Land Analysis of a 33 Acre Parcel in Deerfield, NH

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Advisor: Mike Simmons
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Land Analysis of a 33 Acre Parcel in Deerfield, NH

Foreword

This project is a culmination of four years of undergraduate education and over two decades of growing up on my family’s property in Deerfield, NH. Since my childhood, I have been entranced by the minutiae, so I decided to write a series of vignettes as my thesis. This was a challenge for myself - to blend academic science writing with narrative storytelling - and uncharted territory in that I essentially made up the structure of my thesis. These mini-chapters were to capture the essence of my experiences with the woods as well as be a researched piece of science literature. I wanted to write about where the sun peeks through the canopy, into a pothole, and onto a piece of gravel that, despite being distorted by the silent flow of streamwater, still glimmers. I wanted to write about how the 10:00 sunlight in June drips like gold through the pinnates of cinnamon ferns fronds, and how the munches of slugs on mushrooms is indicative of its whole evolutionary timeline (Vendetti). I was pretty sure that if I spent enough time in the woods, I could eventually piece together the story of this land. But it turns out that intimacy does not equate full understanding. I spent days tracing the rock walls and looking at the canopy, but even with the help of GIS analysis, I could not make sense of the clues. One could say that I lost the forest for the trees - literally - but I also felt my heart stop in ways I could not if I didn’t spend time observing. Where else could I hear the raspy screech of a startled stag, or make searing eye contact with an adolescent bobcat, and smell the crisp morning dew mix with the sweetness of yellow birches.
Deciding on the scope of this project was a not-insignificant problem, and I have finally come to accept what Dr. Cohn told me the first time we met - that I have a book. Alas, I do not have the time nor bandwidth for a book right now, so many pages of my attempts do not make the cut of this thesis. That does not mean that they are wasted; they are just waiting. I did not expect to concede, but I also did not expect to find red pine trees, learn that the rocks in Deerfield are siblings to the rocks in Rabat, Morocco, or discover that there are six levels of fractalling in my mind (Allen, Smith and Hon). I definitely did not anticipate that conducting quantitative forest sampling would rewrite my understanding of these woods, but here we are. C’est la vie.
This satellite image is from the NH Indigenous Collaborative Collective. Please note that figure data layers references are located in the Works Cited and are not noted within the body of this piece. The maps, photos, charts, calculations, and simulations are all mine, but many figures show the use of layers and softwares (such as ESRI’s ArcGIS pro and the USFS’s FVS) that are not. Side note, the reason that some of the maps are made into nice layouts and others are not is because it is time for me to let this thesis go. This is my final academic 75%, and more than anything, I think this alone shows great growth.

To wherever the wind blows,

let me fly free,

and may this knowledge

never part from me.
Property Location, 18 Nottingham Rd. Deerfield, NH

Map Author: Chloe Gross, 2024
My family’s property is shaped like an hourglass and is draped over a funny-looking hill. Composed of 33 acres across multiple ecological communities, this property seems to be a collection of ecotones - gradient spaces where woods melt into fields and conifers smudge into hardwoods. Growing up I’d known that the perennial garden used to be a sheep barn, the cow path used to herd animals up the hill, and that the logging road was created in the 1990s. But it was only after spending a winter semester living at home - and consequently spending much more time exploring the property - did I decide to write my thesis on the history of this land.

The natural place to start was with the “inhabited” part of the property that includes the house, barn, gardens, rock walls, and apple trees. The house is cape-style, red brick (probably from the Boston area), and has a milk cellar with a capped spring (Zerbey, Santoro, Reber). The barn is a New England style barn with timbers fit with wood pegs. These were most likely milled at one of the various sawmills just down the road at the Lamprey River (Wikipedia Contributors, “New England Barn”, Dudley 772-778). There is a wagon with leather seating up in the hay loft, milk bottles and shards of glass under the barn, and rusty pulleys, nails, and handsaws that poke up in the garden each spring. Considering that I find almost anything to be quite interesting and therefore worthy of further research, investigating even just this aspect of the property would be Herculean, so I moved on to the history of the people who called this place home.

That did not turn out to be a simple venture either. Currently, this property is owned by Nancy and Erik Gross who signed the contract in 1998 (Historic Properties. Prior, these acres had been owned by a smattering of people, some of whom sliced off bits of the property to sell or keep as their own (Historic Properties). One owner tore down a wooden building - perhaps an original structure- adjacent to the brick house (Historic Properties). Another, maybe one of the Col. Hiltons, meticulously selected the locations of the trees surrounding the house - five maples (one red, four sugar), one southern-facing horse chestnut to provide spring shade and fall sun, and two spruces in the northwest corner to buffet the prevailing winds (Dudley 772-778).
Native Americans of the Abenaki people undoubtedly tread this property long before European colonists settled in the area in the early 1700s. Since the building of the Parade’s garrison, this particular property has seen European wealth, military officers, and families whose generations go back to the likes of John Winthrop, Governor Thomas, Reverend Samuel, Thomas Dudley, and Anne Bradstreet (“Town History,” Moore, Dudley 772-778). The brick house is not only unique to Deerfield today, but was a flaunt of opulence before the passing of New England’s sheep industry and farming communities (Dudley 772-778). Time is written in the old maples, the skid roads, and the fence posts, and the more I learn, the more questions I have.

Right now this property - primarily reforested farmland - is in the Town of Deerfield, County of Rockingham, and State of New Hampshire. This place is a 35 minute drive to Dover, 25 minutes to Manchester, and 35 minutes to Concord, but was once far enough from church at the Nottingham Square to warrant Deerfield’s incorporation as a separate town in 1766 (History of Nottingham, Deerfield, and Northwood, New Hampshire 1878). The Deerfield Parade was a drill location for Revolutionary militiamen, and then became a hub of business on the historical route from Portsmouth to Concord (Cogswell 404-408). Now the Parade is just marked by a hand-dug well and an American flag, but nearby are four hay fields remaining from Deerfield’s old ag roots, a cemetery with a wrought iron gate and precarious granite walls, and the final spires of what used to be a cathedral of sugar maple crowns.

Records show that the property at 18 Nottingham road was a long-time farm (Dudley 772-778). Colonel Joseph Hilton, born in Epping in 1747, lived at this property before he died in Deerfield in 1826 (Cogswell 404-408). Hilton served as a Lieutenant in the Col. Scannel regiment and was wounded at the Battle of Saratoga in 1777 (Cogswell 404-408). He reportedly owned many hundreds of acres locally and in Maine and various saw mills on the Lamprey (Dudley 772-778). He was a farmer, blacksmith, and sold flax-oil, and became quite wealthy after receiving his father’s numerous debts at age 18 (Cogswell 404-408, Vagen, “The Progeny
of Ensign Joseph Hilton” 299). It was likely he who built the brick house as such a structure was expensive. Two more generations of Joseph Hiltons were born in Deerfield, and then the property was sold to Stephen Prescott who was a farmer (Prescott, 233).

In learning about these lives, pieces of this property’s land use history started to come together. For a more “unbiased” record of the topography, I decided to look at historical USGS topographical maps. Below are nine maps that show general land use histories from 1919 through 2021 (USGS). This property lies in the middle of the triangle, extending down to the curve of the southernmost road. The brick house is the left of two boxes denoted above Nottingham Rd. In the first half of the 20th century, the area around the house appears to be entirely cleared, from below the house all the way to the Parade. Note that in the past 25 years, the lower part of the triangle has turned almost entirely into forest with little more than the fields remaining open. This checks out: by 1919, the sheep craze of the 19th century would have passed and with the transfer of property ownership, it is likely that some of the open land was abandoned (Wessels 41, “The Great Sheep Boom & Stone Walls”). Sheep were on the property, though, as evidenced by net-like barbed wire that was designed to keep the sheep within boundaries without ensnaring their wool (Schoenian). Given that the green portions of the triangle surround the marsh, are at steep elevations, or lie in boulderfields, it is unlikely that livestock would have ventured much further north than the crest of the big hill. There is barbed wire running on the property line from the bottleneck, along the fields, to the northeast corner. Usually barbed wire is on one side of trees or posts to prevent livestock from busting through the fence, but this is not consistently the case here (Wessels). There’s a sugar maple with five generations of barbed wire on the “fields” side but, a few posts down, the wire is on the “woods” side. There are also the remains of an old gate at the bottleneck. Here are some close-up satellite images of the property.
The area southwest of the house - just to the left of where the 450 foot elevation line meets Nottingham rd - is of particular interest because it demonstrates the passing of multiple stages of succession, or forest maturity. These USGS Topographic maps show the topography of the land and how its uses change over time.

Forested areas are shown in green and open land (such as for agricultural or residential areas) in white. Changes of color on the map indicate that something about the use of the land changed and therefore the appearance of the land itself changed. The early maps (1919, 1944, 1957) show that this lower quadrant is clear of forest even past the streamlet. Over time, the forest grew in and as shown on the 2021 map, now reaches Nottingham road and has started creeping up the hill.

This lower quadrant of the property is wet and thicketed with skinny hardwoods and deformed white pines. The canopy is thin and sunlight highlights the open floor. The various birch, bigtooth and quaking aspen, red maple, and white pine, are all early succession species, meaning that they thrive in full sunlight. Nearest to the road is a vernal pool that serves as a confluence of not only tributaries but biota too. This pool is trod by various wildlife including deer, moose, and fox, and hosts ducks, dragonfly larvae, and salamanders.
In April the pool teems with peepers; they create what I think is the most wonderful sound by which to fall asleep.

North of the pool the slope gently rises into an expanse that is relatively smooth, lacking the rolling hummocks that are created over generations. These “pillows” and “cradles” are formed as trees are windthrown, and, with their roots still attached, decompose into lumps of soil aboveground (Wessels 116-122). The open scar where the rootball once was slowly fills with leaf litter (Wessels 116-122). All forests accumulate some amalgamation of pillows and cradles, so their absence indicates that this area was once plowed, and has now grown in (Wessels 116-122). Rusted wagon wheels lean against a tree and old farm machinery poke out of the leaf litter.

Looking at LiDAR, there are clear marks across the slope of this lower hill, and below that, faint stripes on the upland just north of the vernal pool area (LiDAR NE). It is possible that this portion of the property could have been cultivated, but the adjacent stone wall does not sport a freckling of small rocks that indicates crop fields (Wessels 44). These would have been plucked and cast aside after each spring thaw. Gravity pulls the melted water down, picking up soil particles on the way, uplifting the rocks (Wessels 44). This happens because traditional crop fields are not covered with vegetation throughout the entire year because plant roots anchor the surrounding soil (Wessels 44). Since there are no small rocks on the walls, it can be assumed that the ground was continually vegetated and therefore did not contain annual crops. The last keys are a few old, crumbling apple trees that are the remains of an orchard. What was a patch of at least 40 in the late ’90s is now a scattered half-dozen and even these are being swallowed by the thickets.
This orchard was probably abandoned within the last 50 years because of the trees’ current appearance. Patchy canopy gaps created by the abandoned apple trees created perfect conditions for early-succession white pine trees, which are fast growers that thrive in full sunlight. Apple trees are usually relatively low to the ground, comparatively, for harvesting accessibility, and, at the height of right about where the last apple trees stand, these pines display spasms of branches competing for lead. Upon breaching the canopy, the white pine stems would have been exposed to full sunlight and a full world of pests. Native white pine weevils dine on the leading stems of young pines that grow in full sunlight (Wessels 43). The leading stem forms a tree’s structure, so weevil damage mars the stature of the whole tree. Other examples of white pine weevil damage are “wolf pines,” or pasture trees, whose leaders were mauled by weevils because the tree was growing in full sunlight on a rockwall or edge of a field, such as this 54 inch DBH stem (tree trunk diameter at breast height 4.5 feet (...for 6 foot men, but nose height for me, a 5’3” woman) (Wessels 43).

I thought that I was finished with this portion of the property, but then I found a stand of red pine trees. This discovery was entirely unexpected, as I had never come across or heard of red pines on this property. In my mind, they weren’t “supposed” to be here, because I had only known red pines to exist in sandy soils with blistering sunlight, namely the outwash sands of Bear Brook State Park across town (“State to Chop down Red Pines to Slow Insect Attack”). I didn’t realize until a month or so into trying to reconcile the red pines with my woods-view that it wasn’t just the trees that were making me angry; it was that I had never noticed them, which made me question whether I really knew these woods well at all.
The next distinct section of the woods is the patch of ferns and young hardwoods just north of the property's bottleneck. This covers the crest of the logging road, and, according to John Brooks, has evidence of surface draining on either side - to the southern vernal pool or northern marsh. This area has mild pillows and cradles and many stones of all sizes - gravel to boulder. This area also has a few cedars and junipers, which point to a history of grazing (Wessels 45). In the fall, the canopy is minimal, but the forest floor becomes a sunlit bath of yellow aspen and birch leaves.

Just beyond the crest of this hill is what, according to my mother, I used to call "the deep dark woods." And I would agree with that; the woods transition from sounding as crisp as the air feels, to muffled by a blanket of hemlock needles. Thick carpets of moss soften the skid road as it winds its way down the hill, passing through dewy stands of baby hemlocks, and rumpling over cut stumps. On the left is the property boundary and a streamlet - one that gurgles through rocks in June but sits stagnant in July - a perfect breeding ground for mosquitoes. To the right is the hill that suddenly seems sky-high. Only after emerging from the maze of saplings into the open understory does the magnitude of the hill become clear. I remember the hill feeling like an indomitable force when I was a kid, when my trips out back felt like voyeuring into a fantasy world armed with only bug spray (which, arguably, it still does). The hill is so steep and inconspicuous that I had never really explored it until about a year ago because it just looked like an extension of the midsize white pines and sporadic other trees of which I did not care to know. But as I was following single-track game trails around the hill and into the marsh, I saw a red pine, and then another, and then another, which soon turned out to be a necklace of red pine trees draped on the hill.
Oddly, these pines seemed to be at very similar elevations, but they were not positioned in rows, like a 1930s CCC red pine plantation would be, and they were not homogenous in size either (Butler). The southern red pine stand had 25 inch diameter trunks next to dead 4 inch diameter trunks, with many variations in between. This occurred similarly on the side of the hill, except these trees were lone or in small clumps, and seemingly littered around the hill. To try to understand this, I recorded the locations of these trees with a Garmin GPS unit. When I put these into ArcGIS, it looked like there was a necklace of red pines on the back of the hill, with the majority of the points speckled on the steep sides of the hill at slopes of up to 25%. The below figure shows the locations of red pine trees on this property (red dots) over the soil types (ESRI).

I found this situation odd and considering that these pines are sandwiched between a Lamprey River tributary and a strangely shaped hill, I decided to look to the ground. There are many layers to the Earth’s crust, and they are defined as “soil horizons.” Working from the top down, these include layers such as organic, topsoil, subsoil, parent material, and bedrock. The organic layer is what is generally visible in a forest: it is composed of leaf litter, decomposed plant and animal matter, and a vast array of insects and microorganisms. The topsoil, or soil organic matter (SOM), is what looks more like “dirt:” more sand, silt, and clay particles, mixed in with nutrient-rich particulate organic matter (POM) via decomposers. Some of this accumulates at the bottom of this layer via leaching as mineral
associated organic matter (MAOM). The subsoil has a much higher concentration of salts and is often referred to as mineral soil and contains chunks of the partially weathered rock layer below, called parent material. Parent material informs soil formation because it is the primary provider of minerals, salts, and nutrients, so understanding its history is critical to create soil classifications. The final layer is bedrock, which can come from volcanoes, seabeds, or squished continents.

First, I looked at this property’s soil composition, and it turns out that even the ground is complicated in this triangle. There are multiple soil classifications on this property, but the primary type is Montauk, which is a fine, sandy loam (“Montauk Series”). This hill was created by the Laurentide Ice Sheet in the most recent ice age, the Wisconsin Glaciation (Goldthwait et al. 19-22). This period ended about 12,000 years ago with the warming of the Earth’s climate and consequential retreat of the glacier, but it left behind all of the “stuff” it had picked up along its advance south. As this glacier moved, the ice (a mile thick and covering most of North America!) scoured the surface of the earth, grinding bedrock and trapping dirt and rocks in its mass. Upon retreat, the glacier melted faster than it advanced, all of that dirt and rock was compressed under the glacier, washed out in meltwater streams, or plopped on top of the landscape as ablation till and moraines (such as the islands near Norwalk, CT).

It so happens that this hill is a unique formation of glacial till, called a drumlin (Goldthwait et al. 19-22). This hill, and others nearby (such as the Berglund’s big hill), was formed by the accumulation of that till into a jumbled mass that got stuck under the glacier (Goldthwait et al. 19-22). As the glacier advanced and retreated, it compacted the hill and gouged out the sides, creating the steep slopes and teaspoon-like shape of the top of the hill (Goldthwait et al. 19-22). Though it is not known how drumlins form, people have known for centuries that many drumlins have deep, nutrient-rich soils that are conducive to farming (Goldthwait et al. 19-22). This drumlin, like many others, is classified by NH as “farmland of statewide importance,” just for that reason (“Important Forest Soil Groups”).
These Montauk are “unsorted,” which means that they have many sizes of rocks and stones interspersed within the many sizes of soil particles. Interestingly, all of the red pines on this property are located on these fertile soils. In this figure, the most fertile “IA” soils are shown in green and the red pine trees as red dots.
Just to make things more interesting, the triangle rests on a bubble of “metasedimentary and metavolcanic rock” that is surrounded by Concord Granite. Despite the metamorphic rock being an island within a sea of granite, it is actually the granite that is intrusive (“Igneous Rocks”). Intrusion is when magma inside the earth slowly cools over time. Extrusion would be the cooling of lava on the earth’s surface (“Igneous Rocks”). This bubble of metamorphic rock is part of the “granofels” lithology that is identified by the irregular structure of the rock particles and the lack of linear structures or distinct layers that look like stripes (“Granofels”). Concord Granite, as an igneous rock, is more resistant to weathering than the bubble of metamorphic rock underneath this property.

Speaking to John Brooks, a former mapper for the NH Department of Environmental Services and Shane Csiki, NH’s current State Geologist, they do not think that the underlying metamorphic rock at all relates to the formation of the drumlin or that the melting of the ice block could have created such extreme erosion conditions. But, they also were interested in seeing what my mostly-geologically-illiterate mind came up with, so here we are. I’ll be interested in what they have to say about these hypotheses.

I posit that as the Laurentide ice sheet progressed, it ground down the metamorphic rocks more than the more resistant igneous granites and quartzites, which the glacier mostly slid over. Upon meeting heterogeneity in the bedrock, such as an intrusive formation (for example, Saddleback Mountain), the movement of the till could have changed. If this were so, then some till could have become caught on an obstacle like an extrusive formation.
(Pawtuckaway) and created broad areas of IA soils. Or, due to the changes in speed/physics, till could have started accumulating into a mass that eventually resulted in a drumlin of compacted basal till with potentially a layer of dropped ablation till above nearby (Deerfield Parade). One part of my hypothesis is that the metamorphic bubble agitated the till under the glacier to result in the accumulation of IA soils oriented by the southeastern-moving glacier.

Brooks' 2005 surficial geology map shows a Pleistocene-epoch (Laurentide Glaciation-era) meltwater channel in the area that we now call the Lamprey. This map shows this meltwater channel as a purple arrow and label “fp 415-420.” This arrow curves sharply with the direction of the Lamprey. The map also shows a pink area titled “Freeses Pond Glaciofluvial-Glacisolucrine Deposits,” that originates from the Pleistocene, a geologic epoch that ended about 12,000 years ago with the retreat of the Laurentide Ice Sheet. These pink-coded deposits consist of sand pits, pebble layers, and “minor cobbles” that are often known colloquially as smooth, palm-sized river rocks and are found extensively in the upper Lamprey area.

Overlaid just north of the pink is a dark, curved line that shows where the back of a stagnant ice chunk sat as the glacier retreated north. This line is tagged with the numbers “415-420,” indicating the elevation (in feet) of the spillway. Interestingly, ice contact deposits were found on the northern end of the stagnant block at 525 feet in elevation.

The nearby Lamprey right now is more than just the meltwater channel; it includes tributaries from Northwood, Saddleback Mountain, and mucky-peat marshes in adjacent lowlands (shown in light purple). If the meltwater stream was created from the flow of the
stagnant ice block, why did the channel abruptly change directions and create a gouge in the landscape specifically at the southwest corner of the triangle? And why did the river, after tumbling down 18 feet in elevation over a boulder staircase, then ease its slope?

Again, this is entirely me hypothesizing and making assumptions.

I think this is due to the metamorphic bubble. The meltwater channel was relatively flat to the north where it was on Concord Granite, which is not easily eroded. Right around where the channel changes direction and begins to steepen is where the metamorphic bubble appears. Since metamorphic rock weathers more easily, I would guess that the channel followed gravity through the cracks between the granite and metamorphic bedrock or just created a nice gouge within the metamorphic rock itself. Then, after reaching granite again, the river slows.

This image shows Concord Granite in green and the metamorphic rock in pink with two foot elevation contours in gray. Highlighted are elevations 524 feet and above, which interestingly correspond with the southwestern end of the metamorphic bubble and the slope change from 15-25% slopes to 8-15% slopes on the 18 Nottingham rd drumlin.

Looking at LiDAR, the top of the drumlin looks suspiciously smooth and not just because it is a field. According to the 2005 map, this is basal till that was compacted and scraped over by
the glacier, possibly leading to a deluge of water and debris upon melting, at the same elevation of 525 feet that the ice contact deposits were found north of Freeses Pond. The elevations of 415-420 also correspond to when the smooth shape of the drumlin seems to meet the bumpy ground below. This lower ground also has basal till very shallow to bedrock (3.5 and 4 feet according to the 2005 map), which, since the top of the drumlin is also basal till, would indicate that there was significant erosion that washed away till and, by running through cracks in the metamorphic bedrock, created a bumpy surface made of the remaining chunks of bedrock.

This is visible on the other side of the Lamprey at similar elevations, with the river changing directions upon running into a higher-elevation wall of Concord Granite with a smooth layer of IA soils again at 525 feet in elevation. This leads me to think that the Lamprey could once have been much larger, or at least the impact of meltwater more significant than just tied to the channel. This figure shows blue lines at 522-526 feet in elevation and blue lines at 418-420 feet in elevation, which are similar to some slope changes in the forest soil types.

Returning to the topic of trees, my best estimate for the reason the red pines are on this property is that the steep, well draining, glacial, and acidic mineral Montauk soil created prime
conditions for their success. Red pines like well drained, sandy, acidic, mineral soils, and considering that the largest trees are about 90 years old (from the tree cores), it is most likely that the seeds were deposited in droppings sometime around the CCC red pine plantation era.

Rounding the tail end of the drumlin, the logging road disappears about where the hill starts to terrace into a low, wet, riparian strip before transitioning into a proper marsh. This property spills into the marsh and over the bank for a few dozen feet until hitting a rockwall boundary, but since the marsh is spongy with a decent channel in the middle, it is time to move east, rounding the bend and swell of the hill into a strip that is very wet, very stony, and rather hazardous. Here, it looks Lord of the Rings-esque - there are thickets of hemlock saplings to battle through, large windthrown pines to hurdle, roots that rest on stones, and stones who pose gaping holes in between. Looking to the right, the hill ascends, steep, and thick with dry pine needles so much so that it sometimes requires both feet and hands to grip. Unlike the westward-facing hillside, this back portion is severely pillowed and cradled. Stumps show the remnants of white pine and hemlock trees, some with 36 inch stumps.

Since the logging in the 1990s, the remaining stems - whatever was not valuable to the harvesting company - have grown to become the overstory. Some of the pillows and cradles are obviously results of left-behind logs, stumps, and slash, but there are other gouges that do not appear to have an accompanying decomposing trunks. Many of these pillows and cradles signify that the trees were blown down in the northwest direction, as a result of southeast winds. Given that this forest is now reaching
maturity almost thirty years since its last cut, it would not be unreasonable to posit that those white pines - early successional, fast growers - could have grown to great sizes in fifty years.

The 1938 hurricane blew through central New England from its genesis in the southeast Atlantic (Wessels 123-127). This hurricane threw, snapped, and otherwise felled timber quantities estimated to be over 2.6 billion board feet (Wessels 123-127). Hundreds of people died, infrastructure was destroyed, and although there was a massive timber salvaging effort coordinated by the US Forest Service, less than half of the valuable timber - mainly white pine - was salvaged (Wessels 123-127). Given that there are pillows and cradles indicating blowdown from a southeastern source, and that there are missing nurse log mounds in a prime environment for hemlock regeneration on nurse logs, and that white pines grow quickly, I think that there could have been some major blowdown and then salvaging of timber due to the 1938 hurricane.

After a major disturbance event such as a hurricane, a process such as secondary succession begins. In this situation, with the widespread removal of a dominant canopy, whatever is growing in the understory has a chance to grow. Montauk soils are very good for late-succession hardwoods such as maple, oak, and beech, and less so for pine softwoods and late-succession hemlock ("Montauk Series"). If an exposed patch of these woods were essentially clear cut by the hurricane, the fastest grower would be white pine, despite all present species theoretically starting on an even playing field. Although hardwoods and hemlocks would also sprint towards the overabundant sunlight, white pines would outcompete them for the dominant canopy, leaving them in a "suppressed" state.

Left untouched for 50 years, this back part of the property would have time to produce hefty, quality, straight-grained white pine sawlogs. The 1990s timber harvesters removed the best candidates, mostly white pine (from their stump decomposition) with just a few hemlocks, leaving behind the suppressed understory and any lower quality stems. Abundant sunlight returns, but this time, the late-succession hardwoods and shade-tolerant hemlocks have the
opportunity to grow into a mature canopy without any major competition. This results in the funny hodgepodge of birches, oaks, maples, conifers, beeches, and other random individuals that currently occupy the canopy. Any remaining canopy gaps have been filled in by surrounding trees or have created pockets for new saplings to seed. Thickets of beech, birch, and hemlock are common saplings right now. Hemlock, being shade-tolerant, can wait in the understory for several decades before having enough light to fully grow (Wessels 121). White pine nurse logs provide perfect habitats for the small hemlock seeds to root as during dead wood decomposition, and this patch of woods is a textbook example of white pine-hemlock nurse log commensalism in a Hemlock-Hardwood-Pine forest type (Wessels 121, Andreozzi). The linear sprouting of saplings on nurse logs are seen almost exclusively in hemlock forests. Hemlock saplings are the most shade-tolerant tree species in the northeastern region and its seeds grow well in moss, which is a primary substrate on decomposing nurse logs (Wessels 121). The pairing of pillows (nurse logs and root balls) and cradles (holes where the root ball used to be) indicates that there was a wind-thrown tree that has decomposed over time.
Continuing along the marsh at the base of the hill, presents a set of options. One, to continue straight, lungeing from boulder to boulder to a theoretically less-saturated upland. Two, round the bend of the marsh and follow game trails through hemlock and beech thickets to then jump over a clear-running inlet stream. Three, turn east to face an enchanting cascade of boulders to the left of the hill. The view from the bottom of the hill makes it look like these boulders simply came to a stop, resting on top of each other under thick blankets of moss, creating a boulder field that seems to ascend exponentially.

Not much more than non-tracheophytes (please don’t ask me what that means, my citation is Mike) and algae can grow here: the “soil” is nowhere to be found, only the sinews of yellow birch roots entwine the stones. Leaf litter collects between the rocks and roots, eventually decomposing into a spongy layer of organic matter. Treading lightly doesn’t quite cut it, it is wise to only step on flat rocks, thick roots and tree bases, and exactly where the deer trod not too long before. So easily could one perforate the thin film of fine roots, smack their skull on the quartzite granite, or snap their leg in a crevice which could also unsuspectingly serve as a bobcat den.

Hemlock saplings stand brittle in the rocks, unable to find adequate nutrients despite the constant trickle of water and verdant appearance. Only the yellow birch and an occasional striped maple sapling can exist in these conditions. Both of these species are primarily found in northern forests in New Hampshire, but cool, moist northern slopes can also provide enough shelter for these species to take root. Although commonly found in other hardwood and hemlock
forests, yellow birch seeds are rather picky with their choice of home turf. Physical and chemical limitations of sugar maple leaf litter inhibits yellow birch rooting, but as a moderately shade-tolerant species, yellow birch often sprout later in succession in beds of coniferous needles (Govatski).

Yellow birch seeds - which are only produced after about 30 years of age and reach maximum around age 70 - also often find habitat on nurse logs, stumps, and boulders (Govatski). Yellow birch seeds require contact to acidic, mineral soil, which, given the well draining nature of these surrounding unsorted glacial tills (that also leach a lot of minerals into their surroundings), is also found at this location (Govatski). A taproot keeps these birches upright while lateral roots wind in and around rocks, anchoring itself and everything else around it (Govatski). Few other species can exist in these conditions and the valley is just wide enough to provide a sliver of sunlight through the canopy gap. Without competition, these yellow birches have free reign over this corner of the property, with multiple trunks over 20 inches in diameter with numerous others nearby.

These birches and occasional striped maple provide habitat and food sources to pine siskins, warblers, broad-winged hawks, deer, foxes, porcupines, moose (Gabriel and Walters). I once came upon an adolescent bobcat sitting on the rock wall bordering the field, so I would not doubt that it could find a home around here (Gabriel and Walters). One particularly enchanting birch has hollow at the base of its 29.3 DBH trunk, and from a vantage point across the valley, it looks Winnie the Pooh-esque.
In trying to read this landscape, I had started taking tree cores. This involves a long, hollow rod with a bit, called an increment borer. Twisting it into the tree and extracting the core, I then counted the rings to estimate the age of the tree. I did this for multiple trees: two red pines, which only turned out to be around 90 years old, one white pine, a sugar maple with five eras of barbed wire sealed within the bark, an eastern hemlock that I estimated to have sprouted around 1850, and finally, one of the monstrous yellow birches. Yellow birches produce a chemical called methyl salicylate that, when a live twig snaps, effuses a wintergreen scent (Govatski). Considering that this tree was so old and I was coring the trunk, I didn’t expect to smell anything, but as soon as I extracted the core, the sweet, tangy scent was stronger than I had ever smelled it before - it was delightful, and somehow made the process of coring that tree in those woods even more sacred.

After much mounting, sanding, and squinting, I think the rings on the core amount to around 122. I did not reach the center, so my estimation of the total age of the tree (extrapolated from the 122 rings, 8.5 inch core length, and 23.0 inch DBH) is about 176 years old. The largest yellow birch I measured in the area was 29.3 inches in diameter.

Beyond this area was a corner of the property that I didn’t even know existed until sampling with Dad. It is upland, hosts multiple large boulders over four feet high and 10 feet long, and is an entirely different soil type. A few conifer stumps lie about, indicating that the cutting did not end at the boulder stream, but that they must have come from behind the marsh.
too, and some hefty oak and beech trunks. This far corner converges multiple rock walls and the barbed-wire fence posts that define the boundary through the rocks and up the hill to the fields.

Given the complexity of the woods on this property I finally decided to conduct a forest inventory. This gave me a quantitative picture of the tree species and structure composition of these woods that was more than just a “vibe check.” This procedure involves the use of multiple tools, namely a DBH tape and a prism. The prism is a piece of glass that is curved to a “factor” which it is calibrated to represent the amount of cross sectional basal area per acre that of all the trees counted would sum to.

20 factor prisms are good for sampling mature forest stands with many species and multiple age classes because it selects a good number of trees to get a representative sample at each plot without creating unnecessary labor of counting too many trees. Alternately, fixed radius plots are a pain because they require the measurement of each tree within a plot whose dimensions must be measured individually. For this property, I used the ArcGIS pro software to create a grid that would place one plot point on each acre of land. I chose this method instead of random sampling because I wanted a full picture of the woods on this property. Random sampling would scatter 33 points - the same amount per acre - all at different places, but would not guarantee an equal representation of the variable nature of these woods. A handful of plot points could end up in one particular area and none in a vast swath of the property because the likelihood of a plot landing in any part of the property bounds is equal. While all sampling data is a subselection and therefore cannot entirely represent the whole, it would be misleading to use randomly sampled data as the basis for understanding the property in total. This would be less of an issue if this property was homogenous in species composition and age structure, but, as discussed, these woods are highly diverse.
At each point, which we located using the ESRI map and geolocation app on my phone, I used a 20 factor prism to identify “in” and “out” trees. The prism precisely distorts the location of the tree at which it is pointed according to the calibration of the prism. When extended and looked through at eye level towards the tree, if the distortion appears to overlap with the actual trunk of the tree, it is counted as “in” and the measurement of its diameter at breast height (4.5 feet aboveground) (DBH) is taken. If the tree is “out,” then it is disregarded, whether or not one’s opinion about how well that tree may represent the stand. Depending on the location of the tree in relation to the plot center, a tree with a two inch width could be counted as “in” while a 20 inch trunk could be “out” just by a few feet of distance. There were instances where a two inch sapling was mere inches away from the plot center, and technically were “in” when viewed through the prism, so it was counted. Displaced trunks that are borderline to the real trunks can be counted every-other or calculated with 0.5 if more precision is required. If one wanted to delve into the world of “tree math,” one could use the Plot Radius Factor and DBH to calculate the Horizontal Limiting Distance, but that problem is not for today. Additionally, I recorded the DBH, species, live/dead status, plot number, and any other relevant notes.

Given that I had spent much time exploring these woods, I thought I had a solid understanding of the forest composition, but doing a quantitative sampling revealed how little I had seen. While I was correct in keeping tabs on the species richness (the number of species present in a community), I had not accurately estimated the amounts of those species. The
Forest Vegetation Simulator (FVS) is a product created by the US Forest Service to aid in stand projections based on the sampling of individual trees. It does a lot of math, produces a lot of tables, and creates lots of happiness for those who enjoy its 3D models.

One basic parameter is trees per acre - this includes the dominant canopy trees, suppressed understory trees, and saplings. It is important to remember that these numbers do not tell the whole story of these woods, these data are only informed by the conglomeration of individual trees caught by the prism. Nevertheless, broken out by species, eastern hemlock and red maple clearly dominate, and this is pretty consistent with what the woods actually look like. Black birch follows, but interestingly, white pine is not well represented in trees per acre, unlike my conceptual understanding of these woods.

![Graph showing trees per acre by species for Deerfield, NH stand](image)

The discrepancies in my understanding qualitatively versus quantitatively are well explained in the next figure: basal area per acre by species, which represents how much square footage of wood each species makes up per acre. Here, eastern hemlock still dominates, but the basal area of red maple sharply drops compared to the trees per acre. This tells us that though there are many individual red maple trees, they are not large in diameter and therefore have less basal area.
To visualize this more literally, see the simulation image below.
FVS shows us a pretty good 3D representation of the tree composition - species and stand structure - from the sample. We see that there are numerous coniferous trees in the canopy and a few dominant deciduous trees. This makes sense in terms of the land use history and the geography of the area, particularly the logging in the 1990s and the cool, north-facing slope.

Something we look out for in science is how representative the sample is of the whole. When looking at this FVS projection, I can see some stark differences than what the forest looks like in real life. Take the cluster of dead saplings at the bottom left part of the model. There is no stand that looks like that, but at the plot point, a small dead sapling was counted “in” and so was included in the stand inventory and therefore informed the FVS projection. It is important to note that sampling does not lend an entirely accurate representation of a whole, no matter how precise the data may be. And though this model represents the forest composition by virtue of its sampling and therefore not a full picture of what the forest actually looks like, it is still a highly useful tool in forest management. Below are 25-year projections based on the data I collected. Note how the canopy remains mostly coniferous (dark green) and that many of the “suppressed” middle-canopy deciduous trees (light green) turn into dead wood (brown sticks) as they are out-competed.
But what this visualization didn’t show me was the essence of the forest. Even with the luck of catching one of the huge birches in my sampling, the data could not show me the Shirley Temple curls of yellow birch bark or the iridescent rainbows of tangled roots around blocks of untouched quartz. I pursued An Answer to my questions, but that kind of incomprehensible finale doesn’t really exist. It was only after looking back at all of the pieces I had found that I realized that there is no key to the puzzle, but many small pieces. Those seemingly disparate glimpses allowed me to learn a little more about this property’s past.

And isn’t that what science is about? Science does not “prove” anything - it reduces uncertainty. Our capacity for this is unlike any other time, but it is all still in pursuit of clearing the muddy water, bit by bit. So even though the end never really existed, my search was not in vain. I may never know the full story of this land, but I do know that I can speak to its history with a whole lot less uncertainty than I ever could before.
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