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Sustained Change: Design Speculations on the Performance of Fallow-Scapes in Time along the Erie Canal National Heritage Corridor, (ECNHC), New York

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Abstract: The paper explores the potential for adaptive mitigation at the Montezuma Wildlife Refuge, Seneca Falls, NY, USA, and surrounds, focusing on landscapes along the historic Erie Canal that inadvertently lowered the water table and shrunk adjacent wetlands. Now the Erie Canal National Heritage Corridor (ECNHC), Montezuma, NY, USA, the canal, and surrounds lack a clear identity but have the potential to be repurposed as green infrastructure to support climate mitigation through the application of natural climate solutions, namely reforestation. Reforestation has been shown to produce the highest potential performance for carbon sequestration, along with a multitude of co-benefits. However, most studies assessing capacity for climate mitigation using nature-based approaches operate at a high level via remote data and do not test hypotheses at smaller scales that require groundtruthing data, parcel-by parcel approaches, and an understanding of landowner values. The initial research question is: can landscape architecture design research contribute to a higher performance of secondary forests and non-productive farmland (fallow lands) for carbon sequestration, while at the same time activating economic territories and improving their landscape qualities? Comparative cartographies are developed to assess secondary forests, including past and future projections. Fallow lands are examined through mapping at various scales, fieldwork, and informal interviews. We find that farmland along the canal has been abandoned over time due to conditions that make farming difficult, such as periodic flooding, ponding of water due to poorly drained soils, and steep drumlin slopes. These same conditions have contributed to a landscape armature—an assemblage of landscapes including the old canal, barge canal and associated heritage landscapes, abandoned farmlands, and existing forests and wetlands. Secondary forests already existing in the area are high performing in relation to carbon sequestration but may lack climate resilience due to threats such as the emerald ash borer (EAB). Design intervention can help support enhanced sequestration, resilience, and adaptation by introducing unique tree plantings in the form of groves and hedgerows. Sustainability is approached by integrating quantifiable performances of secondary forests with projections of spatial, ecological, and cultural values and the continuing monitoring and management of forests over time. The aim is to build a method to test these lands with designs for tree plantings that reveal their potential for increased carbon sequestration, habitat connectivity, and enriched landscape identity.

Keywords: research by design; fallow; carbon; sustainability; landscape armatures; climate mitigation; forests

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Citation: Goula, M.; Vanucchi, J. Sustained Change: Design Speculations on the Performance of Fallow-Scapes in Time along the Erie Canal National Heritage Corridor, (ECNHC), New York. *Sustainability* **2022**, *14*, 1675. https://doi.org/10.3390/su14031675

Academic Editor: Fabio Di Carlo

Received: 1 January 2022
Accepted: 23 January 2022
Published: 31 January 2022

1. Introduction

1.1. Motivations and Background

The disciplinary interest in the future of agriculture and rural landscapes is demonstrated in recent exhibitions, publications, exhibitions, and research [1–3]. At the same time, the resiliency of rural landscapes is threatened due to reduced agricultural productivity, the degradation of soil and water resources, health challenges, the vulnerability of communities, and changing climate regimes [4]. This global issue [5] makes rural lands an optimal testing ground for a critical revision of sustainability protocols to address what sustainability might mean in this context, and therefore expanding its semantics and interfering in its applied protocols.

Historically, the urban–rural relationship was built on flows of food and raw building materials from the countryside and into the city. Considering "natural" or "biological" solutions [6–10] to climate change, namely, reforestation [11–15], it might be assumed that the rural landscape is perfectly suited to offset the impacts of greenhouse gases generated by cities. Over the past several decades though, the rural has become increasingly urbanized, through uses such as industrialized farming and mining, solar and wind energy production, data storage facilities, and certainly residential and recreational sprawl. Due to the imperative for climate action, we will need to reconsider and radically expand rural performance to counter the unavoidable impacts of energy-demanding cities during the transition to less carbon-intensive modes of transportation and energy production, and to commit to the responsible use and regeneration of resources.

1.2. Abandonment of Rural Activity: An International Phenomenon

The abandonment of farming activity has multiple socioeconomic and physical causes. In this research, we focus on the causes of abandonment related to the physical conditions of a site that make farming difficult, some of which are already worsening with climate change, such as flooding, the ponding of rainwater on fields, hydric and poorly drained soils, and steep slopes. We use design research methods to explore scenarios for adaptive mitigation [16] and better performance of abandoned lands through "nature-based" approaches to climate mitigation. Abandonment is often proof of a medium's resistance to a practice, in this case, the production of commodity crops such as corn and soybeans. We focus on this "resistance" as an inherent quality of our study landscapes, linked to persistence and therefore, sustainability. Resistance is one of four aspects of resilience and is defined as "the ease or difficulty of changing the system"; the greater the force required to change, the greater the resistance [17]. Rather than altering the inherent physical conditions of lands to homogenize and force desired uses, this research aims to understand and exemplify the value of wetness to support biodiversity, adaptability, and responsible productivity, all considered part of the sustainable landscape.

1.3. Sustainability Framing and Critique

Sustainability as an operational frame encourages the responsible use of materials and resources, and efficient and ethical water, land, and waste management. Yet scholars have been critical about how sustainability contributes to meaningful planning and building protocols, and most importantly, how it integrates the qualitative aspects of places, landscapes, and designs in time [18–20]. Perhaps the question we need to ask in an era of uncertainty is how to reframe sustainability to integrate a dynamic understanding of landscapes and to introduce protocols and tools that deal with time, change, and uncertainty as structural components of the design process.

This issue introduces the notion of a global ecology, a set of relationships and interconnections made evident by human-induced climate change. Contributions of greenhouse gases from a handful of industrialized nations such as China, the US, India, and Russia have transformed the entire planet's atmosphere in a brief hundred years' time. Is the concept of sustainability still relevant in the new climate regime, in a world where uncertainty is the only constant? What are the possibilities for localized constructed natures to mitigate climate change, a global phenomenon, in territories defined by their resistance to typical human uses? How might designed tree plantings (constructed natures) enhance the performance of the rural by increasing the capacity of rural landscapes to sequester and store carbon? In what ways might the design, planting, and management of these forests intersect with socio-cultural systems in terms of landowner values, heritage-based tourism, and local economies, to become truly sustainable?

1.4. Design for Climate Mitigation

Conventional agricultural practices conflict with the increasingly urgent need to mitigate climate change. Adaptive mitigation includes practices that lower global CO_2 levels while producing regional benefits such as heat stress management, flood management, and enhanced agricultural resilience [16]. Landscape-based, or natural climate solutions, such as agroforestry practices, may provide effective CO_2 mitigation via changes in land use and management. In their 2017 paper, Griscom and coauthors outline the potential of twenty different "natural pathways" to climate mitigation [6]. The report found that reforestation, avoided forest conversion, and natural forest management have the highest mitigation potential (measured in CO_2/year). However, to encourage the understanding and effectiveness of these natural solutions, further study at scales appropriate to land management (the parcel, the ECNHC, Montezuma, NY, USA) over time periods of relevance (short-term financial gain, a generation's increase in economic assets, permanent carbon storage) is needed to understand the complex assemblages of natural and cultural conditions in real places, including physical conditions, ecological trajectories, and current and potential performance for CO_2 mitigation.

Adaptation to climate change in the northeastern US will involve a significant amount of land cover change, and will require changing crops and innovating farming modes. Since the 1970s, the state of New York has seen a steady increase in annual precipitation, and models predict that by 2040–2070, the "100 year" storm will occur every 50–60 years [21]. Summer heat stress, rain intensity, and an increased flood risk are cited as emerging challenges for NY farmers [22] and will test the resiliency of conventional farming. Additional pressures on NY farmland are likely to come from extended and record-breaking droughts elsewhere in the US, such as California's Central Valley, CA, USA.

A 2020 report titled New York Agriculture and Climate Change: Key Opportunities for Mitigation, Resilience, and Adaptation [12] quantifies the potential for fallow agricultural lands in New York state, USA, where 1.4 million acres (~566,560 hectares) are wooded and 1.7 million acres (~687,966 hectares) are "underutilized or former agricultural lands". The report ranks the proper management of woodlots and the reforesting of abandoned farmland among the highest priority strategies to mitigate greenhouse gases in NY, USA using the SMART framework. In order to achieve a high SMART ranking, a strategy must include co-services, be measurable, achievable, and realistic, and offer some degree of permanence. Afforestation includes co-benefits such as soil health, profitability, and biodiversity. The amount of carbon sequestered is measurable and verifiable, and if managed in 100-year timeframes could be considered "permanent" carbon storage as per the SMART framework.

1.5. Problem, Scope, and Aims

Abandoned farmland and secondary forests, what we refer to as fallow areas, largely define the heritage corridor, affecting its performance, experiential qualities, and recreational possibilities. The corridor's fallow landscapes are often inaccessible to the public and are considered unproductive, providing little in the way of economic value to owners. In the past decades there has been an increasing interest in addressing the potential of fallow landscapes in urban areas, but very few and truly diverse approaches conceptually and methodologically, in research or designed landscapes [23–27]. Because the fallow in our study area is constrained by wetness, these areas present an opportunity to shift uses to include performance for habitats, ecological connectivity, CO_2 mitigation, and corridor identity. The gap in the data and knowledge about the fallow, along with a substantial mismatch between available landcover data and specific and current parcel conditions, defines the scope of the research and suggests a mixed set of methods that first includes the development of original cartographies of the fallow across our study area through time, ground truthed through fieldwork.

We begin with the strategy of reforestation due to its promised performance discussed above, although we understand that there are productive synergies between planting and forest management. After over a century of installing drainage tile in the wetlands of the US to "improve" them for farming, this research aims to unveil opportunities for the better performance of forests and fallow lands by shifting the paradigm to reveal wetness as a valuable landscape attribute. In addition, the goal is to design and assess forests for carbon sequestration, integrate the heritage value of the canal and its surrounds, and add value to local economies affected by the decline of the canal within the ECNHC, Montezuma NY, USA. The ultimate goal of this research is to build a method to test fallow lands with designs for tree plantings that reveal their potential for increased carbon sequestration, habitat connectivity, and enriched landscape identity simultaneously. All the above are intrinsic parts of research by design and define an approach to improve the applicability of ideas crucial for climate mitigation and adaptation.

The specific research questions addressed during this first part of the ongoing research are:

1. Is the fallow, a term that emphasizes temporal management conditions, a better frame for the research on successional forests—a critical landscape?
2. How should time be considered in research related to sustainability, "permanence" of carbon storage, and the preservation of national heritage?

2. Materials and Methods

2.1. Study Site

This ongoing research showcases the first results of a combined set of methods that aimed to identify the causes, spatial implications, and developed materialities of the extended abandonment of agriculture along the ECNHC, Montezuma, NY, USA. We explored the potential for climate mitigation in the Montezuma Wildlife Refuge, Seneca Falls, NY, USA and surrounds, focusing on landscapes along the historic Erie Canal (1825–1840). The canal has always been a mechanism for landscape change—it inadvertently decreased the water table and shrunk nearby wetlands and it is directly implicated in both the rapid expansion and continuing decline of towns along its corridor. Activating the canal as a change agent again, this time as a national heritage corridor reconnected to its wet landscape and creek corridors, will help mitigate flooding on the local scale and climate on the global scale.

This paper reflects the first outcomes of a combined set of methods applied during the first two years of our study (October 2019–October 2021) and shaped by the idea that the analytical cannot be detached from the projective or speculative. Methods include:

- The identification, quantification, and study of the physical conditions that provoked the evolution of fallow lands through the growth of secondary forests, and to register and interpret their spatial orders, materials (associations of species and soil conditions), and performances;
- The assessment of the performance of both existing and designed forests in terms of their performance for carbon sequestration, potential corridor connectivity, conservation, revenue for landowners, and contribution to the qualities of the ECNHC, Montezuma, NY, USA;
- The testing of forest designs and speculation on their short- and long-term management, integrating aspects of landscape identity and value;
- The development of a toolkit with recommendations that might be applicable to other territories, when adapted to their specific conditions.

2.2. Defining Fallow-Scapes

Fallow has been treated as a background in landscape studies and rarely as a figure. Dating back to the 1520s, fallow meant "plowed land", then "plowed but not planted". Today, Merriam Webster defines the term to mean "usually cultivated land that is allowed to lie idle during the growing season". Recent theoretical and design work on the topic shows that the fallow has become of interest to designers. Gelt defines abandoned farmland as "a land in between", "neither wilderness nor cultivated, and often in need of restoration and recovery to some semblance of natural conditions, frequently through human intervention” [28]. Most lands left idle and without management in the northeastern US will return to forest, and this is the typical trajectory of lands within our study area. These “secondary forests” are defined as “forests regenerating largely through natural processes after significant human and/or natural disturbance of the original forest vegetation at a single point in time or over an extended period, displaying a major difference in forest structure and/or canopy species composition with respect to nearby primary forests or similar sites.” [29]. We found occasions of the reverse, where reforested lands were returned to cultivation, although this is far less typical. In some other cases, we found “sparse” conditions, a term we used to categorize patches of vegetation seen on aerial images that were neither fully forested nor farmed, but somewhere in between, and comprised of herbaceous plant material or patchy woody plants, where succession may have been stalled due to unknown factors.

Fallow’s ambiguity makes it a good frame to test design as management. Fallowscapes are “intermediate landscapes”, in-process natures as described by Desvigne [30], or by Gandy as “unintentional” [31]. The very nature of fallow is defined by the shifting dynamic between farm and forest. Fallow landscapes escape direct attention, but could be repurposed in the coming decades and put to work in mitigating climate change. What is often called abandoned, vacant, or even void derives from an approach that prioritizes a program, a heritage of dominant super-urbanism, with practices involving a superposition on a site, often considered a tabula rasa. Site-specific approaches have informed what Marot suggests is a sub-urbanism [32], where particular conditions of the site (in this case, qualities related to fallow) become a configuring condition for any transformation and enable richer and broader programmatic scenarios. Using the term fallow allows us to overcome the characterizations of these landscapes as unproductive, as official descriptions of abandonment and vacancy often imply, and instead suggests potentiality and changing states in time.

2.3. Fallow Time

Timescales of interest in our research range across climatic change (now accelerating) and associated glacial processes that define the geomorphology of our study region, to eras of shrinking and expanding agriculture, the time required to heal disturbed soils or return agricultural land to forest, or just a season of rest for soils depleted due to repeated cycles of productivity (Figure 1). The sequence and trajectory of change matters, as farming alters the potential of future forests and vice versa, by smoothing micro-topographies and simplifying surface conditions, compacting subsurface soils to form plow pans, altering nutrient cycles, and destroying the soil structure. The slow pace of forest regrowth after abandonment and the migration of tree species northward conflict with the fast pace of climate change and the urgency of climate mitigation, so increasing the rate of change of the fallow through design intervention is essential. Once reforested, fallow time slows to scales and durations reflecting degrees of permanence with respect to carbon storage in both biomass and soil.

2.4. Methods Overview

A key aspect of our research by design process included designing research methods via an iterative procedure that moved both forwards and backwards (Table 1). For example, a mapping exercise defines areas to visit, then fieldwork findings shift the mapping focus or scale. Design prompts transform sites and the questions that the design raises shift the fieldwork and site selection. We tested different methods across several sites nearby and along the canal, with the goal to define a research protocol and then test it on additional sites while adapting, diversifying, and enriching it. The research started with six different modules of methods evolving in parallel. The following methods have been most relevant for research findings so far: the creation of maps using multiple GIS overlays to identify marginal agricultural land (MAG) location and the main physical causes of abandonment of farming activity; a combined methods selection of sites to assess carbon performance and test ideas, fieldwork, multiple representations of the fallow, and design prompts.

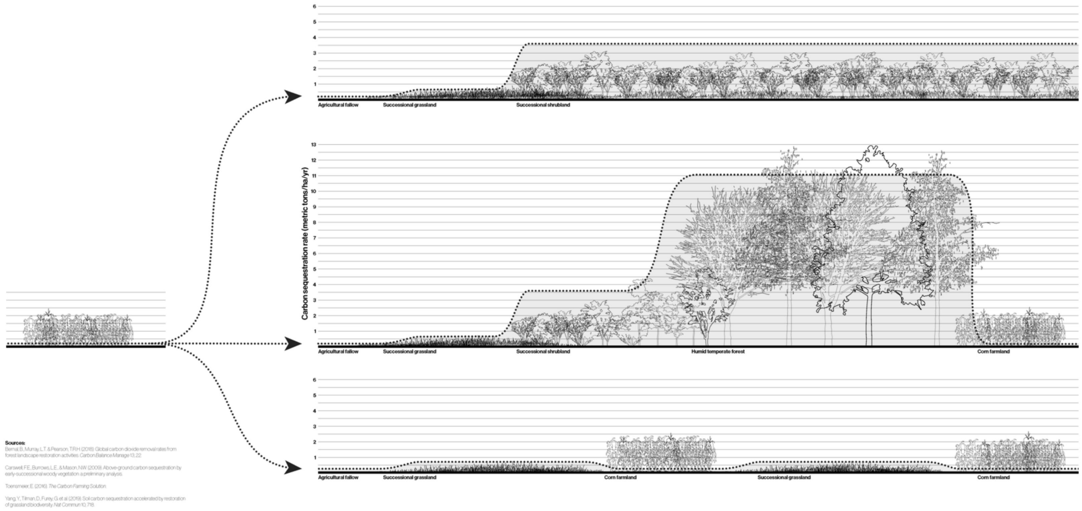

Figure 1. Possible fallow site trajectories after farming and the carbon sequestration potential (Goula, Vanucchi, Malacaman 2021).

Fallow is an extensive landscape (Figure 2). It occupies large portions of land in our study region, a fact that contributes to its criticality [33], but available and accurate data on fallow and abandoned farmland are notoriously difficult to find. One of our first research actions was to develop comparative cartographies to assess secondary forests and the conditions of fallow lands in time, including past and future projections. Our fallow lands map is the product of extensive data overlaying and fieldwork to confirm findings from aerial photographs of the state of New York, USA found in Cornell's digital collection [34]. Note that the photos were only available for years 1938, 1954, and 1963 in our study area. We also used Google Earth for more recent imagery. We layered historical aerials and recent satellite images to register the transition from crop or pasture to different types of secondary forest, to identify old forest (present in our oldest aerial photos dated 1938), and to locate hedgerows. We also traced inversed transitions, from forest to farm, although they are an exception. This examination in time unveiled landscape elements that became crucial in the classification, such as hedgerows, remnants of afforestation actions in the past, hybrids of old and young forest, forest edges, and forests on drumlin slopes.

In many ways, the lack of accessible data shaped our method. For example, the state's available data on land cover types were limited, and although currently being updated, were not available to us when we began this research. Another challenge was the predominance of private land along the ECNHC, Montezuma, NY, USA which made accessibility to contiguous patches of forest (including pre-1938 forests) difficult. We converted these challenges to an opportunity to explore various readings of the fallow as follows:

1. Prioritize "sparse" vegetation cover due to its assumed low performance for carbon sequestration; visit sparse study sites to verify site conditions, survey species, and to have informal discussions with property owners about management of the parcel and to assess their interest in participating in the carbon marketplace;
2. Select fallow patterns that include landscape elements of resistance (armatures formed by wetness including hydric soils, very poorly drained soils, flooding, and ponding, creek corridors, and steep drumlin slopes); contact landowners to request access to survey conditions;
3. Prioritize accessible lands (mostly public), including areas along both the barge canal and old canals, abandoned railways and trails, and assess the conditions.

Table 1. Methods Overview.

Category	Types	Reasons Used
Archival	Literature review on the ECNHC, Montezuma, NY, USA	To bridge segregated visions of the canal
	Archival cartography, including historical aerial imagery, historic wetlands, study on reforestation (pending) International research on agroforestry, design with afforestation practices, design with flood	To construct a comparative set of maps over time
Cartographies, sectional drawings and transects	Use GIS data to identify the location and main causes of abandonment of marginal agricultural lands (MAG)	To identify fallow locations, cayuses, and metrics
	Representation of expected forest communities in section	To prepare for fieldwork and to better understand the role of edges
	Create hybrid maps that identify the ECNHC's character, elements, and structures of value from conventional representations to eclectic, synthetic, hybrid, and innovative forms	To identify the character of the ECNHC, Cohoes, NY, USA to pursue original representations that address issues of value
Combined methods for site selection	Construct a matrix of significant wetness variables (in process)	To support site selection for fieldwork and fallow classification description
	Classification of the fallow focusing on the sparse in aerial imagery	To identify areas not already forested
	Emergence of the concept of armature as a guide to focus on the characteristics of the fallow in this particular landscape	To guide applicability strategies, with a focus on permanence as part of the heritage landscape
	Identify accessible public lands such as parks, waterfronts, schoolyards; flood-disturbed areas, EAB-affected forests, golf courses, industrial areas	To locate accessible sites for fieldwork and guide the future articulation of designed landscapes
Fieldwork	Confirm the fallow and its conditions in Montezuma, NY USA and Baldwinsville, NY, USA	To test the hypothesis
	Confirm the fallow and its conditions along the old canal trail; explore parcels with "sparse" conditions, identify species, and conduct informal discussions with landowners (22 parcels)	To continuously confirm the hypothesis, perform ground truth mapping, and make decisions for sites to test with design prompts
	Conduct field visits of 18 additional parcels with diverse site conditions	
	50′ by 50′ tree plot studies—identify the species, condition, and diameter of all trees within 50′ by 50′ plots (11 plots); quantify carbon sequestration rates and storage using i-Tree tools	To gather the data from tree species specific to forest patches and parcels and compare performance
Pilot designs	Iterations on the heritage elements of the Montezuma, NY, USA forest landscape and local plant community archetypes	To test basic planting pattern ideas into specific site conditions, prioritizing selected armatures, local plant community archetypes, and heritage vegetal elements
	Research on historic forest assemblages	
	Iterations along the canal	
	Iterations on sites identified in the workshops	
Stakeholder interactions	Informal contacts with historians (uneven response)	To understand stakeholder perspectives, confirm transition to fallow, and facilitate conversations regarding design outcomes
	Workshops with landowners and farmers (spring 2022)	
	Conversations and informal interviews with experts	

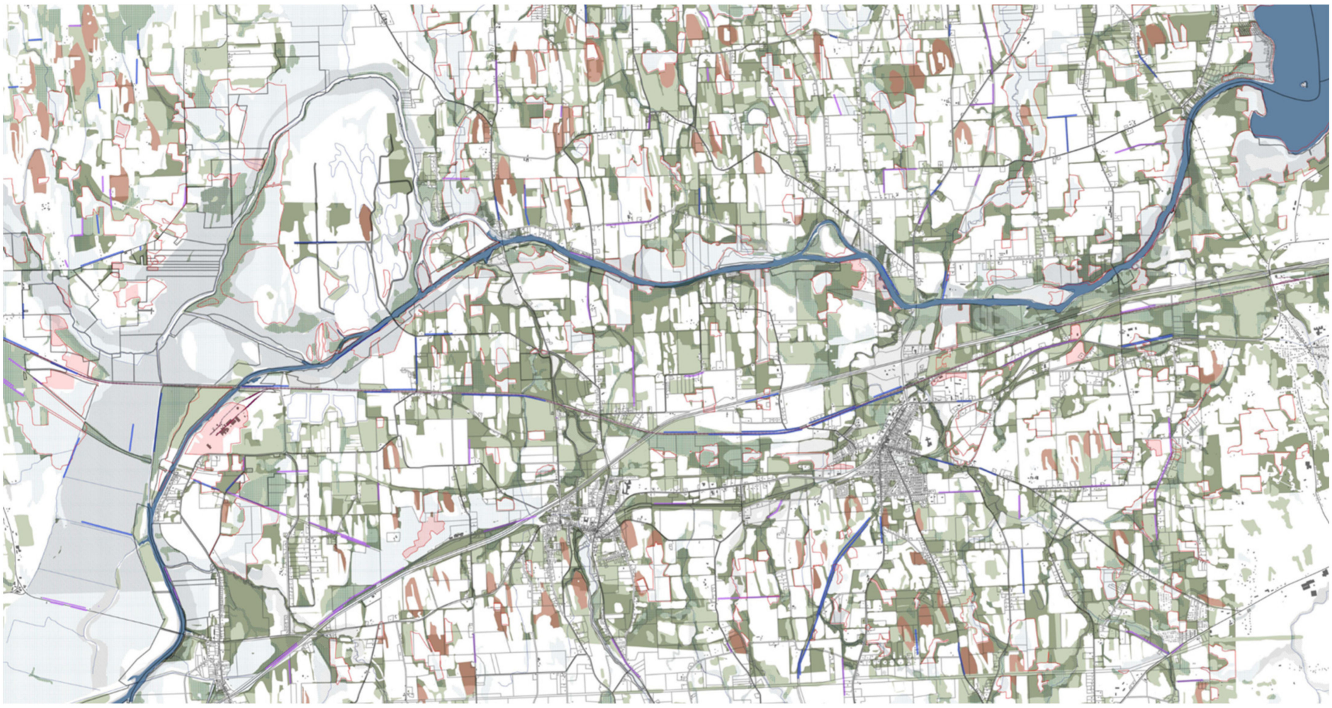

Figure 2. Comparative cartographies trace the deforestation and reforestation patterns over time and provide a critical (and until now missing) base map for fallow lands in the study area. Map legend: (**Pink**) = Deforested 1938–2018; (**Red outline**) = Old forest (reforested before 1938); (**Lt blue**) = flooding; (**Blue hatch**) = Ponding; (**Light green**) = Reforested 1938–1963; (**Dark green**) = Reforested 1963–2018; (**Dark pink**) = Sparse vegetation; (**Blue line**) = Hedgerow expansion; (**Purple line**) = Hedgerow disappeared (Goula, Vanucchi, Zhang 2021).

While the first approach granted us the ability to operate at the level of the parcel and to address the lowest performing areas, the other two methods allowed us to work with a combined set of approaches in different conditions of fallow that were contiguous and interdependent, thus staging the space–time conditions of the fallow. All methods continuously tested how fallow-scapes fitted in and defined the visual and material conditions of the ECNHC, Montezuma, NY, USA. This combination of public and private lands and stakeholders implies the potential of a collective project, with stakeholders being offered to be part of a shared story of decarbonization, biodiversity, and regional heritage, exploring notions of a contemporary rural commons.

2.5. Fieldwork

The Montezuma site is a secondary forest area. There are no maps that provide this depiction; therefore, the research focused on the sparse parcel reconnaissance and forest sampling of $50' \times 50'$ plots within key square mile frames. For each plot, we recorded the location (identified on a satellite map and via GPS coordinates), species, the circumference at breast height, the condition (excellent, good, fair, or poor), and sun exposure of each tree within the frame. For sparse parcels, we prioritized those that were contiguous. Field visits to 22 parcels identified as sparse gave us the opportunity to talk with 11 of 22 landowners about the conditions of their lots, management decisions and values, and whether they would be interested in participating in a reforestation strategy that might provide a small income via the carbon marketplace. To calculate carbon sequestration and storage within each forest plot, we used i-Tree tools developed by the United States Forest Service (USFS), Washington, DC, USA and all the data collected in fieldwork and mentioned above.

2.6. Design Tests

While the ongoing workshops will open the opportunity to any landowner who would like to be a part of the research by design process, (including an assessment of their forest's performance, design iterations for reforestation, and/or sustainable management of existing forests), the extension of the fallow forests in the area demanded a method to approach its most significant aspects with regards to research goals. We follow a general set of rules for design tests. Spatial arrangements are simple for efficiency and are used to question and reflect on design thinking, variables that should be prioritized, and the method itself. Performances for each test are calculated using the same USFS tools.

So far, our design tests include three types of species. The first is a "heritage" tree that is long-lived, large, and continues to sequester carbon at high rates even when mature. These trees include *Pinus strobus* (an important tree for indigenous people in the region) and *Juglans nigra*, and provide long-term carbon storage. The second type has a rapidly growing rate of sequestration but may be relatively short-lived and/or quick to peak in its capacity to convert carbon to biomass. Within this type there are (1) species that peak at around the same age they become profitable for timber harvest (saw logs rather than pulp), such as *Acer rubrum*; (2) species such as *Populus deltoides,* not considered a timber tree but with high rates of sequestration useful for "carbon farming"; (3) species such as *Betula* spp. valuable as timber or veneer species. Trees in the second and third categories must have some value as a product where carbon remains stored. As we proceed with the research, we will test harvest regimes and their impact on overall carbon sequestration rates in time.

3. Results

3.1. Principal Results

One of the major results of this work so far is the identification of fallow-scapes through mapping in time and verification through fieldwork, and the quantification of the performance of successional forests for carbon sequestration and storage. Fallow mapping and the construction of a matrix to systematically categorize the fallow revealed that hydrology and soils combine in diverse situations with different degrees of wetness. Fallow mapping and ground truthing through fieldwork revealed a mismatch between GIS land cover data and the actual conditions at the parcel scale.

A parcel-by-parcel approach would be enormously time consuming and unapproachable within the timeframe of this research. Although we plan to eventually consider the transformation of individual parcels, working with landowners, a key contribution of the research was the identification and prioritization of those fallow land characteristics that allow for the easiest and least costly application of "nature-based" mitigation strategies and to define strategies for fallow transformation through new plantings and harvest/management regimes with the highest performance for carbon sequestration and storage, along with ecological and habitat connectivity, and biodiversity. All strategies proposed also seek to strengthen the heritage and now somewhat eroded identity of the ECNHC, Montezuma, NY, USA through the creation of a pilot landscape definition of the ECNHC, Montezuma, NY, USA.

3.2. What Is Fallow Made Of?

Fallow landscapes in our study region ranged from farm fields with meadow cover (grasses, forbs) to more established goldenrod meadows or wet-adapted vegetation such as *Typhus* spp. or the invasive *Phragmites australis.* Sometimes on "sparse" sites, we found stalled succession due to invasive shrub cover consisting of species such as *Rhamnus cathartica* or *Rosa multiflora*. Often, we found forests in varying stages of succession (Figure 3). Tree species encountered through fieldwork in the forested parcels include *Robinia pseudoacacia*, *Fraxinus* spp., *Juglans nigra*, *Acer rubrum*, *Populus deltoides*, *Acer negundo*, and *Carya ovata*. Average tree diameter on per plot ranged from 3.4 inches to 11.3 inches. The number of trees per 2500 ft^2 plot ranged from 6 to 50. In both tree plot research and general site reconnaissance, we were surprised at the abundance of *Fraxinus* spp. and the degree to which the emerald ash borer (EAB) was decimating ash trees in the region. In some tree plots, 92% of the species were *Fraxinus* spp. Most ash trees in our study plots were already showing signs of blonding, a telltale sign of EAB infestation and damage. Researchers expect a total loss of ash trees in the near future, meaning that large swathes of forest in the area will lose a good portion of their carbon sequestration capacity, and the carbon stored will likely be lost due to wood decay. We see this loss as a potential opportunity to guide future forests toward increased carbon sequestration capacity, biodiversity through assisted migration, and greater resilience to climate change.

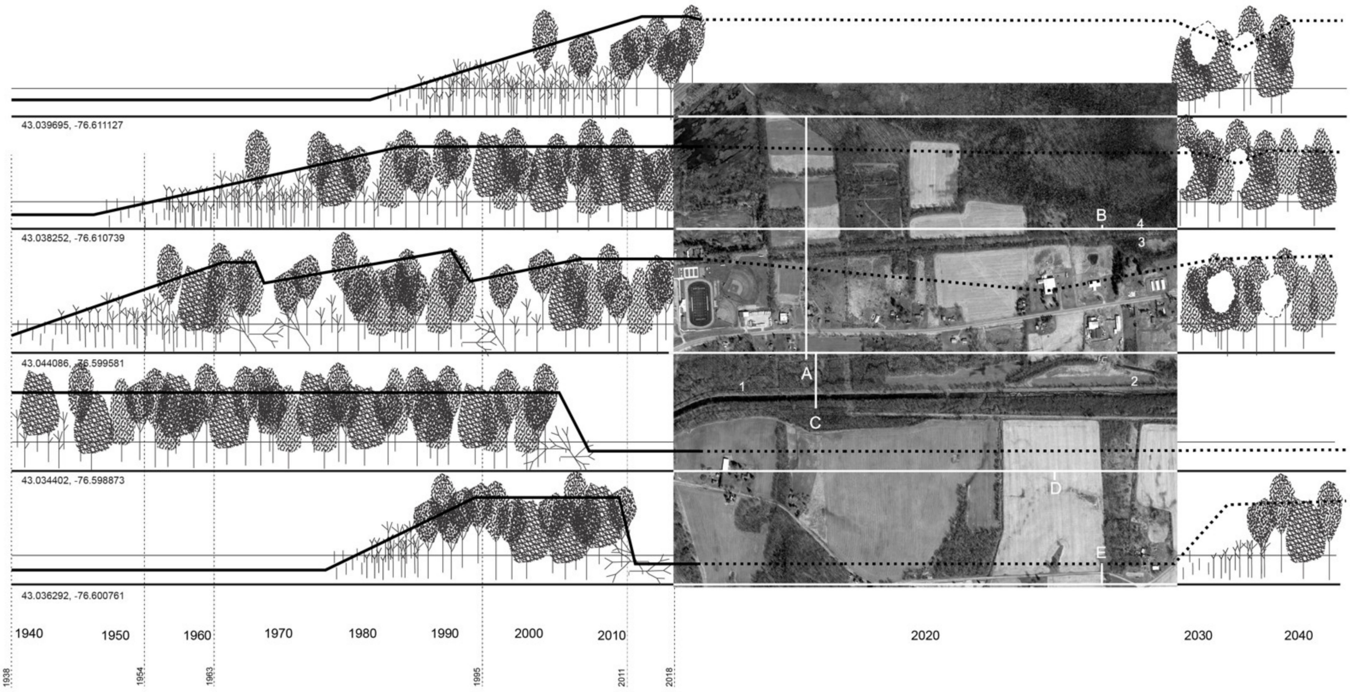

Figure 3. Due to changing conditions and histories across the study area, fallow sites follow distinct trajectories of development. For example, a forest plot M6-Plot 1 near Section (A) was reforested between 1938 and 1963 and contains 25 trees, with 4 species represented: *Fraxinus americana*, *Populus deltoides*, *Rhus typhina*, and *Acer negundo*, with an average dba of 5 inches. This patch of secondary forest sequesters 1094 lbs of carbon per year, but more that 50% is captured by existing ash trees and can be expected to be lost in the coming year or two. Forest plot Mg-Plot 4, near Section (B) was reforested in 1963 and contains a higher density of trees (40) with an average dba of 4 inches. The site contains *Betula* spp., *Fraxinus* spp., and one *Acer rubrum* and *Quercus* spp. each. A total of 85% of the existing trees are Fraxinus. The annual sequestration rate is 1720 lbs, with 73% of that amount contributed by ash. Sections (C–E) depict other trajectories of change from farm to fallow and forest. (Goula, Vanucchi, Dehm 2021).

Secondary forests are already performing in many ways, yet their performance for habitat, climate mitigation, etc., is practically unknown, since so much of the focus is on mature and old growth forests. The lack of representations makes their characteristics and capacities practically invisible. A surprising finding from our tree plot studies was the high performance of successional forests for carbon sequestration. While older forests far outperform these forests for carbon storage, the active annual sequestration rate for young forests in our study area was quite high compared to old forest sites in the Finger Lakes region. This is likely due to two primary factors: (1) according to the USFS tool, as species age their sequestration rate typically peaks and then declines; (2) successional forests tend to have a much higher density of trees. It is important to note that we have so far only measured above-ground carbon stored in plant biomass such as trunks and branches. Soil carbon stores are a very significant pool [15] and are likely to be much lower in younger and disturbed forests [35]. Our focus is on sequestration because climate mitigation requires that we actively pull carbon from the atmosphere, and the capacity to do this makes secondary forests a significant actor in climate change mitigation.

3.3. Armatures

Early on in the research we understood the potential for better landscape performance of continuities in the landscape that we called armatures. The same conditions that cause the fallow contribute to a landscape armature—an assemblage of landscapes including the old canal, barge canal, and associated heritage landscapes, abandoned farmlands, and existing forests and wetlands. This landscape armature (Figure 4) is durable [36], resists development, and provides a structural framework for landscape design that supports place identity, increases multiple performances, and anticipates and directs future change. The armature could be particularly important as a carbon sink landscape because of its ability to resist development and to persist. Longevity in the midst of change is a key characteristic related to sustainability, heritage, and indeed, carbon storage, where permanence is desirable and means carbon is held for 100 [12] or even 1000 years [37].

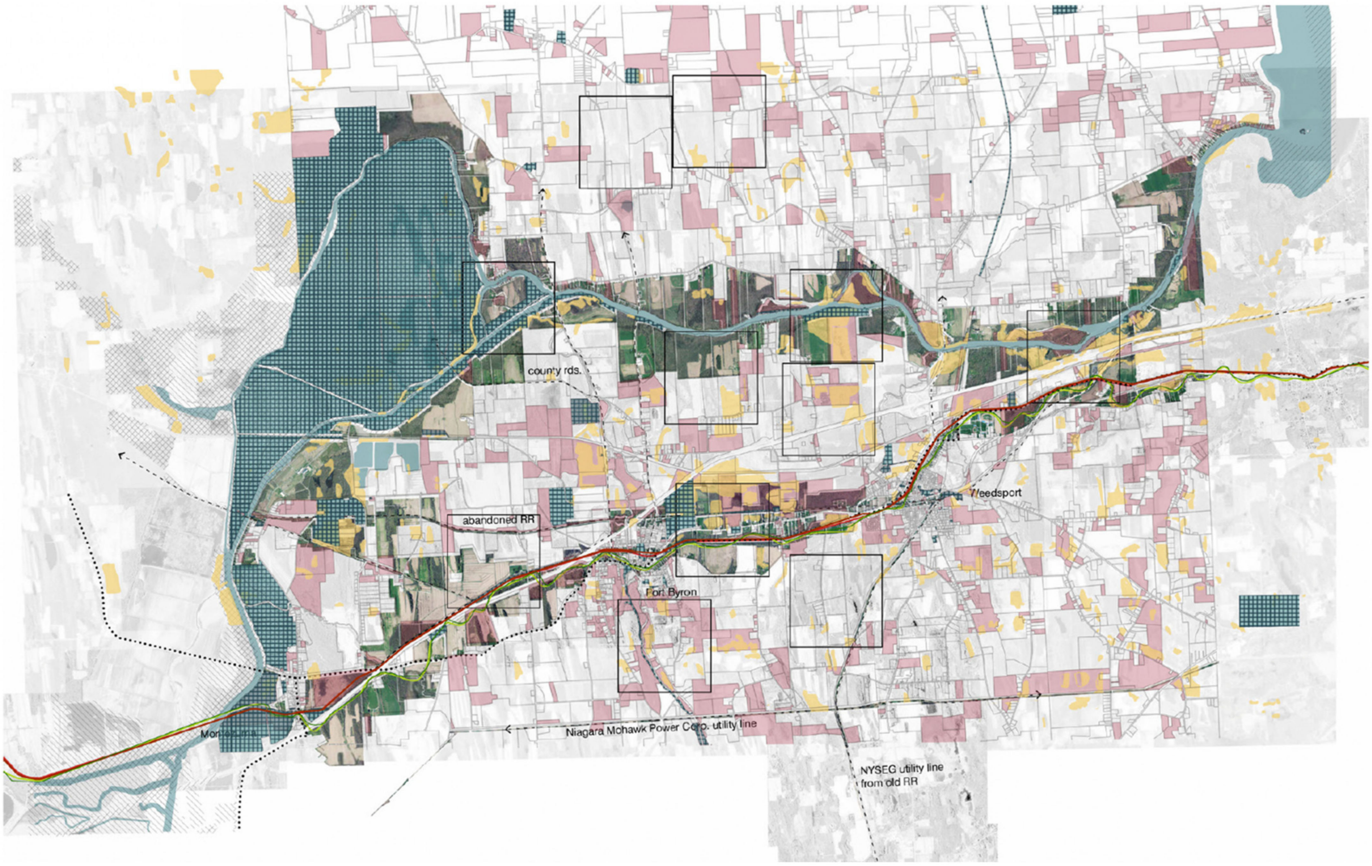

Figure 4. Landscape armatures operate at several scales simultaneously. Here we defined a landscape armature of fallow lands and "wetness" along the old Canal and Barge Canal. The armature provides a land-based structure for corridor identity and future development (Goula, Vanucchi, Chan 2021).

3.4. Results of Design Tests

3.4.1. Design on Public Land, along the Old Canal and Its Trail, and Armature Related to Wetness, History, and Recreation

Design iterations at the old canal site in the village of Jordan, NY, USA (Figures 5 and 6) is on publicly owned land, now underutilized lawn, and is a basic response to spaces with a low existing performance of both carbon sequestration and biodiversity and habitat provision, although they may have valuable recreational functions. These spaces could be used as forested areas that would introduce users to the old canal and tow path. The species chosen for this first iteration are for long-term sequestration, using long-lived trees that would not be harvested for timber.

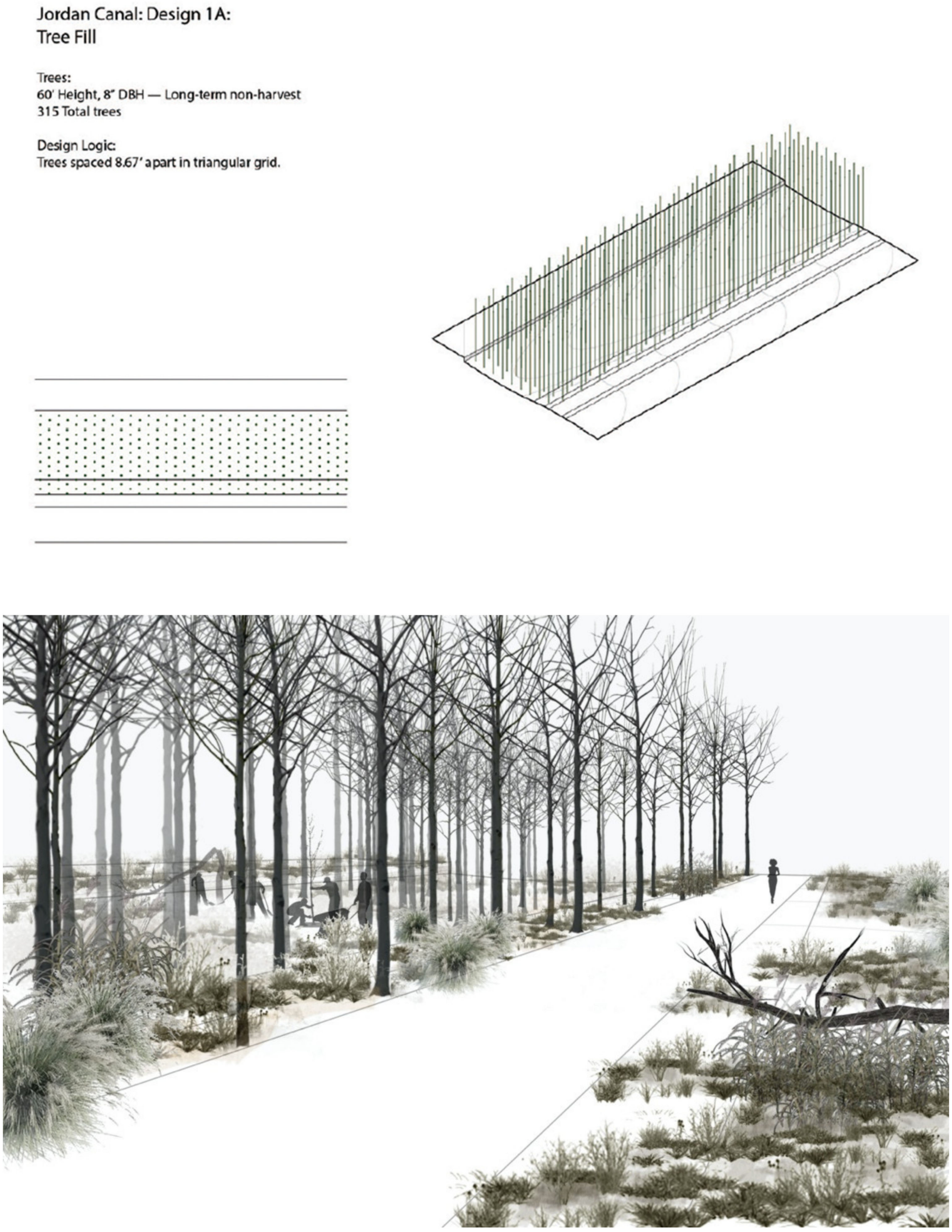

Figure 5. As the render shows, strategic clearings and management allow the forest to grow to a less dense area of permanent forest. Carbon storage performance shifts from above ground biomass to soil stores in the long-term. A second iteration introduces a medium-term harvested species such as *Prunus serotina* for its high-quality timber (especially after 90 years), flowers, and experiential affordances, and as a native species that is a signifier of the Erie Canal corridor (Goula, Vanucchi, Malacaman, Chang 2021).

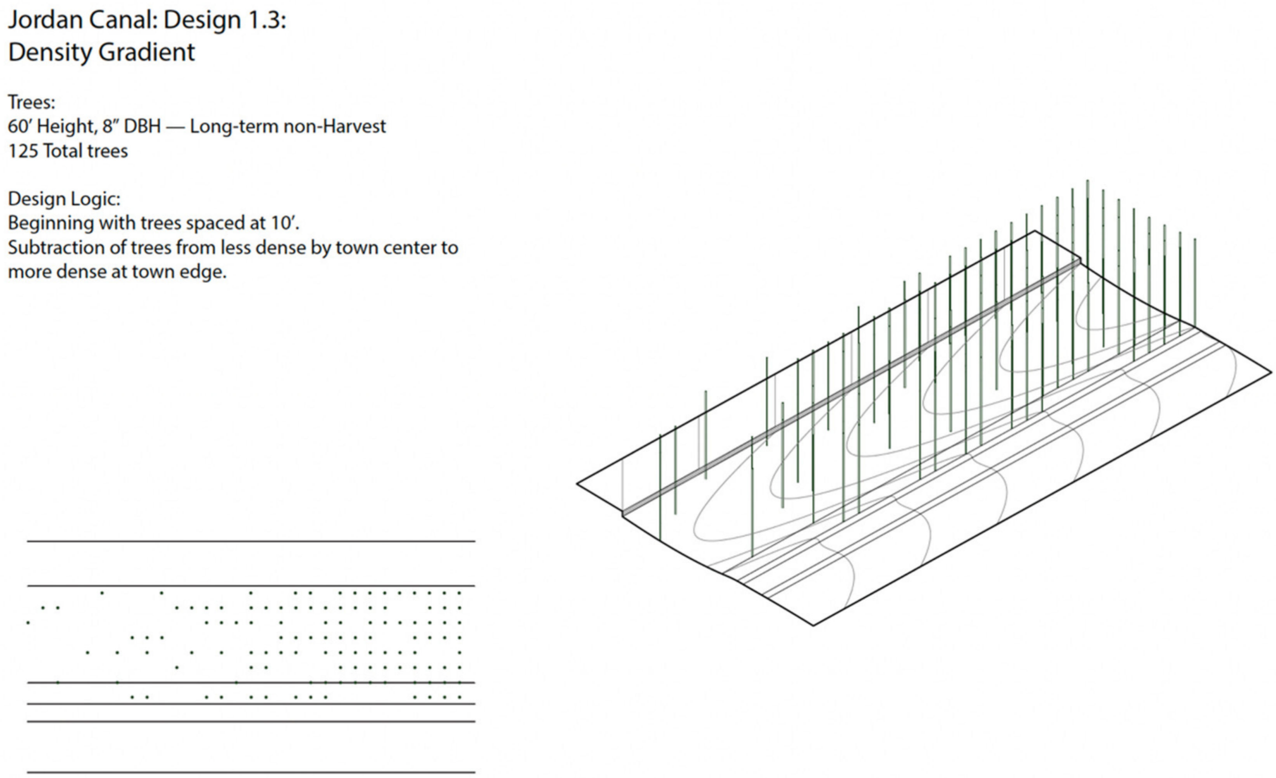

Figure 6. This iteration creates a less uniform space, starting with trees spaced at 10′ on center and subtracting trees with less dense plantings toward the town edge. With only 125 trees, the sequestration performance is lower, but the subtraction patterns define areas for recreational uses for the community (Goula, Vanucchi, Malacaman 2021).

3.4.2. Design of the Canal Basin Itself

The next iterations focus on the canal basin itself (Figures 7 and 8). The water level fluctuation in the old canal depends on the section of the canal, the flow coming from the creeks to the south, and the number of active dams along them. In sections where water levels are typically low and navigation is no longer possible, planting inside the canal basin would make a statement about the future use of the canal as an infrastructure for climate mitigation.

3.4.3. Design of Elevated Lawn Interruptions of the Old Canal

Lawn interruptions to the canal present interesting moments where path users can walk perpendicularly to the canal. If both the canal and the lawn "bridge" are planted, these moments become interesting experientially as two plantings intersect (Figures 9 and 10).

3.4.4. A Test on a Floodable Public Waterfront in the Village of Clyde

The existing waterfront in the Village of Clyde, Clyde, New York, USA is an underutilized and undefined space where flash flooding occurs after heavy rains. Groves and treelines help to establish areas of use, views, shaded paths and loops, and access to the canal (Figure 11). Selecting tree species adapted to flooding is key to a resilient waterfront tied to the canal and its wet landscape.

3.4.5. Incremental Tests of "Working Edges"

Working at the edge of existing forests (Figures 12 and 13) may be more palatable for landowners hesitant to devote large areas of their property to reforestation. Edges are often significant habitats. We also consider short-term harvest rotations for these plantings to maintain their dynamism as habitats and because they are easily accessed with equipment.

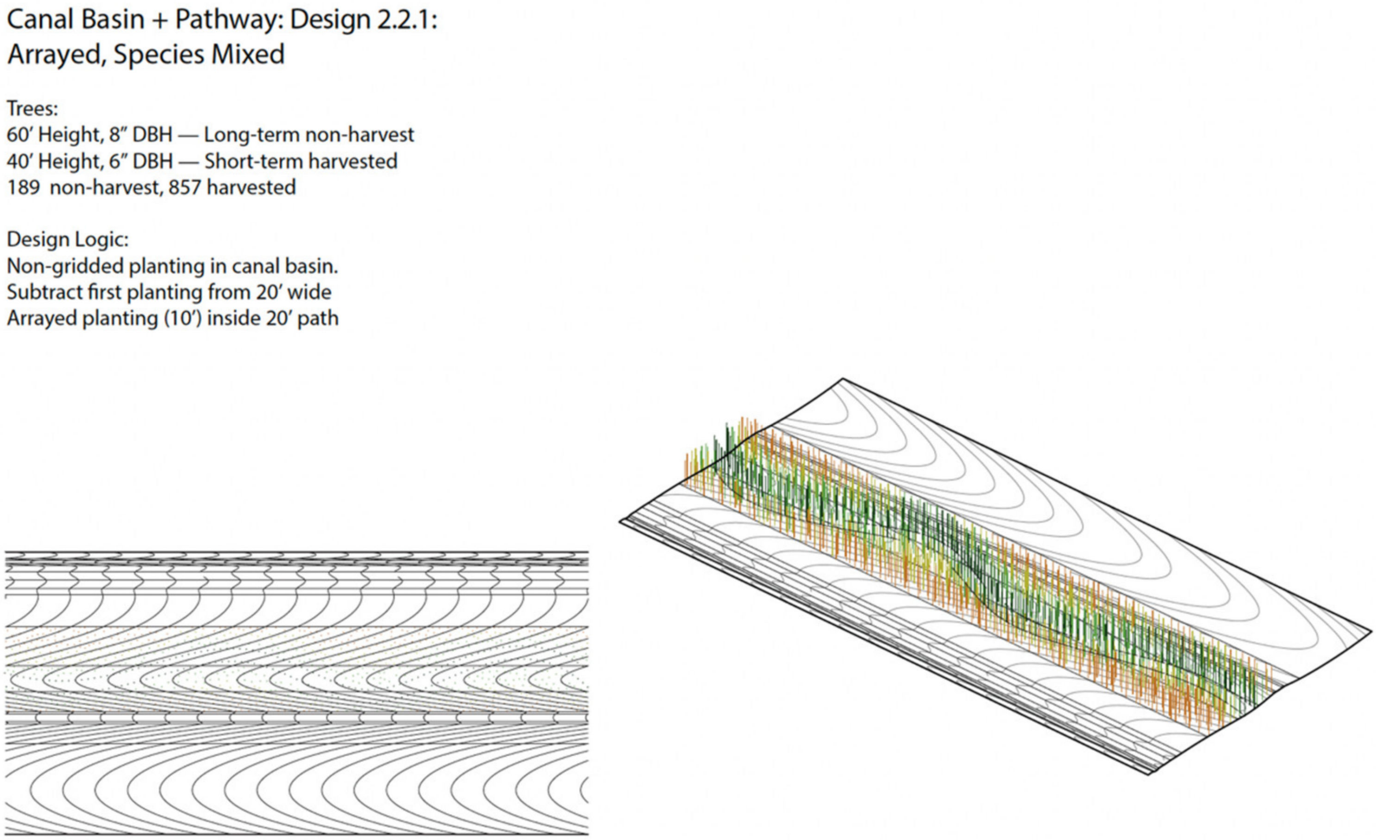

Figure 7. Within the canal basin, a double line of 189 Platanus occidentalis trace a curvilinear path that moves from the lowest part of the canal to its sides and vice versa, accompanied by lines of *Acer rubrum* and *Prunus serotina*. Since the Sycamore will be left in place for their lifespan, the red maples are used to transition as they are more shade tolerant. Multiple grids are applied with different densities, using a mix of species to gain biodiversity. This design was also tested in rectilinear plots and could be applied on waterfronts (Goula, Vanucchi, Malacaman 2021).

3.4.6. Connectivity Corridor

Following the armature of wetness along the canals and major creeks and the fallow growth within the adjacent parcels, a corridor of connectivity emerges (Figure 14). Contiguous parcels have higher potential to be marketed on the carbon marketplace as wildlife corridors, riparian buffers, and trail systems over a single parcel. In addition, carbon marketplace buyers should be attracted to the opportunity to contribute to building the larger story of the ECNHC, Montezuma, NY, USA that provides multiple functions, including public access.

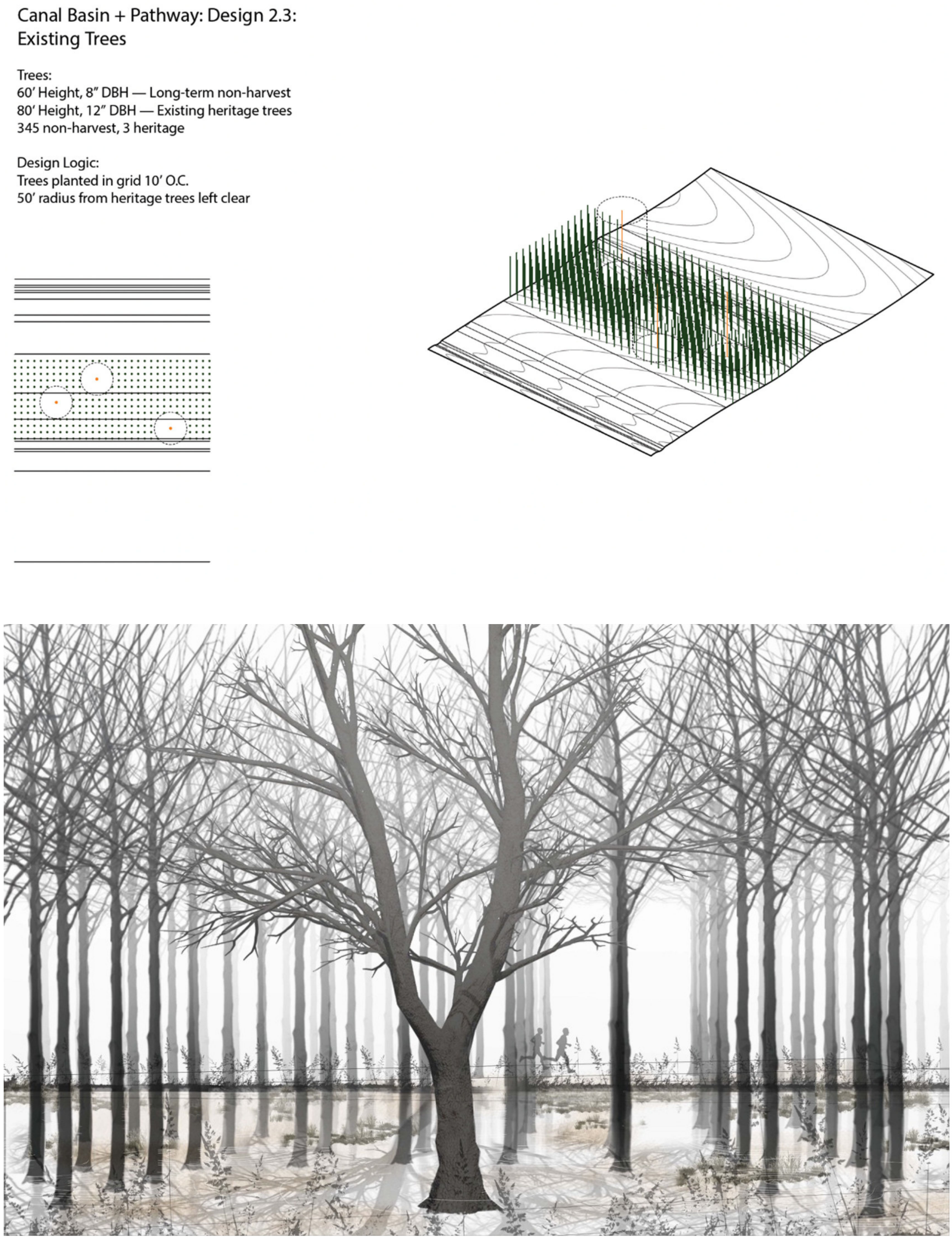

Figure 8. This design test is meant for an area of the canal where young *Fraxinus* spp. dominate. Ash trees are removed to avoid the EAB decay (and loss of viable wood products and carbon), leaving behind several large non-Ash "wolf" trees (*Populus deltoides* and *Platanus occidentalis* are typical). These heritage trees are preserved and respected with a 50-foot radius buffer, while the rest of the site is filled with a grid of 345 non-harvest trees (due to difficult access down steep slopes at this site). Circle clearings become places to picnic and are welcome surprises in the experience of the dense forest. In areas without existing large trees, they can become part of the planting scheme, and short-term harvestable species could be used for the grid in easily accessed sites (Goula, Vanucchi, Malacaman, Chang 2021).

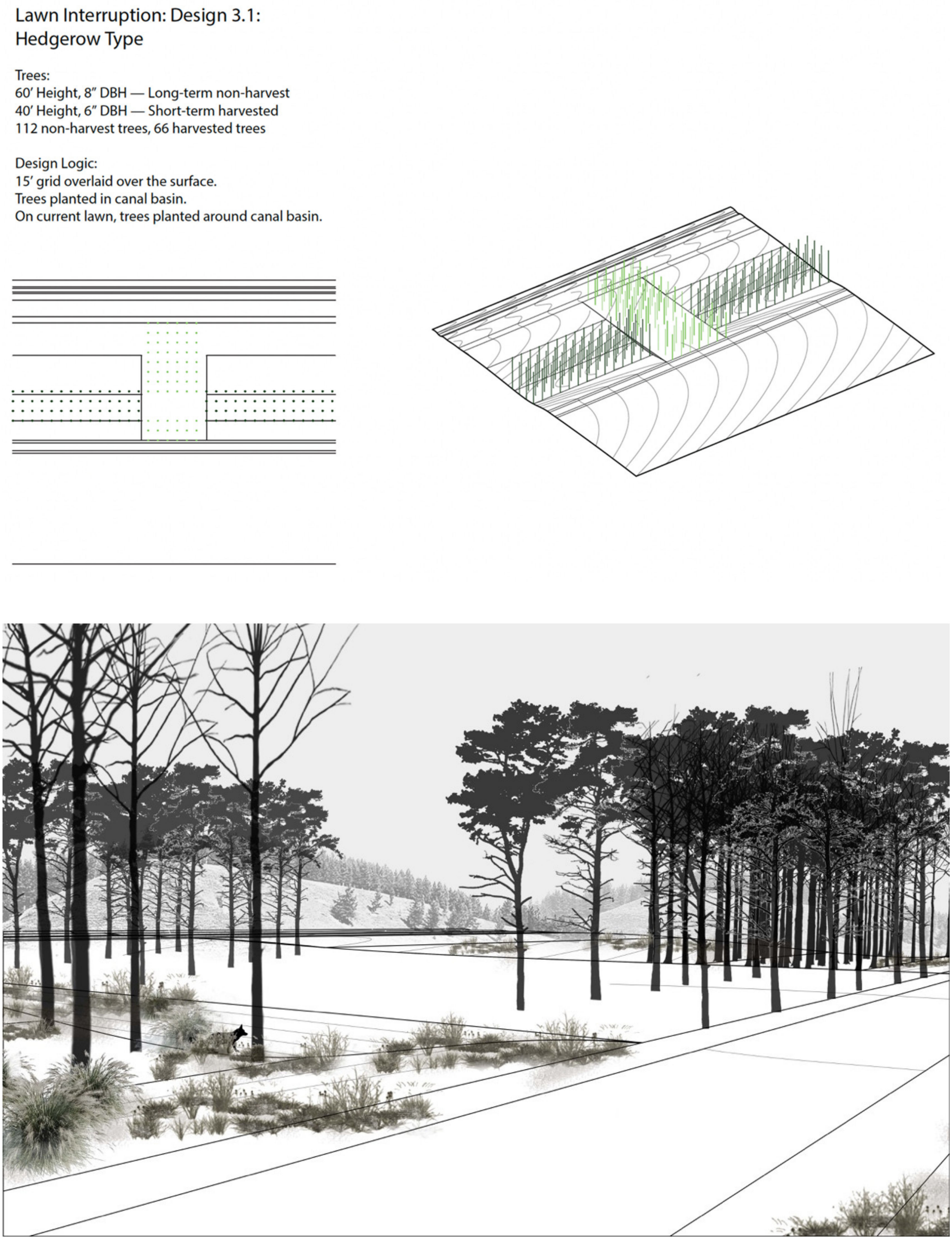

Figure 9. This iteration uses two species—112 non-harvested and 66 *Pinus strobus* or *Pinus sylvestris*, and introduces the effect of deciduous trees with evergreen coniferous species. A drumlin can be seen in the background (Goula, Vanucchi, Malacaman, Chang 2021).

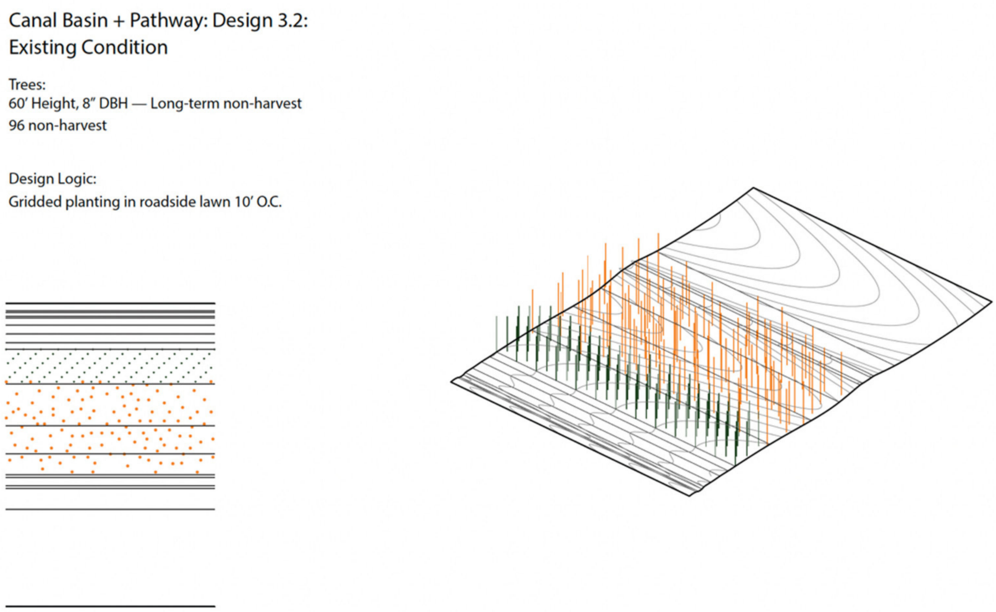

Figure 10. Another iteration focuses on perception from the highway, using a simply gridded grove on a currently underutilized mown area to engage with the perspective of drivers along the road. A total of 96 non-harvested trees in this section contrast with the existing secondary forests in the background and introduce an order and transparency to this space (Goula, Vanucchi, Malacaman 2021).

Figure 11. Heritage species such as *Platanus occidentalis* line the canal's edge, while grids of short harvested groves of *Populus*, etc., combined with understory trees such as *Carpinus caroliniana* showcase ways to create new floodable waterfront spaces for decaying towns along the canal, who are searching for opportunities for business related to eco-tourism, while revealing the multiplicity of waterways still present; beyond the Barge canal, the first canal is converted to a wet, forested trail (Goula, Vanucchi, Llop, Chang 2021).

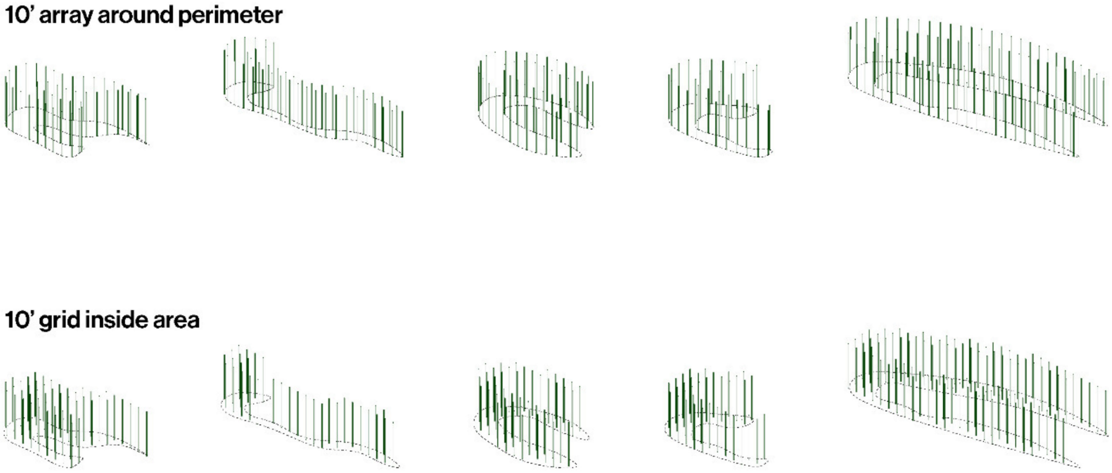

Figure 12. Plantings to emphasize drumlin forms, a common geomorphology in the region (Goula, Vanucchi, Chang 2021).

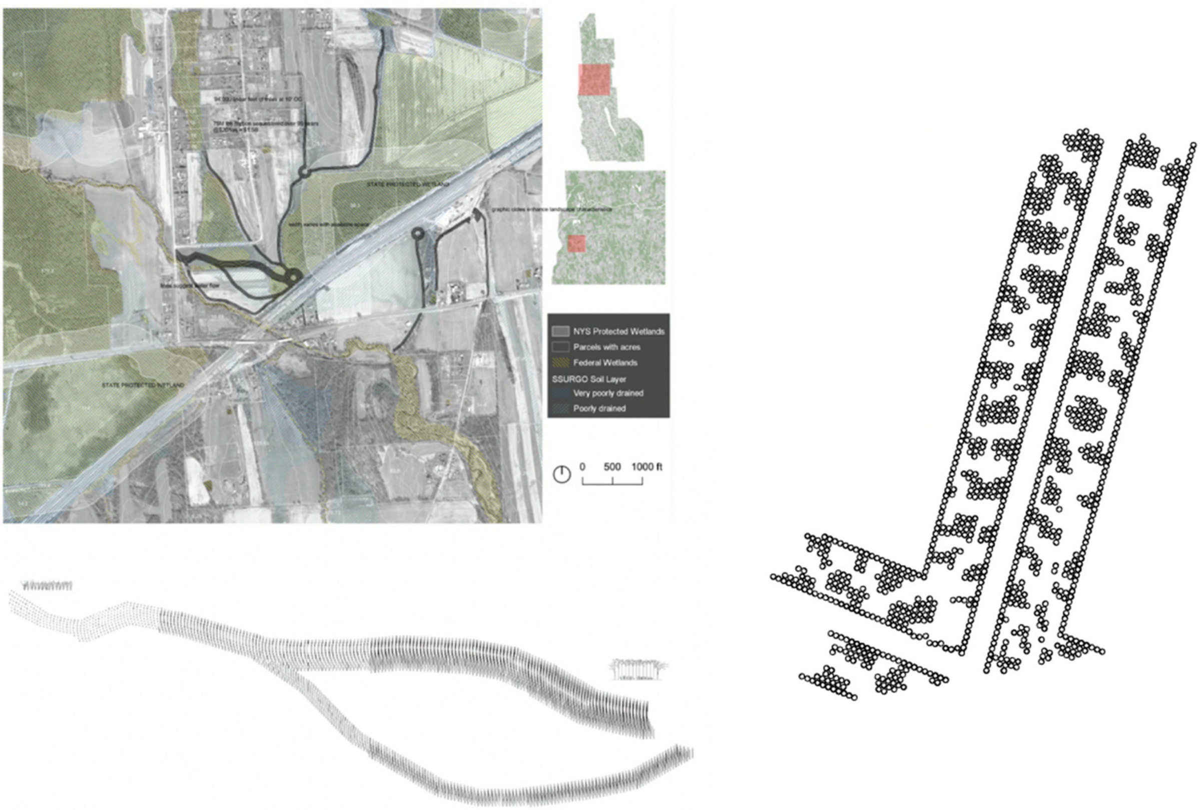

Figure 13. Several options for edge plantings are explored, including adding lines of trees at the edge of existing forest or within the creek and wetland buffers. Lines of trees are also used to create views and could consist of trees harvested on short cycles (Goula, Vanucchi, Dehm 2021).

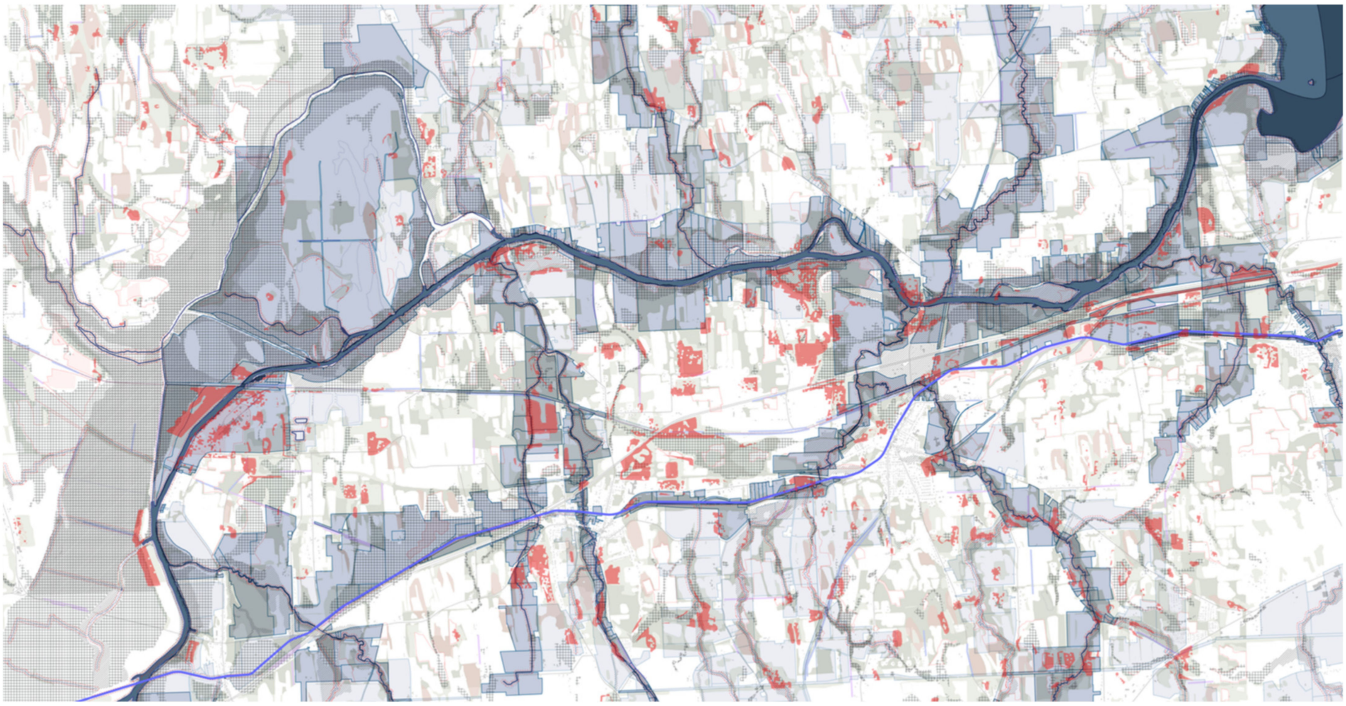

Figure 14. The connectivity corridor drawing becomes a tool for next steps, to select key parcels for forest design tests as preparation for interaction in the coming workshops (Goula, Vanucchi, Chang 2021).

4. Discussion

Outlined in this paper are a series of design research approaches to the reforesting of abandoned farmland to repurpose the ECNHC, Montezuma, NY, USA for climate mitigation and adaptation. We have used nature-based approaches, namely reforestation, since numerous studies have highlighted the high capacity of trees to sequester and store carbon. Research at the scales of the parcel and along a segment of the canal corridor was necessary to test whether the high-level hypotheses regarding the potential of fallow for climate mitigation were currently lacking but needed to confront issues of mismatch between the remote data and actual ground conditions, lack of data, and landowner values. Below are some of our primary findings to date.

4.1. The Fallow Is a Significant Landscape Type for Carbon Sequestration

Fallow-scapes are the exemplification of time landscapes, and are closely linked to specific site conditions. By studying the fallow, we also aimed to adapt our understanding of landscape values from a static perspective and singular permanent values to ones that are transitory and systemic. Fallow landscapes are significant landscapes for the adaptive mitigation of climate change. We are aware of the potential conflict between reforestation and food security, especially as long-term droughts and aquifer depletion restrict food production in other important farming areas in the US. Choosing fallow lands where hydrological (hydric soils, flooding, ponding) and physical conditions (steep slopes) create resistance to conventional farming practices allowed us to avoid the most sought-after farmland. The fieldwork confirmed that the existing secondary forests were high performing in relation to carbon sequestration, although for some fallow lands, their succession to forest had stalled due to cover by invasive shrubs. In some areas, performance for carbon sequestration is at risk of decline due to the dominance of *Fraxinus* spp., currently dying in large numbers due to the EAB. Design intervention using reforestation strategies can play a significant role to address these issues. Planting masses of trees in these areas and in wetland and creek buffers creates a dynamic forest matrix, while identifying a new landscape-based identity for the ECNHC, Montezuma, NY, USA.

4.2. Constructed Ecologies, in This Case, Designed Tree Plantings and Their Management in Time, Highlight the Significant Role That Projective Design Research Can Play to Test Interventions in a New Climate Regime

The design iterations of forests on fallow lands aimed to embrace their potential for climate mitigation, benefits to local landowners, contribution to the heritage and identity of the ECNHC, Montezuma, NY, USA, and experiences for visitors including locals and tourists. This mingling of the ecological, economic, and socio-cultural is what sustainability aims to do. Thinking in longer time scales is necessary when working with forests, and this research works across scales associated with heritage, sustainability, carbon storage permanence, and the migration of species northward. Naturally, when projecting across longer periods of time, uncertainty grows. The design research methods allowed for experimentation with uncertainty via the projection of scenarios of change, including precipitation regime changes, atmospheric change and the urgency for climate mitigation, agricultural paradigm shifts, and changing values as climate change worsens. The design research methods tested the application of ideas from across multiple disciplines at the scale of the parcel, canal corridor, and region, where site conditions can be better understood. Our next steps will involve working with landowners to see how their values inform these ideas.

4.3. The Armature Is a Tool for Heritage, Sustainability, and "Permanent" Carbon Storage within a Landscape of Change and Uncertainty, and Could Help Establish a Rural Commons through Multiple Landowners Working Together toward Adaptive Mitigation

The armatures we have tested so far in addition to the canals include hedgerows, islands, drumlins, and remnants of an agro-forestal pattern. These types of elements contributed to situating the CO_2 mitigation strategies within the context of local history, supporting the permanence of familiar narratives that integrate new imaginaries and hopefully support a renewed sense of collective stewardship in the area. In this open-ended, descriptive process, armatures remain to be uncovered, but so far, armatures of wetness and moisture persist in time, patterns of old forests might become the core of connectivity corridors, and even immaterial armatures through visibility help us define concrete units for design prompts.

Activating the edge between private and public will presumably have an important impact on the perception of the ECNHC, Montezuma, NY, USA, in addition to increasing the potential of repurposing the canal for climate mitigation using lands that perhaps were valued less due to conditions of wetness that resist conventional farming practice. We have focused on the edge of fallow forests, or cultivated land and pasture, to design a working forest that follows existing landscape patterns and creates an interface between public and private lands that can help guarantee access to a wider public to trails inserted at the forest edge. We call this condition an "armature to become", a concept that articulates different conditions in the same collective project. Expecting some trepidation on the part of landowners, we began with temporal occupations, the concession of slim edges, and mindfulness of possible economic benefits in the short-term. However, at the heart of this research, as a facet of sustainable design, is the hypothesis that reforestation practices can contribute to the reclamation of a "rural commons" [38], a collective space that originates in the public and expands wherever there is opportunity toward the private, in operations of mutual gain. The rural commons as a mechanism for adaptive mitigation expands across scales, so that lands are activated locally to construct communities along the canal corridor, in the region, and across the globe.

Author Contributions: Conceptualization, M.G., J.V.; methodology, M.G., J.V.; validation, M.G., J.V.; formal analysis M.G., J.V.; investigation, M.G., J.V.; writing—original draft preparation, M.G., J.V.; writing—review and editing, M.G., J.V.; visualization, M.G., J.V.; supervision, M.G., J.V.; project administration, M.G., J.V.; funding acquisition, M.G., J.V. All authors have read and agreed to the published version of the manuscript.

Funding: This work is supported by Hatch under accession number 102111, from the USDA National institute of Food and Agriculture.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We are grateful for the support of Cornell University Agricultural Experiment Station and for the invaluable contributions of our research assistants in the Cornell University Department of Landscape Architecture, including: Gengjiaqi Chang (MLA'23), Tim Dehm (MRP/MLA'21), James Lynch (MLA'21), Tim Chan (MLA'22), Zikun Zhang (MLA'20), Andrew Curtis (MLA'22), Dom Malacaman (BSLA'22), Esther Xie (BSLA'20), and Joyce Zhu (BSLA'20).

Conflicts of Interest: The authors declare no conflict of interest.

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