A survey of herbaceous plant species and communities at G.W. Hill Demonstration Forest using iNaturalist

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An Independent Study Project

Abstract

A two-year plant identification survey was conducted at G.W. Hill Demonstration Forest, which is owned by North Carolina State University and located in Durham county, North Carolina. The naturalist researcher used iNaturalist to document observations, which included geolocations and photographs. The data was curated on iNaturalist and the digital application was evaluated for benefits and drawbacks. It was found that iNaturalist was a simple and effective tool in gathering research grade data. There were some drawbacks observed when wireless capabilities were unavailable, or the geolocation data was sometimes inaccurate after synchronization. The data gathered in this study was used to create a brochure and plant checklist inventory for students and naturalists who use G.W. Hill Demonstration Forest. The presence of herbaceous plants was used to propose ecological designations to the plant communities at the site. Designations proposed include Piedmont Levee Forest, Mesic Mixed Hardwood Forest, and Basic Mesic Forest. These findings were reported to the NC Heritage Program.

Introduction

This project was proposed to complete the Native Plant Studies certificate program at University of North Carolina Botanical Garden. It consisted of a two-year, independent study project conducted in Durham county, North Carolina. It was conducted under the advisement of plant ecologist, Milo Pyne of NatureServe.

Study Area

Founded in 1929, the G.W. Hill Demonstration Forest is a teaching forest owned by North Carolina State University and operated through the forestry department. Located in Bahama, North Carolina in Northern Durham County, it spans 2,450 acres of land. The forest is

divided by the Flat River, which is a tributary of the Neuse River. While the Hill Forest land area is expansive, most of the research conducted was confined to the A and B blocks as visible on the Fig. 7 map.

Land History

Limited information is publicly available about this forest, although the land has been used to conduct many research investigations by students of NC State as reported on their website (North Carolina State University, ND). A study of the forest's vegetation and soil was conducted by John C. Nehmeth in 1968 from NC State's Department of Botany. Nehmeth described the climate in this area as humid mesothermal with most of the precipitation occurring between April and September. According to Nehmeth (1968), the study area elevation from 380 ft. to 640 ft. and is located on the Piedmont Slate Belt, which consists of mafic and felsic rock (Nehmeth, 1968). Previous soil testing indicated that soil was derived from granite or granoidiorite (Nehmeth, 1968). Nehmeth used five research stands to described approximately thirty-five tree species.

Hill Forest includes cabins for summer camp students studying forestry and conservation at Slocum Camp. All recreational use by the public requires permits including hiking, horseback riding, bicycling, fishing, and hunting. The cost of maintaining the camp and forest is financially supported through timber sales.

NC State's Piedmont Forest Work Crew provides the most easily accessed information regarding plant and animal species. Their website identifies nine trees, two birds of prey, and forty-one mammals. No herbaceous species are identified on their website, and few details of herbaceous plants were included in Nehmeth's 1968 report. Given that there was little information available, this research project was proposed to contribute to the overall knowledge

of the area's flora. This information may be utilized by students, researchers, and the public to learn about plant communities and the habitat contained in G.W. Hill Forest. To aid in gathering data, this project utilized a new computer application called iNaturalist.org to record data.

Purpose

The purpose of this research was conducted with the following goals: to create an inventory list of herbaceous plants growing at G.W. Hill Forest, to evaluate the use of iNaturalist in gathering botanical data, and to provide educational materials that can be used by students or the public to learn about the plant communities living in G.W. Hill Forest.

Method

Research at the Hill Forest site began on March 28, 2015 and continued until July 2017. A project page was set-up on iNaturalist.org at http://www.inaturalist.org/projects/hill-forest-herbaceous-plant-survey titled, Hill Forest Herbaceous Plant Survey. The application was downloaded onto an android phone. When a plant was identified, a photo was taken and uploaded to the app, which synchronized results with the online iNaturalist website. Plant identifications were typically performed only once, so frequency of plants was not recorded. The time, date, and geolocation was automatically pulled from the photo by the iNaturalist application. Only the independent study researcher and the advisor could post observations, but other iNaturalist users were able to comment, confirm, or disagree with plant identifications.

During evaluation of plant communities, the researcher took notes by hand of the dominant canopy and understory tree species. Herbaceous plants were recorded and compared with the geolocation findings on iNaturalist over the previous two-year period. Plant community associations were made utilizing books, governmental websites and with advising from Milo Pyne of NatureServe. Observations were mainly confined to blocks A and Blocks B (Fig 7.).

Results

iNaturalist provides multiple methods of obtaining research data. On the project page, the researcher could search for the number of observations and identifications they had made. Overall, 114 recorded observations were made that were marked as part of the Hill Forest Herbaceous Plant Survey as shown in Figure 1. 102 species were observed. The independent study researcher made 108 observations as shown in Figure 2. This consisted of 96 taxa including 102 species identified to the species level. There were 97 research-grade identifications at the species level. On iNaturalist, a research grade identification includes a date, geolocation, sound or picture, 2/3 agreement on the identification, and agreement by the community that it is in a probable location. A total of twenty people participated in the project observations by confirming or disagreeing with observations. Eighteen of these users were unaffiliated with the project organizers.

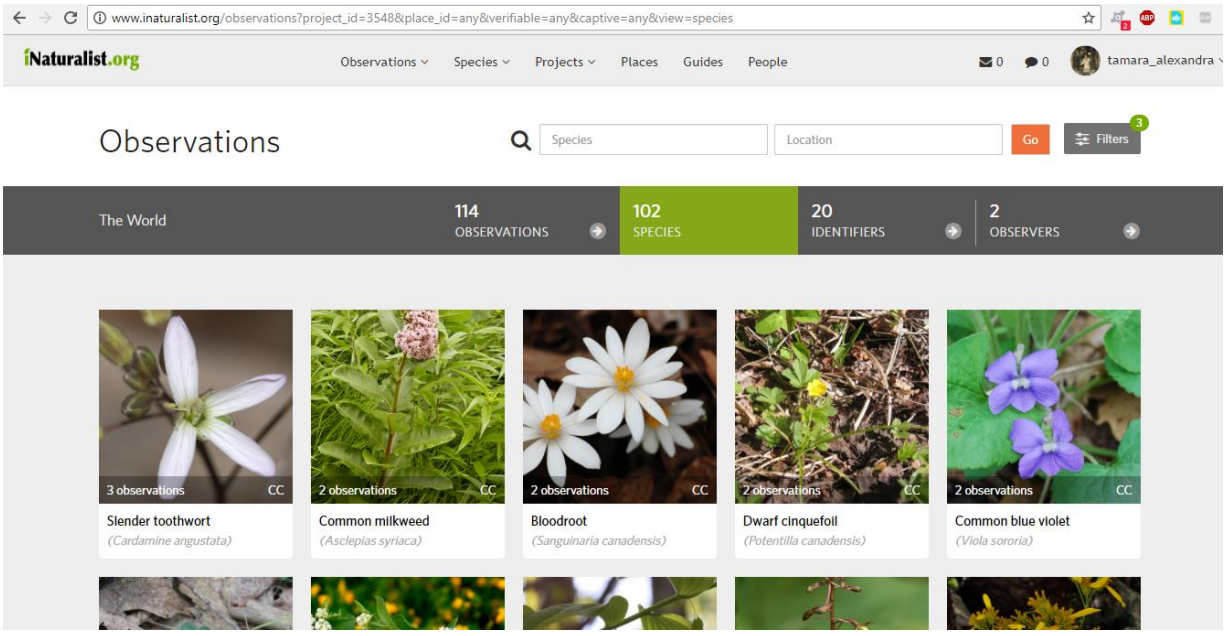

Figure 1. Overall Study Observations

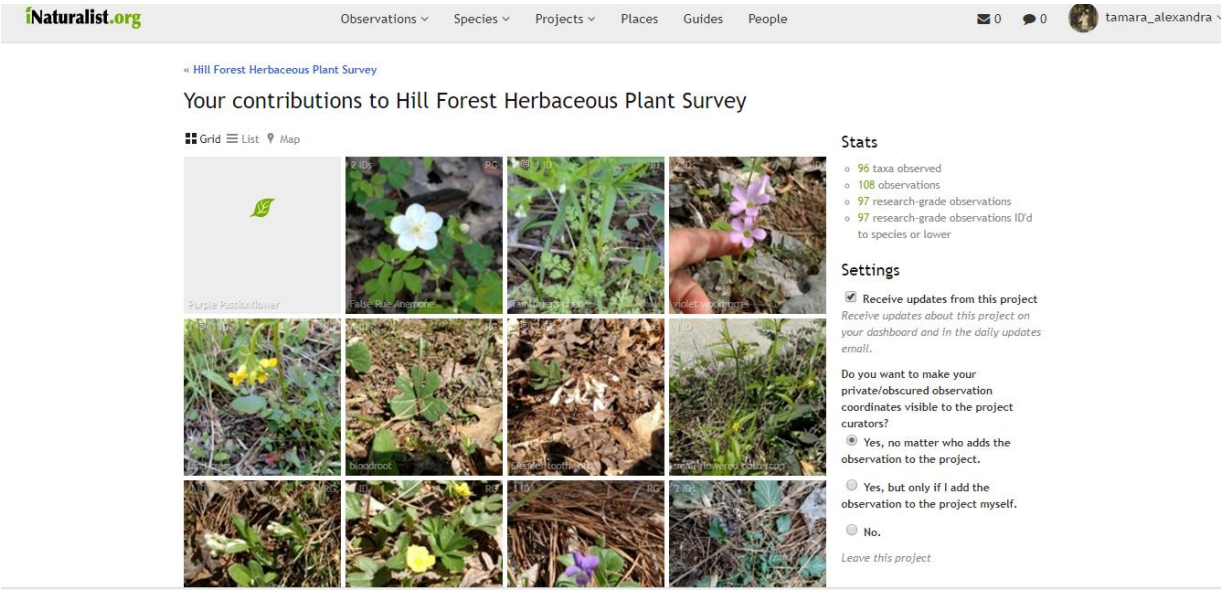

Figure 2. Observations by Independent Study Researcher

iNaturalist allows users to export data into a CSV file according to selected criteria. Below is an example after selecting eight columns of information. "ID Agree" includes the number of people who agreed with the species or taxon identification. "ID Disagree' logs the number times a user disagreed with an identification. This can be seen below in Fig. 3.

Date	ID Agree	ID Disagree	Latitude	Longitude	Scientific Name	Common Name	Taxon Family Name
3/28/2015	1	0	36.20153178	-78.88771992	Erythronium umbilicatum	dimpled trout lily	Liliaceae
3/28/2015	0	0	36.20224105	-78.88705168	Tipularia discolor	Crane-Fly Orchid	Orchidaceae
3/28/2015	2	0	36.20152692	-78.88726825	Heuchera	Alumroots	Saxifragaceae
3/28/2015	0	0	36.2015564	-78.88737755	Erythronium americanum	yellow trout lily	Liliaceae
3/28/2015	1	0	36.19953862	-78.8882796	Sanguinaria canadensis	bloodroot	Papaveraceae
3/28/2015	1	0	36.19919795	-78.88813528	Cardamine angustata	Slender toothwort	Brassicaceae
3/28/2015	0	0	36.199171	-78.88808	Cardamine angustata	Slender toothwort	Brassicaceae
3/28/2015	0	0	36.201544	-78.887432	Erythronium umbilicatum	dimpled trout lily	Liliaceae
3/28/2015	2	0	36.201502	-78.887467	Podophyllum peltatum	mayapple	Berberidaceae

3/28/2015	0	0	36.199667	-78.891943	Parthenium integrifolium	Wild Quinine	Asteraceae
3/28/2015	1	0	36.19916157	-78.8882562	Obolaria virginica	pennywort	Gentianaceae
3/28/2015	2	0	36.1980519	-78.88946203	Mitchella repens	partridgeberry	Rubiaceae
3/28/2015	1	0	36.19783147	-78.8898377	Viola sororia	common blue violet	Violaceae
3/28/2015	1	0	36.19797053	-78.89171607	Hypericum punctatum	Spotted St. John's Wort	Hypericaceae
3/28/2015	1	0	36.1982163	-78.89177113	Potentilla canadensis	dwarf cinquefoil	Rosaceae
3/28/2015	1	0	36.19816235	-78.89165008	Salvia lyrata	lyreleaf sage	Lamiaceae
3/28/2015	1	0	36.19849318	-78.89179035	Houstonia caerulea	azure bluet	Rubiaceae
3/28/2015	1	0	36.20042528	-78.8895706	Aquilegia canadensis	red columbine	Ranunculaceae
3/28/2015	0	0	36.20036408	-78.88968745	Lobelia puberula	Downy Lobelia	Campanulaceae
5/15/2015	1	0	36.20153178	-78.88771992	Houstonia purpurea	summer bluet	Rubiaceae
5/15/2015	1	0	36.20153178	-78.88771992	Maianthemum racemosum	false Solomon's seal	Asparagaceae
5/15/2015	1	0	36.20153178	-78.88771992	Oxalis stricta	common yellow woodsorrel	Oxalidaceae
5/15/2015	1	0	36.20153178	-78.88771992	Viburnum acerifolium	mapleleaf viburnum	Adoxaceae
5/15/2015	1	0	36.20153178	-78.88771992	Polystichum acrostichoides	Christmas fern	Dryopteridaceae
5/15/2015	1	0	36.20153178	-78.88771992	Amphicarpaea bracteata	American hog-peanut	Fabaceae
5/15/2015	1	0	36.20153178	-78.88771992	Uvularia perfoliata	perfoliate bellwort	Colchicaceae
5/15/2015	1	0	36.201128	-78.889642	Packera anonyma	Small's ragwort	Asteraceae
5/15/2015	1	0	36.20153178	-78.88771992	Verbesina occidentalis	Yellow Crownbeard	Asteraceae
5/15/2015	1	0	36.201128	-78.889642	Perilla frutescens	beefsteak plant	Lamiaceae
5/15/2015	1	0	36.20153178	-78.88771992	Eupatorium capillifolium	Dogfennel	Asteraceae
5/15/2015	1	0	36.201128	-78.889642	Pyrrhopappus carolinianus	Carolina desert-chicory	Asteraceae
5/15/2015	1	0	36.20153178	-78.88771992	Trifolium campestre	hop trefoil	Fabaceae
5/15/2015	1	0	36.20153178	-78.88771992	Penstemon digitalis	foxglove beardtongue	Plantaginaceae
5/15/2015	1	0	36.20153178	-78.88771992	Baptisia australis	Blue Wild Indigo	Fabaceae
5/15/2015	1	0	36.24684251	-78.88850873	Baptisia alba	White Wild Indigo	Fabaceae
5/15/2015	1	0	36.20153178	-78.88771992	Chimaphila maculata	spotted wintergreen	Ericaceae
5/15/2015	1	0	36.20153178	-78.88771992	Leucanthemum vulgare	ox-eye daisy	Asteraceae
5/15/2015	1	0	36.20153178	-78.88771992	Impatiens capensis	common jewelweed	Balsaminaceae
5/15/2015	1	0	36.20153178	-78.88771992	Saururus cernuus	Lizard's Tail	Saururaceae
5/15/2015	1	0	36.20153178	-78.88771992	Nuphar lutea	yellow water-lily	Nymphaeaceae
5/15/2015	1	0	36.20153178	-78.88771992	Phytolacca americana	American pokeweed	Phytolaccaceae
5/15/2015	1	0	36.20153178	-78.88771992	Chrysogonum virginianum	Green-and-gold	Asteraceae

5/15/2015	1	0	36.20153178	-78.88771992	Arisaema triphyllum	Jack-in-the-pulpit	Araceae
5/15/2015	1	0	36.20153178	-78.88771992	Athyrium filix-femina	lady fern	Athyriaceae
5/15/2015	1	0	36.20153178	-78.88771992	Lindera benzoin	northern spicebush	Lauraceae
5/15/2015	1	0	36.20016885	-78.88737755	Boehmeria cylindrica	false nettle	Urticaceae
5/15/2015	1	0	36.20153178	-78.88771992	Euonymus americanus	strawberry bush	Celastraceae
5/15/2015	1	0	36.199686	-78.888655	Geranium carolinianum	Carolina crane's-bill	Geraniaceae
5/15/2015	1	0	36.199686	-78.888655	Ranunculus bulbosus	bulbous buttercup	Ranunculaceae
5/15/2015	1	0	36.199686	-78.888655	Rubus flagellaris	Common Dewberry	Rosaceae
5/15/2015	2	0	36.19928	-78.887432	Lespedeza cuneata	Chinese bushclover	Fabaceae
5/15/2015	1	0	36.20016885	-78.876674	Vitis rotundifolia	muscadine	Vitaceae
5/15/2015	2	0	36.199307	-78.884626	Asclepias syriaca	common milkweed	Apocynaceae
5/15/2015	1	0	36.199686	-78.888655	Plantago major	greater plantain	Plantaginaceae
5/15/2015	2	0	36.19928	-78.887432	Securigera varia	purple crownvetch	Fabaceae
5/15/2015	1	0	36.201708	-78.88714	Thalictrum thalictroides	rue anemone	Ranunculaceae
5/15/2015	1	0	36.20018	-78.886273	Actaea racemosa	black cohosh	Ranunculaceae
5/15/2015	1	0	36.20153178	-78.88771992	Stellaria pubera	star chickweed	Caryophyllaceae
5/15/2015	1	0	36.2015564	-78.88737755	Verbesina occidentalis	Yellow Crownbeard	Asteraceae
5/15/2015	2	0	36.201128	-78.889642	Lonicera japonica	Japanese honeysuckle	Caprifoliaceae
5/15/2015	1	0	36.20016885	-78.88737755	Gamochaeta purpurea	Spoon-Leaf Purple Everlasting	Asteraceae
5/15/2015	1	0	36.204108	-78.876354	Triodanis perfoliata	clasping Venus's looking glass	Campanulaceae
6/1/2015	2	0	36.19958403	-78.89312548	Asclepias tuberosa	butterfly milkweed	Apocynaceae
6/1/2015	2	0	36.1994173	-78.89308955	Viburnum rafinesquianum	downy arrowwood	Adoxaceae
6/1/2015	2	0	36.1777915	-78.9039921	Acanthaceae	Acanthus family	Acanthaceae
6/1/2015	1	0	36.19849988	-78.8936532	Polygonatum biflorum	Solomon's seal	Asparagaceae
6/1/2015	1	0	36.19611555	-78.89145163	Elephantopus tomentosus	common elephant's-foot	Asteraceae
6/1/2015	1	0	36.1976687	-78.8915911	Aralia spinosa	Devil's Walkingstick	Araliaceae
6/1/2015	2	0	36.19863785	-78.89184245	Asclepias syriaca	common milkweed	Apocynaceae
6/1/2015	1	0	36.19894147	-78.8917948	Prunella vulgaris	Common Selfheal	Lamiaceae
6/1/2015	1	0	36.19974373	-78.89134245	Parthenium integrifolium	Wild Quinine	Asteraceae
6/1/2015	1	0	36.19968848	-78.89176632	Smilax rotundifolia	roundleaf greenbrier	Smilacaceae
6/1/2015	1	0	36.19962028	-78.89188968	Scutellaria incana	Downy Skullcap	Lamiaceae
6/1/2015	1	0	36.20004907	-78.8913267	Nuttallanthus canadensis	blue toadflax	Plantaginaceae

6/1/2015	1	0	36.20153178	-78.88771992	Verbascum thapsus	great mullein	Scrophulariaceae
6/1/2015	1	0	36.20020128	-78.88911683	Rudbeckia hirta	black-eyed Susan	Asteraceae
6/1/2015	1	0	36.20055725	-78.88879795	Mimosa microphylla	littleleaf sensitive-briar	Fabaceae
6/1/2015	1	0	36.20073008	-78.8886987	Achillea millefolium	common yarrow	Asteraceae
6/1/2015	1	0	36.19926602	-78.88780697	Scutellaria elliptica	Hairy Skullcap	Lamiaceae
6/1/2015	2	0	36.1996	-78.891	Rosa multiflora	multiflora rose	Rosaceae
7/24/2015	2	0	36.2015	-78.887	Vernonia	Ironweed	Asteraceae
7/24/2015	1	0	36.1996	-78.891	Aureolaria flava	smooth yellow false foxglove	Orobanchaceae
7/24/2015	1	0	36.19926602	-78.88780697	Clitoria mariana	Pigeonwings	Fabaceae
7/24/2015	1	0	36.19962028	-78.89188968	Sabatia angularis	Rosepink	Gentianaceae
7/24/2015	2	0	36.19962028	-78.89188968	Solidago	goldenrods	Asteraceae
7/24/2015	2	0	36.19962028	-78.89188968	Helianthus divaricatus	Woodland Sunflower	Asteraceae
7/24/2015	1	0	36.19962028	-78.89188968	Smallanthus uvedalia	bear's foot	Asteraceae
7/24/2015	1	0	36.19962028	-78.89188968	Chamaecrista nictitans	Sensitive Pea	Fabaceae
7/24/2015	1	0	36.199307	-78.884626	Eupatorium pubescens	Roundleaf Thoroughwort	Asteraceae
7/24/2015	2	0	36.1996	-78.891	Pycnanthemum tenuifolium	Narrowleaf Mountainmint	Lamiaceae
7/24/2015	2	0	36.19849988	-78.8936532	Goodyera pubescens	downy rattlesnake plantain	Orchidaceae
7/24/2015	1	0	36.20020128	-78.88911683	Ipomoea pandurata	Wild Potato Vine	Convolvulaceae
10/17/2015	2	0	36.029952	-79.052186	Persicaria sagittata	Arrowleaf Tearthumb	Polygonaceae
3/1/2016	1	0	36.20010975	-78.89158636	Mitchella repens	partridgeberry	Rubiaceae
3/1/2016	3	1	36.20142871	-78.88786116	Claytonia virginica	Virginia spring beauty	Montiaceae
3/1/2016	1	0	36.1999687	-78.88712105	Hedera helix	English ivy	Araliaceae
3/1/2016	1	0	36.19970307	-78.88773829	Anemone americana	round-lobed hepatica	Ranunculaceae
3/1/2016	1	0	36.19970309	-78.88773931	Tipularia discolor	Crane-Fly Orchid	Orchidaceae
3/1/2016	1	0	36.19955885	-78.8877879	Tiarella cordifolia	heartleaf foamflower	Saxifragaceae
3/1/2016	1	0	36.19952509	-78.88779999	Hexastylis arifolia	little brown jug	Aristolochiaceae
3/1/2016	2	0	36.19962183	-78.88777932	Geum canadense	white avens	Rosaceae
3/29/2016	1	0	36.19741174	-78.89188737	Viola sororia	common blue violet	Violaceae
3/29/2016	1	0	36.19975	-78.891749	Potentilla canadensis	dwarf cinquefoil	Rosaceae
3/29/2016	1	0	36.19899542	-78.89886864	Antennaria plantaginifolia	woman's tobacco	Asteraceae
3/29/2016	1	0	36.2003657	-78.888851	Ranunculus abortivus	small-flowered buttercup	Ranunculaceae
3/29/2016	2	0	36.2012878	-78.88817744	Cardamine angustata	Slender toothwort	Brassicaceae
3/29/2016	1	0	36.1754172	-78.8852965	Sanguinaria canadensis	bloodroot	Papaveraceae

3/29/2016	1	0	36.20025902	-78.88428043	Barbarea verna	land cress	Brassicaceae
4/11/2016	2	0	36.200183	-78.886809	Oxalis violacea	violet woodsorrel	Oxalidaceae
4/11/2016	1	0	36.20016885	-78.88737755	Chaerophyllum tainturieri	Tainturier's chervil	Apiaceae
4/11/2016	2	0	36.23804977	-78.89427994	Enemion biternatum	False Rue Anemone	Ranunculaceae
4/5/2017	1	0	36.19962524	-78.89190151	Polygonatum biflorum	Solomon's seal	Asparagaceae
7/13/2017	1	0	36.20016885	-78.89053885	Verbena urticifolia	white vervain	Verbenaceae
7/13/2017	1	0	36.20009084	-78.89151686	Hypericum hypericoides	St. Andrew's Cross	Hypericaceae
7/13/2017	1	0	36.2097213	-78.9180392	Hypericum perforatum	Common St. John's Wort	Hypericaceae
7/20/2017	0	0	36.200063	-78.888657	Passiflora incarnata	Purple Passionflower	Passifloraceae

Fig. 3 Data selected from iNaturalist

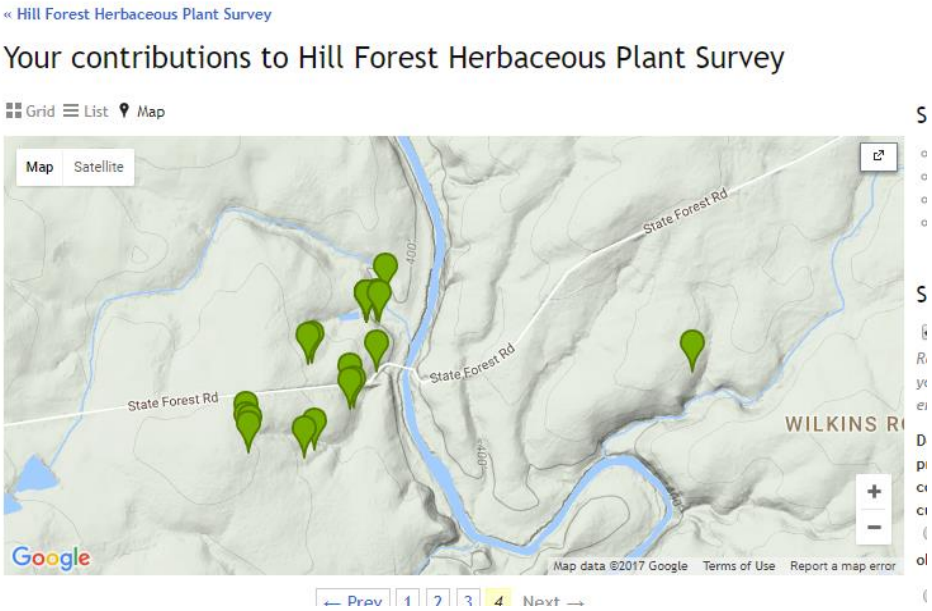

Figure 4. Geolocation Map of Observations

Data was collected on July 20, 2017 of various plant habitats. These included observations of tree canopy, understory, shrubs, vines, and herbaceous layer. Species beginning at trailhead block A and continuing Northeast included dominant canopy species of white oak (*Quercus spp*.), tulip-poplar (*Liriodendron tulipifera*), hickory species (*Carya spp*.), American beech (*Fagus grandifolia*), short-leaf and loblolly pines. Understory trees included holly (*Ilex opaca*), greenbrier (*Smilax rotundifolia*), red cedar (*Juniperus virginiana*), dogwood (*Cornus florida*), red maple (*Acer rubrum*), and musclewood (*Carpinus caroliniana*). Herbaceous layer

included hog peanut (*Amphicarpaea bracteate*), wintergreen (*Chimaphila maculate*), muscadine (*Vitis rotundifolia*), Christmas fern (*Polystichum acrosticoides*), perfoliate bellwort (*Uvularia perfoliate*), partridgeberry (*Mitchella repens*), and strawberry bush (*Euonymous americanus*). Forest edge species along this trail included rose pink (*Sabatia angularis*), St. John's Wort (*Hypericum perfoliata*), reclining St. Andrew's Cross (*Hypericum hypericoides*), and bear's foot (*Smallanthus uvularia*). The association of the above herbaceous species with the dominant canopy trees appears to reflect a Mesic Mixed Hardwood forest.

The B trailhead included many of the same species canopy tree species as the Mesic Mixed Hardwood environment, which was located on the opposite side of the road with the addition some herbaceous species. The upper, dry portion of the B1 tract trail edge included devil's walking stick (*Aralia spinosa*), round-leaved Thoroughwort (*Eupatorium pubescens*), and common milkweed (*Asclepias syriaca*). Herbaceous layer included Rattlesnake plantain, (*Goodyera pubescens*), and heal-all (*Prunella vulgaris*).

Descending down the slope from the B block trail, the mesic mixed hardwood forest changed in character. At lower elevation, dominant species included American beech (*Fagus grandifolia*) and tulip-tree (*Liriodendron tulipifera*). Understory species included sourwood (*Oxydendrum arboretum)*, white oak (*Quercus alba*), red maple (*Acer rubrum*), and musclewood (*Carpinus caroliniana*). The herbaceous layer of the forest floor included rattlesnake fern (*Botrychium virginianum),* lady fern (*Athyrium filix-femina*), Christmas fern (*Polystichum acrostichoides*), heart-leaf ginger (*Hexasylis arifolia)*, spotted wintergreen (*Chimaphila maculata*), black (*Actaea racemosa*), foamflower (*Tiarella cordifolia*), lizard's tail (*Saururus cernuus*). Also noted in this area in previous iNaturalist observations included bloodroot (*Sanguinaria canadensis*) and round-lobed hepatica (*Anemone americana*). The Eastern facing

slops behind Slocum camp also included a similar forest environment with the addition of jack-in-the-pulpit, mayapple, trout lily, Catesby's trillium (*Trillium catesbaei*), and slender toothwort (*Cardamine angustata*). Spring ephemerals in these two areas include spring beauty (*Claytonia virginica*) and meadow rue (*Thalictrum thalictroides*). The combination of the above species indicates possibly Basic Mesic Forest composition. These species could have alluvial associations, but the conditions occur on a slope.

Sycamore and tulip poplar dominated the canopy of the area adjacent to the Flat River. Other common tree species included red maple (*Acer rubrum*), black walnut, holly (*Ilex Opaca*), sweet gum (*Liquidamber styraciflua*), green ash (*Fraxinus pennsylvanica*), box elder (*Acer negundo*), buckeye (*Aesculus spp.),* paw paw (*Asimina triloba*), and American elm (*Ulmus Americana*). Spicebush (*Lindera benzoin*) dominated the understory. Herbaceous plants included *hexastylis arifolia*, false nettle (*Boehmeria cylindrica*), Christmas fern (*Polystichum acrostichoides*), and jack-in-the-pulpit (*Arisaema triphyllum*). Channels divided this area between separate landforms and showed evidence of frequent flooding. The association of sycamore tree with these herbaceous plants, and the existence of fluvial landforms, shows a similarity to levee forest.

Discussion

There were some clear benefits to using iNaturalist to gather data during the plant inventory at Hill Forest. First, it provided a simple way to record data without using multiple devices such as written record, camera, and a hand-held GPS device. This simplified the process of gathering data and contributed to the general ease of use. The application only required a smartphone with camera and wireless capabilities. The user can easily search by common or scientific name to locate the plant they have identified, or the user may select unknown species

to identify later. Each observation automatically included the GPS location, date, and time. The observation could then be added to the study project page to be included in the data set. The data from each area could then be used to look for trends to evaluate a possible plant community.

Another advantage to using iNaturalist is the data can be supported or refuted by other users. This provides additional credibility to the research data. If a specimen is observed in a location that is unlikely it can lose research grade status. The observer can flag an item that needs ID, and other users can propose a class, genies, or species. Users can propose a level of taxonomic classification, which is supported when another user agrees. If a disagreement occurs, the identification will revert to the previously supported level of classification. Users may also leave comments if they notice you have entered a duplicate observation, which allows the researcher to edit their information. When exporting data from iNaturalist, the user can select to include all observations, or only research grade data.

One drawback to using iNaturalist is the reliance on wireless data to upload data on-site. While conducting research, there were frequent interruptions in wife availability. When wireless outages occurred, some data was stored on the phone to be uploaded later. However, when the data synchronized at the later time, some of the information was lost or incorrect. Multiple observations recorded the GPS location of a site while driving away from the research location. In some instances, the time of the observation was incorrectly listed as a different time zone. To have accurate information in the data sets, it is necessary to review all the recorded data. This is best done using a laptop or desktop computer where the interface is more easily navigated than on a smartphone. Another drawback of using iNaturalist is the reliance on battery powered devices. Running smartphone applications and using a cellular phone's camera requires significant battery usage. Frequently, the phone's battery died while conducting research in the

field. A backup phone charger or additional battery is necessary for reliable connectivity, and a hand-held GPS device would be helpful as a back-up device. Many of the drawbacks of using iNaturalist originate from the cellular phones themselves and less so the application itself.

When evaluating dating from the plant communities, the results of the A1 and B1 blocks indicates a strong similarity to the Mesic Mixed Hardwood (Piedmont Subtype) as reported by the fourth approximation by the North Carolina Heritage Program (Schafale, 2012). While this area also includes dominant species such as tulip-poplar and pines, it is best defined as the ecosystem Southern Piedmont Mesic Forest as defined by NatureServe. These areas lack evidence of flooding, have an overstory of mesophytic hardwoods, and lack species that exist in higher pH soils (Schafale, 2012). The downward slopes adjacent to these stands may also exhibit a bluff variant form of mesic mixed hardwood due to the presence of Christmas fern (*Polystichum acrostichoides*), foamflower (*Tiarella cordifolia*), slender toothwort (*Cardamine angustata*), and dimpled trout lily (*Erythronium umbilicatum*) (Schafale, 2012) (Forbes et al., 2011). These mesic areas are most similar to the following categories:

CEGL006075	*Fagus grandifolia - Quercus (alba, rubra) - Liriodendron tulipifera / (Ilex opaca var. opaca)* Forest
CEGL008465	*Fagus grandifolia - Quercus rubra / Cornus florida / Polystichum acrostichoides - Hexastylis virginica Forest*

The lower elevations slopes below the B block and behind Slocum camp include many basic mesic species. This includes Pawpaw *(Asimina triloba*), musclewood (*Carpinus caroliniana*), black cohosh (*Actea racemosa*), foamflower (*Tiarella cordibolia*), Spicebush (*Lindera benzoin*), mayapple (*Podophyllum peltatum*), round lobed hepatica (*Anemone Americana*), Jack-in-the-Pulpit (*Arisaema triphyllum*), and bloodroot (*Sanguinaria canadensis*). It is also possible this is a bluff variant of the mesic mixed hardwood forest above (Schafale,

2012). However, there are multiple spring ephemerals present in these areas, and it should be evaluated in the Spring. It is possible that the density of these indicator plants is too low to define this as basic mesic forest. The presence of these basic mesic indicator plants have been reported to the NC Heritage Program. They plan to investigate these areas in the following Spring to consider if this is the basic mesic forest type.

The near Slocum camp directly adjacent to the Flat River consisted of tree species that indicated Piedmont Levee Forest including Sycamore (*Platanus occidentalis*), Box Elder (*Acer negundo*), American elm (*Ulmus americana*), beech (*Fagus grandifolia*), spicebush (*Lindera benzoin*) and sugarberry (*Celtis laevigata*). It is possible this, more specifically, Piedmont Levee forest of the Beech Subtype. Schafale's Fourth Approximation (2012) reports that this subtype can be differentiated from mesic forests that include *Fagus* due to the presence of alluvial species. These alluvial species included *Arisaema triphyllum*, *Claytonia virginica*, *Erythronium umbilicatum*, *Stellaria media*, *Enemion biturnatum*, *Polystichum acrostichoides*, *Verbesina occidentalis* and *Cardamine angustata*.

The last plant communities included consists of Roadside and Field as well as Forest Edge as described by Spira (2011). Woody species include devil's walking stick (*Aralia spinosa*), Sassafrass (*Sassafras albidum*), greenbrier (Smilax rotundifolia) and Virginia Creeper (*Parthenocissus quinquefolia*). Common herbs include Heal all (*Prunella vulgaris*), Fire pink (*Silene virginica*), Common Milkweed (*Asclepias syriaca*), yarrow (*Achillea millefolium*), and false Solomon's seal (*Maianthemum racemosum*), Rose Pink (*sabatia angularis*), round leaved thoroughwort (*Eupatorium pubescens*), Downy skullcap (*Scutellaria incana*), Indian tobacco (*Lobelia inflata*) and Bear's foot (*Smallanthus uvedalia*).

These disturbed areas provide meadow-like habitat best exemplified along Forest Service Rd. and the power-line clearing on the North side from block A towards the field next to Slocum camp. Species include common ragweed (*Ambrosia artemisifolia*), butterfly weed (*Asclepias tuberosa*), Small's ragwort (*Packera anonyma*), pokeweed (*Phytolacca Americana*), common St. John's wort (*Hypericum perforatum*), wild potato vine (*Ipomoea pandurate*), Columbine (*Aquilegia canadensis*), and Wild Quinine (*Parthenium integrifolium*).

The field between Slocum camp and the power lines in Block A provide a sunny, open area for grasses and meadow plants to thrive. Species observed here included foxglove beardtongue *(Penstemon digitalis*), false indigo (*Baptisia ausralis*), white indigo (*Baptisia alba*), purple coneflower (*Echinacea purpurea*), ironweed (*Veronia noveboracensis*), Sensitive Pea (*Chamaecrista nictitans*), passionflower (*Passiflora incarnata*), and wooly mullein (*Verbascum thapsus*).

Conclusion

After consideration of the possible plant communities found at Hill Forest, a brochure was created to assist students and researchers to observe plant species on the property (Figure 5). This two-page brochure is included at the end of this paper (Figure 5). These included Mesic Mixed Hardwood, Basic Mesic, and Piedmont Levee Forests. The proposed plant community designations were communicated to the NC Heritage Program of the Department of Natural Resources who will investigate these communities next Spring. iNaturalist was effective in creating research grade data for this project, and the applications benefits and drawbacks were discussed. In general, iNaturalist provided an easy method of documenting data, but it requires reviewing due to problems with accuracy when wireless capabilities are compromised. The plant

inventory was used to create a one hundred twenty-three species checklist for individuals to use when attempting to observe botanical species at G.W. Hill Demonstration Forest (Figure 6) .

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Appendix

Fig. 5 Plant Communities Brochure

Forest Edge

Figure 5. Sabatia angularis

Many flowering, herbaceous plants may be seen walking trails of Hill Forest where sunlight is able to reach the forest floor. Woody species include devil's walking stick *(Aralia spinosa)*, *sassafrass (Sassafras albidum)*, greenbrier *(Smilax rotundifolia)* and Virginia creeper *(Parthenocissus quinquefolia)*. *Common* herbs include Heal all *(Prunella vulgaris)*, Fire pink *(Silene virginica)*, *common milkweed (Asclepias syriaca)*, yarrow *(Achillea millefolium)*, and false Solomon's seal *(Maianthemum racemosum)*, rose pink *(Sabatia angularis)*, round leaved thoroughwort *(Eupatorium pubescens)*, downy skullcap *(Scutellaria incana)*, Indian tobacco *(Lobelia inflata)* and bear's foot *(Smallanthus uvedalia)*.

Roadside & Field

These disturbed areas provide meadow-like habitat best exemplified along Forest Service Rd. and the power-line clearing on the North side from block A towards the field next to Slocum camp. Species include common ragweed *(Ambrosia artemisifolia)*, butterfly weed *(Asclepias tuberosa)*, Small's ragwort *(Packera anonyma)*, Pokeweed *(Phytolacca Americana)*, common St. John's wort *(Hypericum perforatum)*, wild potato vine *(Ipomoea pandurate)*, columbine *(Aquilegia canadensis)*, and wild quinine *(Parthenium integrifolium)*.

Figure 6. Penstemon digitalis

Meadow and Prairie-Like Species

The field between Slocum camp and the power lines in Block A provide a sunny, open area for grasses and meadow plants to thrive. Species observed here include foxglove beardtongue (*Penstemon digitalis*), false indigo (*Baptisia ausralis*), white indigo (*Baptisia alba*), purple coneflower (*Echinacea purpurea*), ironweed (*Veronia noveboracensis*), sensitive pea (*Chamaecrista nictitans*), passionflower (*Passiflora incarnata*), and wooly mullein (*Verbascum thapsus*).

The GW Hill Demonstration Forest

is a 2,450 acre forest founded in 1929 as a teaching laboratory for North Carolina State University. It is currently used by forestry students, researchers,and the public for recreational use. It is located at 915 State Forest Rd. in Bahama, North Carolina.

Hill Forest

A guide to the plant communities

Figure 1. Baptisia alba

By Tamara Matheson - in completion of Native Plant Studies Certificate Program at University of North Carolina Botanical Garden.

For geolocation data, visit: http://www.inaturalist.org/projects/hill-forest-herbaceous-plant-survey

Plant Communities

Figure 2. Maianthemum racemosum

Mesic Mixed Hardwood Forest

This is best exemplified in Block A1 and the upper area of B1, which is dominated by tulip-tree (*Liriodendron tulipifera*), oak species (*Quercus spp.),* hickory species (*Carya spp.),* flowering dogwood (*Cornus florida*), American hornbeam (*Carpinus caroliniana*), red maple (*Acer rubrum*), and American beech (*Fagus grandifolia*). Understory trees include American holly (*Ilex opaca*) and strawberry bush (*Euonymus americanus*). Shrubs include maple leaf viburnum (*Viburnum acerifolium*) and downy arrowood (*Viburnum rafinesquianum*). Herbaceous plants noted in this area include Christmas fern (*Polystichum acrosticoides*), partridge-berry (*Mitchella repens*), Solomon's seal (*Polygonatum biflorum*), crane-fly orchid (*tipularia discolor*), perfoliate bellwort (*Uvularia perfoliata*), and downy rattlesnake plantain (*Goodyera pubescens*). The Mesic Mixed Hardwood forest changes in composition as the land grades downwards towards the creeks leading to the Flat River.

Figure 3. Arisaema triphyllum

Basic Mesic Mixed Hardwood Species

These areas are in the descending slopes of Block B and the East-facing slopes of Block A behind Slocum camp. These east-facing downward slopes includes a canopy of beech and tulip-trees with an understory of sourwood, red maple, spicebush (*Lindera benzoin*), and paw paw (*Asimina triloba*). The herbaceous layer includes hog peanut (*Amphicarpaea bracteate*), round-lobed hepatica (*Anemone americana*), Jack-in-the-Pulpit (*Arisaema triphyllum*), dimpled trout lily (*Erthyronium umbilicatum*), wild geranium (*Geranium maculatum*), foamflower (*Tiarellia cordifolia*), rattlesnake Fern (*Botrypus virginianus*), false rue anemone (*Enemion biternatum*), bloodroot (*Sanguinaria canadensis*), Catesby's Trillium (*Trillium catesbaei*), may apple (Podophyllum peltatum), black cohosh (*Actaea racemose*), (*Trillium catesbaei*), spotted wintergreen (*Chimaphila maculate*), and rue anemone (Thalicrum thalictroides).

Figure 4. Fluvial landform adjacent to Flat River

Piedmont Floodplain (Levee Forest)

The slopes descending to the Flat river grade into a floodplain with characteristics of Piedmont Levee forest. It includes a canopy of sycamore (*Platanus occidentalis*), tulip-tree (*Liriodendrin tulipifera*), box edler (*Acer negundo*), green ash (Fraxinus Pennsylvanica), and American Elm (Ulmus americana); an understory of musclewood (*Carpinus caroliniana*), sugarberry (*Celtis laevigata*) and widespread spicebush (*Lindera benzoin*). Herbaceous layer includes rue anemone (*Thalictrum thalictroides*), wingstem (Verbesina alternifolia), false nettle (*Boehmeria cylindrica*), jewelweed (*Impatiens capensis*), mayapple (*Podophyllum peltatum*), Jack-in-the-Pulpit (*Arisaema triphyllum*), Spring beauty (*Claytonia virginica*), arrowleaf ginger (hexastylis arifolia), and slender toothwort (*Cardamine angustata*).

Fig. 6 Hill Forest Plant Checklist

G.W. Hill Forest Plant Survey Checklist

p. 1

	Species (* non-native)	Common Name	Type	Blooming Times
	Achillea millefolium *	common yarrow	forb	April - July
	Allium vineale *	wild garlic	forb	May-June
	Actaea racemosa	black cohosh	forb	May- August
	Amphicarpaea bracteata	American hog-peanut	forb	August-September
	Anemone americana	round-lobed hepatica	forb	March-April
	Antennaria plantaginifolia	woman's tobacco	forb	March-June
	Apocynum cannabinum	hemp dogbane	forb	July-August
	Aquilegia canadensis	red columbine	forb	March-May
	Aralia spinosa	devil's walkingstick	shrub	June-September
	Arisaema triphyllum	jack-in-the-pulpit	forb	March-June
	Asclepias syriaca	common milkweed	forb	June-August
	Asclepias tuberosa	butterfly milkweed	forb	May-September
	Athyrium filix-femina	lady fern	fern	n/a

	Aureolaria flava	smooth yellow foxglove	forb	July-September
	Baptisia alba	white wild indigo	forb	Aril-July
	Baptisia australis	blue wild indigo	forb	April-July
	Barbarea verna *	land cress	forb	April-June
	Boehmeria cylindrica	false nettle	forb	June-August
	Botrypus virginianus	rattlesnake fern	fern	n/a
	Cardamine angustata	slender toothwort	forb	March-May
	Cardamine concatenata	cut-leaf toothwort	forb	March-May
	Centrosema virginianum	spurred butterfly pea	forb	June-August
	Cerastium fontanum	common mouse-ear chickweed	forb	June-August
	Chaerophyllum tainturieri	tainturier's chervil	forb	March-April
	Chamaecrista nictitans	sensitive pea	forb	July-Aug
	Cichorium intybus	chicory	forb	June-October
	Chimaphila maculata	spotted wintergreen	forb	June-Aug
	Chrysogonum virginianum	green-and-gold	forb	April-October
	Chrysopsis mariana	Maryland Golden-Aster	forb	August-October
	Claytonia virginica	Virginia spring beauty	forb	January-May
	Clitoria mariana	pigeonwings	forb	June-August
	Daucus carota *	Queen Anne’s lace	forb	June-August
	Echinacea purpurea	purple coneflower	forb	June-August
	Elephantopus tomentosus	common elephant's-foot	forb	August-November
	Enemion biternatum	false rue anemone	forb	March-April
	Erigeron annuus	annual fleabane	forb	May-August
	Erigeron strigosus	daisy fleabane	forb	April-May
	Erythronium umbilicatum	dimpled trout lily	forb	February-April
	Euonymus americanus	strawberry bush	shrub	May-June
	Eupatorium capillifolium	dogfennel	forb	August - October
	Eupatorium serotinum	late boneset	forb	September-November

G.W. Hill Forest Plant Survey Checklist

p. 2

Species (*non-native)	Common Name	Type	Blooming Times
Gamochaeta purpurea	spoon-leaf purple everlasting	forb	March-June
Geranium carolinianum	Carolina crane's-bill	forb	March-July
Geranium maculatum	wild geranium	forb	April-May
Geum canadense	white avens	forb	April-June

	Goodyera pubescens	downy rattlesnake plantain	forb	May-September
	Hedera helix *	common Ivy	forb	September-October
	Helianthus divaricatus	woodland sunflower	forb	July-September
	Hieracium venosum	rattlesnake weed	forb	May-September
	Hexastylis arifolia	little brown jug	forb	March-May
	Houstonia caerulea	azure bluet	forb	April-July
	Houstonia purpurea	summer bluet	forb	April-May
	Hypericum hypericoides	reclining St. Andrew's cross	forb	July-October
	Hypericum punctatum	spotted St. John's wort	forb	April-July
	Hieracium venosum	yellow star grass	forb	March-June
	Impatiens capensis	common jewelweed	forb	July-October
	Ipomoea pandurata	wild potato vine	forb	July- Aug
	Lespedeza cuneata *	Chinese bushclover	forb	July-October
	Leucanthemum vulgare	ox-eye daisy	forb	May-August
	Lindera benzoin	Northern spicebush	shrub	March
	Lonicera japonica *	Japanese honeysuckle	forb	June-October
	Lobelia inflata	Indian tobacco	forb	July-November
	Lobelia puberula	downy lobelia	forb	July-October
	Maianthemum racemosum	false Solomon's seal	forb	April-May
	Microstegium vimineum *	Japanese stilt grass	forb	August-October
	Mimosa microphylla	little-leaf sensitive-briar	forb	April-July
	Mitchella repens	partridgeberry	forb	May-October
	Nabalus altissimus	tall rattlesnakeroot	forb	August-November
	Nuphar lutea	yellow water-lily	forb	March-October
	Nuttallanthus canadensis	blue toadflax	forb	March-September
	Obolaria virginica	pennywort	forb	March-May
	Oxalis stricta	common yellow woodsorrel	forb	March-October
	Oxalis violacea	violet woodsorrel	forb	April-June
	Packera anonyma	Small's ragwort	forb	April-May
	Parthenium integrifolium	wild quinine	forb	June-July
	Parthenocissus quinquefolia	Virginia creeper	forb	May-August
	Penstemon digitalis	foxglove beardtongue	forb	April-June
	Perilla frutescens *	beefsteak plant	forb	August-October
	Phytolacca americana	American pokeweed	forb	July-October
	Plantago major	greater plantain	forb	June-October

	Podophyllum peltatum	mayapple	forb	March-May
	Polygonatum biflorum	Solomon's seal	forb	May-June

G.W. Hill Forest Plant Survey Checklist

	Species (* non-native)	Common Name	Type	Blooming Times
	Pseudognaphalium obtusifolium	rabbit tobacco	forb	July-October
	Pycnanthemum pycnanthemoides	Southern mountain mint	forb	July-September
	Pycnanthemum tenuifolium	narrowleaf mountainmint	forb	June-September
	Pyrrhopappus carolinianus	Carolina desert chicory	forb	March-May
	Ranunculus abortivus	small-flowered buttercup	forb	April-July
	Ranunculus bulbosus	bulbous buttercup	forb	May-June
	Rosa multiflora *	multiflora rose	shrub	April-June
	Rubus flagellaris	common dewberry	forb	May-June
	Rudbeckia hirta	black-eyed Susan	forb	June-October
	Sabatia angularis	rosepink	forb	July-October
	Salvia lyrata	lyreleaf sage	forb	April-May
	Sassafras albidum	sassafras	tree	March-April
	Sanguinaria canadensis	bloodroot	forb	March-April
	Saururus cernuus	lizard's tail	forb	May-August
	Scutellaria elliptica	hairy skullcap	forb	May-July
	Scutellaria incana	downy skullcap	forb	July-September
	Securigera varia *	purple crownvetch	forb	June-September
	Silene virginica	fire pink	forb	April-August
	Smallanthus uvedalius	bear's foot	forb	July-October
	Smilax rotundifolia	roundleaf greenbrier	shrub	March-May
	Sonchus asper	spiny sow thistle	forb	July-September
	Stellaria pubera	star chickweed	forb	March-May
	Stylosanthes biflora	pencil flower	forb	May-September
	Symphyotrichum pilosum	hairy white oilfield aster	forb	August-October
	Thalictrum thalictroides	rue anemone	forb	March-June
	Thaspium barbinode	hairy-jointed meadow-parsnip	forb	May-July
	Thlaspi arvense	field pennycress	forb	April-June
	Tiarella cordifolia	heartleaf foamflower	forb	April-July
	Tipularia discolor	crane-fly orchid	forb	July-September

p.3

	Trifolium pretense *	hop trefoil	forb	June-August
	Trillium catesbaei	bashful wakerobin	forb	April-June
	Triodanis perfoliata	clasping Venus's looking glass	forb	April-May
	Uvularia perfoliata	perfoliate bellwort	forb	March-May
	Verbascum thapsus *	great mullein	forb	June-November
	Verbena urticifolia	white vervain	forb	July-September
	Verbesina occidentalis	yellow cownbeard	forb	August-November
	Vernonia noveboracensis	New York ironweed	forb	August-September
	Viburnum acerifolium	mapleleaf viburnum	shrub	April-August
	Viburnum rafinesquianum	downy arrowwood	shrub	May-June
	Vitis rotundifolia	muscadine	forb	June
	Viola sororia	common blue violet	forb	March-May

Observations conducted from March 2015-July 2017 by Tamara Matheson in completions of Native Plant Studies independent study project for the UNC Botanical Garden. Geolocation, date, and photos of above observations available at: http://www.inaturalist.org/projects/hill-forest-herbaceous-plant-survey

p. 4

Fig. 7. Map of Hill Forest produced by Friends Of Hill Forest.