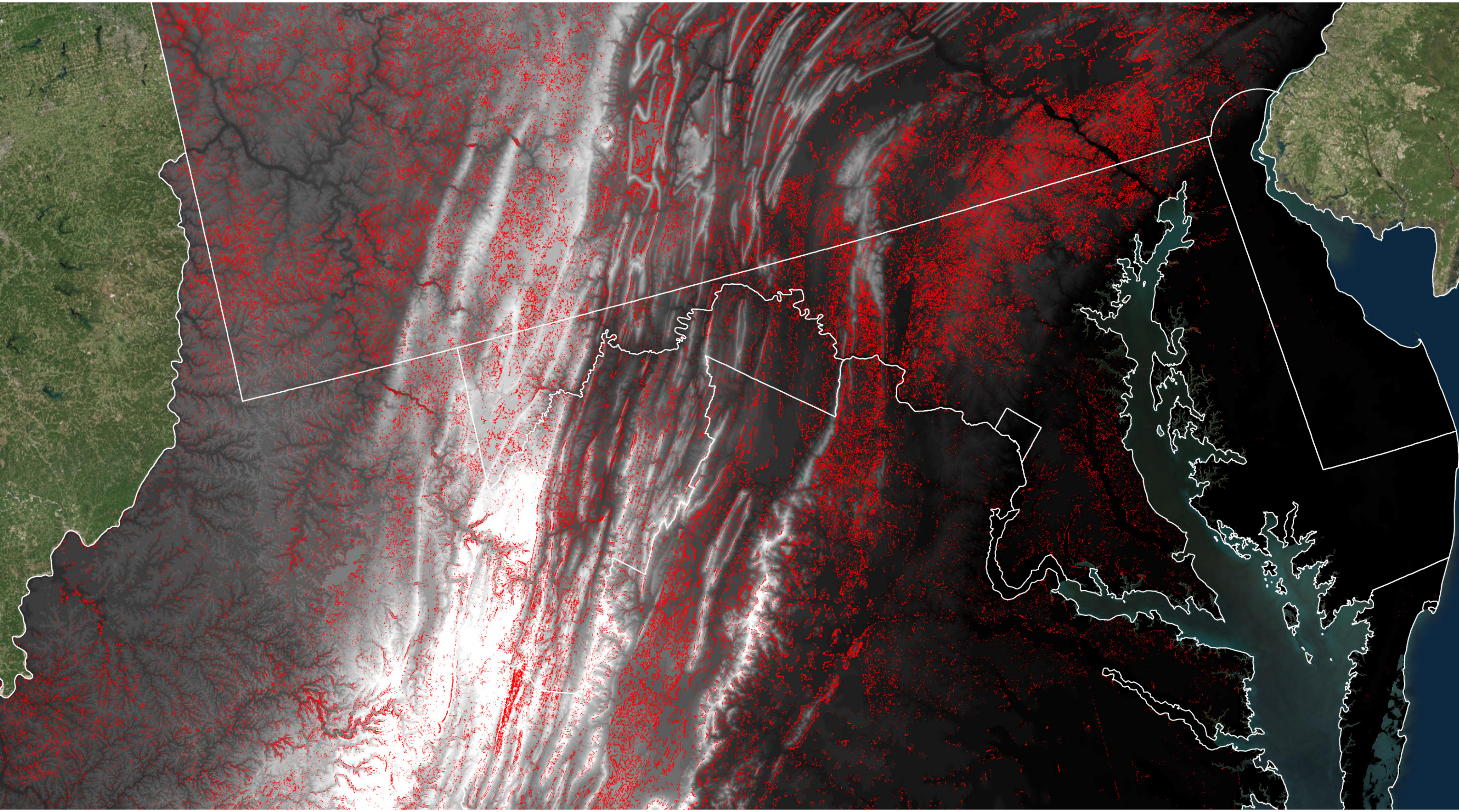


Agroforestry in the Temperate Landscape

Precedent, Practice, and Design Proposal

Agroforestry in the Temperate Landscape
Precedent, Practice, and Design Proposal

Alexander N Darr

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Landscape Architecture
In
Landscape Architecture

Nathan Heavers (Chair)
Paul Kelsch
John Munsell

June 6, 2019

Alexandria, Virginia

Keywords: Landscape Architecture, Agroforestry, Perennial Agriculture, Land Management, Water Quality

Agroforestry in the Temperate Landscape

Precedent, Practice, and Design Proposal

Alexander N Darr

ACADEMIC ABSTRACT

Temperate agroforestry systems are an important area of research and practice in Eastern North America with the goal of creating more diverse, productive, and environmentally sound agricultural landscapes by using trees as key crops. There is extensive published research on contemporary temperate agroforestry models as well as tropical indigenous agroforestry systems, but publicly accessible properties that demonstrate these practices are currently limited.

These practices, which include: Alley Cropping, Multi-functional Riparian Buffers, Short-rotation coppice, Non-timber forest farming, and novel crop breeding have potential to radically reshape American agricultural practices. As sediment and erosion control becomes stricter in agricultural land, and if future carbon tax or pricing legislation comes into play, non-tillage based agricultural practices will become more prevalent throughout the United States and the rest of the world.

In the Mid-Atlantic region of the United States, where this project is based, orchards are a common perennial cropping system, but at present the industry is reliant on chemical inputs that have an economic and ecological cost associated with them. Developing, demonstrating, and popularizing systems that incorporate native, crop-bearing perennials, in a manner that is legible, aesthetically pleasing, and well-integrated into the surrounding topography and agricultural vernacular, this thesis offers a masterplan to create a proof-of-concept demonstration site to landowners curious about incorporating low-input agroforestry practices.

This thesis presents a series of unpublished manuscripts based on research of historical agroforestry practices in temperate North America. These manuscripts focus on agroforestry practices as they were practiced over nearly 500 years of American history. These findings culminate in the proposition of a design for an agroforestry research and demonstration farm in the Mid-Atlantic United States.

The goal of this design is to recontextualize a historic dairy farm in Maryland, USA with the construction of a new education, production, and design center. This center, along with its associated infrastructure, the cropping layout, and an interpretive trail through a range of agroforestry systems proposes an immersive environment that allows a visitor to experience agroforestry at its many scales, from garden to cultivated wilds.

Agroforestry in the Temperate Landscape

Precedent, Practice, and Design Proposal

Alexander N Darr

GENERAL AUDIENCE ABSTRACT

Temperate agroforestry systems are an important area of research and practice in Eastern North America with the goal of creating more diverse, productive, and environmentally sound agricultural landscapes by using trees as key crops. There is extensive published research on contemporary temperate agroforestry models as well as tropical indigenous agroforestry systems, but publicly accessible properties that demonstrate these practices are currently limited.

These practices, which include: Alley Cropping, Multi-functional Riparian Buffers, Short-rotation coppice, Non-timber forest farming, and novel crop breeding have potential to radically reshape American agricultural practices. As sediment and erosion control becomes stricter in agricultural land, and if future carbon tax or pricing legislation comes into play, non-tillage based agricultural practices will become more prevalent throughout the United States and the rest of the world.

In the Mid-Atlantic region of the United States, where this project is based, orchards are a common perennial cropping system, but at present the industry is reliant on chemical inputs that have an economic and ecological cost associated with them. Developing, demonstrating, and popularizing systems that incorporate native, crop-bearing perennials, in a manner that is legible, aesthetically pleasing, and well-integrated into the surrounding topography and agricultural vernacular, this thesis offers a masterplan to create a proof-of-concept demonstration site to landowners curious about incorporating low-input agroforestry practices.

This thesis presents a series of unpublished manuscripts based on research of historical agroforestry practices in temperate North America. These manuscripts focus on agroforestry practices as they were practiced over nearly 500 years of American history. These findings culminate in the proposition of a design for an agroforestry research and demonstration farm in the Mid-Atlantic United States.

The goal of this design is to recontextualize a historic dairy farm in Maryland, USA with the construction of a new education, production, and design center. This center, along with its associated infrastructure, the cropping layout, and an interpretive trail through a range of agroforestry systems proposes an immersive environment that allows a visitor to experience agroforestry at its many scales, from garden to cultivated wilds.

Acknowledgments

The explorations and research that underlie this thesis have been possible only due to a community of support, to which I will be forever grateful. Many more have contributed as well via conversations in canoes, bars, back roads, and libraries whose name I never knew, but nonetheless will not be forgotten.

Specific thanks are deeply owed to:

To my parents who have allowed ever expanding tree nurseries in their yard, grafting and equipment storage in their garage; an uncountable number of delicious meals and restful nights in the country when I take weekend trips for sanity or research; and their never ending emotional and editorial support.

To Alexandra Schiavoni my classmate, research assistant, housemate, traveling companion, and daily source of wisdom and support. Your unending enthusiasm for trips to mountain roads, research libraries, and interstate roadsides for the last five years was invaluable.

To Dr. Jeffrey Kirwan for planting the seed of knowledge about American Indian agroforestry practices and the idea to follow the trail of Hernando deSoto to uncover pre-colonization cropping methods.

To Benjamin Fritton and the Reed Family for offering their home and farm as a site for research and design

To Eugene Scheel for his incomparable local knowledge of Northern Virginia history, and for being the first to return my phone call in 2014 about a long forgotten tree farm deep in the woods of Loudoun County.

To the American Philosphical Society Library and staff for allowing access to the archives of J Russell Smith, long before I had enrolled in an accredited graduate program.

To Pete Walton, Aaron Grigsby, and Eliza Greenman for accompanying me on trips to explore the woods of Sunny Ridge, and their assistance with nut and scion collection and propagation.

To the Goose Creek Friends Meeting for support, local knowledge, and hosting of seminars on local tree crop history.

To the residents of Tree Crops lane for their generosity in allowing countless wanderings through their roads and woodlots.

To Nathan Heavers, for having a copy of *Tree Crops* on his desk when I first visited the WAAC, and inspiring me to stay the course.

Table of Contents

Section One Background and Precedent Research

Corsican Chestnut Grove

Chapter One Precedents: Woodland Period to the Colonial Era

Introduction

Agroforestry is a land management system that brings trees into agricultural production systems and appropriate crop production in the forest understory. This system has proved its value to producers and land managers who are increasingly looking to diversify income streams while regenerating ecosystems and sequestering atmospheric carbon. Researchers and practitioners have studied and defined agroforestry extensively over the last thirty years, shaping it into its contemporary form, which is best known as a science and set of practices that incorporate tree crops into livestock and annual crop production systems. However, agroforestry is in fact a new name for ancient practices in which tree-based agriculture systems developed in countless traditional societies across the globe. Despite the acknowledgment that perennial agriculture has been practiced by a diverse array of societies, including African, Polynesian, and South American, very little research has taken place within North America to understand local indigenous agroforestry systems. In fact, it is a widely-held belief that indigenous Americans limited their agricultural practice to annual crops, while opportunistically foraging for the fruits of perennials in the matrix of wilderness surrounding their settlements.

As perennial agriculture continues to increase in popularity and adoption across the United States; and as academics, producers, and policymakers are exploring the potential for these practices to increase soil organic matter, reduce erosion, and mitigate the impacts of climate change; it is vital to understand the context in which these practices have already developed on this continent over the last 8,000 years. While we acknowledge that American Indian communities continue to practice agroforestry in nuanced and diverse ways, the scope of this article focuses on historical accounts of Native American tree-based food production in the American Southeast and offers a brief survey of current archaeological evidence to support the existence of these practices.

Within this paper, the author hopes to broaden the understanding that prior to European colonization of the region, there existed long-term settlements that relied on perennial systems of crop production. That these practices produced significant portions of calorie requirements that produced a surplus, fueling winter survival, trade, and cultural cohesion. If this premise is to be accepted, it follows that these practices must have resulted in wide-ranging alteration of the American Landscape, and that the production and processing of these crops must be considered by ethnologists and landscape historians in seeking an understanding of the change in the American cultural landscape following European invasion and colonization.

In this paper, the author analyzed accounts of the region by Hernando de Soto and William Bartram, two Europeans who embarked on ambitious expeditions into the interior of the temperate American Southeast. These expeditions, though separated by 250 years, and undertaken by men with vastly different motivations, constitute foundational sources if we are to understand the condition of pre-Colonization American Landscape, and the relationships between American Indian societies and the native flora & fauna of the region.

Note: Selections from this manuscript were published in the Association for Temperate Agroforestry Quarterly Newsletter, available at

https://www.aftaweb.org/138-2018-vol-24/volume-24-no-2-august-2018/239-agroforestry-as-observed-by-the-desoto-expedition-of-1538.html?hitcount=0

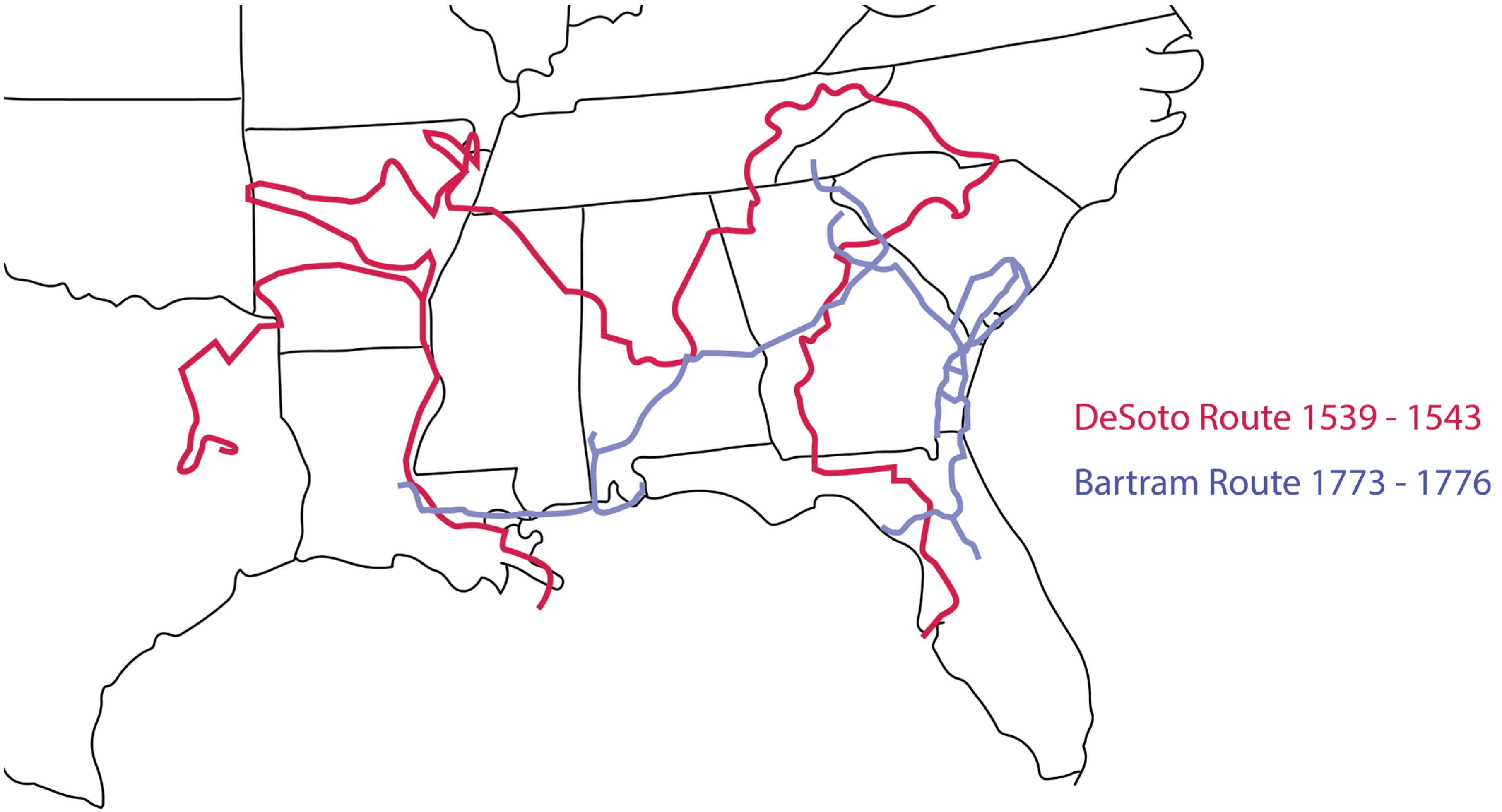


Figure 1.1 - Routes taken by de Soto and Bartram on their journeys through the Southeast

Hernando de Soto Background

To begin our study, we rely on the Narratives of the Hernando de Soto expedition. This journey, without a doubt the most intensively studied of the early Spanish expeditions into North America, represents one of the most significant windows into American Indian cultural practices as they existed prior to European colonization of the continent. The extensive agroforestry practices, hinted at by the surviving DeSoto narratives, offer valuable precedent for the reestablishment of agroforestry practices throughout the Eastern United States.

Following a successful campaign to conquer the Inca in Peru alongside Francisco Pizarro, Soto embarked on the expedition for which he is much better known and is the focus of our attention for the purpose of this paper. Approximately 700 men left Spain with Soto to embark on this expedition and arrived in Cuba in June of 1538 to provision and prepare. Once provisioned with "250 horses… 3,000 loads of cassava, 2,500 shoulders of bacon, 7,500 bushels of corn, and hundreds of swine" (Galloway, 1997) the men embarked for Florida.

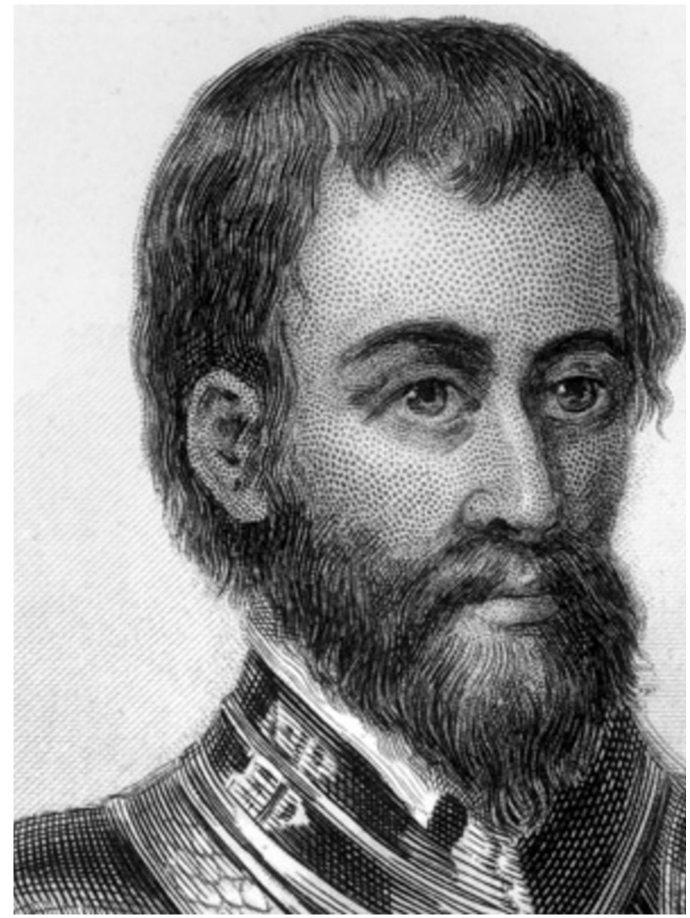


Figure 1.2 - Portrait of de Soto

This ultimately ill-fated, four year expedition would range as far north as South Carolina, west across the Mississippi river, and eventually an escape by the survivors down river to the gulf of Mexico. Along the way, the Spaniards traveled through territories of many nations, and often secured provisions and safe passage by kidnapping local rulers, holding them hostage until the edge of their territory was reached.

We see within the four available narratives, written or dictated by survivors of the expedition, two main categories of evidence for broad-scale tree cultivation that served as staple food for large populations, supplementing their maize crops.

The first are descriptions of the landscape that the party traveled through, showing evidence of cultivation and care, despite appearing wild to the soldier's eye that observed them. The fact that trees are left standing within agricultural fields, and the observation of clear forests points towards an agroforestry system where crop trees are encouraged to grow within fields, whether through preferential clearing, or systematic planting and cultivation.

The second category is of provisions obtained directly from Indian villages, whether via force or gift, that indicate an abundance of tree crop produce that was clearly a preferred food source when compared to the staple crop of Maize.

"The fruits are common to all, for they grow very abundantly in the open fields, without it being necessary to plant or cultivate them. Wherever there are mountains, there are chestnuts. They are somewhat smaller than those of Spain."

"The trees grow wild in the fields without being planted or manured and are as large and as vigorous as if they were cultivated and irrigated in gardens."

"Within a league and a half league about that town were other towns where there was abundance of maize, pumpkins, beans, and dried plums native to the land, which are better than those of Spain and grow wild in the fields without being planted. Food which seemed sufficient to last over the winter was gathered together from those towns on into Anhaica Apalache."

"That land was very pleasing and fertile, and had excellent fields along the rivers, the forest being clear and having many walnuts and mulberries."

"In the open field were many walnut trees with soft nuts shaped like acorns…There were many mulberry trees and plum trees having red plums like those of Spain, and others gray, differing, but much better, and all the trees as verdant all year as if set out in gardens and in a clear grove."

"In the open fields were many plums, both those of Spain and those of the land, and grapes along the rivers on vines climbing up into the trees."

"They fed their horses, repaired the harness, took some plums, grapes, and other dried fruits, which they found in abundance."

"In the houses were found many [walnuts] which the Indians had stored away.

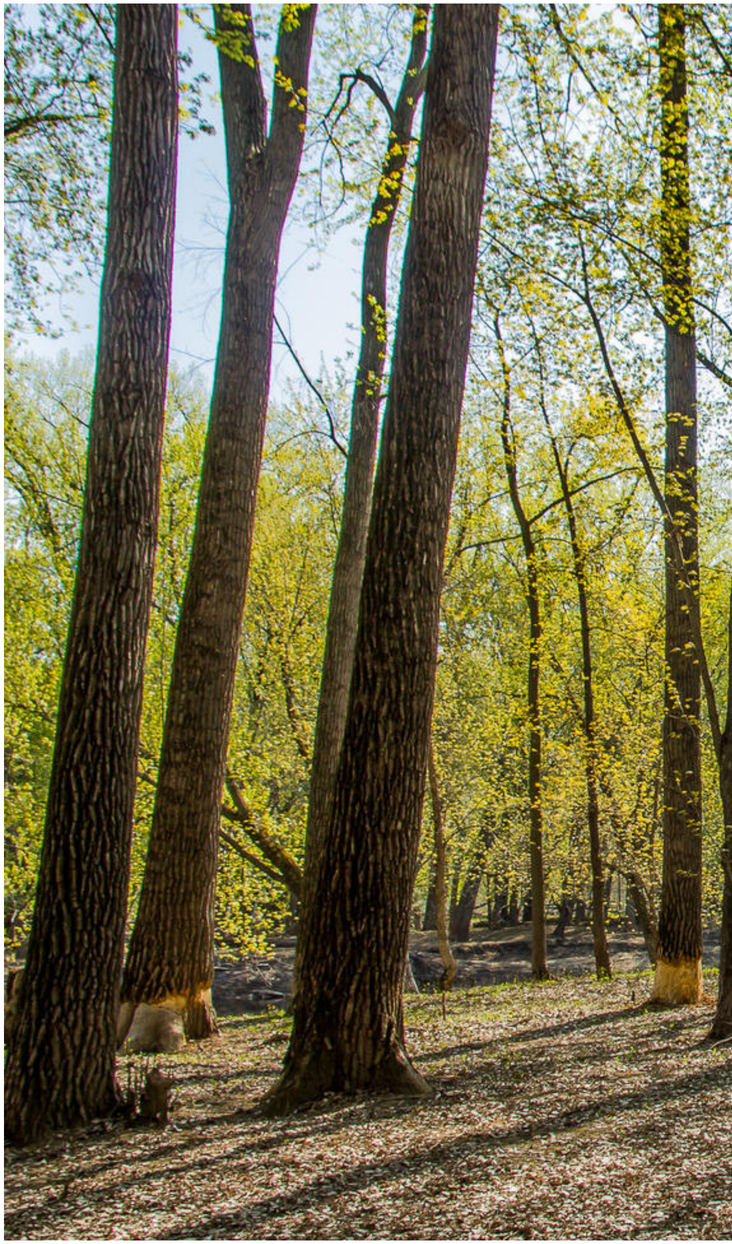


Figure 1.3 Girdled trees in an Appalachian Woodlot

Desoto Narrative Excerpts - *Evidence of Tree Crop Abundance*

"Spaniards found in the town of Aminoia, eighteen thousand measures of corn, with a great quantity of nuts, dried plums, and some other fruit unknown in Spain. Therefore they restored themselves by degrees, for besides these provisions they were very conveniently lodged."

"The plums are of two kinds, red and gray, of the form and size of walnuts. They have three or four stones." (Likely referring to the fruit of Prunus americana, and Diospyros virginiana, respectively)

"Twenty Indians came out to meet him each carrying his basket of mulberries which grow in abundance and good from Cutifachiqui (Columbia, South Carolina) thither and also on into other provinces, as well as walnuts and plums."

"...there was an abundance of butter in gourds, in melted form like olive oil. They said it was bear's grease. There was also found considerable walnut oil which like the butter was clean and of a good taste"

"...the Indians get a large quantity of oil from walnuts"

"…no end of oil from walnuts and acorns, which they knew how to extract very well, which was very good and contributed much to their diet."

"...and there came messengers from Mabila bringing to the chief much bread made from chestnuts, which are abundant and excellent in that region."

"The next day the Christians arrived at a fair-sized village where they found much food and many small chestnuts dried and very delicious, wild chestnuts"

Figure 1.4 Hickory Nuts, Shells & Husks

Bartram

From 1773 to 1777, Quaker Botanist William Bartram travelled the frontier of the American Southeast, collecting specimens and drawings of the species and ecology of what is now the Carolinas, Georgia, Alabama, Mississippi, and Florida. Bartram had been trained by his father, John, himself a noted botanist, in the newly created Linnaean taxonomy, and his studies not only resulted in the cataloging of a multitude of species new to European science, but also marked a "shift from single-species study to the examination of multiple species and their interactions within specific ecosystems." (Wynn, 2018) His narrative is posited by scholars as the first in a tradition of American nature writing, that would inspire not only American writers that would follow including Thoreau, Leopold, and Abbey, but also the Romantic poets of England who were his contemporaries.

Thanks to his focus on describing the wilderness as a whole, as well as its constituent elements, we are able to gain a deeper understanding of some of the cultivated landscapes described by Soto's mean two centuries before. Through his prose, we gain a deeper understanding of the ecological communities that were shaped by earlier inhabitants of the area, and we begin to understand how these systems may have evolved, following the displacement of their designers, into the landscapes we observe in our forests today.

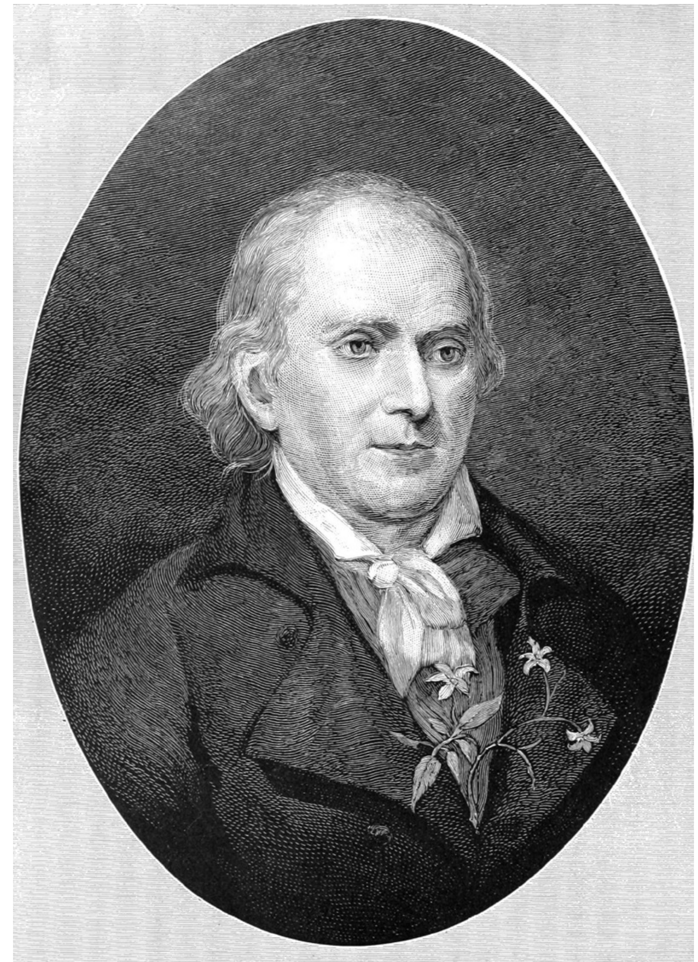


Figure 1.5 Portrait of William Bartram

William Bartram Excerpts

"… a delightful grove of forest trees, consisting of Oak, Ash, Mulberry, Hiccory, Black Walnut, Elm, Sassafras, Gleditsia, &c. This flourishing grove was an appendage of the high forests we had passed through, and projected into an extensive, green, open, level plain, consisting of old Indian fields and plantations."

"We then passed over large rich savannas or natural meadows, wide spreading cane swamps, and frequently old Indian settlements, now deserted and overgrown with forests. These are always on or near the banks of rivers, or great swamps, the artificial mounts and terraces elevating them above the surrounding groves. I observed, in the ancient cultivated fields, I. diospyros, 2. gleditsia triacanthos, 3. prunus chicasaw, 4. callicarpa, 5. morus rubra, 6. juglans exaltata, 7. juglans nigra, which inform us, that these trees were cultivated by the ancients, on account of their fruit, as being wholesome and nourishing food. particularly juglans exaltata, commonly called shell-barked hiccory. The Creeks store up the last in their towns. I have seen above an hundred bushels of these nuts belonging to one family. They pound them to pieces, and then cast them into boiling water, which, after passing through fine strainers, preserves the most oily part of the liquid: this they call by a name which signifies hiccory milk; it is as sweet and rich as fresh cream, and is an ingredient in most of their cookery, especially homony and corn cakes."

"The Chicasaw plum I think must be excepted, for though certainly a native of America, yet I never saw it wild in the forests, but always in old deserted Indian plantations : I suppose it to have been brought from the S. W. ... by the Chicasaws."

"The orange grove is but narrow, betwixt the river banks and ancient Indian fields, where there are evident traces of the habitations of the ancients"

"The surface of the ground upon this bluff, extends a mile and a half or two miles on the river, and is from an half mile to a mile in breadth, nearly level, and a good fertile soil; as is evident from the vast Oaks, Hickory, Mulberry, Black walnut and other trees and shrubs, which are left standing in the old fields which are spread abroad to a great distance; and discovers various monuments and vestiges of the residence of the ancients; as Indian conical mounts, terraces."

Figure 1.6 Bartram illustration of Paw paw fruit

Discussion

By the sixteenth century, American Indian culture in the American Southeast had entered what is known to anthropologists as the Mississippian period that is marked by the development of permanent villages that were continuously inhabited for 50 to several hundred years (Abrams & Nowacki, 2008) This development away from nomadic, hunter-gatherer societies, towards the establishment of complex towns and villages, marked a distinct shift in the landscape that is visible in the archaeologic record, where it has been observed that food related detritus becomes dominated by plant materials as opposed to animal remains. (Moore & Dekle, 2010)

Surveys of charcoal found in archaeological investigations of Indian villages is a primary method for quantifying these shifts, a 1982 study examining American Indian impacts on the ecology of the Little Tennessee River Valley offers a compelling evidence for this shift in settlement patterns that began in the late archaic period (4,000 years before present) and peaked in the Mississipian period (500-1000 years before present.) In their findings of preserved charcoal, a distinct pattern emerges of strong dominance of Upland taxa, which include nearly all of the crop trees identified in this paper (quercus, castanea, morus, prunus, etc..) , and near disappearance of bottomland taxa (populus, platanus, salix, etc…)(Chapman et al., 1982.) These patterns are the likely result of permanent settlement of riversides, where vegetation is cleared of species that are less useful for food and fiber, in favor of agricultural plots dominated by annual and perennial food crops.

It is during this period that initial European expeditions first penetrated the interior of the North American continent. The disease and conflict left in the wake of these expeditions are thought to have resulted in utter disruption of these societies, with the survivors of the diverse cultures encountered by the Spanish forced to reorganize and coalesce into the Muscogee that would be known to English settlers and explorers 150 years later.

Without metal tools for land clearing, slash-and-burn style swidden agriculture is not believed to be practical for these peoples, instead, permanent agricultural fields were likely established that were likely maintained with low-intensity burning and only fallowed for short periods.(Abrams & Nowacki, 2008) The establishment of these long-term settlements and cropping systems allows the cultivation and care of perennial crops to become a viable strategy.

This shift marks a turning point from the largely opportunistic foraging behaviors of earlier epochs, toward more intensive, centralized management that had potential for domestication and coevolution. Archaeologists and ecologists have found evidence for wide-ranging management of forests that may explain the observed phenomenon of relatively higher proportions of nut trees of the Carya, Juglans, and Quercus genera in the vicinity of Indian settlements. Though research into the practice of this management is limited, and exact strategies may be lost to time, it is theorized that a combination of girdling and thinning of unwanted trees, combined with low-intensity fire to reduce competition, may have been practiced throughout the region to maximize nut crops while reducing competition with animals for the produce. (Fritz, 1990)

It is easy to imagine how these practices could have resulted in “clear, open groves” with a park-like or garden-like appearance that were noted by Soto’s men, and which Bartram could still clearly see the evidence of over 200 years later.

Figure 2.1 - Grafted Hickory in Sunny Ridge Woodlot

Chapter Two Sunny Ridge: A 20th Century Experiment in Temperate Agroforestry

Introduction

In the past half-century, a global renewal of interest in perennial agriculture has emerged as a potential solution to the problems of topsoil erosion and nutrient depletion[1,2], consequences of industrial agriculture and global commodity trade. This renewal can be seen in the establishment of agroforestry departments within university academic programs and extension services[3], as well as the rise of the permaculture movement, and the works of independent researchers such as Wes Jackson at the Land Institute seeking perennial alternatives to cereal grains.[4] Considering these developments, it is useful to continue our exploration of precedents for Mid-Atlantic agroforestry by tracing the development of the concept of perennial agriculture in industrialized nations, a concept which was largely catalysed by the work and writing of Dr J Russell Smith.[5]

Critical study of the contributions of J Russell Smith are largely concerned with his role in the establishment of the field of Economic Geography[6]. Widely recognized as a pioneer of this field within the United States, Smith founded the Department of Geography and Industry at the Wharton School, and authored the first college level text on the subject, *Industrial and commercial geography* in 1913[7]. Explored within this text are foundational attempts at developing principles by which to conceptualize an international economy that was increasingly influenced by rapid advances in communication technology, globalization, and the expansionist impulses of the young American empire.[8] In travels associated with this work, Smith began to understand the fundamental relationship between topsoil resources and the prosperity of civilizations, with prescient recognition that these resources are finite, with modern prosperity influenced by millennia of land management strategies of agricultural communities.[9] Smith continued his career in Geography, lecturing at the Wharton School and Columbia University, eventually publishing over thirty texts on the subject over the course of his life[10], including texts titled: *The World's Food Resources (1919)*[11], *North America, Its People and the Resources, Development, and Prospects of This Continent as an Agricultural, Industrial, and Commercial Area(1925)*[12], and *Grassland and Farmland as Factors in the Cyclical Development of Eurasian History (1945)*[13].

Smith's interest in land management and its effects on national interests and societal health led him to pen the work he considered his greatest contribution to humanity[14], *Tree Crops: A Permanent Agriculture*[15]. This text explored the potential for a wide variety of tree species to fill similar niches as those currently occupied by mass-produced annual commodity crops such as corn and the other cereal grains. While these ideas were not widely adopted at the time of publication, interest among scholars and growers has grown since the 1970s[16]. Individual researchers, farmers, and hobbyists are quick to point to *Tree* Crops as a primary source of inspiration[17], yet the story of Smith's influence on the field of perennial agriculture, and the larger environmental movement remains largely unexplored by the academic community, only occasionally referenced in the historical context as a forefather of agroforestry and permaculture[18,19,20]. His theory of 'A Permanent Agriculture' was an attempt to synthesize the perennial based strategies present in the vernacular agriculture of indigenous peoples, American homesteaders, traditional European and Mediterranean practices, and modern, globalized industrial agriculture.[21]

Note: This manuscropt was originally developed for publication in a UK-based journal, readers will note spelling and attribution conventions reflect Oxford style.

This paper explores, through field survey, interviews, and archival research, the agroforestry practices implemented by J Russell Smith at Sunny Ridge, and discusses their relative permanence on the site. These practices, presented in *Tree Crops* as permanent solutions to issues caused by deforestation, overgrazing, and annual tillage, formed the basis for Smith's agricultural experiments. Notable strategies explored here include: terracing steep slopes, alley cropping, integration of livestock with tree crops, and systematic breeding of wild genetic stock to develop improved tree crop cultivars.

This experimental farm, dedicated to perennial agriculture research and practice, developed over the course of J Russell Smith's life and career.[22] The site was developed over a half-century into one of the largest and most significant private endeavours dedicated to the study of sustainable agriculture alongside the widely publicised Land Institute, Rodale Institute, and Leopold Centre. By expanding the original holding up to the forested ridge, Smith could test the various concepts that he explored in his foundational text *Tree Crops: A Permanent Agriculture.*

Other experimental farms in the mould of Sunny Ridge have come and gone since the turn of the 20th century, at various scales, from backyard to commercial orchards, largely originated by colleagues of Smith in the early 20th century.[23,24] However, due to its connection to the originator of the perennial agriculture movement, as well as its relative integrity over half a century of abandonment, Sunny Ridge is likely the most important extant site to study abandoned genetic lines of improved crop trees, as well as the long-term success of Tree Crop experiments in an unmanaged setting.

Despite decades of abandonment, subdivision, and development, signs of Smith's life's work remain abundant and apparent. Due to his use of marginal land, as well as fence rows, property lines, and rights-of-way for his experiments, many plots of original plantings still stand in areas not suitable for housing developments or pasture expansion. Rows of grafted trees now form the understory of second-growth forest that has grown up around the old orchards and nurseries (Figure 2.1). While Smith's writing has proved to be his best-known legacy, due to its influence on modern practitioners, the experimental plantings at Sunny Ridge are a living textbook, worth conserving, studying, and mining for genetic lines that otherwise may be lost. Despite his presence at the forefront of the movements that would lead to modern global commerce as well as modern environmentalism, the site of the experiments where his theories were put to the test via practical study has never received formal study prior to the investigations by the authors of this paper, with no published record of the site's condition following its abandonment in the mid-1950s.

The Rise of Agroforestry

Though the publication of *Tree Crops* received little mainstream attention at the time of its publication, the book found a receptive audience in the group of scientists and writers promoting ecology and environmentalism as a counterpoint to the anthropocentric field of conservation.[25] These thinkers were galvanized by the 'Dust Bowl' an unprecedented anthropogenic environmental catastrophe in the Western US. This disaster was brought on by a period of drought in the 1930s in which overgrazing and mechanized tillage disrupted existing grassland ecosystems, leading to soil erosion and intense dust storms affecting 400,000 km^2 and displacing tens of thousands of settler families[26]. In the wake of the Dust Bowl, this loose group whose members included celebrated environmental leaders Aldo Leopold, Hugh H. Bennet, and Russell Lord as well as many other influential national figures, coalesced into Friends of the Land, an advocacy group of which Smith was a founding member, of whom Lord said "He is way up there in my estimation, among the true heroes of husbandry in our times and a founder and prime mover in Friends of the Land…"[27] This group continued publishing and advocacy activities until Lord's retirement in 1962.

Because *Tree Crops* had presaged the potentially disastrous consequences of unrestrained industrial agriculture, J Russell Smith enjoyed an audience with this group, leading to an invitation to the associations first formal gathering, as well as an outlet for his articles and his 1950 *Tree Crops* revision.[28] Though his writings over the course of the first half of the 20th century did not achieve the mainstream acceptance he had hoped for, his contributions to the adoption of agroforestry as an agricultural practice in the United States in the second half of the century are undeniable.

After reading the first edition of *Tree Crops* in 1934, Arthur E. Morgan, chairman of the Tennessee Valley Authority, a United States government conservation & economic development corporation, ordered the installation of a large-scale tree crop nursery for long-term study.[29] Many trees planted at this nursery included trees sourced from Smith's own nursery at Sunny Ridge. This experiment reportedly received the direct approval of President Roosevelt, who personally visited the nursery, stating "This is wonderful. I think you are doing a marvellous piece of work here." Unfortunately, this program quickly came to an end in 1937 due to shifting political priorities,[30] but similar lines of research are currently being carried out at numerous US institutions thanks to pioneering research and genetic improvement inspired by Smith.[31]

Development of the Theory of Permanent Agriculture

A world traveler at all stages of his career, lessons learned via his field excursions were of fundamental importance to a developing theory of the connection between a civilization's prosperity and its topsoil resources.[32] During his tenure as Head of the Geography department at the University of Pennsylvania, Smith made numerous excursions to Western China, Syria, Palestine, Greece, and North Africa where he witnessed the denuded hillsides and erosion scars on the land left by millennia of farming and forestry.[33] Where powerful empires once stood, the people now lived in poverty, struggling to sustain their families from the depleted land. The cause of this depletion was the progression of: deforestation, to annual tillage for the cultivation of grains, to overgrazing in the steeper regions of the landscape. As vegetation was consistently removed from the hills over generations, root systems holding the water and soil on the hillsides were reduced from those of old-growth forest, to those of sparse pasture. Over time—without vegetation slowing water's course and allowing it to infiltrate the soil—deep gullies cut through the land, transporting soil to water systems where an excess of sediment pollutes streams, and disrupts waterways.[34]

In contrast to this scenario, Smith describes the agricultural systems witnessed on a research trip to Corsica. On this mountainous island, a territory of France, to the west of Italy, Smith found a vast chestnut forest blanketing the ridges. This forest, intensively maintained and improved through breeding and management for nearly 500 years, was the foundation of the island's 'permanent agriculture' and required no tillage, irrigation, or imported fertilizers, but rather relied on long lived trees, intentional genetic selection, and the natural rainfall deposited by the humid winds of the Mediterranean. In Corsica, he describes clear streams, fertile valleys, and prosperous people due to the foresight of adapting their system of agriculture to the physical features of the land (Figure 2.2). Smith connected this experience to patterns he was aware of in the United States, where similar damage to what he had observed in China and Syria, accelerated by agricultural mechanization, had occurred in a matter of centuries rather than millennia.[35]

Figure 2.2 - Scenes from J Russell Smith's travels in Corsica

These travels proved influential to Smith, a fact clearly evidenced by the time and resources devoted to the Sunny Ridge project. Smith insisted throughout his life that his work developing his theory of a Permanent agriculture was not only the most important work of his long career, but a pressing matter of national security. He opined in *Tree Crops* in 1929: "No race…past or present, has been so destructive of soil as have been the farmers of the south-eastern part of the United States during the past century. How long can the United Sates last at present rates of destruction?' In the 1953 revision, Smith goes on to excerpt a 1947 letter from H. H. Bennett, Chief of Soil Conservation Service for the USDA, stating that nearly 25% of American farmland, about 100 million acres, was at risk of severe degradation by erosion.[36]"

With this clear mission now in mind, he set off to develop his small holding of land into a revolutionary centre dedicated to developing the theory and practice of a Permanent Agriculture for the United States.

This theory of a Permanent Agriculture may be summarized by the integration of several key practices into farms around the world, with a specific focus on the utilization of perennial tree crops, with root systems much more capable of holding soil and accessing nutrients and water than their annual analogues. *Tree Crops: A Permanent Agriculture* makes its case for this integration through chapters with titles such as: 'A Corn Tree' The Chestnut, 'The Oak as a forage crop,' and 'The Persimmon, a Pasture Tree for Beasts, and a Kingly Fruit for Men.'

The key practices discussed within tree crops are as follows. Though these practices have been widely applied by agriculturists through history, Smith's work was essential to their integration, systematization, and application to a post-industrial world. These practices now appear throughout the literature, as the foundation of the practice of agroforestry which have been applied to millions of acres of farmland around the world.[37]

- Terracing of steep slopes to reduce the speed of runoff and erosion potential
- Alley cropping—Trees planted in widely spaced rows with annual crops cultivated in the space between rows
- Integration of tree cropping and livestock - cultivating trees within pastures to serve as shade and feed sources, timed grazing between tree rows, selecting for mast crops in woodlands as supplemental forage, and developing novel tree crops as silage and feed sources.
- Systematic breeding to introduce and develop promising genetics to use in the above practices
- With these practices in mind, Smith selected a site and developed an extensive experimental operation.

The Site: Sunny Ridge

Sunny Ridge Experimental Farm was built in Northern Virginia along the Eastern slope of the Blue Ridge Mountain, between Snickers and Keye's Gap. Expanding from 160 acres at the time of purchase in 1900, to over 2000 acres at its sale in 1951, the farm rapidly grew to include both fertile pastures in the valley, as well as rocky land near the ridge (Figure 2.4). The site is characterized by various silt loam species, generally becoming shallower and rockier as one approaches the ridge line, where soils are characterized as very gravelly, cobbly, and flaggy.[38]

While others saw little potential for profit in the rocky ridge land, Smith found it perfectly suited for developing a new method of mountain agriculture. Available at a low price, this land may not have been well suited for corn or pasture, but it was already rich in the very same tree crop species that he wished to study. The composition of native forest at Sunny Ridge includes red oak (*Quercus rubra*), various species of hickory (*Carya. Spp.*), American persimmon (*Diospyros virginiana*), pawpaw (*Asimina triloba*), and beech (*Fagus grandifolia*). At the time the farm was purchased, American chestnut (*Castanea dentata*) was reported by Smith to be a major component of the forest, but by the end of the 1930s, the aboveground portion of these trees had largely succumbed to the chestnut blight fungus.

The focus of the operations at Sunny Ridge was the nursery. This commercial operation achieved multiple goals for the farm including public outreach, providing a site for curious visitors to tour, dissemination of newly developed and discovered tree crop varieties, and providing income to subsidize the experiments and research taking place on the site. This nursery was centered halfway up the ridge to take maximum advantage of the fertility of the valley as well as the research areas farther up the slope. Leading from this central nexus was an array of paths, trails, and roads to experimental areas as well as the homes of farm workers (Figure 2.4, 2.5).

Figure 2.4 - Present Day Parcel Boundaries with historic limits of Sunny Ridge Farm and 2016 Study Area

Site Background: From J Russell Smith's Archives to His Practices at Sunny Ridge

Within the J Russell Smith archives at the American Philosophical Society in Philadelphia, PA, is a remarkable, but fragmented array of cultivar lists, planting plans, hand-drawn maps, and hundreds of pages of correspondence to friends, relatives, and colleagues.[39] Through this correspondence, Smith sought advice, traded knowledge, managed the farm remotely, and encouraged skeptical experts to visit and see his successes in person. These notes and letters began in 1909 and continued through Smith's retirement, into the 1960s. These pages describe the hundreds of cultivars of hickory, pecan, chestnut, walnut, heartnut, butternut, persimmon, honey locust, filbert, and a number of other tree crops, which were trialled, along with colloquial descriptions of their planting locations, i.e. 'by the honeysuckle near the old auto' or 'in the hollow above the burned house.' Though these descriptions are little to go on, they spurred a field excursion in October 2014 to attempt to locate what remained of the plantings at Sunny Ridge.

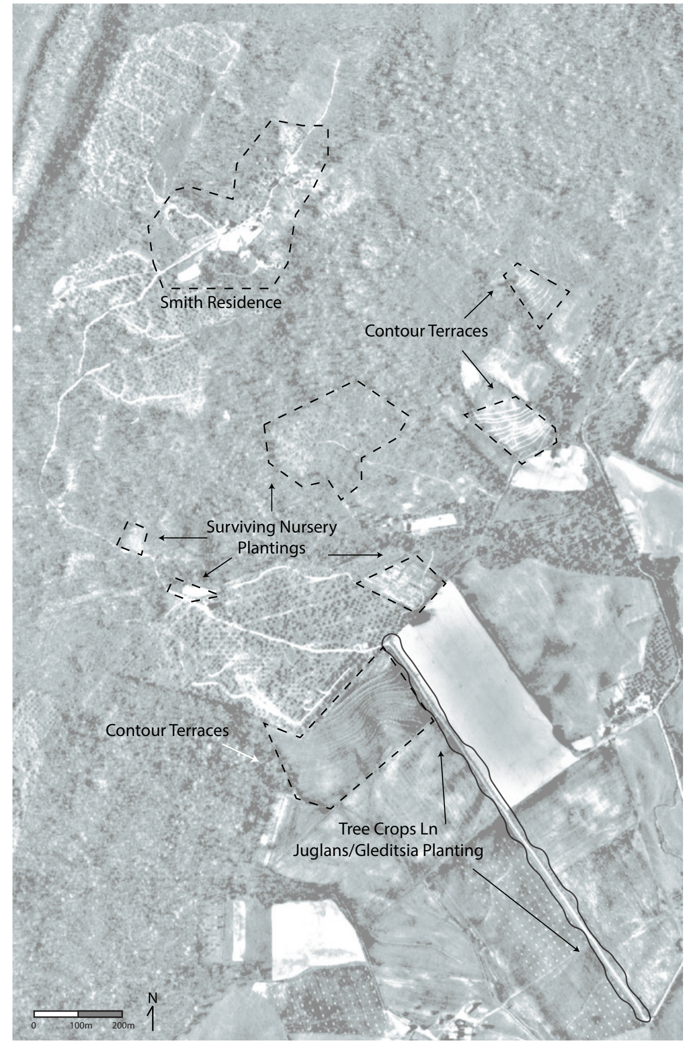


Figure 2.5 - Aerial Photograph ca. 1957, annotated.

After a day of successfully locating a number of old houses associated with Smith and his family, but with no success in finding heritage tree crop plantings, a last effort was made down an old farm lane on another slope of the mountain. With the sun beginning to set, the day took a dramatic turn at a fork in the road where a street sign labeled a private lane *'TREE CROPS LN.'* All along the lane, for nearly a mile, was an extensive planting of honeylocust, pecan, hickory, and walnut, showing clear evidence of cultivation by way of the graft lines 2-3 feet up the stem. Impossible to miss, these grafts cut sharp lines between black walnut rootstock and white-barked Persian scion, between shaggy hickory bark and scaly pecan (Figure 2.6), and between spiny native honeylocust, and domesticated, large fruited cultivars. Continuing up the lane to the first driveway, a local resident greeted us. He knew the significance of the plantings along his lane and promised further knowledge and experience to be shared at a later date. This first encounter with Smith's trees, up to 100 years old, in fine health despite years of neglect, was the first physical evidence of the permanence of his agroforestry practices.

About a dozen additional trips were made to the site between 2014 and 2017, accompanied by various property owners, who had purchased plots of the now subdivided farm, all of whom recognized and respected the efforts that had taken place there prior to their residence. On these outings, over 100 individual specimens were located, relics of the legendary experimental farm that once covered this mountain, now largely overgrown by

Figure 2.6 - Grafted Juglans sp. on Tree Crop Ln

second-growth forest, or developed into suburban lawns. Among these plantings, the trees that have best survived the decades of neglect are the nut trees. Straight rows of grafted hickories stand out from the much larger, scattered, tulip trees that now dwarf them, (Figure 2.7) and scattered varieties of chestnut, have survived the blight and continue to bear fruit.

Among these trees, chestnuts are a common sight, though they are of an unknown parentage, likely unique hybrids of American, European, Korean, Japanese, and Chinese chestnuts. It is known from *Tree Crops* that Smith witnessed the loss of the American chestnut from his land, and conducted extensive trials to hybridize Chinese and European species in an attempt to repopulate his forest.[40] Whatever the genetics, these specimens were observed to be in fine health and still produce large crops judging by the burrs littering the ground.

In addition to the trees spotted in the forest and along Tree Crops Ln, numerous scattered farmhouses, formerly belonging to Sunny Ridge staff, and often pre-dating the farm, were planted with an assortment of specialty trees dating back to the days of the experimental farm and nursery. At some of the houses today, there are living relics of the past. One homeowner mentioned that he had renovated a nurseryman's old house, around which still stood a number of trees that he claimed had been planted after being rejected or returned to the Sunny Ridge nursery.

Figure 2.7 - Grafted Carya sp. in abandoned Sunny Ridge Nursery

Figure 2.8 - Type specimen of Gleditsia triacanthos 'Millwood"

Included among these trees were several honeylocust, walnut, persimmon, and mulberry. Further up the lane, at the house formerly belonging to an overseer of the nursery, stood a massive thornless honeylocust, fully loaded with plump pods up to 18 inches long, and 2-3 times thicker than wild varieties. The owner of this tree was told that it was the source of the 'Millwood' cultivar, which remains the best variety available for honeylocust pod production[41] (Figure 2.8). This tree is a spectacular specimen, over 24' in diameter with a crown spread of greater than 60 feet—a truly remarkable tree that the current owner cherishes for its beauty and legacy.

From field visits and observations, such as these, as well as a preliminary study of Smith's archives at the American Philosophical Society, the scope of and Smith's intentions for Sunny Ridge are increasingly apparent. Using the practice-based framework he set out in *Tree Crops*, the next sections explain the intentions behind the remaining plantings and discuss their relative permanence on the site. Each section describes a practice, as laid out in Smith's theoretical framework, and the evidence for the practical application that remains visible at Sunny Ridge.

Key Practices at Sunny Ridge and their Presence Today

Breeding

The goals of J Russell Smith's Permanent Agriculture revolved around the development of novel cultivars from both native forest trees, as well as suitable trees from around the globe, hybridizing the two when possible to gain benefits from each parent. In nursery lists and field notes from Smith's archive, these goals were clearly reflected in the commercial and experimental work that took place at Sunny Ridge. The establishment of local and national contests supported this practice to encourage farmers, scouts, outdoorsmen, and hunters to take note of the bounty of wild food available around them and submit their best finds for a cash prize. These contests yielded trees selected for their high yield, their large fruit, a form suitable for harvesting, nut shells that may be easily cracked, and other, similar criteria. If a lucky collector happened upon a tree of great potential, these varieties would be cloned via grafting into the fields of Sunny Ridge, creating a new cultivar named for the collector. Current residents on properties formerly belonging to Sunny Ridge speak of finding copper tags in the leaf litter, and rarely attached to trees. These tags may be the only hope of discovering the identity of many of these legacy trees found in the woods throughout the 2,000 acres that formerly made up Sunny Ridge. However, the graft marks, and arrow-straight rows scattered throughout this acreage pose an irresistible question for further research to reintroduce to cultivation some of these uniquely resilient trees that have survived 5 decades of neglect. Genetic comparison of these specimens to known cultivars is a priority to determine novel genetics that may be reintroduced to the trade.

Figure 2.9 - Castanea. sp in Abandoned Nursery

Smith was especially interested in the topic of chestnuts, widely praised throughout *Tree Crops*. He was dismayed by the disparity between the rich hills of Corsica, and the gullied, impoverished Appalachian Mountains, despite both possessing chestnuts as a keystone species. Introduced to North America in 1904, the chestnut blight fungus, native to Asia spread through North America, and rapidly decimated the chestnut forests of the East Coast in the early 20th century.[42] Smith wrote in *Tree Crops*, that given another century or two of life, that he may be able to address the blight via artificial selection from seedlings, but as a pragmatist, he sought chestnut genetics from across the world for trialling.[43] Smith tested European, Japanese, Korean, and Asian species of various cultivars for their crop potential, as well as for the possibility of hybridization with the American species to combine the blight resistance of those varieties with the remarkable stature, taste and longevity of the

American Chestnut. His early efforts in this nationally important venture continue today through the work of the American Chestnut Foundation's traditional breeding program[44], as well as The State University of New York (SUNY)[45] work to modify the chestnut genome to confer immunity to the toxins produced by the fungus. This legacy still stands today at Sunny Ridge. All around the site, on various parcels, there still grow isolated groves, laid out in rows, stunted, showing the effects of blight, but have remained, and lived to reproduce. There also still stands, adjacent to areas that have been cleared for roads or homes, remarkably large, healthy stands of chestnut of unknown parentage. These remnants offer a glimpse into a scene few have experienced in their lifetime, a Blue Ridge slope clothed in the traditional oak-hickory-chestnut forest, an ecosystem which today is exceptionally rare (Figure 2.9).

Terracing

This practice, which Smith had seen utilized with such success in his travels overseas, is unfortunately yet to be discovered at Sunny Ridge. Though there is archival evidence of engineers having been hired to install terraces in small demonstration areas (Figure 2.10), paddocks to be planted with tree crops, no terraces have been found at the site, possibly removed in the grading of lawns when the site was subdivided, or hidden in a portion of the overgrown 2000 acres that has not yet been explored. The terrace is a strategy that has been employed throughout the world for millennia, and Smith was far from the first American to be a proponent of this technique. For the century before Smith's work at Sunny Ridge, terraces for the purpose of drainage had become a mainstream agricultural practice in the South and West. Contrary to this practice, Smith advocated for terraces built to capture rainwater rather than shunting it to a creek. Smith was particularly fond of the *Mangum* terrace[46], a broad, shallow, hillside ditch-terrace system invented by a North Carolina farmer for slowing runoff and mitigating erosion, and which could be continually cultivated with modern farm equipment. These terraces are described in *Southern Cultivator* as such: "The Mangum terrace differs from the ordinary terrace in being a ditch and terrace combined. They are also different in that told style terrace causes the loss of one row of the growing crop to each terrace, while the Mangum style causes no loss, as crops are planted right over the ditch and terrace the same as if they were not there."[47] Along this ditch, a grade of less than 1% is maintained, causing water to slowly disperse through the field, rather than cutting gullies down the slope. In this way, Smith envisioned that terraces planted with chestnuts and alfalfa for example, might salvage hilly slopes from the unchecked flow of accelerating runoff, carrying valuable topsoil to the sea.

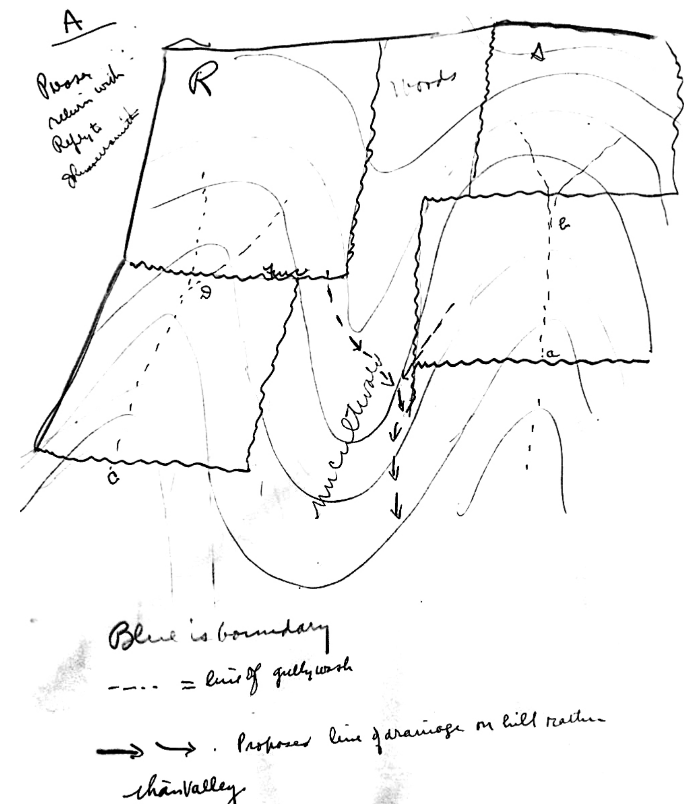


Figure 2.10 - Terrace and drainage sketch
J Russell Smith Archives

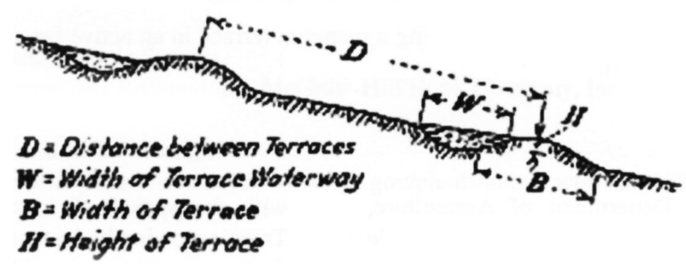


Figure 2.10 - Mangum Terrace Sketch
J Russell Smith Archives

Trees, Animals, & Fencerows

J Russell Smith saw great promise in the integration of tree crops and livestock production.[48] As it stood in his day, and to a far greater extent today, the vast majority of agricultural output in this country is not food for human consumption, but rather feedstock for the production of meat, dairy, and poultry.[49] Finding and establishing new systems that utilize perennial feed sources for these industries remains a critical challenge of developing a sustainable food system. Though this practice has severely lagged behind other agroforestry practices in its adoption in the United States, the fact that Smith was so devoted to experimentation in this field has indirectly contributed to the preservation of these systems at Sunny Ridge. Fencerows apparent in 1937 historical aerial imagery were prioritized for examination in field surveys. And Tree Crops Lane, which was the first clue as to what treasure still grew in the woods of Sunny Ridge, was preserved primarily by its being planted along the existing right of way between two large pastures. On a recent excursion to Sunny Ridge, neighbouring sheep were seen congregating under a honey locust (Figure 2.11), which had recently dropped a prodigious yield of sweet, juicy pods, many of which were at least 14' long, and up to 3' wide when fresh (Figure 2.12). This practice of growing tree crops along existing fence rows and farm roads is one that was highly encouraged by Smith. As crop and livestock farms often have miles of fence lines and lanes, the growth of fruit and nut trees along these rows would not interfere with the movement of machinery of normal farm operations.

> *"In 1916 I planted bunches of pecan seed and black walnut seed along my upland lane in Loudoun County, Virginia, altitude 750 feet. They were not fertilized, cultivated, or in any way protected. It was a test. Both species were able to fight it out with the grass and make a high percentage of survival. In the dryer places it took the seedlings ten years to get five feet high, but they were very stocky and by the end of the decade they had begun to grow more rapidly. There is little doubt that most of the pecans will eventually become large trees if let alone."*[50]

Anecdotes such as these fill Smith's archived notes—evidence of an extensive endeavor that persists in places where development and competition from forests and loggers have not

Figure 2.11 - Sheep grazing on Gleditsia pods along Tree Crops Ln.

undermined his intentions.

Outreach

Always a tireless writer and communicator, Smith devoted countless hours to spreading the word about his dream of a permanent agriculture. These endeavours, out of all of his work, have likely contributed most to lasting changes in the world outside Sunny Ridge. Through his consistent publications in the form of magazine and newspaper articles, Northern Nut Grower industry publications,51,52 and of course the two publications of Tree Crops, Smith used his gifts for communicating his passion both to laymen and professionals. The effects of this outreach are reflected still today at the properties that were subdivided from the original holding at Sunny Ridge. Many current residents know the significance of the land that they now own, including a primary contact for this research, Susan Kasper, a Sunny Ridge property owner since the early 1980s who was particularly inspired by the Tree Crops text. Long interested in sustainable agriculture, Ms. Kasper read the text and when seeking property to begin her own experiments, eagerly purchased a tract of land at Sunny Ridge when she learned it was available.

Collaborating with her neighbors, who were similarly intrigued in continuing the work of Smith, Ms. Kasper organized a series of tree crops conferences to take place at the mountaintop retreat that Smith had constructed in the mid-1930s (Figure 2.13). This property which hosted the conference in 1985 was owned by Dr Fred Sanderson, a key player in the organization of US agricultural policy for the Marshall Plan[53], and reportedly a great admirer of Smith. Other notable residents of Sunny Ridge parcels include: Miles Merwin, who was inspired to found International Tree Crops Institute, an organization for furthering the research and development of the practices proposed by J Russell Smith; and Greg Williams, an experimental horticulturist, who for 30 years published *Hortideas,* a research newsletter on innovative practices for fruit and vegetable production. That this assortment of influential thinkers in the field of sustainable agriculture all chose to live at the site of Sunny Ridge is no coincidence. Each was drawn to this property after reading *Tree Crops* and upon learning of its subdivision, purchased a share of the historic property to learn from and continue the practices that had been pioneered there. In spite of this, there have been no formal research or conservation efforts on the bulk of the land. Much of the site that hosted the most interesting and valuable research has escaped the development that cleared much of the nearby valley for housing, thereby preserving, for now, these extant trees for research

Figure 2.12 - Scale of Tree Crops products collected from Sunny Ridge Site

and inspiration.

Conclusion

Despite the longevity of many of the plantings of Sunny Ridge, the fact remains that what has proven truly permanent was not the plantings in the field, but the writing done to spur the imagination of the people toward his revolutionary concepts of perennial agriculture. Having contributed hundreds of columns and letters to periodicals in addition to his books, the effort devoted to publicity of his concepts cemented his legacy as a fore-father of American agroforestry, despite not seeing the systemic changes to the agricultural system that he had hoped for. While we have not seen mass conversion of corn fields to chestnut groves as he advocated in Tree Crops, traces of ideas Smith promoted are evident around the country. It is undeniable that soil conservation through the use of perennial species gained greater acceptance in the 20th century.55 However, these approaches largely fail to acknowledge the crop production potential of the trees planted to achieve soil conservation goals. For that reason, a need remains for experimental farms like Sunny Ridge, to make the argument that tree crops are an economically viable agricultural technique. In that way, combining the conservation benefits with monetary benefits, adoption of these practices ought to accelerate further, resulting in greater prosperity for farmers, while reducing the loss of nutrients and topsoil into estuaries.

In addition to the extant plantings at Sunny Ridge described, a number of plantings of rare and productive tree crops survive within the nearby Quaker community of Lincoln, Virginia at the historical meeting house of which Smith was a member, and at the farms of fellow Quakers and friends (Figure 2.14). The extent of these outlying plantings shows the influence of Smith's outreach among those who valued his passion for environmental conservation through perennial agriculture. This passion for spreading knowledge of the promise of perennial cropping systems has in fact led to the most lasting effects of his lifelong quest to develop these systems. Through his writing and relationships, the promise of 'A permanent agriculture' has been achieved, though in a very different sense than intended during his lifetime. Though the American agricultural system has remained focused on increasing yields of annual crops, the countless leaders in sustainable agriculture inspired by his work have carried on his work since his death, leading to greater popularization and developments in perennial agriculture.

Smith's archives contain an impressive quantity of correspondence between colleagues with similar interests in sustainable agriculture, spanning 50 years of practical work, testing his theories on the ground. The letters show ongoing communication sharing questions, insights, techniques, and new cultivars. Striking among these letters, were those written near the time of his death, lamenting the short life of individuals and the need for incorporating an endowed foundation to carry on the work of himself and his Northern Nut Growers Association colleagues.

The valuable collection of tree crops at Sunny Ridge has largely gone unnoticed, except by a few enthusiasts and specialists, but its potential to inform and inspire future farmers, designers, and policy makers is great. Further study leading to its preservation is an urgent necessity—from further forays into the 2,000 acres of lawn and wilderness, to conservation of the genetic lines Smith systematically collected and developed. With preservation, this ridge may serve to inspire future innovators, just as the chestnuts of Corsica inspired Smith.

Figure 2.13 - Historic Cabin along Tree Crops Ln

Figure 2.14 - Grafted Carya sp. located at nearby historic Quaker farm

INFLUENCE OF SCALE ON DESIGN AND PRODUCTION GOALS OF AGROFORESTRY SITES IN THE MID-ATLANTIC UNITED STATES

Scales of Operation for Temperate Agroforestry

Agroforestry practices are viable in a range of scales and applications that suit the social, ecological, and production goals of the managers / clients. While conventional agriculture as it is practiced throughout the world is largely monocultural fields laid out in rows for ease of mechanical cultivation and harvest, agroforestry exists as a continuum from straight, mechanically harvested rows of one species of perennial crop (Figure. 3.1), as in a conventional orchard, to highly diverse arrangements of plants, laid out in patterns that suit the climate, topography, aspect, or social needs of a site. (Figure. 3.2) The sub-disciplines of agroforestry, including permaculture and forest gardening, encourage design towards the latter end of the spectrum, while agroforestry systems that are widely encouraged by university extension and regional policy networks tend toward the former.

Figure 3.1 - Wheat and Walnut Alley Cropping

The two ends of this spectrum, though they are anchored by the use of perennials as the keystone of the design, can easily be seen as in conflict, as they take starkly diverging forms. However, the underlying patterns often have more in common than may be immediately apparent, and layout and design strategies are in fact responses to the goals and primary yield desired by the manager.

Integral to understanding the divergence in form between these modalities is the scale at which they are implemented. This paper examines a range of experimental sites of varying scales in the Mid-Atlantic United States that have adopted agroforestry practices for commodity production, community development, and ecosystem service provision, however the scale of the installations have informed the systems design, leading to a divergence in the goals pursued.

While a small-scale site can easily accommodate social production goals including education, recreation, and community development, these sites are often unable to generate sufficient agricultural yields to provide sufficient income via direct or indirect sales of non-value-added produce. (Ferguson and Lovell 2017) The reliance on socially oriented programming and production goals necessitate certain design features such as sheltered space for large groups, food preparation areas, and sensory stimulating environments that create novel and enriching experiences that engage the visitors the site relies on for income.

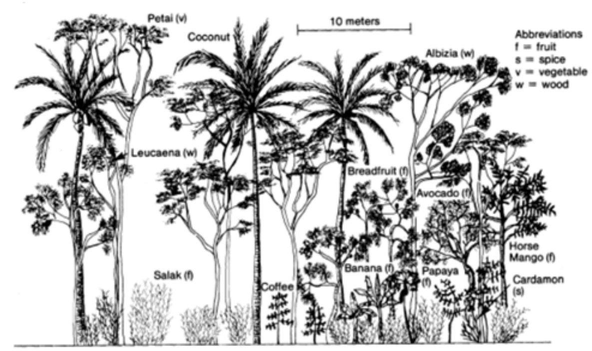


Figure 3.2 - Javanese Agroforestry Diagram

Likewise, on a large-scale perennially focused farm, low diversity, and homogenized layout methods necessitated by industrial agriculture and market forces create a less socially stimulating environment but are able to sustain their operations via direct marketing and commodity production thanks to their economy of scale. However, these advantages are often liabilities when pursuing social and community goals. Because the scales of these properties are difficult to traverse on foot and often rely on chemical and mechanical technologies, many barriers are present that impose spatial and temporal limits on the visitor experience.

By conducting a survey three sites that range in scale from 6 to 3,000 acres, we can begin to understand how and why production goals and strategies tend to organize smaller sites around socially-focused goals, while larger sites implement designs that prioritize production over visitor experience.

The Rise of Contemporary Agroforestry

In temperate regions of the globe, interest in adoption of agroforestry practices at a range of scales from homestead to large agribusiness enterprises. Though systems that integrate trees, crops, and animals in various combinations have been implemented around the world for millennia, it is only in the past several decades that these practices have received formal study and adoption on a global scale. Beginning in the 1970s the international community has increasingly recognized the utility of agroforestry practices in the tropics, but only in the past three decades have these systems been promoted in temperate regions.(Nair et al. 2012)

Agroforestry practices have been brought into conventional farming systems as an approach to mitigate "increased soil erosion, surface and ground water pollution, and decreased biodiversity" on farms of all sizes (Hérault 2014)(Figure 3.3). As adoption increases, scientific understanding has increased commensurately, thereby reducing risk in further adoption and promotion of these strategies by universities, governments, and NGOs. This increase in mainstream acceptance can be seen in the activities of Silvoarable Agroforestry for Europe (SAFE) which has led to national adoption of agroforestry as a carbon sequestration strategy, with France setting an ambitious goal of 600,000 ha (1,482,632 acres) of new agroforestry systems installed by 2020, accounting for 5% of the nation's carbon reduction plan (Workman, Monroe, and Long 2005). European initiatives like SAFE are mirrored in the United States, where University agroforestry departments have emerged, and extension agencies have begun working with funding and cost-share partners to subsidize agroforestry on family farms (Dupraz, Burgess, and Gavaland 2005).

The strategies adopted in these government and university approaches tend toward those that best integrate into conventional agriculture systems which rely on economy of scale and mechanical efficiency. Typically harvested and cultivated by tractor, these practices are typically laid out in rows, with minimal diversity. By implementing these systems in this way, trees may be added to a conventional farm without radically shaping cultivation and harvesting patterns (Heckert 2014). Because conventional farms exist to maximize production of commodity crops while maintaining long-term production capacity, the capability of agroforestry systems to increase yield through cropping in multiple canopy strata, and by sheltering more sensitive annual crops make these strategies attractive to conventional producers.

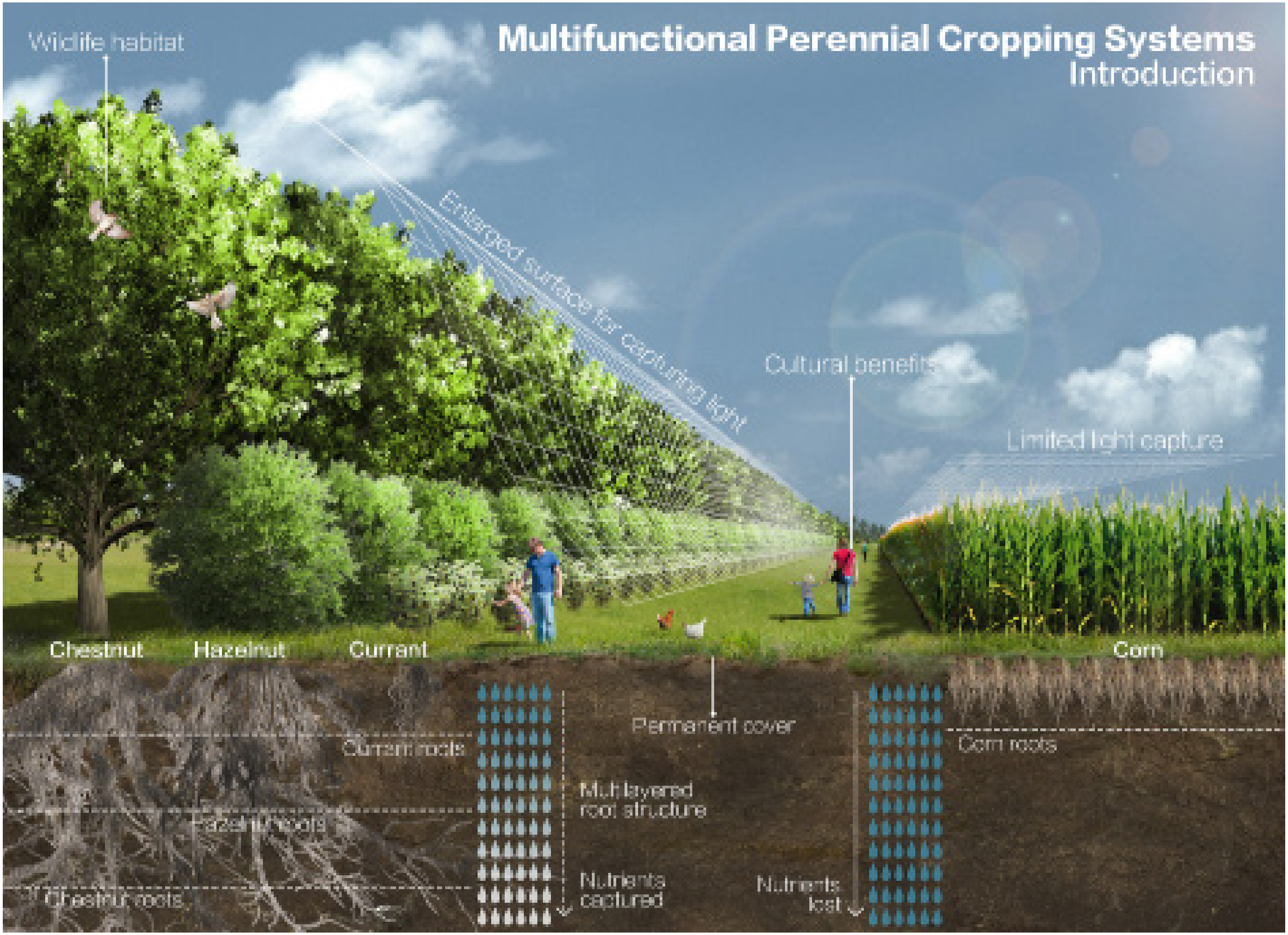


Figure 3.3 - Multinational Perennial Cropping System Diagram

While adoption has been increasing by conventional, large-scale producers, a similar trend towards the promotion of perennial agriculture may be observed in small-holdings and community agriculture organizations (Munsell et al. 2017). These groups often identify as implementing forest gardens or permaculture, a design and ethics system that was developed in Australia in the 1970s around the same time that agroforestry was beginning to be widely promoted by governments and academic institutions. Rather than deploying strategies that bring trees into conventional agricultural systems, these designs deploy perennial crops into home and community gardens. The goals of increasing biodiversity, soil fertility, production, and water quality are the same as in the agroforestry systems described above, but the systems that are designed to achieve these goals are implemented in distinct and novel ways when the primary goal is not commodity production, but rather social development and personal sustenance. Sociological studies of agroforestry adoption in the United States do not exist, but in a study of agroforestry adoption in Cameroon, the authors found that in the case of village-based farms, agroforestry was linked to an increase in cultural and natural capital at a far greater rate than financial capital, leading to the conclusion that there is a link between community development and implementation of perennial agricultural systems. (Jose 2009)

A factor unifying these sites, across scales are the secondary goals of ecosystem services provision. These practices produce externalities derived at the farm scale but which benefit society at regional, and even global scales. Services that extend beyond the farm include clean water, flood mitigation, clean air, carbon sequestration, and biodiversity. (Jose 2009)

Biodiversity services provided by agroforestry systems, beyond crop species planted, are seen in the habitat provided by trees. Where large swathes of native forests have been cleared in favor of agricultural land, agroforestry offers habitat connection and refuge to bats, birds, and insects, in Sweden, increasing crop land covered by trees and shrubs has been shown to increase species richness of birds. This attraction of insect-eating songbirds as well as predatory insects to agroforestry systems has been shown to reduce pest pressure and lower the need for pesticide applications. (Söderström et al. 2001) Meanwhile, a meta-study of tropical agroforestry systems has shown that operating small-scale farms under tree-canopy not only enhances local biodiversity, but also enhances net-revenue because despite lower yields, agritourism and rainforest-safe or shade grown certifications enhance direct marketing opportunities and market opportunities. (Jezeer et al. 2017)

Case Studies

Forested LLC (Figure. 3.4, Figure 3.5) has been selected as a case study for a small-scale perennial agriculture site. Forested is located in a church-owned plot at the end of a cul-de-sac in suburban Bowie, MD. Owned and operated on a long-term lease by Lincoln Smith, MLA, Conway School of Design, the site is six acres, fenced, that is approximately half cultivated with a mix of perennial and annual crops, and half in native forest. The cleared portion is sloped at 2-5% with upper soil horizons of fine sandy loam and lower horizons of sandy clay loam. This soil texture results in very well drained soil that is conducive to growing organic produce in a humid environment due to decreased fungal pressure created by saturated root zones. Smith, a Bowie native, has operated his farm for 7 years and has developed the site as an experimental agroforestry plot to primarily to introduce perennial polyculture cropping systems to the suburban Maryland setting. This goal is pursued via hosting of Permaculture Design Certification (PDC) courses, monthly community meals during the growing season, and using the site as a demonstration to determine optimal species selection and layout for a Mid-Atlantic coastal plain site while promoting his design and consulting services within the region.

The site features over 100 varieties of fruit and nut trees, with nitrogen-fixing support species as well including Black Locust (Robinia pseudoacacia), Silktree (Albizia jullibrissin), New Jersey Tea (Ceanothus americanus). These crops are organized into a number of cells, sometimes referred to as guilds(Ferguson and Lovell 2014) that contain plants selected for their inter-specific compatibility, taking into account factors such as height, shade tolerance, allelopathic effects, pest protection, and soil/hydrology needs. These intensive designs, with each cell intricately laid out and developed to create numerous unique habitats in distinct microclimates is a strategy possible only on a small-scale, where human attention and labor is plentiful. The social factor is therefore necessitated in this design, where volunteers are easily engaged, often seeking to learn about the patterning and replication of these methods in their own plots.

Figure 3.4 - Forested, LLC
Aerial photograph

The broader design is laid out in a strategy that may be described as hub-and-spoke, the site features a central plot that serves as community kitchen, education area, and dining area for community meals that are regularly held on the site, using produce from the farm. The central area also serves as the primary location for annual vegetable production, as well as housing for the fowl that are raised for eggs and pest-control services. Radiating out from the central hub, are four main paths that intersect two circular pathways, spaced 150' apart. The outermost belt spirals into an access route that cuts through the woodlot and intersects a variety of herb, medicinal, and wildlife plots that are cultivated in the understory of the forest. The primary features of this site that attract community participation are the incredible crop diversity and beautiful mandala-like design that is shaped to facilitate human and hand-cart access while maximizing solar exposure to the multiple canopy layers present in each cell.

Though the species richness and curvilinear layout defy standardized, mechanical harvesting and management, this may be seen as a strength of a system that prospers more from its community and social factors over pure agricultural yield. Because of the steady stream of visitors and committed recurring volunteers, opportunities abound for hands-on education while forging community relationships via collaborative harvesting, weeding, and mulching of the perennial crops.

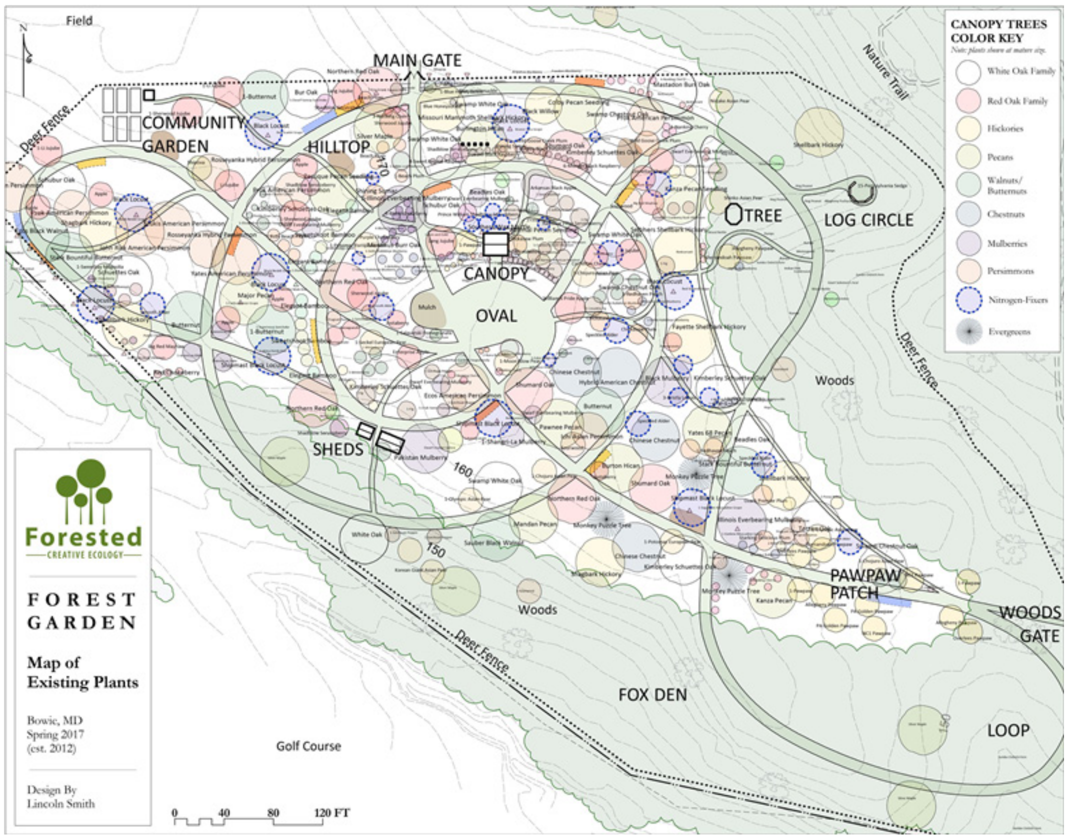


Figure 3.5 - Forested, LLC Planting Diagram

Catawba Sustainability Center

Catawba sustainability center (. 2.5), our medium scale case study site features a 30-acre agroforestry demonstration on a 377-acre working farm in the Catawba valley of Southwest Virginia in Roanoke County. The Center was established in 2010, when the farm was purchased by Virginia Tech as a demonstration site and farm incubator to support beginning farmers from the surrounding region. Located in the Catawba Creek River Valley, adjacent to the Appalachian Trail, at the foot of the popular hiking destination Mcafee's Knob, the site is characterized by silt loam soils, ranging from 0-15% slopes, with the lowest elevations in the floodplain of Catawba Creek.

For the purposes of this paper, the 30 acres of agroforestry demonstrations are of primary importance. Beginning in 2011, a series of agroforestry demonstration plots were implemented to test experimental planting patterns, as well as provide access to extension agents and local producers to see first-hand how agroforestry can benefit their farms and clients. The agroforestry demonstration site features silvopasture, alley crop, contour tree-swales, and a multipurpose riparian buffer.

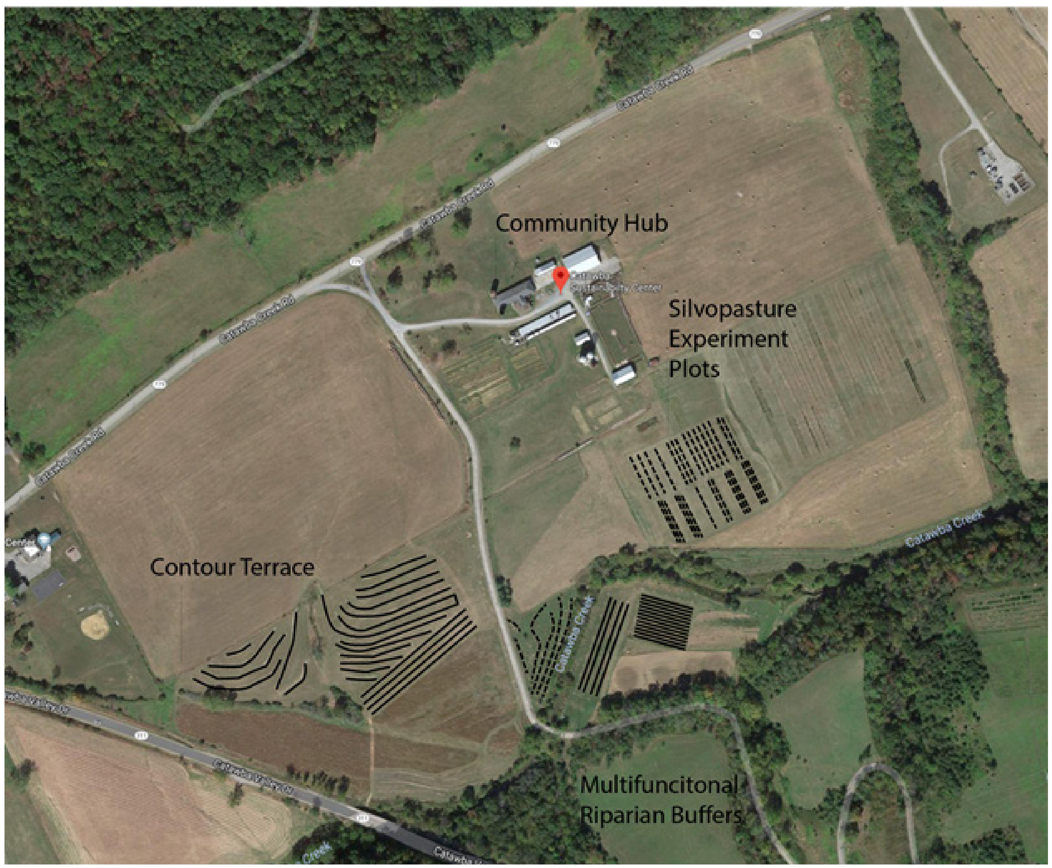


Figure 3.6 – Catawba Sustainability Center Agroforestry Layout

Silvopasture

This area of the site is a tree planting that integrates with livestock production, with various experimental treatments that feature, nut and timber production in layouts that consist of a row of either walnut (Juglans nigra), oak (Quercus sp.), and American chestnut (Castanea sp.) with rows of tulip-poplar (Liriodendron tulipifera) 'trainer trees' on either side. When converting pasture to silvopasture, these trainer trees serve to encourage timber form growth on the high-value timber crops, by mimicking growth conditions found in the forest or in a timber plantation. Without these trainer trees, hardwoods will tend to develop a low, wide-branching canopy that produces significantly less board-feet of marketable timber.(Downing et. al, 2017)

Alley Crop

The agroforestry practice that has likely received the most attention and study, alley cropping is the planting of rows of trees, with annual crops in the space between tree rows. This strategy can be used to produce a harvest in the years before tree crops mature, while inter-row shade is minimal, or as a permanent strategy for long-rotation, high-value timber crops like walnut. In the latter cases, tree species that produce a light shade are preferred, with the wind, heat, and sun shelter provided by the canopy often resulting in reduced water usage and stress on the annual crops, often resulting in higher yields of these crops.

Contour Swales

This strategy, widely used in sloped land throughout the world, is a water holding and erosion control measure where trenches are dug on contour with a trench slope of about 1%. The low slope of these swales allows water to collect at the base of planted trees, reducing loss of water from the site and corresponding erosion issues. Experimental treatment on these plots includes differential swale spacing, depth, and slopes. The plot dedicated to this treatment is located on a south-facing slope to allow for maximum solar exposure to the tree crops.

Multi-functional Riparian Buffer

This strategy, pioneered by Virginia Tech makes use of existing outreach and cost-share initiatives by NRCS in Virginia and other states. These programs subsidize tree planting and fencing of riparian areas as a water quality measure. The planting of trees in riparian areas filters agricultural runoff and allows for the uptake of excess nutrients by woody perennials and grasses before these nutrients can enter waterways. In the system demonstrated at Catawba Sustainability Center, a plant palette that diverges from the standard riparian palette was chosen. Where typical riparian buffers focus on willow, birch, and other fast-growing but non-crop trees, this multi-functional riparian buffer is planted with a diverse arrangement of non-timber crop trees that are categorized as fruit, nut, craft, and floral. Fruit crops chosen are wetland adapted species, including aronia, plum, serviceberry, and elderberry, nut trees include floodplain adapted oaks, black walnut, hazelnut and bitternut hickories, craft trees including willow and alder, grown as coppice for basketry, and floral trees & shrubs including Hydrangea, Pussy Willow, Vibrunum, Callicarpa and others. (Trozzo et al. 2013)

The scale of this particular site allows for a balance between the community development opportunities of smaller forest gardens and permaculture sites, while allowing for the demonstration of the strategies outlined above typically only viable on large-scale production focused sites. This case-study offers a unique hybrid that allows for a socially-productive, publicly accessible experience, while promoting practices that are viable for economic production on family farms of much larger acreages. Because each agroforestry practice is only applied to a small fraction of the total demonstration site, the diversity and varied experience valued in permaculture type plots is present. While these practices are of the sort that are capable of producing commodity scale harvests, the layout is inspired by socially minded designs like Forested, allowing for a social-community focused experience while promoting strategies that users may apply on their larger acreages or extension networks.

Figure 3.7 - Catawba Sustainability Center Birds-eye Photograph

Kentland Farm

Kentland Farm is the primary agricultural research site of the main campus of Virginia Tech in Blacksburg, and our large-scale case study plot. (Figure 3.8) Purchased by Virginia Tech in 1986, the farm is comprised of 6 parcels that total 3,200 acres, with 400 acres of crop research, 700 acres for wildlife, forestry, and conservation management, and 1,800 acres which support the university livestock herds through the production of corn silage, alfalfa, hay, and pasture. (College Farm, 2015) The site is located at 1760 feet above sea level, on an ancient floodplain terrace formed by the New River. Soils are composed of typic Hapludults, which are well-drained due to the slope, but only moderately permeable and fertile.(Bendfeldt et al. 2001)

In 1995, Virginia Tech established agroforestry demonstration plots on 25 acres of land that slopes from 10%-25%. These slopes make the land less-suitable for conventional agricultural production due to concerns over erosion and equipment access. The experimental agroforestry plots at Kentland Farm are likely the best studied example of a production agroforestry landscape in the Eastern United States. (Jacob W. Johnson et al. 2011) These plots are dedicated to the study of silvopasture implementation and performance in the Appalachian Mountains, with a primary focus on the interaction between the tree crop species honeylocust (Gleditsia triacanthos) and black walnut (Julgans nigra) and sheep. Published experiments have included investigations into best practices for establishment and maintenance (Jacob W. Johnson et al. 2013), nutritive quality of honeylocust seed pods (Fannon et al. 2017), and behavior of livestock that utilize the trees for shade and forage. (Fannon et al. 2017)

"The original experimental plots, which have since been expanded, consist of "nine 0.35 ha paddocks, with three replications of treatments consisting of (i) pasture only; (ii) pasture under honeylocust; and (iii) pasture under black walnut." Within these plots, key performance indicators were recorded for the trees, including response to weed control treatments, tree shelters, and fertilization" (Bendfeldt, Feldhake, and Burger 2001)

In addition to the silvopasture plots, a 'resource allocation site' experiment was devised to assess tree performance along differential spacing gradients along the slope (see Figure 3.8) In this experiment tree rows were installed perpendicular to contour with trees spaced 6', 12', 24', and 48' apart, with inter-row spacing 12', 24' and 48' respectively. This treatment will help to determine effects of spacing on soil nutrients, tree development, fruit production, and canopy coverage for use in future agroforestry plantings.

The replication-minded focus of this design is intended to provide a controlled research environment that is not tailored to visitor experience like the other sites examined in this study. Because the site context is a sprawling farm-complex, that is not publicly accessible, production minded goals have been the exclusive focus of the design. The trade off of homogeneity and mechanical efficiency over user experience fully leans towards the former in this case, but the site is no less relevant to the broader community as the Kentland site has produced some of the most specific and replicable research into the implementation of agroforestry practices in the Mid-Atlantic region of the United States.

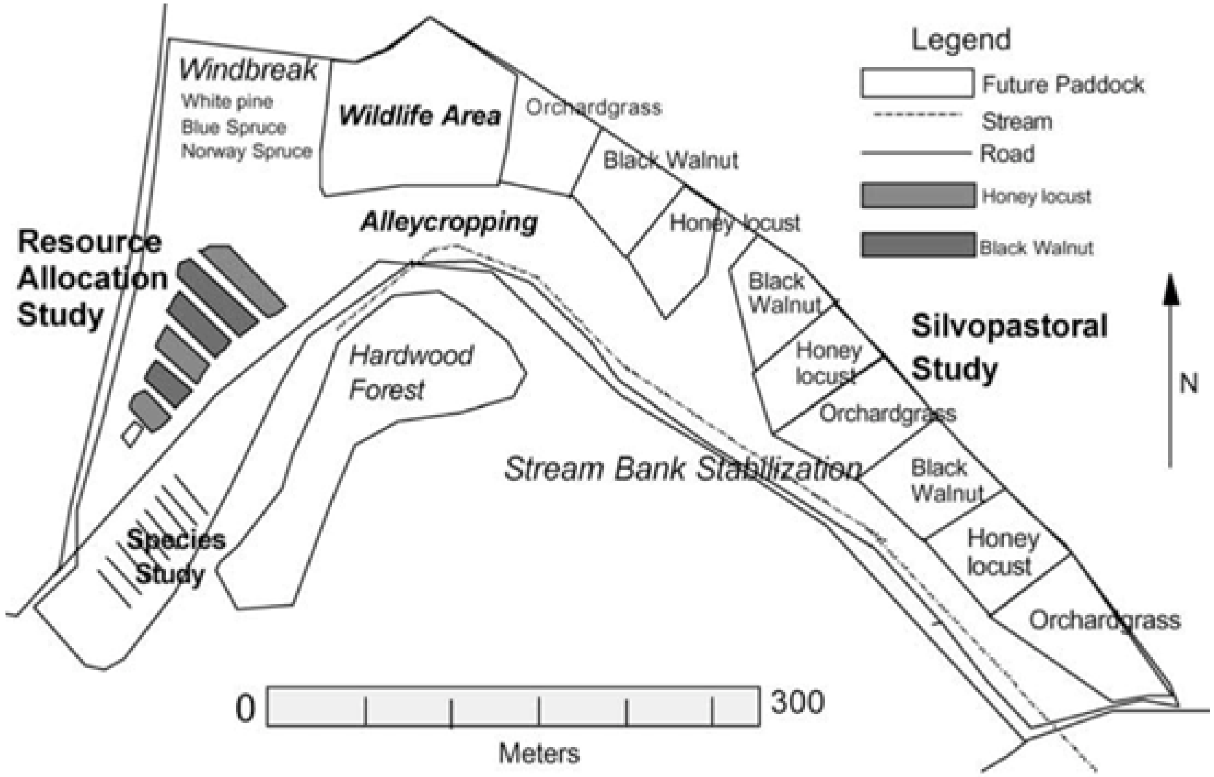


Figure 3.8 – Silvopasture Experiments at Kentland Farm (Johnson 2011)

Design strategies for small-scale sites

Though the sites described above have all successfully implemented designs that utilize woody perennials in an agroforestry setting, there are distinct design strategies that are applied to each that are dependent on the context and scale of each site.

Whether designs are implemented for the benefit of a family, a neighborhood, or a larger town/village, agroforestry systems that are designed at a community scale often seek to maximize the social yield of a site, in the form of building community relationships, recreation, shared experiences, or education often share similarities in layout & design that maximize the potential for these yields, with direct harvest of agricultural products a necessary, but typically secondary goal in the overall system. Because the size of these sites does not allow for the economies of scale necessitated by modern commodity agriculture, social factors often become the most viable production goal for these sites.

In the cases of Forested LLC, and Catawba Sustainability Center (CSC), the primary goal of each design is demonstrating perennial agriculture systems to the local and regional community. Both farms utilize the strategies outlined above, yet adjacencies and network effects of these two designs have further influenced how these strategies are manifested.

Catawba Sustainability Center is managed by Virginia Cooperative Extension and is the site of numerous farm incubator initiatives that help to build skills for underserved community members. The siting of an innovative perennial polyculture system adjacent to this programming allows for the exposure of a diverse community, from extension agents, to refugee farmers, to these perennial cropping strategies. These designs were implemented primarily by students of the Virginia Tech community and continues to provide volunteer opportunities for service-based organizations which include fraternities and other student organizations. In this 25-acre planting, a scale has been achieved where mechanical cultivation is possible, yet human labor remains necessary to promote optimal tree health via mulching, weed control, and harvesting of the multi-functional riparian buffer. These human labor activities, which would be considered a liability in a production-based design, are an asset to this system, where human interaction with the crops allows opportunities for community development, networking, direct exposure to the diversity of crops, and conversation between experts and laypersons on the elements of the design.

Permaculture zone patterning	Community adjacency	Curvilinear design	High crop diversity & unusual crops	Labor intensive design

Figure 3.9 – Patterns common to small-scale agroforestry sites

Another feature of the CSC that helps it to reach its socially oriented goals is the diversity of crops and layouts at the site. As a demonstration and experiment site, the arrangement of 3 distinct cropping strategies (Alley Crops, Silvopasture, and the Multipurpose Riparian Buffer) and a highly diverse species selection, all arrayed around the central farm infrastructure, allow for visitors to the site to quickly investigate and become familiar with each strategy. Though the small-scale of each of these systems will never generate a production yield that will sustain farm operations, the co-location of these strategies provides a unique experience to visitors who are new to agroforestry, or to extension agents and producers that seek hands-on experience with these novel strategies in order to apply them elsewhere.

In the case of Forested, there is a similar goal toward social outreach and demonstration, however it exists on a neighborhood scale rather than the regional scale that Catawba Sustainability Center seeks. This design, laid out in response to topography, features a densely planted, highly diverse system that radiates from a central hub where major functions of the farm are held. These functions, which are all oriented toward hosting visitors from the adjacent neighborhoods, include a weekly volunteer work day, at which participants are encouraged to sample novel fruits in season while tending the trees and shrubs, Permaculture Design Certifications, a curriculum developed by Bill Mollison that involves design strategies for creating sustainable human-scale environments, and community meals where a professional chef curates a unique experience that utilizes the diverse crops that are often unavailable in any local market. These meals reportedly fund a large portion of the farm's operation costs while simultaneously exposing local citizens to the wide array of underutilized crops that are made possible by perennial polyculture style production.

Design Strategies for Large-Scale Sites

Agroforestry as a crop-production system has gained a great deal attention in the 21st century as a strategy to mitigate climate change and top soil erosion through broad-scale carbon sequestration in topsoil through the action of tree root growth in areas formally in row-crop production. These systems have gained acceptance largely because they are able to maintain, or often increase production through introduction of perennial crops, by way of sheltering annual row crops, pasture, or animals to reduce stress, or by filling canopy layers with additional crops to better utilize solar energy. In order to maintain or increase production when compared to conventional, single-crop systems, cultivation and layout are typically compatible with conventional row-crop systems, in order to make use of standardized cultivation, planting, and harvesting equipment. Because these equipment are often very high cost, and commodity production typically operates on a tight profit-margin, these sites tend toward the strategies below that emphasize efficiency and production at the expense of community, social, and use experience.

Alley Cropping	Multi-story cropping	Silvopasture	Low-diversity cropping	Mechanical cultivation

Figure 3.10 – Patterns common to small-scale agroforestry sites

While Catawba Sustainability Center and the experimental silvopasture plots at Kentland Farm are both agroforestry experiments administered by Virginia Tech, in the vicinity of their Blacksburg campus, they have diverging goals, as has been explored above. While the CSC has social and community goals as its primary objective, the secondary objective is to demonstrate how agroforestry practices can fit into a production focused agriculture system. As farms often operate on tight economic margins that necessitate risk-averse cropping strategies, the demonstration of a diversity of management patterns in a relatively small area, allow producers and extension agents the opportunity to compare the differential layout and spacing strategies that are involved in these systems. The CSC setting, when compared to Forested, exhibits a much lower total species diversity, thus allowing easier evaluation of performance of a variety of crops for potential adoption elsewhere. Similarly, the spacing between rows in both the alley crop and silvopasture demonstrations, are designed at 25' spacing, with turnaround space at row ends, in order to allow for tractor access.

In comparison to the CSC, the Kentland Farm demonstrations are not accessible to the public and serve solely as experiments to determine conditions for optimal production of both tree crops and livestock in a silvopasture setting. These systems involve only two species of tree crops, and the only differentiation among plots is the spacing of trees. While this does not serve the social function of the CSC, it is much more standardized, in order to determine specific economic outcomes of implementation of these systems at farms throughout the Southeast and Mid-Atlantic. Over 30 years old now, these systems are among the oldest continually managed agroforestry experiments, and continual observation has allowed for significant gains in knowledge that are directly applicable to producers wishing to implement similar systems at their own farms. By determining factors such as optimal spacing to maximize shade and pasture production, nutrient yields of tree crops for livestock, and performance of livestock in different silvopasture treatments, concrete data is available to producers to assist with decision making when implementing new practices. While CSC allows quick exposure of novel systems to visitors, it has a primary goal of demonstrating a variety of divergent patterns, rather than creating iterations of a single pattern for experimental purposes.

Conclusion

Integral to the decision-making process by producers laying out a farm and selecting systems and strategies to be utilized, is the scale at which the design will be implemented, and the goals of the site throughout its lifetime. Whether the determination is based on an existing site that is available for development, or budget available for implementation, this variable is a strong determinant of the balance of strategies deployed. A tipping point is often noted where larger sites are able to achieve the economy of scale necessary for purchasing of mechanized equipment, and profiting from low-margin, commodity crops required for production-based designs, while social and ecological goals can often be achieved on smaller sites.

As landscape architecture continues to broach the field of sustainable & urban agriculture, the goals and adjacencies noted in this paper are essential considerations for the designer when making layout and production strategy decisions. Though there is a lack of precedent in terms of mature, productive, and profitable agroforestry systems in this region, the research conducted at the demonstration and experimental sites managed by Virginia Tech have produced some of the best technical guidance and experimental data available in the Untied States, and the only data and studies of their type in the Mid-Atlantic. These findings and best-practices have slowly begun to transform attitudes of producers, a typically slow-to-change audience, but the incredible amount of research available to today's designers allows the next generation of sustainability and urban agriculture focused landscape architects the tools needed to create productive landscapes that serve the social milieu in which they are embedded. By further considering the small-scale, socially-minded Permaculture influenced designs of Forested, and others in the region, the findings promoted by Virginia Tech will help to bring practicality and, enhance the value of these landscapes via their efficiency and value-minded experimental design and findings.

Master Plan for a Regional Agroforestry Research Center

Figure 4..1 – Spring house at Morningview Farm

Figure 4.2 – Proposed Site Plan for Agroforestry Research Center

Section Two Introduction

In 2016, while conducting research at Lincoln Smith's Forested, LLC property, I met Lincoln's colleague Benjamin Fritton who had recently been entrusted with a 160 acre property in Middletown, Md, known as Morningview farm due to its eastern aspect. The Reed family, then the owners of the property had left their family farm decades previous, and become successful in land development and commercial real estate. After attending a lecture on the topic of regenerative agriculture led by Fritton, the now elderly Reed's made the decision to commit their land along with a portion of their wealth to the development of a center for research and retreat on this acreage.

After discussion, and many visits and walks of the site, Fritton and the family's son and executor of their will approached me with a proposal to develop a master plan for the site as the culmination of my thesis and research into the potential for agroforestry as a land management strategy in the temperate Mid-Atlantic. The goals of this concept plan would be to create a site where human and natural communities would receive equal treatment in the development of new agricultural systems on the land. In line with the goals of J Russell Smith that I explored in my earlier writing "Rediscovering Sunny Ridge" who operated along the same ridgeline of Blue Ridge Mountain just 20 miles to the South, I set forth to develop a new center for the study of agroforestry as a productive and regenerative system for the Piedmont, as Dr. Smith would call it, an 'Institute for Mountain Agriculture.'

As a guide for development of a new farm property, I have adapted the 'Scale of Permanence' from P.A. Yeomans, an Australian mining engineer, turned agriculturalist who proposed a in 1958 a sequence for addressing the needs of a new agricultural development, based on the energy needed to make changes to the landscape, and therefore the relative permanence of these interventions. A site's Climate, for example, is relatively fixed and next to impossible for a land manager to change. The Land Shape is also difficult to change, though with earthmoving, minor changes can be made. The amount of Water a site has available to it is a natural function of the relationship between the Climate and Land Shape, though with adjustments to the latter, more rainfall can be harvested and stored. Farm Roads are very permanent features and typically last longer than Trees and accordingly Buildings. This scale has been adapted by several agricultural designers in the intervening years since it was first presented in Yeoman's teachings. David Holmgren and Bill Mollison, originators of Permaculture theory, a set of ethics and design tools for reshaping agriculture in a way that regenerates natural and human communities, added social and economic factors, including zones of activity, aesthetics, and economic factors. A debt is owed to these men for popularizing perennial agriculture in the imaginations of many around the world. Their series of Permaculture manuals inspired me to imagine new ways of thinking about human relationships with the land and agriculture in the years leading up to my decision to pursue a graduate degree in Landscape Architecture.

The following pages describe a concept for the study of the wide array of agroforestry systems explored in the opening chapters to this document, in a way that aligns with existing local and federal conservation incentives that would allow for the best use of available funds and the network of expert guidance available in the region. As the site is endowed with several perennial streams, and a multitude of intermittent and perennial springs throughout the farm, water quality informed the patterning and site design to a large extent.

Alongside this mandate, I have applied lessons learned from the exploration of patterning in agroforestry systems of various scales within the regional mileux in “INFLUENCE OF SCALE ON DESIGN AND PRODUCTION GOALS OF AGROFORESTRY SITES IN THE MID-ATLANTIC UNITED STATES.”

Within this section, I will describe the regional context for the site, including urban adjacencies, watersheds and critical habitat therein. This analysis is followed by an assessment of the existing conditions on the site including soils, topography, and historical land use patterns as shown in today’s site conditions, as well as historical aerial photographs available from the last half-century.

Following this analysis of the site as it stood when I made my first visits to explore and experience the landscape, I frame the design development as outlined in these Scales of Permanence, proceeding from Climate and landform inherent to the site, and only made plastic with significant energy and capital investment, through water systems, access and circulation, to vegetation, structures, property divisions, soil management and finally social experience and the human experience on the site.

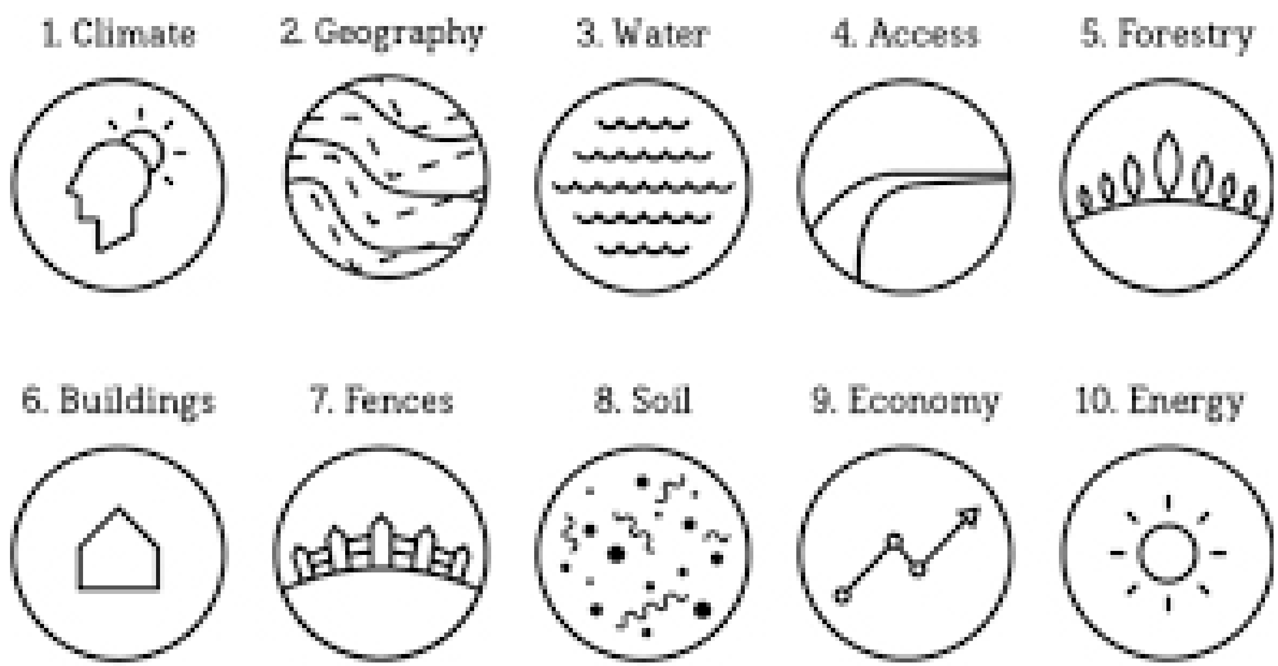


Figure 4.3– Illustrated Scale of Permanence

Chapter Four Site Analysis

The temperate Mid-Atlantic holds no shortage of potential for the development of agroforestry systems designed with the intention of holding soil in the hills. These systems hold the promise of preventing erosion of fertile soils from productive lands and into waterways where it becomes a light and oxygen blocking pollutant. Through the action of tree roots holding mineral soil, and building organic matter through their growth and decay, as well as through the evapotranspiration and rainfall intercepting action of tree canopies, forested hills, as they were experienced by American Indians and early European colonists, are far more capable of addressing the intensifying rainfalls that have become in the norm in the region today.

Throughout the region, being one of the longest settled and farmed in the country, cleared land in the hills near urban centers remains in annual agriculture despite a century of soil conservation guidance and warnings from researchers like J Russell Smith. In the diagram on this page, one can see the red band stretching along the east side of the foothills of the Appalachian Range representing areas in tillage agriculture on slopes of greater than 15%, from Southwestern Pennsylvania to Central Virginia. This belt of fertile land, has accumulated millennia of sediments form the slopes of the Blue Ridge Mountains, and has remained productive for centuries, but at the cost of the health of major water systems of the Chesapeake and Delaware Bays.

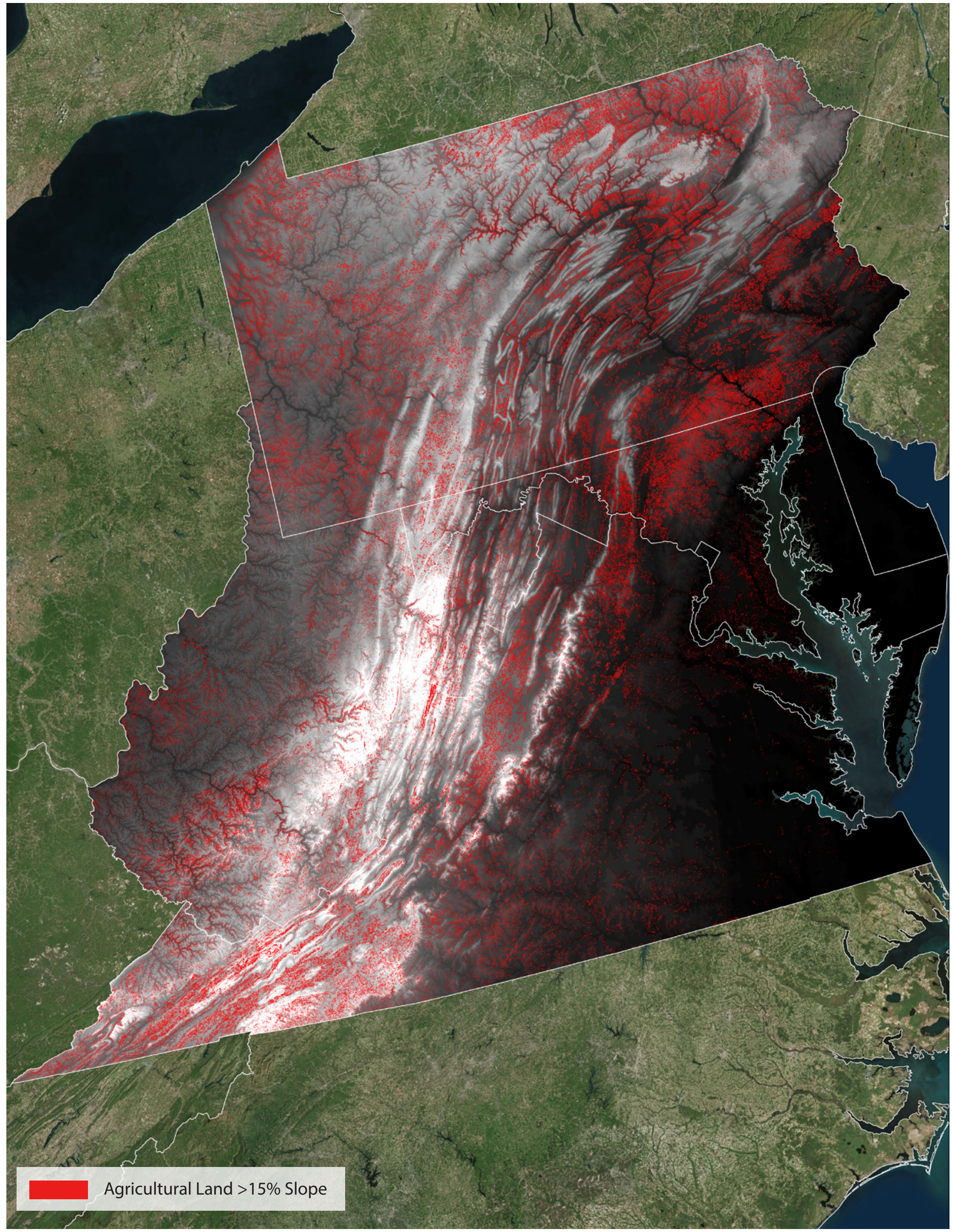


Figure 4.4 – Steep Crop Lands in Mid-Atlantic states, highlighting agroforestry adoption potential in the region

Watersheds

Sediment laden water, rushing through streams past the fall line, finds its way to estuaries of major rivers like the Potomac, Susquehanna, and Rappahannock, where, its energies dissipates in slack, tidal water, releases suspended particles, but retains dissolved nitrogen. Tidal action and storms push these particulates, themselves ionically bonded to phosphorous and other nutrient ions, into the Chesapeake Bay. Nutrient and sediment pollution are the primary pollutants of concern to the Bay, where they feed mass algal blooms that block sunlight, produce toxic compounds, and decrease oxygen content, leading to negative outcomes for most plant and animal life. The erosion of topsoil from agricultural land is a major contributor to these phenomena, accounting for nearly 20% of nutrient pollution, and over 60% of sediment pollution watershed-wide,

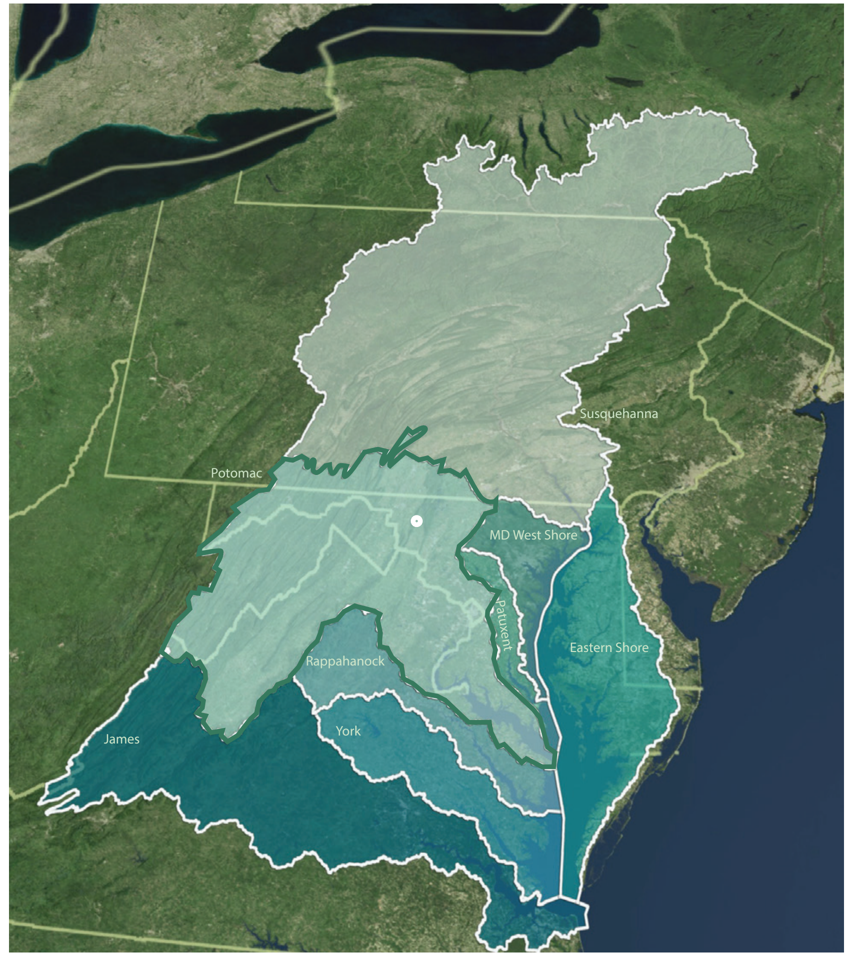


Figure 4.5 – Sub-Watersheds of the Chesapeake Bay

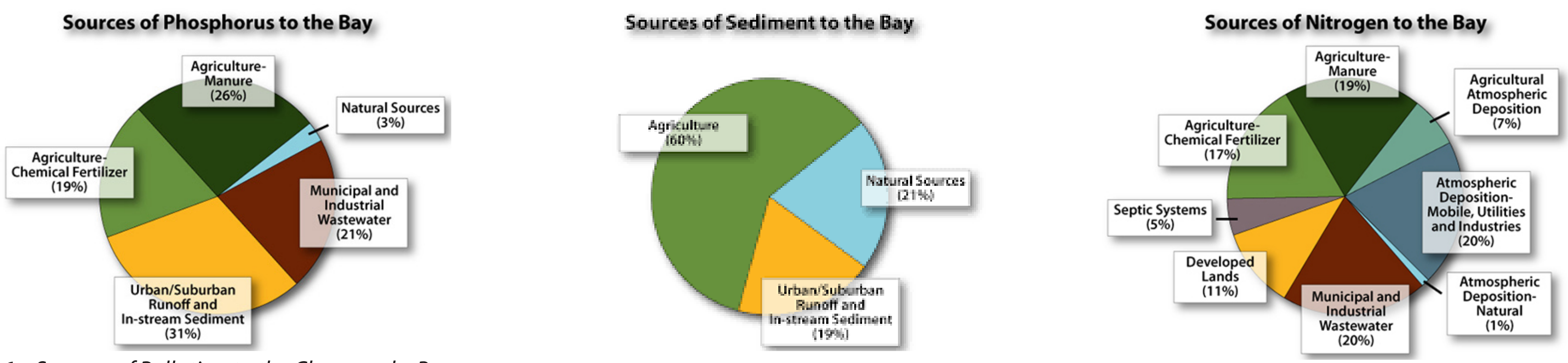


Figure 4.6 – Sources of Pollution to the Chesapeake Bay

Eastern Brook Trout Habitat

The impacts of agricultural runoff on waterways are not limited to the Chesapeake Bay however. In the uplands, habitat for native fishes has seen a downward trend for much of post-colonization history. As slopes were cleared, and streams were straightened and denuded of vegetation, flood intensity, water temperature, and pollutants have driven the ranges of Eastern, Brown, and Rainbow Brook Trout to a tiny fraction of their former range.

Fortunately, in the small hollow where this project site is located, populations of Eastern Brook Trout have begun to rebound since the cessation of agricultural activities in 2014. Following consultation with the National Fish and Wildlife Foundation known range to include Morningview farm, and subsidize conservation efforts in the future, which will be explored later in this document,

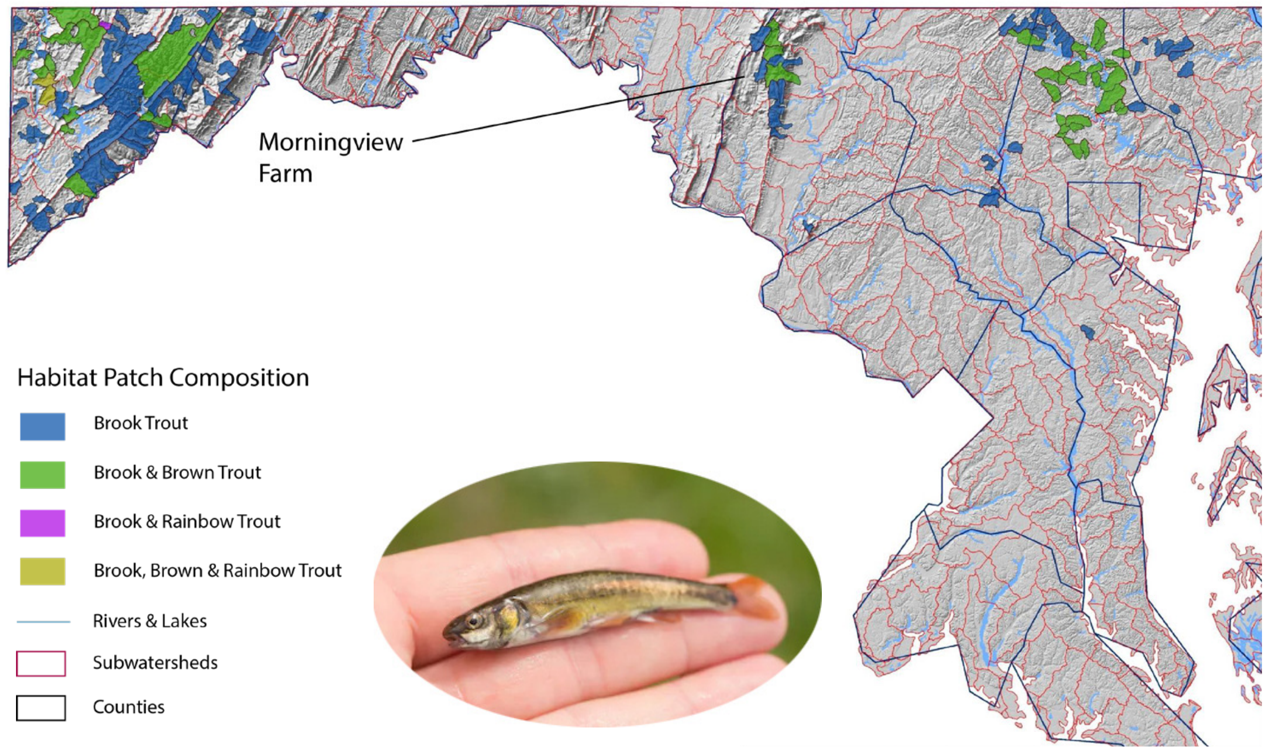


Figure 4.7 – Brook Trout Habitat in Maryland

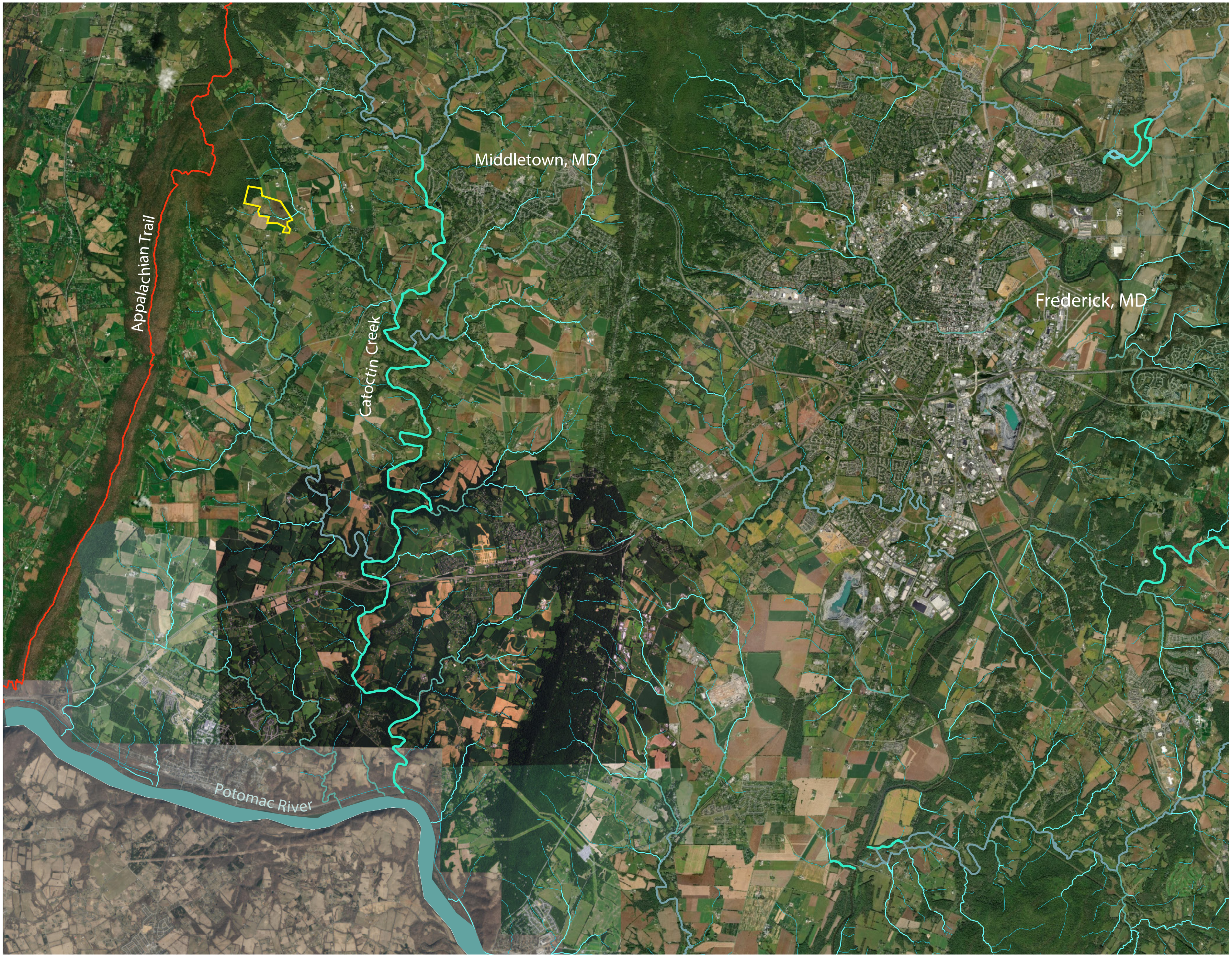
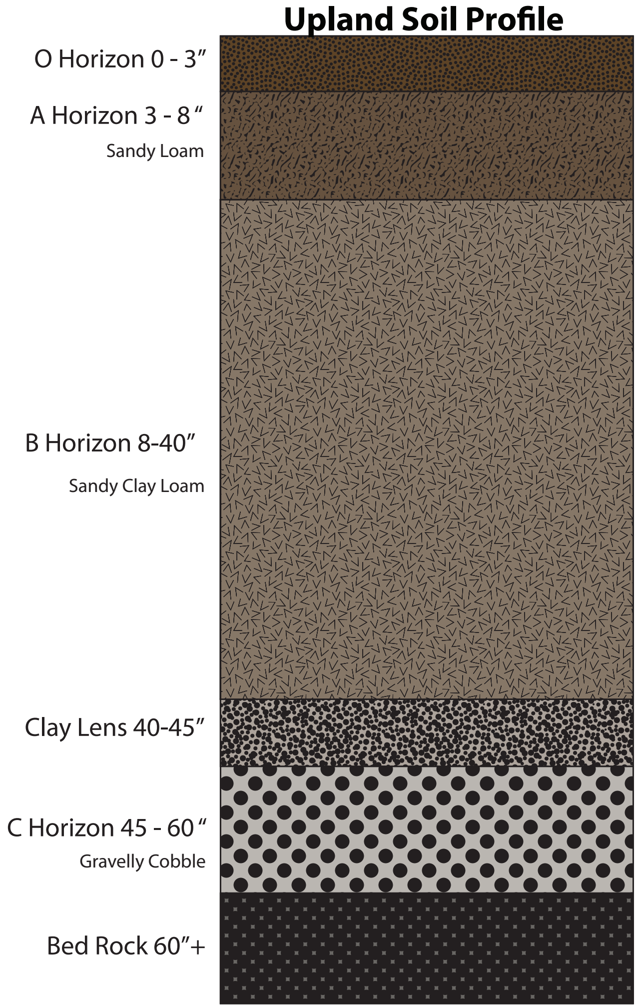


Figure 4.8 – Regional Stream Network



Typical Agriucultural Soil

Frederick County, Maryland

MxB—Myersville-Burkittsville complex, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: kyk2
Elevation: 400 to 1,000 feet
Mean annual precipitation: 37 to 52 inches
Mean annual air temperature: 46 to 57 degrees F
Frost-free period: 135 to 190 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Myersville, , and similar soils: 50 percent
Burkittsville and similar soils: 35 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Myersville,

Setting

Landform: Interfluves, hillslopes
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Gravelly residuum weathered from greenstone

Typical profile

Ap 1-2 - 0 to 12 inches: silt loam
Bt1-2 - 12 to 35 inches: loam
Bt3, BC - 35 to 61 inches: clay loam
C - 61 to 71 inches: sandy loam
R - 71 to 81 inches: bedrock

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: 60 to 80 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 8.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: B

Typical Slope Soil

Frederick County, Maryland

ScC—Spoolsville-Burkittsville complex, 8 to 15 percent slopes

Map Unit Setting

National map unit symbol: kykr
Elevation: 250 to 2,800 feet
Mean annual precipitation: 35 to 52 inches
Mean annual air temperature: 45 to 57 degrees F
Frost-free period: 135 to 190 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Spoolsville, , and similar soils: 60 percent
Burkittsville and similar soils: 30 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Spoolsville,

Setting

Landform: Hillslopes
Landform position (two-dimensional): Shoulder, backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Loamy residuum weathered from greenstone

Typical profile

Ap - 0 to 10 inches: loam
BE, Bt, BC - 10 to 38 inches: loam
C - 38 to 58 inches: channery sandy loam
Cr - 58 to 60 inches: bedrock

Properties and qualities

Slope: 8 to 15 percent
Depth to restrictive feature: 47 to 63 inches to paralithic bedrock
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very high (about 12.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3e
Hydrologic Soil Group: B

Figure 4.9 – Soil Profile and Series Description - USDA Web Soil Survey

Soils at Morning view farm are characterized by deep, well-drained loamy soil weathered from the greenstone ridge of Blue Ridge mountain. These soils have excellent productive potential due to their compaction resistance, water holding capacity and relatively high cation exchange capacity, or fertility potential. Despite the significant slopes throughout the site, uplands of the farm have retained deep soil, with a more highly weathered clay lens between 35-51 inches deep. This soil horizon has weathered in place over millennia, and contributes to the quantity of intermittent springs throughout the property. When soils are saturated after an extended rainy period, water infiltrates vertically through the sandy layers until encountering this lens, where it moves downslope until emerging at a concave landform.

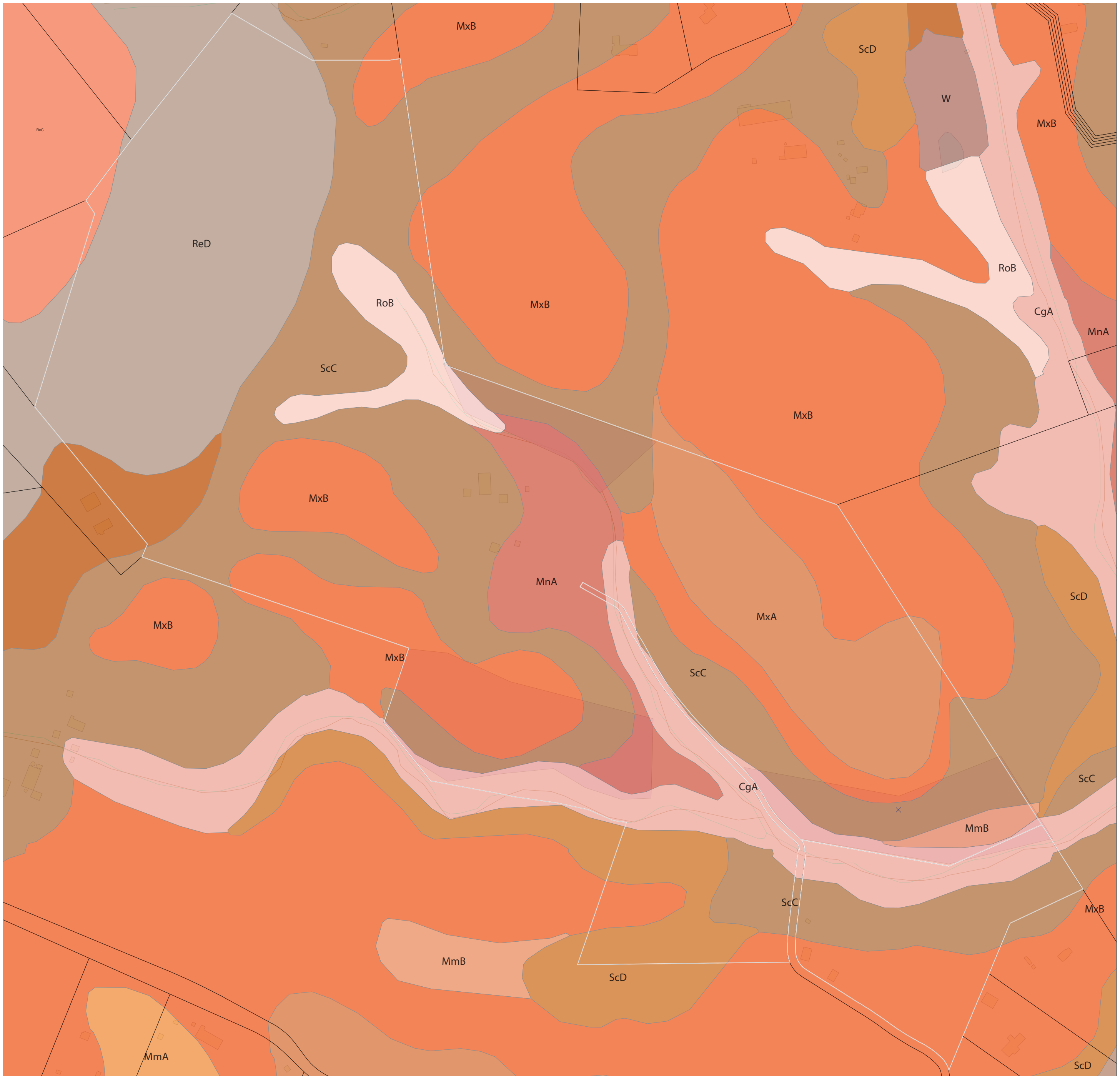


Figure 4.10 – Morningview Farm Soil Map - USDA Web Soil Survey

Slope & Elevation

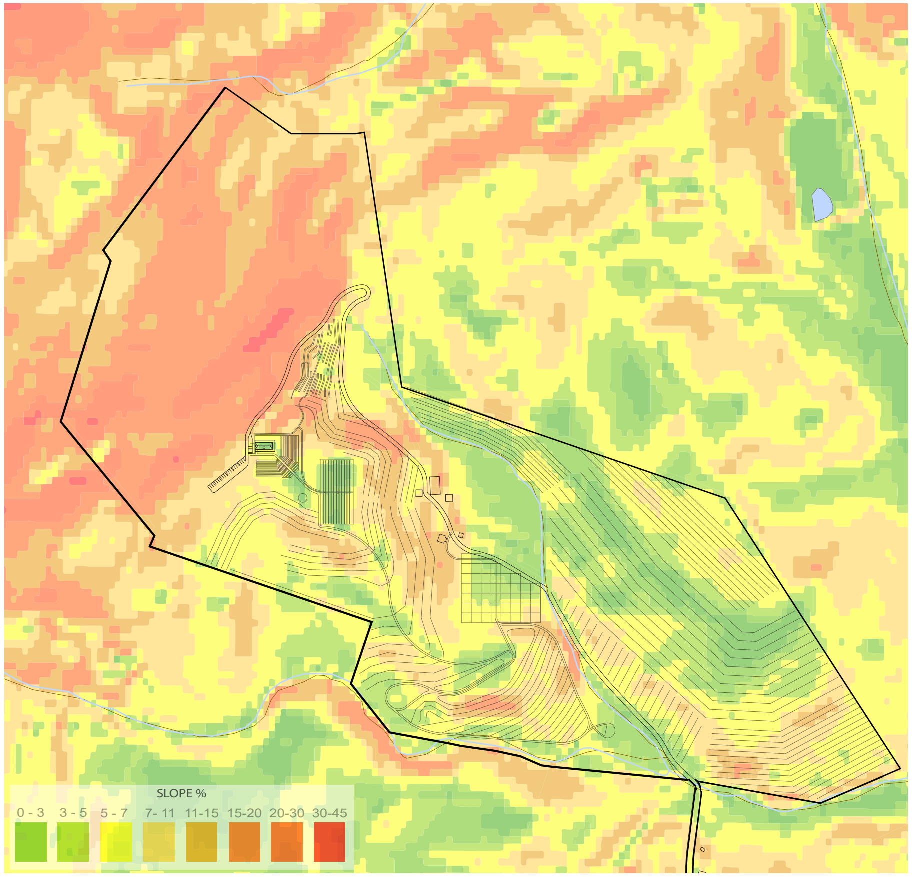


Figure 4.11 – Slope Analysis

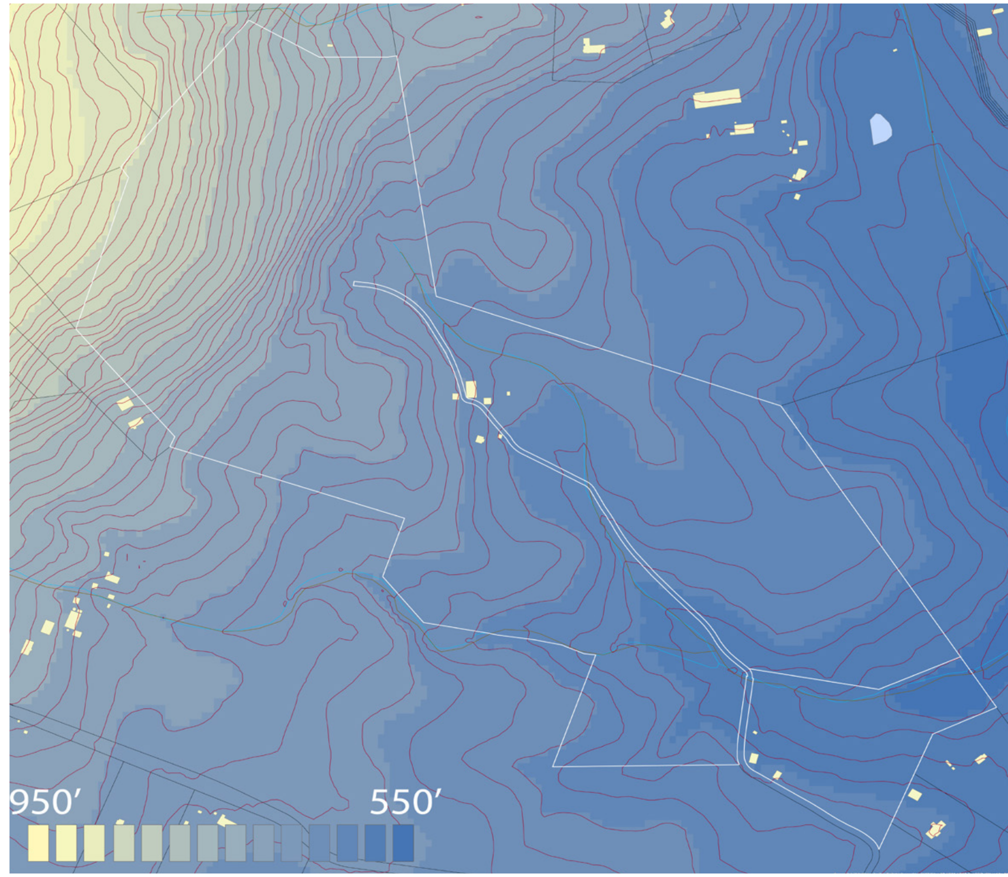


Figure 4.12 – Site Elevation Map

The topography of the site is dominated by the rising slope toward the peak of the mountain to the west. Steep slopes are largely forested, giving way to cleared pasture beginning at about 700' of elevation. At this point, slopes moderate as one descends toward the stream valley, though minor ridge-lines like the large landforms along the property's eastern edge offer significant flat-land acreage for cultivation. The variety of elevations, aspects, and slopes throughout the farm offer many opportunities for experimentation and patterning when selecting cropping and cultivation patterns, and offer significant advantages to exploit micro climates for specialized crops, harvest timing, and cultivar development.

Viewshed Analysis

A consequence of the range of elevation throughout the property is the diversity of views available from strategic points throughout the farm.

These view-shed analyses conducted with Arc Map's spatial analyst toolset exhibit view potentials from two key points on the farm.

The figure at top of page was developed to assess the opportunities for investing in social infrastructure on the highpoint of cleared land, areas visible from the marked point illustrate visible areas.

When this point is compared to the historic farm center, dramatic opportunities are clearly illustrated for enhanced prospect across the valley, and neighboring farms, as well as across to the next ridge-line.

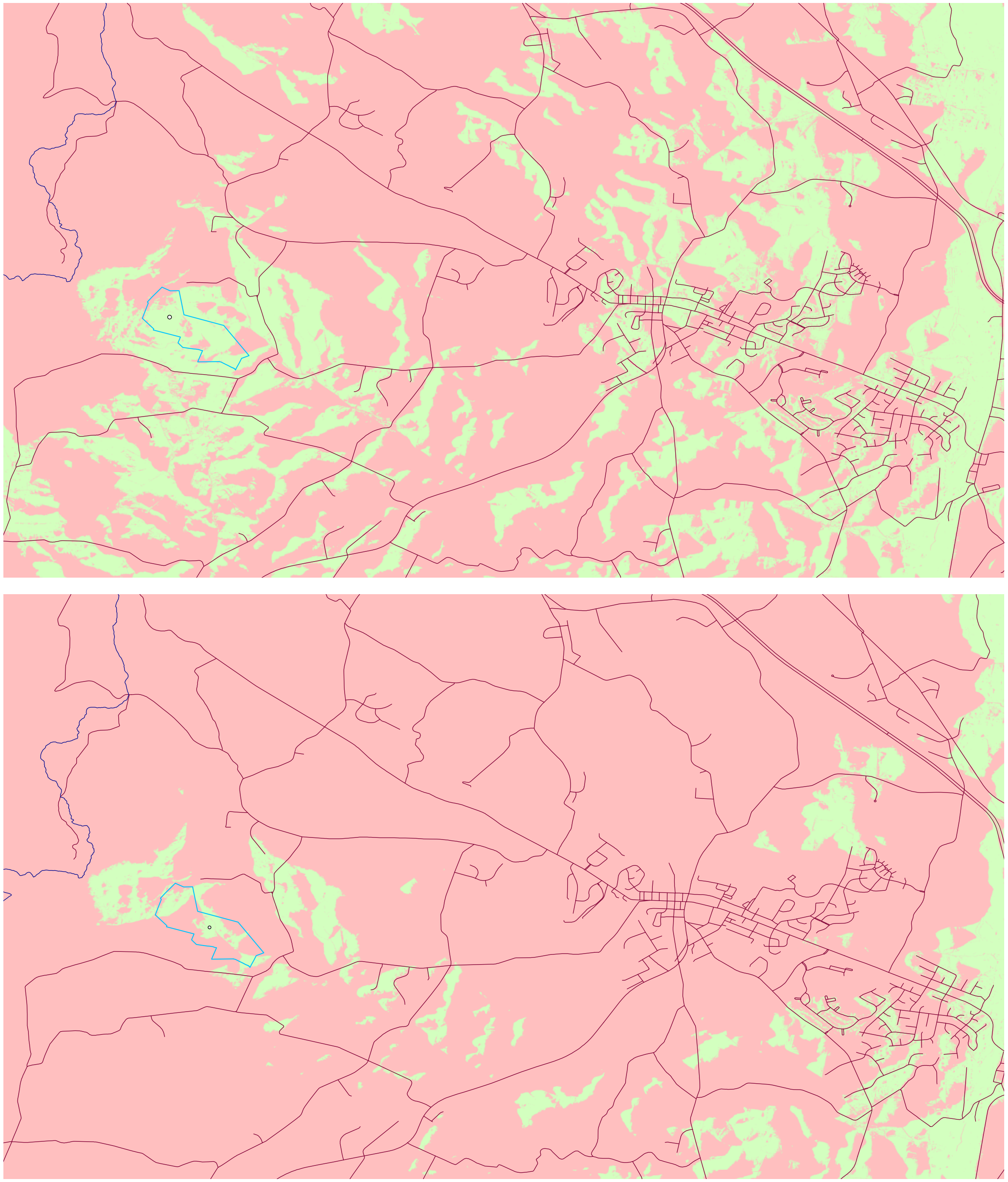


Figure 4.13 – Viewshed Analysis

Historic Aerial Cultivation Pattern Analysis

1968 2000 2017

Figure 4.14 – Historical Aerial Photographs - Frederick County Aerial Archive

An analysis of historic land use patterns at Morningview Farm based on archival aerial photography from the Frederick County Maryland reveals shifting patterns of cultivation over time. These shifting patterns reflect changes in agricultural technology and soil conservation trends. The leftmost photograph in the figure above, taken in 1968, illustrates the use of combined conservation tillage patterns of contour plowing and contour buffer strips that were popular in that era. These practices, evidenced by the light colored bands across slopes of even elevation, can help to reduce erosion rates by as much as 50% when compared to farming perpendicular to contour. These strips of grass between cultivated areas of flatter land, seen in 1968 as dark areas, help to slow runoff and trap sediment before it can continue to accelerate down slope. Study of additional aerial photographs from the era, as well as interviews with landowners and neighbors reveal that mixed crop and dairy farming were practiced at this time. With this knowledge it is likely that the light areas on steeper slopes were planted in perennial fodder and hay crops, while annual crops were cultivated on the surrounding flatter land.

The use of these practices a half century ago illustrate a long term commitment to erosion control practices on this site, and remind us that implementation of patterns to maintain soil fertility and topsoil is a practice that has been practiced throughout time, but has continued to evolve as landowner goals and available technology have evolved.

By 2000, cultivation had shifted from mixed cropping that could benefit form contour strip crops and appears to have shifted entirely to hay crops, perhaps to support a cow-calf operation near the main barn. By 2017, cultivation had ceased, and the fields began to progress through old field successional patterns.

In the figure below, cropping patterns outlined previously are delineated in red, while a shift in forest management is highlighted in green. Judging by existing aerial imagery and land use patterns, the area in the northwest portion of the farm was previously cleared, but was abandoned around 1980. This additional home-site has since grown into young successional forest of Black Cherry (prunus serotina) Tuliptree (Liriodendron tulipifera) and Red Maple (Acer rubrum).

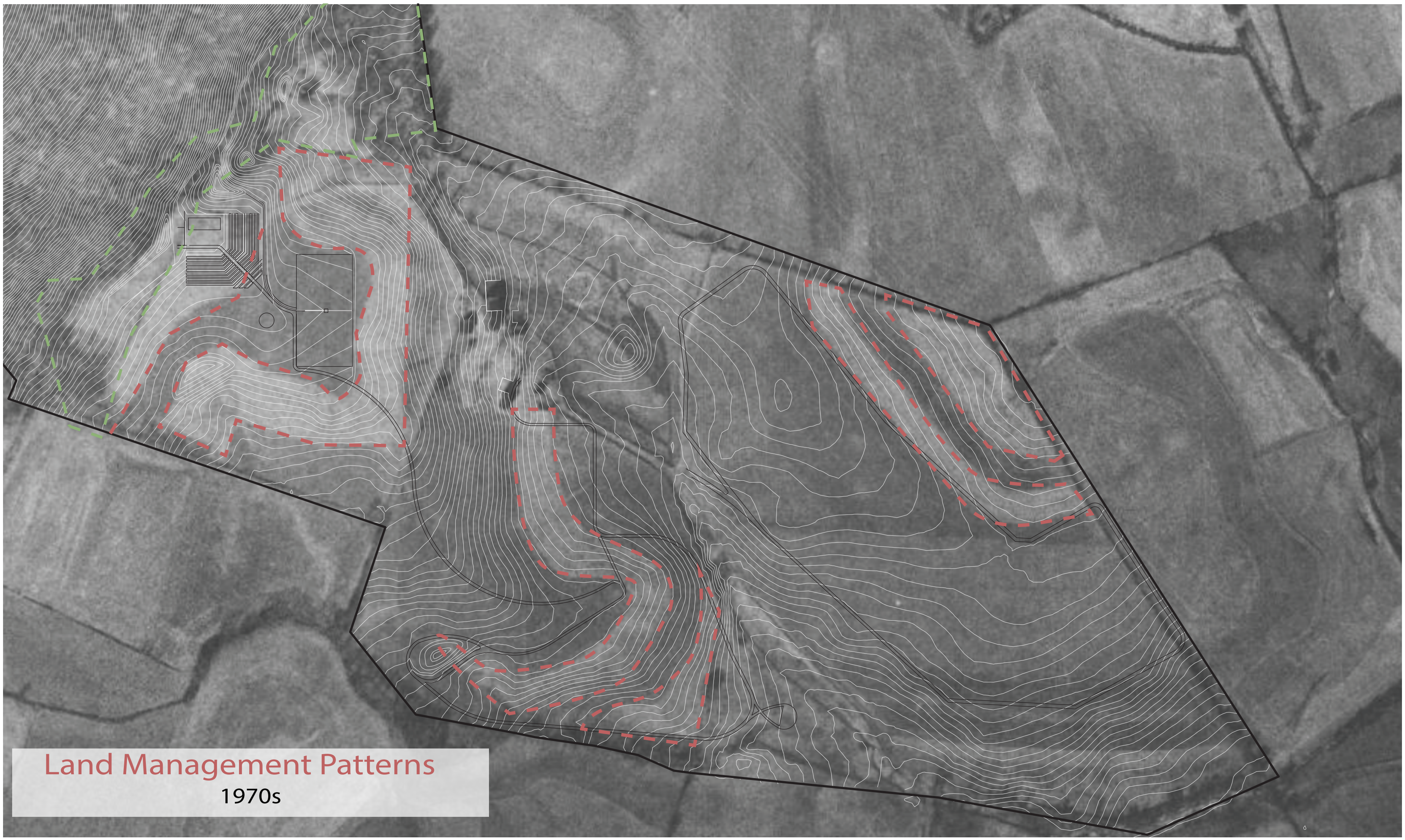


Figure 4.15 – Historic Cropping Patterns, overlaid with proposed design patterns

Figure 4.16 – Existing Forest

This area of recent forest regeneration stands in contrast to forests in riparian areas and those approaching the ridge-line. Only recently regrown, this forest has proved susceptible to invasion by nonnative plant species such as multiflora rose (Rosa multiflora) and Tree of Heaven (Ailanthus altissima). While my proposed design will preserve as much existing forest cover as possible, especially in critical riparian areas, this plot will be selectively cleared for access establishment, forest gardening, and water reticulation.

Sensitivity to the site's historical and existing patterns has helped to guide the design process. Selecting access routes, cultivation patterns and water systems that reflect historical patterns of use developed over generations. The expression of these patterns will be explored in the following chapter, which explores proposed interventions and deployment of agroforestry systems throughout the site.

Figure 4.17 – Site Topography

Viewshed and Site Character

Figure 4.18 – Existing Conditions

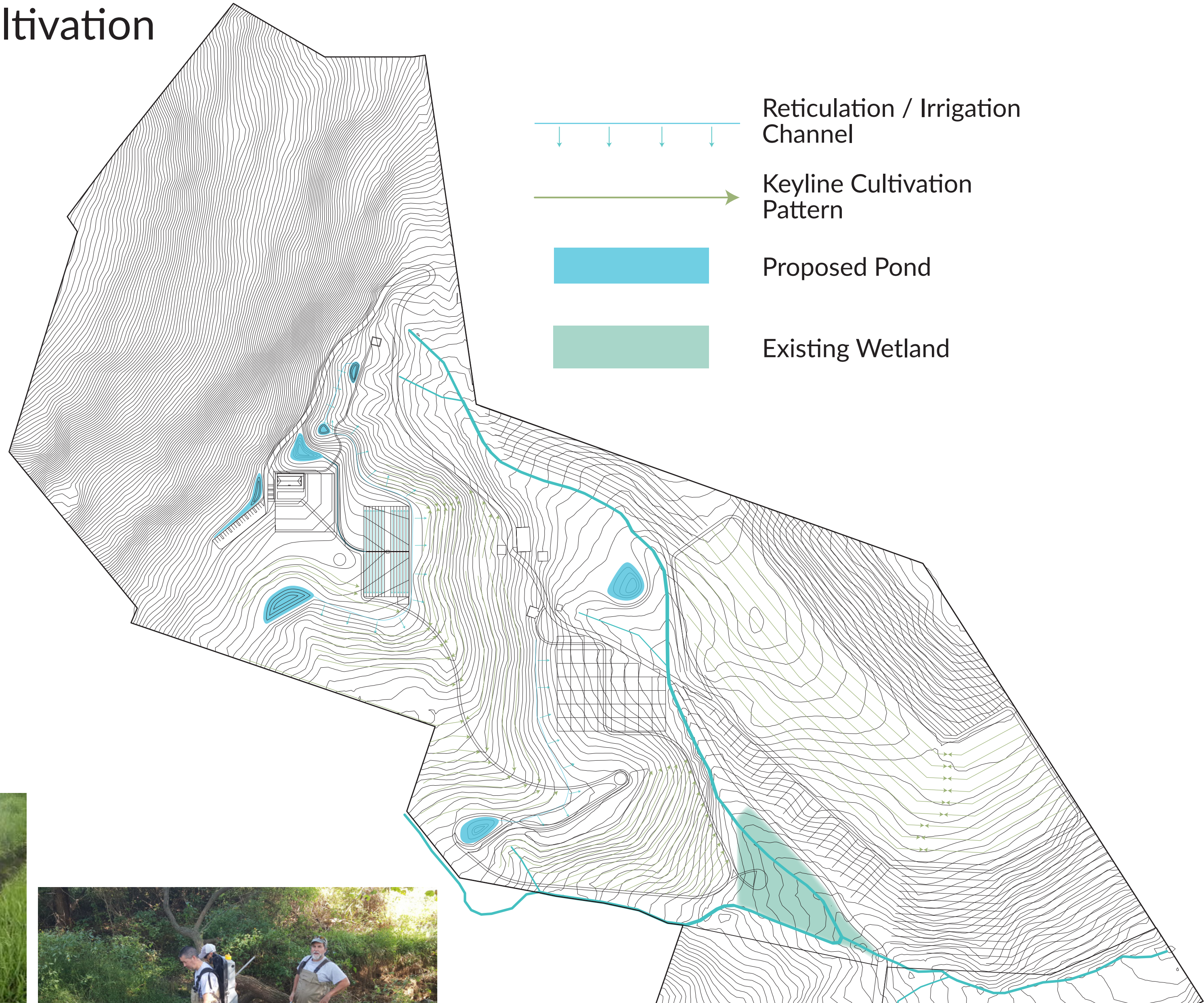
Figure 4.19– Photostations on site

Figure 5.1 – Proposed Site Plan

Figure 5.2 – Proposed Species Matrices

Water Systems and Cultivation

Walking the farm site for the first time I was immediately struck by the abundance of water on the property. From springs, to first and second order streams, as well as a large wetland feature at the confluence of the streams, water courses readily from the ridge-line, through the farm, on its way to the valley below. This availability of water, combined with the recent trend toward higher intensity short duration storm events has led to significant erosion and habitat degradation along the waterway. The erosion of sediment from the stream-banks threatens the marginal fish population below the stream confluence and represents an immediate need for systematic intervention.



Spring Source

Channelizing

Significant erosion below confluence

Figure 5.3 – Water Reticulation and cultivation patterning

One strategy to address the erosion of waterways on the farm, is to slow and spread the runoff of water from cultivated land. Illustrated as deployed on the farm in Figure 5.3 and simplified in Figure 5.4 the cultivation pattern for the farm is based on the Keyline concept, developed by P.A. Yeomans. This system of cultivation rows, deployed 2% off contour +/- 1% form the foundation of the cropping pattern on the farm as proposed. This system, developed for dry-land agriculture, where every drop of precipitation needed to by retained on the land, is adapted here for use in a humid, temperate system. By intercepting minor valleys in the landform with tree rows, planted into subtle berms, runoff is redirected from its point of concentration where there is danger of gully erosion and damaging head-cuts, to the relatively drier ridge at lower elevation.

By creating rows via parallel offset from a 'Key' guideline, evenly spaced rows of similar slope are possible. When compared to plantings that are based directly on the contour elevation, these rows are much more standardized and accessible to mechanized equipment.

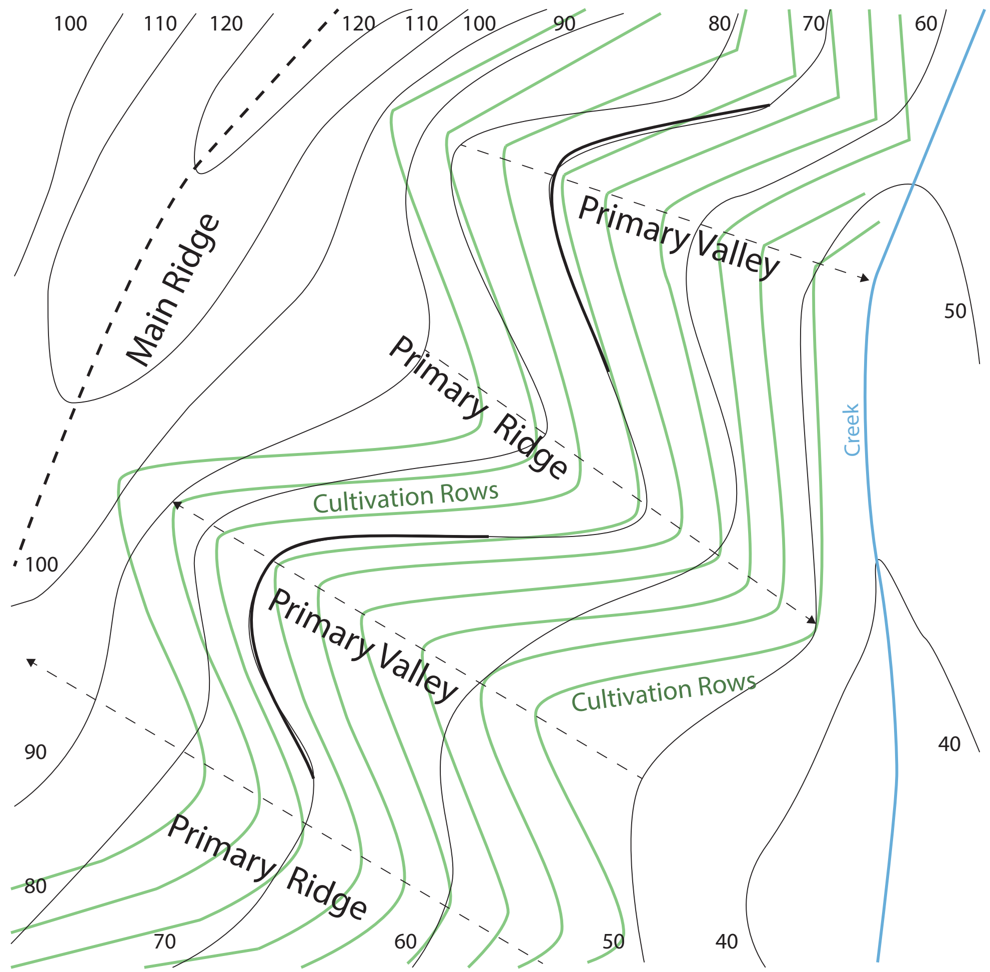


Figure 5.4– Keyline Cultivation Pattern Detail

When compared to straight rows across the topography, this system presents clear advantages with regard to erosion reduction, water harvesting, and allocation throughout the site.

This system is not limited to cultivation patterns, however, by delineating the site in terms of moving water as slowly as possible along contour elevations, rather than perpendicular to them, it keeps water at high elevations allowing it to slowly infiltrate into the water table, emerging in the streams as groundwater rather than sediment laden high intensity stormwater.

Access System

In addition to the cultivation patterns described above, water reticulation as proposed is conveyed along the site's access infrastructure. This water reticulation network distributes runoff via gentle grades along road drainage to storage ponds throughout the site (Figure 5.5)

In the Scale of Permanence, Access is number four of eight. This placement in the ranking is due to the relative ease of constructing and altering road networks when compared to the preceding entries of climate, topography, and water systems. We must think of these systems holistically in order to protect watersheds while allowing full use of the site to achieve our goals of production, preservation, and interpretation.

Where new access is proposed through previously identified marginal forests and existing access patterns, this road drainage is captured and stored in a pond network. Proposed roads have been designed in a manner that minimizes impact to sensitive forest resources, and conforms to existing topography by following contour at as low a grade as possible.

In order to minimize earthworks on steep slopes, cut and fill is balanced as seen in Figure 5.6

By coupling the access network and water storage and reticulation in the design and construction process, new synergies are revealed, allowing us to maximize function while minimizing construction and design costs. This water and access system form the backbone of all systems that we will discuss in terms of deployment of proposed agroforestry systems.

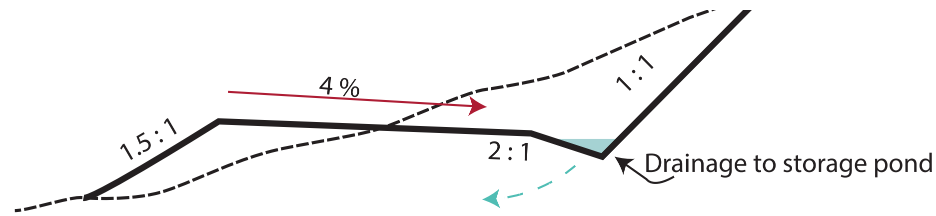


Figure 5.5 –Access road profile and drainage

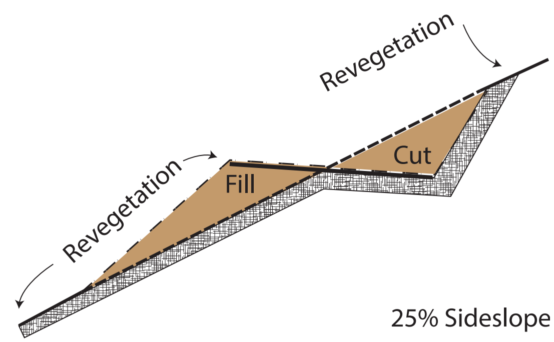


Figure 5.6 – Access Road Grading & Erosion Management

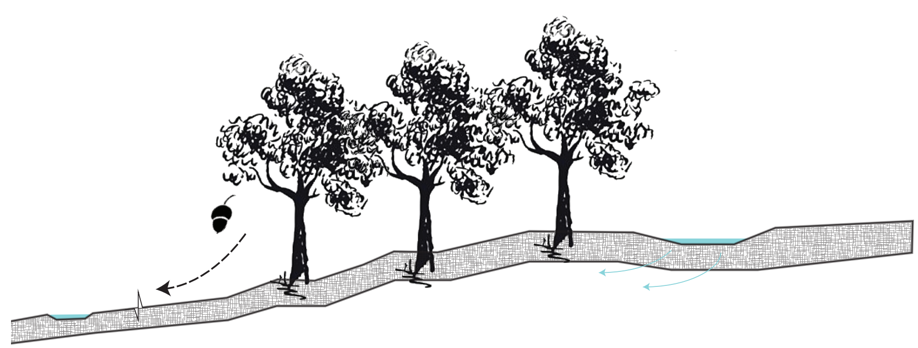


Figure 5.7 – Cultivation& Reticulation Profile

As water is conveyed along the access and cultivation network, it makes its may through a proposed system of ponds, networked via spillways at the top of the dam, and irrigation emitters at the base. This system of reticulation allows ponds throughout the site to maintain equalized water levels while allowing access to irrigation throughout the farm.

Early in the design process, the well-drained soils present throughout the site were identified as a major advantage to tree-crop cultivation due to compaction resistance, easy infiltration and permeability to tree roots and soil life. However until the clay lens was identified (Figure 4.9) between 40" and 48" deep, this permeability was a potential liability to pond construction, which require fine soil textures for the creation of stable dams. The exploitation of this clay layer however will allow for the creation of stable, impermeable layers on the uphill side of dams, without this clay diaphragm, our goal of storing water high on the landscape would be greatly limited.

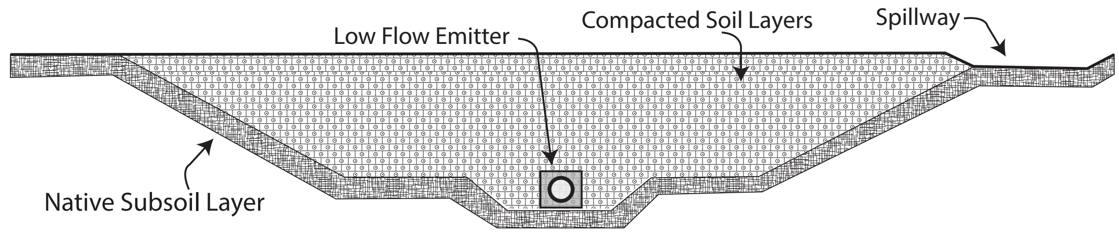


Figure 5.8– Section Along Dam Wall

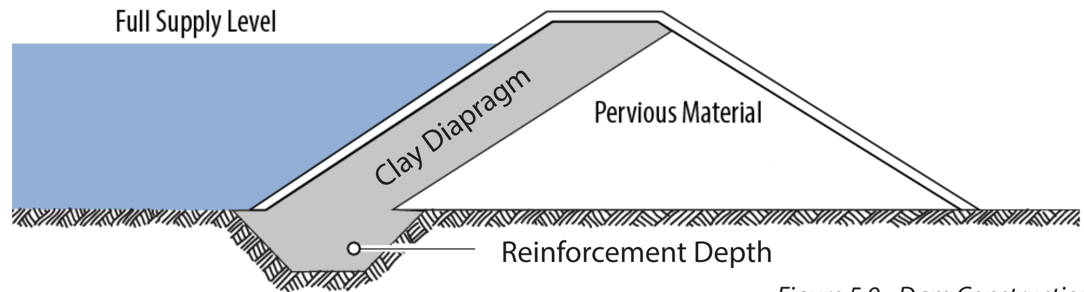


Figure 5.9– Dam Construction

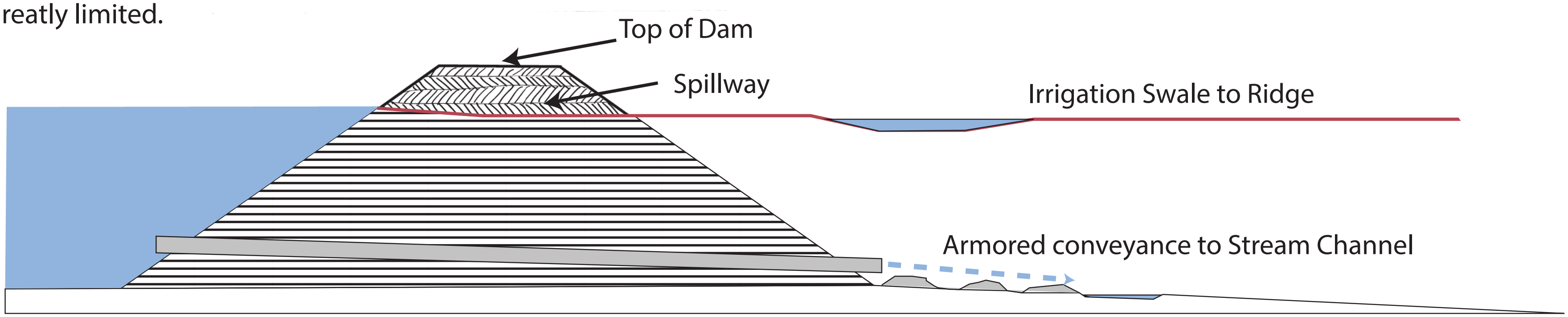


Figure 5.10 – Section across Dam Wall

New Farm Center

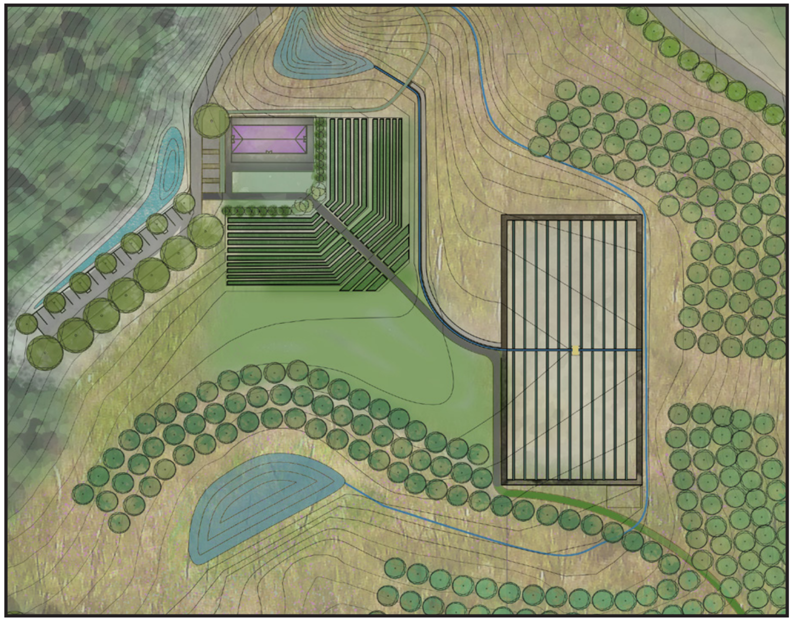


Figure 5.11 – Proposed Center layout

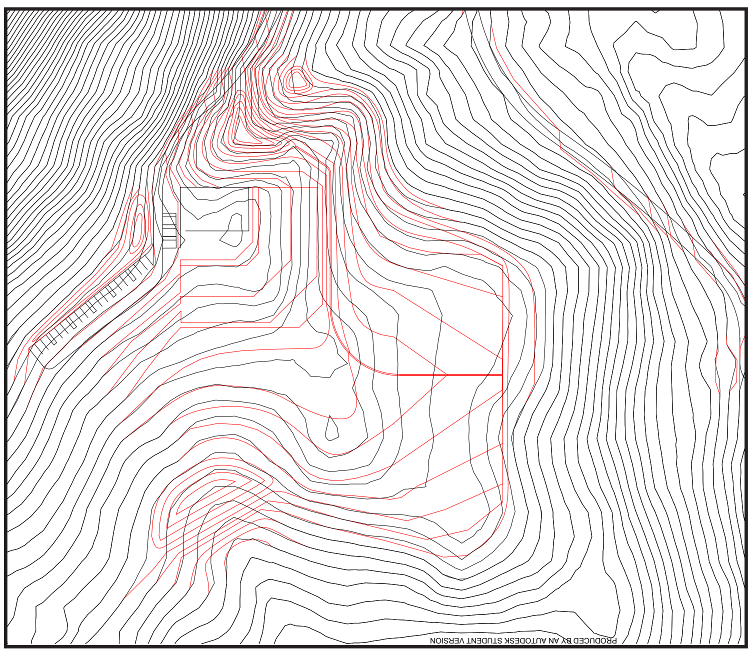


Figure 5.12 – Proposed grading

Constructed on a knoll at the interface between cleared pasture and woods, currently occupied by young trees and old field successional species. This space, once cleared for access and pond construction presents an opportunity for an unobstructed view across the farm, and greater valley, to Catoctin Mountain to the East. Taking advantage of the existing landform, subtle grading extends the natural terrace of the secondary ridge, to create an expanded low slope area for intensive gardening, creating formal garden space for experimentation and breeding of novel perennial crops, as well as more traditional kitchen and herb garden crops.

Associated with the center as well is a large catchment pond, constructed as a gully dam, that arrests a growing head-cut while collecting runoff from entry road and structures for irrigation supply.

Atop this constructed terrace, a building site is proposed that will house a combination community, research, and production center. This multipurpose center will create space for adding value to crops grown on site, training for local and regional community in design, cultivation and processing of novel perennial crops, as well as research and design space for Morningview staff to design perennial crop systems for clients, develop propagation techniques and administer the farm.

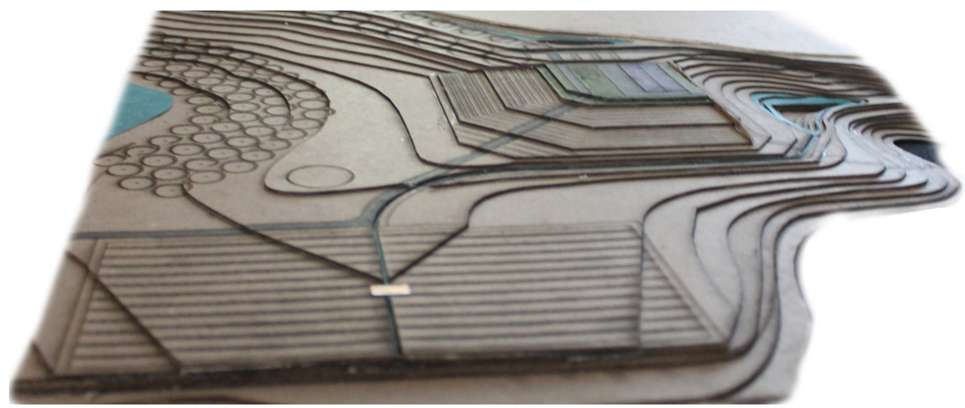


Figure 5.13 – new Center grading model

Figure 5.14 - Bird's eye view across farm

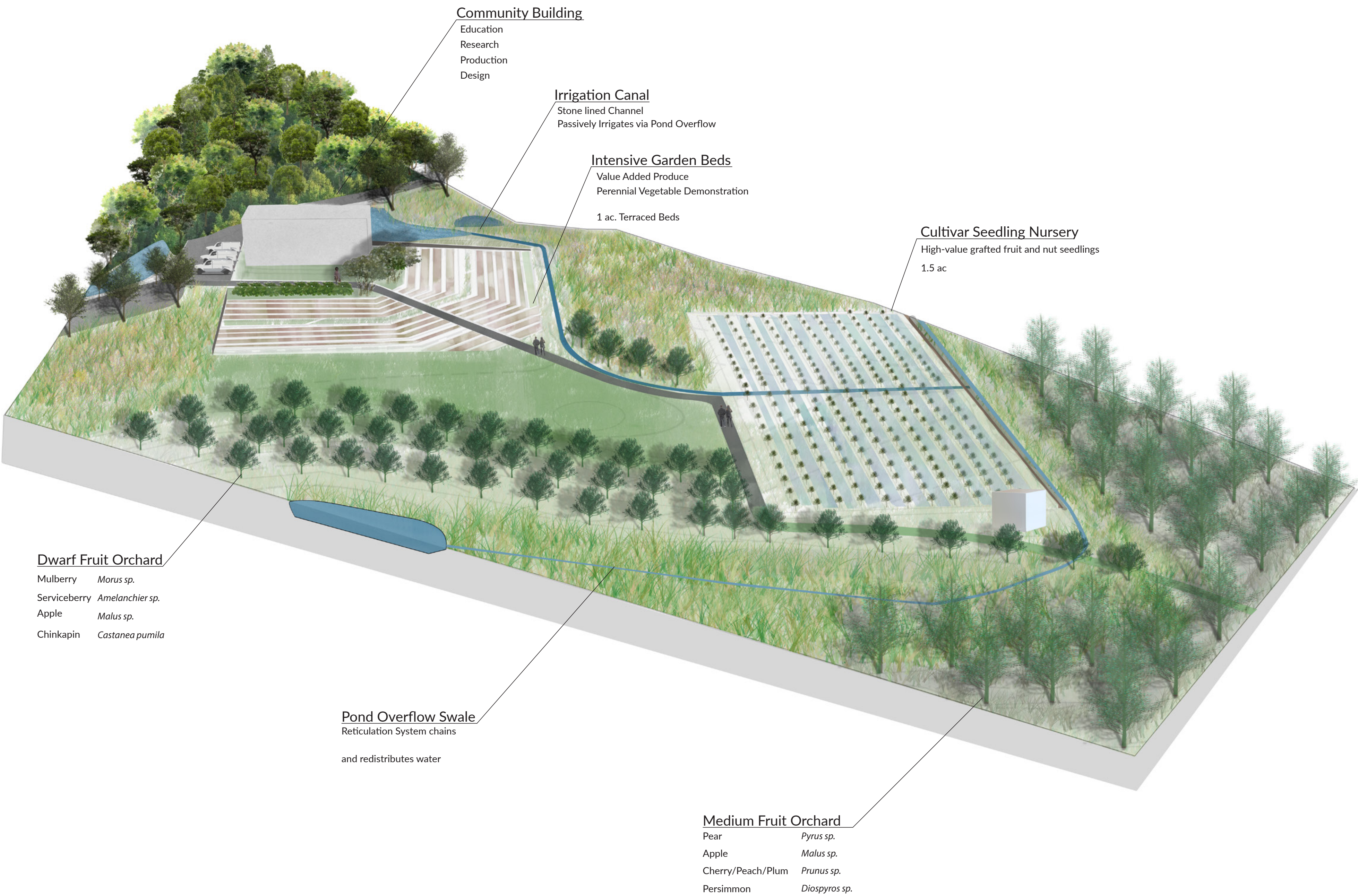
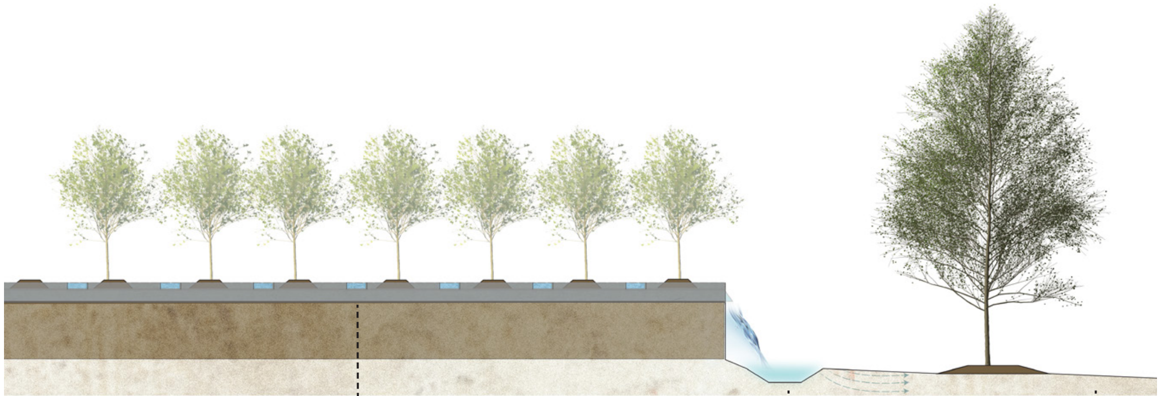


Figure 5.16- Proposed farm Center layout

The earthworks, structures, and tree plantings at this upland site that effectively re-centers the farm from its historic structures in the valley of the farm, reflect the radical transition implied by the shift of the site from annual monoculture to biodiverse perennial tree crops. From this high point of the site, visitors can observe the various systems at work on the site, as well as their siting in the landform and water reticulation network. From the high-point, a network of paths extends throughout the farm, allowing visitors a self-guided interpretive experience. From the top of the farm, forms in the landscape evolve from traditional agricultural forms that are easily relatable to a lay audience. These forms include the terraced garden dwarf fruit orchard laid out in a keyline pattern gently responding to the shape of the land. As one progresses downslope along the interpretative trail, the dwarf orchard gives way to standard sized orchards, transitioning from familiar crops such as apple and pear, to novel crops of persimmon, chestnut, honeylocust, and mulberry, native crops and their analogues that hold productive potential for integration within our region's orchards and farms.

These novel crops and systems are introduced in a progression from formal and high intensity, to low maintenance systems, wild and informal in the riparian zone.

Figure 5.17 - Perspective from base of Center terrace



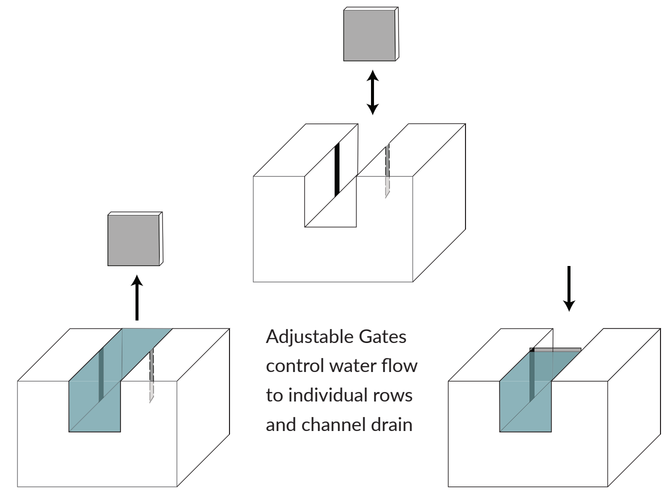


Figure 5.18

Seedling nursery cross-section

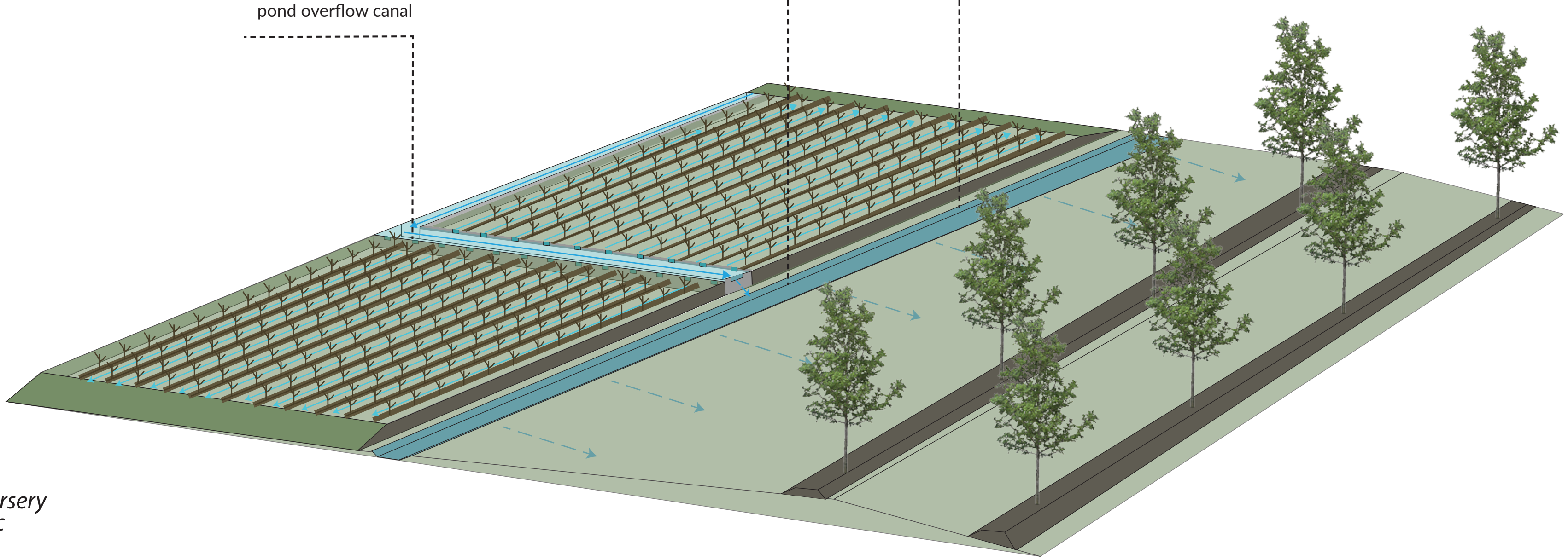


Figure 5.19

Seedling nursery axonometric

As visitors leave the Center Gardens, the path converges with a unique landscape infrastructure system that conveys water via canal from the center pond to a seedling nursery built to propagate rare and valuable novel crops and cultivars. This seedling nursery allows for high intensity production of cloned seedlings, in a raised bed system that may be gravity irrigated.

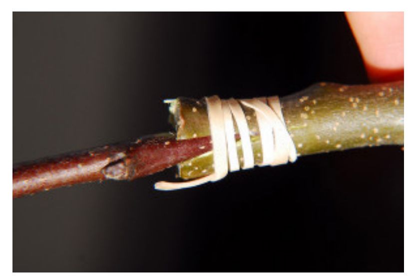
Where the canal enters the nursery, it becomes a diversion channel constructed with a series of adjustable weirs to allow for flood irrigation of the perpendicular raised seedling beds. In this manner, irrigation does not directly interact with seedling foliage or root collar, areas of greatest sensitivity to fungal pathogens. This deep, flood irrigation will encourage large, healthy root systems preparing seedlings better for field success when compared to surface irrigation.

In time of excess rain, overflow water from the pond can be directed into this canal, where it can bypass irrigation weirs, and flow directly into the farm reticulation network, where it can infiltrate and spread water to dry ridge-lines.. This subsurface irrigation via reticulation channel effectively transforms runoff water that would be a liability in the eroding gully system where the source pond is constructed, into an asset that irrigates tree crops and meadow habitat while recharging groundwater throughout the site.

Figure 5.20 Furrow irrigation in plum orchard

Figure 5.21 - Grafting techniques
Clockwise from top

bud graft - Diospyros
patch graft - Juglans
whip and tongue graft - Prunus



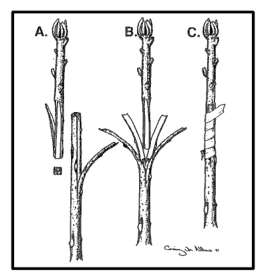


Figure 6.1 – Proposed Site Plan

Figure 6.2 – Proposed Species Matrices

Forest Farming

Figure 6.3 Forest Farm inset

Under the canopy of regenerating forest, selectively thinned for construction of access road to the hilltop shade loving native perennials, and mushroom are grown for medicinal and culinary uses. This cultivation systems allows for thinning of the existing forest, overgrown with invasive trees and vines, releasing valuable timber trees including tulip-tree, black cherry, and allow for future regeneration of oak and hickory.

Broadly termed forest farming, the manipulation of native forest for the production of non-timber forest crops has been practiced for millennia in North America, and can take a variety of forms. In this area of the farm, where disturbance related to road and pond construction will have disrupted the soil and forest, forest farming can occur alongside active timber stand improvement, where the act of cultivating the understory can itself be an act of restoration by way of managing understory vegetation and keyline irrigation.

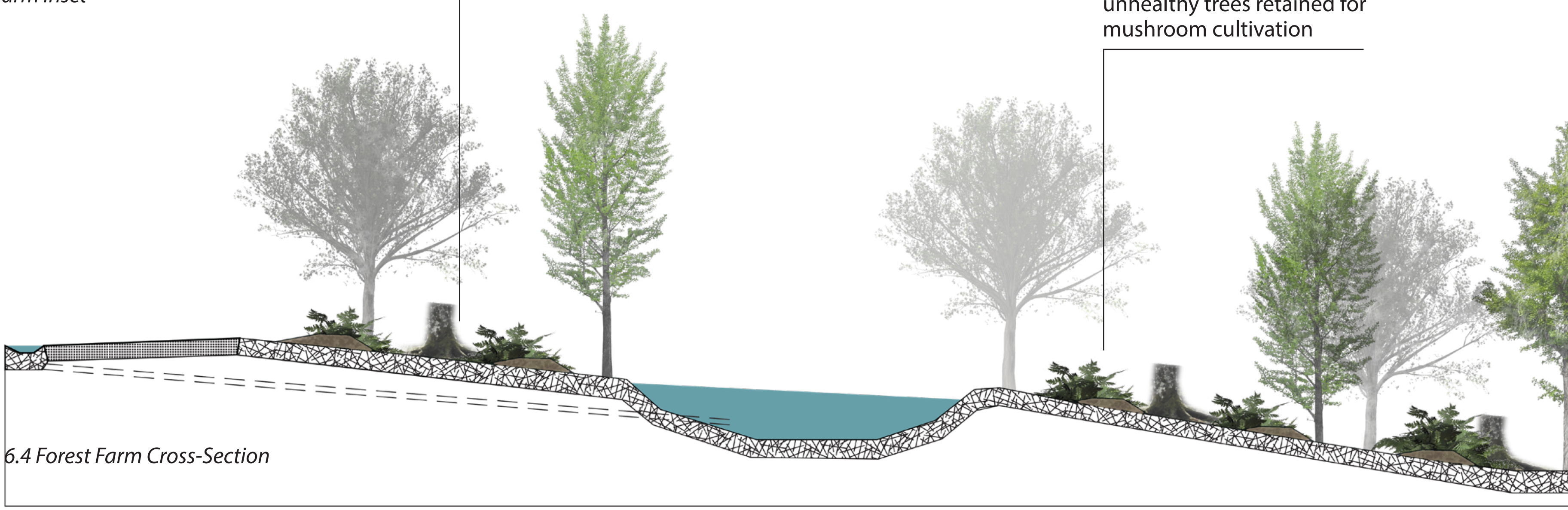


Figure 6.4 Forest Farm Cross-Section

Figure 6.5 Forest Farm Cultivation Plan

Alley Cropping

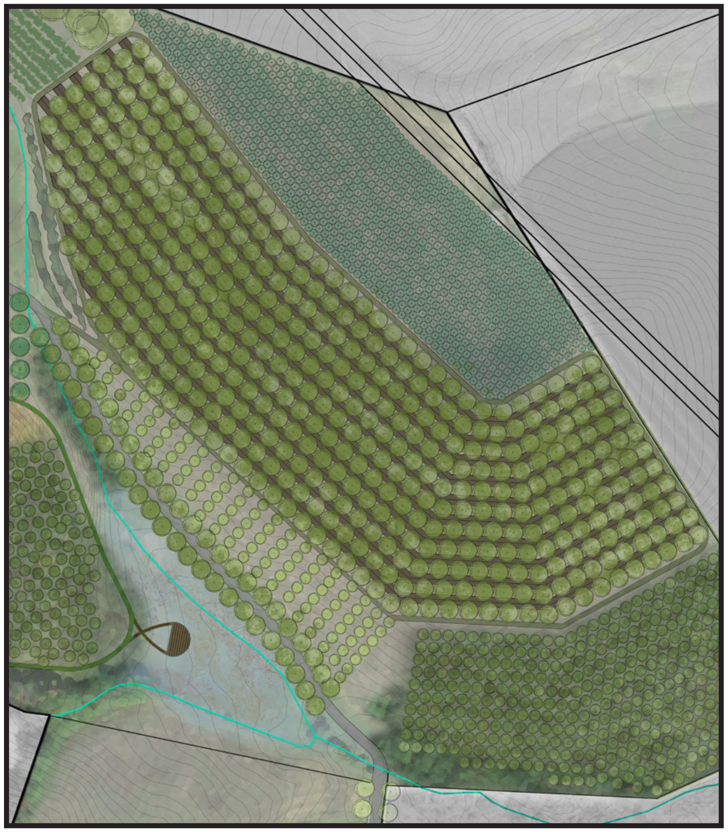


Figure 6.6 - Alley Crop Cultivation Plan

On the opposite side of the spectrum from forest farming, alley cropping is perhaps the highest intensity agroforestry practice, and holds great promise for its adaptability to conventional annual agriculture practices. In an alley crop system, rows of trees are planted with wide spacing that allows them to reach their full productive potential at maturity. At Morningview farm, a large flat area in the Southeast portion of the farm has been selected for installation of this system due to low potential for erosion. Tree rows that form the basis for the layout are arrayed on the keyline pattern used throughout the site that subtly conveys runoff along the rows, arresting erosion and depositing any excess nutrients in the critical root zone of crop trees. . Between rows, conventional annual crops or small perennial crops are planted at their typical spacing. Alley cropping is adaptable to a variety of tree crops including species grown for their timber, food, or fodder potential. The maturing trees cast shade, and provide shelter to annual crops, reducing stress from excessive heat and desiccating winds.

In the design of alley crop systems, care must be taken at establishment to assure compatibility with cultivation and harvest equipment, a primary consideration is the establishment of headlands (Figure 6.7) that are adapted to machinery turning radius to maximize efficiency.

The size of the area devoted to headlands depends on several factors. Typically, the width of the machinery with attached implements is taken into account. The standard is to leave headland space equal to 1–4 times the width of the largest machinery, including implements. This considerable variation in width depends on economics; machine operator; topography at the area approaching the headland, as well as the headland area itself, and the type of cropping system.

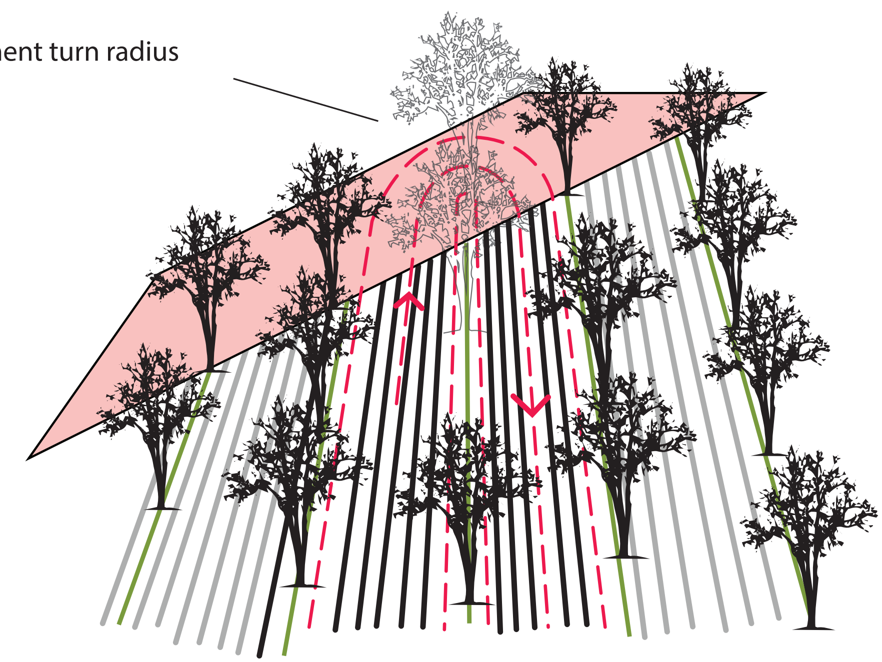


Figure 6.7 - Alley Crop Headlands

As tree crops mature, inter-row crops are gradually shaded out until the tree crops are either harvested for their timber, or cultivation is shifted from intensive annual crops to shade tolerant understory crops and emphasis is shifted to high value fruit and nut crops from the overstory. In the Mid-Atlantic, hickory, walnut, and pecan hold great potential for use in alley crop systems due to their ability to provide both timber and nut crops over the course of their lifespan. Within tree rows, the farmer has the option to grow:

- Short-rotation timber crops such as black locust or alder that can be harvested for posts or firewood, while enriching the soil
- Culinary or medicinal crops for which mechanized cultivation and harvest are not required.

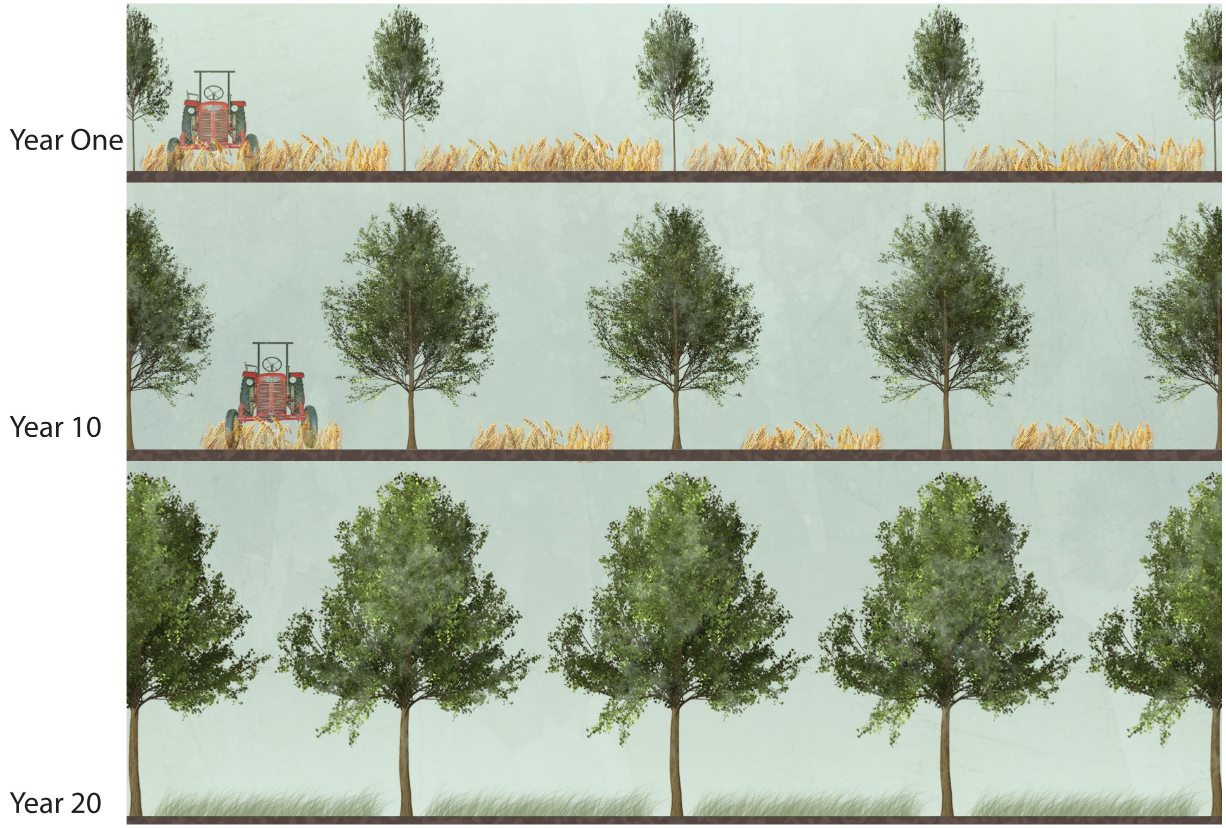


Figure 6.8 - Alley crop field evolution

(Figure 6.8) to the right illustrates this progression from establishment of tree crops, spaced to allow two tractor widths of crops at year one, to one tractor width of crops as trees mature and shade out inter-row zones, to year 20 where ground-cover has been transitioned to pasture grass or shade tolerant understory.

Figure 6.9 - Alley crop field evolution

Entry Alleé

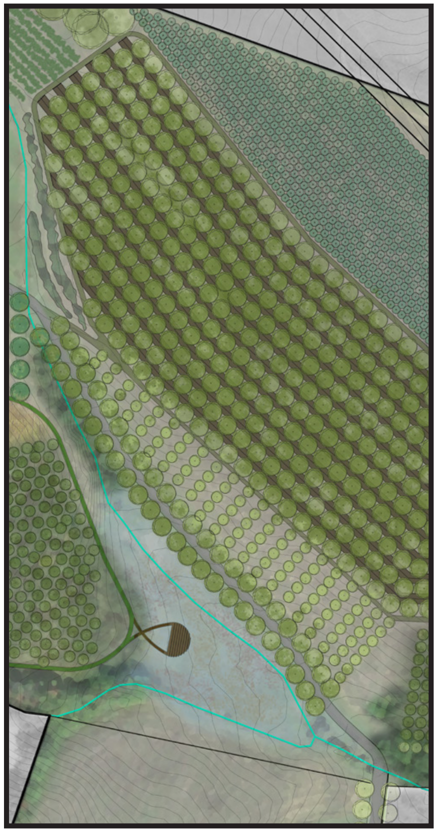


Figure 6.10 - Entry alleé plan inset

At the main entrance to the farm, along the existing farm road built for the historic farm center, an alleé of grafted walnut and honey locust is proposed. This feature alludes to the entry lane at J. Russell Smith's Sunny Ridge, where the discovery of white English walnut, grafted to native black walnut immediately oriented me to the fact that I had uncovered a mature agroforestry planting that was established nearly a century prior.

Figure 6.11 - Entry alleé plan inset

The striking presentation of white and black bark scored at their intersection by a graft union near eye level, signals to visitors that they have arrived at a site where traditional agriculture is merged with radically innovative practices. A primary interpretive goal of the site is to represent to all audiences that these practices are not in opposition, but rather hold potential for integration with the standard agricultural patterning of the region. On the hillside above, cultivars of honeylocust, grown for sugar and seedpod productivity are grown, with their remarkable form and profound fruit signal the promise of breeding and genetic selection that stands to improve native crops to incredible productive potential.

These trees, naturally occurring in riparian areas within their native range protect the adjacent streambank, and sequester any eroded sediment and nutrient that escape from the alley crop system above.

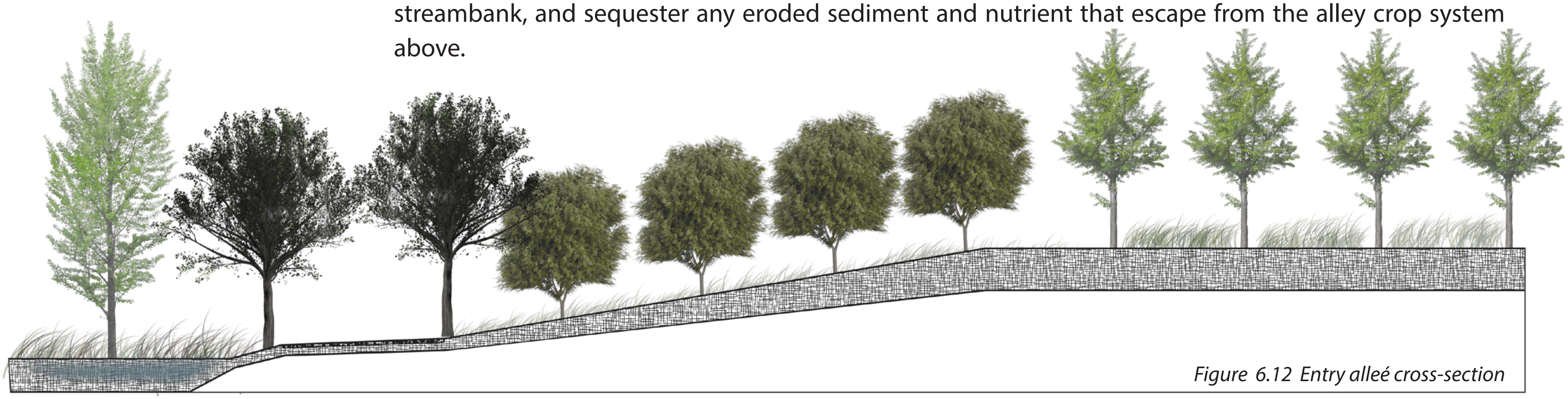


Figure 6.12 Entry alleé cross-section

Figure 6.13 Entry alleé perspective

Chapter Seven Subsidized Agroforestry Systems

In the previous section, I presented how agroforestry practices of forest farming, alley crops, terracing, and orchards are integrated into the farm design, organizing the most productive landforms and soil types of the site in a manner that allows for clear interpretation by visitors while maintaining access for maintenance, cultivation, and harvest equipment. These zones of intensive production were deployed on the site's most accessible and manageable plots.

Throughout the United States, local Soil and Water Conservation Districts have been allotted funds by the federal government to implement soil and water quality conservation practices on public and private lands. The practices funded by these programs vary by locality, but in the State of Maryland, conservation efforts are broadly focused on practices to promote downstream water quality, to achieve Chesapeake Bay restoration goals. These practices aim to reduce nutrient and sediment pollution in the Chesapeake Bay watershed by reducing the flow of nutrient and sediment pollutants from commercial, industrial, and agricultural lands.

Because many agroforestry systems are best implemented in land that was previously free of trees, to facilitate establishment of desirable species, programs that incentivize reforestation of crop and pasture land often synergize with landowner intention to transition to a perennial production model. These incentive programs typically target lands that are within riparian areas, steep croplands, sensitive wildlife habitat, and wetlands. The use of agroforestry practices in marginal lands such as these was a primary strategy promoted a century ago by J. Russell Smith. With the understanding that a transformation of our agricultural system from annual to perennial crops would not happen overnight, Smith understood that farmers would be most likely to adopt new practices if they did not present a risk to their existing income stream. By this logic, land that is too steep, wet, dry, or is otherwise inaccessible to established cultivation patterns is ripe for the implementation of agroforestry practices. If farmers throughout the region establish agroforestry practices in these areas that present low economic risk, any harvest is a net gain, and with most tree crops, the returns increase year-over-year as trees grow and mature.

The perennial nature of these crops naturally entails that access to the planting takes place on a different temporal scale than conventional crops. Whereas many tractor passes must be made through a corn or soybean field each year to cultivate the soil, plant, apply fertilizer and pesticide, and harvest the crop, a riparian or fence-line agroforestry system may only require a yearly mowing for the first several years, followed by periodic pruning and harvest in following years. In this way, access to sensitive areas and disturbance of soil is limited.

With these concepts in mind, the design of this agroforestry demonstration farm has taken advantage of a variety of subsidy, cost-share, and incentive programs, that through creative design can be installed in a way that meets conservation goals of agencies and landowners, while achieving economic goals of farmers. By designing the farm in a way that utilizes these programs, local farmers are exposed to practices that utilize these valuable incentive programs in ways that only enhance their bottom-line, that taking land out of annual crops does not necessarily mean sacrificing their productive capabilities.

The figure below outlines zones that are designed under cost-share programs that incentivize establishment and maintenance of conservation practices. Within this section, practices that fall within two incentive programs are proposed.

Conservation Reserve Enhancement Program (CREP) - This program falls under the umbrella of the Conservation Reserve program administered by the Farm Service agency of the federal government. Under this program, federal funds are matched with state and local funds to incentivize the removal of sensitive lands from annual cultivation. These incentives include installation and maintenance funds, as well as annual rent equivalent to the agricultural value of the soil for each year of enrollment. In the State of Maryland, this program typically funds riparian buffers, or areas of native grasses, perennials, and woody plants within 180' of a stream corridor.

Dominion Power Cost-Share - Due to concerns over vegetation conflicting with utility transmission lines vegetation over 15' high is not permitted within 125' of easement centerline. In order to reduce easement maintenance costs, a variety of grant and cost-share programs are offered by the utility if a landowner manages vegetation in a manner that does not violate the height restrictions.

Figure 7.1 - Subsidized Agroforestry systems

Multipurpose Riparian Buffer

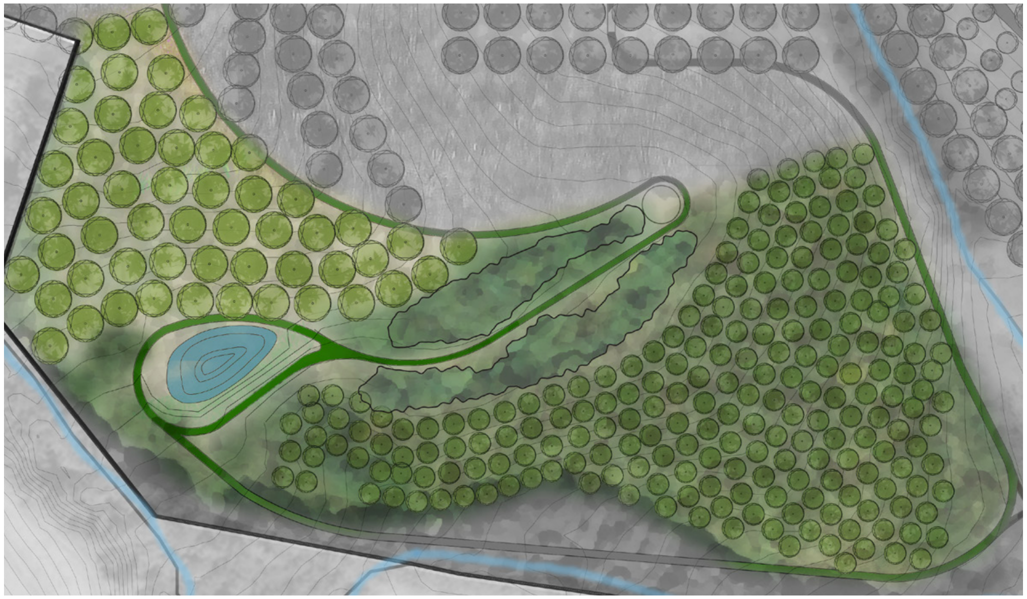


Figure 7.2 - Multipurpose Riparian Buffer Plan Inset

Inspired by the Virginia Tech Extension publication 'How to Plan for and Plant Streamside Conservation Buffers with Native Fruit and Nut Trees' (Trozzo et. al, 2018) This section of the farm follows the guidelines for conservation buffers as set forth in Conservation Practice Standard: Riparian Forest Buffer" (USDA-NRCS 2010) Under these guidelines, the planting of native vegetation is planted in riparian areas at a prescribed density. Weed control via mowing or herbicide around trees is included in the funding, and promotes survival of vegetation within the first 3 years of vegetation establishment.

The demonstration of these systems, termed multi-purpose riparian buffers for their ability to achieve economic production and conservation goals, takes multiple forms throughout the farm, see (Figure 7.3) to demonstrate adaptability to landowner preferences for management, intensiveness, aesthetics, and habitat diversity.

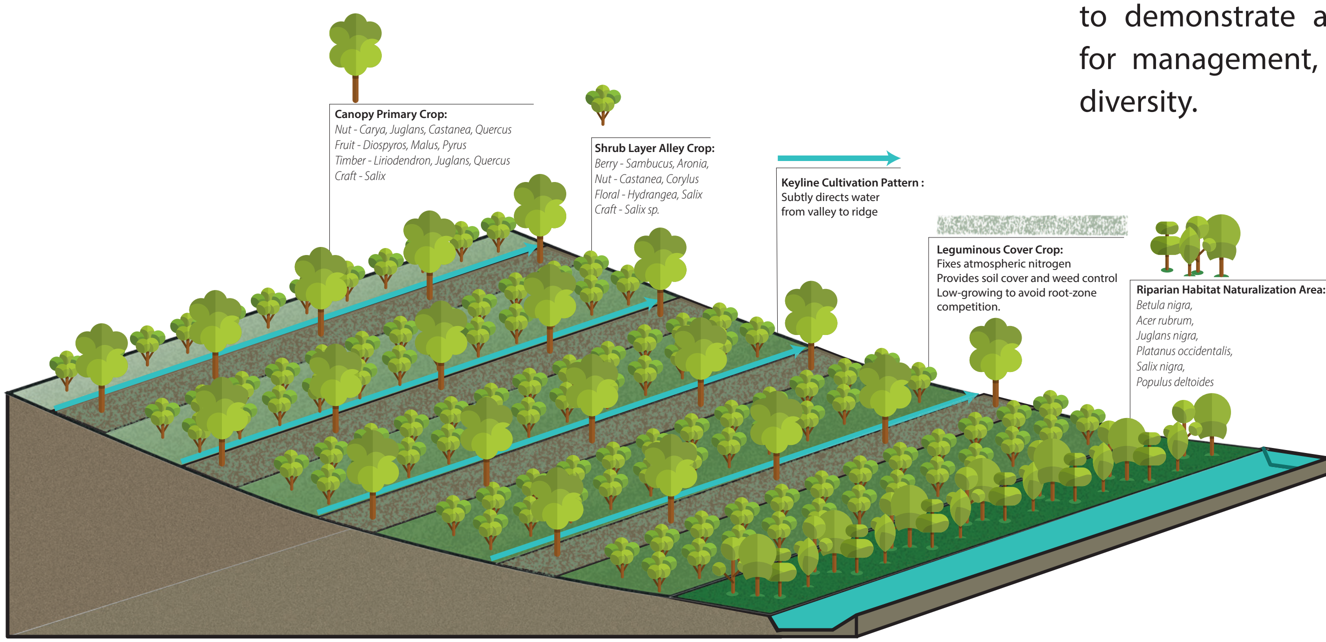


Figure 7.3 - Multipurpose Riparian Buffer Layout Axon

Figure 7.4 - Distributed nucleation

Planting at establishment as required by CREP guidelines, is necessarily much denser than would be found in a conventional tree crop orchard. This requirement accounts for low survival rates of conservation plantings due to herbivory by deer and rodents, and vegetation competition both native and invasive. To meet these guidelines at establishment in a manner that allows for seedling mortality, and statutory canopy coverage requirements, a range of planting matrices has been proposed for deployment at Morningview farm. These planting matrices address spatial and temporal patterning by accounting for growth and mortality of trees as the buffer matures. In the proposed patterns, overstory, understory, and shrub species are spaced in a manner that mimics natural succession of an old field, in years 1-5 shrubs such as Sambucus nigra, Aronia melanocarpa, and Corylus americana establish quickly and will account for the majority of harvest. In years 5-15 these shrubs will begin to be shaded out, and supplanted by understory and small trees such as Asimina triloba, Prunus americana and Castanea pumila. In the long-term time-scale, these small trees are succeeded by overstory canopy species such as Quercus sp. Carya sp. and Juglans. sp. These large canopy trees all bear valuable nut crops, and may be harvested for high-value timber and veneer on a 30+ year rotation, at which point the system may be renewed again.

Figure 7.5 - Multipurpose riparian buffer cross-section Year 3

Figure 7.6 - Multipurpose riparian buffer cross-section Year 15

Short Rotation Coppice

Figure 7.7 -Short rotation coppice plan inset

Figure 7.8 -Proposed coppice stand

In contrast to the long-term establishment and succession of the multipurpose riparian buffer, short rotation coppice offers a strategy to pause temporal succession by harvesting pole-bearing species at a intervals as short as 1-3 years. These species specially adapted to frequent disturbance by floods, fires, and grazing mammals produce a rich flush of stump sprouts in the season following cutting. These sprouts are useful on farm as fuel wood, trellis poles, nursery stakes, and fencing, and may be marketed externally as craft material and live stakes for restoration plantings.

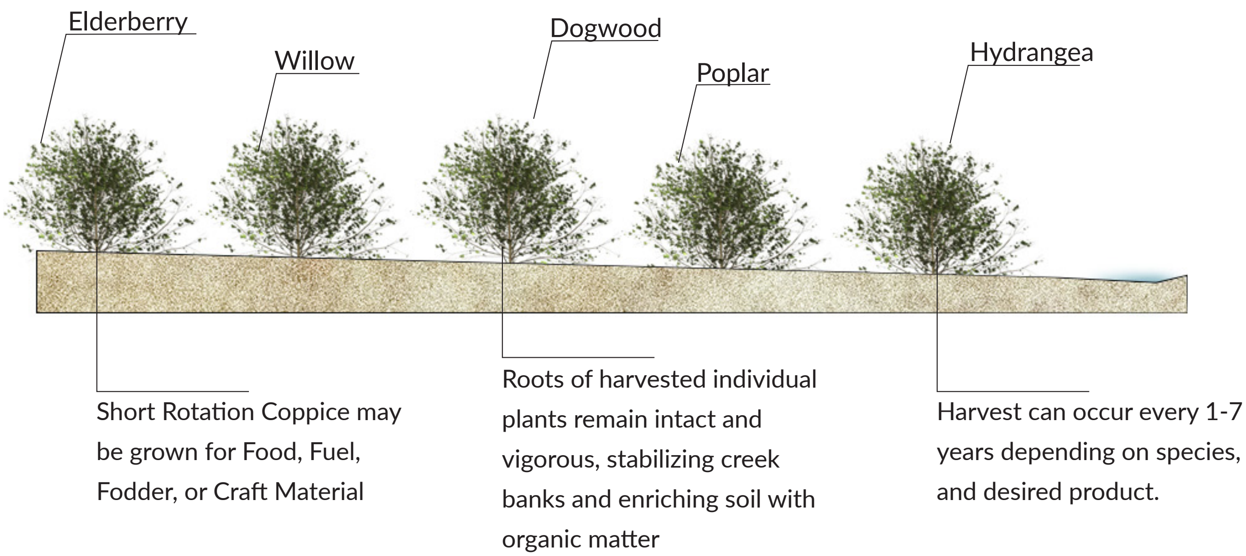


Figure 7.9 -Proposed coppice stand cross-section

Powerline Easement Nursery

Where a Dominion power transmission easement passes through the farm, cutting a corner on the eastern boundary, a unique opportunity for subsidized production exists. Under the terms of the easement signed by previous property owners a cost-share has been established under which the landowner maintains an option for Dominion power to manage vegetation within the easement via herbicide, or alternatively the landowner may conduct their own vegetation management, incentivized by a cost-share program. This arrangement creates the opportunity for Morningview farm to establish a field nursery where trees are grown to marketable size , with mowing and other maintenance costs subsidized by the easement holder.

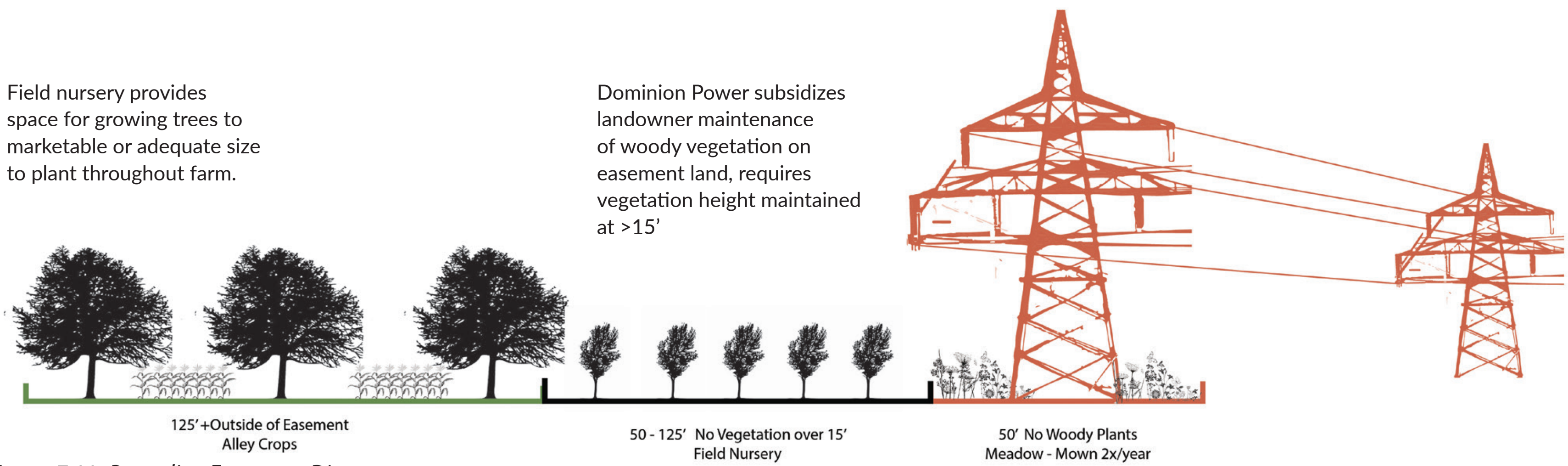
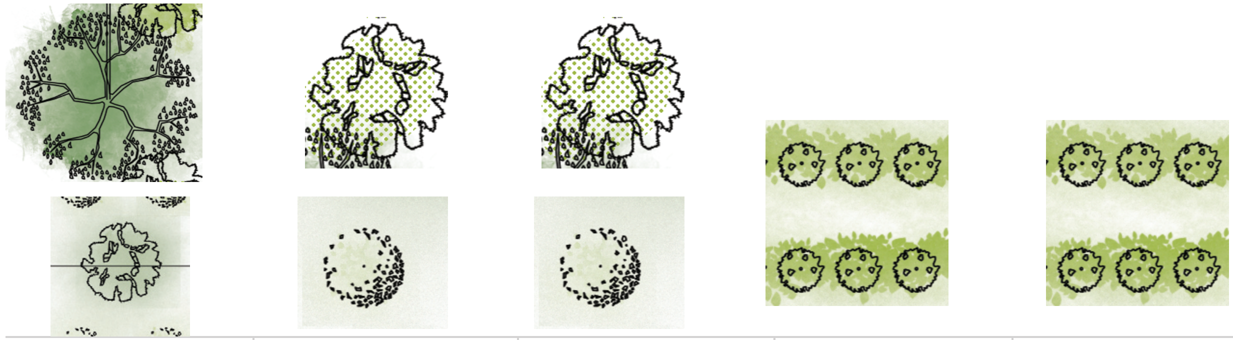


Figure 7.11 -Powerline Easement Diagram

CREP Approved Agroforestry Species List

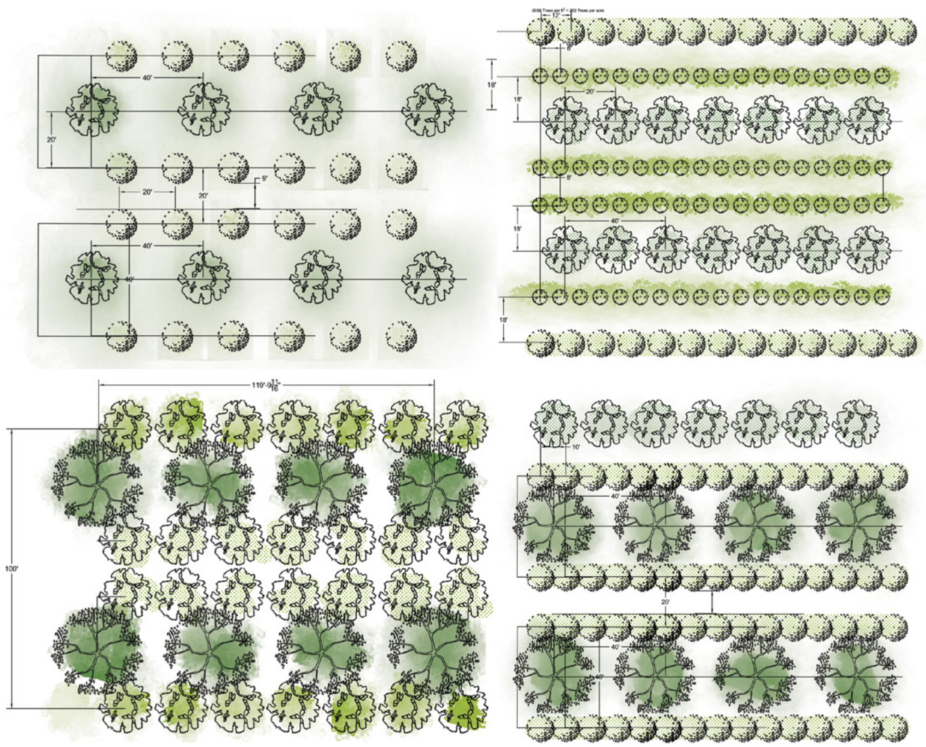


Overstory	Understory	Small Tree	Coppice	Shrub
CROP	**CROP**	**CROP**	**CROP**	**CROP**
Carya cordiformis	Morus rubra	Asimina triloba	Salix discolor	Sambucus canadensis
Carya alba	Diospyros virginiana	Amelanchier sp.	Cornus sericea	Aronia melanocarpa
Carya ovata	Robinia pseudocacia	Prunus americana	Salix contorta	Corylus americana - Uplan
Carya illinoisensis	Gleditsia triacanthos	Castanea mollissima	Hydrangea sp.	Callicarpa sp.
Hican		Malus sp.	Fothergilla sp.	
Quercus alba			Cornus stolonifera	
Quercus rubra			Rhus sp.	
Quercus velutina				
Quercus falcata				
Quercus michauxii				
Juglans nigra				
Castanea dentata				
Magnolia grandiflora				
Riparian Restoration	**Riparian Restoration**	**Riparian Restoration**	**Riparian Restoration**	**Riparian Restoration**
Celtis occidentalis	Betula nigra	Carpinus caroliniana	Alnus serrulata	Viburnum dentatum
Platanus ocidentalis	Acer saccharum	Crataegus sp.		Viburnum acerifolia
Liriodendron tulipifera	Acer rubrum	Cercis canadensis		Lindera benzoin - Upland
	Betula lenta			Cephalanthus occidentalis
	Prunus serotina			Amorpha fruticosa
				Robinia hispida

Figure 7.10 -CREP Approved Species List

CREP Approved Agroforestry Planting Layout

200 Trees/Acre - Container Grown



440 Trees/Acre - Bareroot

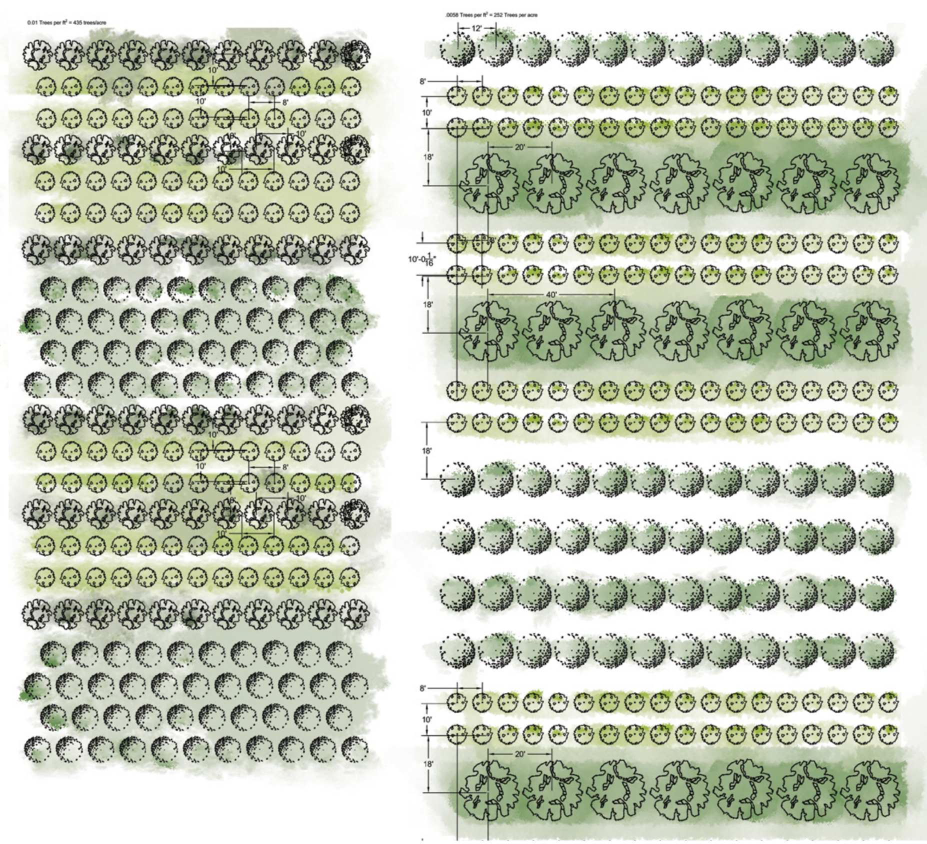


Figure 7.11-CREP Groves Planting Matrix

References & Attribution

All Photographs and Illustrations are the original work of Alexander Darr unless otherwise noted.

References Chapter 1

1 Abrams, M. D., & Nowacki, G. J. (2008b). Native Americans as active and passive promoters of mast and fruit trees in the eastern USA. The Holocene, 18(7), 1123–1137. http://doi.org/10.1177/0959683608095581

2 Chapman, J., Delcourt, P. A., Cridlebaugh, P. A., Shea, A. B., Delcourt, H. R., Archaeology, S. S., … Shea, A. B. (1982). Man-Land Interaction : 10 , 000 Years Of American Indian Impact On Native Ecosystems In The Lower Little Tennessee River Valley , Eastern Tennessee. Southeastern Archaeology, 1(2), 115–121.

3 Clayton, L. A., Knight, V. J., & Moore, E. C. (1993). The De Soto chronicles: the expedition of Hernando de Soto to North America in 1539-1543 . Tuscaloosa : University of Alabama Press .

4 Galloway, P. K. (1997). The Hernando De Soto Expedition : History, Historiography, and "discovery" in the Southeast. Lincoln: University of Nebraska Press.

5 Hudson, Charles M (1997) Knights of Spain, Warriors of the Sun. Athens, GA

6 Jefferson Chapman, Paul A. Delcourt, Patricia A. Cridlebaugh, Andrea B. Shea and Hazel R. Delcourt (1982) Man-Land Interaction: 10,000 Years Of American Indian Impact On Native Ecosystems In The Lower Little Tennessee River Valley. Eastern Tennessee Southeastern Archaeology, Vol. 1, No. 2: 115-121

7 Moore, C. R., & Dekle, V. G. (2010). Hickory nuts, bulk processing and the advent of early horticultural economies in eastern North America. World Archaeology, 42(4), 595–608. http://doi.org/10.1080/00438243.2010.517675

List of Figures Chapter 1

References - Chapter 2

1 Pardon, P., Reubens, B., Reheul, D., Mertens, J., Frenne, P. D., Coussement, T, Verheyen, K, Trees increase soil organic carbon and nutrient availability in temperate agroforestry systems. *Agriculture, Ecosystems & Environment, 247 (2017)*, 98-111.

2 Jim Robbins. (2011, November 21). 'A Quiet Push to Grow Crops Under Cover of Trees.' http://www.nytimes.com/2011/11/22/science/quiet-push-for-agroforestry-in-us.html, accessed 10 January 2018

3 Michael Jacobson, Extent of Agroforestry Extension Programs in the United States. Journal of Extension, 51/4 (2013)

4 Margaret Eppig, 'Russell Lord and the Permanent Agriculture Movement: An Environmental Biography.' PhD dissertation (Antioch University, 2017) pg. 226

5 Virginia M Rowley. *J. Russell Smith* (Philadelphia, PA: University of Pennsylvania Press, 1964) 178

6 Jerome Fellman. 'Myth and reality in the origin of American economic geography,' *Annals, Association of American Geographers* 76 (1986), 313–30.

7 J Russell Smith. Commerce and Industry (New York, NY: H. Holt and company 1913).

8 Trevor Barnes. (2001). '"In the beginning was economic geography" – a science studies approach to disciplinary history', *Progress in Human Geography*, 25/4: 521–44. DOI: 10.1191/030913201682688922

9 J Russell Smith. *Tree Crops: A Permanent Agriculture* (Washington, D.C.: Island Press, 1987) Page 7.

10 J Russell Smith. Contemporary Authors Online. Detroit: Gale, 2002. Literature Resource Center (accessed April 7, 2018). http://link.galegroup.com.ezproxy.lib.vt.edu/apps/doc/H1000092489/LitRC?u=viva_vpi&sid=LitRC&xid=69ddbdf7.

11 J Russell Smith, The World's Food Resources (London: Williams and Northgate, 1919)

12 J Russell Smith. (1925). North America, its people and the resources. New York: Harcourt, Brace and Company.

13 J Russell Smith. (1945). *Grassland and farmland as factors in the cyclical development of Eurasian history*. Washington: United States Government Printing Office.

14 Rowley, Virginia M (1964). *J. Russell Smith* (Philadelphia, PA: University of Pennsylvania Press page 54

15 J Russell Smith, *Tree Crops: A Permanent Agriculture* (Washington, D.C.: Island Press, 1987) Page 335.

16 Michael Gold. Agroforestry systems for the temperate zone. *Agroforestry Systems*, 5/2 (1964), 109-121.

17 Ibid.

18 Rafter Sass-Ferguson, & Sarah Taylor Lovell, 'Permaculture for agroecology: Design, movement, practice, and worldview. A review', *Agronomy for Sustainable Development*, 34/2 (2014)

19 Peter McDonald & James Lassoie, *The Literature of Forestry and Agroforestry*. (Ithaca, NY: Cornell University Press, 1996).

20 David Holmgren, 'Historical Precedents for Permaculture' Collected Writings & Presentations, (Hepburn Springs, Australia: Holmgren Designs, 1991) 2.

21 Smith, *Tree Crops,* op. cit (note 9) 20-25.

22 Rowley, *J. Russell Smith* op. cit (note 5) 172-178

23 David Scanlon, 'A Case Study of Honey Locust in the TN Valley Region'. (Norris, TN: Tennessee Valley Authority, 1980)

24 Jasper Guy Woodroof, *Tree nuts: production, processing, products* (Westport, Conn: AVI Publishing 1900).

25 Randal Beeman, 'Friends of the land and the rise of environmentalism, 1940-1954', *Journal of Agricultural and Environmental Ethics 8/1* (1995), 1-16.

26 C Merchant, *The Columbia guide to American environmental history* (New York: Columbia University Press, 2010), 96

27 Rowley, *J. Russell Smith* op. cit (note 5) 185

28 Eppig, *Russell Lord and the Permanent Agriculture Movement: An Environmental Biography* op cit. (note 4)

29 Scanlon, 'A Case Study of Honey Locust in the TN Valley Region' op. cit (note 22)

30 Rowley, *J. Russell Smith* op. cit (note 5) 183

31 Scanlon, 'A Case Study of Honey Locust in the TN Valley Region' op. cit (note 22)

32 Smith, *The World's food resources*, op cit. (note 11) 529

33 Smith, *Tree Crops: A Permanent Agriculture op. cit* (note 9) 270.

34 Smith, *Tree Crops: A Permanent Agriculture op. cit* (note 9) 20-25.

35 Ibid.

36 Smith, *Tree Crops: A Permanent Agriculture op. cit* (note 9) 7.

37 P. K. R. Nair, *Classification of Agroforesty Systems*. *An Introduction to Agroforestry* (Dodrecht, The Netherlands, 1993)

38 USDA Web Soil Survey, 17763 Tree Crops Lane AOI, retrieved 2/10/17

39 Smith, J Russell. (1900-1964). [Correspondence & archival materials including experimental notes, nursery catalogs, & plant lists] J Russell Smith collection, 1874-1964, The American Philosophical Society Archives, American Philosophical Society, Philadelphia, PA. (These notes are largely unindexed, though there is a folio labelled Sunny Ridge that contains much of the relevant information.)

40 Smith, *op. cit* (note 5) 335.

41 Jacob Johnson et. al, 'Millwood honeylocust trees: Seedpod nutritive value and yield characteristics', *Agroforestry Systems*, 87/4 849–56 (2013).

42 Daniel Rigling & Simone Prospero, 'Cryphonectria parasitica, the causal agent of chestnut blight: invasion history, population biology and disease control. Molecular Plant Pathology', 19/1 (2017), 7-20

43 J. Russell Smith, *Tree Crops: A Permanent Agriculture* (Washington, D.C.: Island Press, 1987, Reprint of 1950 2nd ed.) 127-155

44 F.V. Hebard, S.F. Fitzsimmons, K.M. Gurney and T.M. Saielli, 'The Breeding Program Of The American Chestnut Foundation' *Acta Horticulturae*, 1019 (2014), 135-139.

45 Kim C. Steiner, Jared W. Westbrook, Frederick V. Hebard, Laura L. Georgi, William A. Powell, Sara F. Fitzsimmons, 'Rescue of American chestnut with extraspecific genes following its destruction by a naturalized pathogen.' *New Forests, 48* (2017), 317-336.

46 Smith, *The World's food resources*, op cit. (note 11) 564

47 W. L. Williamson, 'Mangum Terraces', *Southern Cultivator* 64/19 1906;; American Periodicals pg. 19

48 Smith, *Tree Crops: A Permanent Agriculture,* op. cit (note 9) Page 335.

49 USDA World Agricultural Outlook Board, World Agricultural Supply and Demand Estimates. Retrieved on 011/10/16 from https://www.ers.usda.gov/topics/crops/corn/background.aspx

50 Smith, *op. cit* (note 5) 252.

51 Michael Gold, 'Agroforestry systems for the temperate zone' *Agroforestry Systems* 5/2 (1987), 109-121.

52 *Index of Annual Reports 1910-1977*, Northern Nut Growers (Hamden, CT 1983

53 Aerial Imagery and parcel boundaries courtesy of Loudoun County, VA online GIS https://logis.loudoun.gov/weblogis/

54 Committee on Foreign Affairs, 'United States Foreign Policy for a Postwar Recovery Program' *US House of Representatives* (1948) 291-296

55 Benjamin Bradburn 'Evaluation of riparian forests established by the Conservation Reserve Enhancement Program (CREP) in Virginia." *Journal of Soil and Water Conservation* 65/2, (2010) 105-112.

List of Figures Chapter 2

References Chapter 3

Bendfeldt, E. S., C. M. Feldhake, and J. A. Burger. 2001. "Establishing Trees in an Appalachian Silvopasture: Response to Shelters, Grass Control, Mulch, and Fertilization." Agroforestry Systems 53(3): 291–95.

Dupraz, C., P. Burgess, and A. Gavaland. 2005. Synthesis of the Silvoarable Agroforestry For Europe Project. Montpellier: INRA-UMR System Editions.

Fannon, A. G. et al. 2017. "Hair Sheep Performance in a Mid-Stage Deciduous Appalachian Silvopasture." Agroforestry Systems: 1–13.

Ferguson, Rafter Sass, and Sarah Taylor Lovell. 2014. "Permaculture for Agroecology: Design, Movement, Practice, and Worldview. A Review." Agronomy for Sustainable Development 34(2): 251–74.

Fannon, A. G. et al 2017. "Livelihoods and Production Diversity on U.S. Permaculture Farms." Agroecology and Sustainable Food Systems 41(6): 588–613. https://doi.org/10.1080/21683565.2017.1320349.

Heckert, Jamie. 2014. "Planning for Abundance: Permaculture and Radical Transformation." Theory in Action 7(4): 97–106.http://www.transformativestudies.org/wp-content/uploads/10.3798tia.1937-0237.14030.pdf.

Hérault, Bruno. 2014. "Agroforestry in France: Benefits and Issues." Center for Studies and Strategic Foresight: 4.

Jezeer, Rosalien E., Pita A. Verweij, Maria J. Santos, and René G.A. Boot. 2017. "Shaded Coffee and Cocoa – Double Dividend for Biodiversity and Small-Scale Farmers." Ecological Economics 140: 136–45.

Johnson, Jacob W. et al. 2013. "Millwood Honeylocust Trees: Seedpod Nutritive Value and Yield Characteristics." Agroforestry Systems 87(4): 849–56.

Johnson, Jacob William et al. 2011. "Honeylocust and Black Walnut Tree Products within a Temperate Appalachian Silvopasture."

Jose, Shibu. 2009. "Agroforestry for Ecosystem Services and Environmental Benefits: An Overview." Agroforestry Systems 76(1): 1–10.

Munsell, John F. et al. 2017. "Relationships between Agroforestry and Community Development according to Practitioners." Agroforestry Systems (2004): 1–10.

Nair, P K R, Shibu Jose, Michael A Gold, and Harold E Garrett. 2012. 9 Agroforestry - The Future of Global Land Use Agroforestry - The Future of Global Land Use. http://link.springer.com/10.1007/978-94-007-4676-3%5Cnhttp://dx.doi.org/10.1007/978-94-007-4676-3_7.

Stanek, E. (2017). Multifunctional Perennial Cropping Systems. University of Illionois, Urbana-Champaign, IL.

Trozzo, Katie et al. 2013. "How to Plan for and Plant Multifunctional Riparian Buffers." Virginia Cooperative Extension ANR-69P.

Workman, Sarah W, Martha C Monroe, and Alan J Long. 2005. "Program Design for Agroforestry Extension in the South-Eastern USA." Small-scale Forest Economics, Management and Policy 4(2): 149–62. https://link.springer.com/content/pdf/10.1007%2Fs11842-005-0010-0.pdf.

Kern, John. 1996. "Kentland Farm, a New River Plantation". Journal of the Roanoke Valley Historical Society. 13, no. 2: 45-52.

List of Figures Chapter 3

List of Figures: Chapter 4

List of Figures: Chapter 5-7