Rootbound: Exploring Production in Seattle's Urban Forest

Scott A. Boetjer

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Benjamin Spencer
Iain Robertson

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Abstract

The urban forest of Seattle provides many benefits and values to its inhabitants. Trees in particular play significant environmental and social roles in the city by cleaning polluted air and water, providing shelter from sun and rain, beautifying our streets, and protecting pedestrians. There are also physical products we extract from our urban forest vegetation, but these remain limited to mulch, some foods, firewood, and compost. Yet despite these important attributes there remains potential to manipulate the urban forest for our changing needs. This project will present four concepts designed to enhance urban forest productivity. The first three are strategic proposals with a broad aim to improve ecological health and forest resiliency in a future of changing climatic conditions. The fourth, *Rootbound*, is a set of experimental interventions designed to incorporate innovative product development within social and environmental contexts.

The current plan for Seattle's urban forest clearly indicates the goal of its managers; to increase tree canopy and maintain an overall healthy forest. By implementing several new strategic proposals, the urban forest may play a more active role in enhancing ecological and social health. The first is a biochar program using mulch as the feedstock. Up to 90% of urban forest trees are recycled as wood chips and this low-value product can be converted to a high-valuable climate change reduction component. The second proposal will use the urban forest as a seed bank for developing long term resiliency. Heirloom street trees will enable the forest to be more responsive to changes in climate and urban conditions. Third, a regional history of timber forestry inspires the reintroduction of board production to residual sites in the urban forest. Centered on education rather than commercial production, timber trials using vigorous urban forest species may set the stage for future infill projects in Seattle.

The fourth and final concept, *Rootbound*, manipulates root growth as a method of revealing natural urban infrastructures while producing viable, artful urban forest products. Tree roots are often the cause of conflict and damage in the urban setting, but they may be forced into specific forms for productive use in our city. This concept will be presented as designed interventions in the context of four distinct urban forest types. These typologies are distilled from varying environmental conditions and land uses and include: dense urban, residential, residual and industrial. The first intervention will attempt to enliven an otherwise barren public space. Tree containers designed to sit up to four people are arranged in an orchard-like pattern. When completely bound by their roots, each tree is removed to reveal a new type of urban furniture intended to improve the public space and create awareness of alternative forest products. The second intervention enhances playground learning by growing "loose parts;" oversized blocks designed to stimulate teamwork and creativity. Third, the *Rootbound* concept will be applied to an urban wetland restoration project. Trees and other plants have been shown to phytoremediate polluted soils and this intervention will also create useful, artistic products. Finally, the fourth intervention develops an interlocking nurse log system. Urban forest roots grown on a terraced residual site produce biodegradable blocks intended for slope and bank stabilization/restoration projects.

The long term projection of these strategies and interventions is to inspire new methods of productive urban forestry and utilize trees and plants to improve environmental and social health in the built environment. By incorporating them into the City of Seattle's existing Urban Forest Management Plan, our urban forest may begin actively contributing to the broader goal of climate change reduction. Urban forests that exhibit high levels of vegetative growth - such as those found in the Pacific Northwest – should be utilized as a living laboratory for educating, inspiring, and improving the lives of urban forest inhabitants.

1. Introduction

The forest ecosystems of our built environments contain hidden benefits and values that may be revealed through exploration, innovation, and experimentation. Just as a natural-state forest supports a complex network of needs to the various organisms inhabiting it, so does the urban forest provide for its inhabitants including humans and their unique needs. Because of the heavy pressures placed on them from human uses, natural systems (such as soil building and water filtration) are often interrupted. Therefore urban forest ecosystems require human intervention to ensure health and productivity. In a strictly scientific sense, we as humans are organisms in the urban forest and have uses and impacts that reflect the uniqueness of our species. Different urban forest typologies such as dense urban, residential, vacant parcels, and even industrial corridors all have potential to add value and production to the human ecological communities they support.

Historically, forests have played a critical role in the advancement of human civilization. The fundamental element (and ultimately technology) that placed *Homo sapiens* apart from all other life on earth – fire – has its primary fuel source in wood. Forests and their trees still provide firewood, a primary source of heat in many parts of the world. But apart from heat energy, forest are enduring providers of shelter, food, and livelihood for people. They have inspired us to create beautiful works of art. We as humans have long held dear the value of forests and forest products, and have welcomed them into our cities. But one question has been raised. Why do we have trees in cities (Lawrence, 3)? This project will begin to challenge the fundamental reasoning behind this question and attempt to redefine our notions of urban forest benefits.

Trees and other urban forest vegetation types are essential to the health of Seattle and its surrounds. From the lowest growing mosses to the towering climax tree species, the urban forest contains a wealth of biodiversity (see figure 1.4). Despite the heavy pedestrian and automobile traffic, vast layers of concrete and stone, and harsh growing conditions, plants (and animals) maintain a strong presence in our city. In fact, without these heavy uses and impervious conditions, if humans as a species disappeared from the city, the forest would most certainly accelerate its dominance. Concrete and asphalt can easily buckle and erode under the pressure of root growth, wind, and rain. Soil would quickly build as sediment and organic debris quickly collects in the multitude of crevasses and angles. Seed sources are plentiful and with an abundance of moisture, a new post-industrial forest typology would establish itself. This process is what urban foresters are in constant conflict with. Urban forest management is a costly endeavor in Seattle required to maintain the needs of a healthy, productive, and balanced human presence.

Although lush and diverse, the urban forest poses significant problems to its foresters. According to Darren Morgan, Urban Forest Manager for the City of Seattle, the single largest problem facing the urban forest is space. Trees in particular compete with buildings and infrastructure for canopy and root growth and often become the source of economic and social conflict. The cost of removal and repairs is a significant, perennial problem. One effective solution is to simply provide more room for trees to reach maturity. Indeed, mature, healthy trees are the sentinels of a healthy urban forest. But are there ways to utilize the existing limits to tree growth within the city? What happens underground is a struggle between man and nature. Poor soils are the signature detriment to the successful maturation of trees in cities. Trees often struggle to grow and those that do often lead to conflict with forest managers. Even long-lived specimens must ultimately be removed. The questions for me in the context of this project are: how can we maximize the use of available space and how can we effectively move beyond the battle for space within the city? Are there ways to harness the fantastic growth rates of Pacific Northwest urban plants and yet continue to meet the needs of people?

Up to 90% of tree waste material in Seattle's Urban Forest – the brush, limbs, logs, etc. – are recycled as mulch.[1] The remainder ends up as composted soil amendment and firewood (see figure 1.3). Additionally, the large hazard specimen trees that must inevitably be removed are often salvaged for their valuable timber. Niche companies such Urban Hardwoods work closely with local arborists to assess the value of unique trees for the production of high-end furniture. And although mulch is a useful and vital part of managing the living landscape, it is a singular end product. I propose that our city trees and other forest veg-

[1] This figure is taken from an interview with Darren Morgan, Manager of Seattle Department of Transportation's Urban Forestry Division. It is a rough estimate.

etation types can be put to more use. I intend to generate and explore several concepts that use plants for: artful interventions, new forest products, experimentation, and innovation. Trees in the city have high social and environmental value, but the questions remain: how can trees and other plants be identified and utilized to maximize their production potentials?

One of the underlying principles that this project faces is that of time. Many trees require long growth periods to reach maturation, especially under the urban constraints of pollution, desiccation, injury, poor sunlight, and neglect. The national average life expectancy of a street tree is 15-18 years. This is based on a "half-life" expectancy, where half of all planted trees are expected to die within this timeframe (see figure 1.5). There are many instances however where the growth rate of trees in Seattle is higher than those found in a natural-state forest. This is due to primarily to summer irrigation (direct and indirect) and good cultural practices. Trees can grow faster *because* of human intervention. In this context, fast growing and relatively short-lived species may play a more important role in the "turnaround" of experimental or seasonal forest products while continuing to provide traditional urban forest roles in texture, color and beauty. My proposals will intentionally limit the lifespan of selected trees with the intent of creating awareness, art, and sustainable products. The Pacific Northwest is blessed with extremely favorable growth conditions for many plants and the trees of Seattle grow faster and live longer than trees is other cities. One conflict that arises from this vigorous growth is between roots and infrastructure. This problem has inspired me to explore the potential of forcing root growth into various forms, with the aim of improving the ecological and social health of our city.

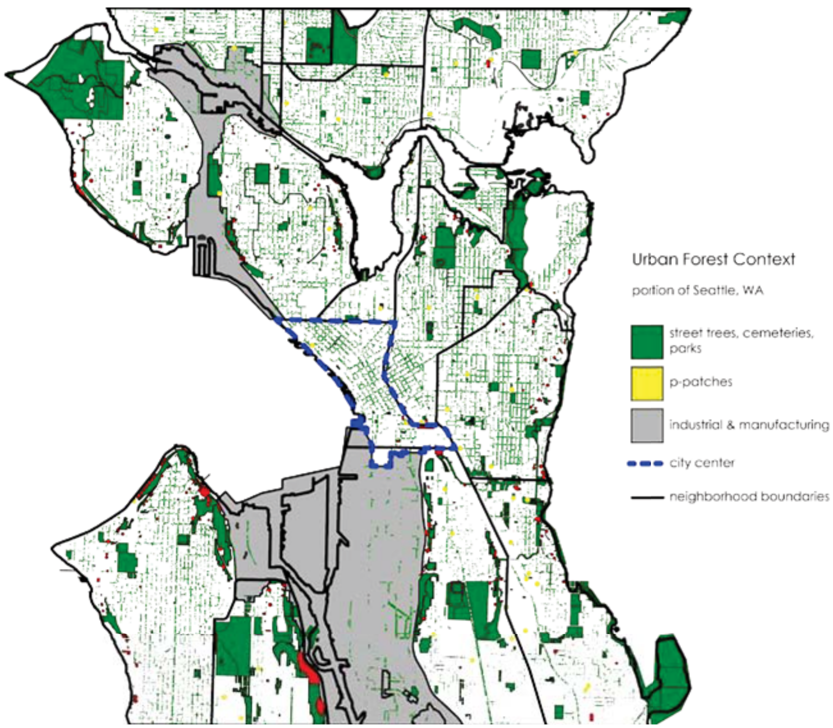
This project will begin with a review of relevant literature and precedents will provide the reference and research basis for the strategic enhancements and experimental interventions. This will include a brief look at the history of the urban forest by comparing it with natural-state forests and their roles in the human experience. The urban forest and more importantly trees have long played a key role in the health of our cities. Following this the project will present a critical position and framework discussion for the design implementations supported by diagrams and photographs. It will begin with a look at the general placement of the project within the urban forest and then focus on specific urban forest typologies distilled from various environmental and surface conditions. These typologies are city center (dense urban), residential, industrial, and drosscape (residual). They will provide the context for three strategic enhancement programs as well as the *Rootbound* interventions.

Next the project will present the three strategic enhancement programs: Biochar, City as Nursery, and Infill Timber. Urban trees can be sources of inspiration, art, and environmental health. These programs are intended to provide a pragmatic, new perspective on urban forest uses and establish a transition into the *Rootbound* concepts.

Upon investigating and observing different plant and tree morphologies it has been found that tree root systems in particular may provide a unique medium for testing new ideas and products in urban environments. This concept of *Rootbound* forces the growth of trees into desired forms. In order to integrate the root growth with urban ecosystem enhancement, this project will ultimately explore the enhancement of four distinct needs within the city. The first *Rootbound* intervention is an effort in urban "place-making." It is a challenge because the making of place is subject to a diverse set of public uses (and abuses). Cities are dynamic because people are dynamic. By placing public elements in heavily used urban environments, the risk-reward ratio is heightened. The second intervention will focus on enhanced childhood learning. Simply put, children are the future inhabitants of our city and their development and integration into the urban ecosystem will help ensure a more vibrant, healthy environment for future generations. The concept will utilize the theory of "loose parts" to improve the playground experience, an important place for early childhood learning. Third, the project will incorporate unique root forms into wetland phytoremediation. Industrial use areas, often found within and on the fringes of any city, continue to pose environmental health problems and therefore represent excellent opportunities for remediation. Seattle in particular is adjacent to several important receiving bodies of water, both salt and freshwater and there are many opportunities to improve water quality and create awareness to the problems of pollution and land use. The fourth and final concept will explore the production of biodegradable retention blocks grown within root binding formwork. The intention is to use urban forest trees for growing products that are used in habitat restoration projects. It allows for a city ecosystem to essentially “give back” to a natural-state ecosystem, the ones upon which we all inherently rely.

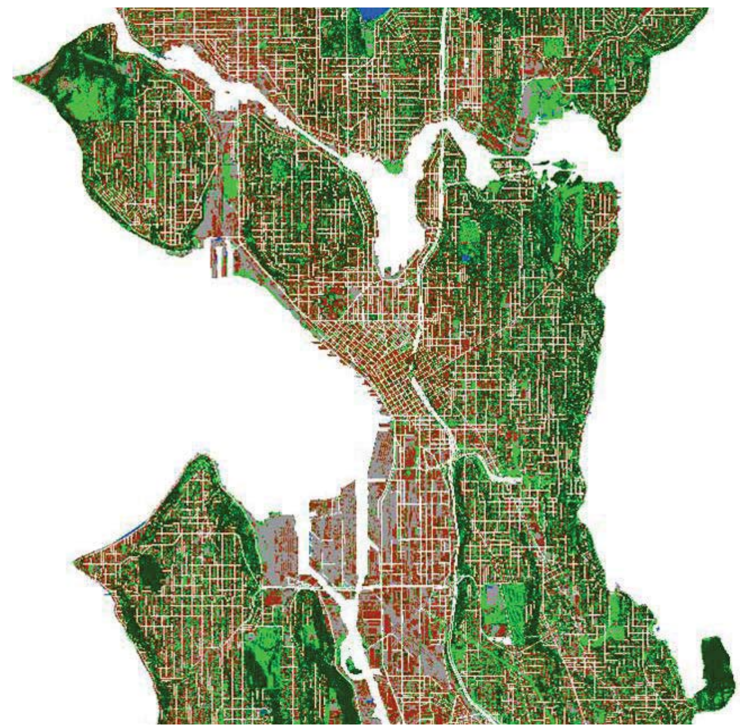
The project will continue with a presentation of a growth trial involving the construction of small-scale forms and selected plant species. This provides *Rootbound* with a physical model which tests the concept with live root material. A section summarizing my results and conclusions will finalize the project.

Figure 1.1: Managed urban forest



source:
GIS Data from the City of Seattle via the Washington State Geospatial Data Archive.

Figure 1.2: Total vegetative cover.



source:
LiDAR & NIR (1 meter) OBIA LULC of Seattle Created by Dr. L.M. Moskal's RSGAL in 2011269-274. http://depts.washington.edu/iufa/

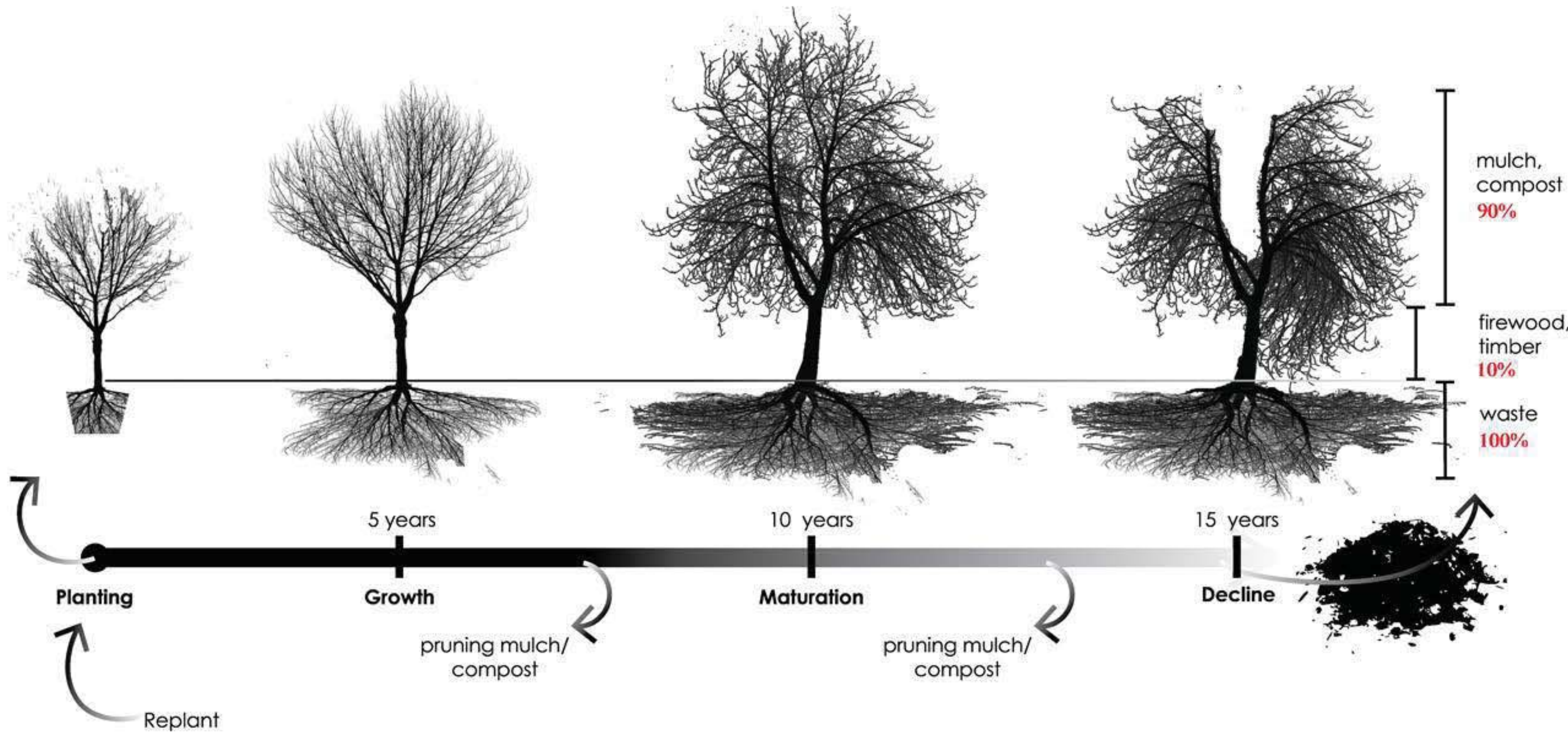
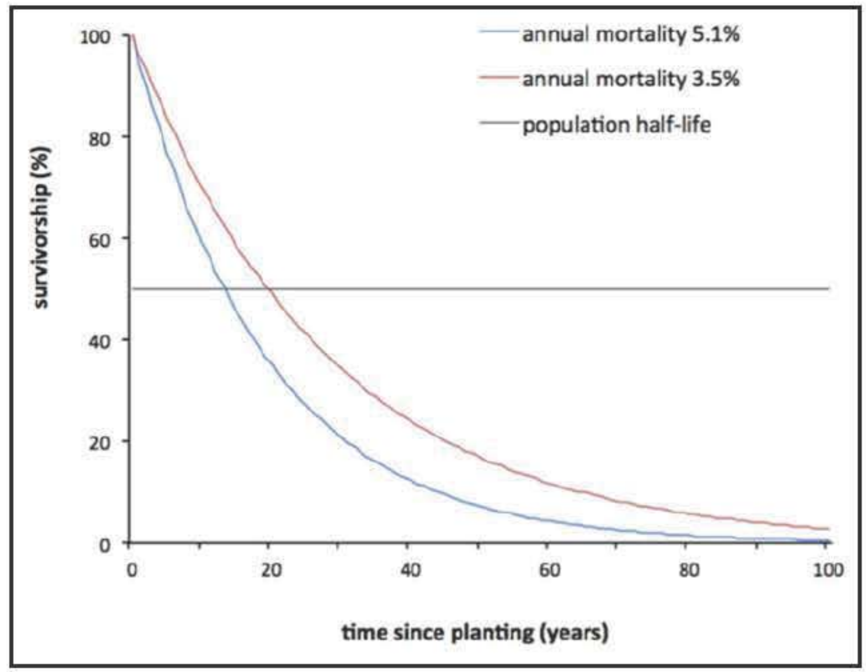

mulch,
compost
90%
firewood,
timber
10%
waste
100%
5 years
10 years
15 years
Planting
Growth
Maturation
Decline
pruning mulch/
compost
pruning mulch/
compost
Replant

Figure 1.4: Forest compostion.

Figure 1.5: Average street tree survival.

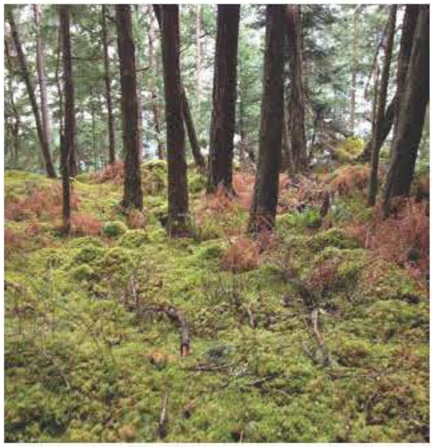


Half-life is "the time by which half of the planted trees can be expected to die."

source:
Roman, LA and Scatena, FN. 2011. Street tree survival rates: Meta-analysis of previous studies and application to a field survey in Philadelphia, PA, USA. Urban Forestry & Urban Greening 10: 269-274.

Figure 1.6

A native lowland forest.



The natural landscape, when examined at this scale, illustrates how soil and topography dictate the order and assignment of species to the various niches. Some will grow where others will not, and vice-versa.

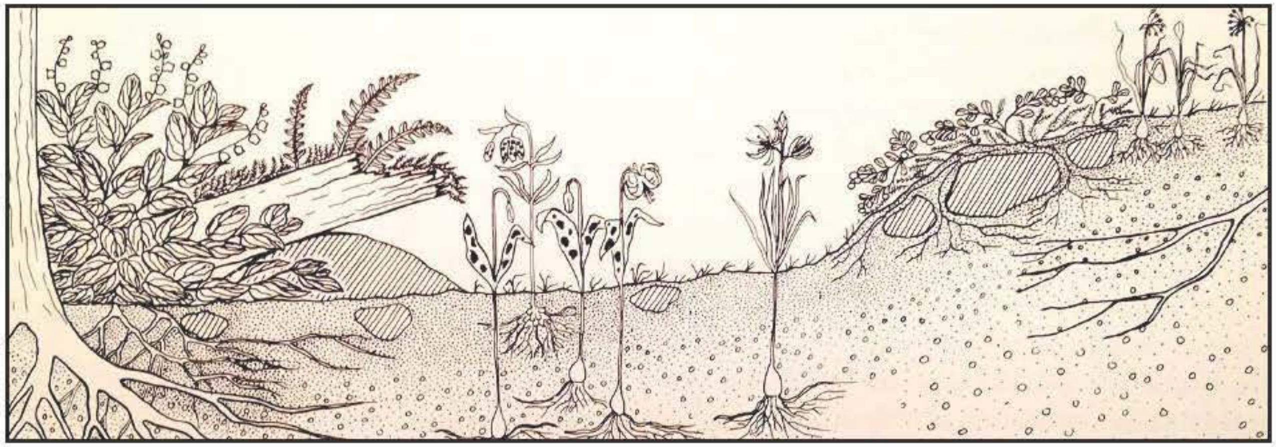
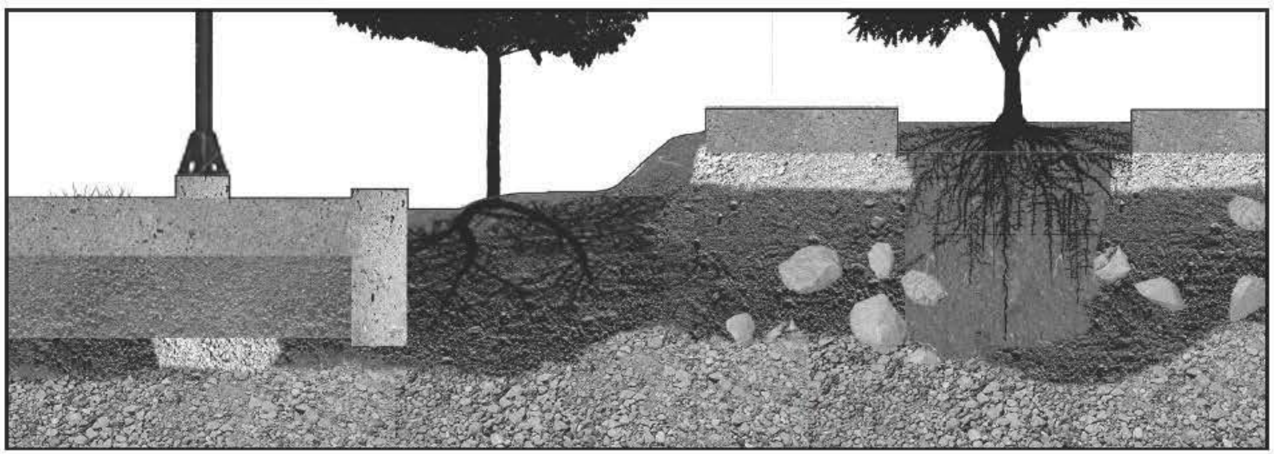


Image from The Natural History of Puget Sound Country, p.121

The urban forest.

The urban forest environment presents unique growing conditions not found in native landscapes. But the processes of survival, maturation, and reproduction are inherent in both. Various species will adapt to differing conditions.



2. Literature Review

Natural-State Forests

Trees have played a critical role in the lives of humans and many other species since the dawn of civilization. Natural-state forests have long provided the necessary shelter and food to sustain life on this planet. The great forests of Europe that once blanketed much of that continent have been significantly reduced, at first by the increase in agriculture and subsequently the wave of cities that have emerged. Around 750 AD Germany was still approximately 90% covered by forest. Only a few centuries later, in the late 13th century, the greatest extent of deforestation in Germany was reached, with forest cover of only 17% (Kowarik, 1). It is estimated that Germany's forest is currently around 30% coverage (coincidentally the current target canopy for Seattle), a result of shifting agricultural practices (e.g. global trade) and improvements in technology. This reading clearly illustrates a direct correlation between human activity and forest presence. But within this large time period, trees made their way into the public realm. What were once held in private gardens reserved for the elite, the beauty and value of urbanized trees (and other plants) became widely available to everyone. As the defensive walls of medieval cities began to grow obsolete, trees were liberated from their gardens and the boundary between natural-state and urban vegetation began to blur. This was the birth of the urban forest.

In Seattle, we experience climatic conditions ideal for the growth of a wide range of plant species. *The Natural History of Puget Sound Country* provides an ecologically historical context for the project. In Chapter 5, the author describes the native forest typology (of Seattle). "The trees, the subordinate plant life of the understory, the animals, and all the rest of the seen and unseen organisms of the forest ecosystem, create a grand symbiosis – a self-perpetuating, mutually advantageous system of life (131)." Kruckeberg continues to describe the prodigious amount of decay, a critical source of nutrients for the successive generation of forest plants. Fallen trees become the so-called nurse logs that harbor a wealth of biodiversity; organism which are extremely efficient at recycling nutrients. This diversity can be illustrated in section and compared to a typical urban forest condition (see figure 1.6). This project in part calls upon this diversity and nutrient cycling for supporting interventions intended to augment natural systems. Urban forest ecologies, even in dense urban settings, can emulate these processes on a small scale but nonetheless contribute to environmental well-being.

Defining the Urban Forest

According to Robert Miller in his volume *Urban Forestry: Planning and Managing Urban Greenspaces*, "The urban forest may be defined as the sum of all woody and associated vegetation in and around dense human settlements, ranging from small communities in rural settings to metropolitan regions (27)." This a good but fairly broad definition within the context of exploring production, but a good starting point nonetheless. The City of Seattle on the other hand defines the urban forest as "all trees in the city on both public as well as private property." Clearly there are major differences and therefore management implications in the definitions presented by these two examples. The way urban foresters frame their discussion and management plans will affect the overall health of the urban ecosystem. For the purposes of this project, the urban forest is defined as a wholly adapted set of vegetative species introduced by both human and non-human methods, which exist in our built environment. The concepts presented in later sections will narrow on specific species and will show that trees and bamboos show the most promise when attempting to enhance production.

A Brief History of the Urban Forest

Why do we have trees in cities (Lawrence, 3)? Historically, trees have been used in the public landscape of cities in two main settings. One is in the spaces used for public activities that the presence of trees enhanced. These include: parade routes, areas for recreation, promenades for pedestrians and public spaces that function as squares or parks. The second way trees have been used in cities is as extensions of the private garden, most often as street trees (Lawrence, 3-4). The urban forest has co-evolved with humans in a highly managed state. Specimen trees, exotic plants and animals and urban agriculture have all contributed to these dynamic, hybrid ecosystems.

Urban Forest Products

What are the values and products we gain from all of the trees, shrubs, groundcovers and vines? Now that we have a definition of the urban forest itself, how can we begin to identify the products one can extract from it? Natural forest products include of course timber and manufactured goods such as paper. These products place a heavy demand on forest systems since they require the greatest removal of biomass. Whole trees are felled for milling timber, creating a loss to the forest ecosystem but a gain to the detached urban environment. In contrast, the harvest of a single wild chanterelle mushroom hardly upsets the local environment, but consequently its benefit is short lived. Within this range lies an enormous bounty that has fostered the construction and sustenance of cities across the globe. If we consider natural forest benefits as extending to the urban forest then the single most important for the City of Seattle is water. According to the City of Seattle website, our two watersheds, those of the Cedar and Tolt Rivers, contain 90,638 City-owned acres of heavily forested lands which provide clean drinking water for 1.4 million people. Without a blanket of trees, the hydrologic cycle of these watersheds would be completely different and would not support the current urban condition. This is the condition of urban forest watersheds. Streets, sidewalks, rooftops and all other impervious surfaces exacerbate the problems associated with denuded landscapes. Fast flowing storm water runoff carries with it urban pollutants such as heavy metals and petrochemicals. Urban watersheds face unique challenges when compared to remote, natural watersheds, and Seattle's proximity to receiving bodies of water highlights the importance of implementing solutions. Urban vegetative cover plays a key role in mitigating runoff and pollution.

When compared to natural-state forests, the urban forests play a much different role in terms of productivity. Food production is one aspect that has grown dramatically over the last 20 years. There are cherries, plums and other fruit trees planted around the Seattle area and P-Patches (community gardens) are a thriving public amenity. Urban-agriculture, farm-to-table and locavores are the hallmarks of the food production renaissance within cities and the drive toward an edible urban forest is growing. Seattle is home to many avid gardeners and through education and awareness, new generations of city residents will increase the demand for food-based landscapes. An article entitled *Producing Edible Landscapes in Seattle's Urban Forest* supports this. In it, the authors present the Community Fruit Tree Harvest (CFTH), an organization dedicated to maximizing the potential of existing trees. "Fruit is generally gathered twice a week during the active growing season and distributed to more than sixty food providers." The integration and management of edible plants into the urban forest plant palette strengthens the concept of extracting value in the form of product.

In general, urban forest products are limited when compared to natural-state forests, but current managers are beginning to challenge this. In fact, research from 1965 has estimated the value of urban forest timber. "If we were to use forestry in its traditional sense, the urban forest value would be expressed in terms of sawtimber, veneer, and other products. It has been estimated that 100,000 board feet of saw timber could be harvested on a sustained annual basis from Boston, Massachusetts (Grey and Deneke, 158)." The authors continue to the point of overlap with this project, which attempts to increase production and therefore value of the urban forest.

> Obviously, in the urban areas of North America the amenity values of trees make this approach difficult. It should be noted that trees are an asset that tend to increase in value over time. They do, however, become a liability at death because they have to be removed. This liability could perhaps be partially offset by a sustained yield management program. This liability can be further offset by the utilization and sale of chips, firewood, and other products.

Urban forest values or benefits are those qualitative attributes provided to humans in the built environment. These are: shelter from sun and rain, habitat, beauty, inspiration and heritage. Automobiles are especially dangerous in dense urban centers and trees provide a safety buffer for pedestrians from roadways. Urban forest vegetation also provides important civic services such as water filtration and erosion control. Trees also add economic value to many properties, as evidenced from examples such as Central Park in New York. As I begin to break down the concept of productivity within cities and ultimately apply designed interventions these values will provide the social, cultural, and environmental benchmarks from which to garner inspiration and reflection. In *The Forest and the City: The Cultural Landscape of Urban Woodland*, Cecil C. Konijnendijk draws from literature and case studies primarily from Europe, a place of rich and diverse cultural background and strong relationships to city forests. First, he provides examples of urban forest use changes. Where once people preferred a more passive interaction with the urban forest they now engage in more active uses. Play- based learning for children is a critical contemporary urban forest use. He finds that "7-16 year-olds in Danish cities use parks more frequently than other age groups (91)." One intervention proposed in this project enhances the learning environment for children by producing urban forest-based playground enhancements. He cites the urban forest as a testing ground not only for the development of new species of trees, but for education and exploration. Many urban forests offer opportunities for finding peace and privacy. In Seattle (just as in many cities), we have a diverse set of cultures coexisting in a dynamic urban environment. Many such cultures place high value on certain plants, and the urban forest provides a platform for engaging heritage. Finally, art can bridge the gaps between cities, cultures, and their forests. "The development of new city forests can be connected with art, as in the case of the German Ruhr area. Abandoned factories, coal mines, new forests, and art are mixed into fascinating 'industrial art settings" (Konijnendijk, 104).

The Potential of Urban Forests

The question of what productivity actually means in the context of the urban forest is clearly defined. But how can we design for production when implementing new ideas? There are obvious values and costs associated with growing and maintaining mature tree in cities. Historically, the most significant forest products to come from our region are timber and pulp products. In the urban context, timber is in fact harvested from city trees, though rare. One of the most promising products for use of waste material (e.g. mulch) in Seattle's urban forest is biochar. Simply put, biochar is the carbon-rich product obtained when biomass, such as wood, manure or leaves, is heated in a closed container with little or no available air (Lehman and Joseph, 1). The primary benefit may be argued to be the long-term sequestration of carbon, thus helping to offset the effects of human induced global warming. Biochar is also a proven soil amendment and water filtration media. Its manufacture and use will be thoroughly explored through the use of two significant volumes: *Biochar and Soil Biota* and *Biochar for Environmental Management*. The former is a scientific text describing the chemical and physical structure of biochar and its effects on soil. The latter is focused on practical production and application methods. Together these texts provide a solid technical basis for which to apply my own use urban forest species in biochar production and application.

Bamboo is one of the world's fastest growing and most useful plants, the two key reasons for my argument that it should be employed as an urban forest producer and product. In *Bamboo: The Gift of the Gods,* this plant is described in-depth and production and construction methods are explored. Bamboo is a plant that crosses many cultural thresholds, a desired outcome of this project. One of the key limiting factors to growing bamboo in our climate is a limited selection of species. But in the application of biochar, this plant is hoped to be proved as a valuable feedstock. It speedy rate of both top and root growth can help to quickly capture non-point source atmospheric CO_2, a common pollutant in cities.

Up By Roots is the most recent work published by James Urban and provides a detailed description for planting successful, mature trees in the urban environment. One of the biggest challenges facing the trees in cities is a lack of good soil conditions. This fact, compounded by the inability of water to reach trees where and when they need it, is the basis for his approach. Soil engineering has long been a requirement for the construction of cities and roads, and Urban presents strategies for accommodating the proper growth of trees through an engineer's lens. The principles provided in *Up By Roots* are relevant to my own proposals and are applied to maximize the potential and productivity of selected tree species. By providing the optimum growing conditions, tree life-cycles can be intensified and shortened, harvest schedules increased, yields improved, and economic risk reduced. The tree health risks inherent in the proposal of intentionally reducing available roots space may be offset using sound horticultural methods and carefully designed growth media.

Given the sensitive nature of the aquatic ecosystems surrounding Seattle, there also arises a need to include the element of environmental stewardship. One critical component of this in the Puget Sound region is the consideration of storm water. *Low Impact Development: A Design Manual for Urban Areas* is a concise book that provides practical guidance for volumetric and spatial arrangement of landscape elements. The authors argue that healthy trees are essential components of green infrastructure and urban forestry. Besides functioning as carbon sinks, trees also reduce storm water runoff through interception, evapotranspiration, throughfall, and flow attenuation (98). Although my proposals intentionally inhibit or constrain the growth of tree roots, the interim growth strategies should incorporate positive ecological functionality.

Another example or form of environmental stewardship can be found in "The Botany of Desire" by Michael Pollan. In it, he presents the story of apples. Apple trees have their origin in the upland forests of Kazakhstan, when bears were the primary consumers of the fruit and dispersers of seeds. The largest and sweetest fruits were selected by bears and over time those specific trees were the ones that flourished. Humans eventually took interest in the sweet nature of apples and they ultimately became the ubiquitous global fruit we know and love today. This example of natural, symbiotic evolution has led to a positive ethnocentric outcome. Human beings benefitted by obtaining the most desirable fruit but the apple trees themselves were able to disseminate around the world. This simple model illustrates the capacity for long-term advantages between plants and people. The urban forest trees in turn may benefit in a similar manner as long as we are careful in selecting and caring for those most suited to the urban ecosystem.

The definition of productivity for this project must include a clause about sustainability. Without a purposeful intent to actively manage the urban forest indefinitely and for our benefit, the resource will quickly dwindle. This has been evidenced throughout history where industry is placed before nature instead of alongside it. One need look no further than Seattle, where Kruckeberg describes the scene in *The Natural History of Puget Sound Country*.

> Puget Sound country after the period of the 1850's was so cataclysmically altered and with such unanimity of purpose that no single voice of conscience could have effectively stemmed the onslaught on the land. Timber, agriculture, mining, and attendant urbanization rolled back the wilderness frontiers to a few remnants now sanctified in parks and other paltry preserves (416).

This is the legacy of the urban forest of present-day Seattle. The lesson taught should not only be applied to preserving the natural forests *surrounding* the City, but to alleviating resource pressure by actively managing the forest within. This project will attempt to provide some solutions to allow the urban forest to thrive independently and provide for its inhabitants.

3. Precedent Review

Project Title: Tree Logic

Artist: Natalie Jeremijenko

Location: MASS MoCA (Massachusetts Museum of Contemporary Art)

Synopsis: Our perceptions of trees change when we view them as a collection of growth responses rather than as immutable symbols of the natural world. The public for a work of art, and for *Tree Logic* in particular, is encouraged to interpret (and debate) motives and outcomes, though the opposite is often true of "real" science, which does not invite public discourse. Through her elaborate framing systems (in this case a metal armature, stainless steel planters, and telephone poles), Jeremijenko revels in exposing the idiosyncratic manipulation intrinsic to combining facts to form data.

Interpretation: The artist has planted 6 sugar maples in containers and suspended them from telephone poles. My art will have the intention of provoking thought and awareness, at the same time providing a valuable physical product that will ultimately benefit the system as a whole, thus closing the nutrient-cycle loop.

Photo courtesy massmoca.org

Project Title: living tree bridges.

Artist: War-Khasis (a tribe in Meghalaya) and *Ficus elastic,* the Indian rubber tree.

Location: Cherrapunji, India.

Synopsis: In order to make a rubber tree's roots grow in the right direction—say, over a river—the Khasis use betel nut trunks, sliced down the middle and hollowed out, to create root-guidance systems. The thin, tender roots of the rubber tree, prevented from fanning out by the betel nut trunks, grow straight out. When they reach the other side of the river, they're allowed to take root in the soil. Given enough time, a sturdy, living bridge is produced.

The root bridges, some of which are over a hundred feet long, take ten to fifteen years to become fully functional, but they're extraordinarily strong—strong enough that some of them can support the weight of fifty or more people at a time. In fact, because they are alive and still growing, the bridges actually gain strength over time—and some of the ancient root bridges used daily by the people of the villages around

Tree bridge in India (courtesy amazing planet)

Cherrapunji may be well over 500 years old (from atlasobscura.com).

Company: Ecovative

Products & Applications: Packaging, insulation, surfboard blanks, synthetic foam replacements.

Materials: High performance biomaterials grown from mycelium and agricultural waste.

Product Launch: 2009

Synopsis: This company produces a product line intended primarily to replace conventional polystyrene or synthetic packaging materials. Agricultural waste such as corn stalks and rice hulls are inoculated with fungal mycelium, which is then placed into molds. Within 5 to 7 days, the resulting growth is dried to prevent fruiting body (mushroom) formation and sold to distributors and retailers. The product has excellent structural and chemical properties and is certified "Cradle to Cradle 'gold,'" an environmental guideline for product standards.[2] This growing business uses natural materials in a forced-growth environment as an alternative to conventional products. The product is 100% compostable.

Interpretation: My products strive to achieve a similar "cradle to cradle" merit. Instead of using fungal mycelium to achieve quick results in a demanding and competitive commercial market, I use the woody root growth of trees and bamboos to create products used to enhance the human experience of the urban environment while benefitting the natural

photos courtesy www.ecovativedesign.com ecosystems upon which it is built.

Project: Imagination Playground

Firm: Rockwell Group

Materials: Large, high-density foam blocks.

Location: Burling Slip, New York City.

Date of Installation: 2010

Synopsis: Traditional playgrounds consist primarily of fixed equipment, such as slides, monkey bars and teeter-totters, all of which focus on developing children's gross motor skills. Imagination Playground is an interactive, transformable environment that prompts children to manipulate their environment and create a play-space of their own with sand, water and loose parts.

Interpretation: The concept for Playground Blocks In Situ attempts to grow similar play blocks on-site using the Rootbound method. Achievable in 2 - 3 years, these high density bamboo root blocks are complete-

projects. Pertaining to urban forest artwork, literature is available but

photo courtesy www.prweb.com

4. Critical Position & Framework for Design

The urban forest of Seattle contains hidden benefits that may be revealed through exploration, innovation, and experimentation. My approach has two parts. First I propose three enhancement strategies or programs that may supplement the current urban forest management plan. They are: *Biochar*, *City as Nursery*, and *Infill Timber*. These three programs presented in the next section are intended to integrate environmental repair, forest longevity, and historical production measures. Each concept is intended to cross-pollinate with the others in order to diversify and augment the benefits of individual concepts. In addition, they complement the second part, the *Rootbound* experimental interventions, by maximizing the lifecycle of urban forest trees.

My observations in the urban forest have led to an interest in the vigorous root growth of trees and the research has revealed that tree roots, including those in other built environments, will readily conform to their constraints (see photos 4.2 and 4.3). Within the traditional existing management practices, these conditions are precisely those to be prevented. As stated previously, trees are often a source of problems in urban settings. They drop litter and foul storm drains and can pose dangerous risks to life and property. Their roots can invade pipes and crack sidewalks. In Seattle, sidewalk upheaval is very common and costly to repair and manage (see photo 4.1 and Tree Data per "Management Unit" in Appendix). But despite the lack of physical space for the average urban tree to maximize its potential in the built environment, there remains room for expanding the value, productivity, and influence of the urban forest. The term *Rootbound* is being used to describe the positive outlook of a negative condition. Figure 4.1 provides an overview of how the concept may be integrated into the urban forest. As stated earlier, *Rootbound* will intentionally limit the lifespan of selected trees with the intent of creating quicker turnaround for these unique forest products.

Varying forest typologies such as city center, residential, industrial, and residual can inform design-related interventions intended to add value, benefits and products to the urban forest inhabitants. These are presented as a matrix of environmental and surface conditions in figure 4.2. Land uses vary in Seattle and the four typologies presented represent a broad selection across them. The first is residential use. This typology represents the widest variety of plant species and is a good source for identifying those species which perform well in the urban forest. Additionally this is where one will find some of the fastest growing urban forest trees as a result of increased maintenance and cultural practices. The second typology is the dense city center. Environmental conditions are especially challenging for the growth of trees and the shortest live plants will exist here. Vandalism, desiccation, pollution, and wind all create havoc for urban forest managers. This is also an environment where trees play a more critical social and architectural role. In contrast, the industrial typology is possibly the most neglected urban forest. Desirable vegetative growth is hampered by exposure and heavy use as well as a wide range of pollutants. Seattle's major industrial areas are located adjacent to waterways so environmental concerns are prevalent. The final typology is one using the borrowed term drosscape. Dross is something described as worthless. Coined by Alan Berger, drosscape as a concept, implies that dross, or waste, may be "scraped", or resurfaced, and reprogrammed for better use. These residual parcels of land are often located between roads and highways and are typically unmanaged, wild urban landscapes. They represent low-risk sites for experimenting within the urban forest due to low public interest and economic value.

Figure 4.1: Adding value to the urban forest.

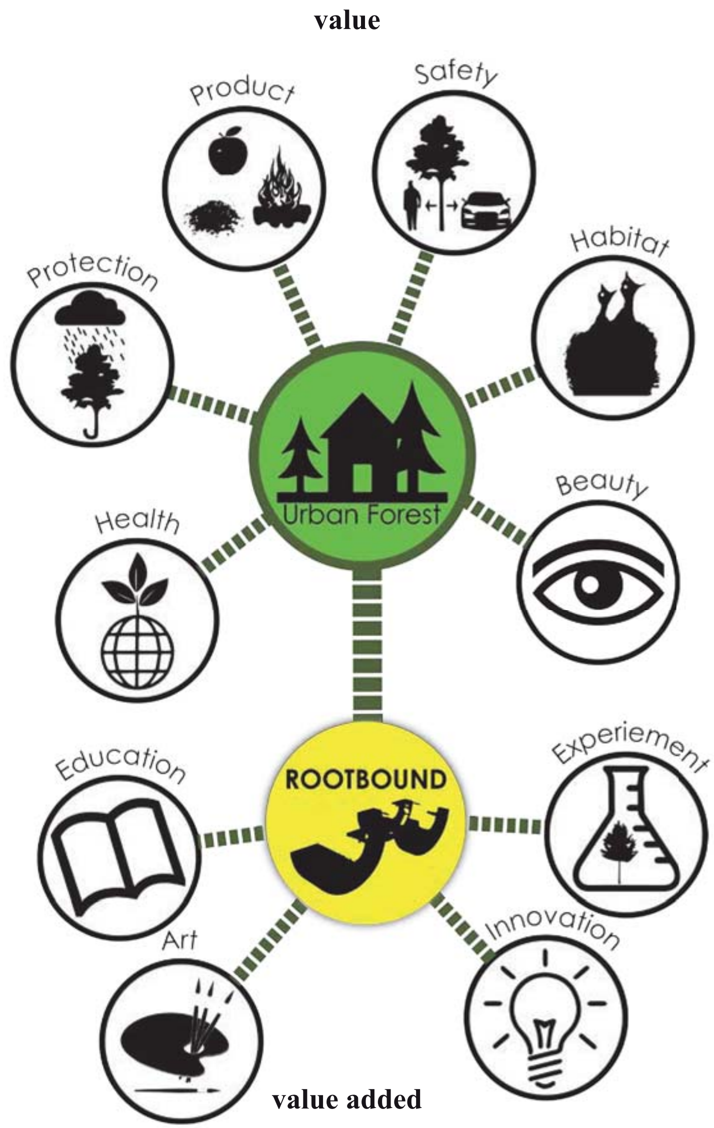


Figure 4.2: Urban forest typology matrix.

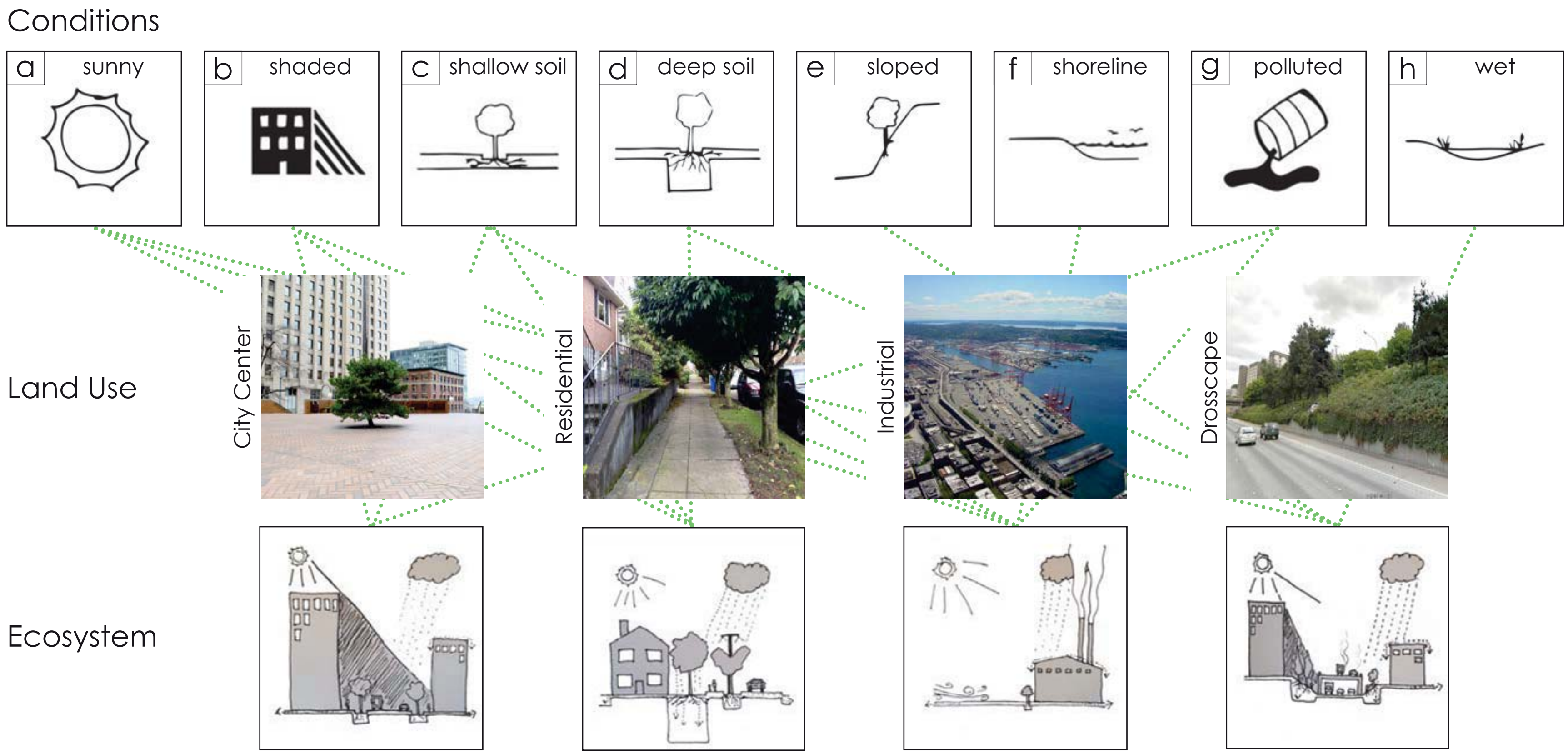


Photo 4.1: Sidewalk upheaval is common in Seattle.

Photo 4.2: Form follows function in the root zone of urban trees.

Photo 4.3: Unintentional form-making.

Figure 4.3: Hidden forms.

5. Enhancement Strategies

Planning for and managing the urban forest of the future requires adapting emergent technologies and introducing proven methods of production from similar industries. The urban forest management goals and methods currently in place in Seattle are designed to increase forest canopy, diversity of species, and overall forest health. Forest products are considered secondary benefits but current City of Seattle managers and those in other states are interested in the concept of a more active role by our cities trees. The following strategies are designed to enhance Seattle's Urban Forest by developing ecologically beneficial products, improving overall forest longevity, and reintroducing a culture and aesthetic based on intensive forest use. These strategies or programs are *Biochar*, *City as Nursery*, and *Infill Timber*. They are practical interventions that can be implemented immediately in our urban forest with little to no risk to managers. The goal is to diversify the productivity portfolio of the urban forest by manipulating or interrupting the lifecycles of specific trees and plants. The subsequent and more in-depth section will present four *Rootbound* strategies as the experimental interventions.

Biochar: Improving Soil Health and Ecological Functionality

Biochar is a product that, when incorporated into the urban forest management scheme, has the ability to offset carbon emissions and improve soil quality. Simply put, biochar is the carbon-rich product obtained when biomass, such as wood, manure or leaves, is heated in a closed container with little or no available air (Lehman and Joseph, 1). It is currently looked upon as an excellent and rather simple method of sequestering carbon, a long term solution for mitigating climate change. But to understand the potential value of biochar in the urban context, the carbon cycle should first be explained. Atmospheric (CO2) carbon is absorbed by plants along with water, soil minerals, and light and converted into sugars (photosynthesis). These sugars are used to grow and produce more vegetation. To simplify, the more vegetation there is, the more carbon is removed or sequestered from the atmosphere. Human industrial activity – specifically the removal and burning of mineral carbon from the fossil pool for energy (see figure 5.1) - has increased the amount of atmospheric CO2. This in turn has led to an accelerated increase in global temperatures through the so called

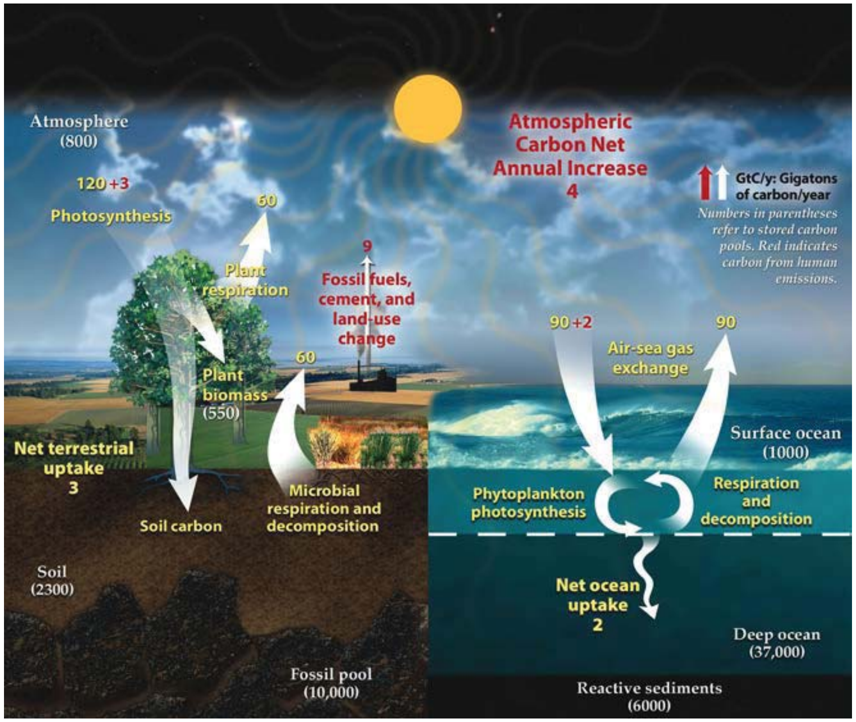


Figure 5.1: Simplified representation of the carbon cycle.

"greenhouse effect". Atmospheric carbon is also absorbed by oceans, an important factor in regulating water pH. Biochar production essentially fast-tracks the conversion of carbon into a long-term mineral state, greatly slowing its release into the atmosphere.

Biochar research has also showed its ability to host a wide variety of beneficial soil microorganisms. The symbiotic relationship between plants and soil organisms is well documented, and is in fact a key to establishing successful plantings, especially in difficult sites such as dense urban land uses.

The opportunity exists to enhance the environmental management of our urban forest by using mulch as the feedstock for a biochar program. Approximately 90% of the urban forests managed waste (through pruning and chipping) is returned to the forest as mulch.

Mulch is a vital component of most new plantings as it helps regulate soil temperature and moisture and inhibits the growth of some weedy plants. During the early stages of the decomposition of mulch however, soil nitrogen may be depleted. By incorporating biochar into new plantings as well as existing ones, the nutrient cycling of the urban forest vegetation may be streamlined and put to more active, long term use. There may also emerge a local commercial market that would help offset the cost of biochar production and help distribute the product into private urban forest plantings such as residential or commercial ownerships.

Figure 5.2: Biochar production model.

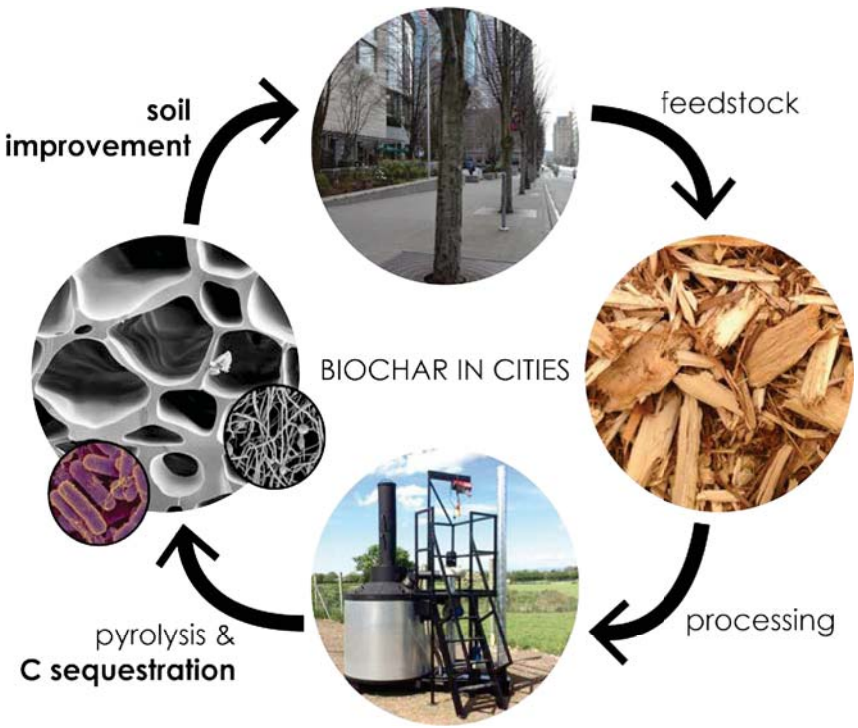
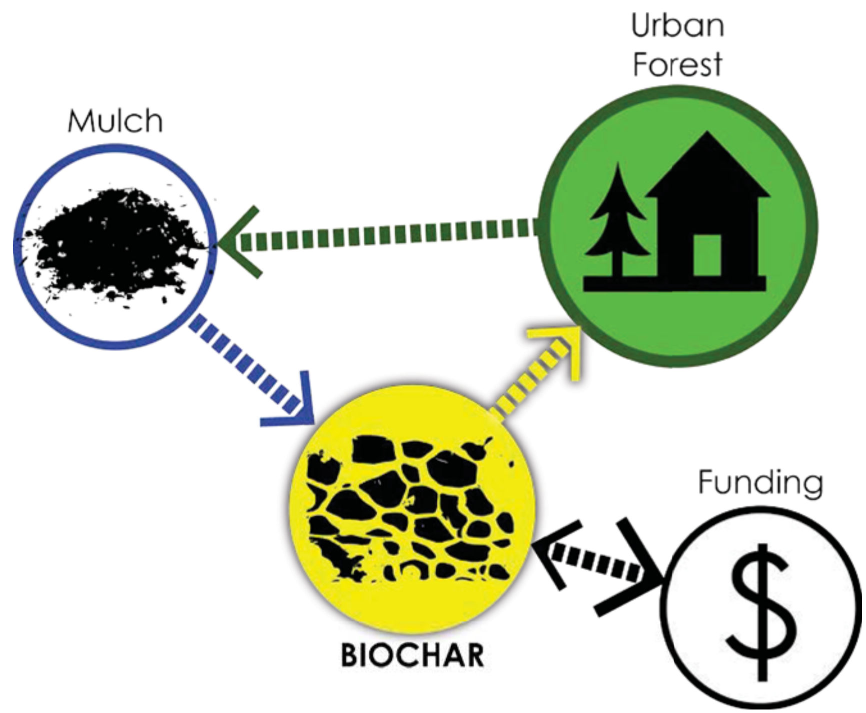


Figure 5.3: Biochar systems model.



City as Nursery: Urban Forest Resiliency & Longevity

There is a term used in plant cultivation called heirloom. The exact definition of an heirloom plant has some variation (most noticeably in the time-since-cultivation), but it essentially implies the long-term genetic development of a specific plant. To give an example, potatoes have been cultivated in South America since at least recorded history. The same species or "cultivars" are still be grown, harvested, and eaten by the people of that region. Although potatoes have since been disseminated throughout the world (through trade) these indigenous heirloom varieties contain the genetic information that makes them biologically successful in their native habitat. The annual responses by the plant to its local environment ensures its success in propagation. Without the intervention of humans, who of course like all animals require food, the plants would remain in their native habitats but continue to evolve in the face of changing climatic conditions.

Figure 5.4: Nursery systems model.

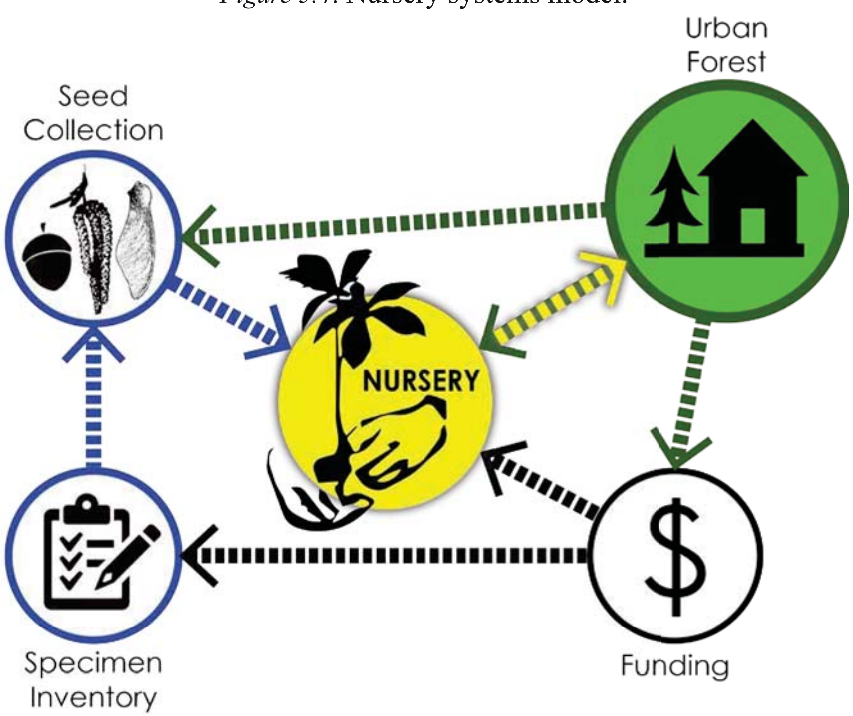
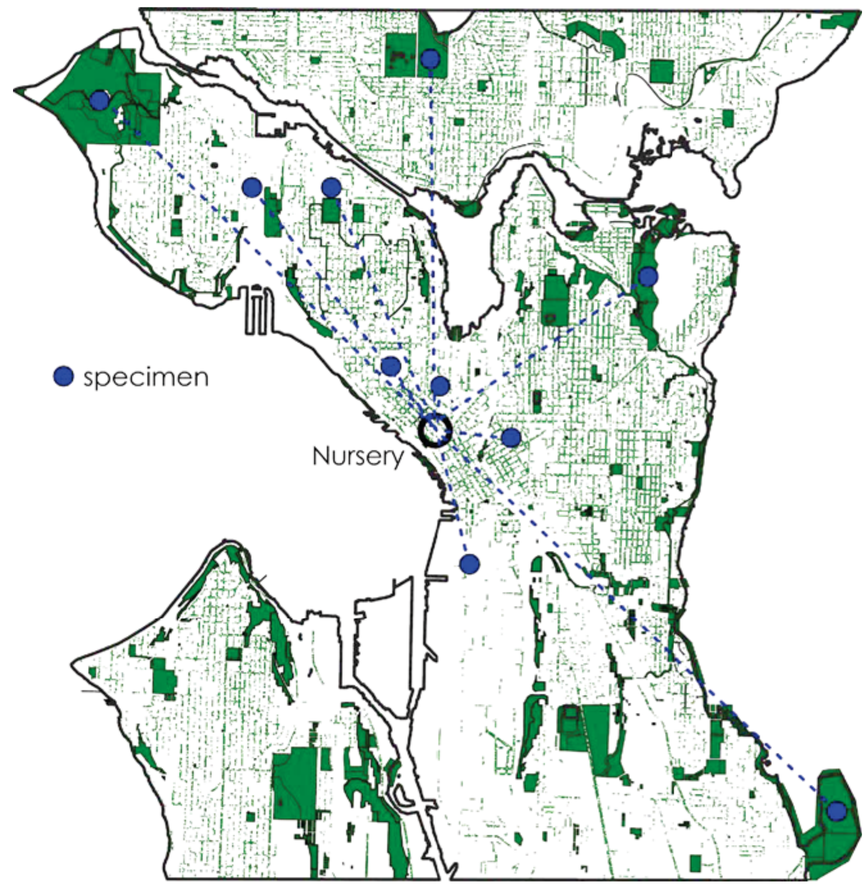


Figure 5.5: Possible seed collection map.



When the need and/or desire for mass production presents itself, sexual reproduction in plants (seedlings) becomes unfavorable because it leads to excessive variability in final products. Cloning and asexual reproduction is now commonplace throughout most industrial cultivation and monocultures dominate our agricultural landscapes. In ornamental horticulture, commercial nurseries develop new tree cultivars by cross-breeding, cloning, and grafting. Seed trials mimic the natural forest by allowing for an exchange of genetic material. The benefits are more resistance to pests and drought, more structurally sound trees (on their own root systems), and an overall more resilient forest.

In the urban forest - where trees are sourced from commercial nurseries - uniformity and mass production prevail. An example is found in the Bradford Pear (*Pyrus calleryana*), an ornamental tree widely planted in U.S. cities. Once touted for its uniform habit and colorful seasonality, this tree has been found to be very susceptible to damage from storms. The mass production and distribution of trees such as Bradford Pear based on aesthetics or disease resistance of a across many climatic zones can lead to unforeseen problems for city managers. I propose to use the trees of Seattle's own urban forest as a source for future plantings within Seattle. Just as the bears of Kazakhstan selected the biggest, sweetest apples, humans may select the healthiest, most beautiful, and most resilient specimen trees for seedling reproduction and genetic development. Essentially, the urban forest could serve as seed source for nursery trials to develop heirloom plants suited to Seattle. Over the long term this will enhance forest health, longevity and resilience to changing environmental conditions.

Infill Timber: Resource Pressure Reduction & Awareness

The highly productive growth rates of Seattle's urban forest lends itself to an experiment in timber or other woody forest products. Aside from the structural timber products that have made the Pacific Northwest famous, there are a number of useful plants that could be trialed in residual spaces throughout the city. Bamboo poles, ash tool handles, willow baskets, and cedar posts may all be grown in our city. Although these may never reach the economic viability of lumber, they can help begin to explore the notion of productivity within the urban forest. The educational and cultural values may begin to outweigh the economic value, especially if plantings are sited on drosscapes within the city. In fact, the primary issue facing the viability of timber production in the urban forest is the same problem facing the street trees; space. There is also a negative perception from the public to the removal of trees. People become emotionally attached to trees in their neighborhood, and conflicts arise when these trees are targeted for removal. The food products currently harvested from the city certainly do not feed the entire, but they do contribute to the mental, social, and emotional state of many of its inhabitants.

The species I've selected for trials in the city are based on: site exposure and orientation, water holding capacity, soil depth, soil temperature fluctuations (for example warming early in spring for bamboo), future land use changes, etc. Fast growing softwood trees and plants are the preferred species. These plants include: bamboo, maple,

Figure 5.6: Urban infill timber systems model.

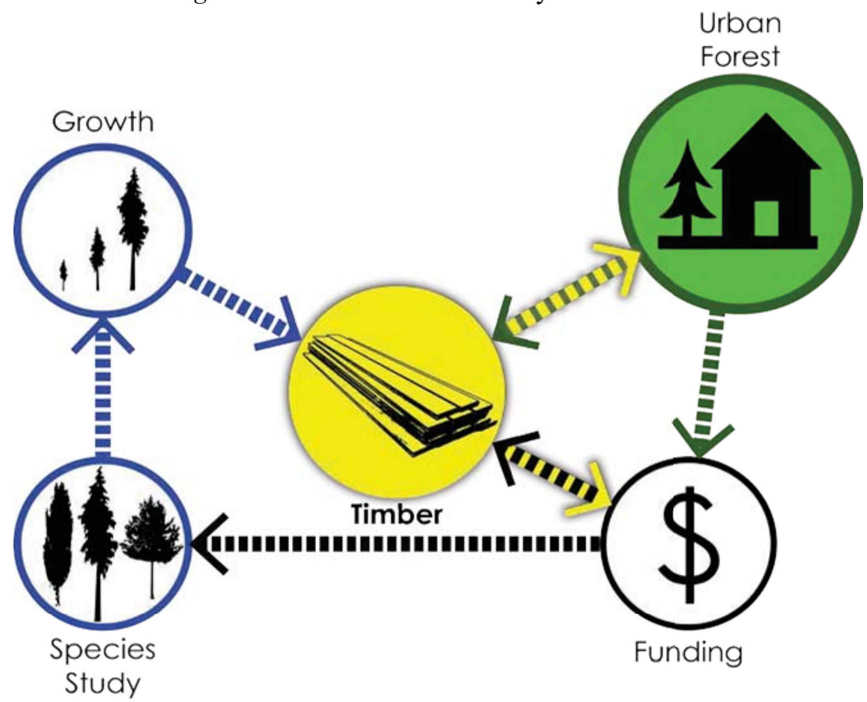


Figure 5.7: Species selected for trials and harvest periods.

Bambusa spp.	Liriodendron tulipifera	Acer macrophyllum
5-10 years	30 years	50+ years

poplar, beech, and ash. A sample working forest may also provide an educational backdrop for visitors and residents to Seattle to encounter the ordered aesthetic of managed timber stands. The Pacific Northwest is home to a long legacy of timber production and Seattle can serve as a demonstration to the effects of logging. A long term vision may see stands of fir being produced in dynamic public parks or open spaces, where the ecologies may be dramatically altered in a controlled urban setting.

6. Rootbound: Testing New Ideas Across Four Urban Forest Typologies

Plants that are said to be root bound are those that have become constrained in their subsurface growing environment to the point of detriment. Such plants will often exhibit signs of stress and most will succumb if not transplanted. Woody plants such as trees may never fully recover and will almost always ultimately die of structural failure or nutrient depletion. In cities where heavy concrete barriers and infrastructures prevail, tree roots do not have the freedom to explore the soil environments as they would in a natural setting. Concrete and heavily compacted soils will force roots to change direction, often into positions which inhibit and undermine the structural integrity of the trunk and crown. In Seattle, the favorable environmental conditions allow these roots to obtain very large sizes, and there are many instances of buckled sidewalks, streets, and underground utilities (see photo 4.1). My proposal tries to harness the growth of these roots into artful interventions. Can roots help shape the social spaces of our city? Can they help our city grow in a more environmentally responsive and sensitive direction? The following interventions are experiments in utilizing plants and putting them to work in and for our urban forest.

Intervention 1: Placemaking Parts

The goal of this design is to grow a new type of urban furniture and artwork while creating new spaces for people to meet and congregate. This site is the North Plaza adjacent to Century Link Field south of downtown Seattle. The site experiences relative extremes in occupancy; high volumes during events at the stadium (or adjacent Safeco field) and low volumes during off season or non-event days. Planting containers are placed in an otherwise devoid urban space. The containers are designed as forms for forcing the root growth of selected tree species into desired shapes. They are also intended to function as seating elements for up to 4 individuals and are placed in close proximity to one another to create small gathering spaces. They are constructed of reinforced concrete and disassemble as 2 symmetrical and removable halves. The bottom of the container is perforated to allow feeder roots to attach to the amended subgrade (see figure 6.5), and allow the tree to grow more rapidly while the roots become "bound" or forced into a normally undesirable shape (see figure 6.1). When the roots are determined to be thoroughly encapsulating the form, the container is separated and the entire tree root mass is removed intact. The wood can then be cured, treated, and reintroduced into the landscape as an artful and functional table.

This concept will require a significant amount of maintenance input to succeed. When placed in containers, trees are susceptible to many urban hazards such as: contamination (garbage, pollutants, etc.), vandalism, storm damage, desiccation, and nutrient deficiency. In order for *Placemaking Parts* to succeed, constant stewardship of these plantings would be necessary to ensure not only their survival, but to achieve a root bound form within a reasonable timeframe. Under good conditions, I would expect this process to take from 6 to 10 years. The trees are selected for aggressive root growth and suitability for container (resistance to drought, pest, and exposure). They are from three genera: *Acer* (maple), *Prunus* (cherry), and *Fraxinus* (ash). In order to limit sensitivity to the harsh, confined environment of a container, seedlings are preferred over cloned cultivars. Trees grown from seed tend to be more stable (no graft union) and present more vigorous root growth. The concept presented earlier as *City as Nursery* can provide the source material for *Placemaking Parts*. Likewise upon removal from the forms, the trunk and branch materials produced in this concept can provide feedstock for the proposed biochar program.

As an experience this concept will at first seem like an ordinary grouping of containerized tree plantings. Over time, the canopy will begin to close in on the space and create a more intimate atmosphere. This canopy creates not only a shaded refuge from the summer sun but also contrasts aesthetically with the barren plaza. At concept maturation the containers are pulled apart to reveal the large root mass which can then be cleaned, cured and treated for rerelease into the plaza as art and furniture. These new parts combine with their original replanted forms to create a new place of interest and awareness of urban forest production.

Figure 6.1: Site located adjacent to Century Link Field.

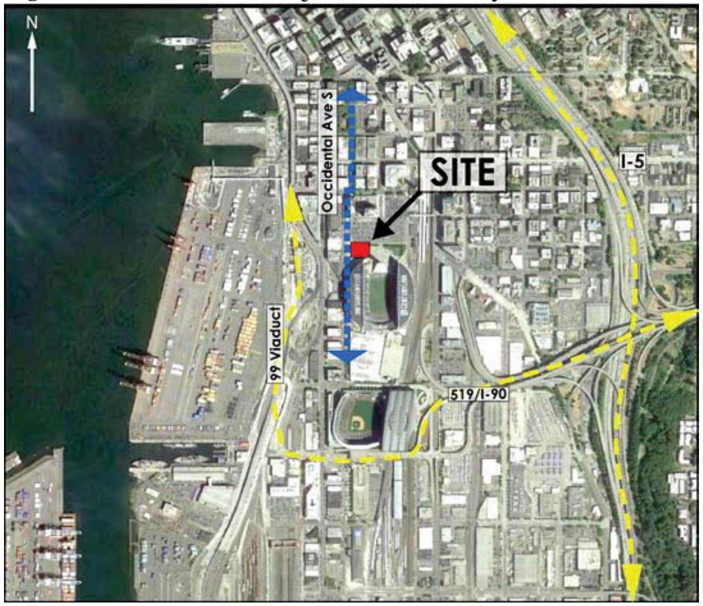


Figure 6.2: Plan of Placemaking Parts.

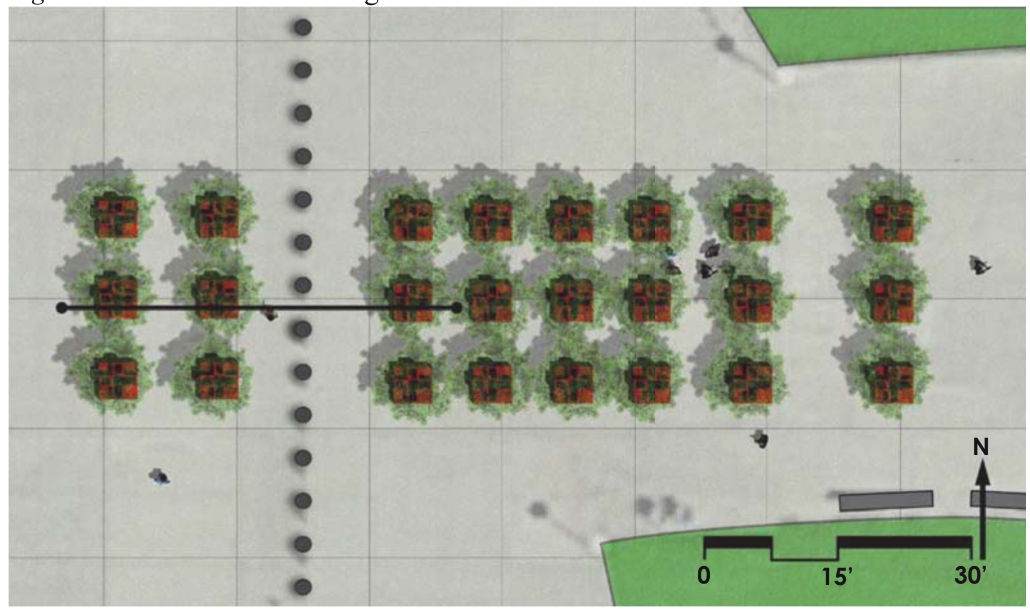


Figure 6.3: System lifecycle.

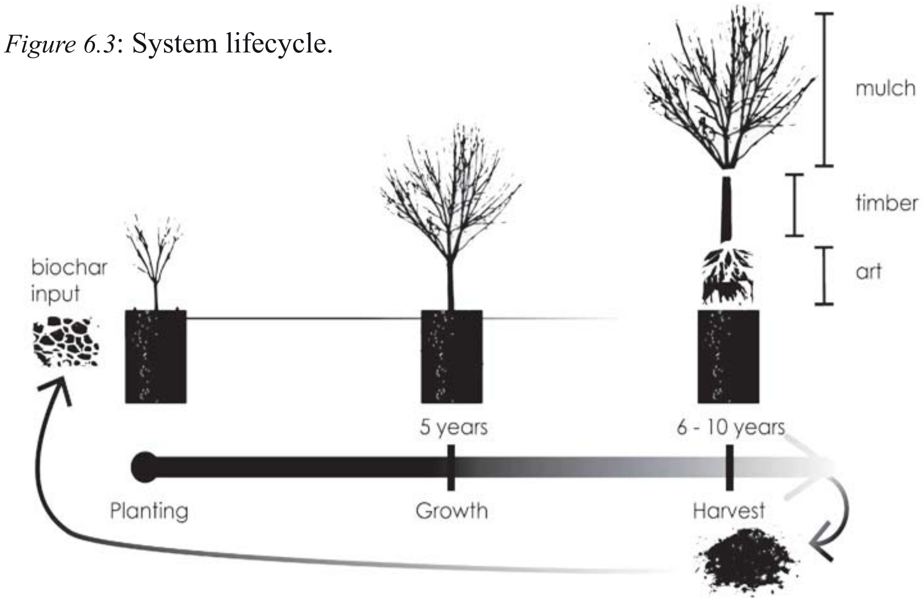


Figure 6.4: Form models and schematics.

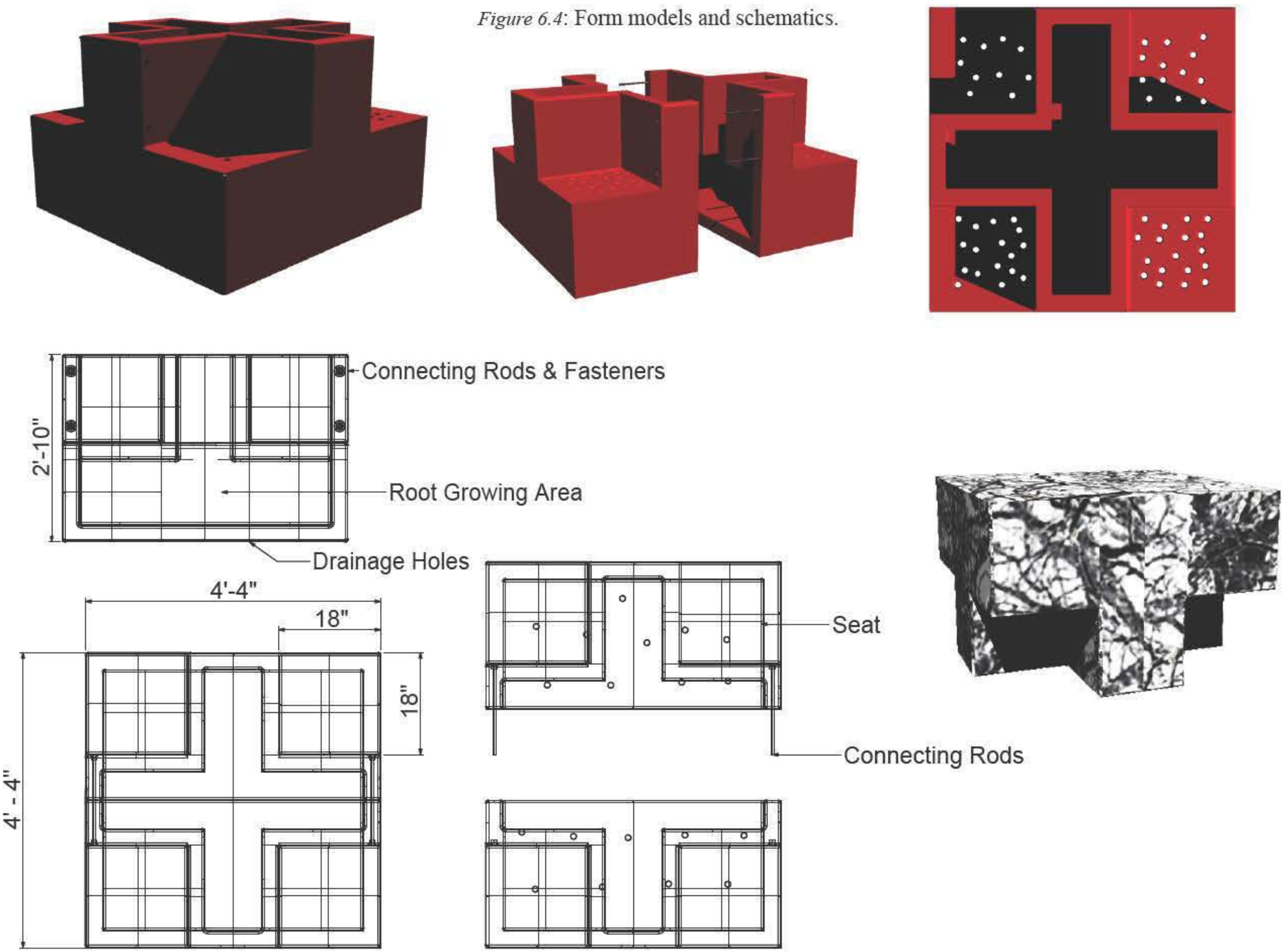


Figure 6.5: A process of space-making.

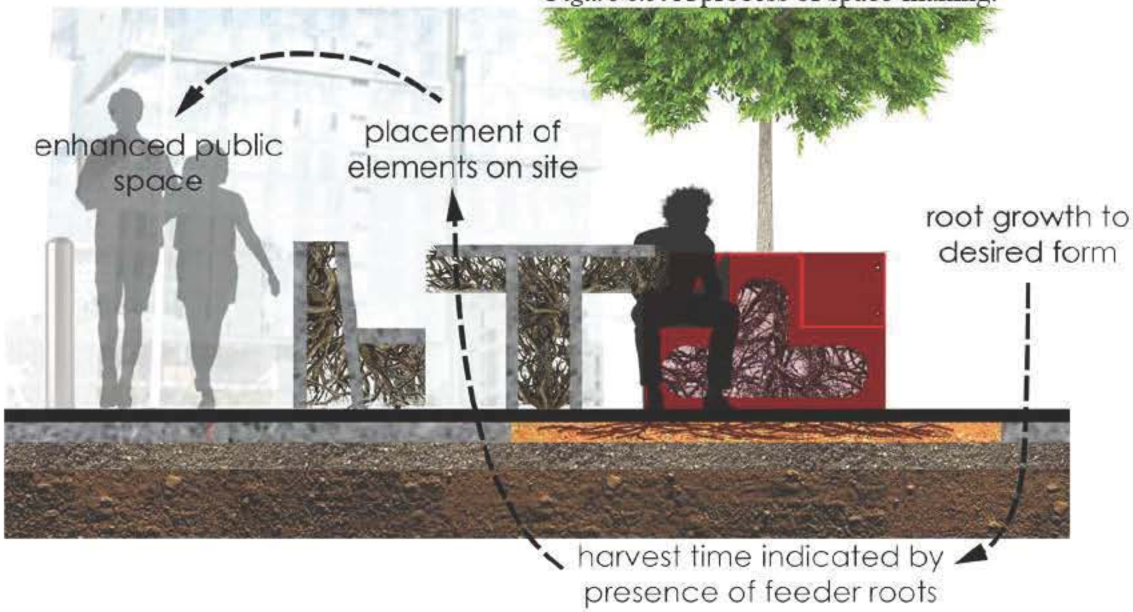


Figure 6.6: Species selected.

Figure 6.7: A new urban forest experience.

Intervention 2: Playground Blocks In Situ

Bamboo is an excellent choice for conducting botanical experiments in the urban forest of Seattle. It is arguably one the most useful plants to humans and plays an important source building material, food, and art in many parts of the world. It has a wide range of growth from tropical to temperate. In our climate, there are certain species, even large ones that grow quite well. Bamboo has been revered for centuries by the many cultures where it grows indigenously, and its widespread dispersal has ensured its permanent place in the urban landscape. To the landscape architect, it provides an important year-round texture and sound aesthetic. Bamboo is available in a good variety of leaf and stalk color and there are several species that do very well in our Pacific Northwest climate. Upon visiting a commercial bamboo grower in Seattle, it was discovered that the root mass of bamboo can be dried and worked into unique artwork. Indeed, bamboo roots and rhizomes, if allowed to dry completely, are woody enough to endure carving and milling. The proposal for *Playground Blocks In Situ* manipulates the root growth of bamboo to create durable, biodegradable, and renewable toys for children.

This concept forces bamboo roots by allowing the roots to fill specialized containers over a 2-3 year term. The plants are then removed en masse, the above ground portions removed, and the roots are then dried. The resulting forms are oversized playground blocks which are then introduced into the playscape where children can freely use them in creative play. This provides an enhanced learning environment, something described in 1971 by Simon Nicolson's concept of "loose parts." His theory was a major advance in this area for landscape architects whose playgrounds at the time were languishing in generic boredom and thoughtlessness. According to Nicolson, "The theory of loose parts says, quite simply, in any environment, both the degree of inventiveness and creativity, and the possibility of discovery, are directly proportional to the number and kind of variables in it (30)." He claims that in order to deepen the learning experience for children, basic building blocks which can be used for creative, social play are critical. He states, "Children learn most readily and easily in a laboratory-type environment where they can experiment, enjoy, and find out things for themselves" (31). Children, just like adults, need certain parts to make a definitive whole, and providing places such as playgrounds with the singular, raw materials for innovation allows children to expand their cognitive vocabulary.

The containers here are planted below grade with just 2 inches remaining above ground (to inhibit lateral rhizomatous growth). They are constructed of unreinforced porous concrete and stainless steel fasteners and the growth media specified will need to contain zero aggregate and be high in organic material. The porous concrete will allow a more free exchange of water and air with the surrounding soil profile and facilitate irrigation across a wider area. The organic matter will encourage vigorous growth and when completely consumed, should yield a solid root mass. A clean media will ensure that rocks or other large soil particles will not become part of a playground block. To design of the block plantings are, in this proposal, a playground maze. Bamboo is an excellent screening plant and this design creates a series of hedges that frame a fun, inviting play area. When the plants become sufficiently root bound to their forms, a "block party" may occur where the neighboring community may participate in a harvest of the roots. The tops are removed and processed into compost and the blocks are immediately introduced into the playground.

The urban forest can play a more active role in the education of children and bamboo is a fast growing, durable plant suitable for this. This is a low cost intervention that can create a new set of blocks every year after the initial 2-3 year set is harvested. This is achieved by staggering the harvest and planting schedule. The construction of the forms should allow for at least 20 years of useful life.

Figure 6.8: Site in Queen Anne, Seattle.

Figure 6.9: A typical playground.

Figure 6.10: Plan of "Maze Phase."

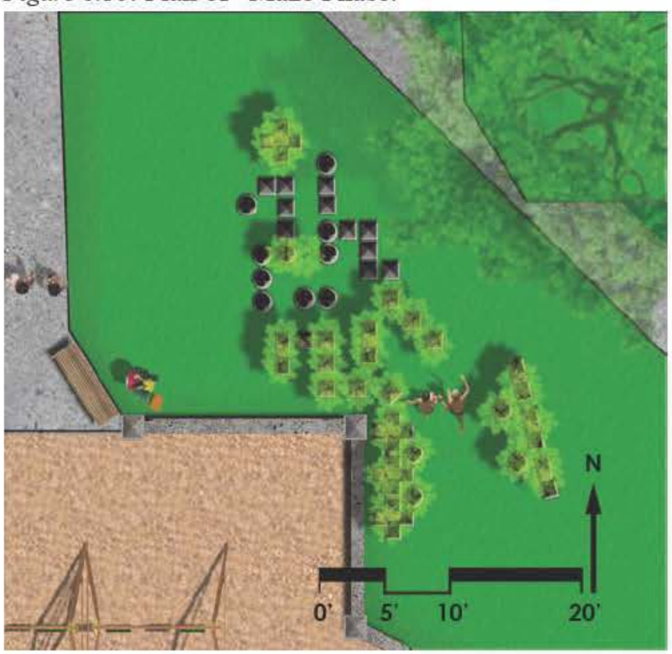
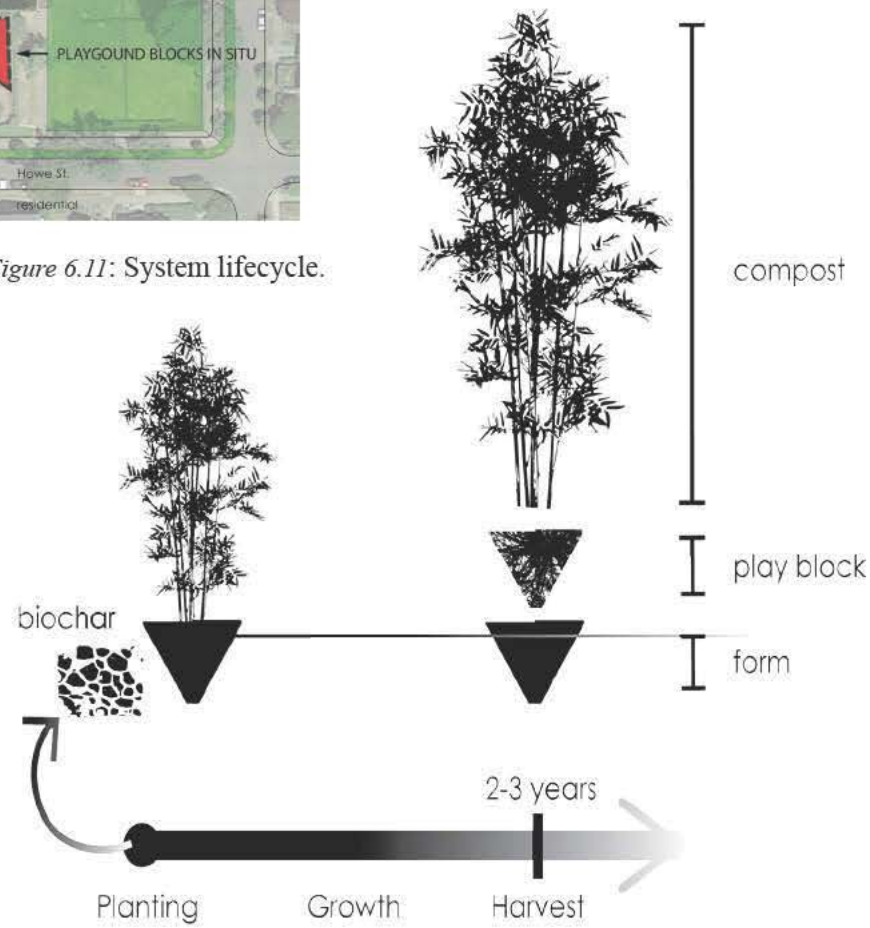


Figure 6.11: System lifecycle.



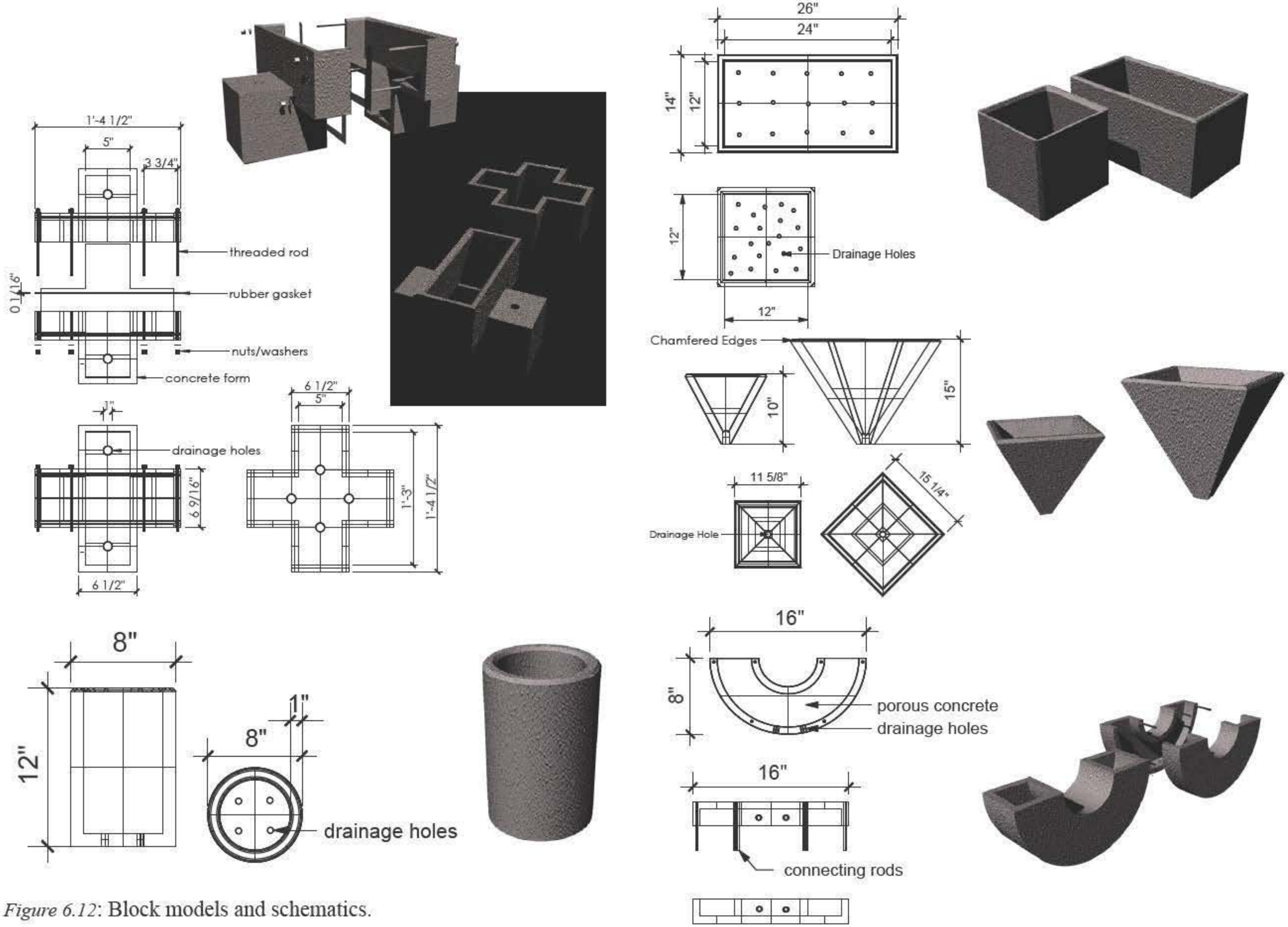


Figure 6.12: Block models and schematics.

Figure 6.13: The "Maze Phase."

Figure 6.14: The “Block Party.”

Intervention 3: Vestigial Wetland Phytoremediation

A careful examination of the urban forest will inevitably reveal parcels of land that receive pollution, refuse, and general neglect. These places are often situated at low points in the topography or at the junction between differing land uses. For example, a vacant lot adjacent to a heavy use (sidewalk or highway) will collect windborne refuse. Water is an excellent carrier of urban pollutants and Seattle is especially prone in this regard. Water is also critical to any habitation and must be cared for as a life-giving element to humans and animals alike. This concept seeks to remediate water and soil pollution by utilizing the urban forest as a living sponge.

What was historically a large intertidal marsh with Salmon Bay on the north end and Elliot Bay to the south, the Interbay is now a functional and heavy-use industrial landscape. There are also many pockets of fallow industrial land where the urban forest plants are well established and the wide range of species are likely indicators of the available soil nutrients, structure and water availability. A unique aspect to this area is the north/south public access through the Elliot Bay Trail. The trail itself is moderately used by pedestrians and cyclists and courses through the middle of this industrial urban forest landscape. At the north end there lies an open ditch between a heavily used rail yard and a typical (approximately 40 car) parking lot. Close observation of the ditch showed a significant amount of windblown debris/garbage and a small amount of open water with oil films on the surface. Situated at the low point between the land uses, the ditch receives surface runoff and therefore pollutants from the parking lot and rail yard. According to the United States Environmental Protection Agency, the most common pollutants from an active rail yard are: solvents, Polychlorinated biphenyls (PCB's), heavy metals, diesel, and herbicides (www.epa.gov/reg3hscd/bf-lr/regional/industry/railyard).

The *Rootbound* forms in this intervention are reminiscent of industrial and waste forms. Large spindles, cones, and barrels comprise a series of perforated tree containers that allow for the passage of water. They are placed midway between the high and low water levels and are estimated to take from 6-10 years to become completely bound by their roots. The trees are then removed and the root mass is placed as art and functional elements (trash cans) along the Elliot Bay Trail. This removal ensures that pollutants sequestered in the plant tissues are removed from the aquatic environment and allowed to be further broken down.

Based on trials in Oregon, *Populus* (hybrid poplar) has been selected as the primary remediation species. They have been shown to uptake low concentrations of volatile organic compounds (VOC's) per the following summary published by the EPA:

> Hybrid poplar trees were planted on site in 1998 to remediate the ground water contaminated with VOCs. By July 30, 2002, the trees had not only survived, but shown considerable growth. Four of the larger trees were selected as the focus of sampling because their roots most likely be in contact with contaminated ground water. Although the water and soil samples proved inconclusive, tissue samples taken from the four trees indicated that the trees were actively removing VOCs from the ground water and soil. Although tissue samples from all sections of the trees revealed contaminant uptake, higher contaminant concentrations seemed to be found in the trunk rather than the leaf tissue…The success of the trees at the Oregon Poplar site supports the notion that phytoremediation may be an innovative technology worthy of nationwide consideration (www.epa.gov/superfund/accomp/news/phyto).

Betula (birch) has shown similar promise and as a native plant with contribute to the overall aesthetic and habitat potential. Other wetland species such as cattail, which are already present on the site, will be further planted and encouraged to augment the phytoremediation process.

Natural forests are both closed and open nutrient cycle systems. On the scale of a single tree, nutrients cycle as leaves drop, decompose, and then return through root update into the same plant. Resident animals such as rodents and insects will also cycle nutrients in a single-tree ecosystem. On a forest scale, nutrients can enter the system by wind, water or carried by migratory animals.[1] Urban forests have similar nutrient cycles, but pollutants are also cycled through the same vectors. Trees in the built environment therefore have responsibilities imposed on them by humans beyond their natural state. It is therefore up to humans to manage these trees (and other plants) as pollutant cyclers and this proposal seeks to accomplish this.

[1] One example from the Pacific Northwest is that of the salmon. When mature salmon have spawned and died following the upriver migration, their bodies become important sources of nutrients for the surrounding forest ecosystems.

Figure 6.15: Industrial Interbay corridor.

Photo 6.1: Vestigial wetland.

Figure 6.17: System lifecycle.

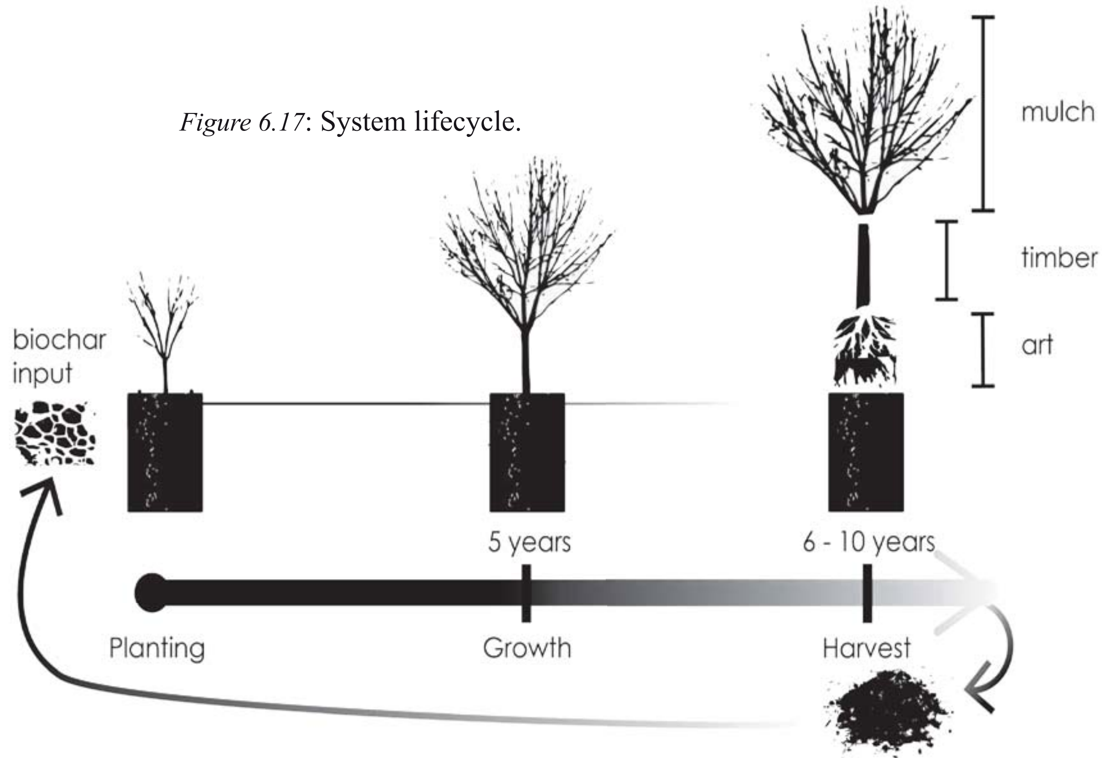


Figure 6.16: Pollutant streams.

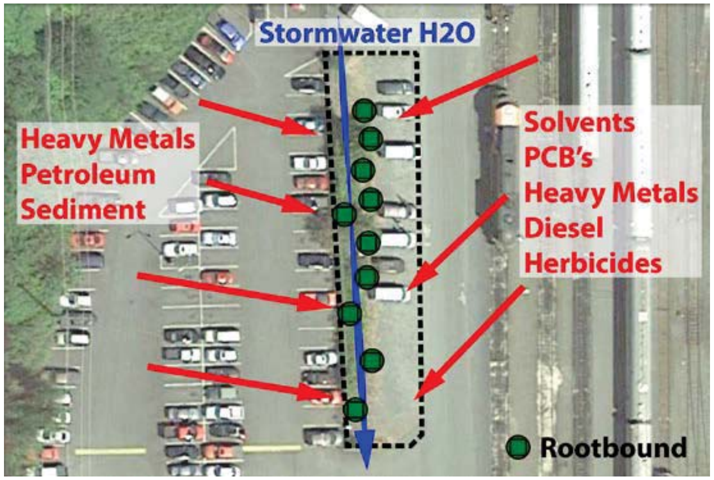


Figure 6.19: Trash can modeling.

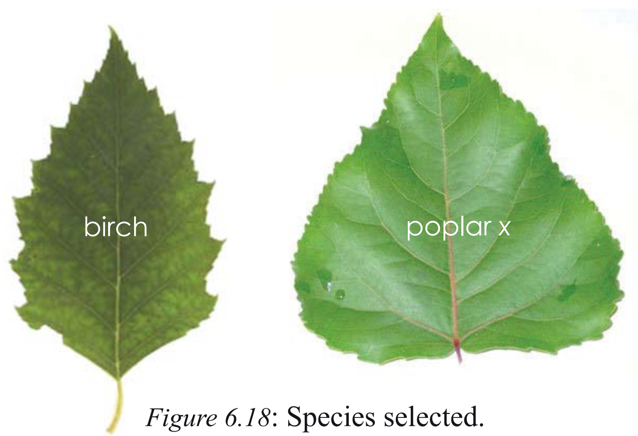
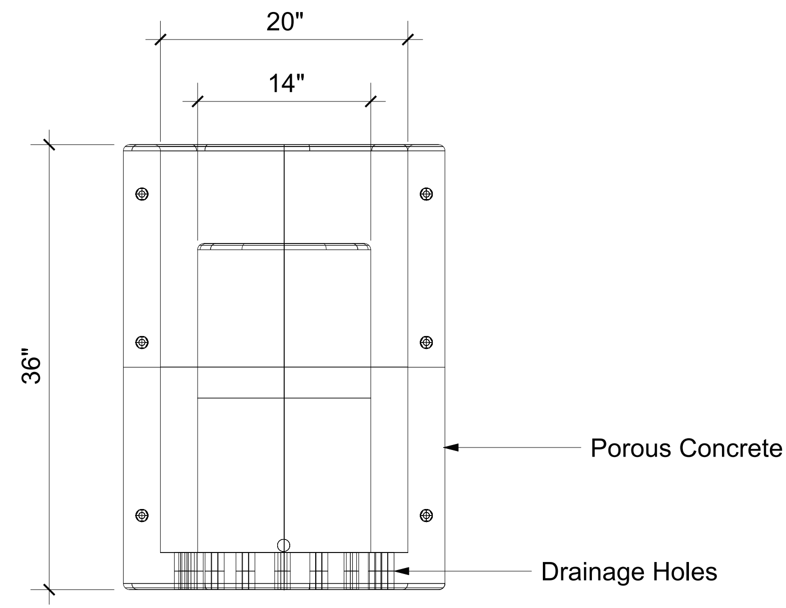


Figure 6.18: Species selected.



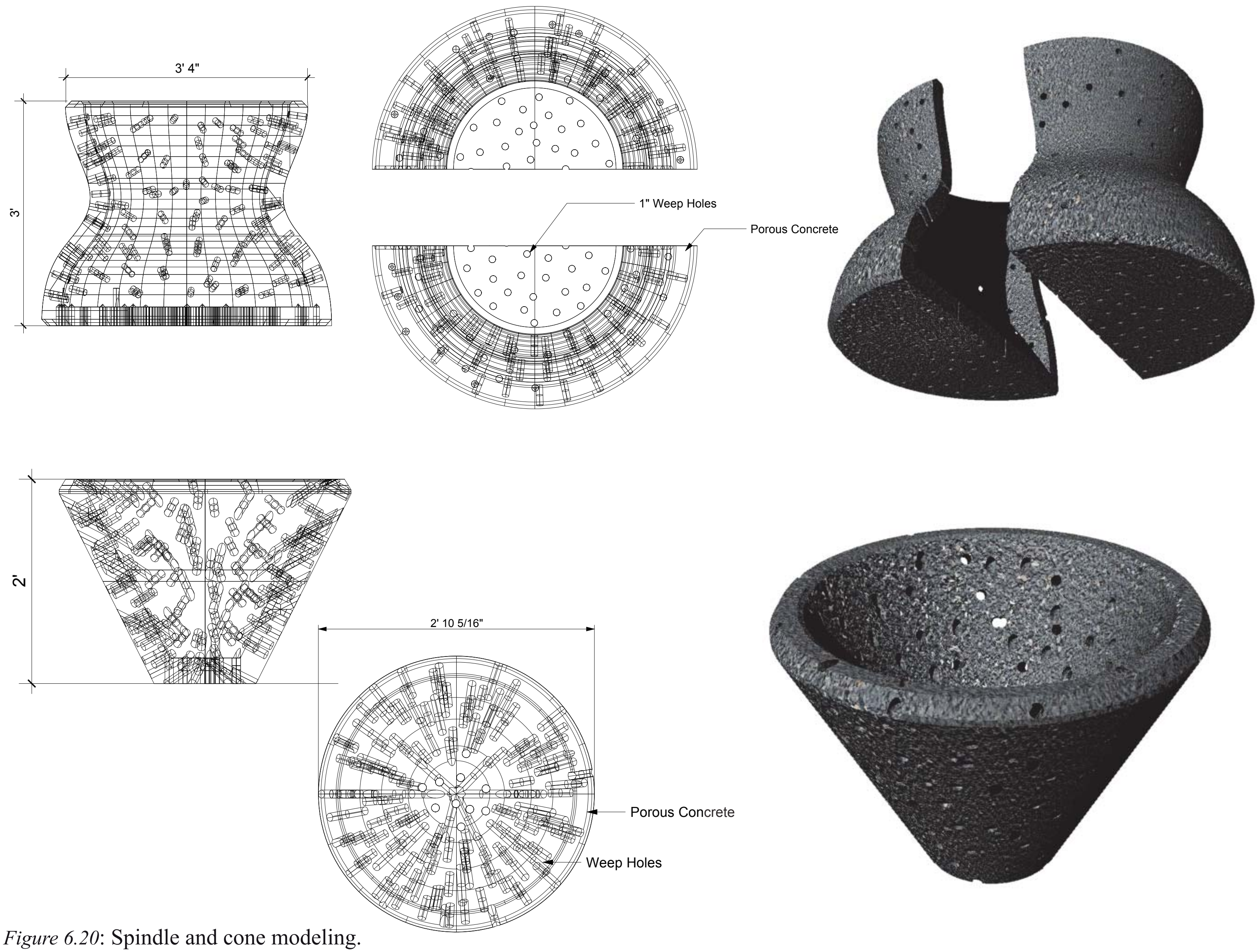


Figure 6.20: Spindle and cone modeling.

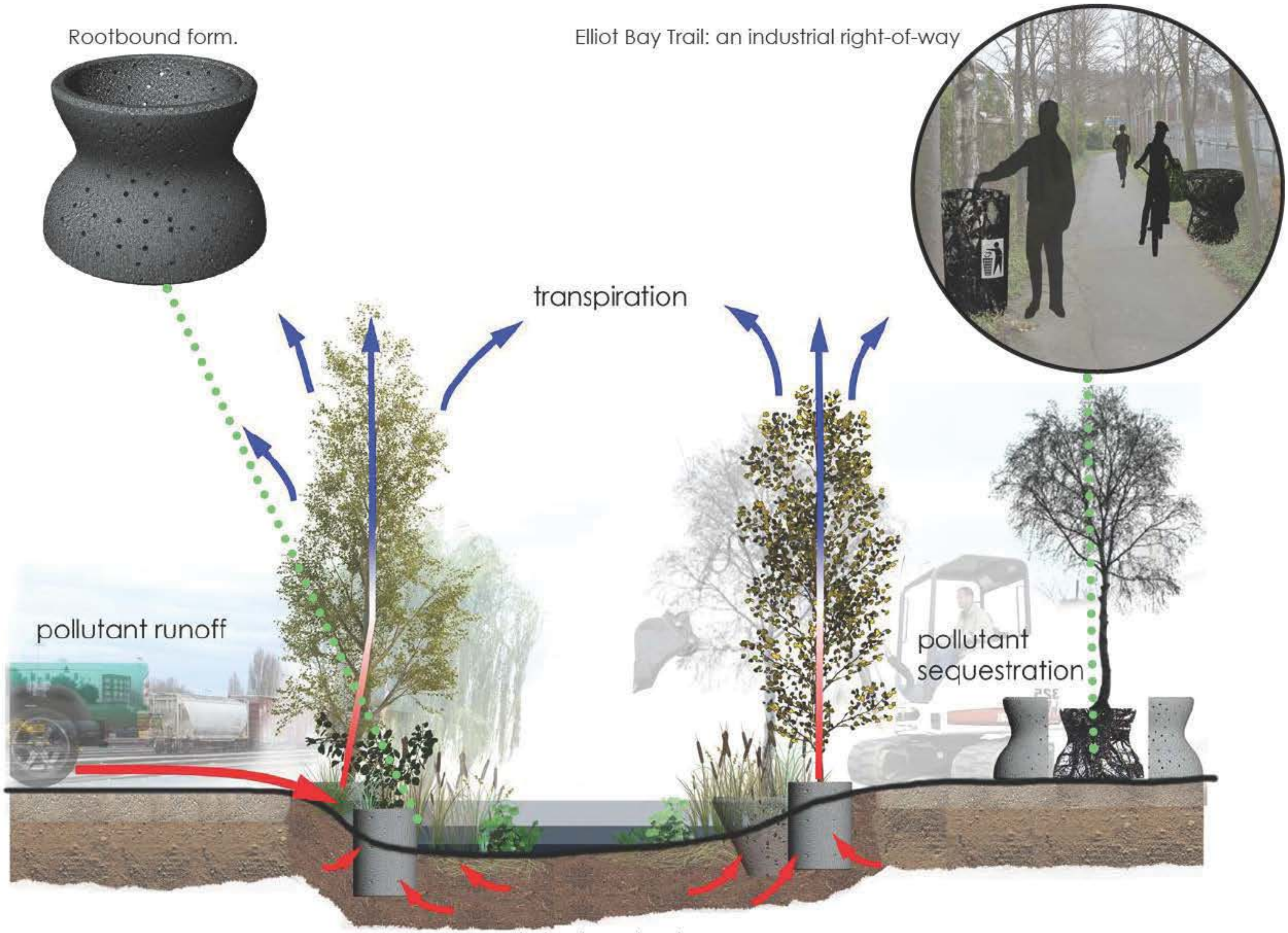


Figure 6.21: Phytoremediation and product placement.

Intervention 4: Nurse Log Retention Units

One challenge that landscape architects are sometimes called to address (and more directly urban planners) is that of so-called residual space. Cities such as Seattle, despite their intense surface coverage of impervious surfaces, towering architecture, and persistent commerce, still have open land that is unused or otherwise deemed useless. As an urban forest typology earlier described as drosscapes, these spaces in Seattle are usually fallow land parcels that lie between highways and roads as defined by the city grid. They often have steep terrain and are heavily vegetated, sometimes with aggressive invasive species such as Himalayan blackberry. In selecting a site for this project, I've tried to find an area that is well framed in the dense urban context and has been left in stasis for an extended period. The site chosen for this intervention is at the south portal of the Battery Street tunnel and is bounded to the northwest by Batter Street, the southwest by Western Avenue and the northeast by the Alaskan Way Viaduct. It has a slope of up to 25%, is covered mostly in tall grasses and is completely surrounded by fencing. The land is owned by the City of Seattle and also contains a non-public parking lot.

The concept is to create or more accurately grow nurse log retention units for use in landscape projects which require low-stress grade retention. The ideal application would also address the need for biodegradable materials and long term re-vegetation planning. Interlocking concrete forms provide a system for terracing the site and maintaining the existing grasses. Depending on the end application, a wire gabion basket is either inserted or omitted from the container. The appropriate growing media is then added and two trees are then planted in either section of the container. As the trees grow, their roots become bound to the form and eventually encompass the majority of the container. This process is expected to take between 7 and 9 years. The tree is then felled and the resulting mass is removed from the form and transported to the landscape project. With an included gabion mesh and medium sized cobble stones, the structure could be used in a semi-structural seat wall or retention design. In products grown without the steel mesh, the root structure becomes an interlocking nurse-log system. This design would be suited to projects where native plants could be allowed to thrive on a decomposing, semi-structural retention system. Over time, the root structure would disappear as permanent plantings mature and overgrow the project.

The species selected for this intervention are *Pterocarya fraxinifolia* (Caucasian wingnut), *Metasequoia glyptostroboides* (dawn redwood), and *Thuja plicata* (western red cedar). All have been chosen for unique characteristics in both the urban intervention site and landscape project environments. Caucasian wingnut is a native tree of the Caucasus (Russia, Ukraine, Iran, etc.) and according to Seattle's City Arborist, has caused problems because of its aggressive and shallow rooting and suckering. It grows aggressively in our temperate climate and is suited to this intervention because of its hardy nature and aggressive rooting. The dawn redwood is a native to China and has been observed in Seattle's urban forest conforming well to curbs and concrete tree pits. The roots have a tendency to fill along concrete edges and it grows rather quickly when provided with adequate organic material. Similar to the Larch or Bald Cypress, it is a deciduous conifer. Finally, the western red cedar has been chosen for its evergreen foliage – a nice aesthetic during the urban winter – and its resistance to rot when in contact with the ground as a nurse log. This native tree was once ubiquitous in the Seattle area but has been largely removed through years of logging and industrial development.

Figure 6.22: Battery St. tunnel, south portal.

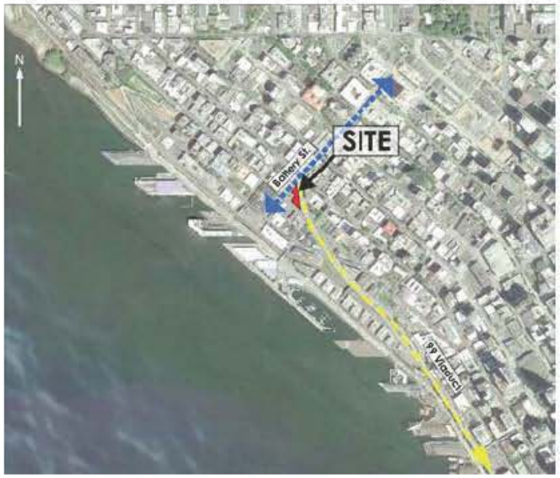


Figure 6.23: Vegetated parcel.

Photo 6.2: A central city drosscape.

Figure 6.24: System lifecycle.

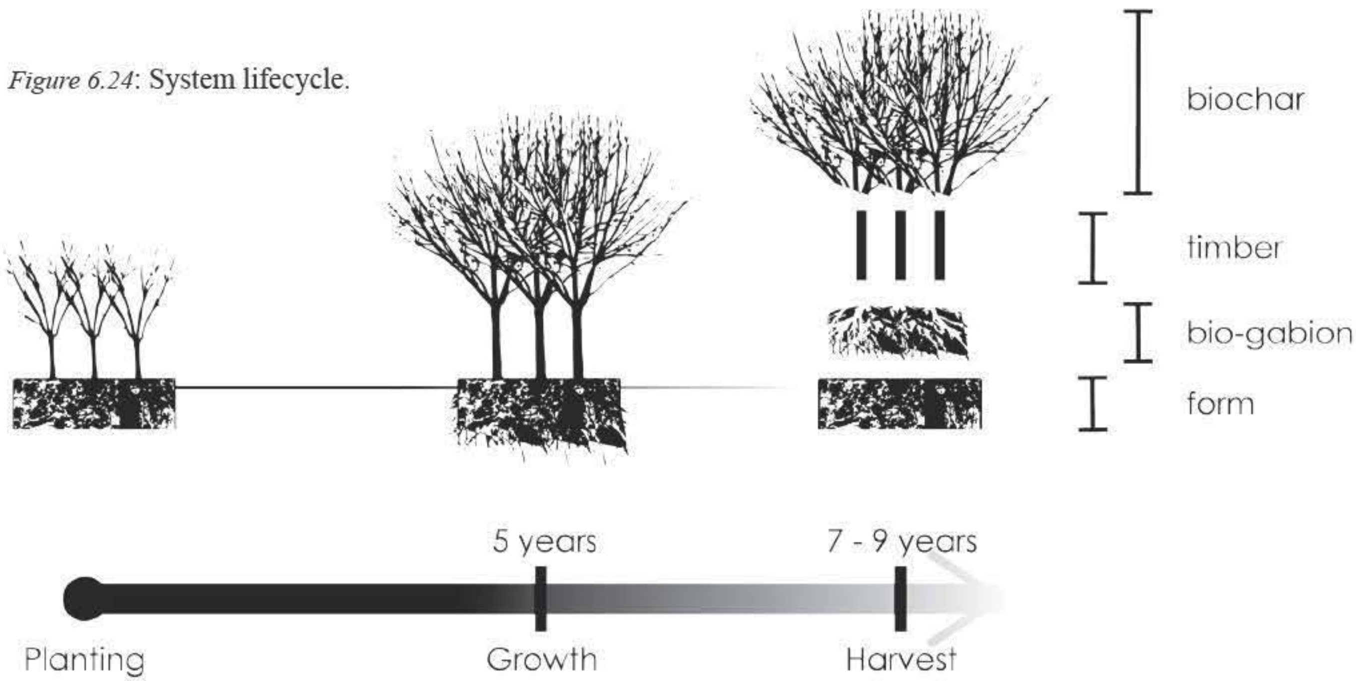


Figure 6.25: System modeling and schematics.

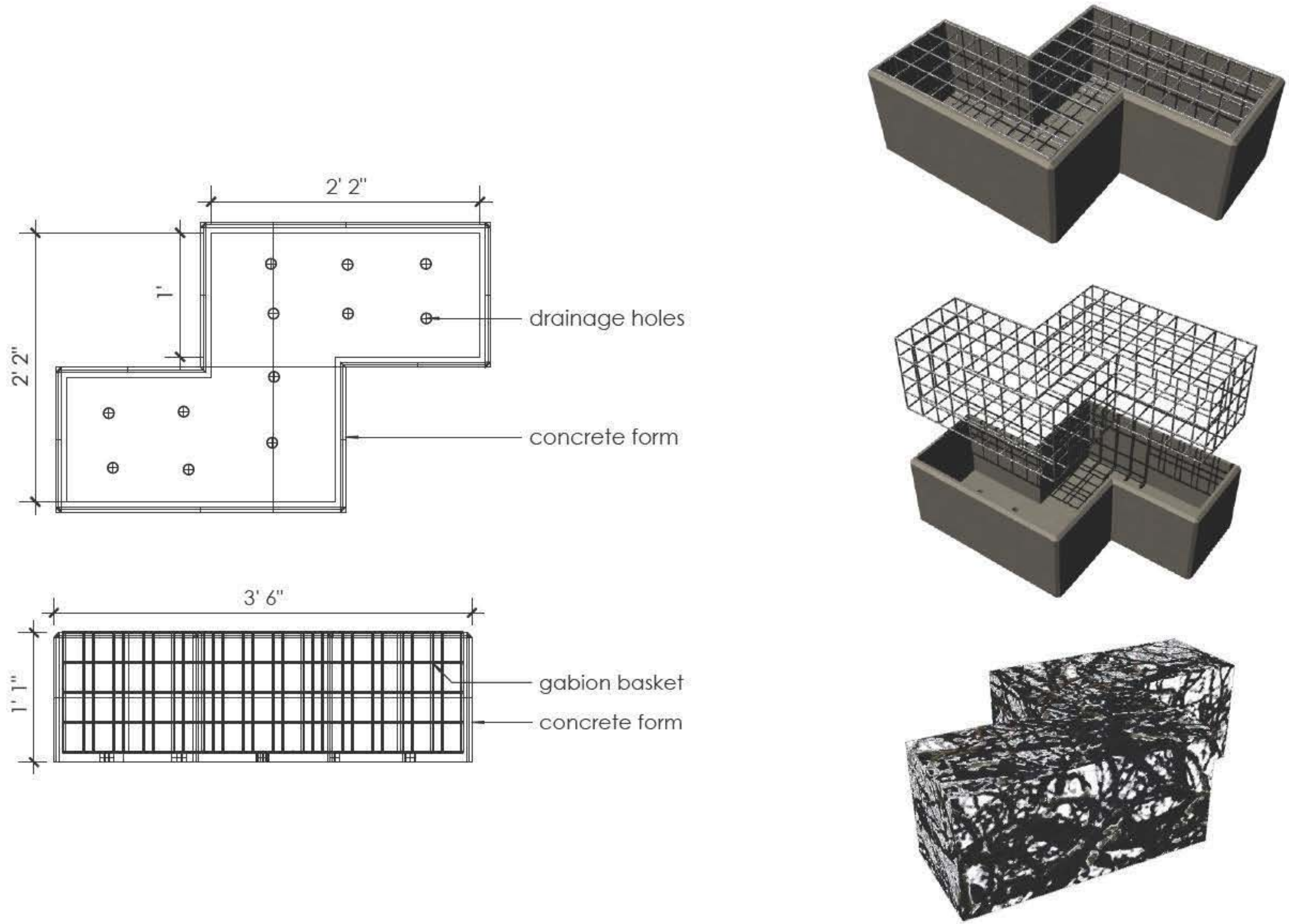
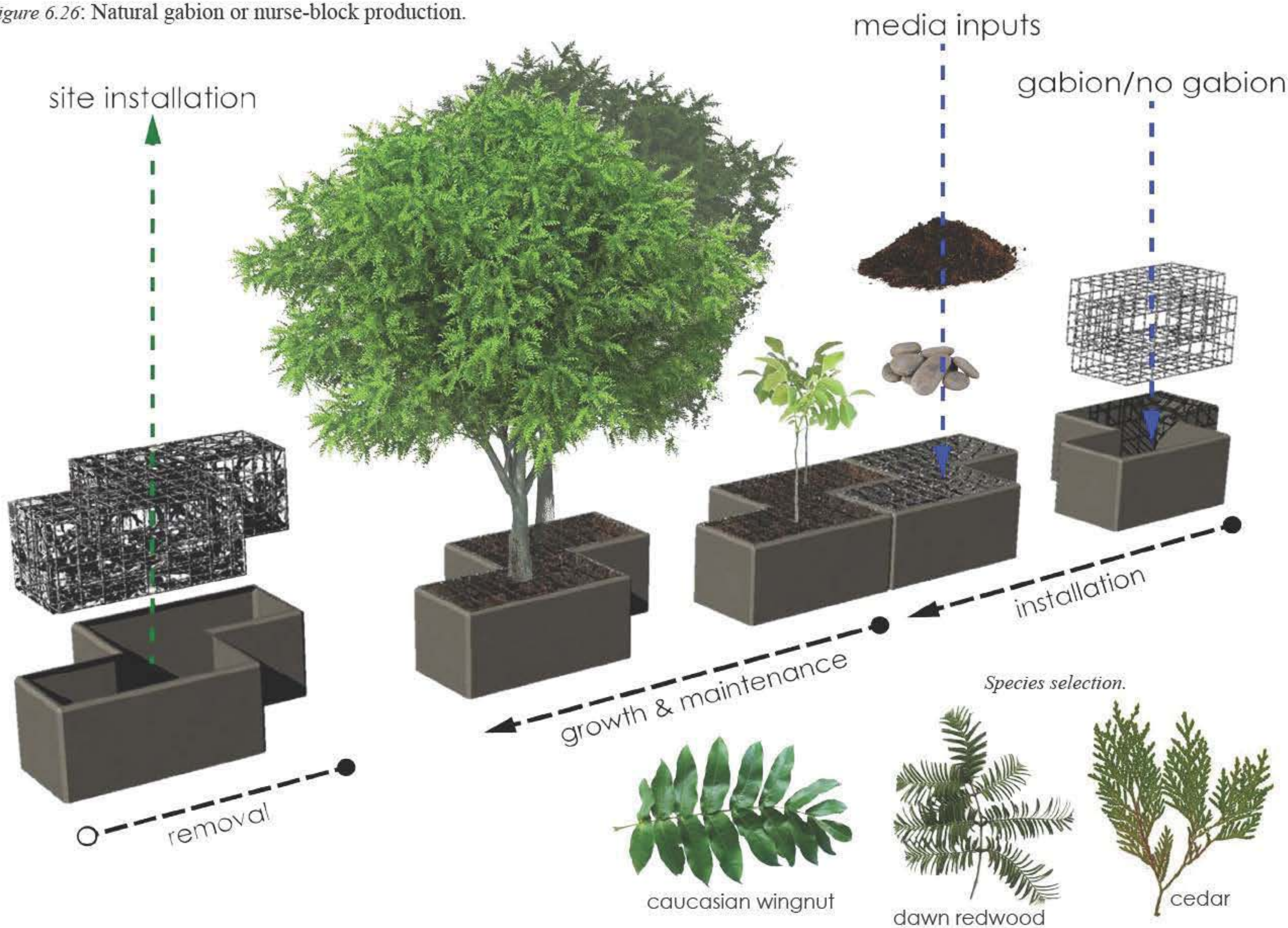


Figure 6.26: Natural gabion or nurse-block production.



7. Experiment

In order to test the Rootbound concept within the relatively short timeframe of this project, an experiment has been designed forcing the growth of several species of plants. It was designed as a way to prototype small products and to simulate large-scale woody plant species root growth; both in response to varied constraints of the root zone. I began by sketching some basic concept forms and then refining them into rough measured schematics. These drawings were then taken to the fabrication laboratory where the forms were cut and assembled using scrap plywood, o.s.b. (oriented strand board), and fasteners. A growing media of Ecoscraps© Organic Potting Mix was added to the containers and plants were divided and transplanted. The lighting used was a set of 4 fluorescent 40W T12/DX, 6500K broad spectrum bulbs. Reflective foil was placed around the plants enhance the light intensity and therefore photosynthesis.

A temporary indoor grow space was established indoors and the plants were set in the custom containers on January 16, 2015. The light duration was gradually increased over the first 3 weeks until a "day" length of 12 hours was achieved. This "tricked" or triggered the growth of both bamboo species, which was indicated by the unfurling of new leaves and the emergence of several new culms. The growth of the plants was monitored for several months. I harvested about 2 dozen seeds from a stand of *Fallopia japonica* (Japanese knotweed) and sowed them in small containers. Only 3 plants germinated and they failed to thrive, wilting at around 4cm in height. The lone container with *Equisetum hamalaea* (horsetail) began to grow as indicated by new shoots, but did not exhibit the vigor of the 2 bamboo species. The plants were then hand irrigated as needed. A bi-weekly fertilization with Alaska Fish Fertilizer 5-1-1 was begun once growth was indicated.

Upon removal or partial removal from the forms on May 3, 2015, the bamboo was observed to have rooted to the bottom of the three containers. These roots however were young feeder roots and there was insufficient root mass to support a complete removal. I reinstalled a Plexiglas side panel to allow for viewing of the roots during the project presentation on May 5 (see photo 7.1). In spite of the lack of complete root mass development, I was able to source and harvest an existing bamboo mat from a local nurseryman. The bamboo plants (species unknown) had been growing in a well-built wooden container for 4 years and had become completely rootbound, with large surface roots and runners clearly visible under a light layer of leaf litter. Culms had begun to extend beyond the form. I removed the wooden frame and top growth and chopped the mat into several large blocks with a spade. The roots were then thoroughly cleaned and dried and smaller blocks were taken to the UW CBE fabrication lab for finishing. The resulting root block (see photo 7.2) clearly illustrates the structural integrity of bamboo roots as a material for creating elements such as those proposed in this project (Playgound Blocks In Situ). A longer duration experiment or actual intervention would be needed to achieve sufficient growth for various types of bamboo and blocks.

To conclude, this experiment has shown that root manipulation is possible during the growth phase of at least one species of bamboo, *Sasaella masamunea* 'Albostriata.' In addition, this species is suitable for use as an ornamental plant for growth in Seattle and is well represented in commercial nurseries and private gardens.

Photo 7.1: Existing root condition.

Photo 7.3: The established experiement.

Photo 7.2: Containers built and planted.

Figure 7.1: Root mass harvested and finished to block form.

Photo 7.4: Root growth extending along and down form.

Figure 7.2: Tetrahedron, O.S.B.

Figure 7.3: Birdhouse, plywood.

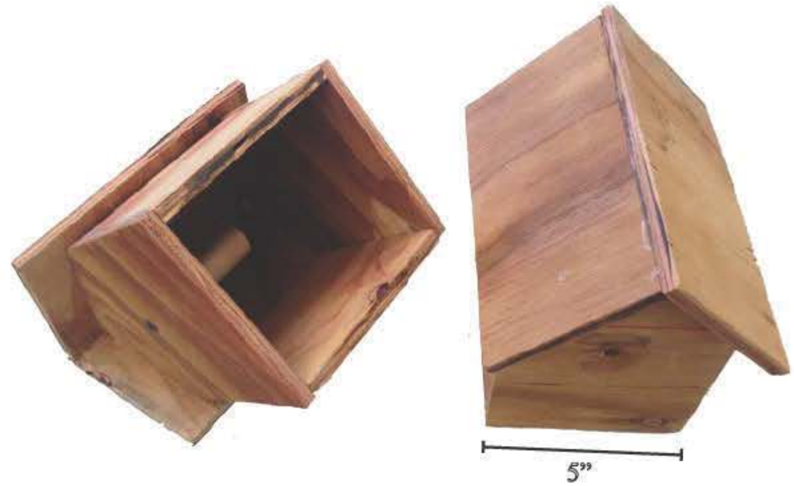


Figure 7.4: Chair, O.S.B.

Figure 7.5: Vase, bamboo.

8. Reflections and Conclusions

This project began as an observation on Seattle's streets. As a recent transplant to the region, I am in constant awe at the vigor and diversity of the Pacific Northwest urban biome. The abundance of water and a cool temperate climate have long given rise to a wide array of flora. Enormous cedar and fir trees tower above a multilayered forest understory. Epiphytic ferns, mosses, fungi, shrubs, and herbaceous plants fill every available niche. In fact rarely do we find any unoccupied space in this urban temperate rainforest. But as the developments of humanity have spread across the land, trees and their counterparts have remained, albeit severely diminished.

The aim of this project was to explore the urban forest as a potential source for benefits and products other than those already provided. These existing values and services (shade, habitat, etc.) are not intended to be replaced nor challenged. I maintain that the urban forest must continue to be managed for the health and longevity of its trees, the seminal species in built environments of the Pacific Northwest. The current methods proposed and being implemented by professional arborists such as James Urban will no doubt enable trees to gain larger size and live longer in difficult sites. Much research and development has been contributed to providing a maximum amount of space for tree roots. Rather than argue against this, my proposals are intended to supplement a healthy and long-lived urban forest (see Figure 8.2). Not all species will respond to the formwork nor can survive in the containerized environment. As such, a larger selection of trees may need to be utilized to broaden the *Rootbound* potential. The trees with the highest observed growth or potential for growth can then be further planted and placed into the appropriate urban forest typological and social contexts.

Other cities should likewise continue to manage their forests for maximum health and longevity. While productivity (if measured in terms of species diversity and growth rates) will vary widely from place to place based fundamentally on climate, explorations and experiments in methods which I have proposed can lead to better connections with its human inhabitants. Context-specific proposals similar to the ones presented here may be implemented in other places. Additionally, it should not be overly ambitious to assume an interconnected relationship between different urban forest municipalities. For instance, certain cities with an excess of drosscape sites may lease this land for timber production by another city. Seed sources and greenhouse facilities may also be shared so that the concept of *City as Nursery* may develop a greater diversity of species while offsetting startup costs for smaller cities. Urban foresters in this way can develop management strategies that truly enhance the long term production and viability of the urban forest. By reducing the pressures on our natural forest ecosystem, we can realize the prospect of a more resilient future.

My interventions are intended to reveal the hidden workings of plants and inspire people to look at the urban forest in a fresh light. Cities are in a constant state of change, where one layer of activity is removed, replaced, or added to by another. Technology continues to advance at increasing rates and the cities of the future will look, feel, and sound different than those of today. The architect Mitchel Joachim has what may seem bizarre visions of the future built environment, but are based on current scientific understandings. Is it inconceivable to utilize the tree growth for a living building scaffold? Or sewer systems designed to mimic the biological processes occurring in our own digestive systems; a living conveyance system capable of handling the waste stream of a city? He describes the Fab Tree Hab in an excerpt from the website.

> The trunks of inosculate, or self-grafting, trees, such as Elm, Live Oak, and Dogwood, are the load-bearing structure, and the branches form a continuous lattice frame for the walls and roof. Weaved along the exterior is a dense protective layer of vines, interspersed with soil pockets and growing plants. Scaffolds, cut from 3D computer files control the plant growth in the early stages (www.archinode.com/fab-tree-hab).

Trees are and should be continued to be utilized for their ability to uptake and store excess nutrients and pollutants. Cities such as Seattle are hybrid organisms based on a cross of human business, commerce, and the supporting service industries with natural system functionality. Trees are also already hard at work in cities, primarily in a struggle to survive. In Seattle, we have a unique opportunity however to put trees to work for us and the climate is ideal for the adoption and growth of a range of experimental interventions. The future of our city may demand more from our urban forest as the pressures on natural

Figure 8.1: The potential for a citywide experiment.

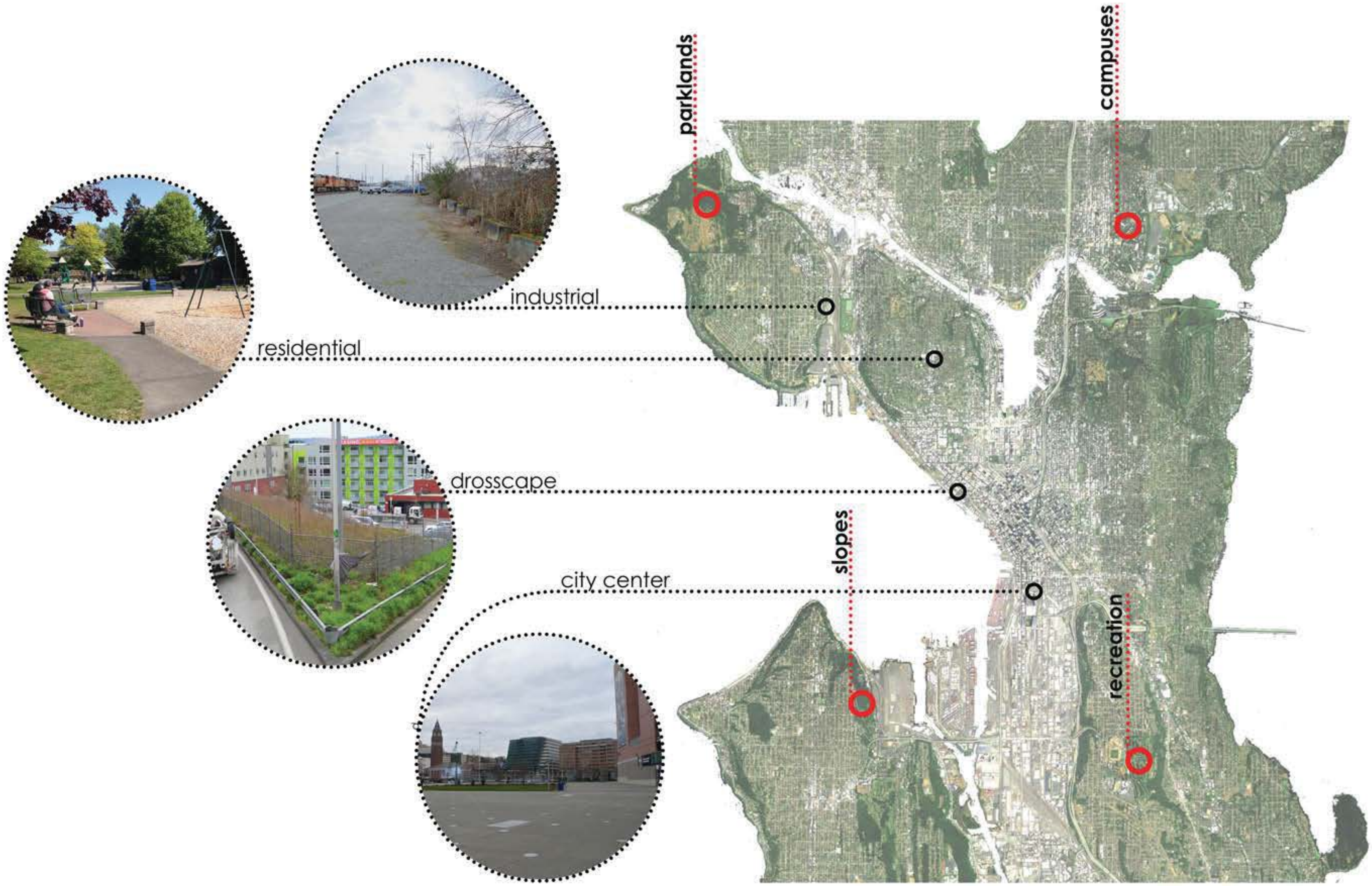


Figure 8.2: A healthy and productive urban forest.

resources continue to increase in the face of increasing population and density.

If we frame our urban existence as life *within* a natural-state forest rather than merely trees living among buildings, we may begin to perceive public life in cities as an integration of contemporary needs, technological advancement, and nature. We must remember that nature provides the foundational support our economic and social systems, and that a positive future for life in cities will include a strong and productive bond with the urban forest.

Appendix

Figures

5.1: Source: U.S. DOE. 2008. Carbon Cycling and Bio-sequestration: Integrating Biology and Climate Through Systems Science; Report from the March 2008 Workshop, DOE/SC-108, U.S. Department of Energy Office of Science (genomicscience.energy.gov/carboncycle/).

Photographs

Courtesy of author unless otherwise indicated.

Citations

US DOE. *Climate Placemat: Energy-Climate Nexus*, US Department of Energy Office of Science. (p. 1) (website)

Prepared by the Biological and Environmental Research Information System, Oak Ridge National Laboratory, genomicscience.energy.gov/ and genomics.energy.gov/

Interview Transcripts

Darren Morgan

Manager, Seattle Department of Transportation

Urban Forestry Section

Phone interview conducted October 9, 2014

1. What are your key responsibilities as Manager for the Urban Forest of Seattle?

   Plant and maintain trees in the public right-of-way. Goal of 30% canopy by 2037. Regulate and educate the public. Manage operations and fleet. Direct City Arborist and Landscape Architecture unit. Work directly with the larger public and private projects. Create the Urban Forestry Stewardship Plan.

2. What are the most serious problems with Seattle's urban forest?

   Tree and sidewalk issues. Space (soil volume) for growth is the primary concern. Also inappropriate initial plantings lead to social issues such as conflict with the ADA and increased costs. There is a strong need to assess individual tree conditions; to develop an inventory/database.

3. Can you describe the forest products that come from our public trees?

   Mulch to landscape areas and logs/firewood provided free to the public. 90% mulch and 10% composting to soil. Another example is the recent removal of a controversial heritage tree in Capital Hill (Raywood Ash, *Fraxinus oxycarpa* 'Raywood') was salvaged to provide timber for creating furniture on site.

4. What are the most favored tree species for new plantings?

5. What are the least favored tree species? Which ones cause the most conflict?

   Ornamental cherries, Norway maple, cottonwood, willow (fast growing/weak-wooded)

Nolan Rundquist

City Arborist, Seattle Department of Transportation

Urban Forestry Section

Phone interview conducted on 04/17/2015

1. What are your key responsibilities as Arborist for the Urban Forest of Seattle?

   Delegate, policy development, street tree removal, risk management, heritage tree management, permitting, customer service, monitoring, operations manager for trees and landscape. Works with Landscape Architects office on code requirements and city projects.

2. What are the most serious problems with Seattle's Urban Forest?

   Number 1 problem is space, especially underground. Competition with infrastructure and vehicles. In general, the general public is against most tree removals.

3. Can you describe the forest products that come from our public trees?

   He is working on ANSI A300 standards committee for developing use of forest products. Specifications for timber and products alongside Bandit Chipper© company. Referred me to a company in Tampa, FL that processes chips for waste-wood utilization.

4. What are the most favored tree species for new plantings? What trees would you like to see planted that currently are not?

   Acer platanoides x A. truncatum "Pacific Sunset" is a new, promising maple cultivar. New varieties are driven by nurseries and popularity.

5. What are the least favored tree species? Which ones cause the most conflict?

   Bradford pear has long term maintenance issues. Sweetgum has troublesome roots. Black cottonwoods exhibit excessive branch dropping. Lindens have a tendency to sucker.

6. What and where are the most cherished specimen trees?

7. What species may be suitable for timber production (at least on a trial basis)?

8. What species exhibit the strongest surface rooting habit?

   Maples, katsura.

   Caucasian wingnut (Pterocarya fraxinifolia) 24th NW in Ballard between 5400-5600 block.

   Dawn redwood on 2nd Ave. in Belltown.

9. What is the average lifespan of a Seattle City street tree?

   Ornamental flowering trees average 30-35 years. Med size species 45-50 years, and large species 50-70 years (referring to trees throughout the urban forest on average). Space is the limiting factor.

Tree Data per "Management Unit"

Residential (singe/multi combined)

Acres in MU	35,667
% of city land base	67%
Canopy coverage	31%
Number of trees	576,700
Maintenance costs (yr)	$10,706,800
Stormwater Mitigation Value (yr)	$8,399,000
Air Cleaning Value (yr)	$1,745,000
Carbon Sequestration (tons CO_2)	$21,900
Carbon Sequestration ($ value)	$663,000

Industrial

Acres in MU	6,214
% of city land base	11%
Canopy coverage	8%
Number of trees	68,100
Maintenance costs (yr)	$2,043,000
Stormwater Mitigation Value (yr)	$855,000
Air Cleaning Value (yr)	$341,000
Carbon Sequestration (tons CO_2)	2600
Carbon Sequestration ($ value)	$78,000

Citywide

Acres in MU	54,324
% of city land base	100%
Canopy coverage	18%
Number of trees	1,377,500
Maintenance costs (yr)	$14,054,300
Stormwater Mitigation Value (yr)	$20,643,000
Air Cleaning Value (yr)	$4,894,000
Carbon Sequestration (tons CO_2)	52,400
Carbon Sequestration ($ value)	$1,584,000

City Center

Acres in MU	810
% of city land base	1.5%
Canopy coverage	9%
Number of trees	9,700
Maintenance costs (yr)	$485,000
Stormwater Mitigation Value (yr)	$97,000
Air Cleaning Value (yr)	$49,000
Carbon Sequestration (tons CO_2)	400
Carbon Sequestration ($ value)	$11,000

Transportation Corridors/Street Trees

Acres in MU	14,412
% of city land base	16%
Canopy coverage	16%
Number of trees	130,000
Maintenance costs (yr)	$3,900,000
Stormwater Mitigation Value (yr)	$1,820,000
Air Cleaning Value (yr)	$780,000
Carbon Sequestration (tons CO_2)	4,900
Carbon Sequestration ($ value)	$150,000

source:
City of Seattle's Urban Forest Management Plan, April 2007: 62, 63, 67, 73, 82

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