Designing a resilient apple:
a landscape design approach

A Design Thesis

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Abstract

Malus domestica (the apple) is a historic and culturally important fruit that has been cultivated and bred for specific qualities, reducing its genetic diversity, and making it susceptible to pests and disease. This thesis promotes a landscape architecture approach to improve apple resiliency through the creation of novel apple orchards that are simultaneously productive, experiential, and educational. These apple orchards could shift public perception of apples and perhaps persuade people to demand variety and growing standards that promote biodiversity, improving resilience of the apple. South Hill Cider in Ithaca, NY serves as a case study site, offering a model of how the orchard typology could be adapted to propagate novel apple cultivars, apply and test emerging methods of management and maintenance, and engage customers in advocating for a more resilient future for the apple.

Acknowledgments

I would like to start by thanking Assistant Professor Anne Loftin Weber. From the early stages of my research and conception of this thesis, Anne's passion for agricultural landscapes served as a constant source of inspiration for me. Throughout the process of creating this document Anne always seemed to know when I needed a push, a virtual pep talk, or a few minutes to share stories about our children. I am grateful for the steady hand Anne brought to this project, and the constant belief she had in me to get it done.

I raise a glass of cider to Steve Selin, founder and owner of South Hill Cider. Steve was not only willing to have his property be the testing ground for this thesis, he was delighted to share any information I asked of him. Steve's comfort with exploring new ideas, experimenting, and going all in on a project is what makes South Hill Cider a special place and it's what gave me the confidence to put forward some radical ideas. I hope this thesis serves a purpose as South Hill Cider continues to grow and bloom in the future.

I cannot forget to acknowledge my classmates and the support they provided me. Despite the pandemic sidelining in-person meetings, the occasional text, phone call and accidental meetings in studio rejuvenated my spirits, allowed me to hear that I wasn't alone in my struggles and ensured me that we were in this together. Thank you.

Lastly, and most importantly, I would like to thank my wife, Rachael. For 16 weeks, while I sat staring at computer screens, Rachael was working full-time, raising our 2 year old, growing our new baby due in June, cooking meals, and performing all the household tasks to keep our family above water. In addition to all of this, she supported me through the low points of my school work and brought energy and laughter into our home every day. Without Rachael, this thesis would not have been possible.

There are so many more people to acknowledge who have educated me, provided support, inspiration and much needed critical feedback. For the long list of people whose names are not written here. Thank you.

Table of Contents

Introduction

Agriculture has a critical influence on planetary health. According to the Intergovernmental Panel on Climate Change Fifth Assessment Report, agriculture and land use account for nearly 25% of all anthropogenic greenhouse gas (GHG) emissions (IPCC, 2014). Conventional agricultural practices also have a well-documented effect on soil degradation and soil erosion. In addition, agriculture is the largest contributor to global biodiversity loss (Dudley et al., 2017).

Agriculture's impact on planetary health is changing the climate and degrading ecosystem functions. Adopting more sustainable, regenerative agriculture methods will play a key role in preventing the most severe change, but science hypothesizes that some of the changes to climate and ecosystems cannot be reversed (IPCC, 2014). Therefore, we also need more resilient food crops that will be able to remain productive despite both known and unknown changes in their climate and ecosystem.

The genesis of this thesis was an interest in designing alternative food production methods that improve resilience. In 1973, ecologist C.S. Holling, coined the term "resilience" when describing ecosystems. Holling (1973) described resilience as "a measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables." Although Holling used the term to describe the characteristics of a system, the term can also be applied to individual organisms.

Considering the size and complexity of the food system as well as the constraint of a 16-week academic semester, this thesis focuses on improving the resilience of one food crop, *Malus domestica* (the apple). The apple was chosen as a pilot crop because it is a perennial crop requiring long-term investment and planning. This multi-year time frame makes it a candidate for planning and design to create an optimal situation. In addition, the apple is a well-known fruit that is grown locally in New York state, especially in Central and Western New York.

The following pages of this thesis cover five main sections. The first section reviews the history of the apple as well as its present-day challenges. The second argues the critical role landscape architecture can play in creating a more resilient apple. The third defines the three questions that drive this thesis inquiry. The fourth section describes the site selection process to test design concepts. Finally, the fifth section proposes a design for the site, guided by a set of design tools.

Background

Complete apple genome sequencing has confirmed two leading hypotheses about the origin of *Malus domestica*, the domesticated apple grown for human consumption (the apple). First, the apple originated in the Tien Shen mountains of Central Asia as *Malus sieversii*. Second, during the process of domestication *Malus sieversii* acquired genes from several different apple species, such as *Malus sylvestris* endemic to Europe and *Malus orientalis* endemic to Caucasus, to create the apple (Wang et al., 2018).

The process of domestication is estimated to have begun over 4000 years ago, around 2000 B.C.E. Trade routes like the Silk Road traveled through the Tien Shen mountain range in Central Asia (Apple, 2021). Travelers would discover *Malus sieversii*, eating the apples and taking them on the road since they kept well. *Malus sierversii* was dispersed across Europe and Asia, cross breeding with crab apple species native to these regions, creating hybrid species (Wang et al., 2018). As a heterozygote the apple was able to adapt to new climates and soils over time. Along the journey, human selection for the largest and tastiest apples already began to shape the apple of the future.

The discovery of the grafting process to propagate apples allowed humans to further control the selection of specific apple qualities and clone apple varieties to prevent alteration (Pollan, 2001). Humans recognized certain apple varieties had desirable fruit that would not always be present when the seeds from that variety would be planted. However, if small cuttings from apple tree varieties bearing desirable fruit were grafted onto other trees, the desired fruit traits would remain the same. As new, seed planted, apple varieties with desirable traits were discovered, they were propagated through grafting techniques to preserve the variety, effectively halting evolution, but satisfying human desires.

Colonization and global trade exponentially increased the number of domesticated apple varieties that were notable enough to be recorded and documented. European colonists and early settlers brought the apple with them to the New Worlds (Jentsch, n.d.), planting the tree in almost every continent across the globe. Most apple trees were planted from seed due to transportability and adaptability. In North America, Native Americans quickly adopted the apple, distributing and planting it throughout the Northeast (Wilson, 1905). For early settlers on the American frontier, growing apples for cider was a necessity because it provided a safe drinking source that can be stored for long periods of time (Pollan 2001). All this planting from seed and hybridization with endemic *Malus* species led to thousands of new varieties.

Policy, consumer preferences, and technology created the circumstances that substantially reduced the number of apple varieties in circulation, decreasing genetic diversity within the species. Technological improvements in transportation and mechanical agricultural tools allowed farmers to specialize in apple production and expand their operations while still having outlets to sell product (Jentsch, n.d.). In the United States, cider's dominance as the preferred drink in the diminished as other grain-based alcohols, like beer, became widely available and safe sources of drinking water are established (Kerrigan, 2014). In 1920, the Prohibition Act made all alcohol illegal, including cider, making thousands of apple varieties no longer useful. The Prohibition Act and a growing demand from consumers for dessert apples led to the apple industry re-branding itself for dessert apple production. The phrase, "An apple a day keeps the doctor away" is coined as a marketing tool (Pollan 2001). This consumer shift further refined the selection criteria for apples to be sweet, durable, uniform, and aesthetically beautiful. Only apple varieties that met this narrow set of criteria were grown. The apple has had over 16,000 documented varieties, according to Daniel J. Bussey (2016). Of the 5,000 varieties the USDA has permanently stored, only about 700 are commercially available. Thirty-one apple varieties are advertised in New York State. 9 apple varieties account for 80% of production in the United States. The Malling family of rootstocks is used on approximately 90% of all commercially grown apple trees globally (East Malling Research, 2014).

This decrease in apple diversity and disruption of evolution through clonal propagation has reduced the resilience of the apple (Pollan 2001). The apple is now susceptible to large number of pests and disease because the plant species does not have a large and varied set of adaptive traits to use to overcome stressful changes. In 1880, New York State's Agriculture Experiment Station at Cornell was established, in part to accelerate apple research on pest and disease because of their negative effect on apple production (Sutor, n.d.). The apple research program has continued since then because of persistent threats to this economically significant crop. An uncertain future holds even more challenges for the sensitive human-created apple. With a long history, global presence, and the apple's cultural and economic significance to humans, humans have a responsibility to grow apples with ecological as well as economic incentives.

Figure 1. The apple's journey to New York State

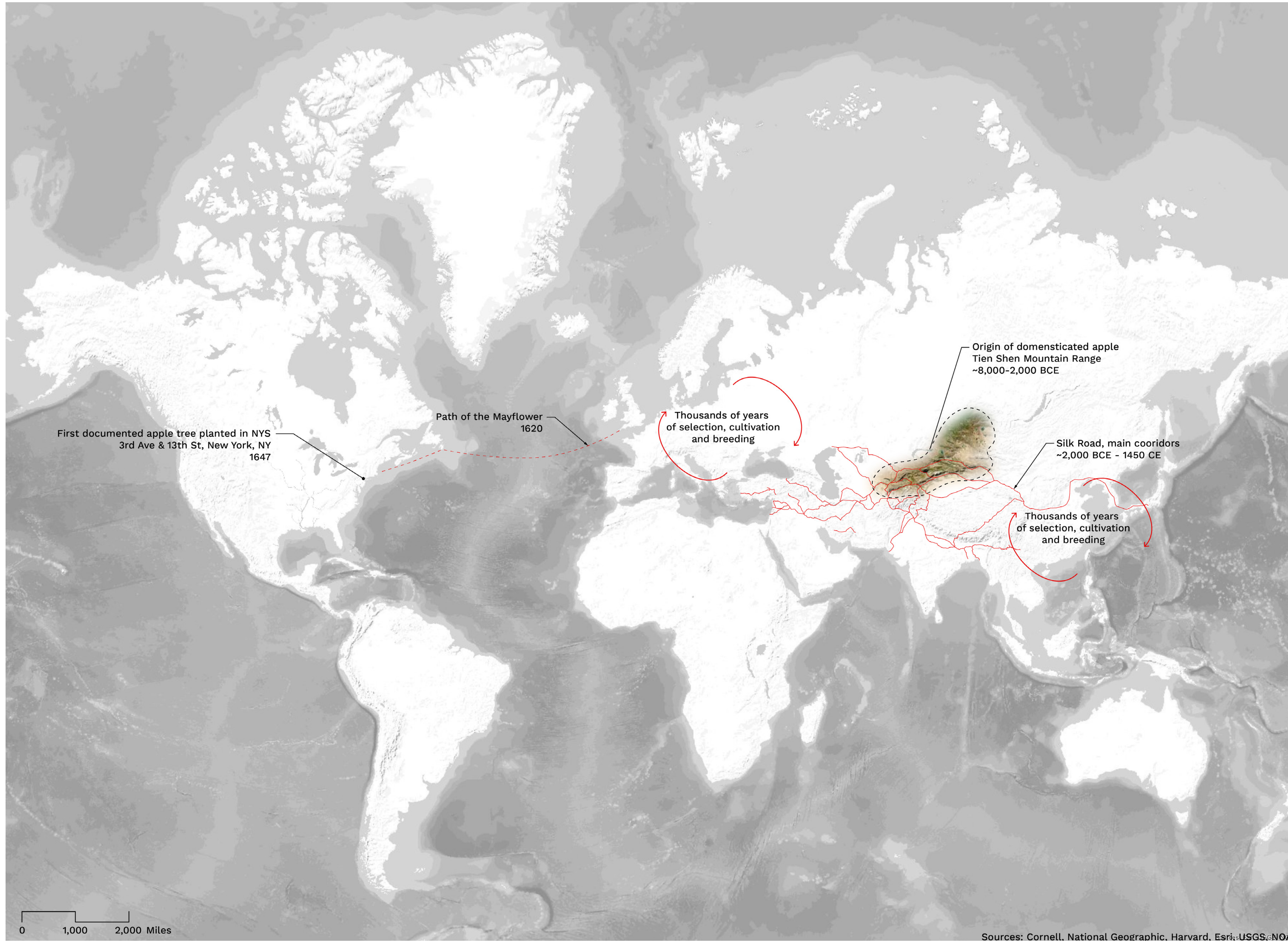
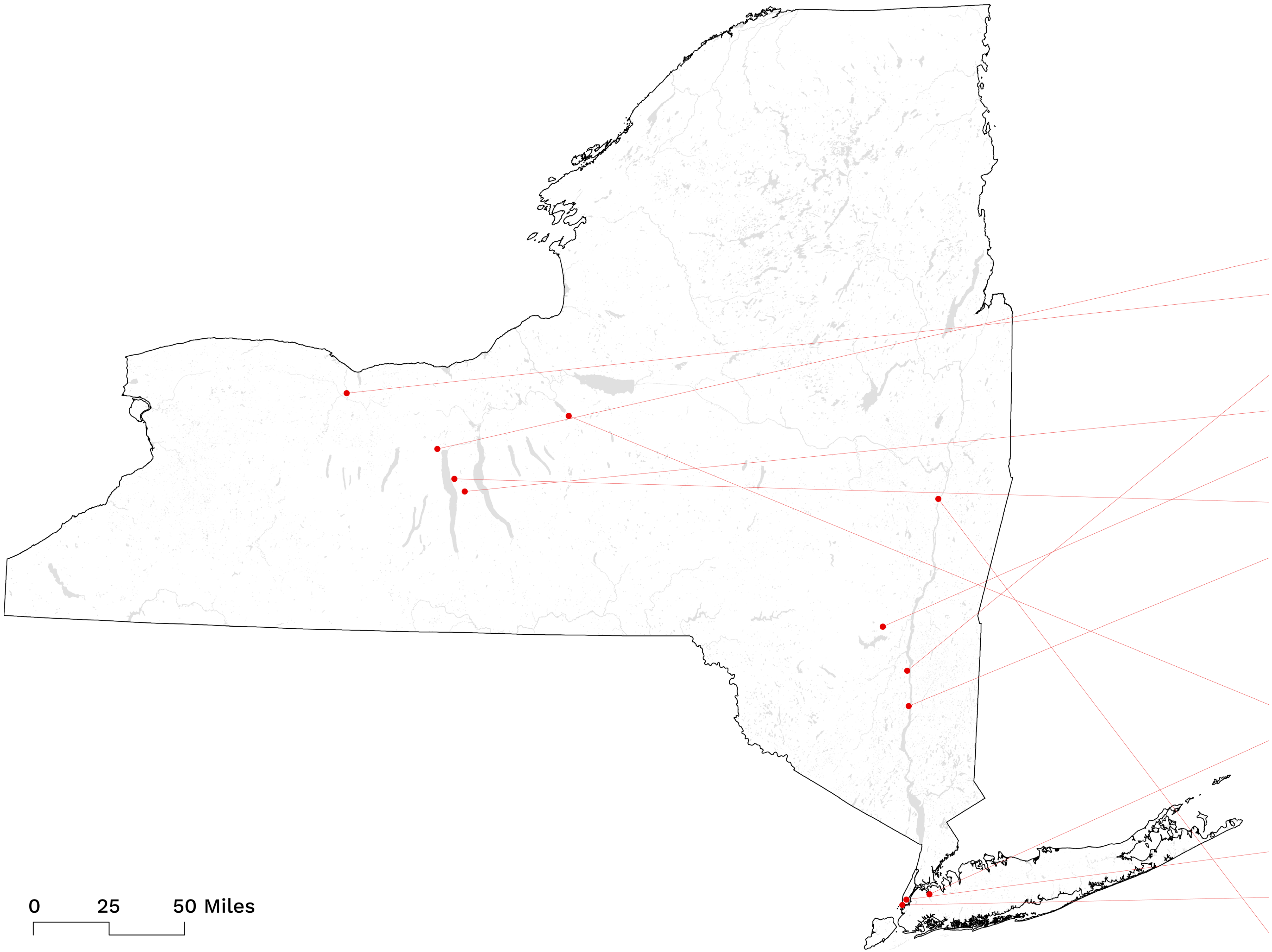


Figure 2. A brief history of the apple in New York State



2020 Approximately 22 apple varieties are grown commercially in New York State

1976 New York declares the apple as the State Fruit

1941 Commercial controlled atmosphere storage begins in New York State

1933 Twenty-first amendment ends prohibition.

1920 National Prohibition Act enforces prohibition in the United States.

1905 "Apples of New York" by S.A. Beach describes 1,000 varieties of apple existing in New York State at the time.

1875 18,278,636 apple trees documented in New York State Census, covering almost 1% of all land in the state.

1870 New York State Agriculture Experiment Station is established.

1839 Mount Hope Nursery established by George Ellwanger and Patrick Barry.

1825 Erie Canal is opened, giving apple producers along Lake Ontario and Lake Erie access to a larger market.

1820 Robert Pell establishes first designated commercial apple orchard in Eastern NY.

1800 Fayette, Ovid and Farmersville become hotspots for apple production for next 50 years.

1800 Jonathan Hasbrouk discovers the "Jonathan" apple variety near Woodstock, NY.

1791 Elkanah Watson describes Kendaia, a former Onōdowa'ga:' (Seneca) village known by colonists as "Appletown", as having extensive old orchards on a "fine tract of land"

1790 "Farmer's Turnpike" becomes one of the first designated public roads near present day Newburgh, NY.

1780 Settlers are required to plant orchards as part of their land claims.

1779 Sullivan Campaign. Major General John Sullivan and Brigadier General James Clinton, under the orders of U.S. President George Washington, destroy more than 40 Haudenosaunee villages, their croplands, orchards and food stores.

1748 Asa Danforth planted first documented apples in Western New York.

1730 Prince Family Nursery/Linnaean Botanic Garden is founded by Robert Prince. Became the largest supplier of fruit trees in the "New World", producing most of the grafted apple trees in Northeast. Existed until 1869.

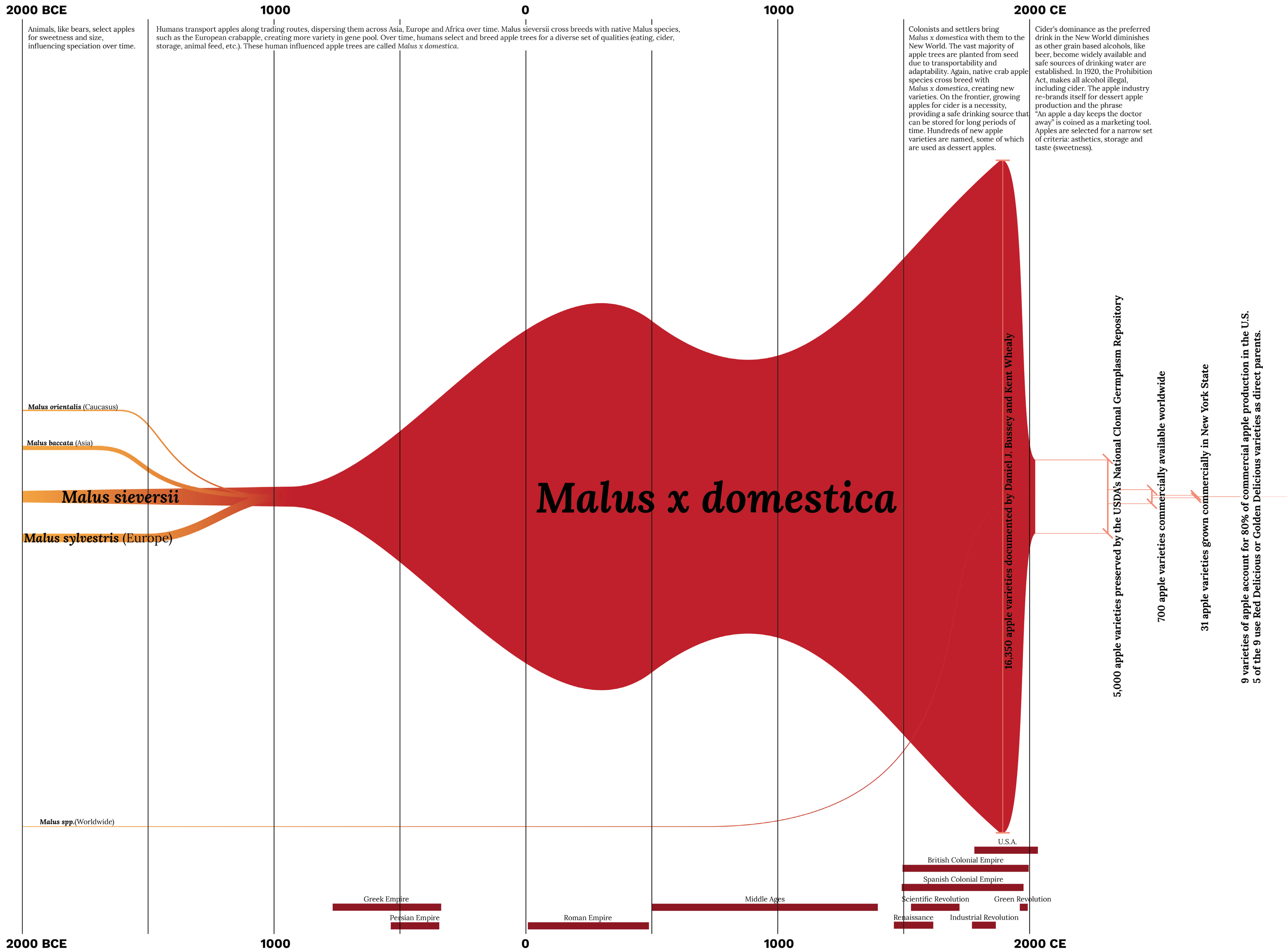
1671 Native American orchards are documented in Ulster County.

1647 The first recorded planting of an apple tree was on the corner of E 13th St and 3rd Ave in NYC by Governor Peter Stuyvesant.

1626 Dutch establish New Amsterdam on Manhattan Island.

1624 Dutch settle in Hudson Valley at Fort Orange.

Figure 2. Number of apple varieties throughout time



Human activity such as greenhouse gas (GHG) emissions, land use change, waste production, and chemical use is changing global environmental systems and raising the temperature of the Earth. These human activities will induce different climate changes on specific locations throughout the world. In New York State climate change is already having a significant impact on agriculture and will become more pronounced in the future, according to NYSERDA (Horton, et al., 2014). Temperature inconsistency and extremes and abnormal rain distribution patterns and frequency have upended seasonal and food production rhythms.

These climate changes will add more pressure on the already stressed apple tree. Temperature inconsistency has led to early spring warm periods followed by late season frost damaging flower buds, preventing flower fertilization, and decreasing apple production (Wolfe, et al., 2018). A higher frequency of 90-degree temperature days (Horton, et al., 2014) is placing stress on plants and water sources. Intense sun can also damage apple fruit. Overall mild winters and longer periods of warm weather are allowing new pests and disease species to survive in New York State. Moreover, existing pests may be able to remain active for longer periods of the year, having more opportunity to reproduce (Wolfe, et al., 2018). Precipitation changes are resulting in very wet periods and very dry periods throughout the year, and these changes are likely to bring more exrtemes in the future (Horton et al., 2014). While many apple varieties are tolerant of drought once the root systems are established, very few varieties can survive of extended periods of wet soils. There is a need for orchard design to adapt to these changes, as well as apple varieties that can handle these extremes.

The apple can be made more resilient to climate change by increasing diversity and adjusting production methods. Changes to production methods that support the apple are becoming more common in the industry (Miles, et al., 2020). Water management facilitates water movement away from tree roots and into storage during wet seasons and out of storage towards newly planted trees during dry periods. Orchard management practices such as cover cropping and adding soil amendments improve soil functions such as water holding capacity and availability (Wolfe, et al., 2018). These production changes need to be bolstered with changes to the apple tree itself as well.

As mentioned previously, genetic diversity within a species provides a better opportunity for a subset of that species to survive changes to their environment because they will have traits, unique from their peers, to adapt to those changes. Increasing diversity for the domesticated apple can be done by reintroducing known species into commercial production or creating new varieties by planting apples from seed and through structured plant breeding programs (Courtney, R., et al., 2017). These initiatives exist today, especially in specialty apple production, like craft cider apples (Miles, et al., 2020).

Figure 3. A change in plant hardiness zones.
Source: NOAA, 2011

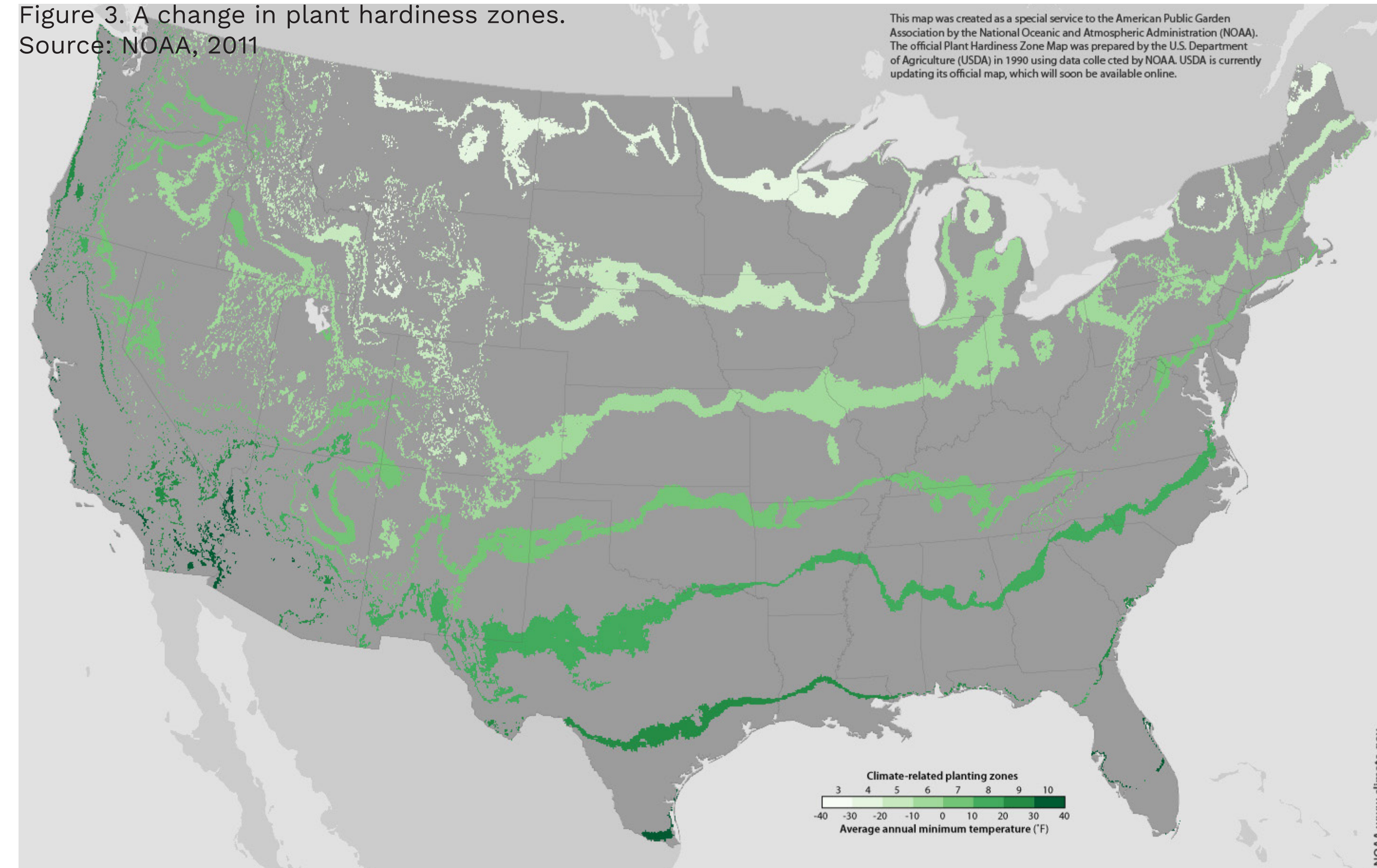
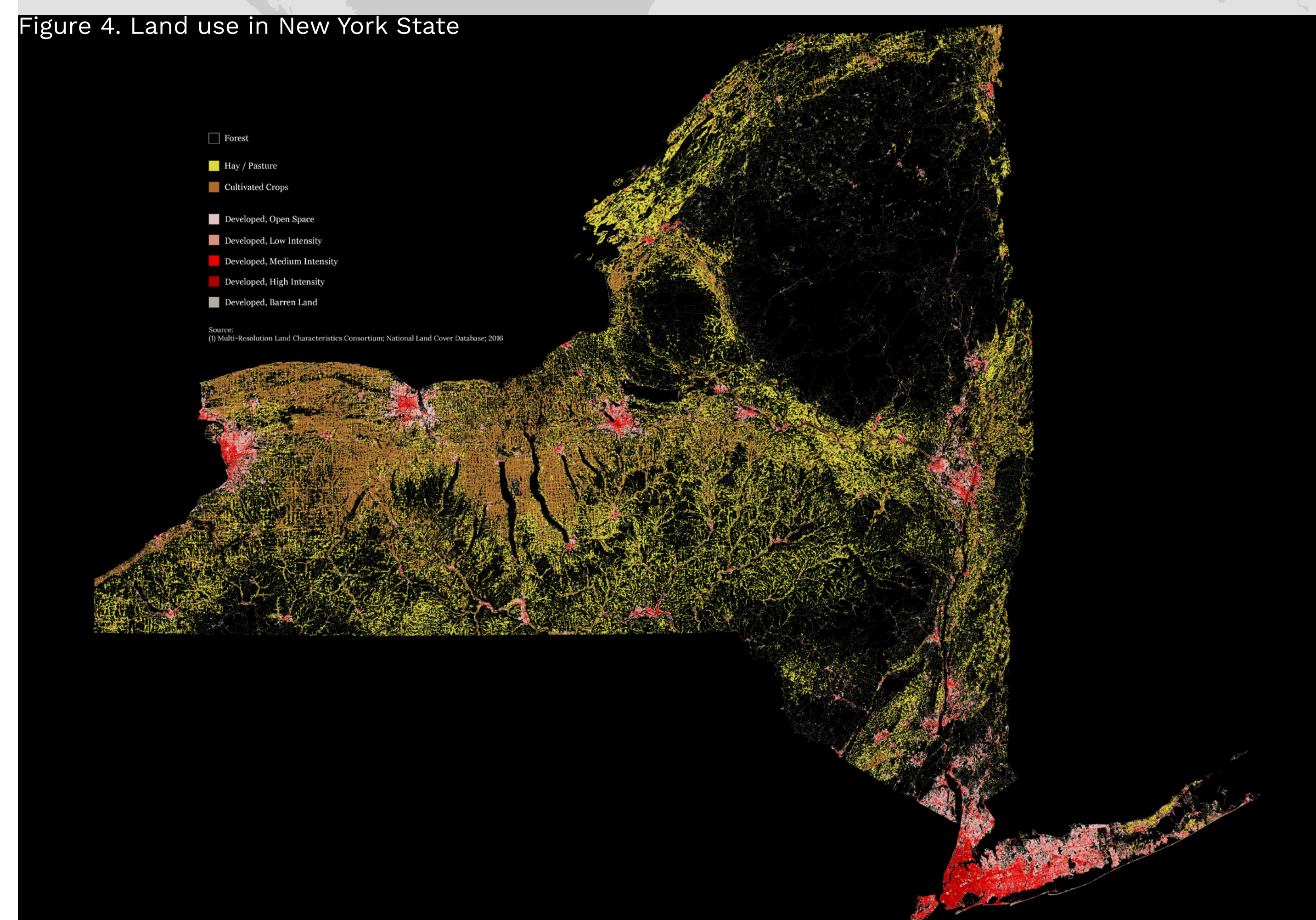


Figure 4. Land use in New York State



The case for landscape architecture

In order to create a more resilient apple, the orchard and how humans interact with it need to be redesigned. Successful creation of more resilient apple varieties through plant breeding and/or genetic modification will not solve the systematic issue. History has shown that policy, consumer preferences and climate have had the most substantial impact on the genetic diversity of the apple (Pollan 2001). For example, the popularity and need for cider in American culture, combined with the practicality of apple seed transportation to the frontier led to a proliferation of apple varieties. The Prohibition Act made cider making illegal. Since most cider apples were not palatable unprocessed, there was little purpose in growing them, causing a decrease in apple varieties. Finally, human desire for sweet and beautiful things led to a ruthless food market shaped by consumer preferences and government policies that requires fruit products to be delicious, attractive, durable, uniform in shape and size, large, and have a long shelf life, only the best varieties were accepted. Once a great tasting, blemish free, colorful unprocessed apple variety was discovered, it was captured in time via clonal propagation to preserve its traits, increase production, and sell to the market. Current breeding programs are creating new varieties, but these new varieties, with better taste and more resistance to pests and disease, will simply replace existing varieties instead of adding to them. This is because consumer and market patterns will likely remain unchanged, shifting their focus onto the new and improved varieties, still based on a narrow set of criteria, banishing the old ones. Decades later, the new varieties will be threatened by new issues and the process of creation, use, degradation, and re-creation will continue to repeat itself unless consumer preferences are changed.

To create a more resilient apple for the future, not just the present situation, consumers need to demand more variety in their apples. If the consumer preferences shift, the production process will follow to meet the demand. Human preferences are shaped by experiences. If enough people have the same perception of an experience, a consensus can be established within that community. Therefore, a space designed for a specific human experience has the potential to induce community change.

Landscape architects can design apple orchards that provide exceptional human experiences, potentially influencing people's understanding of the apple and their consumer choices. The landscape architect's focus on the human experience is what separates the profession from other scientific disciplines such as pomology, agronomy, ecology, entomology, et cetera. This difference may be the key to influencing the food system.

Thesis Questions

This research into the apple's history and its present-day challenges, combined with the argument presented for landscape architecture to influence systematic change has led to three thesis questions:

1. How can an orchard be designed for resiliency?
2. How can an apple orchard create a positive, engaging, and educational experience for humans - reshaping the understanding of what an apple can be?
3. How can an orchard be designed to simultaneously improve the resilience of the apple as well as create a positive and educational experience for humans?

Site selection and analysis

To speculate on design approaches to these three thesis questions, a real, site specific landscape needs to be selected for testing. South Hill Cider, an apple grower, cider producer and food and beverage business in Ithaca, NY, quickly established itself as a prime test site.

New York state is the second largest producer of apples in the United States (USDA National Agricultural Statistics Service, 2019) and the apple is the New York state fruit, which means the state government recognizes the value of this fruit and support its success. Second, the Finger Lakes region, where South Hill Cider is located, is in the heart of apple production within the state (Jentsch, n.d.), but also a national tourism destination with higher education institutions that attract an international community (DiNapoli, 2017). This combination of productive land and people coming to enjoy it creates an opportunity for new experience. In addition, the region is also home to Cornell University's Agricultural Experiment Station (Cornell AES) and Cornell AgriTech, world famous apple research institutions that could provide expertise and perhaps funding for projects (Figure 5). Lastly, due to pandemic travel restrictions, choosing a site within driving distance from Ithaca, NY allowed for multiple site visits.

Site selection was also focused on productive apple orchards that welcome the public on site. As mentioned, human engagement and experience are critical components to influencing change. Based on this, I focused my site selection to u-pick orchards and craft cideries (Figure 6).

Figure 5. South Hill Cider's proximity to Cornell apple research

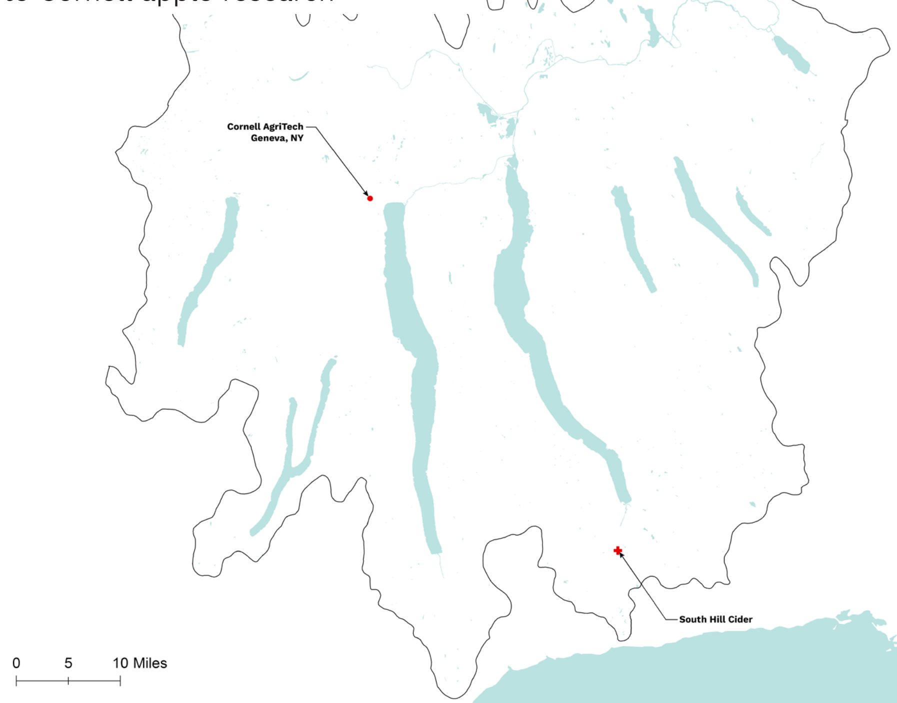
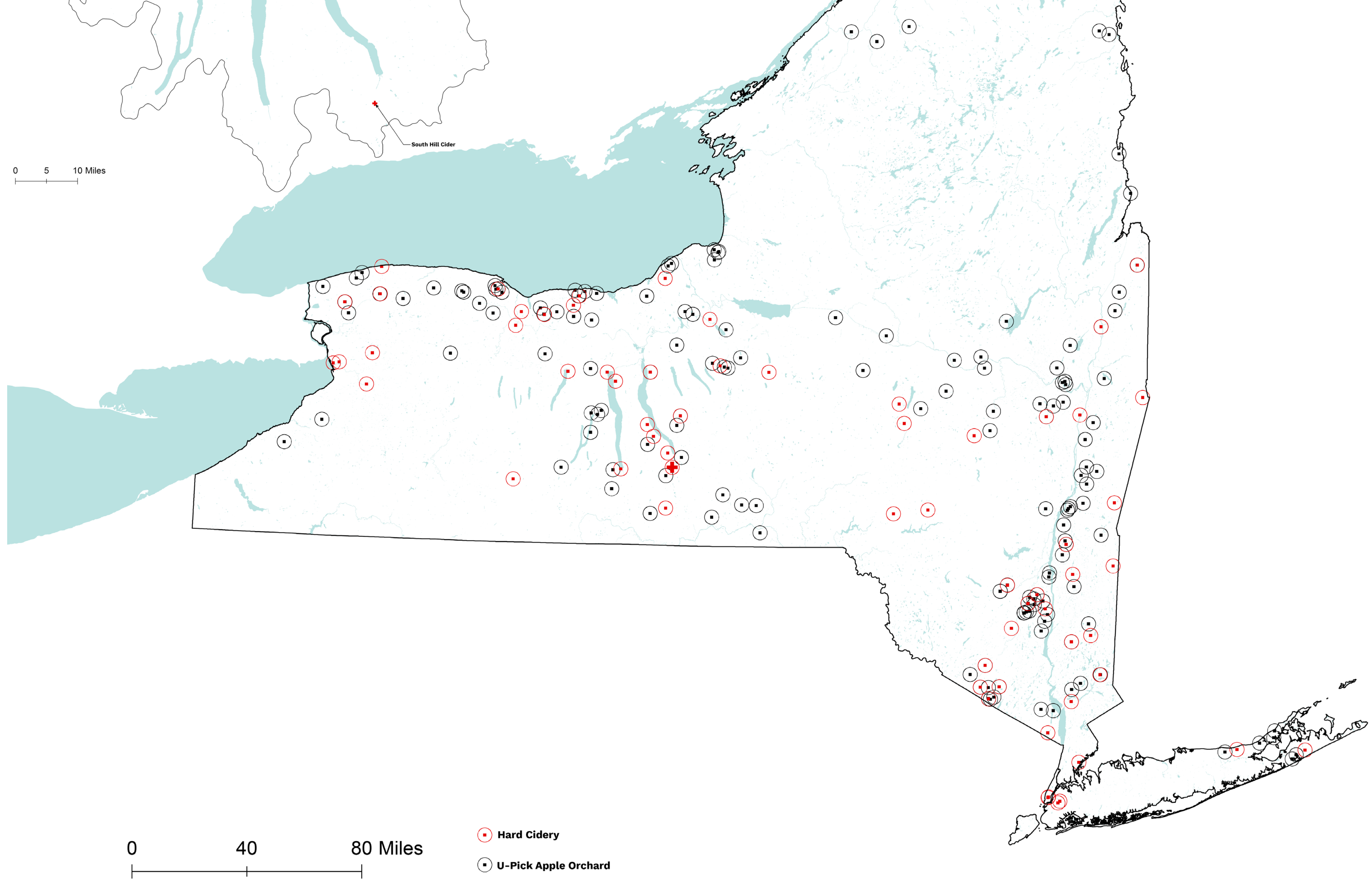


Figure 6. Cideries and U-Pick apple orchards in New York State



Ultimately, craft cideries proved to be the most viable sites for testing these thesis questions. Craft cider (cider) has considerable economic potential since the specialty drink market is projected to increase until at least 2023 (Peck, et al., 2018). Cider apples are more diverse than dessert apples because variety selection is based off an entirely different set of criteria. Instead of sweetness, aesthetics and durability, coveted cider apples can be bitter, sweet, acidic, or all three (Merwin 2015) and, because they are processed for juice, do not need to meet aesthetic standards (Figure 7). Unusual apple qualities are often celebrated for cider, allowing cider makers to differentiate their product from the rest of the market. In addition, cider apple orchards often welcome the public on site for extended periods of time since growers often share orchard locations with production facilities, tasting rooms and other customer-facing features.

South Hill Cider is located less than five miles from downtown Ithaca, a well-known tourist location in the Finger Lakes region and the home city to Cornell University and Ithaca College (Figure 8). The cidery is also near academic researchers making partnerships with local research institutions a possibility. Perhaps the most notable aspect of South Hill Cider, it is the only land connection between Buttermilk Falls State Park and Robert H. Treman State Park that has trail infrastructure already running through it (Figure 9). This South Hill Cider land connection completes a green loop of public and private conservation lands, all part of the regional Finger Lakes Trail system.

Site Analysis through research, mapping, on-site soil testing and field surveillance revealed characteristics of the site that informed design. Sitting near the top of a valley wall with open fields located north and northwest of the site afford long distance views of the surrounding landscape, a patchwork of forest and fields (Figure 10). These views also make this location great for watching sunsets, especially in the warmer seasons when the sun sets closer to due west in the Northern hemisphere (Figure 23). The open landscape also exposes this site to dominant winds originating from the Northwest, headed Southeast (Weather Underground, n.d.) (Figure 12). These winds are usually low velocity and create good air circulation

Figure 6. Dessert apple varieties
Source: New York Apple Association

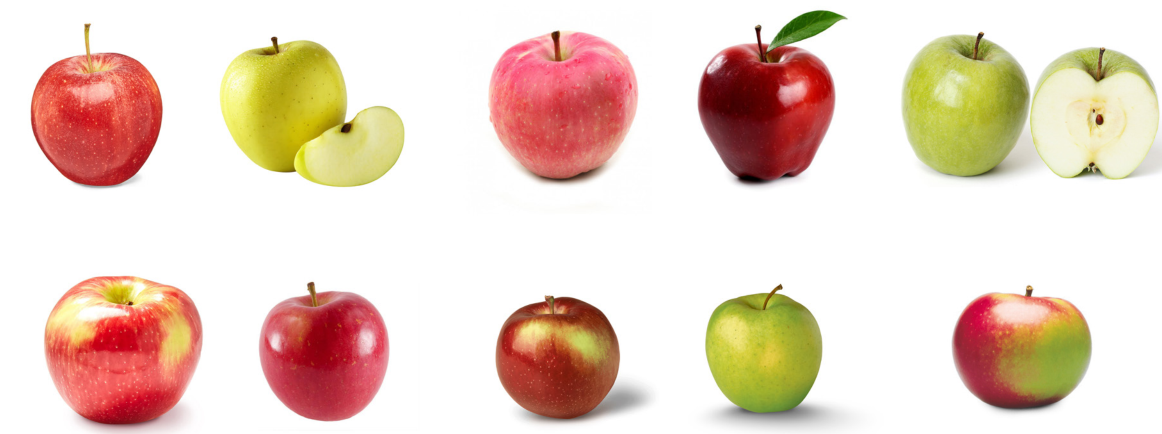
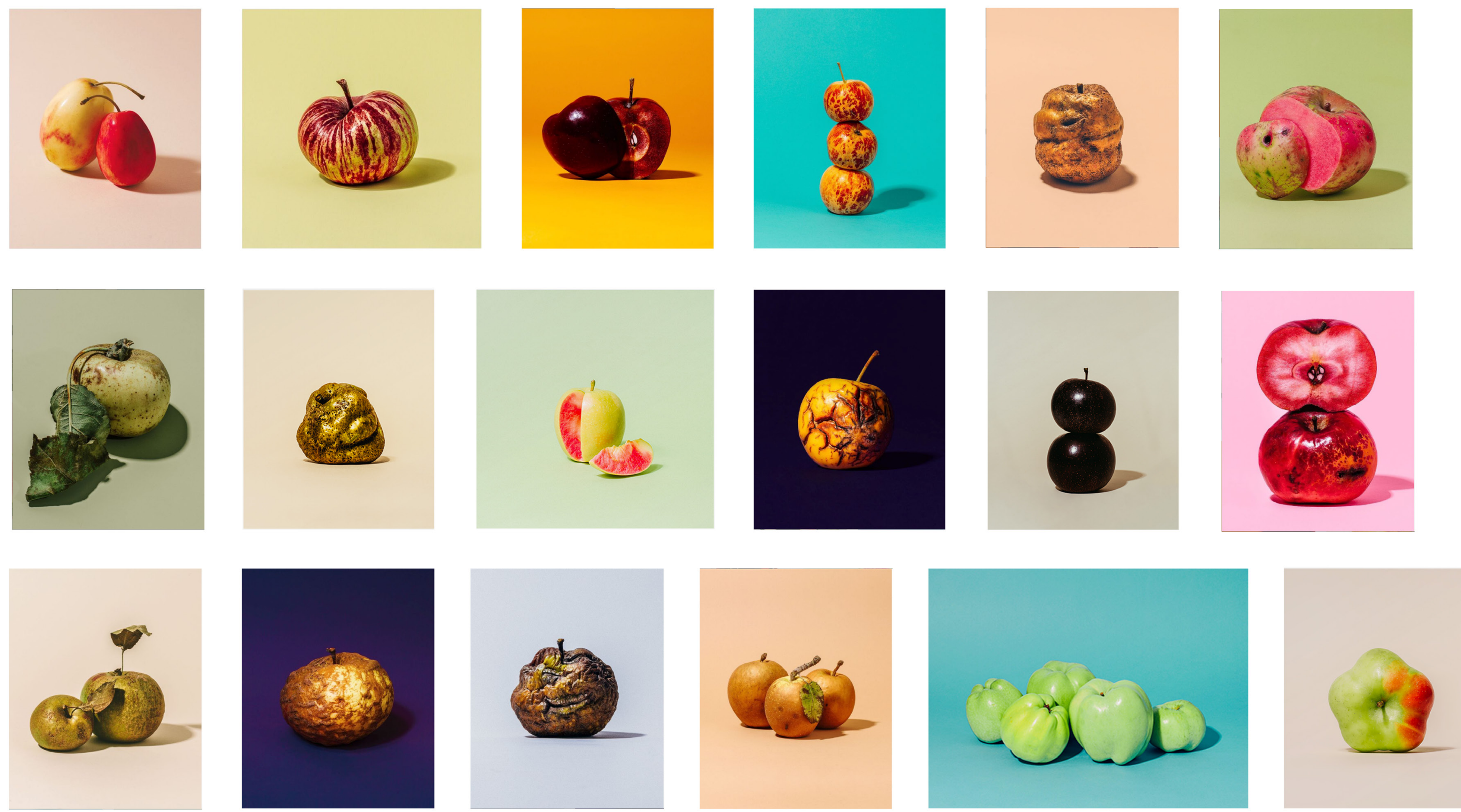


Figure 7. Cider apple varieties
Source: William Mullan



in the orchard, which helps prevent fungal and bacterial communities from growing. In addition, the breeze is welcomed in the warm season, especially as the summer climate includes more days above 90 degrees Fahrenheit. However, the wind frequently increases velocity which can damage low-grade infrastructure on site such as outdoor umbrellas and newly planted trees that are not established or provided with supportive infrastructure, such as trellising. In addition, the wind adds to the cold in the winter months, making outdoor events less comfortable.

Historical aerial photos, dating as far back as 1938 (Cornell, 1938), reveal most of this site has been used for agricultural production for nearly 100 years (Figures 13-16). Based on the historical imagery, USDA Natural Resources Conservation Service soil surveys, and onsite soil testing, the soil has degraded in agricultural quality from a silt loam condition (Soil Survey Staff, NRCS USDA Web Soil Survey) so a silty clay or silty clay loam condition (Figure 17). In addition, the soil characteristics are known to create conditions of excess water and potential for soil erosion (Soil Survey Staff, NRCS USDA Web Soil Survey), making agricultural use more difficult. To date, drainage tile has been installed on site where apple trees are planted. The small percentage of land that has been left fallow since the 1950s and 1960s has returned to a Hickory-Oak-Ash forest condition (Mohler, et al., 2006) (Figure 19), but the understory is dominated by invasive species such as *Lonicera maackii* and *Rosa multiflora* if not managed. These invasive species suppress other plant growth, limiting plant diversity within the forest.

Figure 8. Proximity to Ithaca
Less than 5 miles from Ithaca Commons, South Hill Cider is easily accessible to locals, students and tourists.

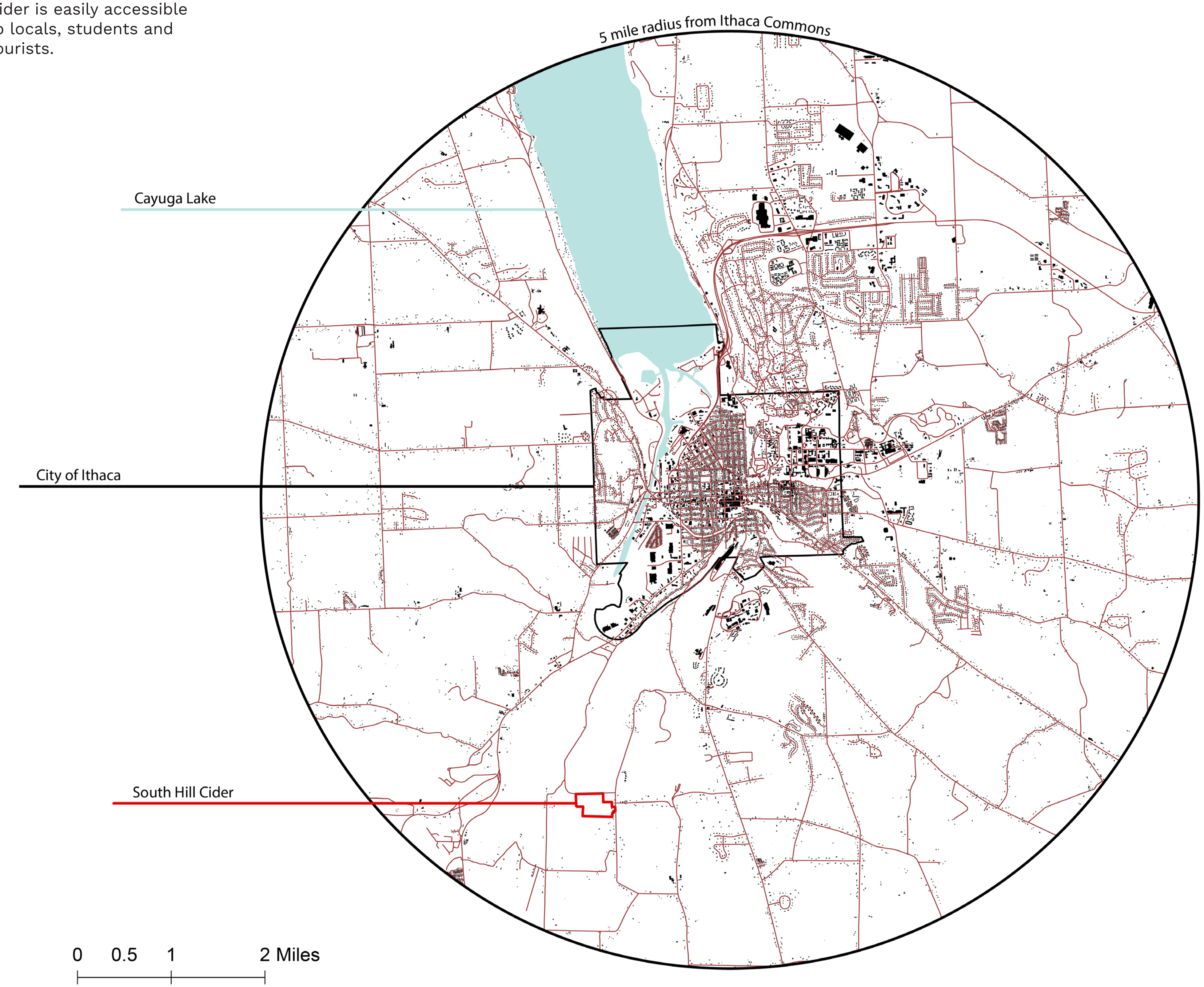


Figure 9. A critical link
This diagram identifies South HIll Cider as a critical peice in a green ring of public parks and nature preserves.

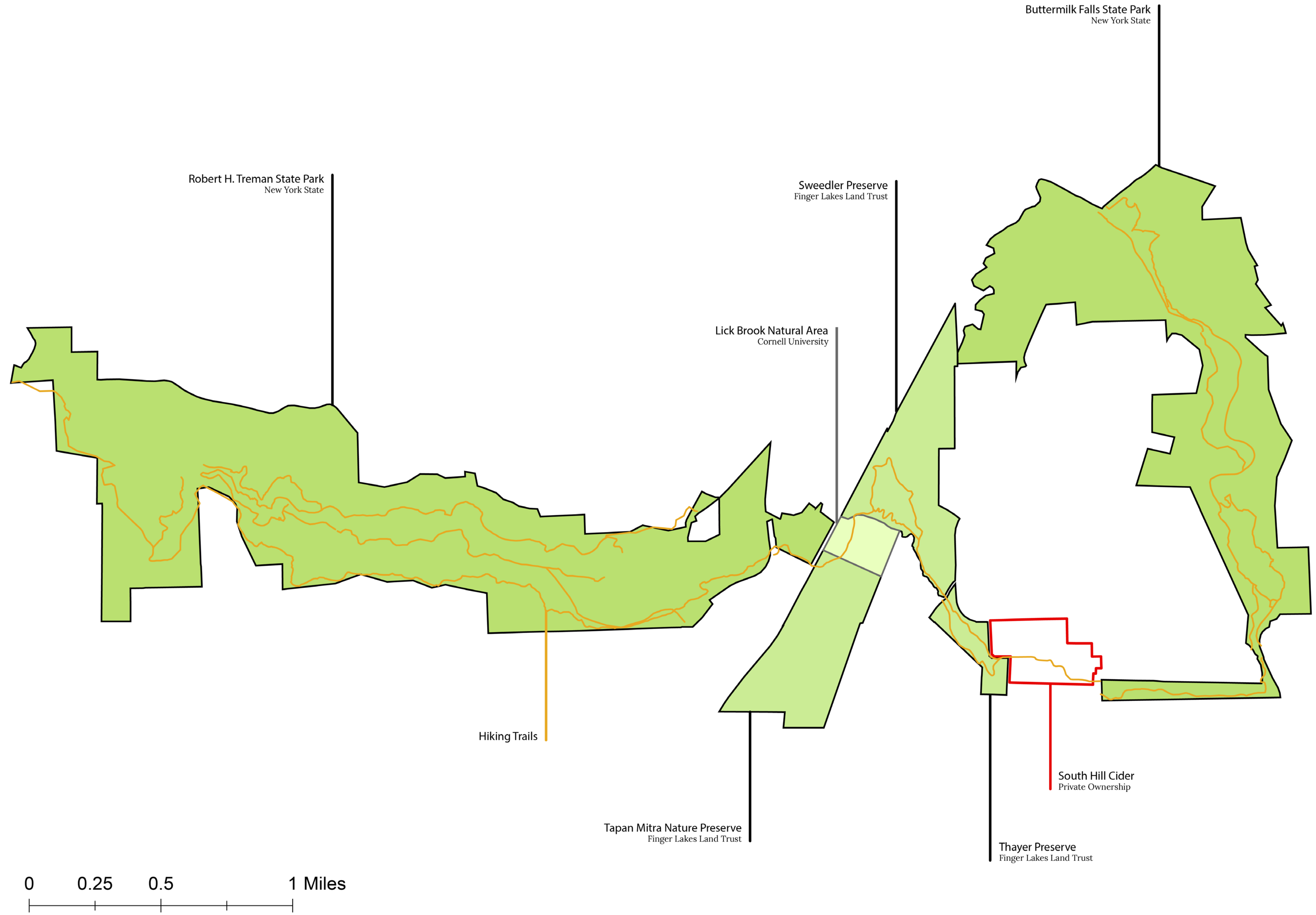


Figure 10. Existing conditions Map of South Hill Cider

Figure 11. South Hill Cider contour and surface water flow map

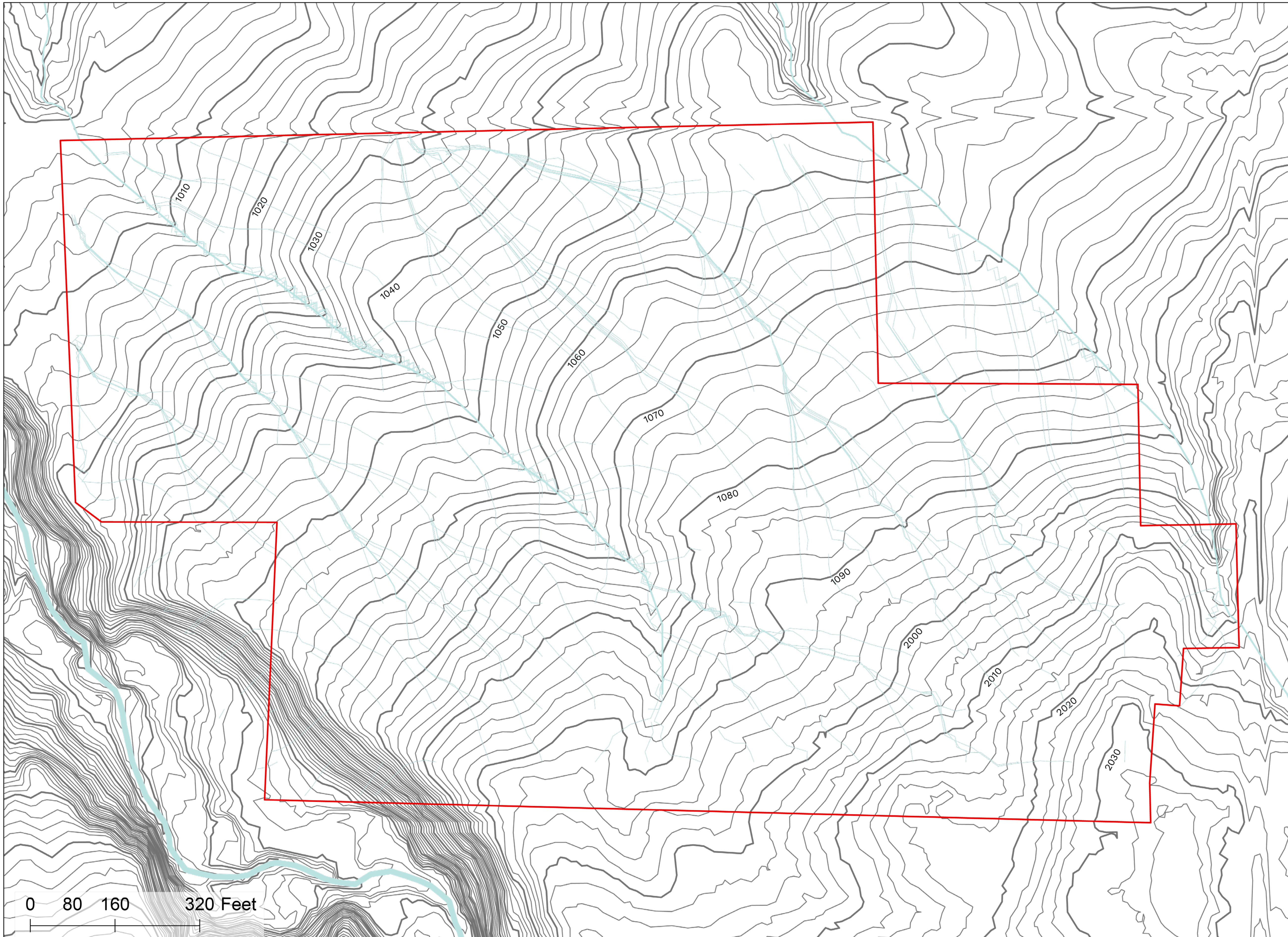


Figure 12. South Hill Cider viewshed and prevailing wind directions map

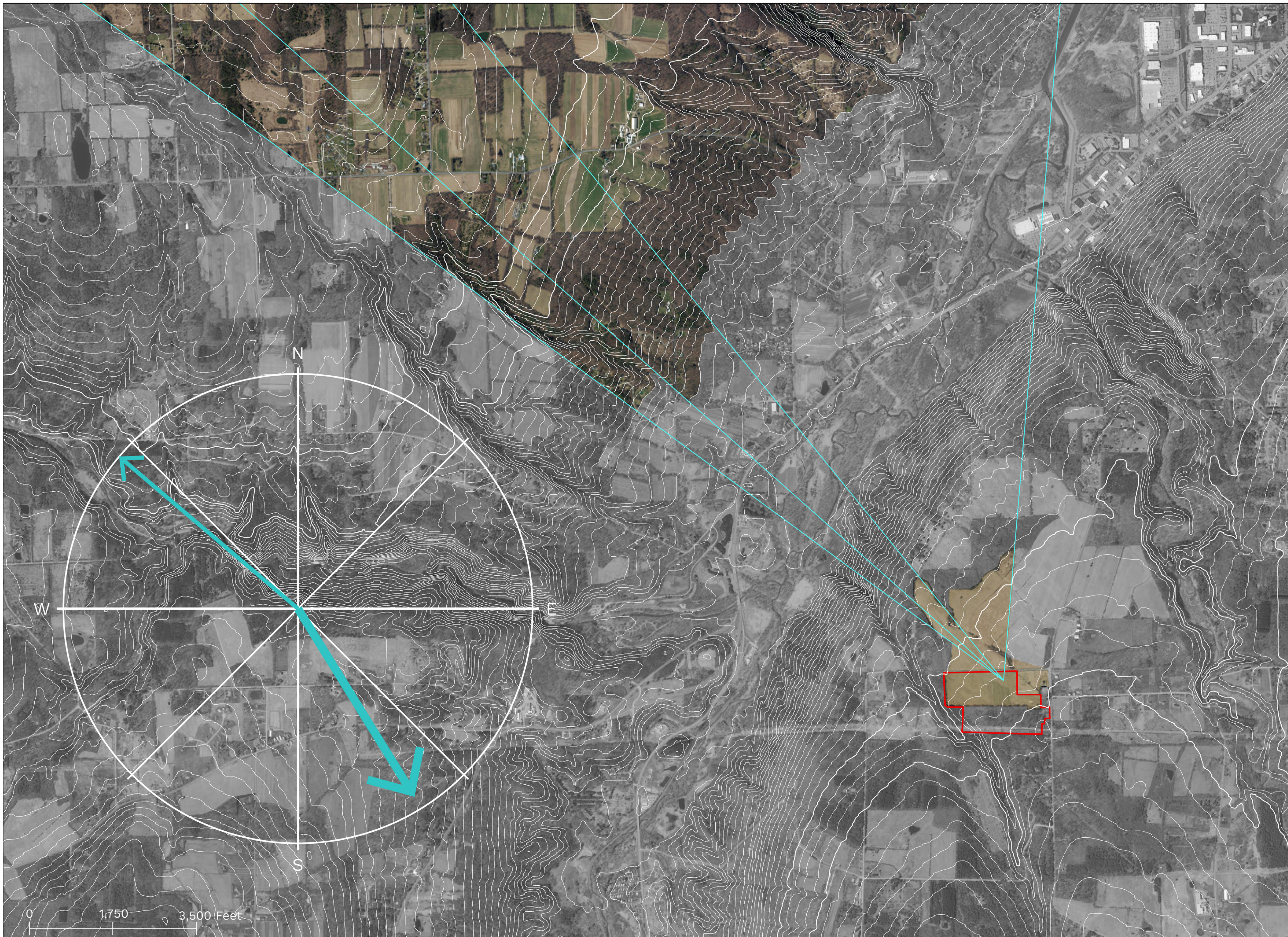


Figure 13. 1938 Aerial Photo of South Hill Cider
Source: Cornell University

Figure 14. 1954 Aerial Photo of South Hill Cider
Source: Cornell University

Figure 15. 1964 Aerial Photo of South Hill Cider
Source: Cornell University

Figure 16. 1991 Aerial Photo of South Hill Cider
Source: Cornell University

Figure 17. South Hill Cider Soil Analysis

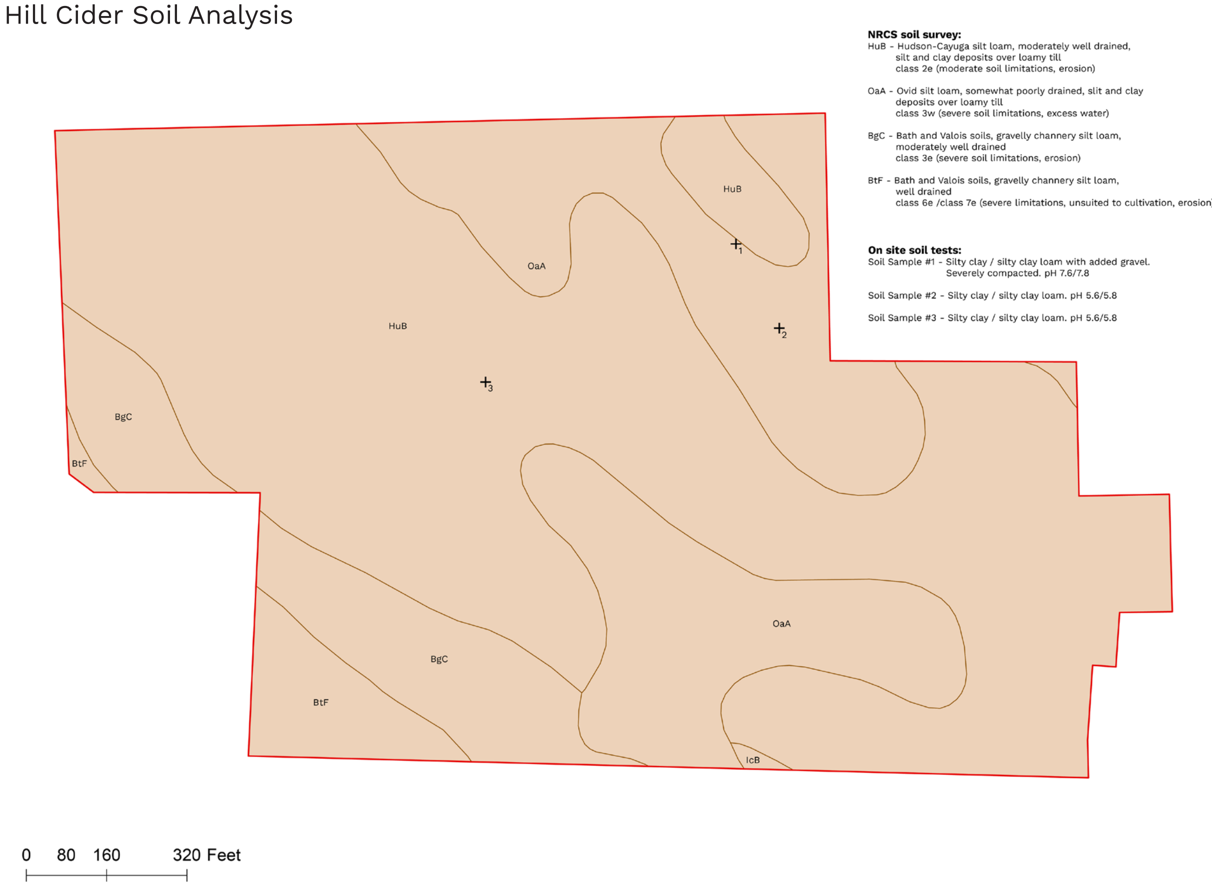


Figure 18. South Hill Cider vegetation types

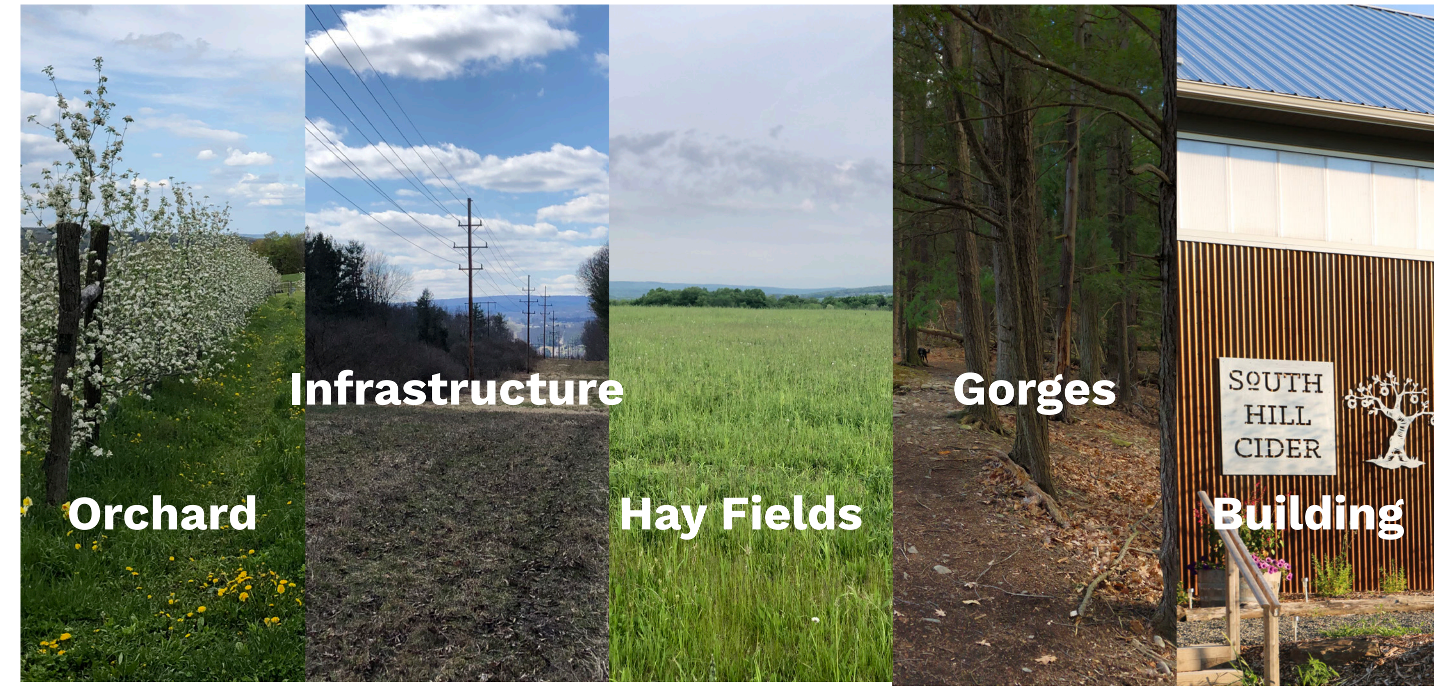


Figure 19. South Hill Cider vegetation cover analysis

Figure 20. South Hill Cider soil photograph

Figure 21. South Hill Cider section series analysis

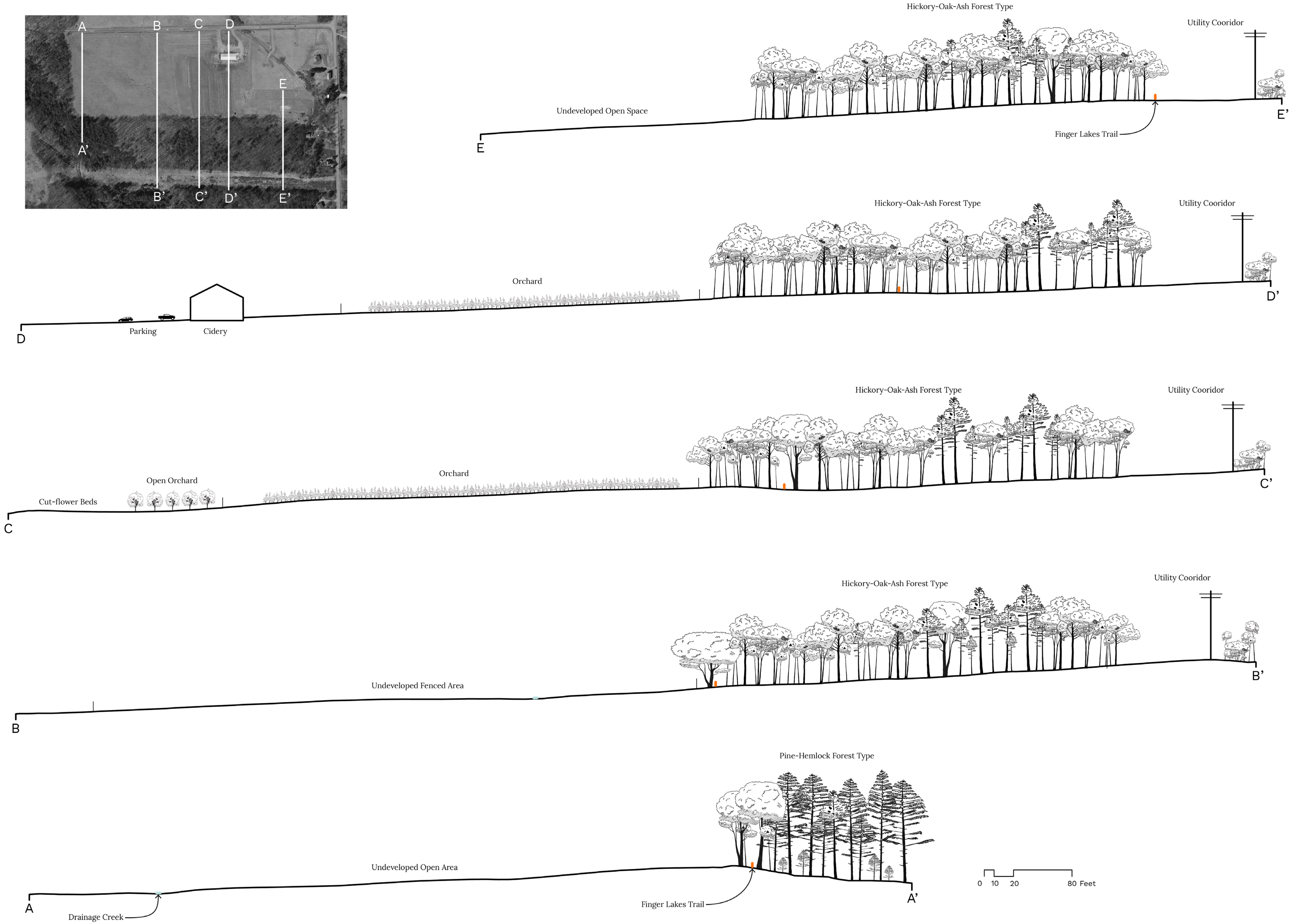


Figure 22. South Hill Cider photographs: Customer area, East view

Figure 23. South Hill Cider photographs: Customer area, West view

Figure 24. South Hill Cider photographs: Existing orchard

Figure 25. South Hill Cider photographs: Drainage ditch, spring time flow

Figure 26. South Hill Cider photographs: view from the “Big Oak”

Figure 27. South Hill Cider photographs: back of cidery

Designing an apple orchard for resiliency: Tools for design

The design for South Hill Cider is based on a series of individual design tools that increase the apple's resilience. Ultimately these tools can be classified into three broad categories:

1. Increasing the genetic diversity of the apple.
2. Increasing the number and quality of landscape features that insulate the apple from stress.
3. Creating landscape features that improve the human experience.

Of course, landscape management and maintenance methods are also critical to improving the resilience of the apple and are also at the forefront of design decisions.

Diverse genetics

The first design tool is to increase apple genetic diversity on the orchard by growing as many varieties as possible. This can be achieved in three ways. First, plant as many commercially available varieties as possible. Second, introduce forgotten and experimental varieties to test their feasibility in the field. This has potential to be done in partnership with research institutions like Cornell. Third, plant apple trees from seed. The diagrams shown in Figures 28 and 29 demonstrate the incredible diversity in apple forms and spatial requirements among different apple varieties and maintenance methods. Apples planted from seed are the most volatile and a high risk, high reward situation with low probability of producing apples the desirable qualities. However, the trees that survive would be adapted to the location they are planted and potentially produce cider with truly unique flavors and attributes. These apples could be integrated into the apple production industry beyond the site, adding to the pool of diversity.

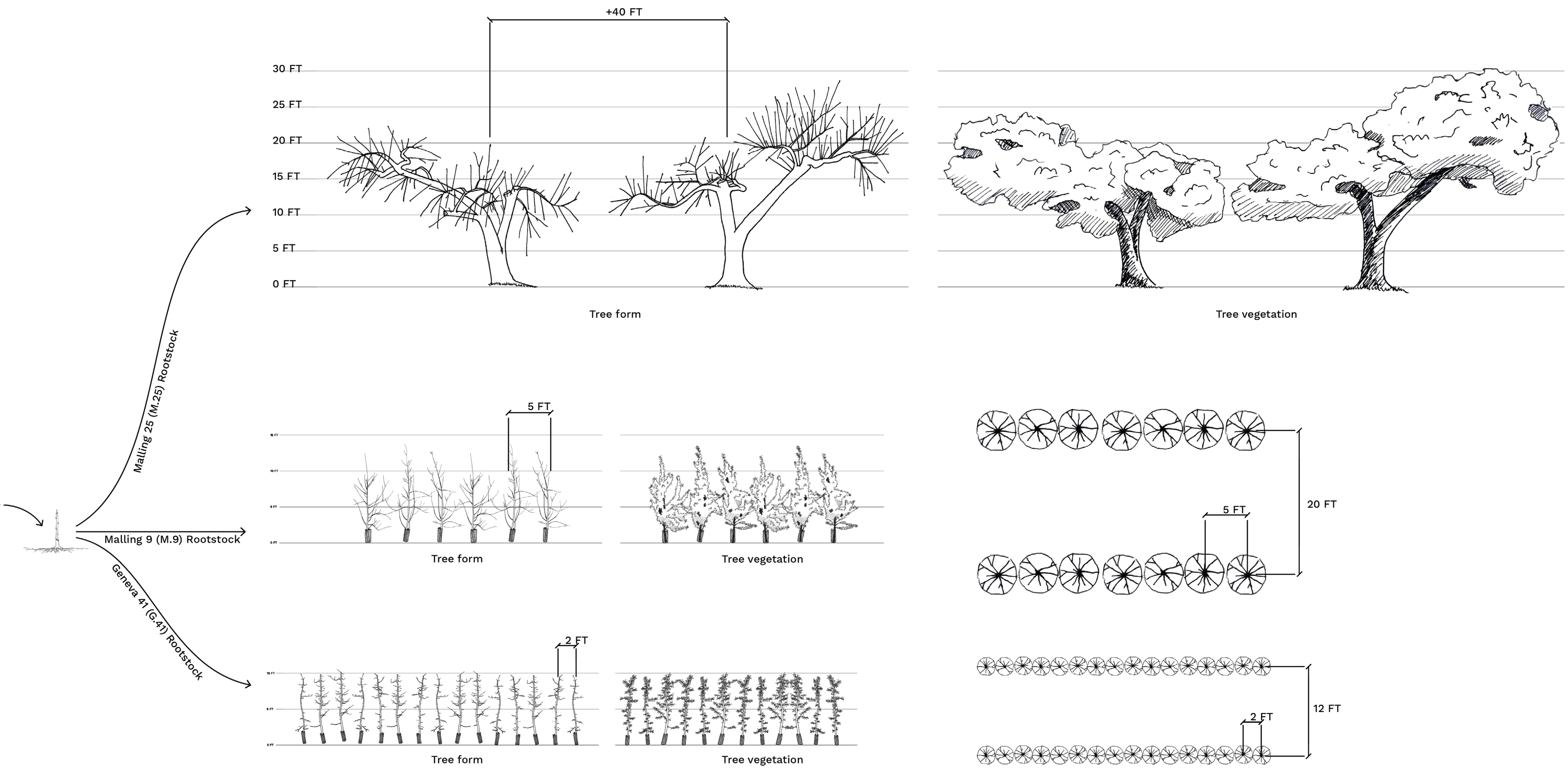
Diverse plant arrangements

The second design tool is to diversify the orientation and arrangement of apple tree plantings to create diversity in environmental conditions. Traditionally, apple trees planted in straight lines, or rows, allowing for easy use of machines, creating an orderly pattern for maintenance activities, and efficiently using all available growing space. The diagrams drawn in Figure33 and 35 showcase how alternative row orientation could respond to site specific conditions, utilizing plant arrangement to create different micro-climates. A North to South row orientation with between row spacing at least 90% the height of the trees optimizes sun exposure for each tree within the row. Alternative row orientations would create partially shaded conditions for trees. Although this is currently not a best practice for optimal growth and disease prevention, extreme temperatures and drought brought on by climate change could make alternative row orientations beneficial to apple trees. A Northwest to Southeast row orientation is an alternative that would run parallel to prevalent wind directions at South Hill Cider, allowing air to move up and down all the rows. Air circulation can mitigate disease pressure by evaporating moisture from the above ground portion of trees. A Northeast to Southwest row orientation at South Hill Cider would run parallel to the existing topography, slowing surface water flow during rain-events, providing more time for water to absorb into the soil and reduce erosion. During periods of drought, this row orientation could be critical to improving production by trapping more water in the soil, potentially making it available to the trees. For all row orientations, between-row widths would vary based on the expected heights of the apple varieties being grown and the types of machinery being used on site for maintenance and operations.

Diverse species

The third design tool is the incorporation of plant species that facilitate ecosystem services and functions that specifically benefit the apple, improving its resilience (Figure 31). The plant species shown in the plant palette tables (Figures 38-40) were all selected for their ability to provide pollinator habitat, decrease the occurrence of pests and disease, or provide beneficial insect habitat. Pollinators are critical to fruit production since apple trees require the assistance of insects to reproduce. The Danforth Lab, led by Professor Bryan Danforth in Cornell's department of

Figure 28. Standard commerical production
Clonally propagated, arranged and oriented to maximize production.



entomology, has shown that wild bee species are significant contributors to apple seed set (Russo, Park, Blitzer, et al. 2017). In addition, more diverse and abundant wild bee communities led to higher harvest seed set on apple orchards but was not impacted by increased abundance of honeybees (Blitzer, et al., 2016). To keep wild bee species abundant on an apple orchard, pollen sources need to be provided year-round in addition to the apple (Russo, Danforth, 2017). The plants chosen in this planting palette have been proven to be preferred by wild bee species (Russo, Danforth, 2017).

Disease and pest reduction is primarily achieved by ensuring their preferred host plants, such as juniper, red cedar, hawthorn, quince, crab apple and serviceberry, are not nearby (Douglas, n.d.). In addition, fragrant plants such as Allium spp., lavender, and mint may deter mammal predation on apple species (Larum, n.d.) (Cold Hardy Fruits, 2019). These fragrant plants typically flower, providing alternative pollen sources for wild bee communities. Habitat for natural predators of common apple pests is provided by simply including plant species preferred by these beneficial insects (Larum, n.d.) (Cold Hardy Fruits, 2019). All the apple companion plants selected are perennial species to reduce annual labor requirements to pruning and weeding, after an establishment period. These companion plants are intended for use across the site, including the orchards, but are arranged with maintenance and management practices in mind. Instead of being planted immediately around each apple tree, companion plants will be arranged into buffer strips (Figure 34). This strategy leaves a clear area around each tree for easy observation of apple tree health, removes preferred habitat for moles and voles, and improved pest sighting by beneficial predators such as hawks, chickens, and predatory insects. In addition to companion plantings, traditional grass strips and mulch are used to reduce weed pressure and maintain a living soil cover. Together, the perennial companion plants, turfgrass alleys and annual application of mulch improve soil health by injecting organic matter into the soil to feed soil organisms and maintain a living root system year-round to hold soil in place and provide structure.

Figure 29. Planting from seed for diversity
When planted from seed, apples can take a variety of forms and sizes.

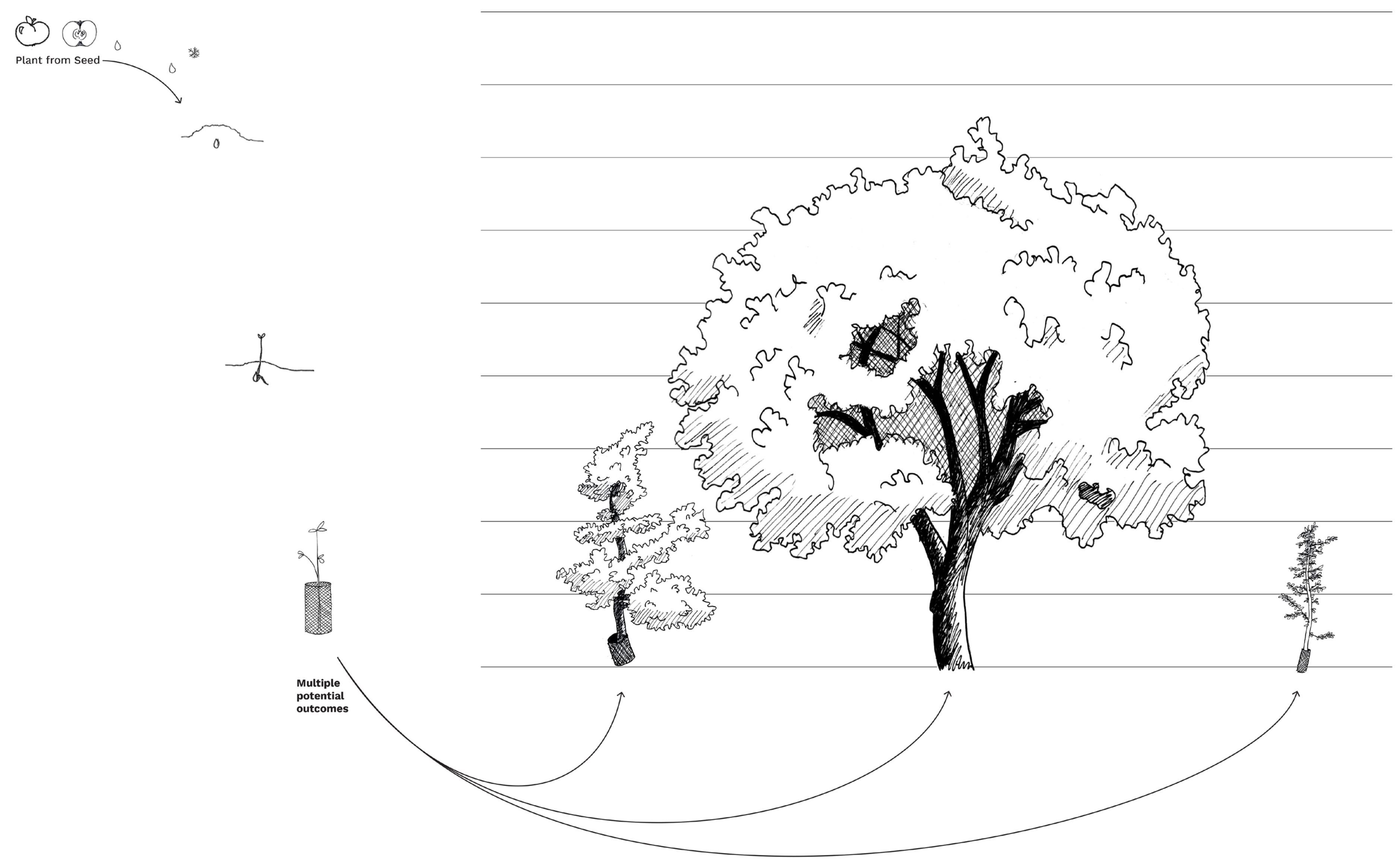
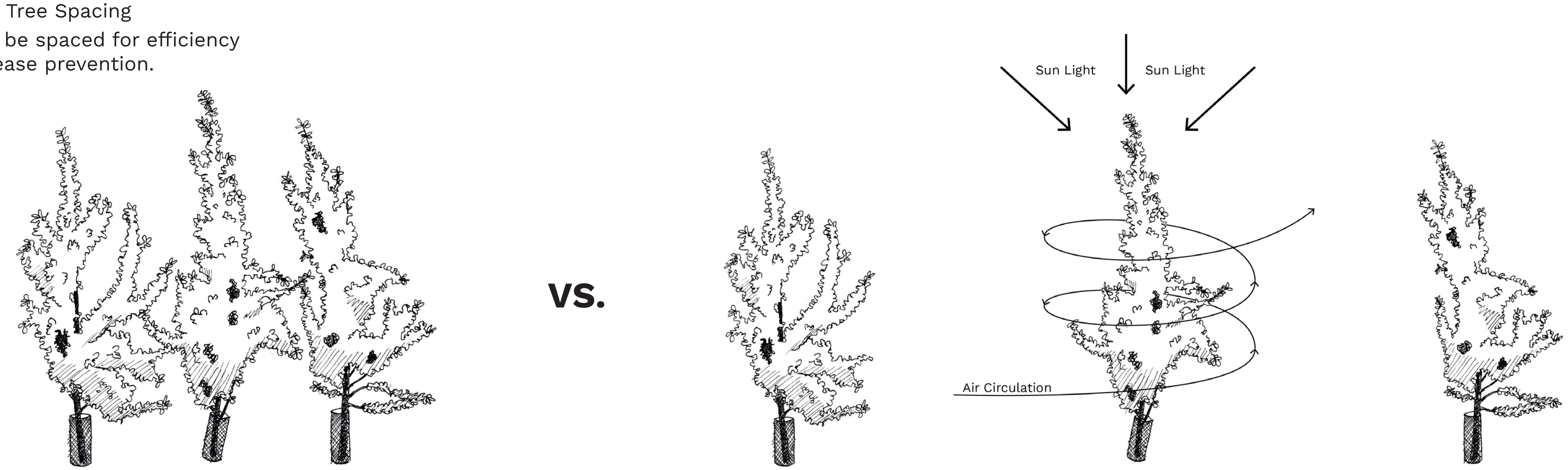


Figure 30. Tree Spacing
Trees can be spaced for efficiency or for disease prevention.



Diverse experiences

The fourth design tool, already embedded into the first three tools, calls for the incorporation and arrangement landscape features that activate the human sensory experience. The planting palette described in the third design tool includes plants that activate sight, smell, and even taste through a diversity of colors, flowers, shapes, sizes, and edible qualities. These plants can be arranged to generate movement through orchard, obscuring and revealing views, emphasizing the surrounding landscape, and channeling or breaking down prevailing winds. Infrastructural features such as simplified access into fenced orchards via stiles allows for human and dog entry, but not major apple predators, such as the white-tailed deer (Figure 44). Consistent signage to encourage use, educate through storytelling, and simplify way finding help create an improved customer experience and utilization of the entire landscape.

To fund the installation and maintenance of these design tools across the landscape, the South Hill Cider business must perform well financially. Incorporating design strategies that improve the landscapes aesthetic qualities as well as production performance, such as the design tools described above, can be incorporated into the businesses branding and on-site customer experience to amplify financial returns. For example, growing unusual and potentially unique varieties of apples could create cider flavors only found at South Hill Cider, differentiating itself in the growing craft cider market. For customers who enjoy supporting businesses with aspirations beyond production, South Hill Cider could tell a story about their goals to influence the food system by increasing demand for apples and apple products that promote growing diversity. For workers at South Hill, creating a beautiful space to work in has the potential to improve mood and influence positive customer interactions, adding to a positive customer experience. Although improving the financial position of South Hill Cider is not a direct goal of this project, doing so is an indication that consumer demand for diversity in apples and apple products is increasing. And that is a direct goal of this project because it will influence more growers and policy makers to follow a similar model.

Figure 31. Strategies for improving resilience of the apple

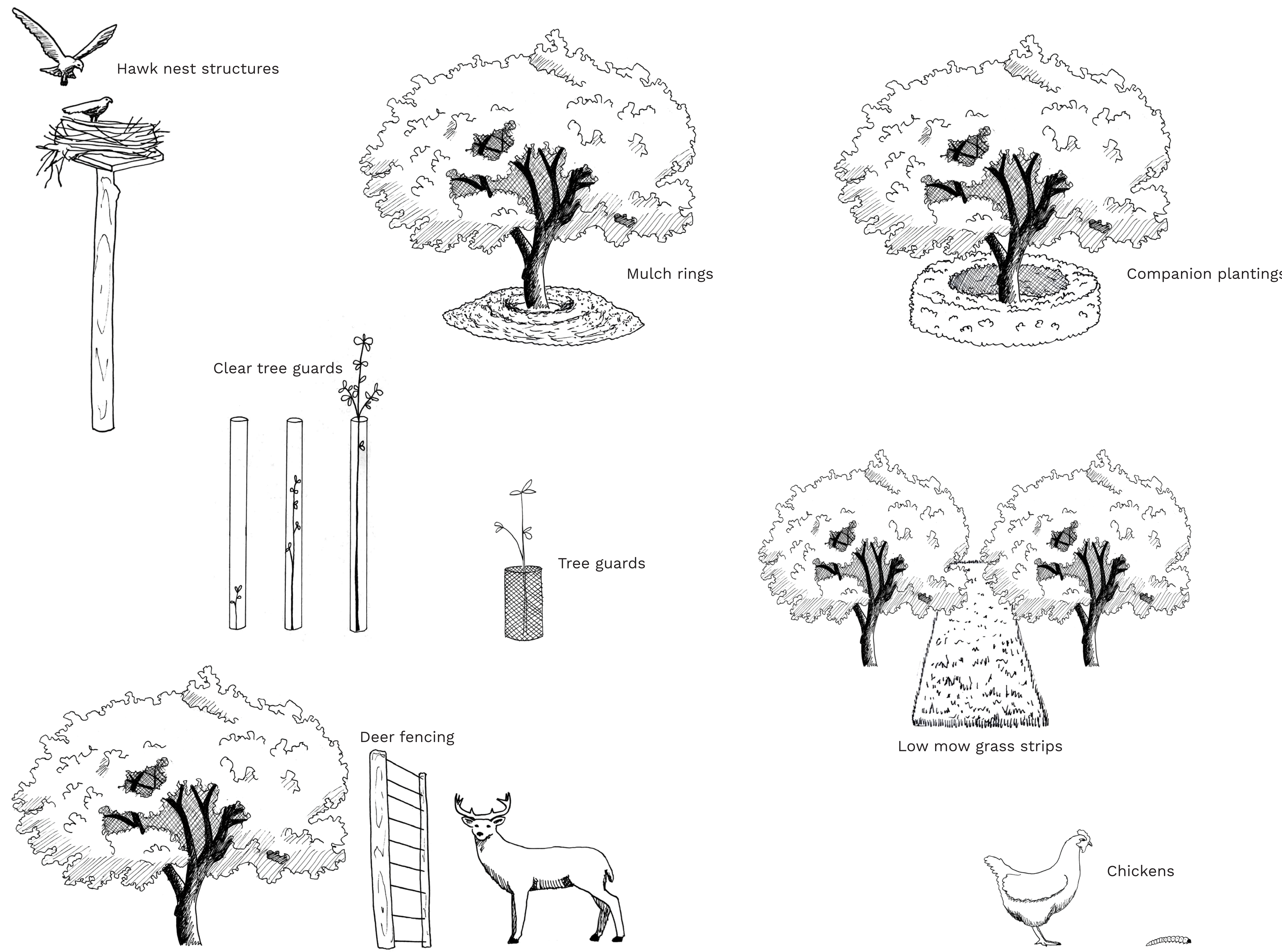


Figure 32. North-South orientation, optimizing sun

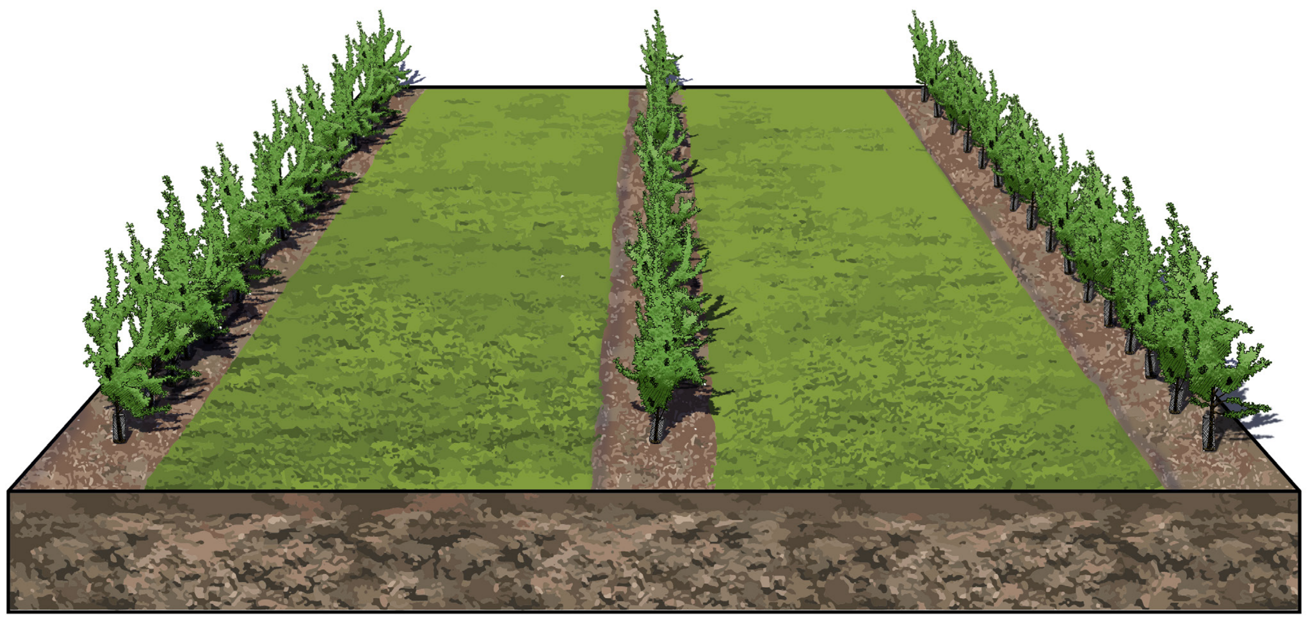


Figure 33. Rows oriented along contours, slowing surface water flow

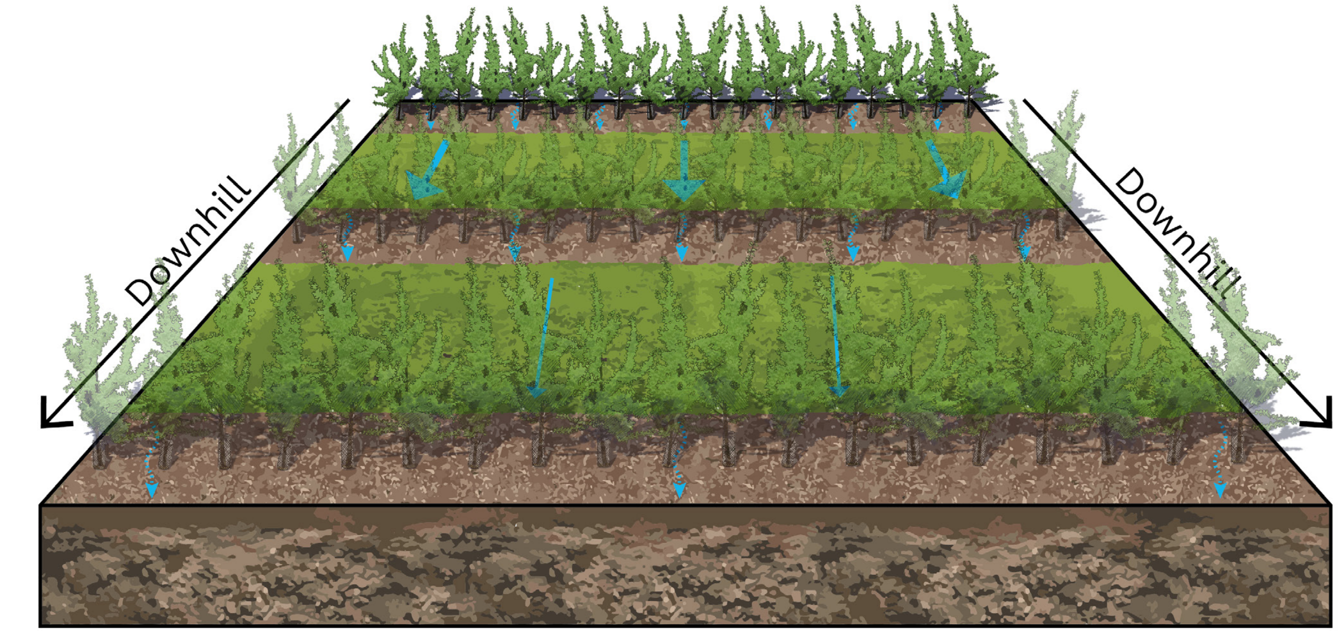


Figure 34. Incorporating buffer strips of companion plants

Figure 35. Rows oriented parallel to prevailing winds, allowing air circulation across the entire row

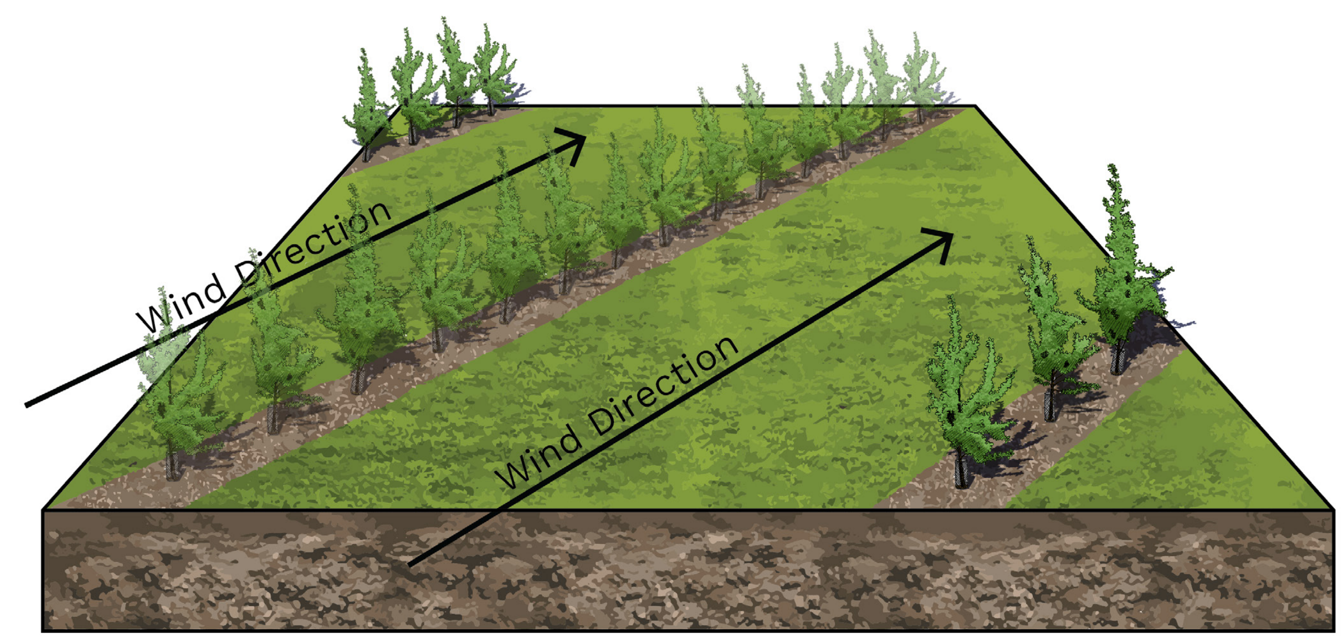


Figure 36. Variable row spacing, allowing for a variety of apple tree forms to thrive

Figure 37. Wild apple trees, planted from seed, exposed to the conditions of the site

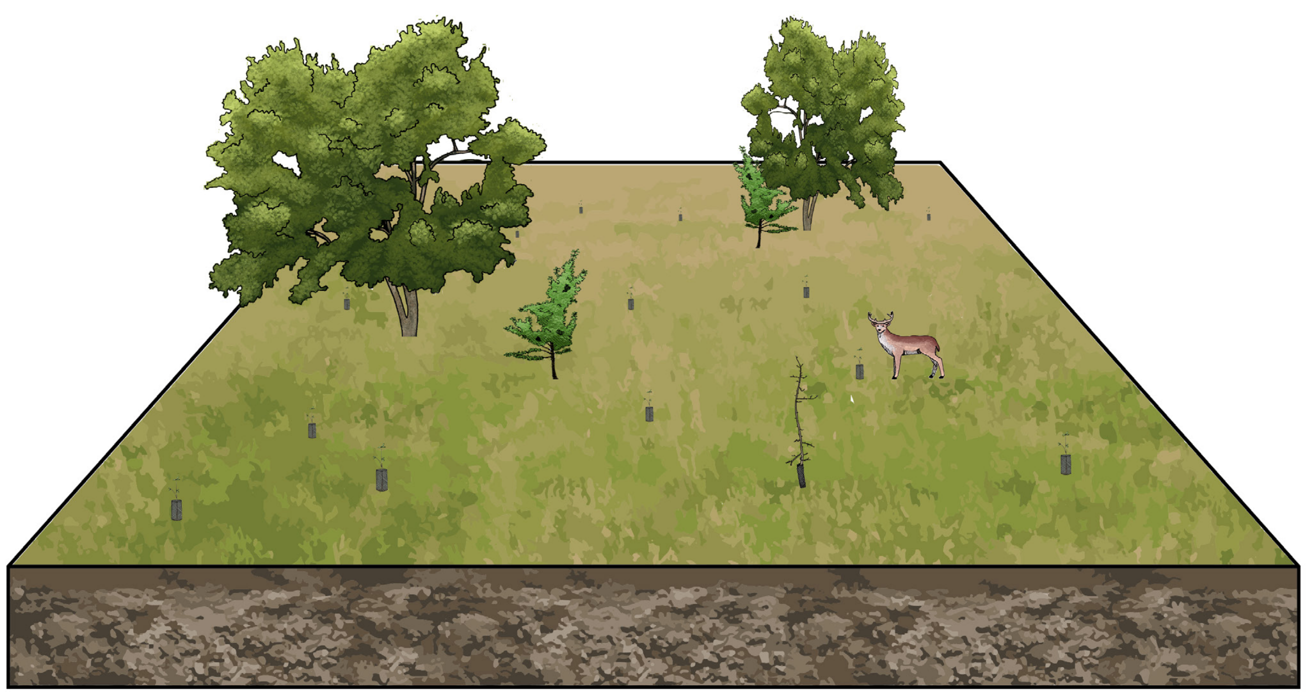


Figure 38. Apple companion plant palette

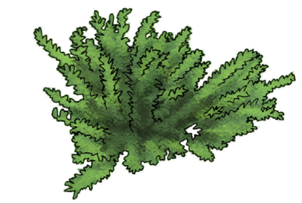
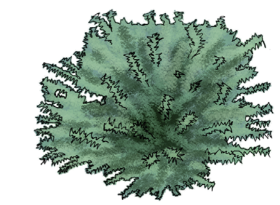
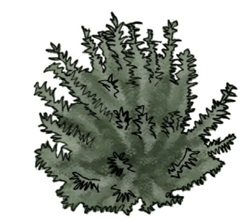
Plant Species	Primary Function	Photograph	Drawing
Acer campestre Hedge Maple	Pollination		
Salix myricoides Bayberry Willow	Pollination		
Salix purpurea 'Nana' Purple osier Willow	Pollination		
Salix eleagnos Rosemary Willow	Pollination		
Lonicera canadensis American fly honeysuckle	Pollination		

Figure 39. Apple companion plant palette, continued

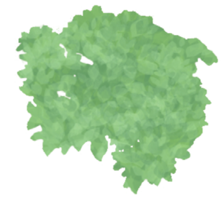
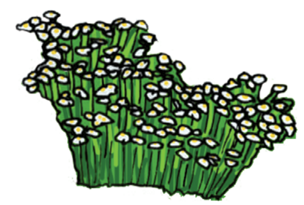
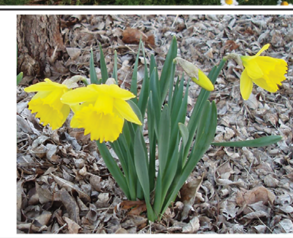
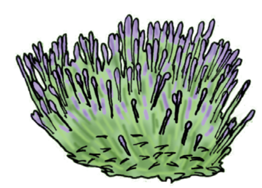
Plant Species	Primary Function	Photograph	Drawing
Fragaria spp. Strawberry	Pollination		
Taraxacum officinale Common Dandelion	Pollination		
Chamaemelum nobile Roman Chamomile	Pest Protection		
Narcissus spp Daffodil	Pest Protection		
Lavandula angustifolia Lavender	Pest Protection		

Figure 40. Apple companion plant palette, continued

Plant Species	Primary Function	Photograph	Drawing
Mentha canadensis American wild mint	Pest Protection		
Echinacea purpurea Purple Coneflower	Pest Protection		
Allium schoenoprasum Chives	Pest Protection		
Allium sativum Garlic	Pest Protection		
Allium tricoccum Ramps	Pest Protection		

Designing an apple orchard for resiliency: Site design

This section is an application of the design tools described above to the South Hill Cider project site to create an orchard that is productive, resilient and experiential. Visual in nature, this section relies heavily on a series of plans and perspective drawings to illustrate the design concept. The design concept breaks up the site into three distinct areas of design: production, experimental and wild. The plan shown in Figure 41 delineates the location of these three areas across the site. The production areas goal is to maintain productive efficiency while allowing for better human access to experience this space more freely. The experimental orchard makes use of alternative row orientations to take advantage of topography, water flow and sun conditions across the site, amplifying their influence on the apple tree, creating more diversity in micro-climates. Additional apple varieties and species are also incorporated into this experimental area, testing their potential for apple production. The test area plants apple trees from seed, allowing for the most genetic diversity and the potential for completely new varieties, adapted to the site conditions, to grow.

Figure 41. South Hill Cider proposed master plan

Production

The goal of the production specific area is to improve the resilience and customer experience within existing orchard. As illustrated in Figure 42, 43 and 44, the tree varieties within this area will be proven commercial cider varieties, dwarf trees known for production, apple quality and disease resistance. This area will adhere to traditional orchard design with North to South row orientation, high-density spacing, and mulched planting beds with low mow turfgrass in between rows. Surrounded by ten-foot-high deer fence, the use of fence stiles, shown for easy access and clear signage encouraging people to enter the space will be critical (Figure 44). The experiential quality of this area could be described as clean, repetitive, uniform and expected.

Figure 42. South Hill Cider proposed master plan, Production area zoom in.

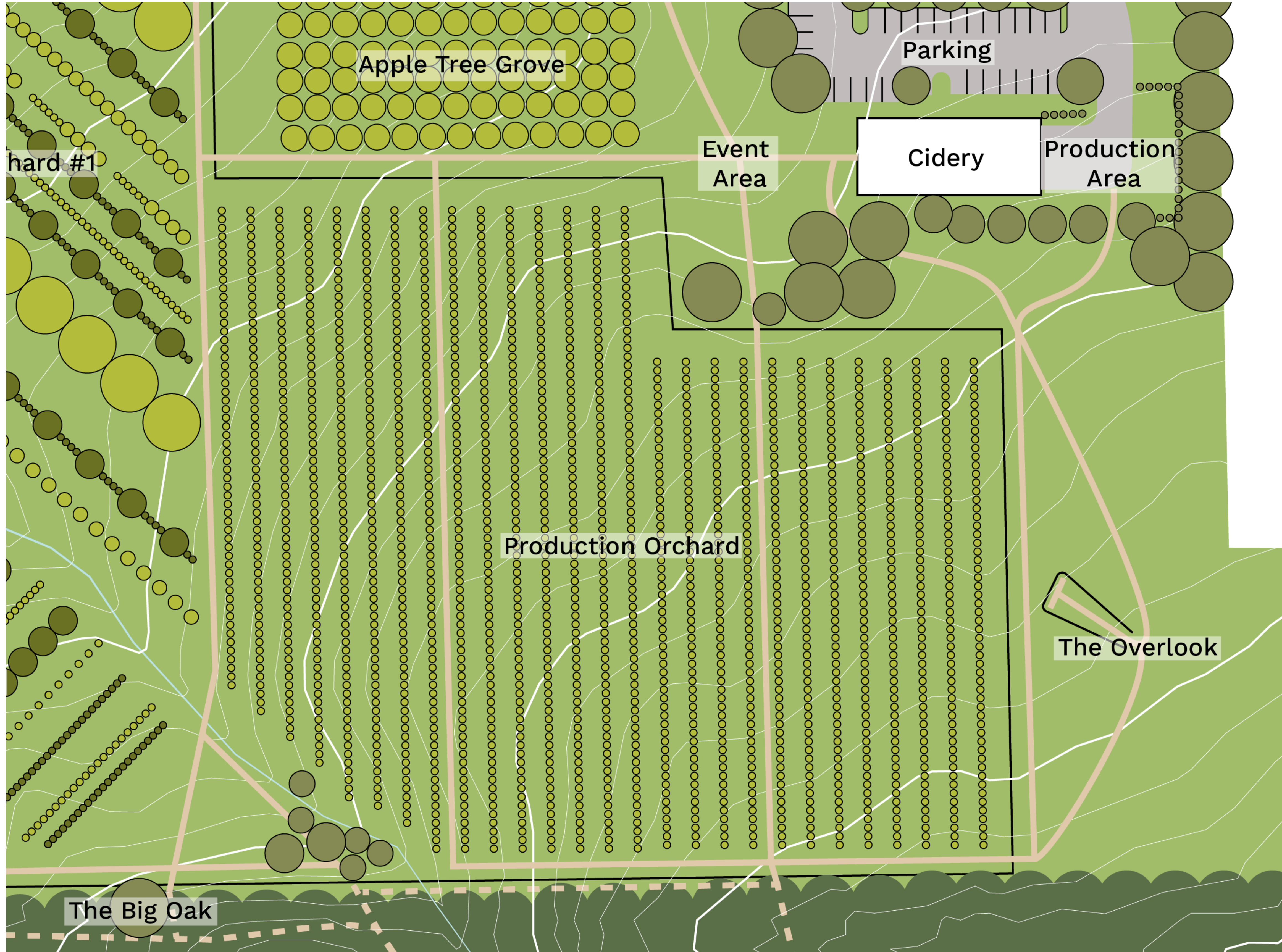


Figure 43. Production area perspective
Northern view into orchard

Figure 44. Production area perspective
Southern view into Finger Lakes Trail

Experimental

The experimental area shifts the goal from production to experimentation, as the name suggests. It bends the rules, testing alternative strategies for apple production and apple variety performance while still adhering to some foundational principals. Ideally this area would be operated in partnership with local research institutions, like Cornell University, to bring scientific rigor and global awareness to these experimental plantings. This area will grow a variety of apple varieties and rootstocks, not usually found on production orchards. Row orientation would be variable to create different micro-climates and determine their impact on production. Row spacing will be dictated by the height of the apple varieties grown in each row. Like the production area, tree planting beds will be covered with mulch and separated by turfgrass alleys, but each row will also be separated by a buffer strip of non-apple species that support apple production or mitigate pests and disease in some way. Traditional deer fencing will be combined with hawks' nests and owl boxes to reduce small mammal populations that damage apple trees. Chickens will be pastured within this area to experiment their influence on insect pest populations and automatic fertilization of soil with chicken manure (Figure 46). This area could be described as surprising, diverse, unexpected, and interesting.

Figure 45. South Hill Cider proposed master plan, Experimental orchard zoom in

Figure 46. Experimental area perspective

Wild

The wild area departs from any resemblance to traditional orchard production and steps into the radical unknown (Figures 48-50). Hundreds of apple trees are planted from seed into an open hay meadow with only simple clear tubes as deer protection. Simple signs will designate the origins of the planted seeds, allowing viewers to realize the difference between commercial propagation methods and seedlings. This area is unmanaged, except for low-mown walking paths to encourage movement and exploration across the space. Apple trees are left to adapt and mutate, or die. The ones that survive bring new diversity into New York State and create apple varieties unique to South Hill Cider.

These three areas of design are integrated into a single master plan, creating a diverse experience for people (Figure 41). Pathways, signage, and the prospect of the perfect Instagram photo will lure people across the site, visiting each area. Transitions between each area are emphasized by fence stiles, gates, plantings, and signage, but a consistent path of low mown turfgrass and the presence of apples trees unify the grounds. The three areas of apple production, production, experimental and wild, are complemented by features such as a lookout point, an open-space customer area dappled with shade trees for large events, an improved parking area and the existing Finger Lakes trail running through the forested areas and connecting to pathways on site.

Figure 47. South Hill Cider proposed master plan, Wild area zoom in.

Figure 48. Wild area perspective
Phase 1, planting

Figure 49. Wild area perspective
Phase 2, growth and adaptation

Figure 50. Wild area perspective
Phase 3, harvest and replanting

Conclusion

Malus domestica (the apple) is a historic and culturally important fruit that has been cultivated and bred for specific qualities, reducing its genetic diversity, and making it susceptible to pests and disease. Current and future climate changes, induced by human activity, will increase the stress on this already vulnerable plant species, threatening its future. To permanently increase genetic diversity in the apple, we need to move beyond the creation of a few new varieties selected for a narrow set of characteristics to replace existing varieties. Instead, we need to create a consumer demand for variety in apples, initiative a shift in the food system.

New forms of apple orchards can be designed to be simultaneously productive, experiential, and educational. These apple orchards could shift public perception of apples and perhaps persuade people to demand variety and growing standards that promote biodiversity. South Hill Cider serves as a case study for this approach and offers strategies that could be translated to other apple orchards, especially cider orchards with customer facing components on site.

The lack of genetic diversity and fragility within *Malus domestica* is emblematic of nearly all crops in the global food system. To reliably produce plant foods that look and taste the same every time, they need to be clonally propagated. However, this assurance of a certain quality and flavor is preventing plant adaptation, increasing risk of failure. A demand for variety and diversity from all foods (in addition to many other changes such as management practices, closing nutrient loops, shifting towards perennial crops, etc.) will be necessary to improve the resilience of our food system.

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