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ABSTRACT

Title of Thesis: BANISHED INTO EXISTENCE: AGRITECTURE AT THE INTERSECTION OF ARCHITECTURE & AGRICULTURE

Yan Konan, Dual Master of Architecture & Real Estate Development, 2023

Thesis Directed By: Michael Ezban, RA, ASLA, Professor of the Practice, School of Architecture, Planning, and Preservation

Building operating emissions account for 28% of global greenhouse gas emissions while building components account for 11%. To mitigate these effects, we must reduce the carbon footprints of construction activities, building materials, and sequestering carbon dioxide in forests and farmland. Industrial hemp is a solution to all these challenges. Hemp is a carbon-negative crop, absorbing more carbon dioxide than trees, and thus represents a unique sequestration opportunity. By using hemp as a construction material, we can improve the thermal efficiency of our buildings, consequently reducing operational carbon. Finally, by substituting hempbrick, a mixture of hemp and various binders, for more carbon-intensive materials, we can reduce the embodied carbon of the built environment. This thesis proposes a productive hemp landscape that will be open to the public as an agritourism destination. The project will raise public awareness about hemp cultivation as an agricultural opportunity and demonstrate the potential of hemp as a construction material, highlighting its multiple possible contributions to tackling the climate crisis.

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BANISHED INTO EXISTENCE: AGRITECTURE AT THE INTERSECTION OFARCHITECTURE & AGRICULTURE

by

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Thesis submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
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Preface

This thesis advocates the reintroduction of industrial hemp into the United States construction industry to demonstrate industrial hemp's application in architecture and agriculture. This interactive farmland will provide the USDA with a hybrid farm, a visitor center, and an industrial hemp manufacturing facility. Using the campus of the National Library of Agriculture in Beltsville, Maryland, Beltsville Agricultural Research Center, USDA Agricultural Research Center as a model, "Agro-Tourism" will be implemented to convert the property into a tourist destination where visitors can learn about human activities and industrial hemp farm processes. Additional agrivoltaics technology will be added to selected areas of the property to enable dual-purpose land usage.

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Table of Context

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Table of Figures

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Chapter 1: Climate Change & the Construction Industry

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Carbon Footprint

Humankind has impacted the Earth's landscape, increased natural resource usage, and significantly accumulated pollutants since the 18th century. Carbon dioxide levels in the atmosphere have risen by over 40% since the mid-nineteenth century, and climatologists estimate they are at their most significant position in at least 14 million years. High concentrations of greenhouse gases, particularly carbon dioxide, are caused by human activities such as burning fossil fuels and land development. Most of a human's carbon footprint is frequently created by their method of transportation, their dwelling, and, ultimately, food.[1]As carbon dioxide levels continue to rise, consequences such as ocean acidification, rising sea levels, frequent violent storms, mass extinctions of species, food scarcity, and growing economic disparity will become more common.

Modifying energy use and transportation modes can help lower total carbon footprints. Using renewable energy to power homes and businesses and updating to more energy-efficient lighting are excellent strategies to reduce environmental impact. Wind power, for example, generates electricity with no direct carbon dioxide emissions. Other lifestyle interventions that can help minimize carbon footprint include reducing meat intake and shifting shopping habits to items that need fewer carbon emissions to produce and transport.[2]

[1] "U.S. Environmental Protection Agency." *US EPA*. Accessed December 4, 2022. https://www.epa.gov/.
[2] The Editors of Encyclopedia Britannica. "Carbon Dioxide." *Encyclopedia Britannica*, November 21, 2022.

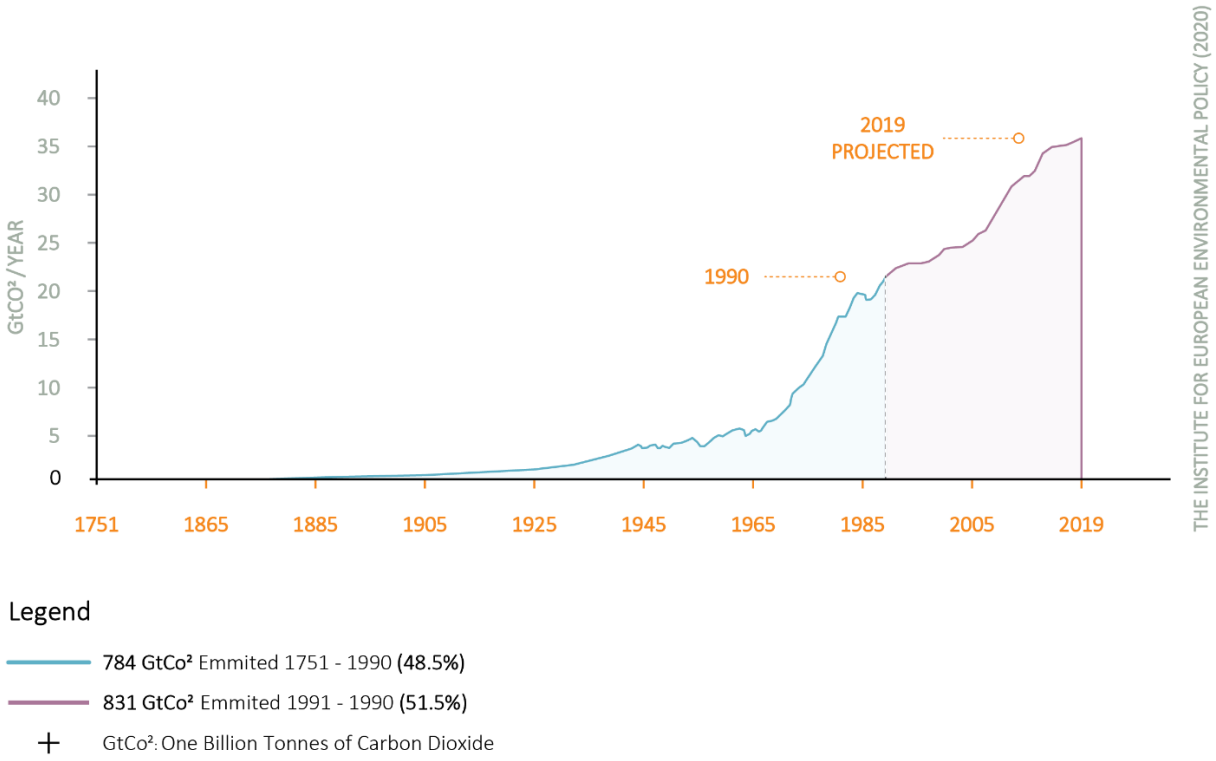

Figure 1. Annual Global CO_2 Emissions (1751 – 2019). Source: Carbon Budget Project (2017). Drawing by Author.

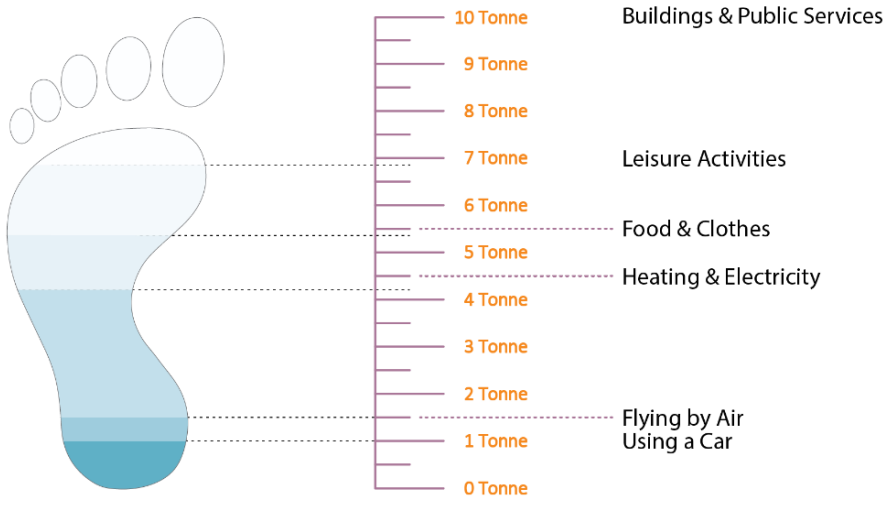

Figure 2. Distribution of CO_2 footprint. Source: United Nations, Climate Action. Drawing by Author.

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The Influence of Building Energy on the Ecosystem

Infrastructure Impact on the Climate

The International Energy Agency predicts that by 2040, buildings will account for most of the global emissions; nevertheless, there will be insufficient energy to meet this growing demand. Fossil fuel reserves are gradually depleting, while consumption will peak within the next three decades. As a result, lowering building energy consumption and improving energy efficiency are necessary to mitigate the global energy demand rise. It would also significantly enhance the global natural ecological environment and provide a lower-carbon future for humans to thrive.[3]

To achieve zero emissions by 2040, we must first comprehend embodied carbon and adopt new standards for humanity such as reusing, reducing, and sequestering. "Reuse" encompasses a wide range of operations, from deconstructing structures to renovating existing buildings using recycled materials. "Reduce" incorporates material optimization and the specification of low to zero-carbon materials. “Sequester” implicates developing carbon sequestering sites and using carbon sequestering materials.

Concrete, steel, and aluminum account for 23% of total global emissions, most of which come from the built environment. Through policy, design, material selection, and specification, there is a tremendous opportunity to reduce embodied carbon in these high-impact materials.[4]

[3] Li, Lingyan, Wanming Sun, Wei Hu, and Yongkai Sun. “Impact of Natural and Social Environmental Factors on Building Energy Consumption: Based on Bibliometrics.” *Journal of building engineering* 37, no. 102136 (2021): 102136. https://www.sciencedirect.com/science/article/pii/S2352710220337682.

[4] “UN Environment and International Energy Agency (2017): Towards a Zero-Emission, Efficient, and Resilient Buildings and Construction Sector.” *Global Status Report* (2017).

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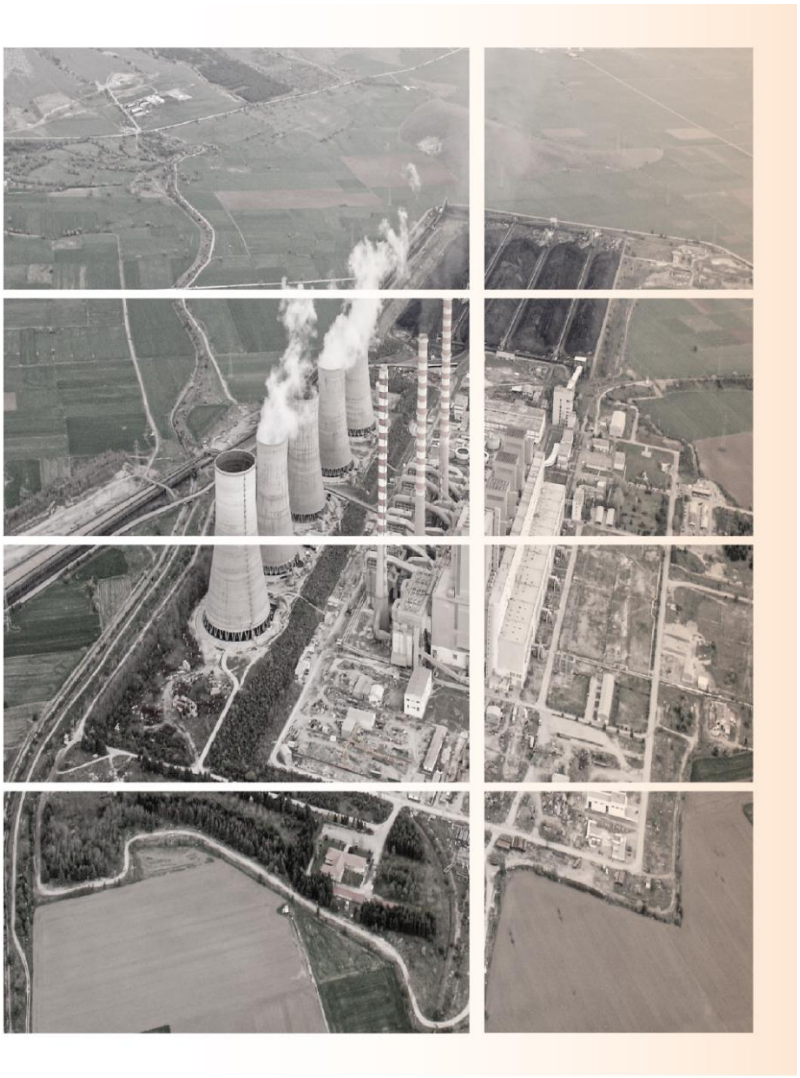

Figure 3. Fossil Fuel Plant. Source: Shutterstock. Diagram by Author.

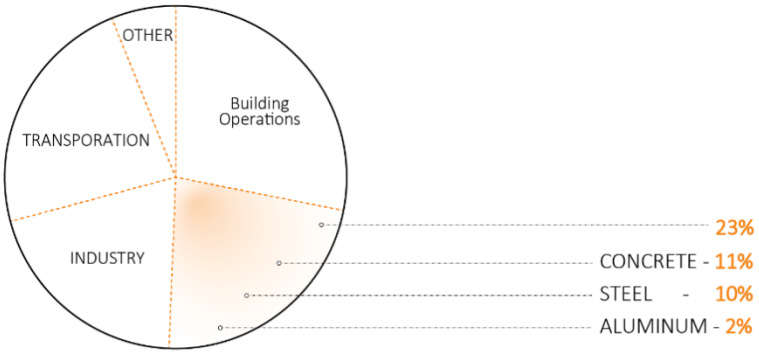

Figure 4. Material Annual Global CO_2 Emissions. Source: IEA (2022). Drawing by Author.

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Materials used for insulation are another significant option for reducing our embodied carbon in homes. When it comes to global warming potential, insulating materials vary widely. High global warming potential are typical of spray foam and rigid foam insulating materials. straw, hay, and other agricultural byproducts like cellulose have been shown to sequester carbon over long periods and have a low global warming potential.[5]

Insulation also has a role in operational energy use, as it reduces energy consumption for heating and cooling by preventing heat transfer. The expense of heating and cooling a home may be reduced, and comfort increased with proper insulation. Most conventional insulating materials function by delaying both conductive and convective heat movement. The resistance of an insulating material to conductive heat flow is measured in terms of thermal resistance, or R-value, the higher the R-value, the better the insulating performance. The R-value of insulation is determined by its type, thickness, and density.

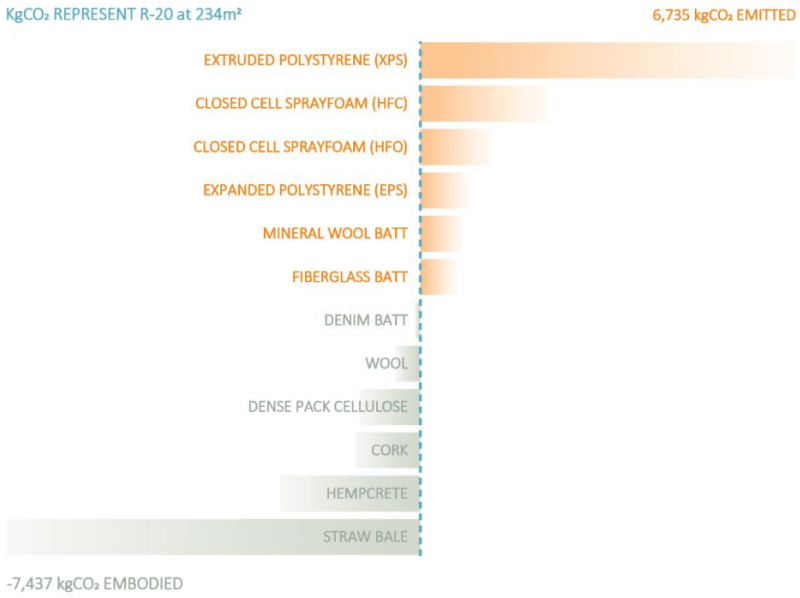

Figure 5. Carbon Impacts of Insulation. Source: Builders for Climate Action – 2019. Drawing by Author.

[5] Pontolilo, Brian. "Does Your Insulation Have Low Embodied Carbon?" *GreenBuildingAdvisor*. Last modified July 21, 2020. Accessed December 11, 2022. https://www.greenbuildingadvisor.com/article/does-your-insulation-have-low-embodied-carbon.

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Sustainable Construction Materials

There is a demand for sustainable building materials, including those manufactured locally. The goal is to use raw materials derived from renewable resources and require minimal energy input throughout their life cycle. We need outstanding thermal performance to reduce carbon emissions when used. Low-impact materials best characterize the type of material that's desperately needed if we are going to achieve any progress in decreasing the building industry's massive contribution to carbon emissions. A product that uses minimum fossil fuels has no detrimental effects on human health and is environmentally friendly over its entire life cycle.

Those who advocate for using natural building materials, such as stone, lumber, soil, clay, straw, hemp, sheep's wool, and reed, have a precise vision for the construction industry's future. Such materials have been used for thousands of years to construct healthy and protected dwellings; some even have excellent thermal performance. Similarly, towards the end of a building's life cycle, natural materials used in construction may be buried or let to break down naturally rather than going into a landfill.

However, not all organic materials are truly renewable. Even while slow-growing hardwoods like oak store much carbon, they are not a sustainable resource since they cannot replace themselves quickly enough through natural regeneration. In contrast, wheat, straw, and hemp shiv, which are "waste" or by-products of rapidly growing crop are genuinely renewable, low-impact, and long-lasting materials.[6]

[6] Stanwix, William, and Alex Sparrow. *Hempcrete Book: Designing and Building with Hemp-Lime*. Uit Cambridge, 2014, 58.

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Natural Insulation

Natural low impact insulating materials such as hemp, wood fiber, sheep's wool, and straw are frequently disregarded in favor of synthetic alternatives. These materials have yet to be widely utilized enough to be generally available in typical builders' merchants. In some cases, it remains expensive due to the current relatively low demand. However, putting them to good use has many advantages. They use locally sourced materials and have low-energy production procedures. Denser natural insulations used as a solid walling material, such as straw bale and hempbrick[7], do not contain such additions as synthetic polymer binders or chemical fire retardants, while lightweight insulation blankets manufactured from natural fibers typically do.

Natural materials have a "hygroscopic" property, an ability to draw in and retain water vapor from the air, which is lacking in most manufactured materials. Natural insulating materials containing cellulose, such as wood, hemp, and straw, are effective at retaining moisture since their cellular structure is biodegradable. Thus, natural materials can "buffer" moisture levels in the indoor atmosphere by absorbing water vapor during periods of high relative humidity.[8]

[7] Hempbrick: Made by combining chopped stalk of the industrial hemp plant, a lime-based binder and water.
[8] Stanwix, William, and Alex Sparrow. *Hempcrete Book: Designing and Building with Hemp-Lime*. Uit Cambridge, 2014, 58.

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Carbon Sequestration

Greenhouse gas emissions reductions in all sectors must be supported by large-scale carbon capture and storage methods to satisfy climate obligations. Concrete mixture materials such as mortar can sequester carbon via carbonation processes, and plant biomass materials such as timber, bamboo, or agricultural products store carbon via photosynthesis. These two classes of construction materials have an inherent ability to store carbon dioxide.[9]

Hemp also offers a new avenue for carbon sequestration in building products. Capturing carbon through industrial hemp[10] involves various procedures following the growing stage, which allows for sequestration both in soil, aided by hemp cultivation, and in the hemp product itself. Hemp plants absorb four times as much carbon dioxide as trees. It absorbs carbon dioxide while growing, making it a carbon-negative crop. One hectare of hemp may offset the carbon footprint of two automobiles for an entire year.[11]

There is a critical distinction between temporarily capturing carbon in biomass and effectively sequestering it from the atmosphere. Hemp plants have robust deep root systems that firmly retain the soil, which aids in soil erosion stabilization. It is particularly beneficial in carbon sequestration since it absorbs carbon from the air and distributes it back to the soil throughout its plant life. Additionally, hemp can be cultivated without fertilizer, promoting sustainable agriculture.

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[9] Arehart, Jay H., William S. Nelson, and Wil V. Srubar III. 2020. "On the Theoretical Carbon Storage and Carbon Sequestration Potential of Hempcrete." *Journal of Cleaner Production* 266, no. 121846: 121846. https://doi.org/10.1016/j.jclepro.2020.121846.

[10] *Industrial Hemp: Derived from the Plant Species Cannabis Sativa L. and Utilized to Manufacture a Wide Range of Industrial and Consumer Products*, n.d.

[11] *Pebblemag.com*. Accessed June 5, 2023. https://pebblemag.com/magazine/living/hemp-solve-climate-change.

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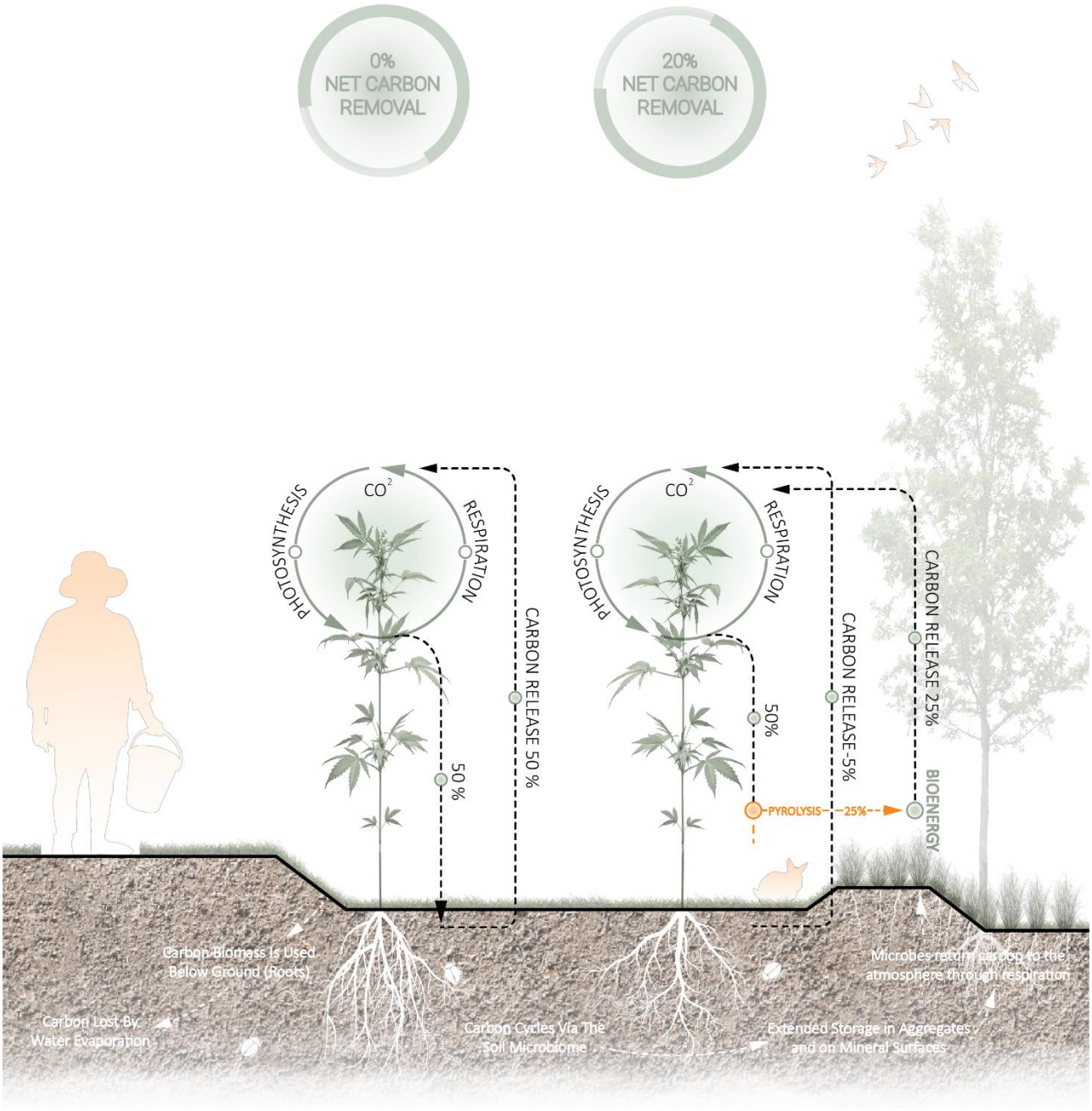

Hemp eliminates pollutants from the soil and absorbs carbon dioxide from the air

SOIL CARBON

CARBON SEQUESTRATION BY
PHOTOSYNTHESIS: CARBON NEUTRAL

BIOCHAR

BIOCHAR SEQUESTRATION:
CARBON NEGATIVE
(REDUCES EMISSIONS FROM BIOMASS)

Figure 6. Hemp Carbon Sequestration. Drawing by Author.

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Chapter 2: Industrial Hemp Farming

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Hemp in History

The Origins of Industrial Hemp Cultivation

Figure 7. Exploring Hemp at a Global Scale. Drawing by Author.

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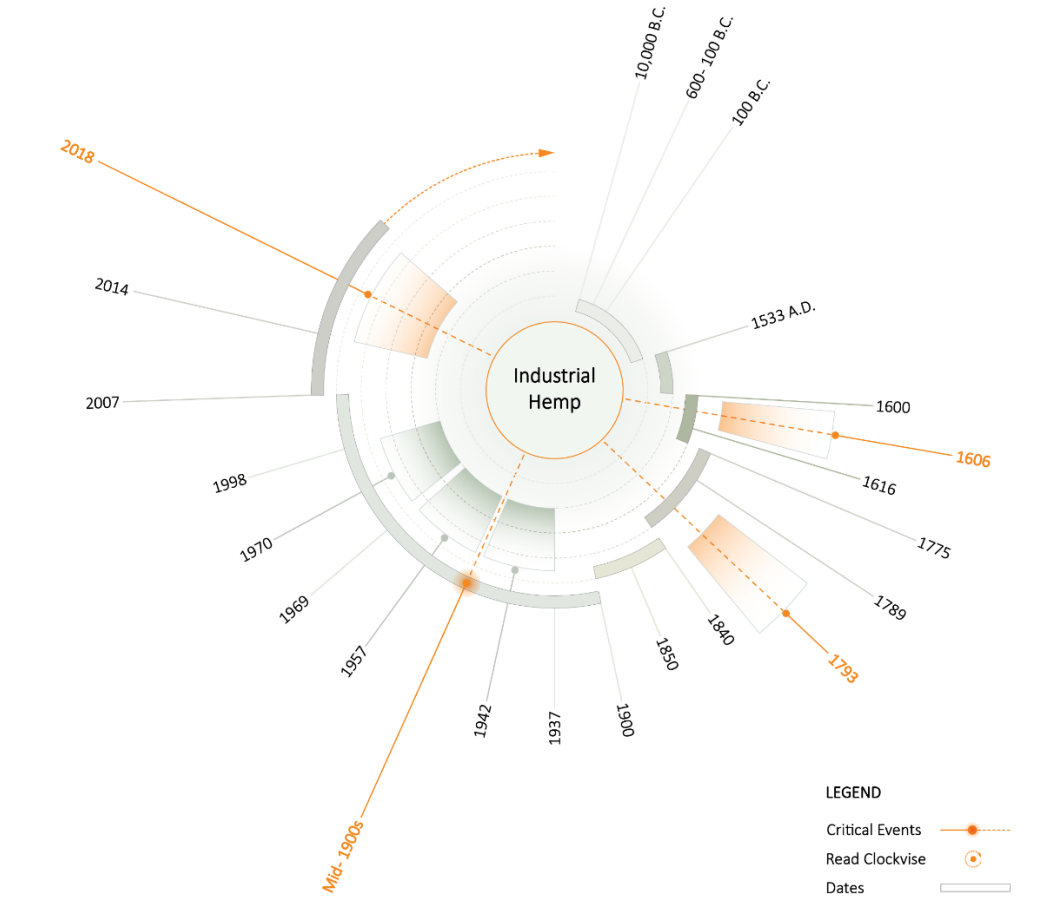
Hemp is among the first plants cultivated by humanity and was utilized in Central Asia as early as 4000 BCE. The plant originated in Taiwan before being harvested in China, where it was employed to manufacture textiles and paper.

Hemp spread to Europe throughout the Middle Ages, and Spain began producing hemp paper using procedures similar to the Asian cultures. Hemp was becoming an essential European product at the time. Demand for hemp fibers surged as medieval Europe built warships and sailing technology. Hemp was applied to produce ship sails, rigging, ropes, and caulking, a method used to seal the crevices between the wooden planks. Sailors' garments and ship logs were commonly made of hemp. Other extractions such as hemp oil was employed in lamps, and the seeds were a vital food resource for the crew.[12] Spanish conquerors sailed to the Bahamas, Angola, Portugal in 1545, where hemp was introduced as a commodity. In 1550, enslaved West Africans transferred by Portugal's Don Joao III carried hemp seeds to Brazil. In 1533, King Henry VIII of England issued a royal proclamation requiring farmers to produce hemp in England or face a fine.[13]

[12] Williams, David W. *Industrial Hemp as a Modern Commodity Crop, 2019*. Edited by David W. Williams. American Society of Agronomy, 2020.
[13] "History of Hemp in America: From Spanish Expeditions to WWII." *What Is Hemp*. Last modified July 9, 2020. Accessed June 5, 2023. https://whatishemp.com/history/.



- 10,000 B.C. Early dating hemp cords from Taiwan and China are used with pottery
- 600- 100 B.C. Evidence of hemp rope, paper, fabric, being used in Europe and Asia
- 100 B.C. China develops paper largely made of hemp

- 1533 A.D. King Henry VIII fines farme for not growing hemp

- 1600 Hemp is used by Native Americans for a wide range of purposes including textiles
- 1606 The U.S. is introduced to hemp. The earliest people in the U.S. to make use of hemp were the Native Americans
- 1616 Jamestown settlers in the U.S plant hemp for clothing, rope and ships sails

- 1775 The territory of Kentucky a future leading producer begins growing hemp
- 1789 Elijah Craig establishes one of the first hemp rope facotries in Georgetown, Kentucky
- 1793 Cotton gin is invented; cotton becomes preferred material for textiles

- 1840 In the U.S., medical preparations with a cannabis base are available
- 1850 Cannabis is added to U.S. pharmacopeia

- 1900 Tobacco replaces hemp as the main crop in Kentuncky
- 1937 Marihuana Tax Act is passed; High taxation of hemp sales begins
- 1942 The Hemp for Victory campaign launches. Ecouraging farmers to grow hemp fiber to create ropes for the U.S. during WWII

- Mid- 1900's Cannabis is ruled illegal and classified as a schedule one restricted drug
- 1957 Wisconsin planted the last U.S. hemp crops
- 1969 The Marihuana Tax Act of 1937 is ruled unconstutional

- 1970 The Controlled Substances Act classified hemp as an illicit narcotic, grouping it with Marihuana in the Cannabis family
- 1998 The U.S. begins to deport food grade hemp seeds and oil

- 2007 The first hemp crop liscences in more then 50 years are granted to two North Dakota farmers
- 2014 The 2014 Farm Bill allows for protected hemp research allowing hemp to be cultivated for reasearch purposes

- 2018 The 2018 Farm Bill officially legalizes the production of industrial hemp, clearing to regain its standing as an agricutural commodity in all 50 states

Figure 8. A Global Timeline of Hemp. Drawing by Author.

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The history of hemp in the Americas may be traced back to the early Spanish explorations in the 1500s. Hemp's history in the United States commences in 1605, with the first records in North America. Native Americans cultivated hemp fibers to make long-lasting fabrics, ropes, and medicine. The Native American Peace Pipe was used in rituals to smoke hemp for nutrition, healing, and enlightenment.[14] In 1619, King James issued a royal decree mandating every farmer in England's north American colonies to cultivate 100 hemp plants for export, or colonists would be imprisoned.[15]

However, over time negative perceptions about cannabis plants, from which both the drug marijuana and hemp derive, began to impact cultivation in the US. In 1937, the "Marihuana Tax" largely terminated the hemp industry until the 1990s, except for a brief reprieve during World War II, when the "Hemp for Victory Campaign" encourage hemp production for the manufacture ropes supporting war operations. Despite its historical utility as a multipurpose crop, global output declined in the nineteenth century and accounts for just around 0.5% of natural fibers today.[16] The 2018 Farm Bill re-established hemp's legitimacy as an agricultural crop in the United States by abolishing long-standing federal restrictions on its cultivation. Since then, research into hemp extract and its derivatives as a sustainable textile fiber and input has risen noticeably, reigniting interest and acceptance in hemp. Additionally, as a result of breakthrough research and a changing cultural context, numerous states have approved the use of cannabis to treat medical conditions.

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[14] Hearons, Kathleen. "Giving Thanks: A History of Native Americans and Cannabis." *Head Magazine*. Last modified November 25, 2020. Accessed June 5, 2023. https://headmagazine.com/giving-thanks-a-history-of-native-americans-and-cannabis/.

[15] "History of Hemp in America: From Spanish Expeditions to WWII." *What Is Hemp*. Last modified July 9, 2020. Accessed June 5, 2023. https://whatishemp.com/history/.

[16] Rupasinghe, H. P. Vasantha, Amy Davis, Shanthanu K. Kumar, Beth Murray, and Valtcho D. Zheljazkov. "Industrial Hemp (Cannabis Sativa Subsp. Sativa) as an Emerging Source for Value-Added Functional Food Ingredients and Nutraceuticals." *Molecules (Basel, Switzerland)* 25, no. 18 (2020): 4078. http://dx.doi.org/10.3390/molecules25184078.

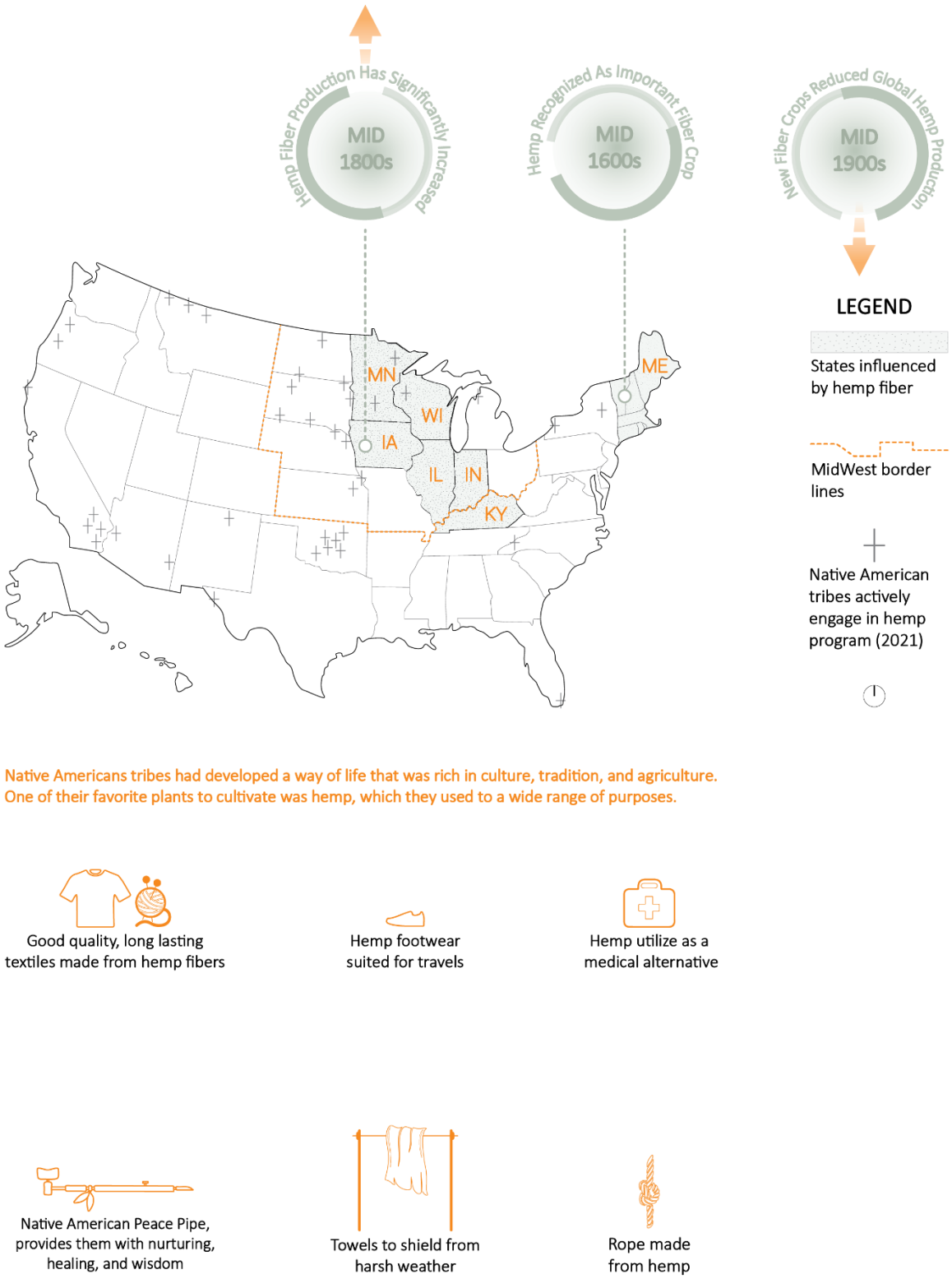

Figure 9. The Influence of Native Americans. Drawing by Author.

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Field Architecture

Cannabis: Marijuana Vs. Hemp

Although both hemp and marijuana plants come from the cannabis Sativa L. species, the two cultivars have distinct development patterns and medicinal advantages. Cannabis mainly refers to two marijuana plants having psychoactive properties (Cannabis sativa, Cannabis indica). The primary distinctions between hemp and marijuana are the percentages of two cannabinoids found in each plant, delta-9 tetrahydrocannabinol (THC) and cannabidiol (CBD). THC is a cannabis molecule that affects consciousness and induces euphoria. Marijuana has a THC level of 15-30%, classifying it as a controlled substance. Hemp, on the other hand, has a THC concentration of 0.3%, making it a legal crop under the 2018 Farm Bill Act.

Hemp and marijuana have diverse qualities due to differences in plant components and chemical concentrations, making them useful in various circumstances. Since marijuana contains more than 0.3% THC and its plants have less fiber than hemp types, its primary usage is for psychoactive purposes.

Industrial hemp crops produce taller plants with more fiber, which increases the yield and hence the price of hemp commodities such as rope and textiles. In general, industrial hemp plants are more resilient than cannabis plants; these plants are cultivated in proximity in fields and harvested similarly to fiber grasses. In contrast, cannabis plants are spaced apart rather than crammed together to produce the highest yield of bud.[17]

[17] Clarke, Robert C., and Mark D. Merlin. "Letter to the Editor: Small, Ernest. 2015. Evolution and Classification of Cannabis Sativa (Marijuana, Hemp) in Relation to Human Utilization. Botanical Review 81(3): 189-294." *The Botanical review; interpreting botanical progress* 81, no. 4 (2015): 295–305. http://dx.doi.org/10.1007/s12229-015-9158-2.

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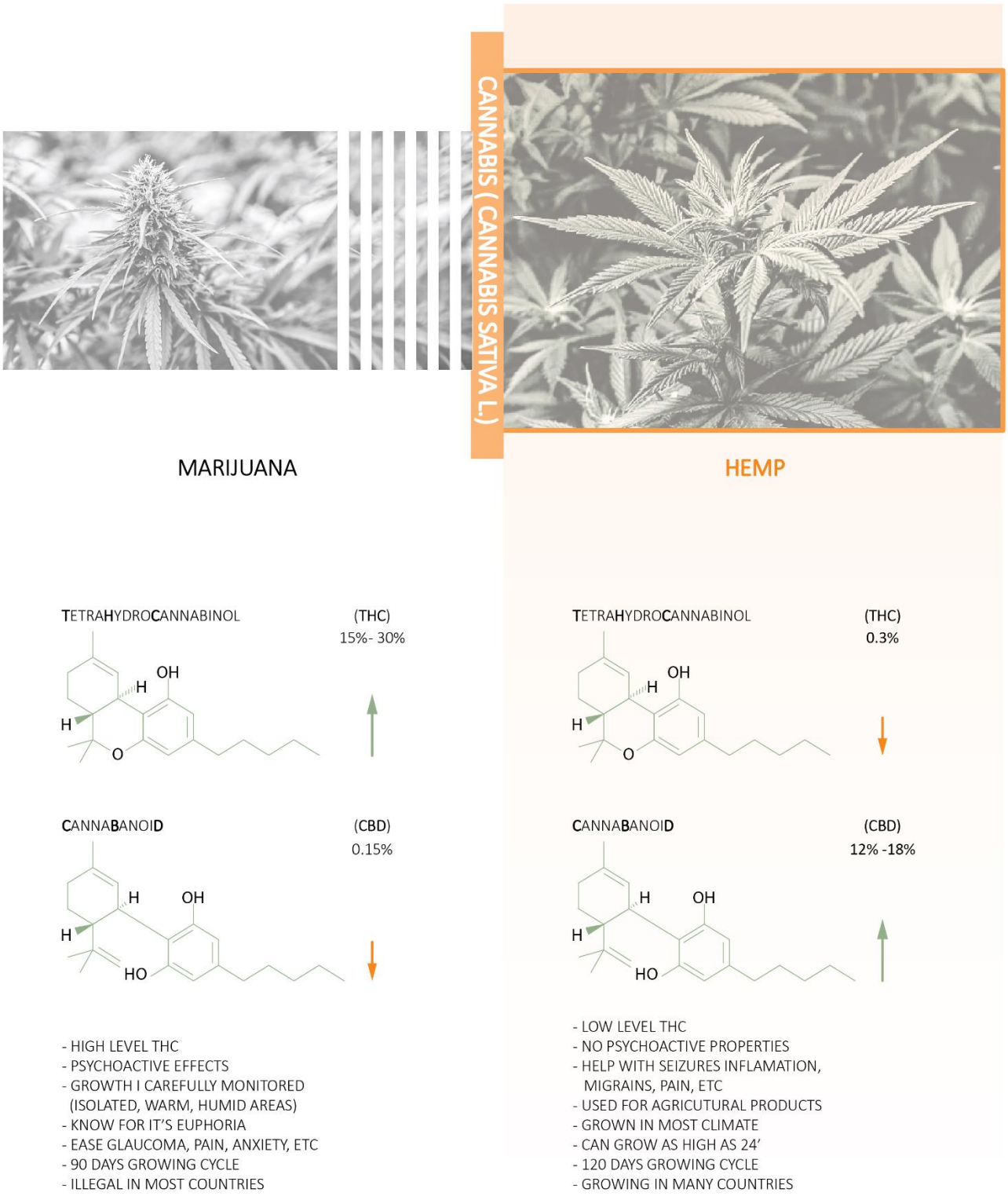

Figure 10. Cannabis Subspecies. Source: Shutterstock. Diagram by Author.

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Physical Properties of Industrial Hemp

Hemp is a fast-growing annual that may reach a height of five feet to fifteen feet and generates just a limited number of branches near the top of the plant. The duration of the growth cycle ranges from 90-120 days. The plant responds to the changing seasons by slowing its growth and developing flower buds as the days become shorter. The stem is hollow and thin, measuring between 4mm and 20mm in diameter depending on the growing circumstances and the variety. The "blast" fibers found in the bark of the woody stem vary from three to six feet in length and are incredibly robust. Fibers are graded on several characteristics, including fineness, length, color, uniformity, and strength, all of which are affected by the harvesting date.

The hurd, the inner woody stem, has traditionally been underutilized. However, this is fast changing as new applications, such as packing filler and animal bedding, are currently being explored. Hemp seeds have a variety of uses, including food, and the plant’s oil is used in various technical and industrial applications.

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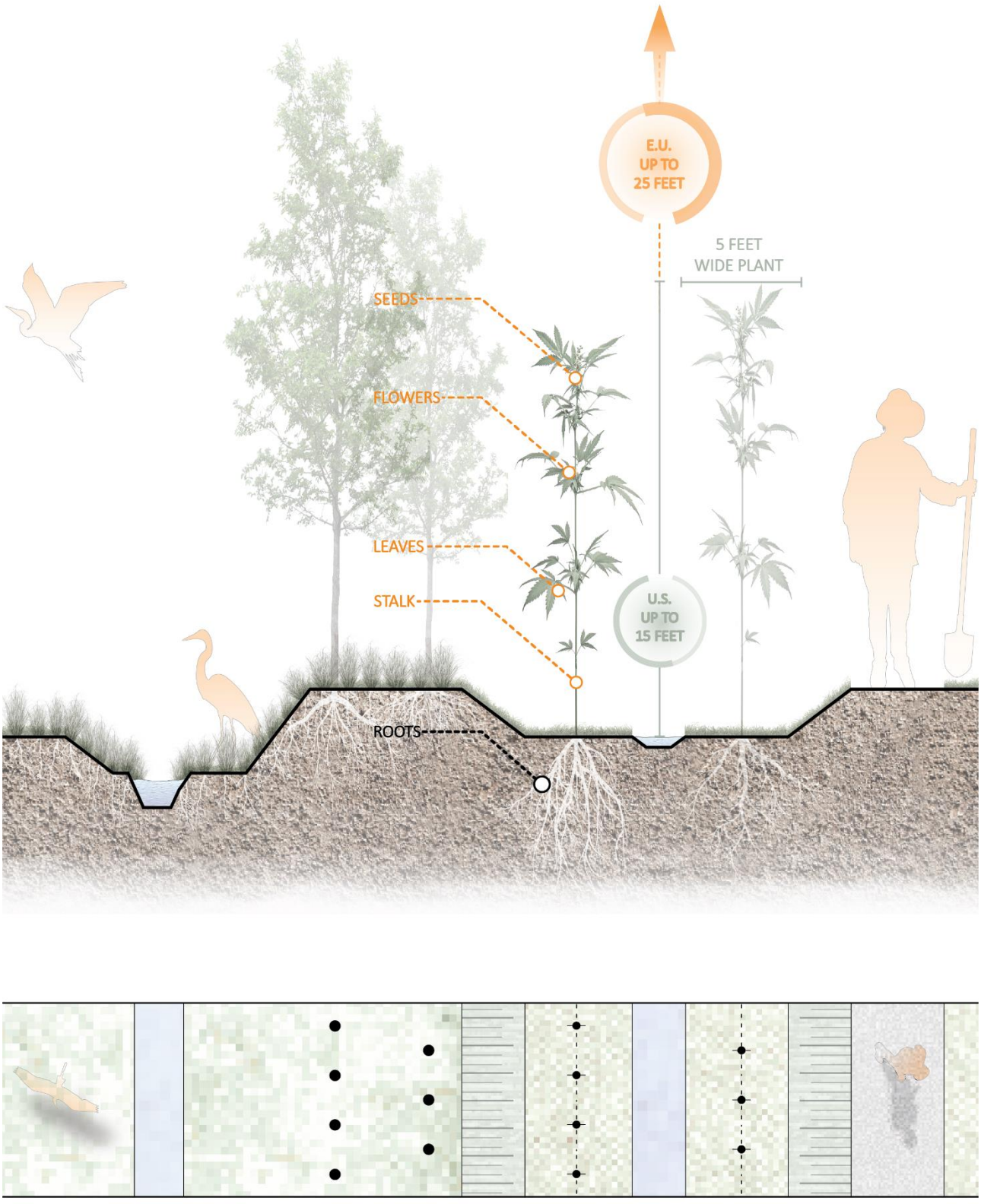

Figure 11. Hemp Organism Structure. Drawing by Author.

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Life Cycle of Industrial Hemp Plant

Industrial Hemp grows through various stages, each requiring a different combination of nutrients, water, and sunshine. The ideal time to harvest hemp substantially impacts a farmer's yield. The plants may not thrive to their full potential if harvested prematurely. Simultaneously, a delayed harvest might be ineffective since the vitality of the plants is reduced.

Stage 1: The seeds are ready to germinate when they are a dark brown color, firm, and completely dry. Sprouting can be encouraged by moistening seeds while they are contained in a paper towel.

Stage 2: At this stage of their development, plants require sufficient light and water and the maximum possible exposure to light. Cotyledon, also known as seed leaves, and the distinctive fan leaves will multiply.

Stage 3: Inflorescence refers to the hemp flower head, a precursor to the blooming stage. Each inflorescence comprises a stalk and several branches that terminate in flower clusters. Here, the vegetative stage ends, and the blooming stage begins.

Stage 4: The blooming growth stage is the final step in the life cycle of the hemp plant. The plant will spontaneously produce flowers whenever the daily light exposure is less than 12 hours.

Stage 5: Once the hemp plants attain maturity, they are ready to be harvested and processed. Most farmers' harvesting season opens in October. Harvesting procedures vary according to the type of hemp farmed. Industrial hemp harvesting may demand the use of sophisticated machinery.[18]

[18] Desjardins, Jeff. "The Anatomy of a Cannabis Plant, and Its Lifecycle." *Visual Capitalist*. Last modified September 11, 2018. Accessed December 4, 2022. https://www.visualcapitalist.com/anatomy-cannabis-plant/.

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Stage 6: The stalk is milled into hemp hurd or shive, subsequently used to manufacture building materials. Fibers serves in the production of textiles and paper. The seeds are used for food and feed, while the flowers are processed CBD products.

Farmers must monitor their crops during development and harvest, which occurs 100 days following planting. The drying and curing phases are crucial components of the process. Growers may confirm that their harvest is free of parasites and contains less than 0.3% THC.

Over the past few decades, cannabis plants have changed tremendously due to human intervention. Structure, bud type, flavor, and impact are just some ways different strains distinguish themselves. Different strains of cannabis can be created by crossing breeding male and female plants from those strains. The resulting hybrid will have traits from both origins. To maximize plant yield, keep male and female plants apart. Male plants pollinate female plants, causing the female plants' blossoms to become tangled with seeds.

Female plants are known for their high THC, CBD flowering, and bud production. To identify a female, look for an open flower with distinctive tiny hairs called pistils; this clearly indicates a male plant without these characteristics. As the earliest visible sign of sexual maturity, female plants are easily distinguished from their male counterparts by the absence of pistils on the latter.

During the last month of a male plant's life cycle, its pollen membranes will swell and open, dispersing its pollen over the surrounding area. Seeds for future hemp cultivation are obtained by keeping male plants around to pollinate female plants. If developing trichome-rich buds is the aim of the harvest, male plants must be eliminated from the growing area as soon as they are identified.

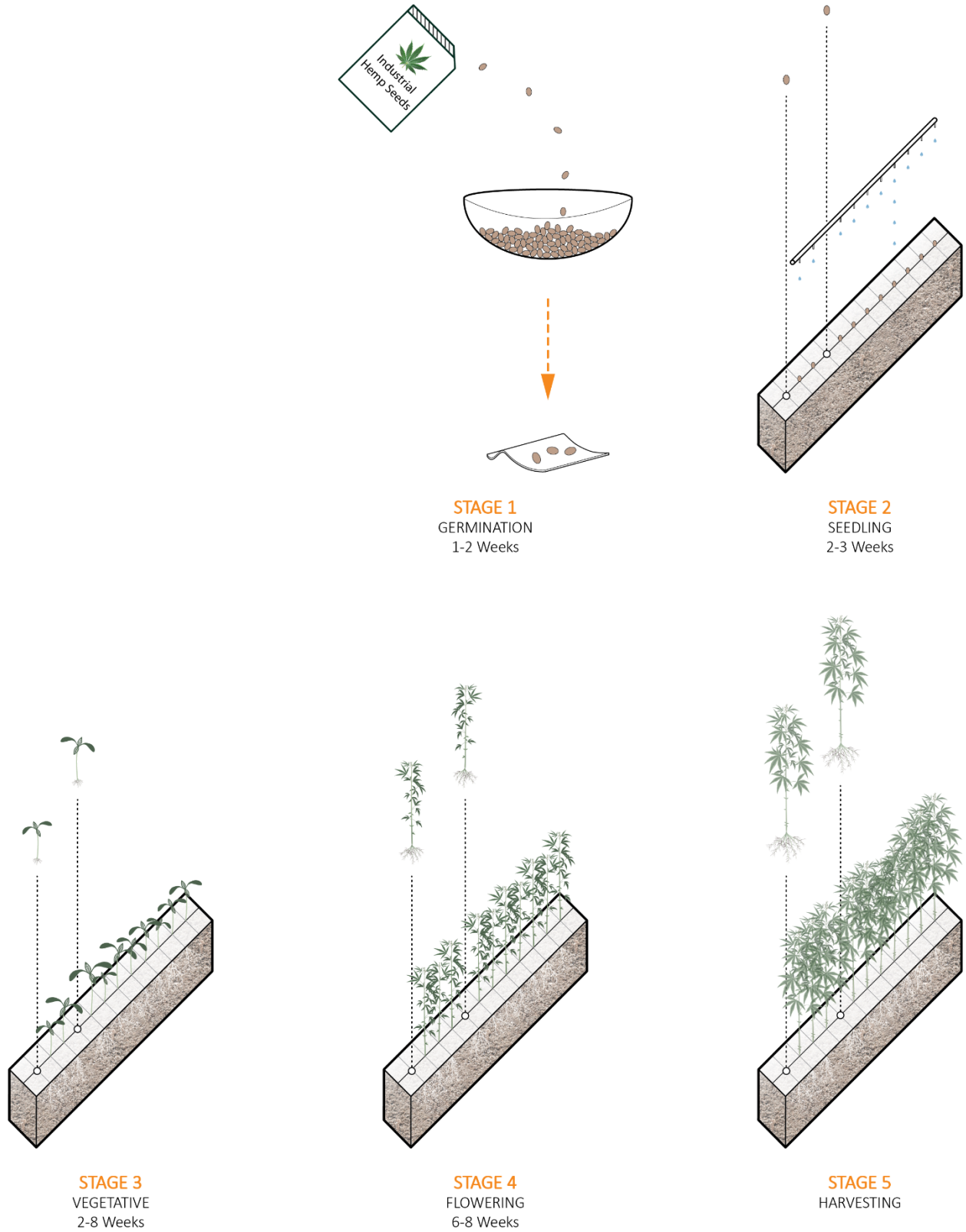

Figure 12. Cultivating Hemp. Drawing by Author.

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Plant Ecology

Plant-Species Interactions + Food Resources

In the United States, industrial hemp has been reintroduced and is gaining traction across agricultural landscapes. As a wind-pollinated crop, it does not generate nectar but releases a substantial amount of pollen during the blooming phase. These pollen supplies are appealing to a variety of bee species as well as other farm animals. When it comes to attracting bees, plant height is exceptionally significant. The plant will attract a greater variety of bee species as it grows in height.

Hemp is a dioecious plant, which can be divided into male and female plants. Bees are disinterested in female hemp flowers due to the lack of nectar that pollinators require for carbohydrates. Male hemp flowers, in contrast, are rich in pollen, which is a vital source of nutrition for insects. Hemp seeds are consumed by various birds, including game birds such as quail, pheasants, and doves, as well as non-game birds such as cardinals and finches. Insects found in hemp fields may provide food for birds and farm mammals. Although rodents, rabbits, and deer may consume hemp, digesting a plant with a high quantity of THC may be harmful.[19]

Effect on Soil and Crop Rotation

Hemp's roots go deep into the earth, binding the soil together and reducing erosion for other vulnerable plants to thrive. Fiber hemp is a natural weed suppressor due to its quick growth and deep canopy and decreases soil fungal and parasite infestations, so it does not require fungicides or pesticides to grow. Hemp's roots assist in minimizing soil erosion and nutrient depletion by remaining in the ground; they can pull nutrients from the soil, and they are helpful

[19] Higgins, Samantha, Russell Jessup, and Dmitry Kurouski. "Raman Spectroscopy Enables Highly Accurate Differentiation between Young Male and Female Hemp Plants." *Planta* 255, no. 4 (2022): 85. http://dx.doi.org/10.1007/s00425-022-03865-8.

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for phytoremediation because they can take up and store heavy metal contaminants. When leaves regularly fall during the growing season, wet organic matter is supplied to the soil. Hemp, because of its good impact on soil quality, is a prospective candidate for inclusion in crop rotation programs meant to increase the yield of the primary crop. Hemp is also a pioneer plant for land restoration due to its rapid growth rate. Furthermore, the biomass from hemp is use as an industrial raw material in composites, tissue, paper, and chemicals.[20]

Crop Production

Industrial hemp farming is less environmentally harmful and consumes fewer resources than the cultivation of another crop. Hemp is an ideal alternative for carbon sequestration since it can be grown in various agricultural conditions and begins producing flowers, particularly after the first four to five weeks after emergence. The crop type determines the planting density. Fiber hemp is planted tightly to enhance stalk production; however, oilseed and CBD hemp are grown widely apart to maximize the yield of the flower. While some current crop types reach five feet in height, highly seeded fiber versions can reach fifteen feet. The industrial hemp stem and seeds are removed, while the flower buds of narcotic-type cultivars are collected. The plant density, day length, soil nutrients, and moisture all have a part in forming the plant's structure.[21]

[20] Piotrowski, Stephan, and Michael Carus. "Ecological Benefits of Hemp and Flax Cultivation and Products." *Eiha.org*. Accessed December 2, 2022. https://eiha.org/media/2014/10/Ecological-benefits-of-hemp-and-flax-cultivation-and-products-2011.pdf.

[21] Rupasinghe, H. P. Vasantha, Amy Davis, Shanthanu K. Kumar, Beth Murray, and Valtcho D. Zheljazkov. "Industrial Hemp (Cannabis Sativa Subsp. Sativa) as an Emerging Source for Value-Added Functional Food Ingredients and Nutraceuticals." *Molecules (Basel, Switzerland)* 25, no. 18 (2020): 4078. http://dx.doi.org/10.3390/molecules25184078.

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Marketing & Economy Considerations

Projecting for the Future

Industrial hemp is marketed as a fiber, a seed, or a multipurpose crop. While precise market data for hemp is not commonly accessible, according to Vote Hemp, the total retail value of hemp products in the U.S. in 2020 was roughly $5 billion and is estimated to hit approximately $18 billion by 2027. This figure includes food and personal care items, clothing, vehicle components, and building materials. Hemp based goods are ecologically beneficial, renewable, and associated with less harmful manufacturing methods. The paper produced from hemp fiber contains fewer toxins than paper made from wood fibers.

The hemp industry continues to introduce significant agricultural and technological innovations to cultivate industrial hemp plants effectively. Public awareness about the benefits of industrial hemp is also growing, which will promote the commercial expansion of the crop.

China continues to dominate the global industrial hemp market, producing roughly half of the world's fiber hemp supply.[22] The renewed interest in hemp crops traces back to the need for sustainable farming methods, as hemp has more fiber and nutrients than other crops. Farmers must get a cultivation license for hemp from the state where they live to grow hemp. When state pilot programs to cultivate industrial hemp in the USA commenced, the number of farmers license to grow hemp climbed from 292 to 3,852 as of 2018. The approval of the 2018 Farm Bill has led to a further expansion of agricultural land. There is rivalry for land with other crops and

[22] Johnson, Renée. "Hemp as an Agricultural Commodity." *Fas.org*. Last modified 2018. Accessed December 2, 2022. https://sgp.fas.org/crs/misc/RL32725.pdf.

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medicinal Cannabis, which can pose a problem with its ability to crossbreed with hemp. As hemp cultivation is rising significantly in many regions, it will surpass consumer demands.[23]

Specialists have acknowledged the potential for industrial hemp to be profitable, but also the challenges it may encounter. The agriculture sector is encountering several issues, including the need to restore supply systems, breed varieties with modern characteristics, improve harvesting equipment, update processing and manufacturing, and seek untapped markets. Researchers at the USDA, several land grant institutions, and state agencies have conducted feasibility and marketing studies in the last two decades. Hemp has an estimated gross value per acre of roughly $21,000 from seeds and $12,500 from stalks, according to more current accessible market statistics.[24]

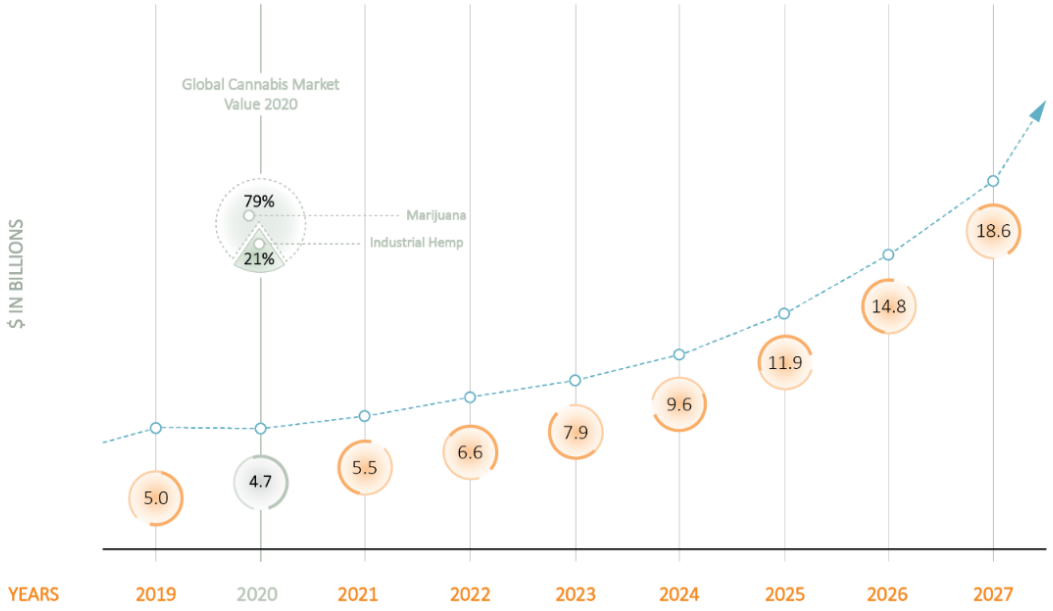

Figure 13. Global Hemp Market Value (USD, Bn). Source: Allied Market Research. Drawing by Author.

[23] Mark, Tyler, Jonathan Shepherd, David Olson, William Snell, Susan Proper, Suzanne Thornsbury, and Suzanne Thornsbury February. "Economic Viability of Industrial Hemp in the United States: A Review of State Pilot Programs United States Department of Agriculture." *Usda.gov*. Last modified 2020. Accessed December 2, 2022. https://www.ers.usda.gov/webdocs/publications/95930/eib-217.pdf?v=4149.6.
[24] Johnson, Renée. "Hemp as an Agricultural Commodity." *Fas.org*. Last modified 2018. Accessed December 2, 2022. https://sgp.fas.org/crs/misc/RL32725.pdf.

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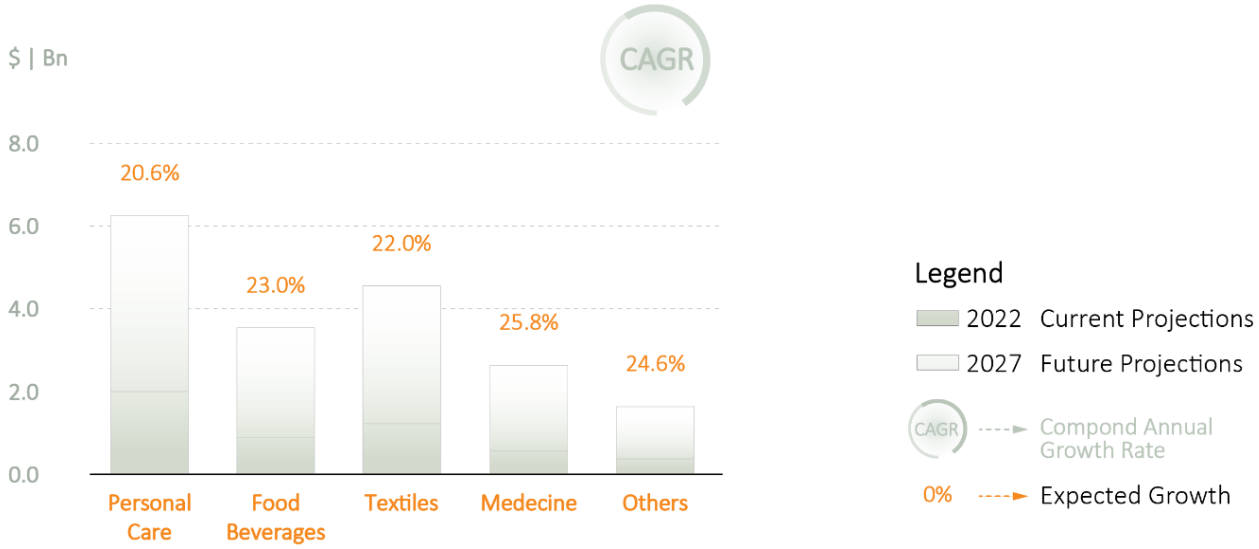

Figure 14. Global Hemp Market by Application. Source: Allied Market Research. Drawing by Author.

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Chapter 3: Hempbrick

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Hempbrick

Characteristics Of Hempbrick

There is a growing interest in returning to the use of natural materials for building construction because of the growing understanding that they contribute to the long-term health of the structural fabric and its inhabitants. Timber, stone, dirt, animal hair, straw, hemp, lime, reed, and burned clay are parts of numerous natural materials used in construction. The most significant advantage of these materials is their versatility. Humans and other animals have been using them for ages, if not millennia, to keep warm and dry. Hempbrick is one of the new natural materials that has emerged due to this resurgence of interest in older approaches. These new materials and procedures are based on traditional technology but are adapted to fulfill our future construction demands.

Utilizing hemp in building construction is not revolutionary. During the sixth century, the Merovingians from France built their bridges using pillars set in mortar manufactured from hemp. To make mortar sturdier, the Romans would mix hemp fiber into it. Recent studies have proven that hemp is a feasible construction material due to its great thermoacoustic and sustainable features, although it is still illegal in many countries. Because of its adaptability, hemp is used to make a wide variety of products, including panels, covers, sheets, and even bricks.[25]

In the mid-1980s, French researchers experimented with diverse materials to discover a suitable substitute for deteriorated wattle and daub in medieval timber-framed buildings. They sought a substitute that would preserve a structure's health by maintaining its vapor-permeable

[25] Souza, Eduardo. "Hemp Concrete: From Roman Bridges to a Possible Material of the Future." *ArchDaily*. Last modified July 30, 2020. Accessed November 9, 2022. https://www.archdaily.com/944429/hemp-concrete-from-roman-bridges-to-a-possible-material-of-the-future.

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fabric while also providing insulation. The resolution was experimenting with hempbrick. A hempbrick wall has excellent moisture absorption and evaporation qualities. Hempbrick walls are good insulating material due to the large amount of air they can trap inside. The density added by the lime binder provides the completed material with considerable thermal mass.[26]

Hempbrick is made by combining the chopped stalk of the industrial hemp plant with a lime-based binder, and allowing it to cure, as discussed further below. Hempbrick provides a natural, healthy, sustainable, local, low-embodied-energy building material that has zero carbon. Carbon dioxide taken up by the plant when it was growing is locked up by the plant in its woody fibers, and at the end of the building life the hempbrick can be left to compost and be used as a soil additive rather than going into landfill.[27]

[26] Stanwix, William, and Alex Sparrow. *Hempcrete Book: Designing and Building with Hemp-Lime*. Uit Cambridge, 2014, 23.
[27] Global Hemp Group. "Are There Sustainability Advantages to Building with Hempcrete?" *GLOBAL HEMP GROUP*. Last modified April 3, 2021. Accessed December 13, 2022. https://www.globalhempgroup.com/global-hemp-group-blog/sustainability-advantages-to-building-with-hempcrete-d4x3g.

Figure 15. Hempbrick Characteristics + Metrics. Source: Homeland Hempcrete. Drawing by Author.

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Why Hempbrick?

As a highly insulating material with significant thermal mass, hempbrick has excellent thermal performance within structures of a building, and there is increasing evidence that it performs much better in real-life situations than is suggested by steady state modeling. Given its high thermal longevity, hempbrick warms up rapidly and holds its warmth when the outside temperature decreases, making the material a thermal insulator. Furthermore, hempbrick is naturally capable of absorbing and retaining moisture. According to a French study, it can hold up to 596 kg of water per cubic meter. It can endure a maximum relative humidity of 93% and still hold that much water. Due to its water and heat retention capabilities, hempbrick helps keep interior environments stable and comfortable. Walls, floor slabs, ceilings, and roof insulation benefit from using hempbrick since it is renewable, "breathable," and insulating.

Hemp can completely transform the construction industry. Traditional insulation methods are hazardous to the environment since they use nonrenewable resources. They have also been connected to a wide range of harmful impacts on health. Hempbrick is produced using a renewable resource that is biodegradable and can be recycled in other structures. It can decompose into the soil, enriching it with lime and organic materials, making the lime-based binder is the sole environmental cost of producing hempbrick.

Hempbrick is also long-lasting. Given its extended lifetime, insurance companies in the United Kingdom provide lower rates for houses insulated with hempbrick. Hempbrick useful properties include its resistance to fire, quick curing time, low weight, acoustical performance, and resistance to mold and insects.

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Furthermore, the cost of employing hempbrick as insulation is much cheaper than the materials mentioned. Hempbrick's structural properties are also improved. Because of their additional strength when paired with wood, wooden pillars, and columns, for example, may benefit more from their implementation. Every stage of the process, from harvesting the hemp plant to creating hempbrick to establishing a structure with hempbrick insulation, consumes significantly less energy than concrete and other conventional materials used in todays' building industry.

Problems with Hempbrick?

The two primary disadvantages of hempbrick are its structural fragility and the cost of building with it. Hempbrick walls do not bear compression well and require structural features to support any load. As a result, hempbrick has been used in conjunction with timber framing. More significantly, due to its porous structure, a hempbrick wall needs many casting and drying cycles, which is costly, time-consuming, and even weather dependent.

Several recent improvements resulted in approaches to speeding up construction with hempbrick. One approach is to make hempbrick bricks with the framework cast-in-situ. Another method employs prefabrication to bring conventional hemp building technology indoors, such as hardwood frames and shutters. Since several units may be worked on simultaneously while drying, this approach eliminates the weather constraint and offers economies of scale.

Hempbrick's ability to absorb water, which helps it to regulate indoor environments, can also be a challenge. A hemp hurd[28] can absorb four times its weight in water. When hempbrick is submerged in water for a lengthy period without adequate ventilation, biodegradation, freezing

[28] Hemp hurd: Because of its woodchip-like consistency, hemp hurd is called "hemp shives" and is derived from the hemp plant's lightweight, soft, woody core.

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complications, and the formation of salt crystals can diminish its overall durability. The curing period and permeability of hempbrick vary depending on the type of lime binder employed. Binding hempbrick with natural hydraulic lime (NHL3.5) enhances its capacity to release water vapor into the air while decreasing the volume of water it absorbs. This binder can minimize the increased risk of bio-decay found in carbonated limes.[29]

[29] Yadav, Madhura, and Ayushi Saini. "Opportunities & Challenges of Hempcrete as a Building Material for Construction: An Overview." *Materials today: proceedings* 65 (2022): 2021–2028. https://www.sciencedirect.com/science/article/pii/S2214785322039062.

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Application & Benefits + Threat of Hempbrick in Construction

Cast-In-Situ

Because of its lower compressive strength than other construction and its low conductivity, hempbrick is primarily used as insulation. There are several construction methods applied for hempbrick.

Cast-in-situ hempbrick is a method of construction in which hemp concrete is made on-site and then cast into forms using shuttering or formwork to construct a structure's walls, floors, and roofs. Hempbrick is not load-bearing; hence it is always cast around a structural frame (wooden structure) that carries the bulk of the building's weight. For the construction of new buildings, it is a standard procedure to build a softwood stud frame and embed it within hempbrick walls.

Several mechanical mixers are used to blend hemp hurd and binder with water. The most suitable one will depend on the volume needed, the application technique, and the location's accessibility. The mixed hempbrick should be inserted or sprayed into the area left by the wooden frame panels. After a brief setting, the wooden frame panels (if temporary) are removed, and the hempbrick is allowed to cure progressively over the following weeks.[30]

Spray-Application

Spraying hempbrick is a standard procedure across Europe, and while it has upsides and downsides, it remains a popular choice in the region. Machine design and tool innovations are constantly enhancing the process. The spray-applied method for cast-in-situ hempbrick is similar to the hand-placed approach but with total machine delivery.

[30] Stanwix, William, and Alex Sparrow. *Hempcrete Book: Designing and Building with Hemp-Lime*. Uit Cambridge, 2014, 29.

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The hemp and binder slurry are mixed at the sprayer's nozzle. When sprayed, hempbrick binds tenaciously to the surface it is applied. Hempbrick is typically laid out from this surface in many layers until the required wall thickness is attained. However, to make the most of this application technique, an open, easily accessible structural frame is essential, as spraying machines cannot spray around corners. The use of spraying has the potential to reduce the workforce size required to install hempbrick, especially on larger-scale structures. It is an excellent way to build large houses or residential apartments.[31]

Hempbrick Blocks

Considering the advantages of off-site drying, making hempcrete blocks is the most natural application for this material. However, this construction method is inherently inefficient due to the necessity for a mixer and formwork panels to create the block in the factory. Additionally, several steps are required to incorporate the block into the final structure. For a hempbrick wall, the blocks are moistened on the surface and layered with a thin mortar of hydraulic lime and sand. They are laid out in courses that prevent heat from escaping via the mortar joints between the outside and interior walls. The blocks are readily cut with a hand saw, which helps fit them precisely around the structural frame, but the frame should be designed around the size of the blocks to increase building speed and save waste.

[31] Ibid, 31.

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Pierre Chevet Sports Hall

Lemoal and Lemoal architects designed the Pierre Chevet Sports Hall in Paris, France; it is the first public building in the country to use hempbrick and timber structural components. The 4,000-square-foot facility includes a workout center and changing facilities with the sports hall's structural framework being partially vaulted.

The use of durable, high-performance materials was the priority for this project. Hempbrick blocks formed the walls integrated with wooden half-vaulted porticoes, expanding the space for sporting activities. These hempbrick blocks were applied because of their beneficial properties and high thermal, acoustic, structural, and fire-resistance performances. The plants used to make the fibers were grown around the project site in France, and the final product formed less than 300 miles away.

Hemp is often used inside or outside a building structure, with a finishing layer of plaster as the standard application. In the Sports Hall, an added layer of cladding protects the building's exterior and prevents damage during maintenance. The cladding panels were put in place independently to make it easier to repair them in the future. The internal walls of the lower floors were finished with hemp plaster, and the acoustic properties of the hempcrete blocks were optimized by leaving them exposed to the higher parts.[32]

[32] Kumar, Anand. "This Sports Hall in France Is the First Carbon-Negative Public Building in the World." *Wonderful Engineering*. Last modified December 23, 2021. Accessed June 5, 2023. https://wonderfulengineering.com/this-sports-hall-in-france-is-the-first-carbon-negative-public-building-in-the-world/.

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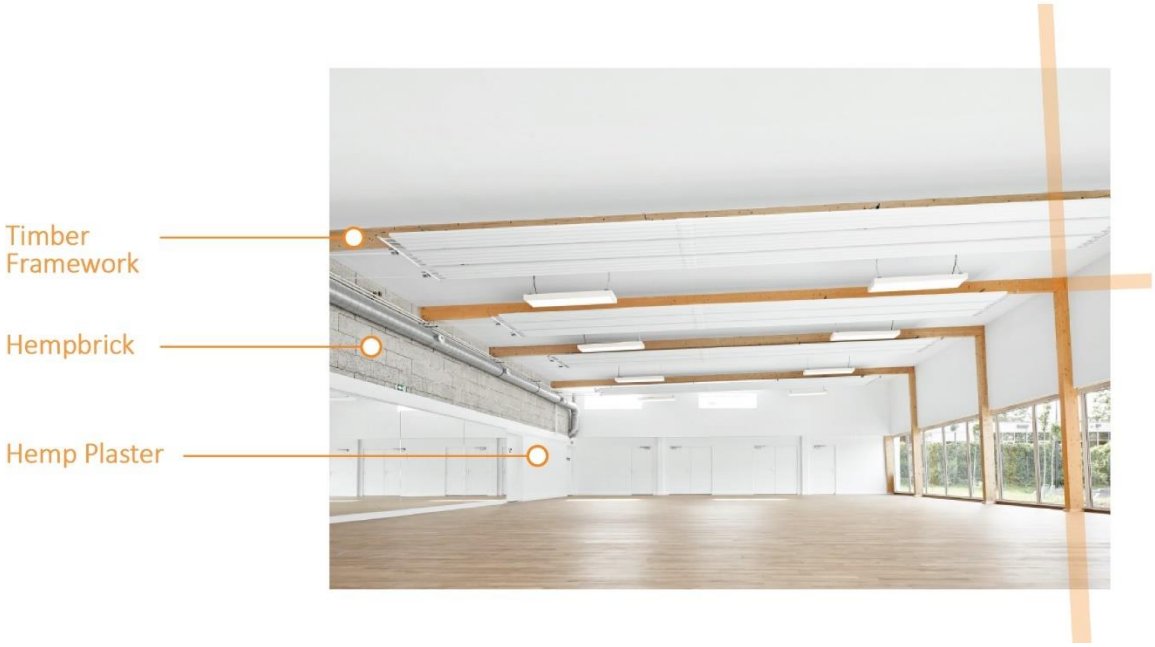

Figure 16. Pierre Chevet Sports Hall. Source: ArchDaily. Diagram by Author.

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The Voice of Urban Nature

The Voice of Urban Nature is made entirely of locally sourced and biobased materials, including its sturdy structural columns and prefabricated hemp-lime timber modules. The raw materials were acquired as close to Almere and Amsterdam as feasible. All the wood comes from local cultivation, trees cut down in nature preserves, or recycled sources in Amsterdam and Almere.

The hempbrick is created from hemp fibers cultivated in Almere and a pink color derived from madder plants growing in Brabant. Because it was critical to use locally obtained materials, Fiction Factory, the pavilion's developers, was involved in the design process. Before the final design was completed, they gathered the necessary resources to ensure the 100% local, biobased, and demountable principle was followed. At the end of the Expo, the pavilion's prefabricated and demountable components will be relocated to Almere or Amsterdam. After their lifecycle, the pavilion's modular components are broken down into non-hazardous compounds.

The six garden islands illustrate the potential for ecological diversity in urban settings. Each microhabitat focuses on a specific topic. Plants, soil organisms, and fungal cultures are all interconnected in this garden. In addition to showcasing how urban nature offers animal habitat, the garden of building and living also contains crops that humans utilize for construction materials. The food garden is a visual and aromatic celebration, full of familiar and exotic eating plants like sweet potatoes and others.[33]

[33] Caballero, Pilar. "Floriade Pavilion - the Voice of Urban Nature / Overtreders W." *ArchDaily*. Last modified September 14, 2022. Accessed June 5, 2023. https://www.archdaily.com/988920/floriade-pavilion-the-voice-of-urban-nature-overtreders-w.

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Figure 17. The Voice of Urban Nature. Source: Archdaily. Diagram by Author.

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The Push House

Despite its modest facade, the 3,400-square-foot Push House in Asheville, North Carolina, contains several cutting-edge innovations. Hempbrick is utilized for the house's walls and the lifts between the external supporting studs. Hemp hurds was mixed with lime and water on site. Hempbrick, the foundation of a breathable wall system, is non-structural and has more in common with filler straw bale than concrete.

It has a unique ability to absorb carbon and trap air pollutants over time and an insulating property of R-Value of 2.5 per inch when grown and applied. The material's high thermal mass also maintains a steady interior temperature. Pure panel, another one-of-a-kind product manufactured from recycled paper, is employed for the interior wall surface. It comprises a rigid skin with a corrugated paper core, like cardboard. Thirty reused window frames are also equipped with carefully positioned high-tech glass to provide maximum natural light without excessive heat accumulation. In conclusion, this home's $133 per square foot final cost may be attributed in part to its open layout, which lets in more natural light.[34]

[34] *Inhabitat.com*. Accessed June 5, 2023. https://inhabitat.com/nations-first-hempcrete-house-makes-a-healthy-statement/.

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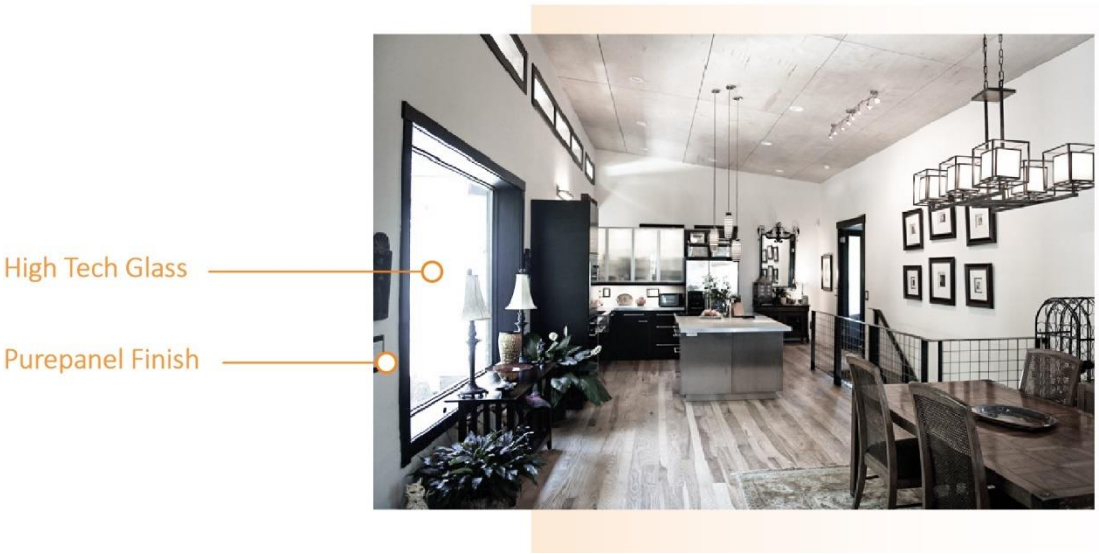

Figure 18. Paris-Saclay, Lisières Campus Sud. Source: Michel Desvigne Paysagiste. Diagram by Author.

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Natūralus Pluoštas

Natūralus Pluoštas (Natural Fiber) in Kdainiai FEZ, Lithuania is a hemp processing facility which specializes in cultivating and processing raw hemp material to create premium European-origin hemp fiber and wool for use in the textile and apparel industries globally. Their mission is to revive the centuries-old culture of hemp farming in the Baltics, Europe, while encouraging its usage in textile, sustainability, and environmentally friendly material. Natūralus Pluoštas, a division of the ICOR group, invested 8.2 million Euros into this venture. This facility contributes to the growing need for hemp on a global scale by manufacturing hemp fiber, shives for both textile and industrial purposes.

The facility can process 30,000 tons of hemp stalks annually, from which 10,000 tons of hemp fiber is extracted. This is projected to increase to 20,000 tons of hemp fiber annually once the factory's capacity expands to phase two. The facility's land area is 2.5 hectares, and the building is 7000 square meters. Natūralus Pluoštas provides hemp seeds to farms and guidance and harvesting services before purchasing the product from the farmers. The company expects to harvest 20,000 tons of hemp fiber on 2,000 acres.[35]

[35] "Natural Fiber." *Naturalfiber.Eu*. Accessed June 5, 2023. https://www.naturalfiber.eu/en/news/hemp-stalk-processing-factory-naturalus-pluostas-is-open.

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Figure 19. Half Natūralus Pluoštas. Source: Delfi. Diagram by Author.

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Chapter 4: Agrivoltaics

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Challenges + Response for Agrivoltaics

The Significance of Agrivoltaics

Food production will need to quadruple in the next three decades to meet the demands of a growing population. At the same time, the resources for this food production are dwindling. According to the World Bank, agriculture uses over 70% of global freshwater withdrawals. If we continue with typical agricultural practices, there will not be enough water to produce even our current level of food production, much alone what we will need by 2050, due to the fast changes occurring within the global climate.

Combining food and energy production, a concept known as Agro-Photovoltaics (APV) or Agrivoltaic, is generating significant attention as a possible answer. Farming beneath a solar panel canopy enables farmers to generate power while increasing crop yields.[36]

Implications Affecting Agriculture

In the United States, farmers have been heavily impacted by a perfect storm of economic meltdown brought on by low commodity prices, trade disputes, and climate change. More than 100,000 farms in the United States closed between 2011 and 2018. As a result, the potential to utilize land more economically while still producing crops for the country is a lifeline that could save many farmers from going bankrupt.[37] Farmers must investigate a variety of alternatives to keep their financial side of the business in the context of development demands, growing expenses, and decreasing profits.

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[36] "SunBioSys – Combining Agriculture and Solar Power to Achieve Impact and Higher Yield per Hectare…." Sunbiosys.Eu. Accessed June 5, 2023. https://sunbiosys.eu/.

[37] Ferrell, Matt. "Solar Panels plus Farming? Agrivoltaics Explained." *Undecided with Matt Ferrell - Exploring How Technology Impacts Our Lives*. Undecided with Matt Ferrell, October 5, 2021. Accessed June 5, 2023. https://undecidedmf.com/episodes/solar-panels-plus-farming-agrivoltaics-explained/.

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Possible Response

In addition to conserving water and building long-term food production systems, researchers from Oregon State University discovered that converting just 1% of American farmland to agrivoltaics could yield 20% of total U.S. power with minimal compromise. Farmers all around the globe are adopting this practice. Implementing solar panels on farms will only solve some issues facing the agricultural sector. While it may not be the perfect solution, it is a tangible, achievable approach for addressing climate change and changing American agriculture towards more sustainable production.[38]

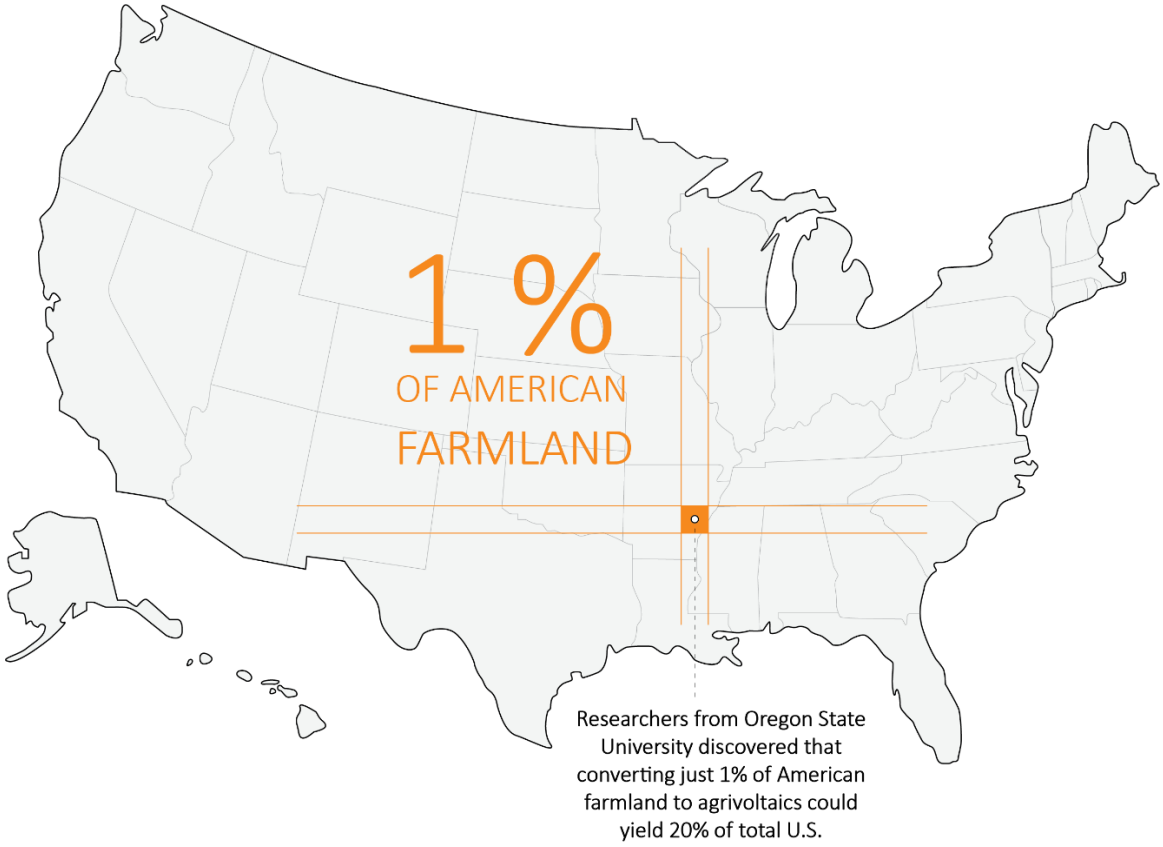

Figure 20. Covering American Farmland to Agrivoltaics. Source: Oregon State University. Drawing by Author.

[38] Bryce, Emma. "On a Mere 1% of Farmland, Solar Panels Could Provide 20% of US Electricity." *Anthropocene | Innovation in the Human Age*. Anthropocene Magazine, January 15, 2021. Last modified January 15, 2021. Accessed December 13, 2022. https://www.anthropocenemagazine.org/2021/01/on-a-mere-1-of-farmland-solar-panels-could-provide-20-of-us-electricity/.

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Solar parks

There have been solar parks in rural regions for over two decades. The main concern with these solar projects is that the land below them is unusable since current agricultural equipment cannot fit through the narrow gaps between the rows of panels. A conventional solar park serves grazing poultry, geese, sheep, and raising beehives. These organisms assist solar farms since they eat unwanted vegetation but do not harm the panels themselves, lowering maintenance costs. However, this is not the case with larger mammals like pigs, goats, horses, or cattle.

Alternatively, crops can also be planted in the empty areas between the solar panel rows. Since part of the land is used for solar energy and a portion for farming, it is still classified as "alternating land use" rather than "dual land use." Areas between rows will be shaded during certain hours of the day, changing the properties of the soil and the varieties of crops that may be cultivated.

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Symbiotic Relationship

The Application of Agrivoltaic

Agro-Photovoltaics (APV) allows for greater synergies than traditional solar and agriculture applications. By mounting panels on stilts, it allows agricultural equipment to pass below. To protect stilts from machines, maintain a particular distance between rows in this design.

Panels are installed using actuators instead of permanent panel installation, enabling the panels to tilt in one or two directions, allowing for both solar energy and plant development optimization. It is imperative during the early phases of development for various crops.[39] Thus, solar panels strategically placed immediately above each crop growing area could perfectly control how much sunshine reaches each plant, allowing for maximum growth with minimal water waste. If solar panels are placed above the plants, they could harvest the sunlight that usually is discarded. By positioning the panels above the ground, cattle, farm employees, and even agricultural machinery may work comfortably in the cool shade under the canopy.

It is a symbiotic relationship that benefits both parties. Plants planted immediately beneath solar panels contribute to keeping the panels at a comfortable temperature. The heat may cause damage to solar panels, reducing their productivity. According to OSU studies, panels positioned suitably over plants can enhance electricity generation by up to 10%. Furthermore, excess electricity can be stored in batteries or distributed to the grid. As a result, the sun's light is being used efficiently in two ways: first, to grow valuable crops, and second, to generate a second source of cash from the generation of solar power.

[39] "SunBioSys – Combining Agriculture and Solar Power to Achieve Impact and Higher Yield per Hectare…." Sunbiosys.Eu. Accessed June 5, 2023. https://sunbiosys.eu/.

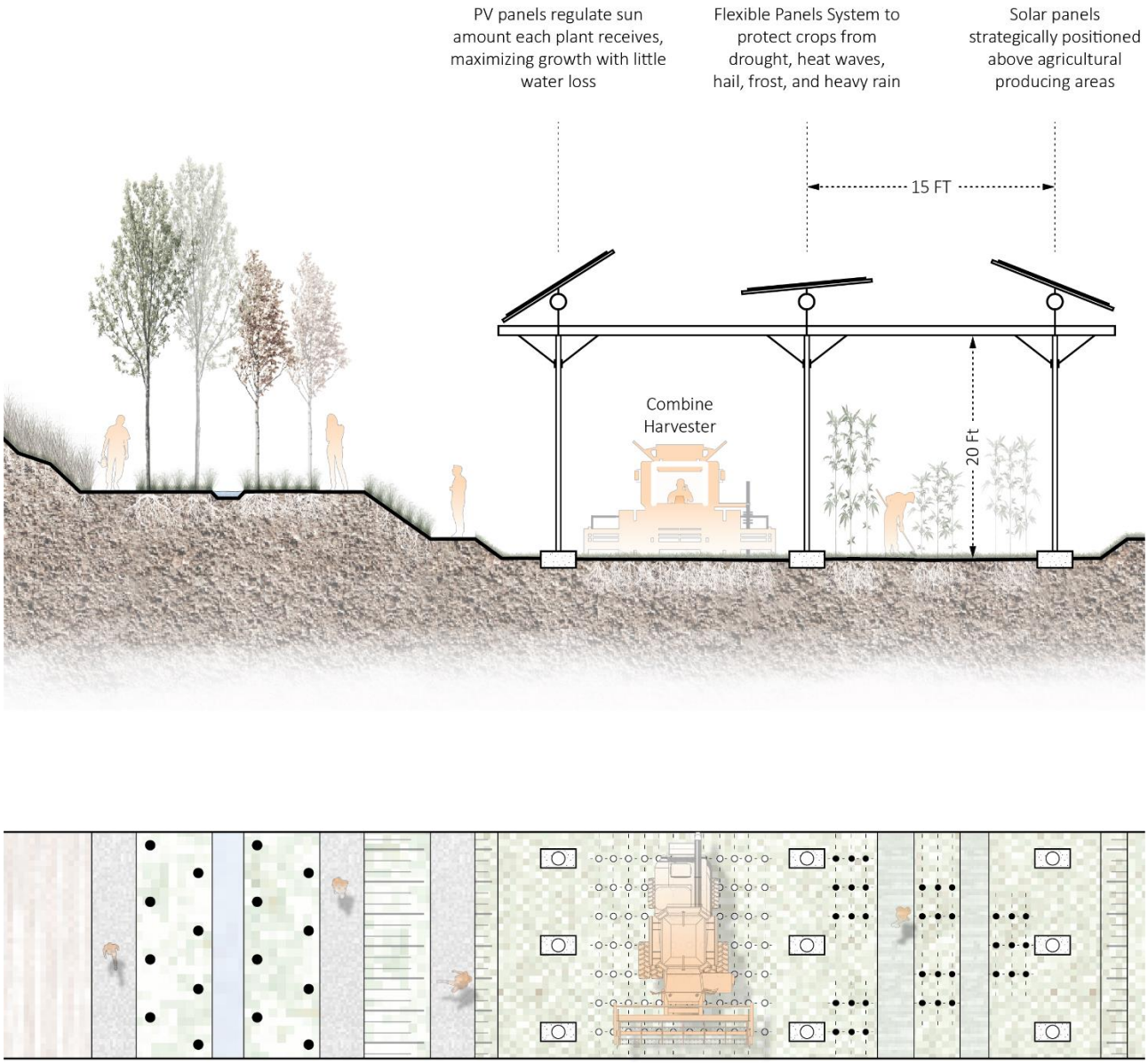

Figure 21. The Application of Agrivoltaics with Hemp. Drawing by Author.

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Case Study: Sun'Agri

As part of a program to investigate how agrivoltaics perform in specific crop environments, a subsidiary of French solar developer SunR has constructed a viticulture agrivoltaic system in the wine-producing area of Piolenc in Herault in Southeastern France. The experiment collaborates with the local chamber of agriculture as part of a program funded by the French environmental and energy management agency. A system of 280 panels with a generating capacity of 84 kilowatts covers 600 square meters. The panels are positioned 4.2 meters (14 feet) above ground and operated by an artificial intelligence system developed by Sun'Agri over a decade. The soil quality, climate, and crop growth model are all included in the algorithm that evaluates the optimal panel tilt. In addition, the system can move the panels into an appropriate position to shield crops from climate extremes, including drought, heat waves, hail, frost, or heavy rain.[40]

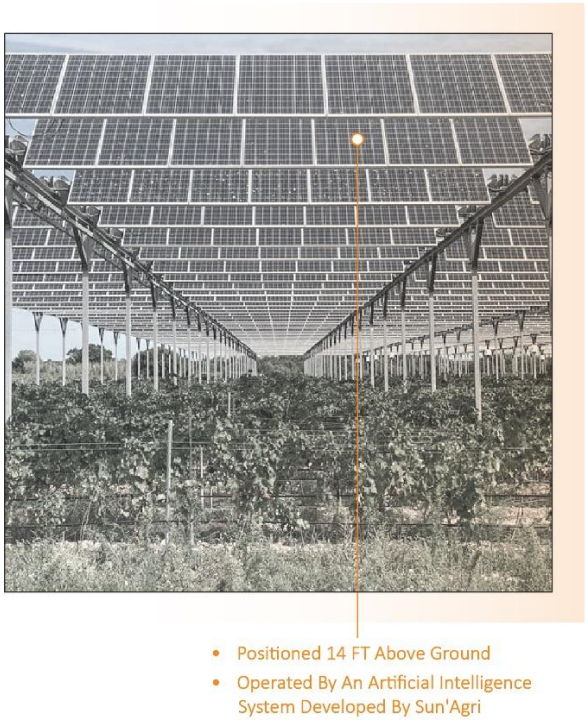

Figure 22. Agrivoltaics Artificial Intelligence System Developed by Sun'Agri. Source: Sun'Agri. Diagram by Author.

[40] "Accueil - Sun'R." *Sun'R*. Last modified January 6, 2022. Accessed June 5, 2023. https://sunr.fr/.

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Technology of Agrivoltaic

Early Stages

Although APV's fundamental ideas have been established for four decades, the field remains in its beginning phases. It has just lately begun to develop. More effort is undoubtedly needed to ensure its economic viability on a global scale, and research is underway to determine the best methods to modify the system for growing as wide a variety of fruits and vegetables as feasible. The potential of agrivoltaics is undeniable, and the technology has the potential to significantly reduce tensions between agricultural landowners and solar developers in densely populated regions. Freestanding APV installations also provide a valuable habitat for other plants and wildlife. With careful management the extra protection from excess harmful sunlight improves the health of the soil and increases the level of nutrients creating important ecosystems for plants and insects, which in turn increases the availability of food for field animals as well as birds and bats, including important pollinator species that help improve crop production.

Agrivoltaics technology itself is improving all the time. Panels can now be made translucent to allow finer control of the amounts and specific wavelengths of light that are either absorbed by the panels or allowed through to reach the crops. And there are even completely mobile PV systems like this one from U.S company tracker Sled, providing plug and play style modularity and mobility regardless of what the terrain or topography it's deployed on.[41]

[41] "SunBioSys – Combining Agriculture and Solar Power to Achieve Impact and Higher Yield per Hectare…." Sunbiosys.Eu. Accessed June 5, 2023. https://sunbiosys.eu/.

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Chapter 5: Agritourism

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What is Agritourism?

About Agritourism

In addition to photovoltaics, agritourism represents an opportunity for small farms to increase revenues by using land for multiple purposes.

Agricultural tourism, also known as agritourism, varies significantly from one region of the country to another. According to the American Farm Bureau Federation, agritourism is an operation at a functioning farm, ranch, or agricultural plant performed for the delight of visitors that provides revenue for the farm. The term agritourism describes traveling to a functioning farm or other botanical or agricultural enterprise for the dual purposes of leisure and education. Additionally, it allows visitors to take part in the daily activities of the farm or participate in the agricultural process.[42]

Farmers can keep more profits from directly selling their crops to customers through roadside booths and other retail establishments that add value to agricultural goods. Tours, workshops, overnight stays, corn mazes, harvest festivals, and other similar activities are examples of how farms are used for educational or recreational purposes for agritourism. Agritourism can also include the use of farms for private events like weddings, receptions, and parties.

[42] "Agritourism Overview." *National Agricultural Law Center*. Last modified May 31, 2013. Accessed November 25, 2022. https://nationalaglawcenter.org/overview/agritourism/.

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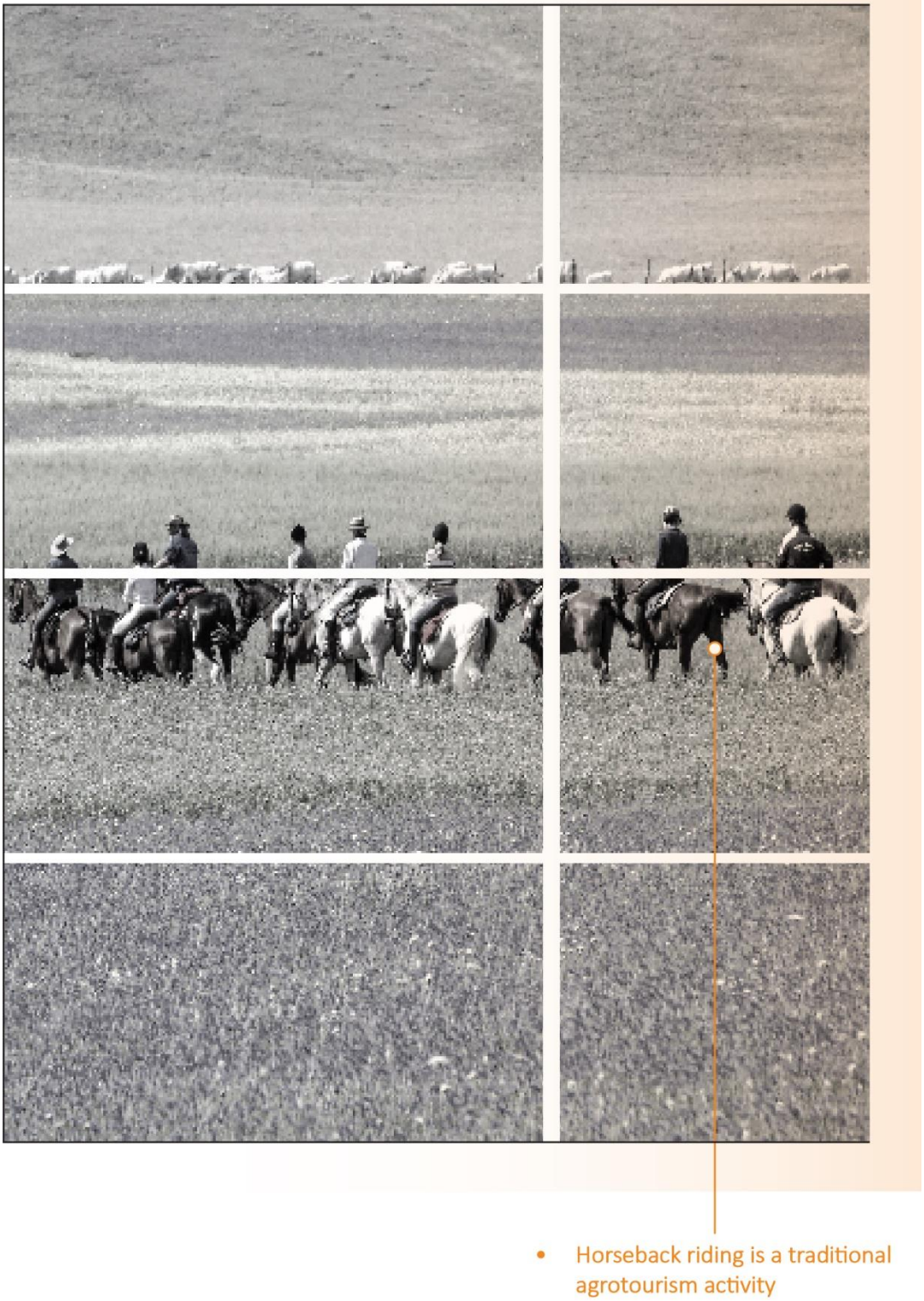

Figure 23. Horseback Riding into The Farmland. Source: Shutterstock. Diagram by Author.

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Agritourism Services

The spectacular natural landscape, clean air, and rural architecture contribute to agritourism's attraction. Humans participate in agritourism as it satisfies their emotional need for animal interaction and social benefits, but most importantly, it satisfies their desire for rural scenery uncluttered by architecture. Products and services offered by agritourists fall into various categories. They range from agri-food and beverages; primary agritourism; agri-recreation and agri-sport; agri-therapy, and cultural tourism. Within each specific activity category, products and services are distinguished.

Farm stays, cottage stays, agri-hotels, self-service beds, and agri-camping are all distinct types of agri-tourism accommodations. When it comes to agritourism, agri-food services are essential. There are four agri-food services: home meals consumed by the farmer's family, picnics in the fields, canteens, and restaurants managed by farmers or food-processing businesses. Primary agritourism refers to farm-based tourism that revolves around the actual farming process. Primary agritourism offers experiences like farm tours, zoos, safaris, and hands-on encounters with animals and the environment, as well as the chance to see crops grow or livestock be raised, or even help prepare beverages.

Agritourism offers a market opportunity for such commodities through direct sales of farm products, "pick your own" sales, stands with agricultural produce, and farm shops. Agri-sport is a broad term that includes many different types of outdoor recreation, including strolling, hiking, horseback riding, activities that call for an extensive area, hunting, and fishing. In conclusion, agritourism's ability to provide a diverse range of services is evidenced by the scope and scale of its range of goods, services, and other activities.[43]

[43] Sznajder, Michal, Lucyna Przezborska-Skobiej, and Frank Scrimgeour. *Agritourism*. Edited by M. Sznajder, L. Przezbórska, and F. Scrimgeour. Wallingford, England: CABI Publishing, 2008.

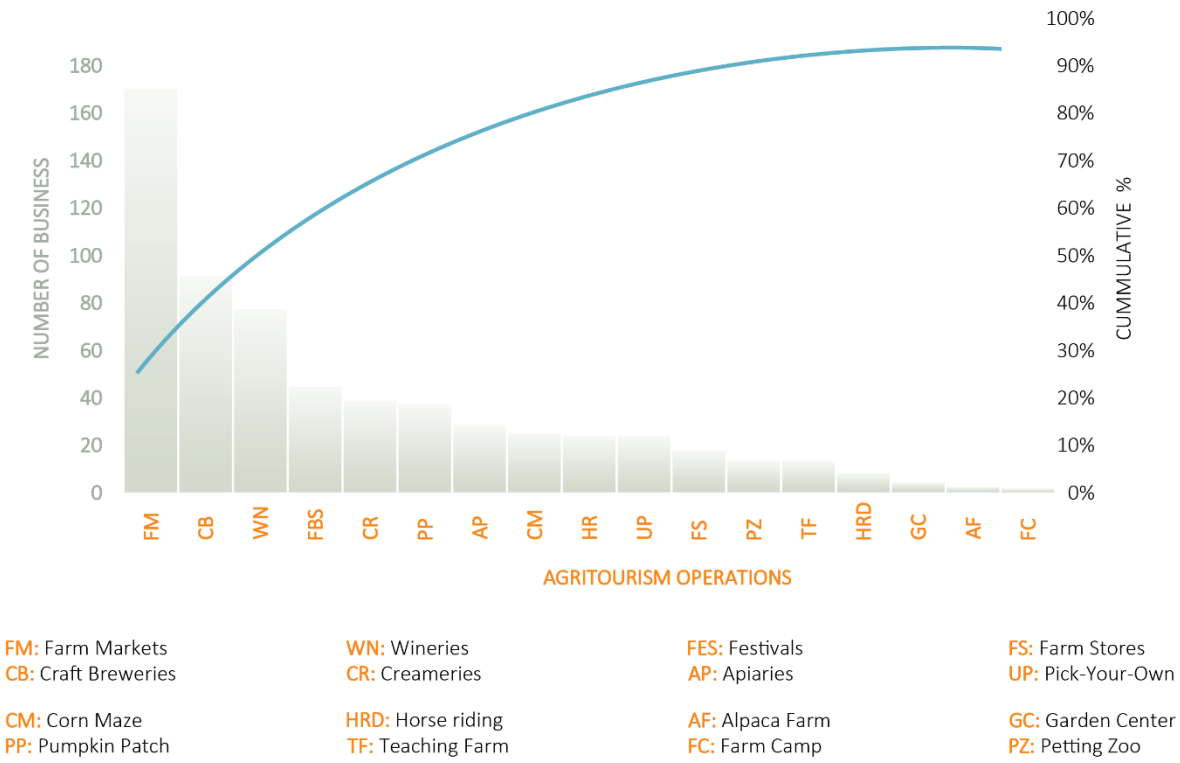

Figure 24. Frequency of Agritourism Services in Maryland. Source: UMES Extension. Drawing by Author.

Figure 25. Median Income Level by County. Source: UMES Extension. Drawing by Author.

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The Importance of Agritourism

The growth of agritourism has provided farmers with a new source of revenue and an approach to direct marketing. By providing a source of revenue beyond conventional farming, agritourism can support farmers and preserve farmland for productive use. According to the Census of Agriculture, the income generated by farms through agritourism has increased dramatically, tripling between 2002 and 2017. After adjusting for inflation, income from agritourism increased from $704 million in 2012 to about $950 million in 2017. Revenues from agritourism only accounted for 5.6% of all income from farms that year.[44]

Economic activity from agritourism significantly increases when farms are situated near natural attractions or in proximity to outdoor activities. Although farmers in less populated areas were more likely to pursue agritourism, those in more populous counties generated more money from farming and livestock overall. Local food sales tend to be greater in general on farms that are closer to cities.[45]

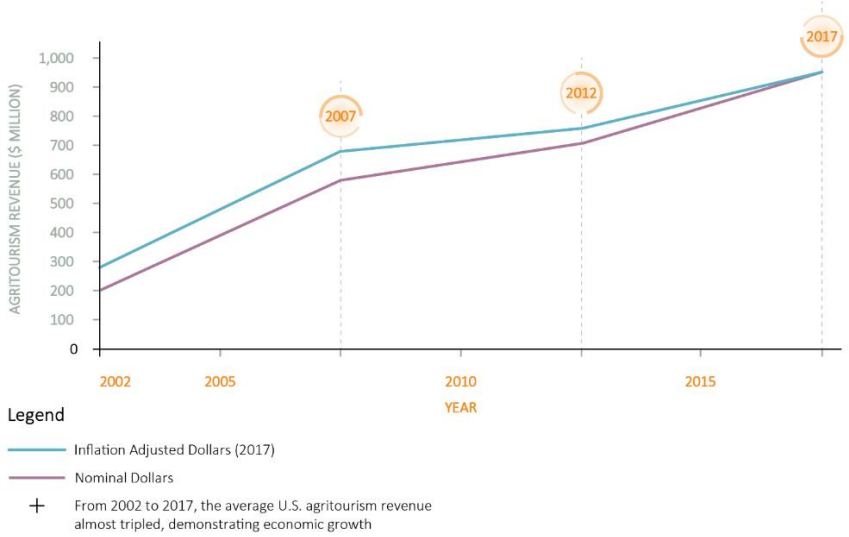

Figure 26. Agritourism Revenue Tripled Between 2002 and 2007. Source: ERS.USDA. Drawing by Author.

[44] Whitt, Christine. "Agritourism Allows Farms to Diversify and Has Potential Benefits for Rural Communities." *Usda.gov*. Accessed November 26, 2022. https://www.ers.usda.gov/amber-waves/2019/november/agritourism-allows-farms-to-diversify-and-has-potential-benefits-for-rural-communities/.
[45] Ibid.

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Agritourism in Maryland

UMES (University of Maryland Eastern Shore) has spent the last few years expanding its extension programs with federal and state funding to serve the community of Maryland. Agritourism is one of the sectors that has been identified for improvement. Maryland's General Assembly enacted House Bill 252 in 2018 to establish agritourism in the state. The law defines agritourism as any activity on a farm that is open to the public for tourism, recreation, or educational experiences.

United States Agricultural Income Decline

There has yet to be a statewide inventory of Maryland's agricultural tourism resources. Across the state of Maryland, there are currently 485 agritourism sites. The metropolitan region of Washington and Baltimore has the highest concentration of agritourism. The western portion of Maryland and the Eastern Shore have a far more minor concentration of agritourism opportunities, yet they continue to prosper in agriculture.

Agritourism principles in Maryland extend well beyond conventional farming to encompass a wide range of additional objectives, such as conserving natural resources, economic growth in rural areas, and preserving ecological biodiversity.

Throughout the state, farm markets account for most of this service. Then comes the vineyards, creameries, bee farms, and agricultural festivals. Distribution of these types of services differs by county and area. Agricultural markets are in the metropolitan counties in the north-central part of the state.

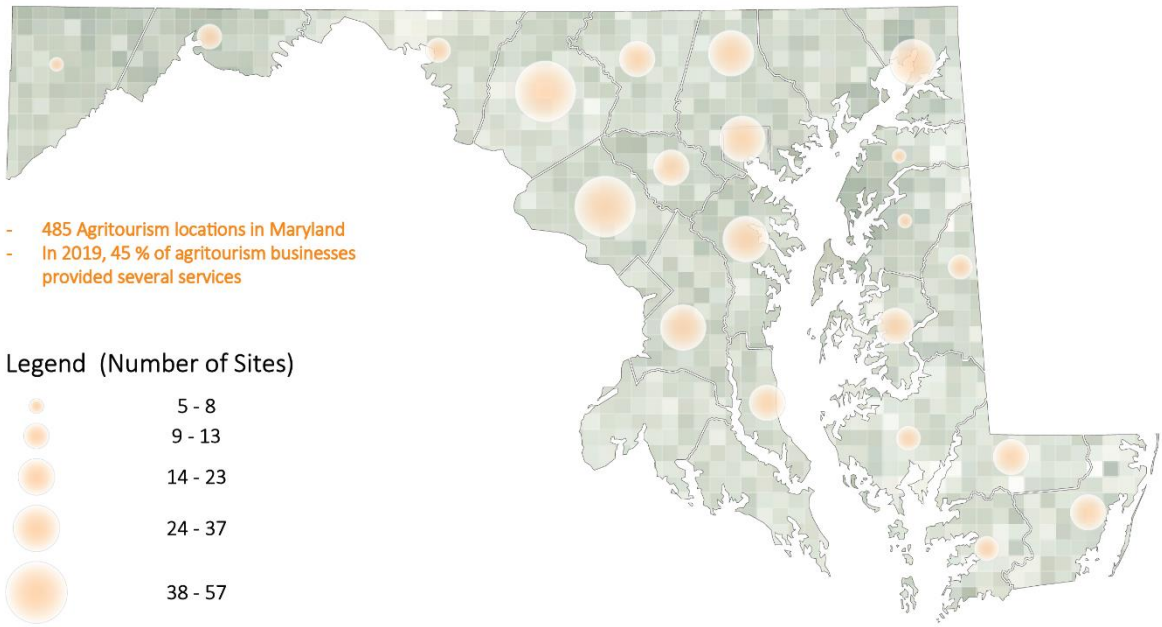

Figure 27. Agritourism Locations by County. Source: ERS.USDA. Drawing by Author.

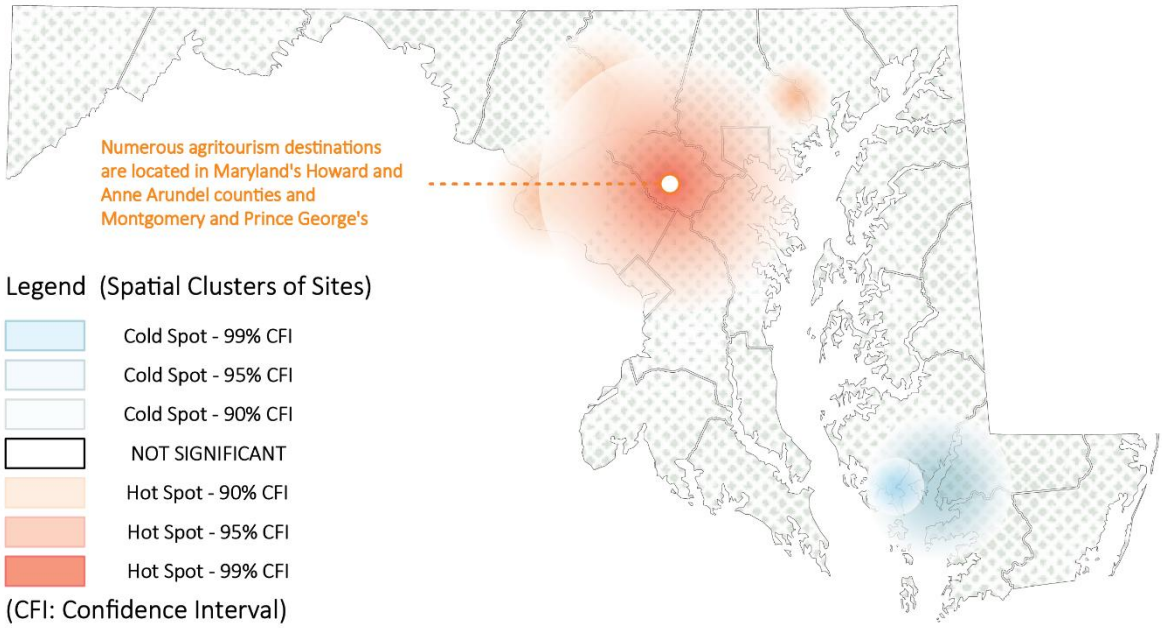

Figure 28. Agritourism Locations Clusters. Source: ERS.USDA. Drawing by Author.

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Factors Affecting Participation & Location of Agritourism Facilities

Agritourism's stakeholders and operators are primarily influenced by two sets of circumstances: location-based and consumer considerations. Based on characteristics of the proximity to major metropolitan centers, as cultural hubs and economic powerhouses, these cities can draw tourists from all over the state and even the world. The population concentration represents the local financial strength. Considering how close and easily accessible the state's major roads are to these agricultural areas, this is an essential part of the state's transportation infrastructure. After plotting the median income throughout all counties, it varied from $40,000 in the south to $100,000 in the north-central urban counties.[46]

Consumers Proximity

Given the importance of location to the success of agritourism ventures, it is crucial to situate operations close to potential users. Agritourism destinations are in each county's leading cities with populations greater than 10,000 residents. The average distance between cities and agritourism destinations was around two miles.

A good transportation infrastructure is vital for agritourism. As a result, the proximity and accessibility of the destinations are relevant. Agribusiness access to transportation lines influences the demand for cost-effective labor. Labor is typically seasonal at many agritourism facilities.[47] The US-40 has the most accessible ways, with more than 600 routes to typical tourism destinations, including most routes to agritourism sites. It implies that the US-40 in the north-central area is a significant node for agritourism growth.[48]

[46] *Umes.edu*. Accessed November 25, 2022. https://wwwcp.umes.edu/extension/wpcontent/uploads/sites/Maryland-Agritourism-Study_PDF-1.pdf, 27.
[47] Ibid, 19.
[48] Ibid, 23.

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Income Generator

What piqued the interest of small and medium-sized farmers in agritourism is the market to generate additional revenue to keep agricultural holdings, maintain assets, and for employment. There have been three surges in agritourism growth during the last 15 years. It happened in 2002, 2007, and 2012. It demonstrates the rises in revenue from peak average income from agritourism across the United States every five years.

Maryland's income from agritourism has been steadily increasing in our region over the last few decades, notably in Montgomery and Frederick counties. These two counties have routinely recorded significant agritourism profits. Montgomery County had a 27.8% increase in annual earnings from agritourism. Montgomery earned 2.8 million dollars from agriculture in 2002 but 14.5 million dollars in 2007. Frederick County had a similar tendency, with a 13.5 percent yearly revenue increase.

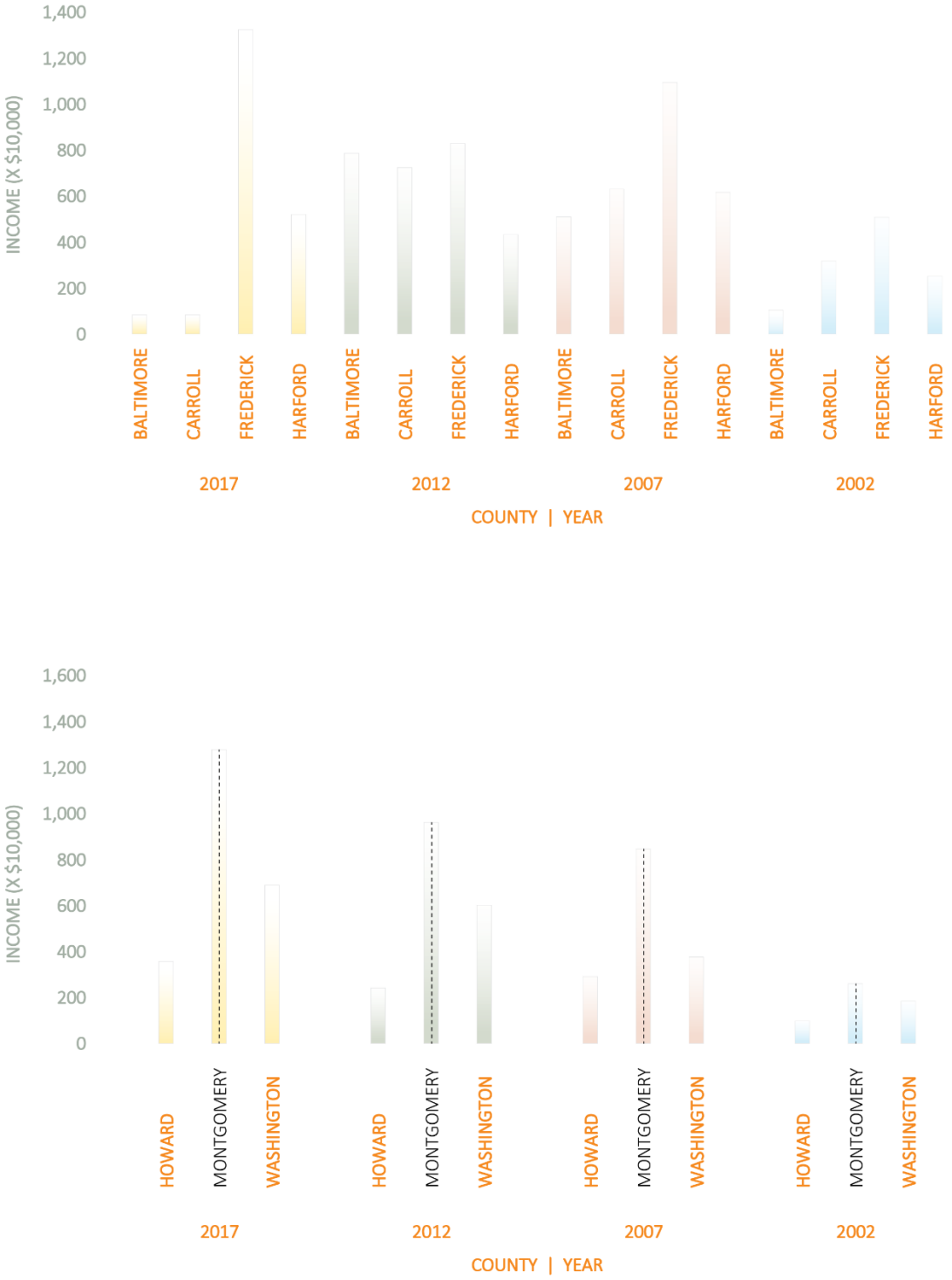

Figure 29. Revenue from Agritourism Recreational Activities. Source: UMES Extension. Drawing by Author.

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The Challenges & Future of Agritourism

One of the most significant challenges is the inconsistency in legal frameworks and regulations regulating agritourism. There is also the question of direct marketing products from farm to table. Other problems include privacy concerns, the opening of farmlands to leisure, and the installation of long-lasting road signs—the transportation network's difficulties. Seasonal labor was also mentioned as a challenge—establishing networking possibilities and training in agritourism technologies such as marketing.

The growing number of farms and ranches that rely on agritourism should encourage more producers to learn more about the industry. Due to the decline of small and medium-sized farms and ranches, agritourism revenue provides a realistic approach to keeping these farms alive, especially in areas that are popular with tourists. The keys to success and development obstacles in agritourism might be uncovered with further study. Eventually, we will better understand the characteristics of successful operations and the factors that led specific farms to embrace agritourism.

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Chapter 6: The Site

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Prince George's County

Prince George's County, Maryland, is a local government that includes urban, suburban, and rural communities east of Washington D.C. In addition to the Port of Baltimore, the region is served by three major international airports. Baltimore (BWI), 21.3 miles away; Washington Reagan National Airport (DCA), 22 miles away; and Washington Dulles International Airport (IAD), 32.5 miles away, are the nearest airports. Prince George's County's electronics and aerospace sectors are growing, and tourism is thriving. SGT, Inovalon, Verizon, and MGM National Harbor are among the top private enterprises contributing to the local economy yearly.[49]

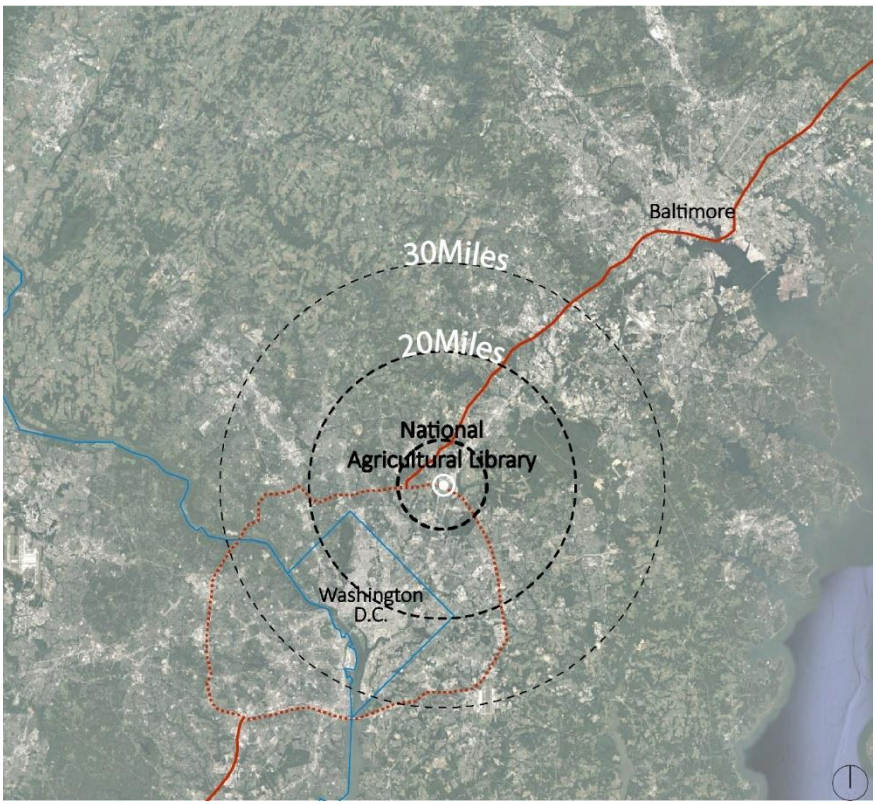

Figure 30. Site Overview. Source: Google Earth. Diagram by Author.

[49] County, Prince George's. "Brief Economic Facts." *Maryland.gov*. Accessed June 5, 2023. https://commerce.maryland.gov/Documents/ResearchDocument/PrGeorgesBef.pdf.

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Beltsville, Maryland

According to the United States Census Bureau, Beltsville has a total area of 7.2 square miles, of which 7.1 square miles are land, and 0.38% is water[50]. Beltsville, Maryland, is easily accessible by Interstates 95 and 495 and Route 1 and 50. The proposed location will include the Beltsville Agricultural Research Center, the USDA Agricultural Research Center, and the National Agricultural Library in Beltsville, Maryland. The 105-acre farming parcels intersect Route 1. A mix of uses, including commercial retail, single-family homes, apartment developments, and industrial facilities, borders the community.

Figure 31. Site Context. Source: Google Earth. Diagram by Author.

[50] "Beltsville Agricultural Research Center : USDA ARS." *Usda.gov*. Accessed June 5, 2023. https://www.ars.usda.gov/northeast-area/beltsville-md-barc/beltsville-agricultural-research-center/.

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Zoning

The site is currently zoned R-O-S (Reserved Open Space), allowing farming, large-lot dwellings, and public preservation zones. For this development to comply, a change to the current zoning ordinance will be necessary to allow for Commercial Service Commercial (C-S-C) district. The inclusion of this new specialty crop within the context of agriculture is consistent with the concept behind the National Agricultural Library, which serves as a resource for individuals interested in learning more about the vast varieties of plants and how they can improve the quality of their surrounding ecosystems.

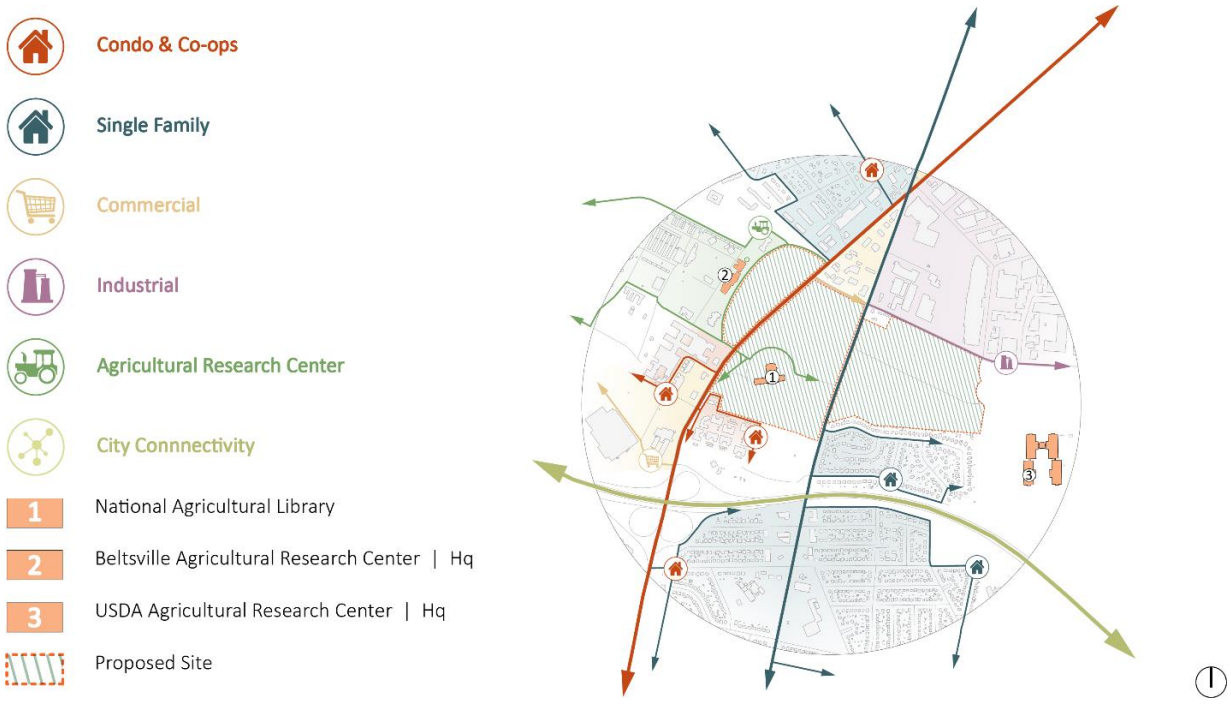

Figure 32. Zoning Analysis. Source: Zoningpgc. Drawing by Author.

Transportation

Interstates 95 and 495, U.S. Routes 1 and 50, all connect to Prince George County. MARC (Maryland Area Commuter) trains serve nine stations around the county along the Baltimore-Washington corridor. Washington Metropolitan Area Transit Authority operates 70

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bus lines and a rail system WMATA [51]. Prince George's county has been working to strengthen its transportation network, especially as a county heavily reliant on automobiles.

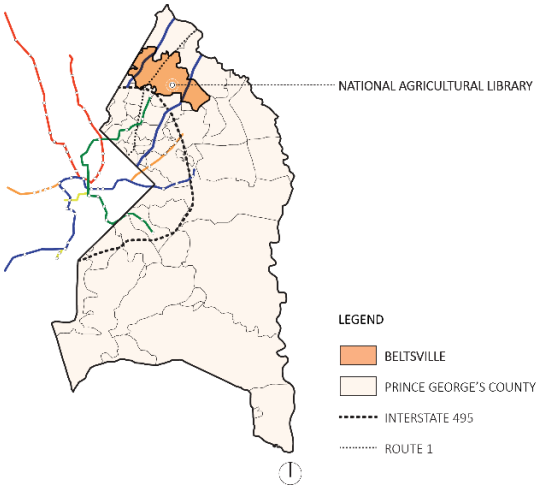

Figure 33. Prince George's County Transit way. Source: PGTransit. Drawing by Author.

The Purple Line will be a 16-mile light rail line between Bethesda in Montgomery County and New Carrollton in Prince George's County. It will directly connect to the Metrorail Red, Green, and Orange Lines. The Purple Line will connect to local bus routes, the MARC rail, and Amtrak. Despite their proximity to Washington, D.C., a relatively small fraction of workers in each district commute using public transportation. The average commute time for Prince George's County residents is 37 minutes, which is 4.0 minutes longer than Maryland's average.

COMMUTERS - PRINCE GEORGE'S COUNTY	RATE
Workers with 60+ minute commute	**19.5%**
Left for Work from 12 AM to 6 AM	17.3%
Worked Outside County of Residence	18.6%
Drove alone	65.9%
Carpooled	10.4%
Walked to Work	1.8%
Public Transportation	13.1%
Worked from Home	6.5%

Figure 34. Commuting in Prince George's County. Source: Stacker. Drawing by Author.

[51] County, P. G. (n.d.). *Brief Economic Facts*. Maryland.gov. Retrieved February 12, 2023, from https://commerce.maryland.gov/Documents/ResearchDocument/PrGeorgesBef.pdf

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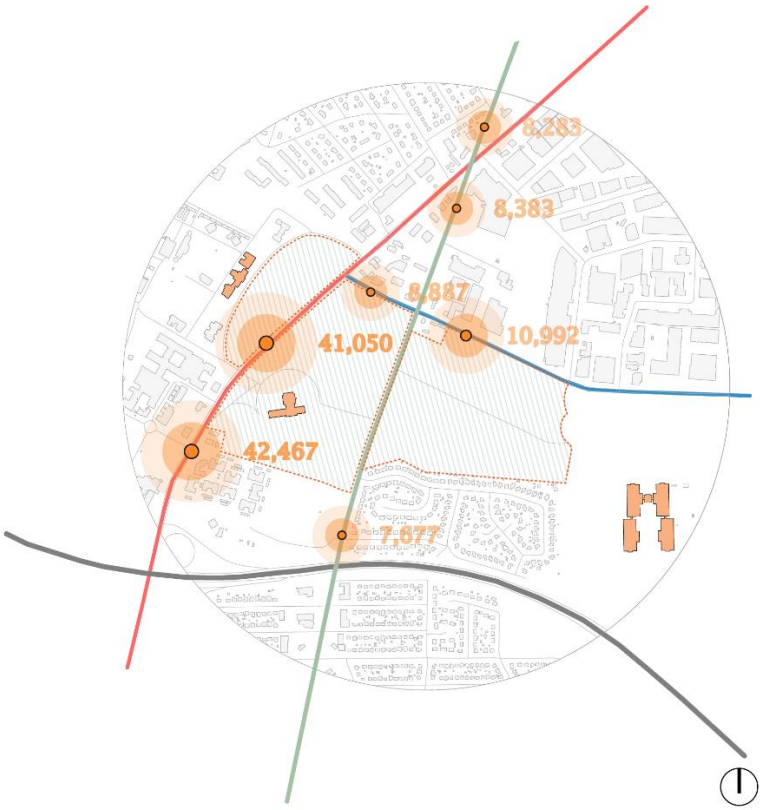
Due to its proximity to the intersection of Baltimore Avenue and Rhode Island Avenue, the proposed site is located in a very congested area. The average daily traffic volume on Baltimore Avenue is 41,050 vehicles; however, according to AADT (Annual Average Daily Traffic), 50,000 vehicles may be considered a considerable level of traffic, drawing much attention to the site.[52]



	STREET	CROSS STREET	COUNT YEAR	AVERAGE DAILY VOLUME
1	Baltimore Avenue	Sunnyside Avenue	2022	41,050
2	Sunnyside Avenue	Rhode Island Avenue	2020	8,887
3	Rhode Island Avenue		2022	8,383
4	Sunnyside Avenue	Rhode Island Avenue	2021	10,992
5	Rhode Island Avenue	St Marys Street	2022	8,283
6	Rhode Island Avenue	Paducah Road	2022	7,677
7	Baltimore Avenue	Ikea Center Boulevard	2022	42,467

Figure 35. Beltsville Traffic Count Report + Site Analysis. Source: Costar. Drawing by Author.

[52] "Office of Highway Policy Information - Policy." *Dot.gov*. Accessed June 5, 2023. https://www.fhwa.dot.gov/policyinformation/hpms/volumeroutes/ch5.cfm.

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Pedestrian Infrastructure

Beltsville has a walk score of 39, a total of 29 for the transportation system, and a score of 42 for bicycling, with a population of 17,922.[53] Pedestrian crosswalks and proper pedestrian access must be improved in schools, public transit, parks, and other community centers.

National Agricultural Library

The United National Agricultural Library (NAL) in Beltsville, MD, is one of the five national libraries in the US (along with the Library of Congress, among others) and one of the world's largest agricultural research libraries. U.S. Department of Agriculture (USDA) field libraries are coordinated via this organization, as is the Agriculture Network Information Center (AgNIC), a national network of state land-grant colleges. While all NAL's holdings are available at the library's physical location, the library is constantly innovating new ways to make its collections available to consumers worldwide via the ubiquitous Internet and the adaptability of digital forms.[54]

[53] "Beltsville Apartments for Rent." *Walk Score*. Accessed June 5, 2023. https://www.walkscore.com/MD/Beltsville.
[54] *Librarianshipstudies.com*. Accessed June 5, 2023. https://www.librarianshipstudies.com/2020/11/united-states-national-agricultural-library-nal.html.

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Figure 36. National Agricultural Library Site Plan. Source: GIS Map. Drawing by Author.

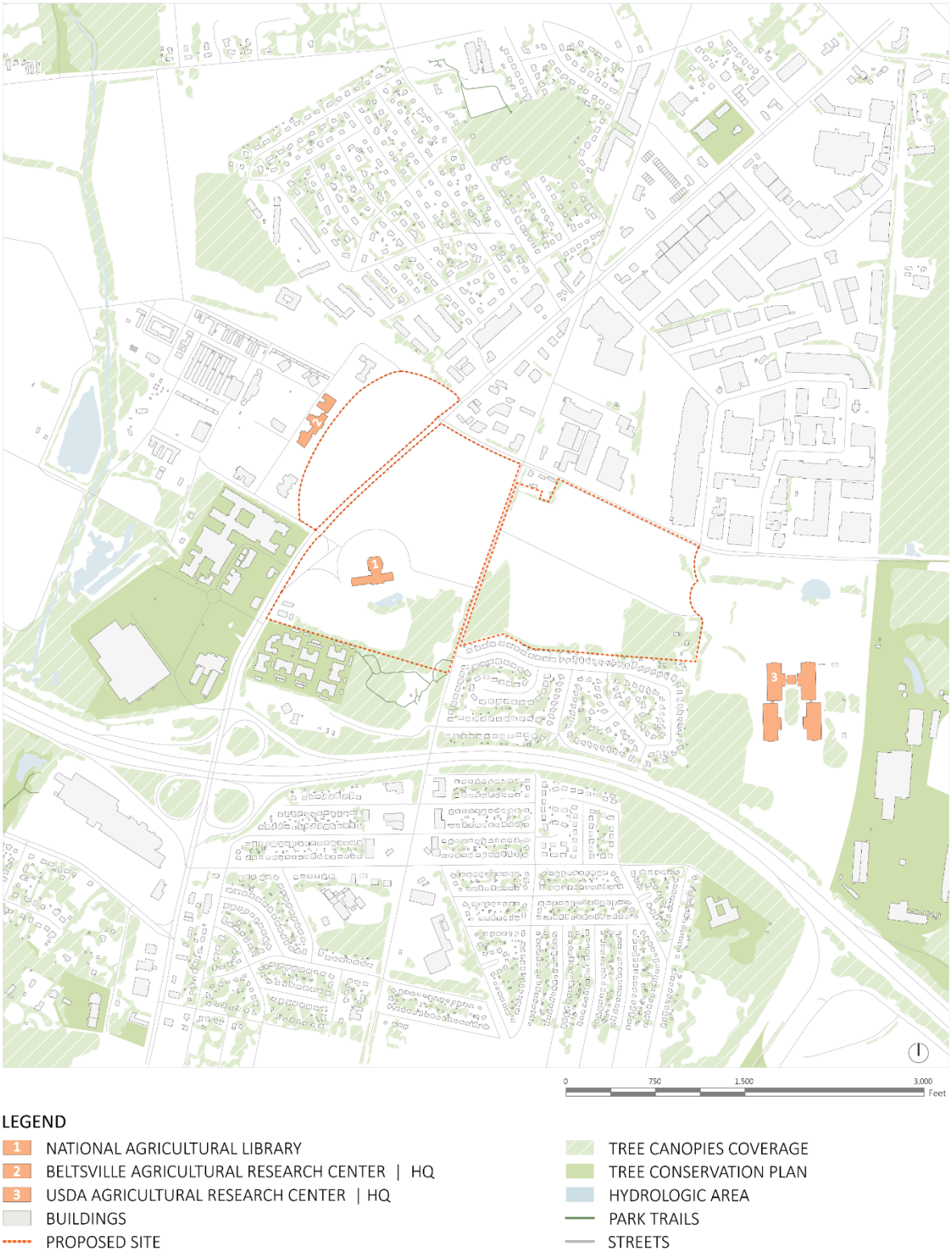

Figure 37. National Agricultural Library Urban Tree Canopies. Source: GIS Map. Drawing by Author.

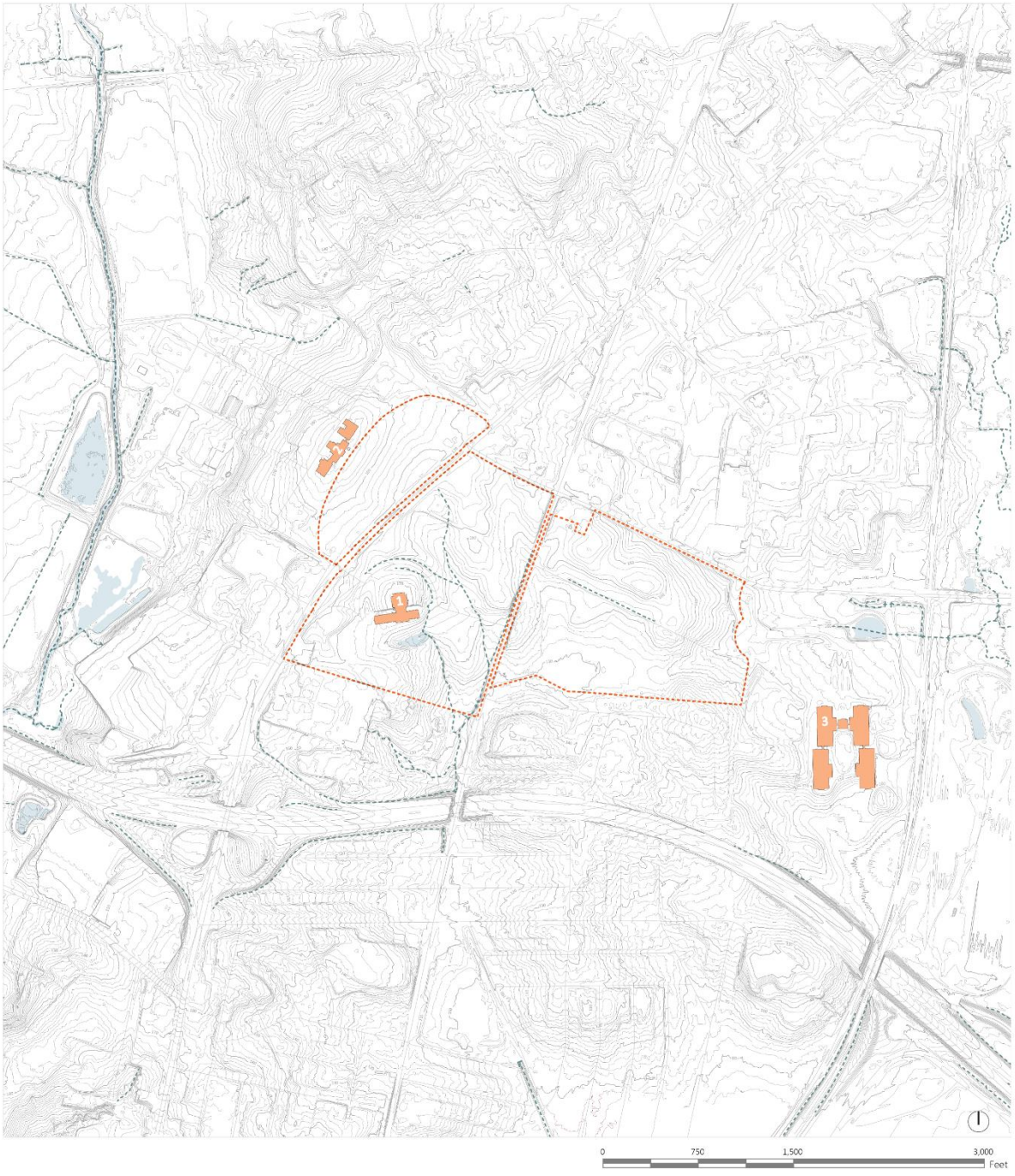

Figure 38. National Agricultural Library Topography + Hydrology Context. Source: GIS Map. Drawing by Author.

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Location

The National Agricultural Library, located in Beltsville, Maryland, is 15 miles northeast of Washington D.C., near the intersection of U.S. Route 1 and Interstates 95 and 495. The central library is housed in the seventeen-story Abraham Lincoln Building in Beltsville, Maryland. It is located on the Henry A. Wallace Beltsville Agricultural Research Center grounds. In addition, NAL operates the Reference Center in Washington, District of Columbia. This branch is located at the USDA's South Building.

Site History

On May 15, 1862, Abraham Lincoln signed the Organic Act that established NAL. In 1863, the library's collection contained 1,000 works from the Agricultural Patent Office. By 1889, the library had 20,000 books, so an Amherst College librarian was hired to establish a categorizing system. The library was located on the second floor of USDA's main headquarters. In 1893, William Cutter was appointed Department Librarian, and he modernized and renovated the library. The library relocated to the USDA's Independence Avenue South Building in 1932. Throughout WWII, the USDA was restructured to meet the demands of the war requirements. On the 100th anniversary of the library's founding, Orville Freeman renamed it the National Agricultural Library, making it the third national library in the United States. Congress appropriated funds in 1964 to plan a new library in Beltsville, Maryland, on the grounds of the Beltsville Agricultural Research Center. The new facility was constructed between 1965 and 1969. In 2000, Dan Glickman christened the Abraham Lincoln Building structure.[55]

[55] Ibid.

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Site Selection

The National Agricultural Library in Beltsville, Maryland, is one of four national libraries in the United States. It holds information relevant to agriculture and related disciplines. The collection's range and depth make it a one-of-a-kind resource, with many materials not found anywhere else in the world.

Given the site's background and history, it is the best urban location for the demonstration of this thesis proposal. The National Agricultural Library is already a knowledgeable setting and is a landmark in the area complemented by the Beltsville Agricultural Research Center and USDA Agricultural Research Center; adding a "Productive Hemp Mosaic Landscape" to this campus would influence public Agritourism experiences and new construction ecologies. Existing campus structures would complement the proposed program.

Figure 39. Site Surroundings. Sources: Costar. Images + Drawing by Author.

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Chapter 7: The Design

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The concern

Regarding overall global greenhouse gas emissions, construction operations account for 28%, while building components account for 11%. Reducing carbon dioxide emissions during construction and the use of building materials with reduced carbon footprints are critical to mitigating these consequences. These issues could be resolved using industrial hemp, a carbon-negative crop and a practical choice for sequestration.

By using hemp as a construction material, we can improve the thermal efficiency of our buildings, consequently reducing operational carbon. Finally, by substituting hempbrick, a mixture of hemp and various binders, for more carbon-intensive materials, we can reduce the embodied carbon of the built environment.

This thesis proposes a productive hemp landscape that will be open to the public as an agritourism destination. The project will raise public awareness about hemp cultivation as an agricultural opportunity and demonstrate the potential of hemp as a construction material, highlighting its multiple possible contributions to tackling the climate crisis.

Design Parameters

During the design process, it was critical that this development be visible from the street and accessible from more than one street corridor. Another criterion for integrating the construction within the site was to create an interaction between the current campus and the proposed building.

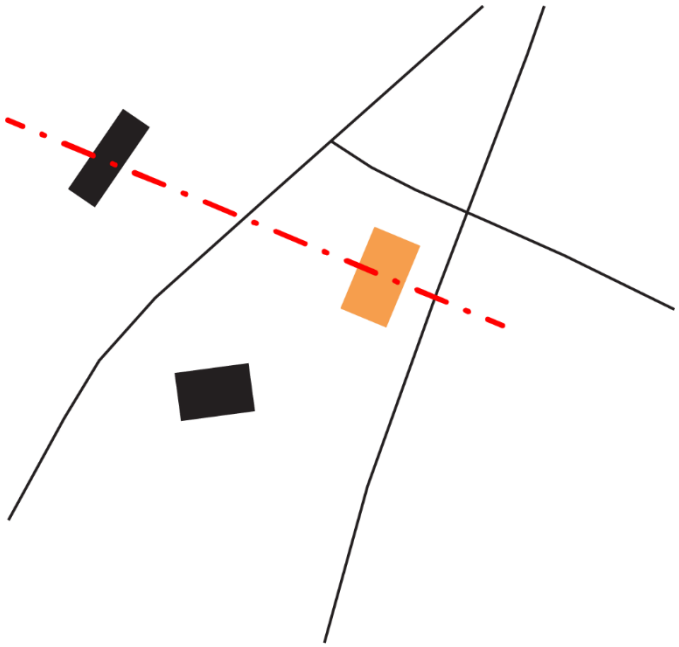

Figure 40. Axial Relationship. Drawing by Author.

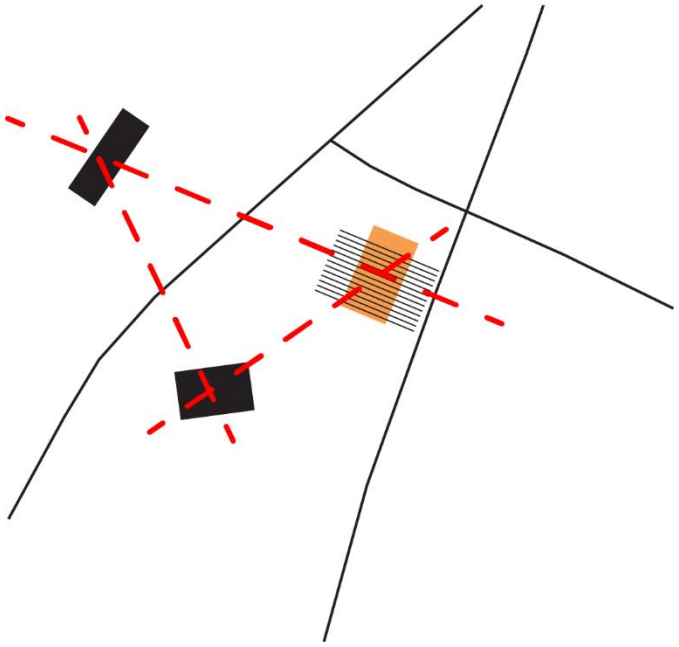

Figure 41. Campus Relationship. Drawing by Author.

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Hemp Mosaics

Various hemp mosaic designs were developed to choose a location for The Intersection and how it would relate to the current campus. Another component that was considered was the visitor experience. The idea was to create an environment where visitors could walk through the hemp mosaics landscape rather than the combine harvester circulation pathways.

Figure 42. Hemp Mosaics Study Scenarios. Drawing by Author.

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Proposed Site plan

The Intersection is integrated into an existing campus that includes the Beltsville Agricultural Research Center Headquarters and the National Agricultural Library. The Intersection is surrounded by a hemp mosaics landscape extending on 77 acres. Prospect mounds can be spotted throughout the hemp landscape. These mounds rise around 8 feet above the ground and will act as a viewing platform for tourists exploring the hemp mosaics surroundings.

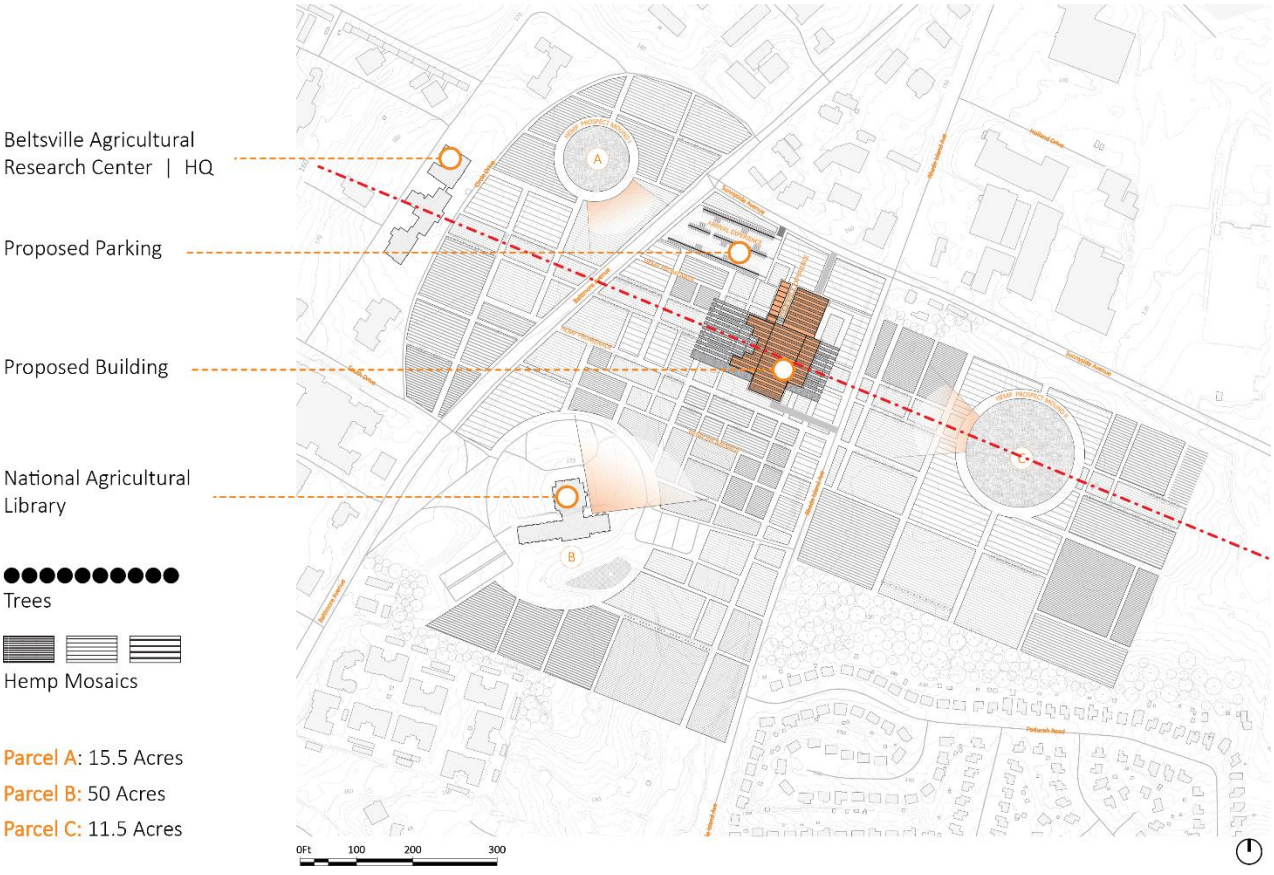

Figure 43. Proposed Site Plan. Drawing by Author.

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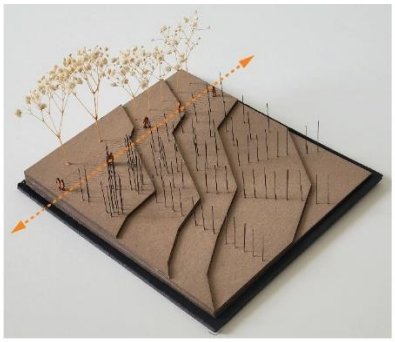
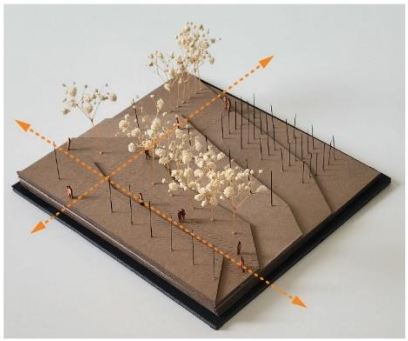
Visitor Promenade Experiences

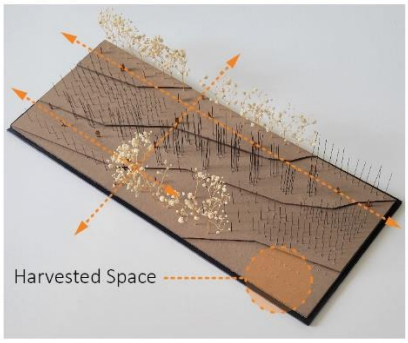
While designing the hemp mosaics landscape, several techniques were considered. One of the strategies used was to imagine what kind of human promenade experience could be created by integrating trees with hemp mosaics.



Scenario I: Single Path Experience + Trees Experience



Scenario II: Dual Path Experience + Trees Experience



Scenario III: The Synthesis

Figure 44. Proposed Hemp Mosaic Experience. Model + Diagram by Author.

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Site Organization

The Intersection is positioned on an axis with the Beltsville Agricultural Research Center Headquarters and a prospect mound. It is also accessible via Baltimore Avenue and Rhode Island Avenue. The development's orientation allows visitors to have direct internal and external visual relationships with the hemp mosaics landscape. A series of hemp plants will greet visitors arriving at the site before approaching the Visitor Center. The exterior hemp mosaic landscape includes The Visitor Promenade Experience and The Combine Harvester Circulation Pathway.

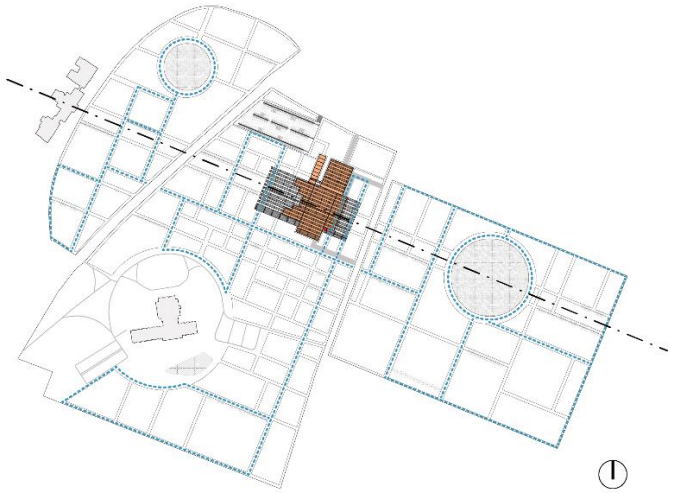

Figure 45. Combine Harvester Paths. Drawing by Author.

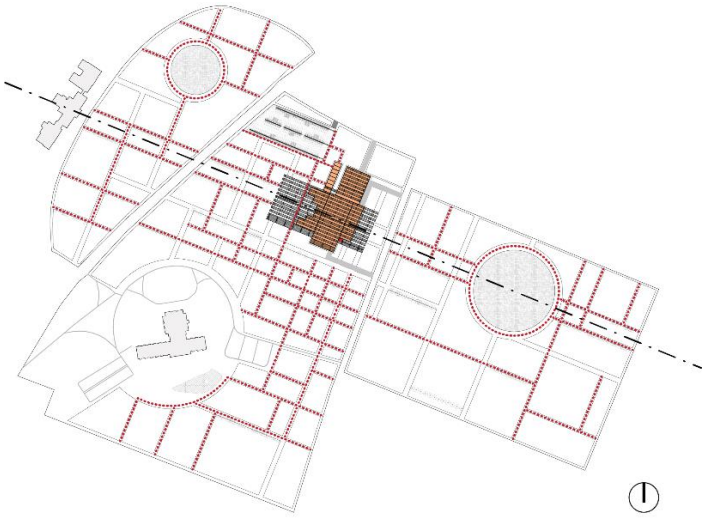

Figure 46. Visitor Experience. Drawing by Author.

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The synthesis of The Visitor Promenade Experience and The Combine Harvester Circulation Pathway demonstrated that both could coexist within this productive hemp mosaics landscape.

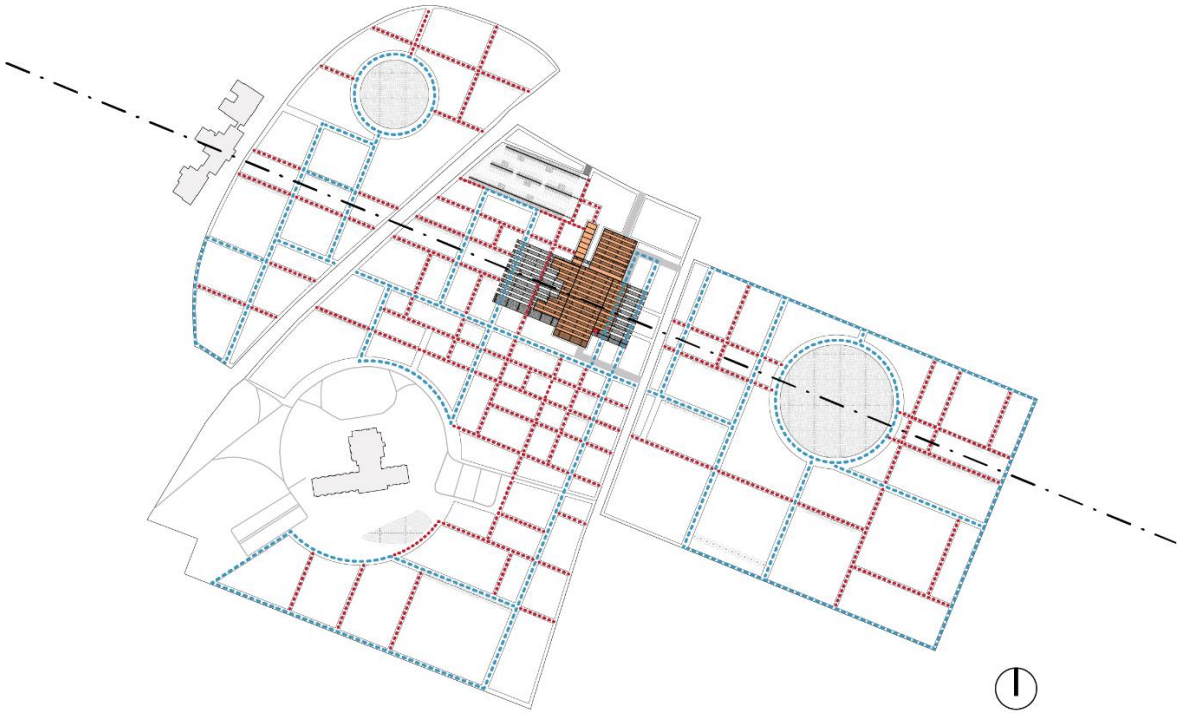

Figure 47. The Synthesis. Drawing by Author.

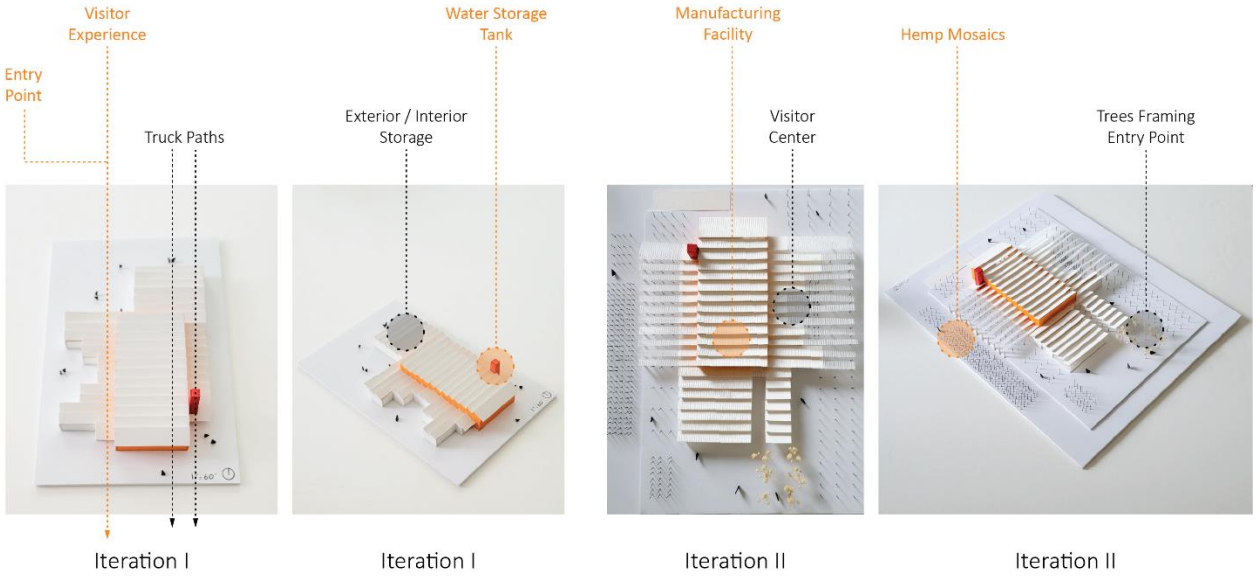

Figure 48. Study Models. Model + Diagram by Author.

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Harvesting and Storing Hemp

There are several hemp harvesting techniques available to enhance land efficiency. Hemp is easily cultivable without pesticides and provides an environmentally beneficial culture, mainly because it requires minimal maintenance and nearly no watering. Hemp is a partly resistant plant with a high growth rate that takes minimal energy. Hemp supplies rapid cultivation and a sustainable yield within a four to five-month life cycle.

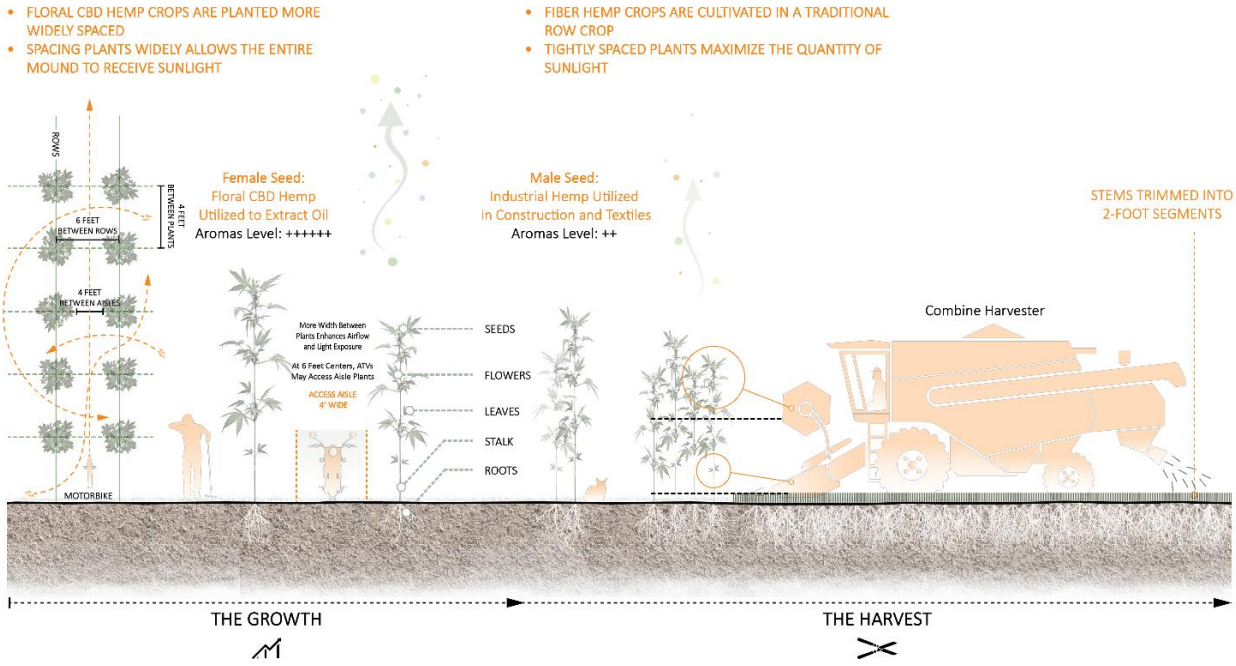

Figure 49. Harvesting Hemp. Drawing by Author.

Fiber hemp requires retting, a procedure that begins after cutting. Retting separates hurd and bast fibers by breaking the chemical bonds between them. Field retting includes leaving plants exposed to exterior conditions for an extended period. Depending on the available equipment, hemp is packaged into round or large square bales. Hemp should be stored in a secure, temperature-controlled area for maximum efficiency.

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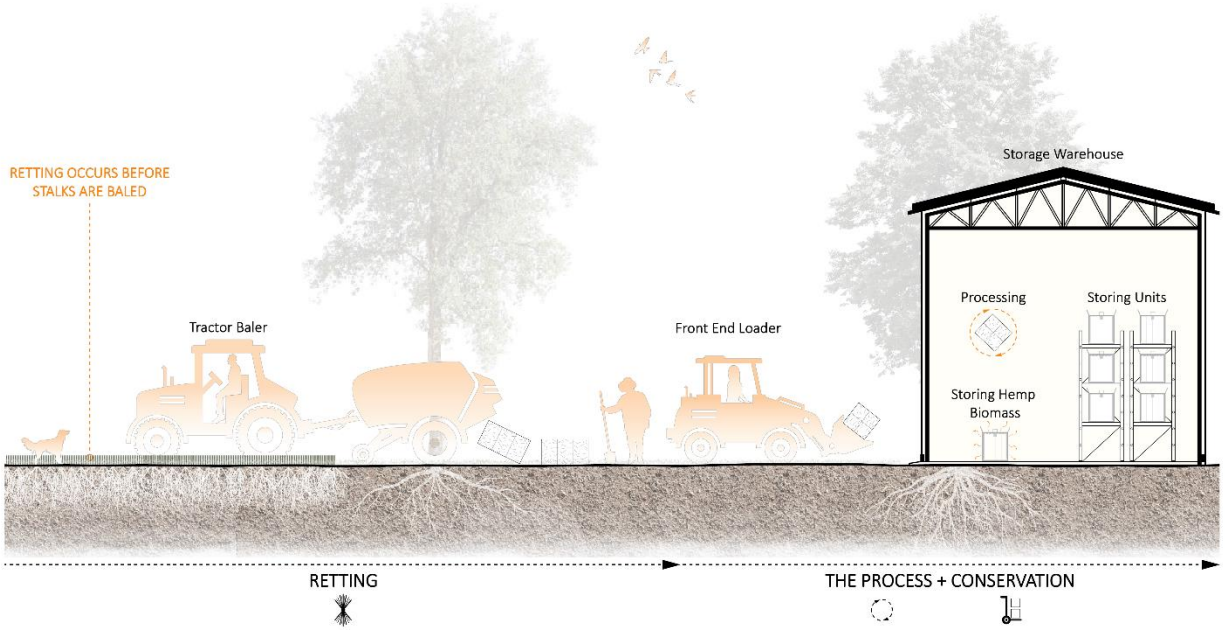

Figure 50. Storing Hemp. Drawing by Author.

Construction

The intended construction of this project will consist of five stages. The overall development period will be approximately 4 years, from initial planning to final project stabilization. Hempbrick is a novel building material (in the United States) that may lead to delays in the approval process owing to unfamiliarity with the construction documents.

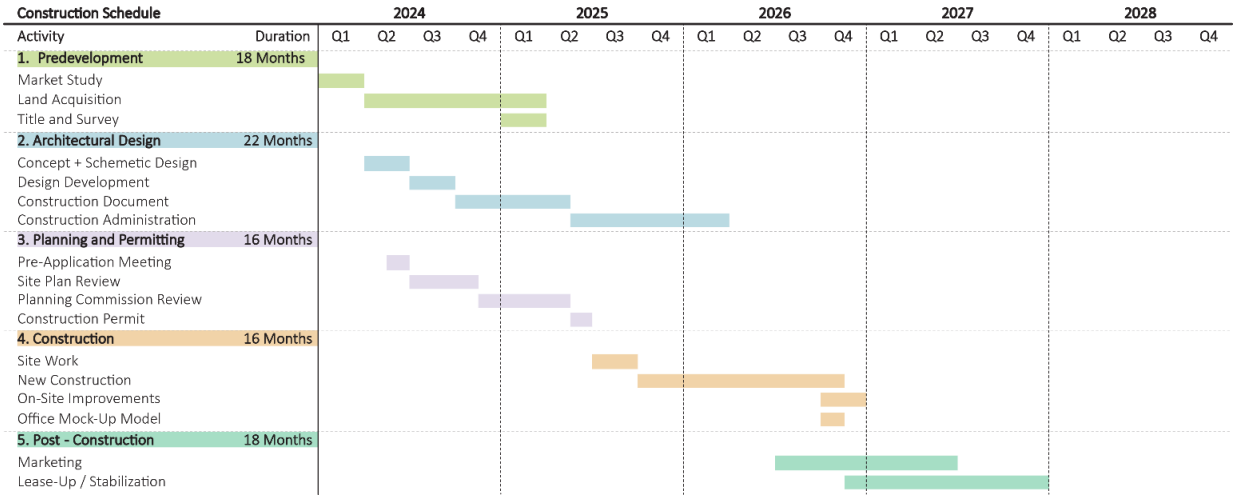

Figure 51. Construction Schedule. Drawing by Author.

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All the biogenic materials utilized in this development will be carbon neutral. These include CLT, timber, and hempbrick. The building will consist of hempbrick dyed orange to insulate the walls and CLT panels for the floors and roofs. To offer structural support, glulam columns, and beams will be employed. Additionally, concrete will be applied for the foundation. Crushed seashells will be implemented as a promenade and parking lot surface. Low-E (Low-Emissivity) glass will surround the windows on the exterior of the structures.

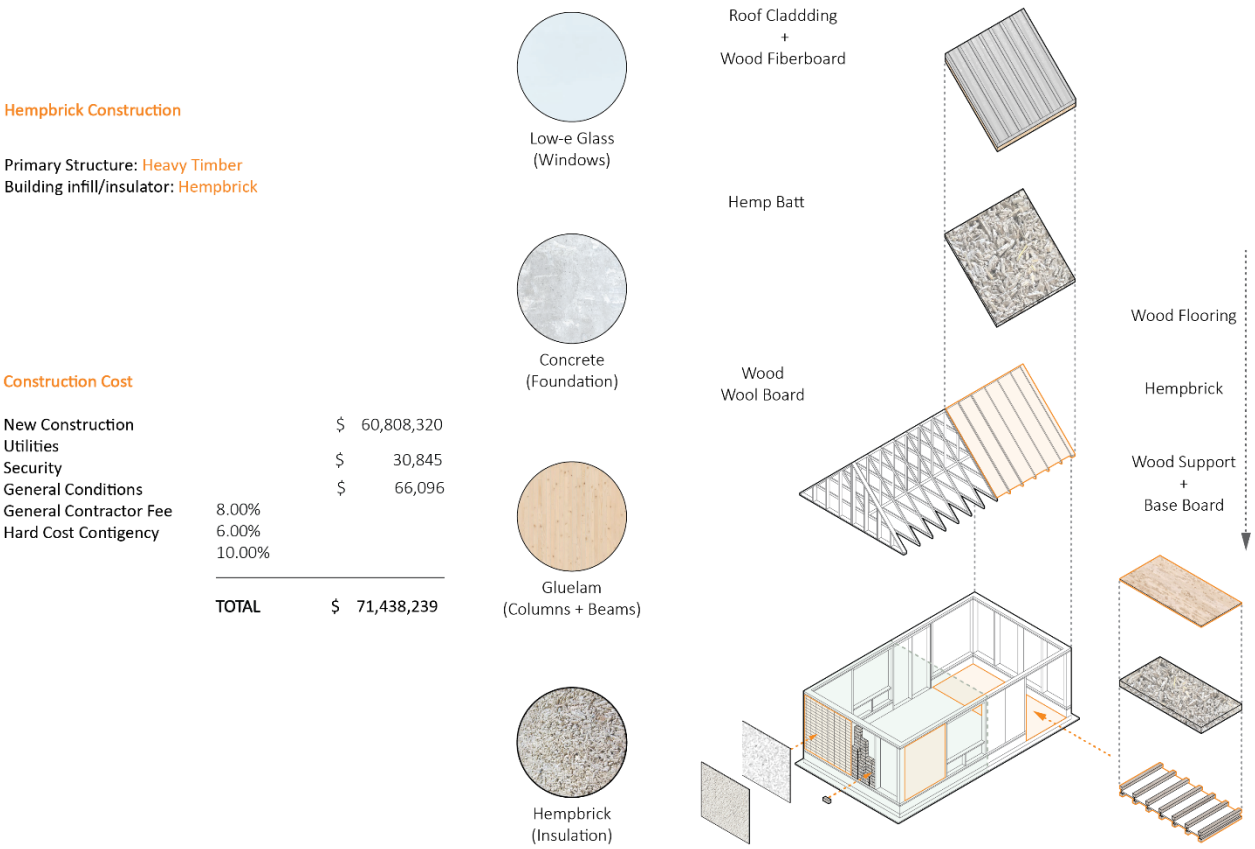

Figure 52. Material Palette + Construction Cost. Source: Shutterstock. Drawing by Author.

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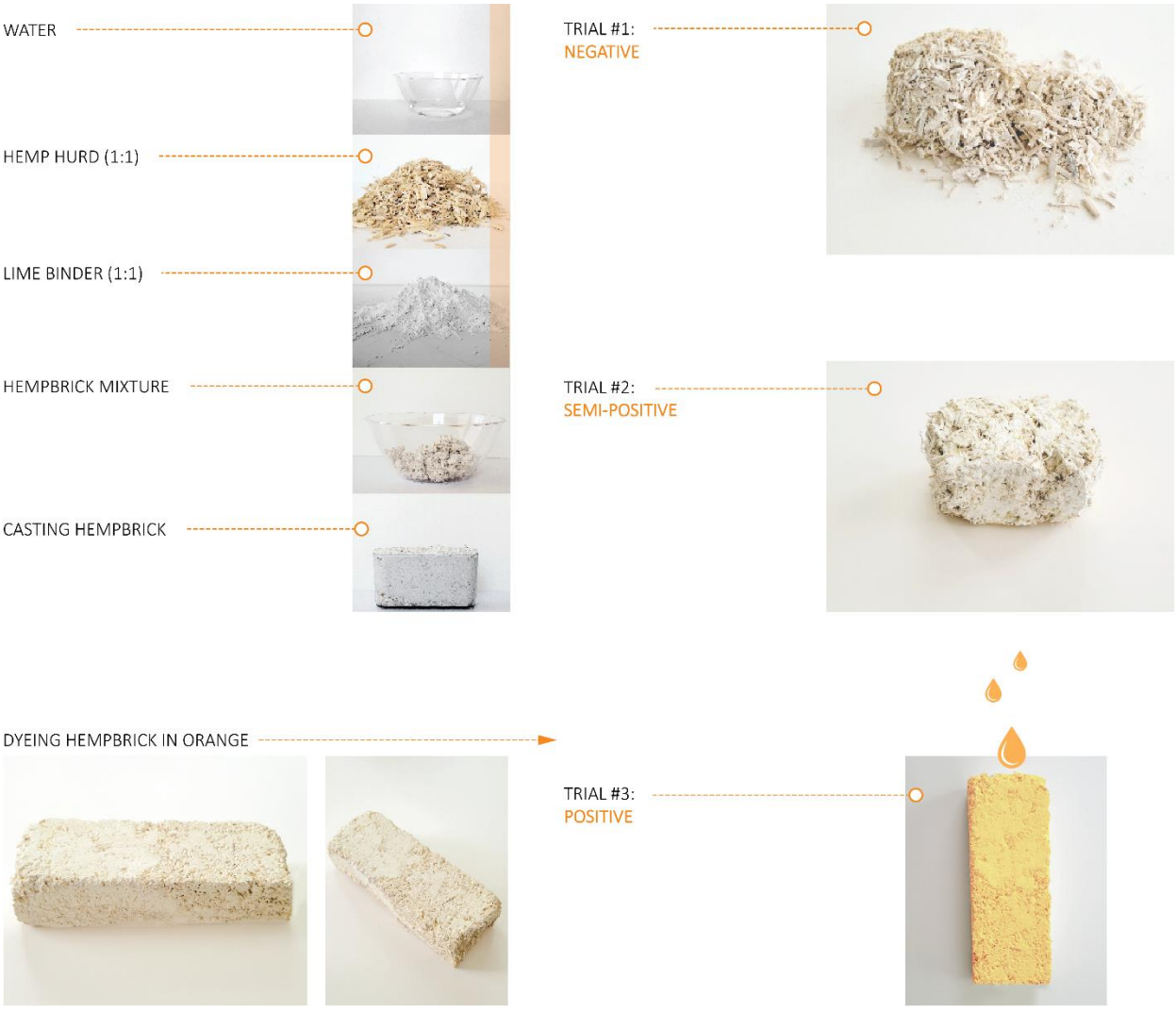

Figure 53. Casting Hempbrick. Model by Author

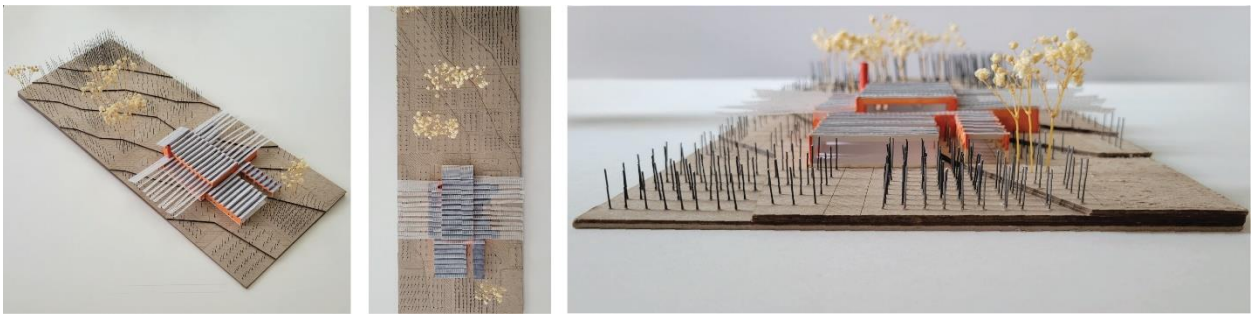

Figure 54. Proposed Final Model. Model by Author

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Figure 55. Lateral Section Perspective. Drawing by Author.

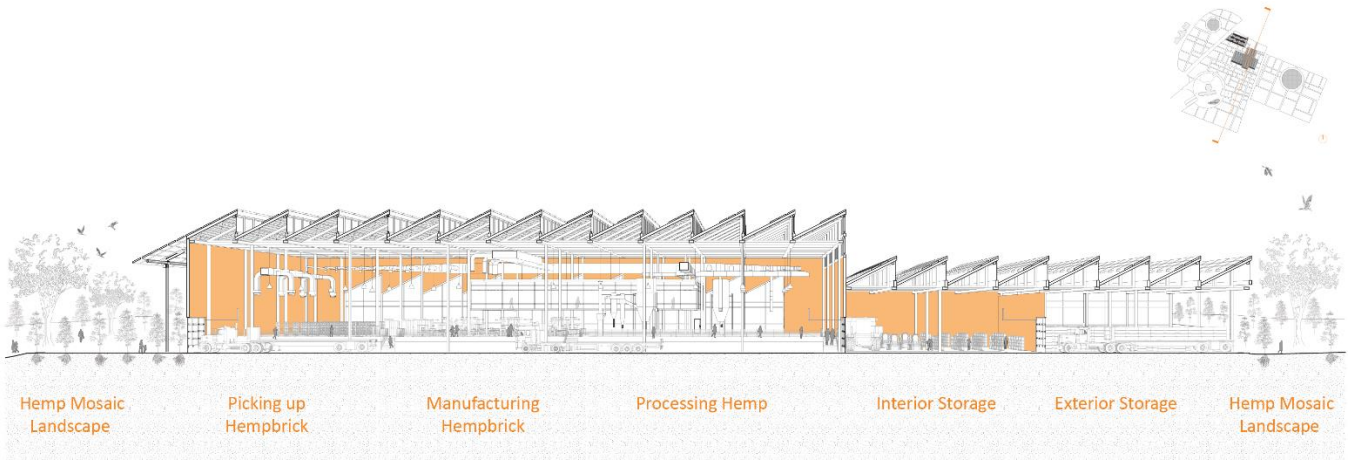

Figure 56. Longitudinal Section Perspective. Drawing by Author.

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The Experience

As they get closer to the site, tourists will notice trees and hemp growing in a pattern that leads them toward the visitor center.

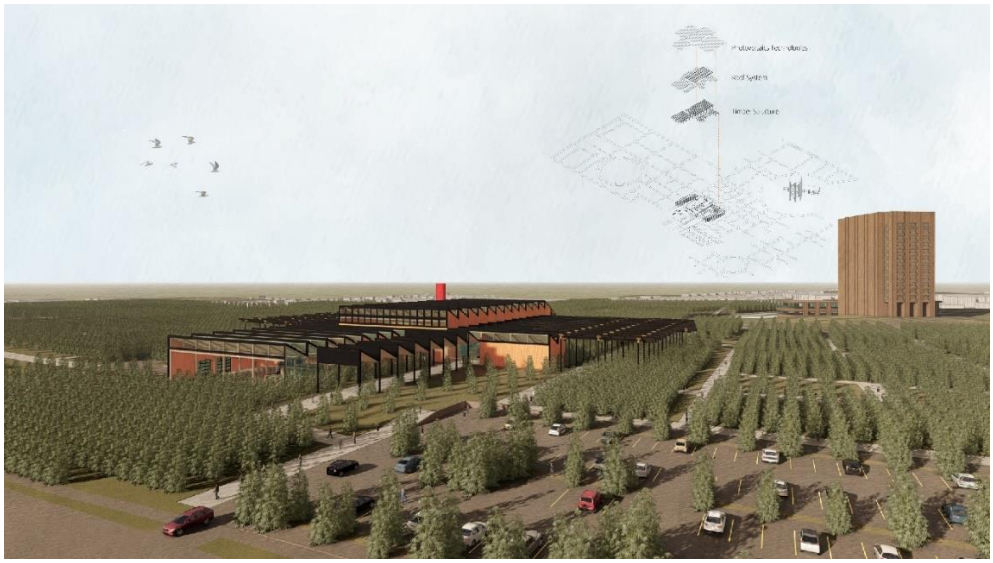

Figure 57. The Intersection Overview of Hemp Mosaics Landscape. Mixed Media Drawing by Author.

Visitors can take tours of the hemp experience located inside the Visitor Center. These tours will inform visitors about the process of hemp, including how it is first extracted into fibers and then processed into hempbrick.

Figure 58. The Greeting. Mixed Media Drawing by Author.

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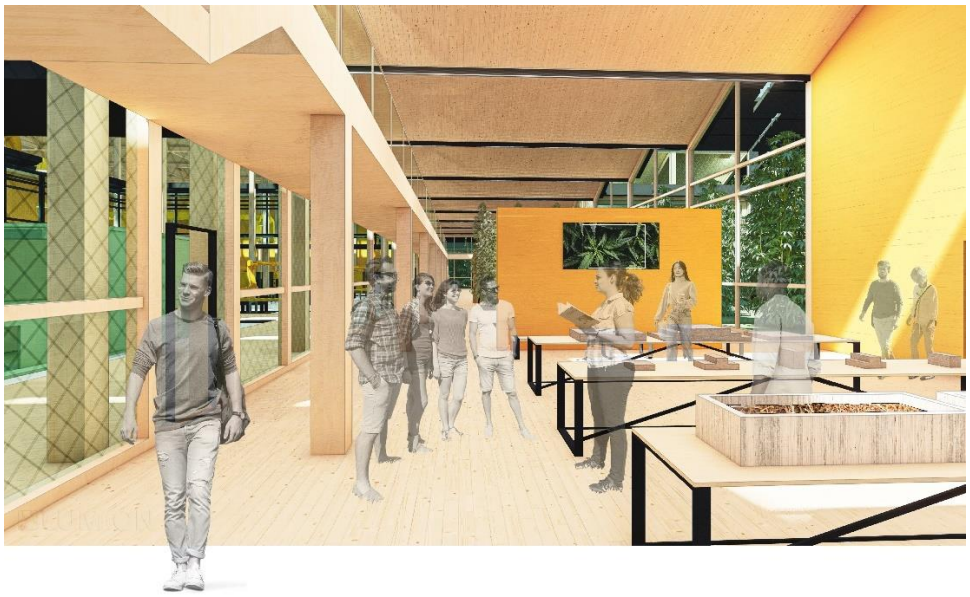

Figure 59. Interior Hempbrick Experience. Mixed Media Drawing by Author.

In this interactive exhibit, visitors will learn about hemp's cultivation and processing, displaying hempbricks of several sizes. The location of the Visitor Center regarding the Manufacturing Facility allows for a direct linear progression from learning about the plant's development to seeing hempbricks being processed.

Figure 60. Interior Hemp Experience + Drying + Baling. Mixed Media Drawing by Author.

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A catwalk gives a 360-degree view of the Manufacturing Facility and is the designated location for public visits. The Manufacturing Facility is divided into four sections: decoration, manufacturing, storage, and a loading dock where trucks pick up hempbrick.

Figure 61. Manufacturing Facility: Decortication + Manufacturing + Storing. Mixed Media Drawing by Author.

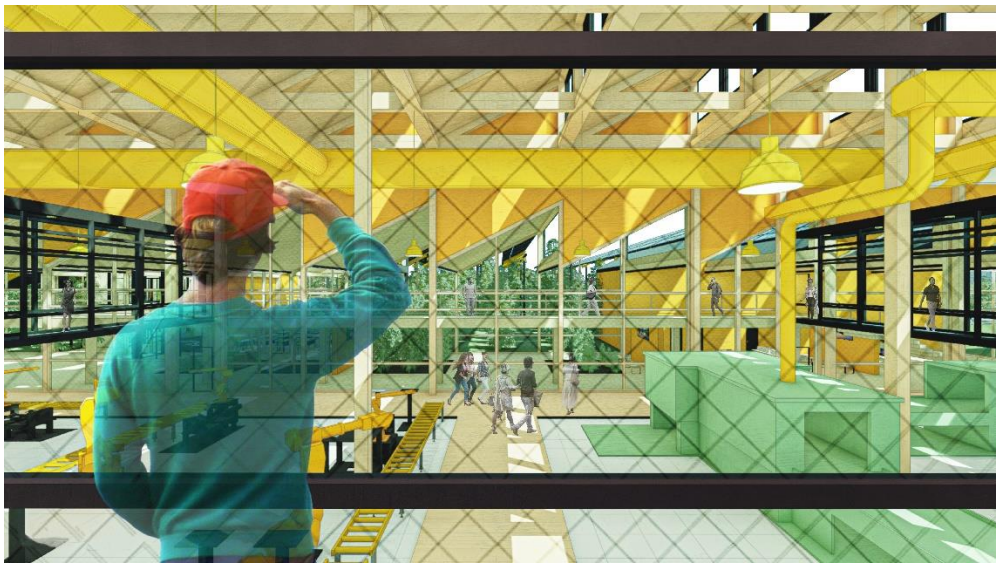

Figure 62. *The Catwalk Experience.* Mixed Media Drawing by Author.

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The tour concludes with an overview of the site's landmark, The National Agricultural Library, and the hemp mosaic landscape.

Figure 63. Tour Conclusion. Mixed Media Drawing by Author.

When visitors have finished exploring the Visitor Center, they can head outdoors to the hemp mosaic landscape and journey down the exterior promenade, where they will encounter hemp in various sizes.

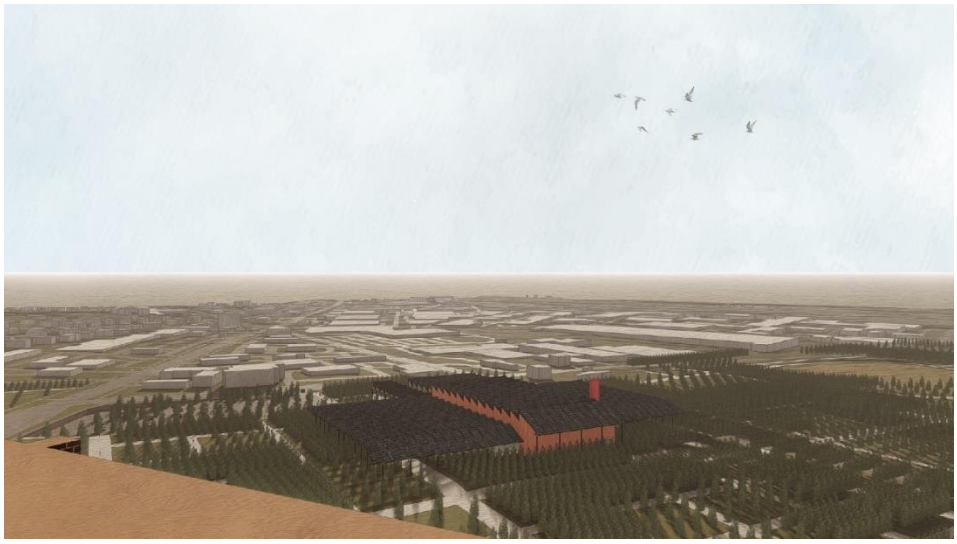

Figure 64. Arial View of the Site. Mixed Media Drawing by Author.

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Chapter 8: The Vision

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Application

Architects use plant-based materials in building construction, but few investigate the relationships between the land where the material is produced and the building itself.

Figure 65. Biogenic Materials. Source: Shutterstock. Diagram by Author.

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Conclusion

The goal of this experiment was to propose to study this idea of architecture and agriculture relationships through the design of a Hempbrick Farm—an experiential, carbon-negative hemp farm with a public visitor/manufacturing building. I propose architecture that is produced by the very same crops that surround it.

Figure 66. University Of Maryland Extension Hemp Landscape. Image by Author.

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