ground near the trees. Sometimes there would be evidence of nuts having been eaten and a mouse-size hole in the ground. (Areas 1, 4, and 5.) I have also found nuts partially eaten by Flying Squirrels, leaving their characteristic hole in the top or side (Areas 2 and 3). Also, all the *C. cordiformis* nuts that I brought back to my house to study disappeared or were eaten in place by rodents (leaving chisel-cut shells and husks) until I learned to keep them in glass jars or a metal box. I suspect White-Footed and/or Golden Mice, both of which have been observed in my house.

Wind is a factor in the dispersal of Hickory nuts, probably sending them further from the parent tree than do squirrels. I have seen the tall Hickory trees at my house bend over in strong winds, spring back like a slingshot, and send mature nuts to the ground hundreds of feet away, where they bounce or roll even further.

C. cordiformis nuts, which float, are also dispersed by water, mostly downstream, but also upstream or uphill during floods when the falling flood water deposits leaves, sticks, nuts, and other debris in a line along the side of a hill marking the extent of the flood. (Areas 1, 2 and 3.) *C. cordiformis* nuts remain viable for more than one year.

I think the primary animal dispersers and planters of *C. cordiformis* in my Study Area are White-Footed or Golden Mice, and Flying Squirrels (rather than Gray Squirrels). There are many mature, bearing Shagbark Hickory (*C. ovata*), Black Walnut (*Juglans nigra*), White and Red Oaks (*Quercus* spp.), in addition to the *C. cordiformis* near "Bitternut Creek" (Areas 3, 4, and 5), but I see few Gray Squirrels there. On February 10, 2013, I saw only one Gray Squirrel nest in the area. On the same day, at my house, I counted 16 Gray Squirrel nests with the naked eye, standing in one place. (At my house, in addition to the mature Southern Shagbark (*C. carolinae-septrionalis*), Mockernut (*C. tomentosa*), Pignut (*C. glabra*), and Red Hickory (*C. ovalis*), White and Red Oaks (*Quercus* spp.), there are bird feeders, on which I have counted 24 Gray Squirrels at one time.)

However, the linear distribution of *C. cordiformis* in Area 1 (Piedmont Alluvial Forest), with a recurring pattern of a single isolated Population II tree, large enough to produce a crop of nuts, surrounded by several Population I trees, to me suggests original distribution by birds, most likely the White-Breasted Nuthatch or Red-Bellied

Woodpecker, both common in the area. Isolated Population I trees in the southern part of Area 1 and in Area 6, Basic Oak-Hickory Forest, are 250' to 500' from the nearest nut-bearing Population II or III tree. This distance seems too far for distribution by rodents.

The Population II trees themselves in the southern part of Area 1 occur in a line along "Little Bitternut Creek," 100' to 250' from each other, as if their original distribution was by birds. They are now surrounded by Population I trees. The closest source of seed for the Population II trees is the Population III trees in the northern part of Area 1, nearer to the confluence with "Bitternut Creek."

White-Breasted Nuthatches and Red-Bellied Woodpeckers, both year-round residents, are often seen and heard in the *Carya cordiformis* areas. They both cache food in crevices in bark or holes in trees. Blue Jays also cache food in trees and in the ground, but are rarely seen or heard here, except for the coldest, snowiest days in winter, when one may, with great fanfare, come to my bird feeder. Crows nest in forests in the vicinity, also cache food in the ground, and are in the area in the nesting season, but are often gone from here by the time Hickory nuts are available. (However, there may have been more Crows and Blue Jays in the past when there were more agricultural fields.)

Some of the other permanent and winter-resident birds frequent in this area could also eat and disperse the small, thin-shelled *C. cordiformis* nuts even if they may not be attracted to the larger Hickory nuts: Carolina Chickadee, Tufted Titmouse, Downy Woodpecker, Hairy Woodpecker, Yellow-Shafted Flicker, as well as Wild Turkey. These birds all eat acorns in the winter, including the bitter acorns of the Red Oak group.[24] *C cordiformis* nuts are about the size of or smaller than many acorns and could be eaten by small birds.

Drought and Major Canopy-Opening Events in the Past 25 Years

Drought

When I began identifying *Carya cordiformis* in 2007, our area was in the midst of a more-than-decade-long drought, which, I hope, has now ended. This drought

[24] Martin, et al. Ibid.

was a significant weather event in my area. *Carya cordiformis* is known as being a "water-loving" Hickory. How would this drought affect the trees I was studying?

I have been keeping rainfall data for my garden since 2006. My garden weather station is the closest one I know of to the *C. cordiformis* areas.

Yearly Rainfall				
2006	37.00"	2011	33.64"	
2007	32.82"	2012	29.64"	
2008	46.98"	2013	43.99"	11 year average:
2009	40.71"	2014	43.26"	40.90"
2010	36.75"	2015	57.23"	
		2016	47.94"	

The generally accepted yearly average for rainfall for the Piedmont is 44"-48"; the 30-year average rainfall for Pittsboro has been 44".46". We are still way below the average here, even with the more normal last four years. I don't have any historical rainfall averages for this particular area. It could be that this area has a history of being drier than the average, given that the farms here were abandoned in the 1930s because of drought.

The extreme drought we experienced here began in the mountains in 1998, progressed to the Piedmont in 1999, became worse in 2002, and persisted in my area until 2015. (There were also state-wide droughts in 1926 to 1927 and 1986.[25])

In the recent drought, our area was part of a narrow north-east to south-west trending strip of Chatham County that experienced extreme drought, even though there could be rain a mile away. Pittsboro was not in this extreme drought area, but our area was, as well as land along Highway 902 in the southwestern part of the county where dead trees were noticeable from the highway. An experienced well-driller said that 2002 was the worst year, the year that farmers bought and trucked in water or sold their cattle. The springs in my area were still running in 2002 but disappeared in the next two years. Many large and old trees near my house died. By 2005, the springs were dry and have only begun to come back in the winter of 2016-2017.

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[25] Robinson, Peter. North Carolina Weather and Climate. University of North Carolina Press, Chapel Hill, NC, 2005, pp. 141-143,

I began this study, looking for *Carya cordiformis* in the Fall of 2007 in the middle of this drought, marking them with orange flagging tape in 2009 through 2011. In February 2012 I began using the GPS device to record their location and circumference. Some of the small trees had already died in the drought. Most of the trees were marked in February and March of 2012, with a few more in the Fall of 2012 and Winter of 2013. I walked the completely dry creekbed of "Bitternut Creek" in the Winter of 2012-2013.

I prepared cross-sections of four small *C. cordiformis* that had died. The growth rings of these trees showed that they grew much more in the winter than in the spring-summer, showing the importance of winter precipitation and the availability of ground water.

Annual Rainfall 2006-2012
(at my weather station)

2006	37.00"	2010	36.75"
2007	32.82"	2011	33.64"
2008	46.98"	2012	29.64"
2009	40.71"		

The seven-year average, 2006-2012 is 36.79", 10" to 12" below the 30-year average for Pittsboro.

Drought is a particular problem for plants growing in the Pittsboro soil. Once the often wet soil dries out, it will not accept water. Only weeks of very slow, frequent rains can begin the process of restoring water to this soil, and even then, only a few fractions of an inch at a time. Many of the *C. cordiformis* I have found are growing in Pittsboro soil. Many of the largest ones are growing in Cid soil, which, I think, reacts the same way as Pittsboro to drought. *C. cordiformis* must have some ability to survive drought. The largest ones would have also experienced the drought of the late 1920s.

Carya cordiformis, a "water-loving" Hickory, has (along with many other trees) managed to survive in this area, in this drought, in these problem soils, for many decades, at least. Many of the small (Population I) trees have died; some of the medium (Population II) trees have also died during the period of this study.

Population II, tree #211, 7" DBH, near "Bitternut Creek," died in the drought. This tree was very close to Population II, tree #214, 6 5/8" DBH. Perhaps there was not enough water for two trees of the same size so close together.

The larger trees (Populations III and IV) so far have not shown any signs of succumbing to drought, although I know that, in general, larger trees take a longer time to die. However, the larger trees have already selected the best locations. Most of these are growing near "Bitternut Creek," on the North side of a hill, in rocks or in rock piles.

Hurricane Fran

The 120 mph winds of Category 3 Hurricane Fran, September 6, 1996, radically changed the composition of forests in the north-facing ravines in my neighborhood, and especially in Areas 2, 3, and 4 in my Study Area. I had been an infrequent visitor to Area 3 (Piedmont Flood Plain Forest) before the hurricane, but I remember the very large trees, closed canopy, and relatively open, walkable, understory in the floodplain of "Bitternut Creek," and on the north-facing hill to the south of it (Area 4, Basic Mesic Forest), that was there, unusual for my neighborhood.

The hurricane swept from northeast to southwest through Area 2, Piedmont Mafic Cliff, across the northeastern part of Area 3, and crossed "Bitternut Creek", in the vicinity of the Rock Pile, uprooting almost all the large trees there, still in leaf, and leaving a huge southwest-facing pile of tangled tree trunks and branches which spanned the creek and continued up the hill to the south (Area 4). After the hurricane I made the mistake of trying to climb through this tangle of trunks and branches to get home without having to backtrack. I remember noticing some unusual yellowish buds on at least one of the large trees in the pile, but I could never make my way back there. I now wonder if it was a *Carya cordiformis*, perhaps a "mother tree." It was certainly a lot larger than any of the *C. cordiformis* I have found in this study. The remains of this Fran-downed pile are still visible today. On February 12, 2012, one trunk measured about 85 feet long and 15" DBH after 16 years.

Now, in Area 3, there are large trees east and west of the hurricane corridor, but in the corridor itself there are only a few species of fast growing trees and shrubs, Flowering Buckeye (*Aesculus sylvatica*), Silverberry (*Eleagnus unbellata*), and 75 Population I *Carya cordiformis* responding to the sudden opening of the canopy and the rain and flooding from the hurricane. The large blow-down occurred near the area where the soil changes from Nanford-Badin to Cid.

Area 2 (Piedmont Mafic Cliff) was also greatly changed by the opening of the canopy. Large trees, mostly oak (*Quercus* spp.) that shaded the rocky banks were downed, and both sides of "Bitternut Creek" became drier, most noticeably on the west side where all but two of the Spicebush (*Lindera benzoin*) growing there died and the many spring ephemeral wild flowers have yet to make a comeback. On the east side, two Population I *C. cordiformis* have appeared growing up through the rocks.

The northern parts of Areas 4 and 5 (Basic Mesic Forest) north of the Spreading Maple Tree were also changed when the hurricane wind crashed into the side of the hill and downed the large trees there, individually but not in a huge pile. There are now approximately 35 Population I *C. cordiformis* growing on the side of this hill in the hurricane area.

The hurricane opened up a big gap in the canopy in Area 1, Piedmont Alluvial Forest, near the (downed) Black Walnut tree. There are now about ten Population I *C. cordiformis* growing nearby.

The hurricane came in the first week of September 1996, and blew all the leaves and the green nuts off the Hickory trees at my house. The squirrels ate as many of the green nuts as they could right away, but the immature nuts rotted on or in the ground, and the squirrels quickly were without food for the winter. I am assuming the same thing occurred in the *C. cordiformis* areas, although the tannin in the nuts may have enabled them to last longer. For this reason, I am assuming that not many of the 1996 *C. cordiformis* crop of nuts, if any, were viable and that few germinated the following spring (1997). However, the later crops of nuts would have had a head start because so much of the canopy had opened up, and there may have been more water available.

In September 1954, Category 4 Hurricane Hazel downed large oak trees in Area 2. Their trunks persisted well into the 1990s and are still visible. The two

Population II *Carya cordiformis* in Area 2 could have grown up in response to this canopy-opening event.

Tornado

The tornado of March 29, 1991, passed close to the western boundary of Areas 3 and 4, blowing down large trees in my neighbor's yard. Some trees nearby were blown down, but I don't know if there was any damage in the Study Area itself. However, there could have been more light reaching these areas as a result. There are now 18 Population I *Carya cordiformis* growing near the western edge of Area 3 West that could have been a response to the canopy-opening by the tornado.

Ice Storms

Our area experiences an ice storm about every two years, where trees are downed or broken off at the top, leaving gaps in the canopy, especially in the pine-dominated areas. Recent major ice storms occurred in March 1993, January 1996, January 2000, December 2002, and December 2005. Isolated Population I trees scattered throughout the Study Area could have taken advantage of these canopy gaps.

Aside from the tornado, hurricanes, and ice storms, there are strong winds every year that drop dead trees and branches, or the dead tops of trees, especially in the drought, allowing more sun to reach the forest floor.

All these events have opened up the canopy and created conditions that *C. cordiformis* requires—light and water.

Pine Beetles

Area 5 (Basic Mesic Forest) was formerly a forest of about 30-year-old Shortleaf Pine, *Pinus echinata*, until the early 1990s, when an infestation of the Southern Pine Beetle, *Dendroctonus fontalis*, gradually eliminated about 90 per cent of the Shortleaf in that area, opening up the canopy. There are now 78 Population I and 14 Population II *Carya cordiformis* growing in this Area.

Most of the older (Population II) trees in this Area are growing at the edge of the "Bitternut Creek" floodplain (the northern border of Area 5). Two more are growing in or near the old roadbeds that mark the southern border of Area 5. Since Pine Beetles tend to invade trees on the edges of a forest, both the roadbed and the floodplain would have been more open to light in the past than the center of the forest.

Other species of pioneer trees have also grown up here, but there are more young *Carya cordiformis* in this Area than any one other species of tree. I usually don't see this unless the young trees are pines or Sweetgums.

The Influence of Land Use on the Location of Bitternut Hickory

When I first began locating *Carya cordiformis* in Area 3 (Piedmont Bottomland Forest), I noticed a rusted mid-20th century three- or four-strand barbed wire fence that was half buried and lying in the leaves on the ground, running west to east on the south-facing hill. I flagged it with orange flagging tape to keep myself from tripping on it or tearing my clothes. When I came back to mark the *C. cordiformis* in that area, it was obvious that they followed the old fence line, south of it, never north. I'm assuming this fence followed the edge of a former agricultural field because large pines are growing north of it. Seventy-five to eighty shade-intolerant *C. cordiformis* have grown up on this south-facing hill, a large portion of which was in the corridor opened up by Hurricane Fran.

Also in Area 3 on the north side of "Bitternut Creek" there is a large Rock Pile where apparently long ago rocks were cleared from the floodplain and piled on top of an outcrop too big to move, as if the floodplain was used (or to be used) as an agricultural field. Bottomlands, often flooded in winter and spring, were commonly farmed in summer. The floodplain obviously hasn't been used agriculturally in some time, given the size of some of the trees growing there now. There are three large Population III *C. cordiformis* growing in this part of the flood plain.

This Rock Pile is very close to, or at, the transition from Nanford-Badin to Cid soil. West of this Rock Pile on the Cid soil, the land is rocky and five Population III and the one Population IV *C. cordiformis* occur there. On the south side of "Bitternut

Creek" there is a smaller rock pile, slightly upstream, as if there might have been a plan to dam the creek. There is no evidence that this ever happened.

Most of the *Carya cordiformis* I have found are growing along old farm roads, the imprints of which are visible in the low winter sun or after a light snowfall. These areas were more open to the light after abandonment of the farm than they are now. I think all of the Population III and IV trees, the largest ones I found, are growing in--or by--old roads or in rock piles where rocks had been dumped from the edge of an agricultural field.

Most of these old roads have several roadbeds, having been moved one or more times, probably because they got too muddy. Most of these old roads have not been used for a long time, probably not since the mid-twentieth century, if then, given the era of the trash left behind.

How long can an old roadbed influence where a tree grows?

Old roads provide openings for sunlight and a passageway for birds and mammals who may disperse seed. The old roadbeds are lower than the surrounding landscape and hold or channel water, possibly washing away seeds that fall, but also holding moisture. The compacted soil of old roadbeds may discourage tree growth, keeping the area more open.

The several roadbeds of the old farm roads in the floodplain of “Little Bitternut Creek” (Area 1) bring a lot of water to the area from the surrounding hills. Except for a few trees growing on the creek bank, all the *C cordiformis* I found in this area are growing on the edges of, or near, these old roads.

Could it be ground disturbance as well as sunlight that influences where *C. cordiformis* grows? How long does a little tree wait for a gap in the canopy?

There is an old road near my house that was traveled occasionally until the 1950s and then used as a Jeep road by the hunting club until the early 1970s. It is on a hill on Pittsboro soil. A lot of water runs down this road during heavy rains and water collects in the ruts at the bottom of the hill where the land flattens out. There are still no trees of any kind, of any age, growing in this old road, even where it continues on flat land. A few *Eleagnus umbellata* are growing at the edges. There are trees on both sides, and the canopy is closed, for the most part.

The road that forded “Little Bitternut Creek,” which forms the southern boundary of Area 5, had also been used as a Jeep road by the hunting club until

about 1970, and was barely passable by a tractor in 1974. With close observation, this road can still be located on current satellite photographs. There are at least 36 Population I and two Population II *Carya cordiformis* growing in or on the edge of the remnants of this road on the west side of the creek, most on Pittsboro soil (Area 5) (Basic Mesic Forest). They range from 3/4" to 2 5/8" DBH.

The old roads have now become conduits that bring water to new areas and passageways for animals that may disperse the seed of *C. cordiformis*. The old fields have grown up in trees, providing food and habitat for animals. The transition from agriculture to forestry has allowed more *C. cordiformis* to grow up and become seed producers. There is less light until a blow-down occurs, but the forest holds more moisture, another requirement for *C. cordiformis* ,than the agricultural fields.

There are parts of three former farms in my Study Area. Almost all the *C. cordiformis* I found are growing on land that was part of only one of these farms. All of Areas 2, 3, 4, 5, and 6, and most of Area 1 were part of this farm, the land of which seems to have been intensely used for agriculture.

The poorly drained southern part of Area 1 on Pittsboro soil had been used as a woodlot and few young *C. cordiformis* have grown up there. Some of this land is rocky and has never been plowed.

A large part of the Study Area was part of another farm which was clear cut and converted to a pine plantation in the 1950s and was timbered in 2001. Most of this land has Georgeville soil. I didn't find any *C. cordiformis* on this former farm, not even growing in a small low-lying area of Pittsboro soil.

The few relatively isolated *C. cordiformis* growing in Pittsboro soil in the southern part of Area 1 are not located near old roads, but are growing near large "border trees" and a ditch that marked the boundary between two farms, a place that may have been more open to light in the past before pines grew up in the fields.

The largest *C. cordiformis* (Populations III and IV) are growing in places unsuited for agriculture, land that is too wet, too clayey, too steep, too rocky. Perhaps they have less competition from other trees in these areas.

Bitterness, Astringency of the Fruit

When I first began this project, studying Hickories (*Carya* spp.) in general, the most interesting phenomenon I noticed was that the "Pecan" Hickories, the lowland, swamp-dwelling, "water-loving" Section Apocarya--, *C. aquatica*, *C. cordiformis*, *C. illinoinensis*, and *C. myristicaformis*, were noted for having bitter nuts (with the exception of *C. illinoinensis*, Pecan, which has sweet nuts covered with a bitter, reddish, furry integument which readily separates from the seed coat of the nut). Anyone who has mistakenly tasted some of it, knows its bitterness. Actually, the taste is more astringent, like an unripe persimmon.

Is there a connection between the wetland habitats of these trees and the bitterness of their fruit? Does the bitterness help preserve the fruit during floods? Reduce mold and mildew? Deter predation? What is the bitter substance?

Bill Burke, Curator of the UNC Botany Library,[26] suggested that the bitter compound is juglone, an orange compound present in all species of the *Juglandaceae*, known to move from the roots to the leaves to the nuts in Walnuts, *Juglans* spp., and Pecans, *C. illinoinensis* (and presumably the not commercially important *C. cordiformis*) during the growing season. [27]

The late Don Stone of Duke University,[28] specialist in the Juglandaceae, thought the bitterness was not caused by juglone. He thought the bitterness might be to deter predation.

Walnuts and Hickories produce other compounds too: "Hickories (*Carya* spp.) contain high levels of phenolic compounds, including juglone, isoquercitrin, and condensed tannins; these compounds have been implicated in disease resistance. "[29]

The astringent taste of an unripe persimmon is caused by tannins, which are present in many trees and other plants, including *C. cordiformis*. These tannins move throughout the tree during the growing season, from roots to fruits, protecting the bark from fungi and bacteria, and the immature fruit from predation until ripe

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[26] Burke, Bill. Verbal communication. September 21, 2007.
[27] Borazjani, A., C.H. Graves, Jr., and P.A. Hedin. "Occurrence of Juglone in Various Tissues of Pecan and Related Species." Phytopathology, vol. 75, no. 12, pp. 19-21.
[28] Stone, Don. Verbal communication. October 1, 2007.
[29] Diehl, Susan V., Clinton H. Graves, Jr., and Paul H. Hedin. "Cytochemical Responses of Pecans to *Cladosporium Caryigenium* . . . " Phytopathology, vol. 82, no. 10, 1992, p. 1037.

and ready for dispersal.[30] The persimmon and other fruits then become sweet and tasty to attract animals, which disperse the seed.

The Bitternut and other lowland Hickories, however, retain the bitterness in their nuts even after they are (presumably) mature. The nuts are available in the fall of the year, preceding the winter, which is often the wettest time of the year. Perhaps the bitter tannins protect the seed from water until needed for germination in the spring. *Carya cordiformis* nuts experience embryo dormancy, require stratification, and remain viable for more than one year.[31]

The *C. cordiformis* nuts I put in a plastic mayonnaise jar, wrapped in a wet paper towel, showed no signs of mold for two years. Perhaps the bitter tannins protect the seed from mold, fungi, and other rotting agents present in a wetland environment.

How Old Are These Trees?

Several young *Carya cordiformis* were alive in 2009, but subsequently died in 2010-2012 because of the drought. I took slices of four of them to count their growth rings. The bark and some of the outside rings had worn or been eaten off, making it hard to count the rings accurately. I am assuming these trees died in 2011.

Table 11

The Ages of Four *Carya cordiformis*

Popula-tion	Tree #	DBH	Age in Years	Growth Rate	Year of Germination
I	---	7/8”	10	0.0875”/yr.	2001
I	---	1 15/16”	19	0.1020”/yr.	1992
	189	2”	25-26	0.08”/yr.	1985-86
I	136 This tree was 30’ tall.	3”	29	0.1034”/yr.	1982

[30] Diehl, Graves, and Hedin. Op. cit.
[31] Smith, H. Clay. Op. cit.

The average growth rate for these trees, 0.09323”/year, is much less than that quoted in Smith, H. Clay, "Bitternut Hickory," showing the influence of the recent drought:

> Second growth bitternut hickory on a good site in the Ohio Valley reached the following average heights and diameters:
>
> 10 yrs. – 2.0 in. – 10’ 50 yrs. – 9.2 in. – 62’
> 20 yrs. – 4.0 in. – 24’ 60 yrs. – 11.4 in. – 69’
> 30 yrs. – 6.0 in. – 40’ 70 yrs. – 13.0 in. [32]
> 40 yrs. – 7.6 in. – 52’

These numbers show a growth rate in DBH of 0.2" per year for the first 30 years, getting less until 50 years, and then increasing (average 0.1929"/yr.). In Appalachian hardwood stands in Pennsylvania, Hickories, in general, grow at a rate of about 0.12"/yr. DBH.[33]

Carya cordiformis in my Study Area could be comparable to those of the Ohio Valley, because, although there may be less water available, there could be adequate water, and the growing season here is longer due to lower latitude. Also, *C. cordiformis* is known as a fast growing Hickory. However, the average DBH for the four Population I trees that I sampled (DBH per year .0932”) is about half the average (48 per cent) for Ohio Valley and 78 per cent for Appalachian hardwood stands. These trees were not able to grow enough to maintain life. Their growth rate is not necessarily representative of those trees still living.

[32] Smith, H. Clay. Carya cordiformis, Bitternut Hickory, in Silvics of North America, Vol. 2.. Hardwoods. USDA, Forest Service. Agriculture Handbook 654, 1990.
[33] Ibid.

Table 12

Comparison of Tree #136 with Average Growth of *Carya cordiformis* in the Ohio Valley and Hickories, in General, in Pennsylvania Appalachian Hardwood Stands

Tree	DBH	Age	Height	Average DBH/Yr.	Average Height/Yr.
#136	3”	29 yrs.	30’	0.1034”	1.0344’
Ohio Valley	5.8”	29 yrs.	38.67’	0.2”	1.3333’
Appalachian Hardwoods	3.48”	29 yrs.	---	0.12”	---

I wanted to get a rough idea of the ages of the *Carya cordiformis* that are still living. I decided not to take cores from these trees because of the great stress they have experienced during the recent drought.

Because the rainfall in the past five years (2012-2016) has been within the 44” to 48” range for normal in the Piedmont, it seemed reasonable that the growth of these trees since 2012 could be a good average for estimating their age.

Rainfall 2012-2016 (five years)

2012	29.64”	
2013	43.99”	
2014	43.26”	Five-year average = 44.41”
2015	57.23”	
2016	47.94”	

In December 2016, I re-measured the circumference/DBH of 22 selected *C. cordiformis* that I could find relatively easily. These trees were originally measured in February 2012, four years ten months earlier.

Table 13

Growth Rate of Selected *Carya cordiformis*

February 2012 to December 2016

Popula-tion	Tree #	Area	Increase	DBH/yr.
I	1	1	0.0975”	0.0166”
I	2	1	0.1989”	0.0414”
I	3	1	No change	---
II	6	1	0.3183”	0.0663”
I	7	1	No change	---
I	9	1	0.0795”	0.0166”
I	13	1	0.1194”	0.2488”
II	18	1	0.4376”	0.0912”
II	23	1	0.1193”	0.0249”
II	26	1	1.2246”	0.2551”
II	41	1	0.9547”	0.1989”
I	43	1	0.5969”	0.1244”
III	47	1	0.9151”	0.1960”
III	53	2	0.7162”	0.1492”
II	56	2	No change	---
III	58	3-E	0.6366”	0.1326”
III	110	3-W	0.7162”	0.1492”
IV	112	3-W	1.3926”	0.2901”
III	113	3-W	0.3581”	0.0746”
III	166	3-W	1.1141”	0.2321”
III	200	4	0.2387”	0.0497”
III	209	4	1.2335”	0.2570”

Table 14

Growth Rates of the Four Populations of Selected *Carya cordiformis*, February 2012 to December 2016

Popula-tion	Number of Trees	Average Growth Rate	Average Rate of Four Populations
I	7	0.0640”/year	
II	6	0.1061”/year	0.15365”/year
III	8	0.1544”/year	
IV	1	0.2901”/year	

The trees all grew at different rates, with some in each population growing at rates higher than the average for the Ohio Valley, and some in Populations I and II not growing at all. The average rates increased with increasing DBH. The older trees may have been better poised to take up the water from the recent rains. They also may have better locations.

The average rate for the four populations (0.15365”/year) is close to the average of the growth rates of *Carya cordiformis* in the Ohio Valley (0.1929”/year) and Hickories, in general, in Appalachian hardwood stands in Pennsylvania (0.12”/year)—0.15645”/year. I think my averages are reasonable to use to estimate the ages of these trees considering the variety in their locations and access to water and light.

Population IV, tree #112 in Area 3 West, DBH 18.2630”, grew at a rate of 0.2901”/year (more than the average in the Ohio Valley). This tree is the largest *C. cordiformis* in my Study Area, and is located close to “Bitternut Creek” on the South, and a gully on the North, and could have taken advantage of the recent heavy rains. If it grew at 0.2901”/year for its whole life, it would be 63 years old. This tree looks much older than that. It has the thickened twigs of an older Hickory.

Population III, tree #166, DBH 14.1648”, also in Area 3 West, but not so close to “Bitternut Creek,” growing in rocks at a higher elevation, grew at a rate of 0.2321”/year. At that rate, the tree would be 61 years old. If it grew at the averaged rate, it would be 92 years old, a more reasonable estimate.

However, since the four populations of *Carya cordiformis* grew at different average rates, increasing with age, and since trees don't grow in DBH at the same rate from germination to maturity, I have used four different averages for the four populations to estimate their ages.

For Population I, I used the Population I average of 0.0640"/year. For Population II, I averaged the Population I average with the Population II average 0.1061"/year to get 0.0851"/year. For Population III, I averaged the rates for Populations I, II, and the Population III average of 0.1544"/year to get 0.1082"/year. For Population IV, I used the averages of the four rates, 0.15365"/year to estimate the age of the one tree.

Table 15

Possible Ages of *Carya cordiformis* Based on Averaged Growth Rates

Population Growth Rate	DBH 2012	Estimated Age 2012	Germination	Number of Trees
Population I 0.0640"/yr.	1/2"-3 3/4"	8-59 yrs.	1953-2004	263
Population II 0.0851"/yr.	4"-7 1/2"	47-88 yrs.	1924-1965	60
Population III 0.1082"/yr.	8"-13"	74-120 yrs.	1892-1938	20
Population IV 0.15365"/yr.	16 7/8"	110 yrs.	1902	1

All these trees are trying to recover from the stresses of the drought, and some may be growing more slowly than they would be otherwise. Some of the younger trees may be dying: they have growth rates that are quite a bit lower than the trees that died in 2011

The older trees have found good locations. When they first grew up, there was more light available than there is now because most of the land was open, in agricultural fields. There may have been less water available, except near the creeks, because there would have been more exposure to sun. The oldest trees have experienced extreme drought at least twice.

According to these estimates, Population IV, tree #112, may be younger than Population III, tree # 209, although it looks older. It may have grown faster because it is in a very good location.

Observations

Fan Moss (*Forsstroemia trichomitria* [Hedw.] Lindb.), an epiphytic moss in the family Leptodontaceae, (similar to *Leucodon julaceus*), is growing up the trunks of almost all the smooth barked trees, including *Carya cordiformis*, in the northern part of Area 1 (Piedmont Alluvial Forest) and all of Area 3 (Piedmont Bottomland Forest). It grows up their trunks, not at the base, mostly on the north side, but on some trees all the way around the tree. It is yellowish brown and curled up when dry; dark green when wet. It is very noticeable. It doesn't grow on the shaggy-barked trees—Cedar, Pines, Shagbark Hickory (*C. ovata*)—but on almost all the other hardwood trees in the bottomland areas.

This moss is very different from the mosses that grow on the Hickories and other trees at my house, which are generally only, or mostly, on the north side, and starting at the base. It is not growing on isolated Population I *C. cordiformis* Tree #1, or any other trees in that location.

I have also noticed that the leaves of *C. cordiformis* are more torn up at the end of the growing season than those of the other Hickories in my area. The leaves are dotted with holes, covered with small, black, teepee-shaped galls, hairy and spiny when opened, on the leaf itself, not on the veins, but often next to the veins. These galls look like Chinkapin pods when open. I think the insect responsible for this is probably the Pecan Leaf Phylloxera (*P. notabilis*), or the Southern Pecan Leaf Phylloxera (*P. russellae*), or both.

One of the first things I noticed about Bitternut Hickory, *C. cordiformis*, when I began locating them in 2009 was that they seemed more resilient than the Hickories at my house. After breakage or damage by the Twig Girdler (*Oncideres cingulata*) or other injury, they send out four to eight sprouts from the top or from the ground. They have a lot of buds close together at the ends of branches where they have broken or been cut off.

The Twig Girdler is active on Hickory trees in general. It makes a circular cut around a twig or the top or trunk of a young tree, causing it to die or break off and has removed the tops of many of the Population I *Carya cordiformis* in this study. Those that have survived the drought have produced four to five new sprouts in the girdled areas. I have never noticed this occurring in the upland Hickories near my house.

One *C. cordiformis* (Tree #108, 4 1/2" DBH) was broken in half with its top fallen over to the ground. It had grown at least four vertical sprouts from around the breakage. I have never seen this in other Hickories.

I have observed that the *C. cordiformis* in my Study Area leaf out about two weeks later in the spring, and keep their leaves at least two weeks or more longer in fall, than do other Hickories growing in the same locations. This is particularly noticeable in Area 1 (Piedmont Alluvial Forest), Area 3 (Piedmont Bottomland Forest) and Area 4 (Basic Mesic Forest).

In Area 1, isolated Population I Tree #1, easy for me to see, is growing near several Pignut Hickories (*C. glabra*) and Southern Shagbark Hickories (*C. carolinae-septentrionalis*) of similar size, making it very easy to compare. Tree #1 leafs out about two weeks later in the spring than these Hickories, and is still green in the fall when the other Hickories are brown or bare. There is also a possible *C. cordiformis-tomentosa* hybrid of similar size to Tree #1, growing in Georgeville soil, that leafs out and drops its leaves on the same schedule as Tree #1.

In Areas 3 and 4, near "Bitternut Creek," the *C. cordiformis* will still be in leaf after the leaves are gone on the *C. ovata* of the same size growing nearby.

In the spring, the Hickories near my house (*C. carolinae-septentrionalis, C. glabra, C. ovalis*, and *C. tomentosa*) often get hit by late frost after they have begun to leaf out. The flowers and new leaves get blackened, especially at the top of the tree, and the trees take a long time (sometimes six weeks) to recover. If *C. cordiformis* is not "tricked" by early warm spells, but waits until later to leaf out, that could be a factor in its being more hardy and having a more northern range than other *Carya* spp.

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