2023

Pfizer Sanford

LANDSCAPE STUDY

Pfizer Global Supply Sanford, NC
Phase 1 Findings and Recommendations

NC STATE | Initiative for Community Growth + Development

Contents

INTRODUCTION

The Sanford Pfizer campus is a 240- acre tract located in Lee County, North Carolina. The site is within the southeastern edge of the Piedmont and on the northwestern edge of the North Carolina Sandhills. The campus has roughly 65 acres devoted to buildings, parking lots, and landscaping, primarily clustered in the northern portion of the property with a maintenance area at the southern end. The remaining roughly 175 acres are natural areas of forest, field/ meadow, or wetland. The property is enclosed by a chain link fence that is approximately eight feet high, with a gap in the fence in the wetland area. Hydrological features on the property include a wetland area, which surrounds Little Buffalo Creek, a small pond located near the maintenance shed area, a small, highly landscaped pond near the buildings, and an ephemeral stream that runs through the largest forest area where the hiking trails are located. Other notable features include a small patch of bamboo off the main road, and an abandoned fill mound near the maintenance area that is now mowed grass.

The study team conducted a biodiversity assessment and an ecosystem service assessment of the property in the summer and fall of 2023. We focused primarily on the natural areas of the campus in both assessments, although we include the developed areas in our estimates of ecosystem services provided by the campus. For the biodiversity assessment, we included both vegetation and wildlife using plant identification surveys, stand delineation assessments, and wildlife camera trapping methods. For the ecosystem service assessment, we used the Ecosystem Intelligence tool created by EcoMetrix. This software uses a combination of specific field data that we collected on the site using the Ecosystem Intelligence app, as well as remotely sensed or existing reference data for the location. The EcoMetrix team assisted in all aspects of the assessment and in the use of the software program. Field work was primarily completed by two NC State University students, Valerie Friedmann and Alejandra Betancourt Rial, with oversight by Dr. Meredith Martin.

Summary of biodiversity assessment

We found a high diversity of both plants and wildlife on the Pfizer Sanford campus. We documented a total of 87 unique plant species on the property, which is surely an underestimate, and captured at least 11 wildlife species, including bobcat, coyote, river otter, beaver, raccoon, and deer. The presence of keystone wildlife species such as beaver as well as apex predators such as bobcat and coyote, indicate that the property supports a vigorous and healthy food web, which is in turn indicative

of healthy ecosystems.
We also delineated multiple different vegetation types at different successional stages, including upland mixed hardwood forest, bottomland hardwood forest, wetland, young mixed pine-hardwood forest, early successional plant communities, and mowed grasslands. This mosaic of different vegetation types across the property provides a diversity of food sources and habitat types to support the varied wildlife species that we encountered. Unfortunately, we also documented the presence of multiple invasive species on the property, which can be detrimental to healthy ecosystem function and the provision of ecosystem services.

Summary of ecosystem service assessment

The entire 240 acres of the Pfizer Sanford campus provide an estimated 1210 acres worth of ecosystem services when all services are combined. Each acre of the property provides a mean of 5.0 service acres per acre, while the natural vegetation areas provide a mean of 6.10 service acres per acre. This is possible because each acre of forest, for example, provides carbon sequestration services, air quality services, biodiversity services, soil quality services, water quality and quantity services, aesthetic services, and more, all at the same time. We found that the services provided by the natural areas were comparable to those provided by a highly functioning reference biome in several categories, including climate services, but were lower than expected in water quality and quantity provisioning. All services were significantly lower/impacted by the developed areas, but water quality and quantity were also impacted by the extremely clay-dominated soils on the property. The forested areas generally provided the most service value, but the wetland provided unique water related services even though it provides less value in other areas such as carbon sequestration or noise regulation.

Summary of recommendations

Maintain a mosaic of successional stages, but shift the balance away from mowed fields.

Forests and other natural vegetation can provide multiple different ecosystem services at the same time, but there are trade-offs in the ability to maximize these different services depending on the type and structure of vegetation. There is high value in maintaining a diversity of ecosystem types and successional stages on the property for the diversity of plant and wildlife species this can support, and so we recommend continuing to maintain some early successional meadow areas through periodic dormant season mowing every one to three years. However, many of the fields that are currently mowed would provide higher value ecosystem services if they are left to undergo natural regeneration into forest. We highlight particular areas that would gain the highest value if left to regenerate in the recommendations section of the report. The

include fields surrounding the pond, as well as fields on the property border.

Use targeted invasive species management across the property.

While some species are too far established to be able to fully eradicate, we do recommend active management targeting the bamboo patch and the Bradford (Callery) pear on the property. We also suggest altering landscaping practices to focus on native species plantings to ensure that invasives such as Bradford pear are not reintroduced and to prevent new invasive species establishment.

Protect wildlife connectivity and maintain wetland ecosystem health.

The wetland area is key to the wildlife populations on the property, both for the habitat it provides but also as the only access point between the campus and the broader landscape. We therefore recommend ensuring that the fence remains open in the wetland, and encourage continuing the practice of periodic trash management. We suggest that these clean-up days could also integrate some invasive species management to enhance ecological integrity on the campus.

Consider restoration efforts of the abandoned fill mound.

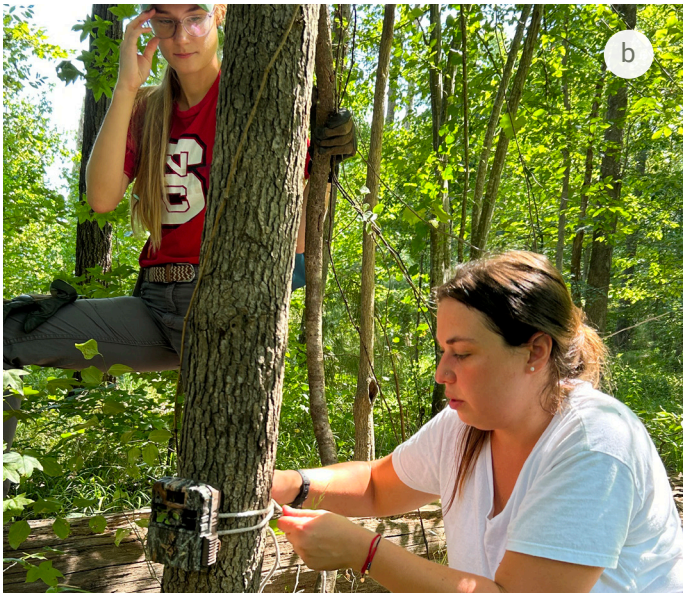
The abandoned fill mound showed particularly poor ecosystem service provisioning in almost all categories due to the soil degradation there. The poor soil quality means that more active restoration (i.e. planting) may be necessary to improve vegetative cover in this area, but at a minimum we suggest the cessation of mowing here to prevent further soil compaction or erosion, and to give natural regeneration a chance to establish.

Biodiversity Assessment

METHODS : FIELD OBSERVATIONS AND DATA COLLECTION

We performed a biodiversity assessment of the Pfizer Sanford campus that recorded both plant and wildlife diversity. To assess ecosystem and plant diversity, we walked the property many times over the course of the summer and fall of 2023 and recorded all observed plant species, as well as notes about species dominance, vegetation type, and other key habitat features. We returned periodically to each site to attempt to capture any herbaceous plants that had been missed in early assessments, but we note that we likely are missing many plant species because fieldwork was concentrated in summer and fall, and therefore spring ephemerals and other seasonally flowering plants were not visible at the time of data collection. We identified species using a combination of our existing plant ID knowledge and assistance from plant ID apps such as iNaturalist and Seek, as well as plant ID reference books. Seek and iNaturalist are also valuable resources for plant ID. Both apps are free to download and use, and are quite user friendly. Another potential resource for interested members of the community is this identification key to most common trees in North Carolina: https://content.ces.ncsu.edu/identification-of-common-trees-of-north-carolina

We delineated the property into stand and vegetation type using both ArcGIS and the Ecosystem Intelligence mapping tool. We delineated stands based on dominant vegetation, successional status, topography, and hydrology. We cored several pines and oaks in the forest stands using an increment borer to assess forest age. We sampled four trees in



a) An increment core being taking from a pine tree. The number of tree rings represents the age of the tree at this height. b) Valerie Friedmann and Alejandra Betancourt attach a wildlife camera to a tree in the bottomland hardwood forest.

the mature upland mixed hardwood stand, two trees in the bottomland forest stand, and one in the young mixed forest stand. We processed the cores by mounting and sanding them and counting rings to the pith. Cores were taken at roughly 1.3 m on the tree, and so ages reflect the age at which the tree reached this height (generally considered the point at which the tree was released), not necessarily its total biological age.

To assess wildlife diversity, we employed wildlife camera traps to capture pictures of fauna on the site. We used four Browning trail cameras around the forest, wetland, and pond. We strategically moved the cameras every few weeks or every month to maximize wildlife captured. Cameras were installed at roughly knee height, and were directed toward areas believed to have high traffic (i.e. water features, wildlife trails, and other signs of wildlife disturbance). We checked the cameras every few weeks to ensure that batteries were charged and to clear the memory cards.

VEGETATION TYPES AND PLANT DIVERSITY

There are many different vegetation types currently present on the Pfizer Sanford campus due to a combination of underlying physical site diversity as well as the legacies or current and historic management. Across the property we documented at least 87 plant species in the natural areas, which is surely an underestimate (Table 1. in the index). We are confident that more plant species are present, including ephemeral wildflowers that are only visible during spring, that were not included due to sampling constraints. We also are not including planted ornamentals within this estimate. We found 27 total tree species across the natural areas of the 240 acre property, which is impressive when considering there are roughly 100 tree species present on all 7,000 acres of the Duke Forest property, for example. Such high vegetative diversity in the landscape on a property of this size is unique and valuable, and supports a high diversity of wildlife species as well. As an example of this, we provide a summary of insects that the plant is known to host in each of our species tables. These insects form the basis for pollination services, a food source for birds and other animals, and contribute to ecosystem functioning in many other ways.

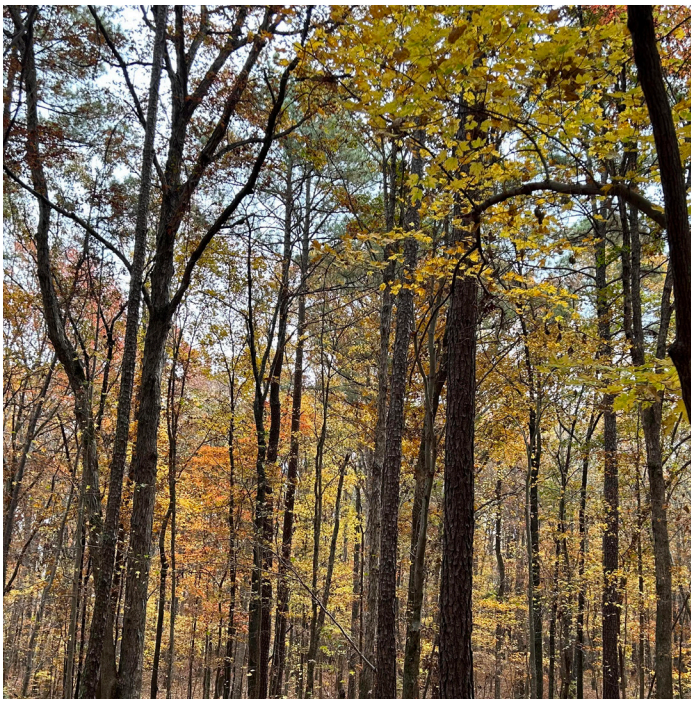
We found five major vegetation types, with minor variations present across the landscape. The dominant vegetation types present are (1) upland mixed hardwood forests, (2) bottomland hardwood forest, (3) wetland, (4) meadow/grassland, and (5) early successional plant communities. Other smaller distinct vegetation communities include the bamboo grove, the pond and its associated aquatic vegetation, and the various landscaped areas. The site currently has forests at different stages of succession present, ranging from grassland to early successional shrubland to young forest to mature forest. Multiple forest types and levels of succession on one site is beneficial for wildlife because they provide many different services

and can support more wildlife than one type can alone. In the sections below, we describe these main vegetation types and highlight the dominant and keystone species, along with other features of interest.

Upland Mixed Hardwood Forest

The predominant forest type on the Pfizer Sanford campus is an upland mixed hardwood forest with a canopy dominated by white oak, red oak, loblolly pine and hickory species. American beech is absent in this forest type, and tulip poplar, while present, is rare (Figure 2, Table 2.). This is a common forest type historically found throughout North Carolina, but currently more restricted to areas with more xeric (dry) soils. Xeric soils tend to favor the more drought tolerant oak and hickory species over other more mesic competitors (such as beech and tulip poplar), and therefore we find this forest type on upland sites with slightly sandier soils that drain water more rapidly. The understory of this forest also contains a high density of more drought-adapted species such as hillside blueberry, another indicator of drier site conditions.

The largest example of this vegetation type is found in the center of the property as the main forested area of the campus, but the forest type is also present in the northern corner behind a fence and in smaller strips on the property edges. These two areas show mature forest with a stratified canopy into overstory, midstory and understory layers based on the shade-tolerance of the different species. The midstory is primarily composed of sourwood, black tupelo, and flowering dogwood. The understory has an abundance of muscadine grape and hillside blueberry. Canopy stratification into multiple stories enhances the tree diversity on a site, which in turn leads to higher wildlife habitat values.



The upland hardwood forest is a mature stand with a stratified canopy where different species occupying the top canopy (predominantly oaks and hickories with some pine), a midstory (sourwood, black tupelo, and dogwood), and an understory (blueberry, muscadine grape, and ferns). The fall foliage is vibrantly colored due to this mix of hardwood species.

Figure 1. The Five Major Vegetation Types Found on the Pfizer Sanford campus

Overall, these upland mixed forest stands support vibrant wildlife communities, in part due to the high quantity and quality of hard and soft mast produced by the species here. Hard mast (acorns from oaks and hickory nuts) is a valuable food source for a wide range of birds and mammals and is an especially important food source during winter months as the hard and dry nature of these nuts means they can remain a viable food for many months. Soft mast, such as muscadine grape and hillside blueberry, is also abundant in the mixed hardwood forest stands, and serves as an important seasonal food source for migrating birds and other species. Muscadine grape is a woody vine that is native to North Carolina and is valuable to both wildlife and humans due to the grapes it produces. The grapes are eaten by songbirds, gamebirds and mammals. The

grapes appear in August and may be seen until October. Hillside blueberry is a native deciduous shrub. It does not typically grow more than three feet tall and its berries are eaten by songbirds, gamebirds and mammals. It also supports many species of bees and is a host plant for the brown elfin butterfly.

The mature forest also contains a remarkable quantity of white oak regeneration. Researchers

Figure 2. Plant species identified in the Upland Mixed Hardwood Forest found on the Pfizer Sanford campus

and forest managers throughout the eastern US have noted a dramatic decline in white oak regeneration due to a complex combination of mesophication, fire suppression, deer overpopulation, and historic high grading (exploitative logging). The presence of so much white oak regeneration on this property is therefore extremely valuable, and is likely due to the xeric soil conditions, the light conditions created by the edge environments and the mature canopy conditions, and potentially to lower deer populations due to the fencing.

Another feature of note in the mature forest is the high quantity of deadwood present. A dead tree, standing or on the ground, has tremendous wildlife value. If it is still standing it is called a snag, and if it is on the ground it is called downed wood. Snags and downed wood are an essential source of food and shelter for many species of amphibians, birds, small mammals and reptiles also play a key role in nutrient and carbon cycling.

Although the entire upland mixed forest area in the center of campus can be considered a single stand, there are several smaller features within it that are worth noting. There is an ephemeral stream that runs through the stand, which is an important hydrological feature. The ephemeral nature of the stream means that there is not a permanent flow of water but rather only flowing water after precipitation. Ephemeral streams are associated with increases in plant diversity as the area has much more mesic (productive) soils and can host a suite of more mesic or even hydric plant species. The ephemeral stream

Muscadine grape is common throughout the property, and provides a valuable seasonal soft mast food source for wildlife. Acorns and hickory nuts provide a valuable source of hard mast which can last throughout the winter for many birds and animals.

BOX 1: KEYSTONE SPECIES - WHITE OAK

A keystone species is an organism that has enormous impact relative to its abundance on the ecosystem in which it lives. They can be ecosystem defining and are often thought of as the glue that holds their ecosystems together. An example of a keystone species at this site is white oak (Quercus alba). White oak is a common native tree species that has tremendous wildlife value. The white oak acorn is an important component of the 'hard mast' present in the upland mixed hardwood forest. The white oak acorn has a lower tannin content compared to red oak acorns, and is therefore preferred by most wildlife species (i.e. it is easier to digest and has better flavor). The acorn is key food source for a range of animals and birds, including deer, songbirds, quail, turkeys, and many other animals. The white oak is also a host plant for many insects, including many species of butterflies, moths, and walking sticks. The tree itself provides shelter and nesting material. White oaks are slow growing, shade tolerant, long-lived late successional species, which makes mature white oaks even more valuable on the landscape.

area in the main upland forest contains species such as cinnamon fern and royal fern, which are both indicators of wet sites. This adds to the overall diversity, as they complement the dry-adapted species such as bracken fern, which are specialists that are only found on xeric soils. This moister area also likely hosts spring ephemeral plants, which are species that are only visible during early spring. The stream is also a valuable feature for wildlife, and as such should be protected as much as possible. There is also a small patch in the main upland

hardwood stand where there is a much higher density of pine trees rather than hardwoods. This area is visible in aerial imagery showing the darker coniferous needles compared to the brighter deciduous leaves. An increment core from a pine in this area revealed that this area is younger—we counted 38 rings, indicating that the pine total age is likely 40-45 years. In contrast, the pines cored in the rest of the mature upland hardwood showed 54 and 55 rings, indicating a total age of roughly 57-60 years (Figure 3.). Together with the older age of the large oak cored in the mature forest (92 rings, or roughly 100 years old), evidence suggests that this area was once a pasture land where a handful of larger oaks were left as shade trees. The field was likely abandoned 60-70 years ago, when the mixed pine and hardwood species established. The area was likely logged, when many of the initial pines would have been removed and many of the slower growing and more shade tolerant oaks and hickories would have been released to replace them in the canopy. The small pine concentration may be a relic of this logging event where enough light was created in this area to allow for the establishment of a new, younger, cohort of pines rather than simply releasing the other more shade tolerant hardwoods present.

The Pfizer Sanford campus had abundant downed wood in the upland and bottomland hardwood forests. Downed wood is a valuable habitat feature for wildlife, and in the small image we see holes made by woodpeckers and a nest of ants underneath. The insects that are housed in downed wood help with decomposition and nutrient cycling, and also serve a key role in the food web for many birds and animals. .

Bottomland Hardwood Forest

The bottomland hardwood forest stands are located near the wetland and the pond. The conditions are more mesic (wetter) than the

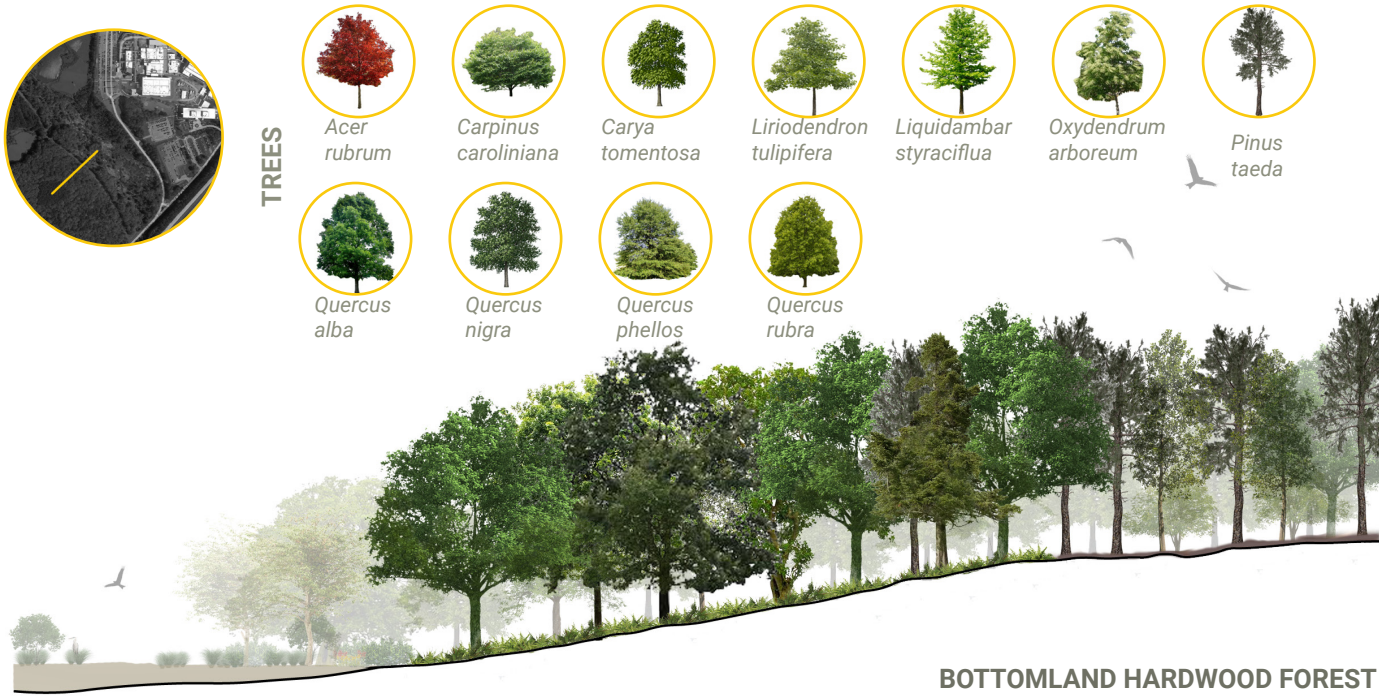
Abundant white oak regeneration in the upland hardwood forest.

upland mixed hardwood forest stands due to differences in topography and soils, and as a result, the species composition is different. Notably there is more tulip poplar, musclewood, and oak species that are tolerant of mesic soils, such as water oaks and willow oak rather than the upland oak species seen in the upland forest (Figure 4., Table 3). We note that these species and structure differences are not due to differences in age or successional state, but rather are a reflection of underlying site conditions and species niches.

These bottomland forests are also mature stands with canopy stratification into overstory, midstory and understory species. The overstory here is dominated by tulip poplar, willow oak and water oak. The midstory consists primarily of red maple, sourwood and musclewood. The understory contains muscadine grape and greenbrier vines and some hillside blueberry, although it is overall much less dense compared to the upland stand. This area also provides valuable hard and soft mast for wildlife, increases the overall biodiversity on the property due to its different species composition, and provides important forest cover and access points to the wetland.

1. Mature Mixed Upland Hardwood Forest- Loblolly Pine- 53 Years Old
2. Mature Mixed Upland Hardwood Forest- Loblolly Pine- 36 Years Old
3. Young Upland Hardwood Forest- Loblolly Pine- 18 Years Old
4. Mature Mixed Upland Hardwood Forest- Loblolly Pine- 54 Years Old
5. Bottomland Hardwood Forest- Red Oak- 67 Years Old
6. Bottomland Hardwood Forest- Loblolly Pine- 38 Years Old
7. Mature Mixed Upland Hardwood Forest- Red Oak- 92 Years Old

Figure 3. Sample increment cores indicating the age of trees in the Upland Mixed Hardwood forest on the Pfizer Sanford campus



Wetland

There is a wetland located between the parking lots and the bottomland forest area of the site. The wetland surrounds Little Buffalo Creek, and although there was no water present at the time of the assessment, the area is clearly occasionally inundated by the creek. The wetland contains some trees, but mostly is dominated by shrubs and a vigorous and dense herbaceous layer (Figure 4.). Trees present were species adapted to floodplain and hydric conditions, including green ash, loblolly pine, willow oak, water oak, American elm, and slippery elm (Table 4.). Shrubs included elderberry, which tends to thrive in wet areas, and high amounts of blackberry brambles, both of which provide excellent soft mast for birds

Figure 4. Plant species identified in the Bottomland Hardwood Forest found on the Pfizer Sanford campus

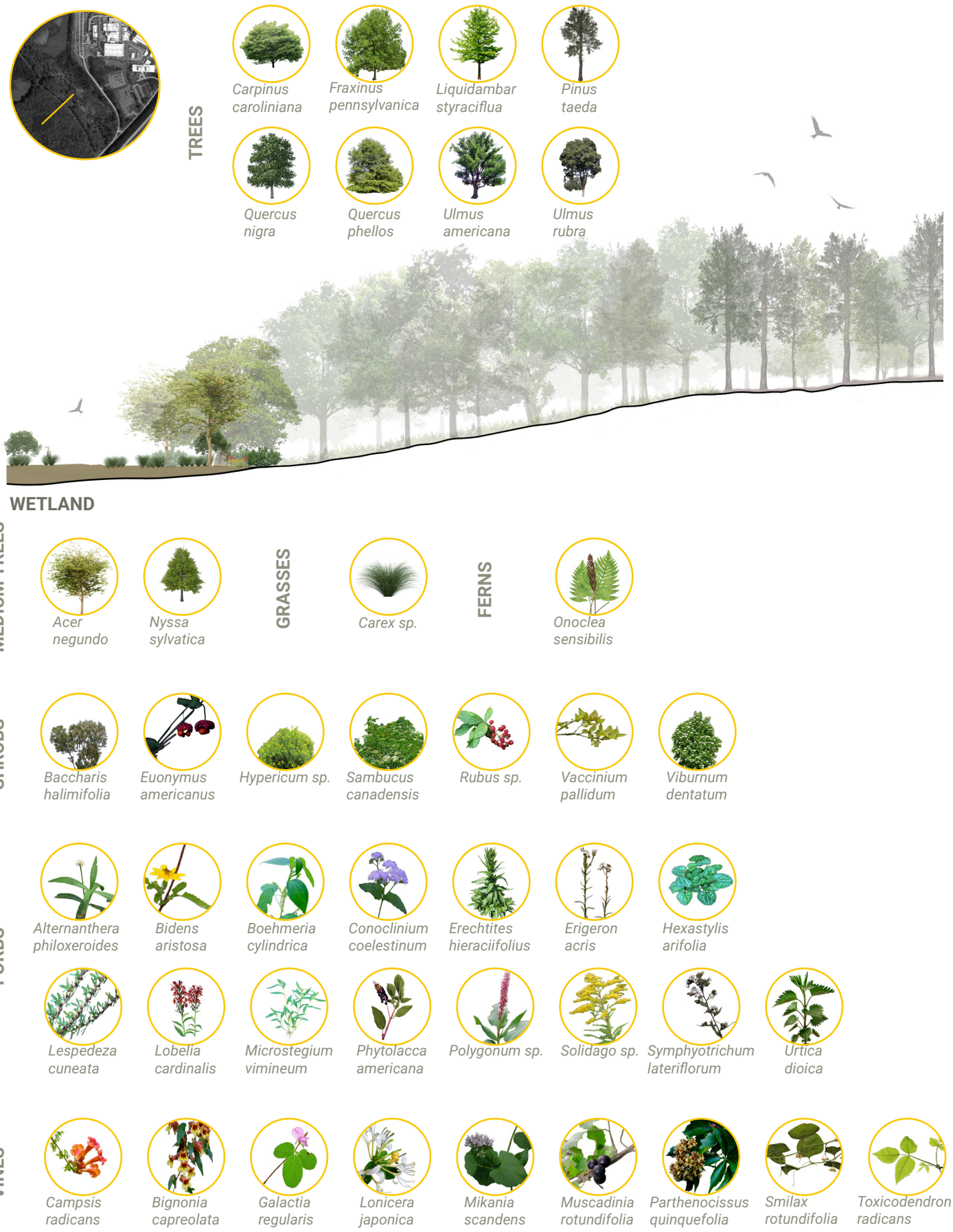


Figure 5. Plant species identified in the Wetland found on the Pfizer Sanford campus

and other wildlife. Herbaceous species included a number of different goldenrods and asters, as well as native wildflowers such as cardinal flower.

Another feature of note in the wetland is the high number of snags (standing dead trees). Snags are common in wetlands when flood conditions are variable, as trees may establish at a time when a section of the wetland is relatively dry, but then be killed later by a particularly large flooding event. These snags offer tremendous wildlife value, to the point that many wildlife management plans will specify a desired density of snags per acre. Snags provide especially key habitat for a number of bird species, including woodpeckers and birds of prey.

Unfortunately there is also a high density of invasive species present in the wetland, including lespedeza, Japanese honeysuckle, Japanese stiltgrass, and alligator weed. The most established is Japanese stiltgrass which has thoroughly proliferated much of the wetland. Japanese stiltgrass, like many invasive species, has a negative effect on ecosystems it is introduced to because it aggressively invades the landscape and out-competes native species. Unfortunately, Japanese stiltgrass is exceptionally difficult and expensive to remove. However, the alligator weed that grows along the water in the wetland has not yet reached the same level of establishment as the Japanese stiltgrass and it may be possible to eradicate it from the site.

Little Buffalo Creek runs through the wetland area. The vegetation close to the creek is primarily herbaceous grasses, sedges, flowers, and shrubs, with some occasional trees on higher ground farther from the periodic creek flooding.

The wetland is host to many flowering plants, including a number of different goldenrod species and wetland indicator species such as cardinal flower and elderberry. Note the large number of insects pollinating the goldenrod here also form part of the wider food chain for other wildlife, and the elderberries provide soft mass berries.

The high density of snags (standing dead trees) in the wetland provides valuable wildlife habitat, especially for birds of prey and woodpeckers.

One of several mowed fields on the Pfizer Sanford campus. These areas host low levels of biodiversity and lower ecosystem service provisioning compared to other vegetation types on the property.

The pond contains a variety of native tree, shrub and herbaceous species that specialize in wet environments such as this

Bamboo grove

A grove of fishpole bamboo (Phyllostachys aurea) is located around the culvert that the Little Buffalo Flows through. Fishpole bamboo is invasive, and as is typical of invasive plants, it is notoriously difficult to contain and prevents native plants from growing. The bamboo forms an extremely dense clump with high shade that prevents any understory species or trees from establishing, and also does not provide any wildlife value. In the management recommendation section we discuss ways in which this could be eradicated.

Abandoned Fill Mound

One of the mowed areas is a large abandoned fill mound located at the southern end of the property near the maintenance area. This mound is made of mixed, degraded soil that contained a higher proportion of gravel compared to surrounding soils, and is a relic of prior land use. The grass growing on top is sparse, and bare mineral soil is visible not only on the small dirt road going up the mound, but in other patches as well. This exposed soil is an indication of poor fertility, and also means the area is prone to erosion as the soil is not protected by vegetation.

Pond

The small pond on the Pfizer Sanford campus is surrounded by a thin swath of forest and then mowed grass field. The pond is small in size,

but contained a number of wetland specialist shrubs growing into the edges. This shrubby vegetation provides unique wildlife habitat for aquatic species (amphibians such as frogs, toads, and salamanders often lay their eggs attached to stems extending from the edge), and also provide flower nectar for pollinators as food sources. The water itself is an important wildlife resource, and we did see a large number of species using the pond in our camera trapping (Figure 6.).

Mowed Utility Strip

There is a small linear strip of land between the upland and bottomland hardwood forest stands in the center of the Pfizer Sanford property that is maintained for utility lines. The area is primarily dominated by invasive Japanese stiltgrass, although there are also a few native herbaceous species present. Managing or removing the invasive species in this area would likely be impossible to achieve. As is, the area potentially provides some open space for wildlife to travel through.

Early Successional Plant Community

Early successional communities are present in several areas on the site, and can be distinguished from the more frequently mowed grasslands. These plant communities originated from mowed fields that have been left to regenerate naturally, and have therefore been colonized by a variety of species that are adapted to grow in high sun environments.

This mowed utility line represents a transition point between the higher and drier upland hardwood forest and the lower and more mesic bottomland hardwood forest type. The area is completely dominated by invasive Japanese stiltgrass (the light green grass in the image).

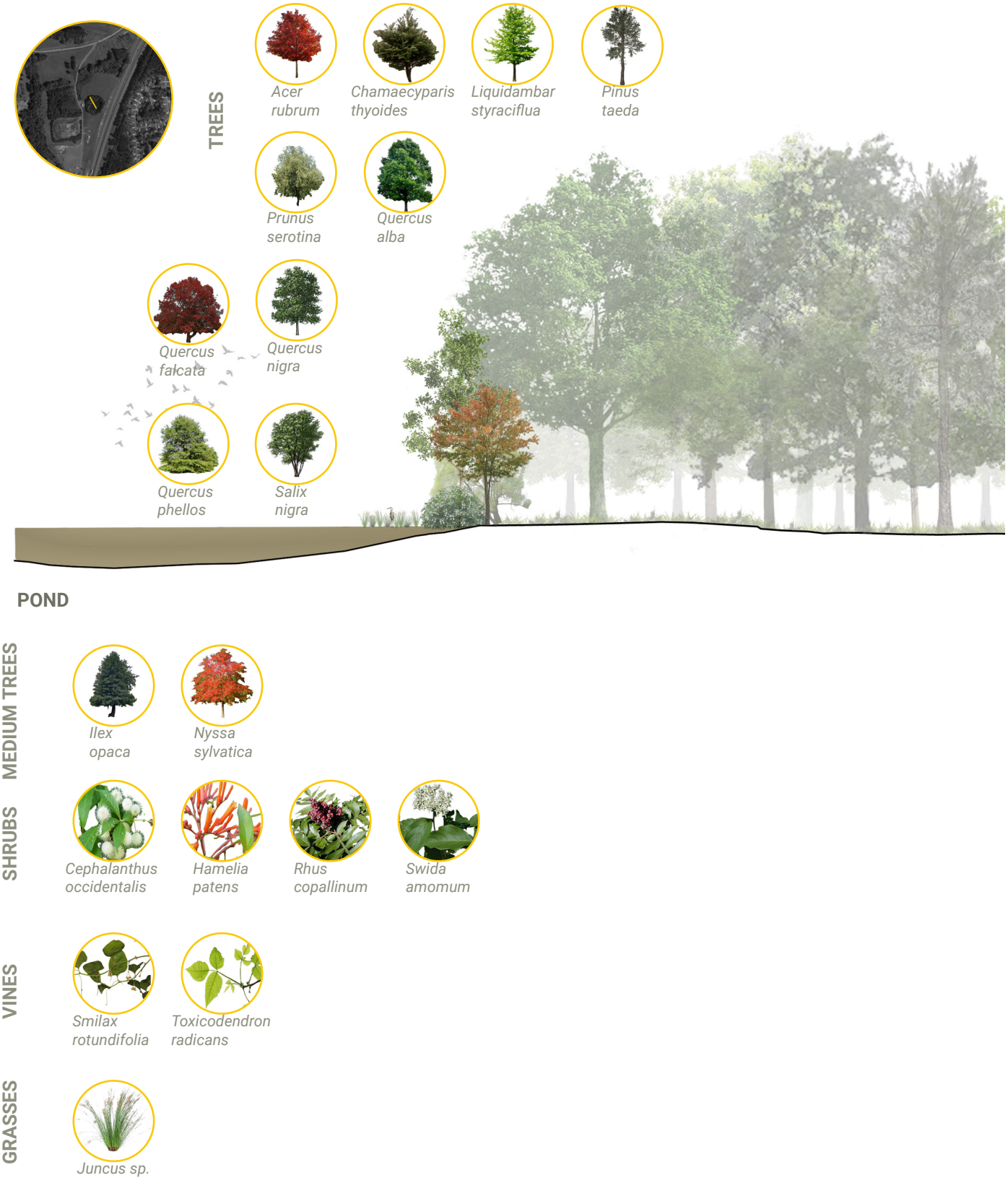


Figure 6. Plant species identified at the Pond found on the Pfizer Sanford campus

An early successional field on the Pfizer Sanford campus provides high wildlife value and a diversity of grass, forb, and shrub species. The wildflowers here can also provide aesthetic values, such as this purple wild ageratum or this spotted beebalm.

They therefore contain a mix of herbaceous perennials, grasses, shrubs and shade intolerant small trees (Figure 7.). The most common species in these areas are grasses, brambles, sea-myrtle, dog-fennel, lespedeza, broomsedge, Japanese stiltgrass, goldenrod, sweetgum saplings and oak saplings (Table 5.). These also likely contain other flowering perennials that are more identifiable in spring months.

Early successional plant communities on the property contribute to the diversity of wildlife habitats present. Many birds and small mammals rely on the presence of these more open areas as nesting sites and for food sources in the seeds, berries, and insects that can be found there. These areas also add to the overall plant diversity on the property, as they contain species that cannot grow under the shaded conditions created by closed canopy forest or in the hydric conditions of the wetland.

Early successional plant communities on the property contribute to the diversity of wildlife habitats present. Many birds and small mammals rely on the presence of these more open areas as nesting sites and for food sources in the seeds, berries, and insects that can be found there. These areas also add to the overall plant diversity on the property, as they contain species that cannot grow under the shaded conditions created by closed canopy forest or in the hydric conditions of the wetland.

If these areas are left unmowed, they will continue to undergo natural successional

Figure 7. Plant species identified in the Early Successional Plant communities found on the Pfizer Sanford campus

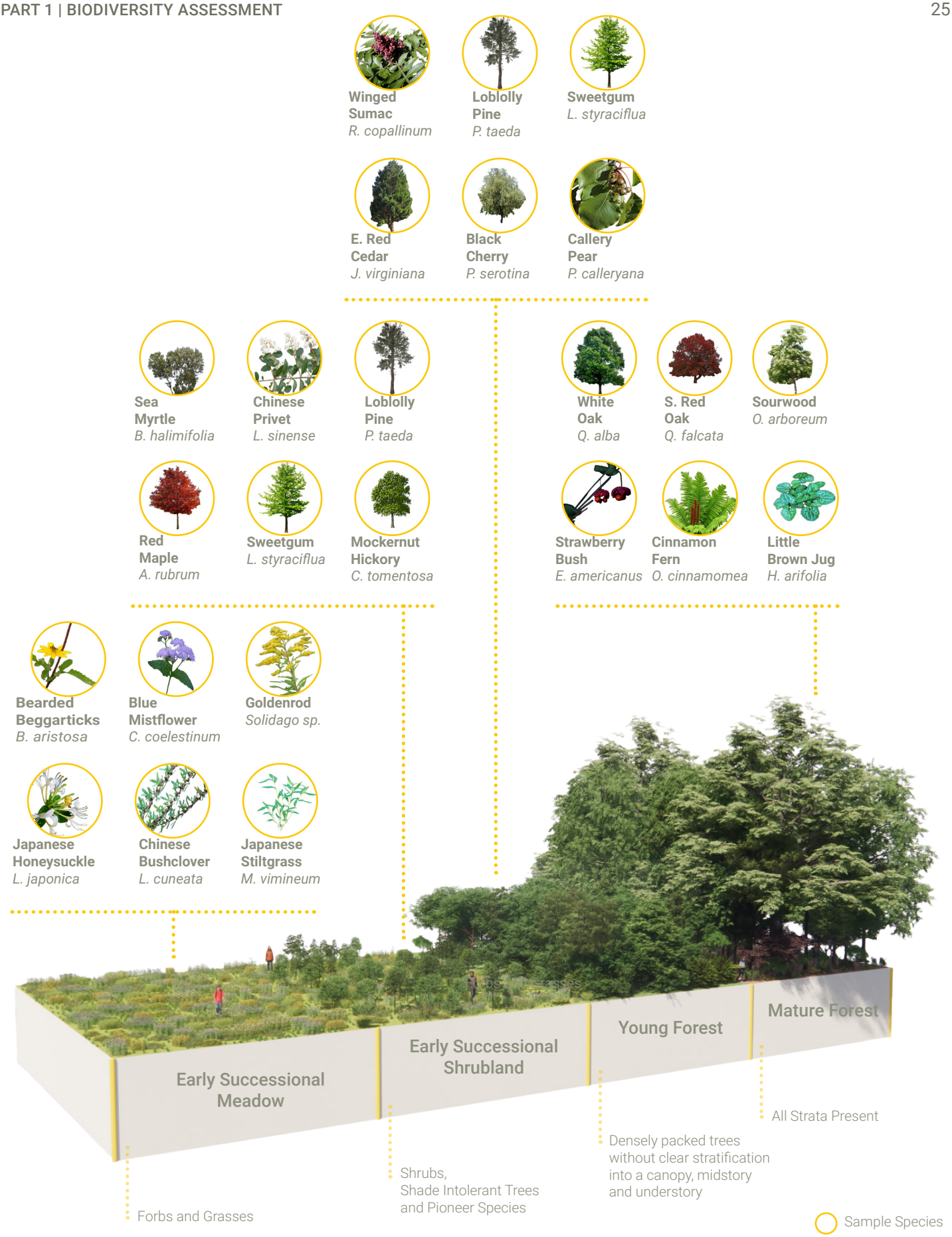


Figure 8. Successional trajectory on the Pfizer Sanford campus

processes, and would eventually become dominated by young forest of loblolly and mixed hardwoods, and eventually mixed upland hardwood forest. We discuss this process in more detail in the succession section below.

Successional trajectory across the property

Historically much of this property was agricultural land that has since been abandoned and returned to forest or continued to be mowed as open field spaces. We can still see evidence of past plowing in the soils, where there is a clear line demarcating the depth to which a plow would have reached. Plowing mixes the nutrient rich topsoil and organic plant material into the mineral soil below to the depth that the blade reaches, and thus creates a distinctive pattern where the upper portion of soil is brown in color due to incorporated topsoil while the lower layer below the plow blade abruptly changes color to an almost pure red clay.

Once a field is abandoned either as degraded pasture or through the cessation of mowing, early successional shrub and tree species begin to establish (Figure 8.). These tend to be species that are dispersed by birds (i.e. bramble berries) or wind (i.e. pine seeds) that are fast-growing and adapted to high light conditions (shade intolerant). We see this successional state in the early successional areas of the property. If succession continues, eventually the trees grow until canopy closure. At this point, many of the herbaceous and shrub species can no longer survive in the shaded conditions, and we will be left with a young, dense forest with small trees and little to no midstory or understory. This type of young forest is currently present near the pond and around the abandoned fill mound. This

A small soil pit dug in one of the mowed grassland shows signs of prior plowing in the abrupt shift from brown soil at the depth of a plow blade to the red clay-dominated soil below.

A young pine forest on the property near the abandoned fill mound shows another successional stage between early successional shrubland and mature upland hardwood forest. This dense forest type provides cover for wildlife, as well as other ecosystem services.

younger stand is estimated to be roughly 20-25 years old based on tree ring data (the pine that was cored was 18 years old at the point of the core). Here the trees are pine with some of the more shade-intolerant hardwoods also present. Trees are smaller in both height and diameter, and are more closely spaced in this 'stem exclusion' phase of stand dynamics.

As succession continues, the competition between trees in the young stand will eventually lead to competition mortality, where some trees will be out competed for light and other resources and will eventually die. Over time, this mortality will create enough canopy gaps and light for other more shade-tolerant species to either establish or be releases, leading to the canopy stratification into overstory and midstory that we see in the mature mixed hardwood forest and the mature bottomland forest. The higher light conditions created by this mortality also allow for the development of a more diverse understory of ferns, shrubs, and herbaceous species. The type of late-successional, or 'climax' community in any given area will be determined by the underlying soil conditions, with upland mixed hardwood forests developing on most of the property and bottomland forests developing in lower lying areas.

The existence of these multiple successional stages—from grassland to early successional shrubland to young forest to mature forests—is a great strength of the property, and could be enhanced with management to ensure continued successional development as well as the maintenance of early successional areas.

Thorny olive is one of several invasive species on the property. This species was found in the early successional habitat and on forest edges, and is a species that thrives in full sun environments. The berries are edible to wildlife and people.

Japanese stiltgrass is a common invasive species in North Carolina, and was found on large swaths of the Pfizer Sanford campus. Stiltgrass is shade tolerant, fire resistant, and spreads copious amounts of seed that remain viable for years, making it extremely difficult to eradicate.

Invasive Plant Species

The primary forest health concern for the site are the invasive species that were noted (Figure 9.). Invasive plants are non-native plants that out compete native plants for resources and are very disruptive and harmful in the ecosystems they invade. Japanese stiltgrass has thoroughly proliferated some areas of the wetland, bottomland forest, and early successional plant communities. Japanese stiltgrass is prohibitively expensive and difficult to remove once it is established. Bradford (Callery) pear and Chinese privet have been noted in the young forest stands near the pond and the maintenance shed, and could be removed more easily as they have not yet reached an overwhelming number. Other invasive species such as lespedeza, Japanese honeysuckle, thorny olive, and Chinese privet are also present, with varying levels of establishment. We discuss invasive species management in more detail in the management recommendations section at the end.

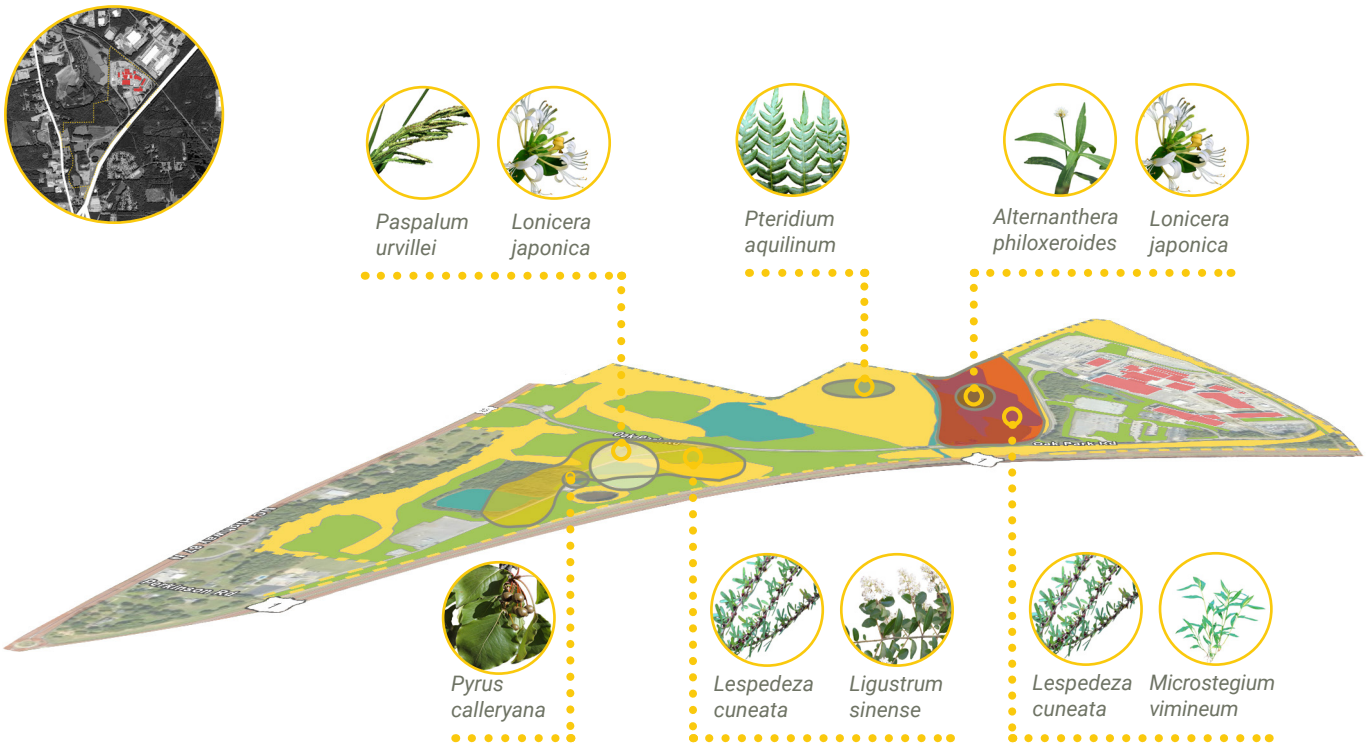


Figure 9. Invasive plant species identified across the Pfizer Sanford campus font size should match in all figures

WILDLIFE ASSESSMENT

The trail cameras set around the Pfizer Sanford campus captured many different animals living on the property, including coyote, beaver, opossum, river otter, bobcat, raccoon, white-tailed deer, eastern gray squirrel, and eastern cottontail rabbit (Figure 10, Table 6.). The abundance of wildlife captured on the cameras confirms our assessments that the current site conditions are ideal for wildlife. Wildlife need food, water, and cover to survive. As noted in the vegetation assessment, the different vegetation across the property provide abundant food sources. The upland mixed forest and bottomland forests provide large amounts of hard mast in the form of acorns and hickory nuts, while the forests, the wetland, and the early successional areas all offer sources of soft mass in the form of blueberries, blackberries, muscadine grapes, elderberries, and more. There are several water sources on the property, including the pond, the ephemeral stream, the wetland, and Little Buffalo Creek. Finally, the variety of successional stages offers a range of cover types, from dense shrub cover to dense young forest to complex, stratified mature forest. Finally, the large amounts of deadwood create both cover and food sources (insects) for a range of species

While we did not directly count birds, insects, reptiles or amphibians, we note that all of the above high-quality habitat features that could, and likely do, support a diverse set of these species. A few bird species were captured by

Although we did not formally count bird species, we did capture a great horned owl in the upland mixed hardwood forest and a great blue heron at the pond in camera trap photographs.

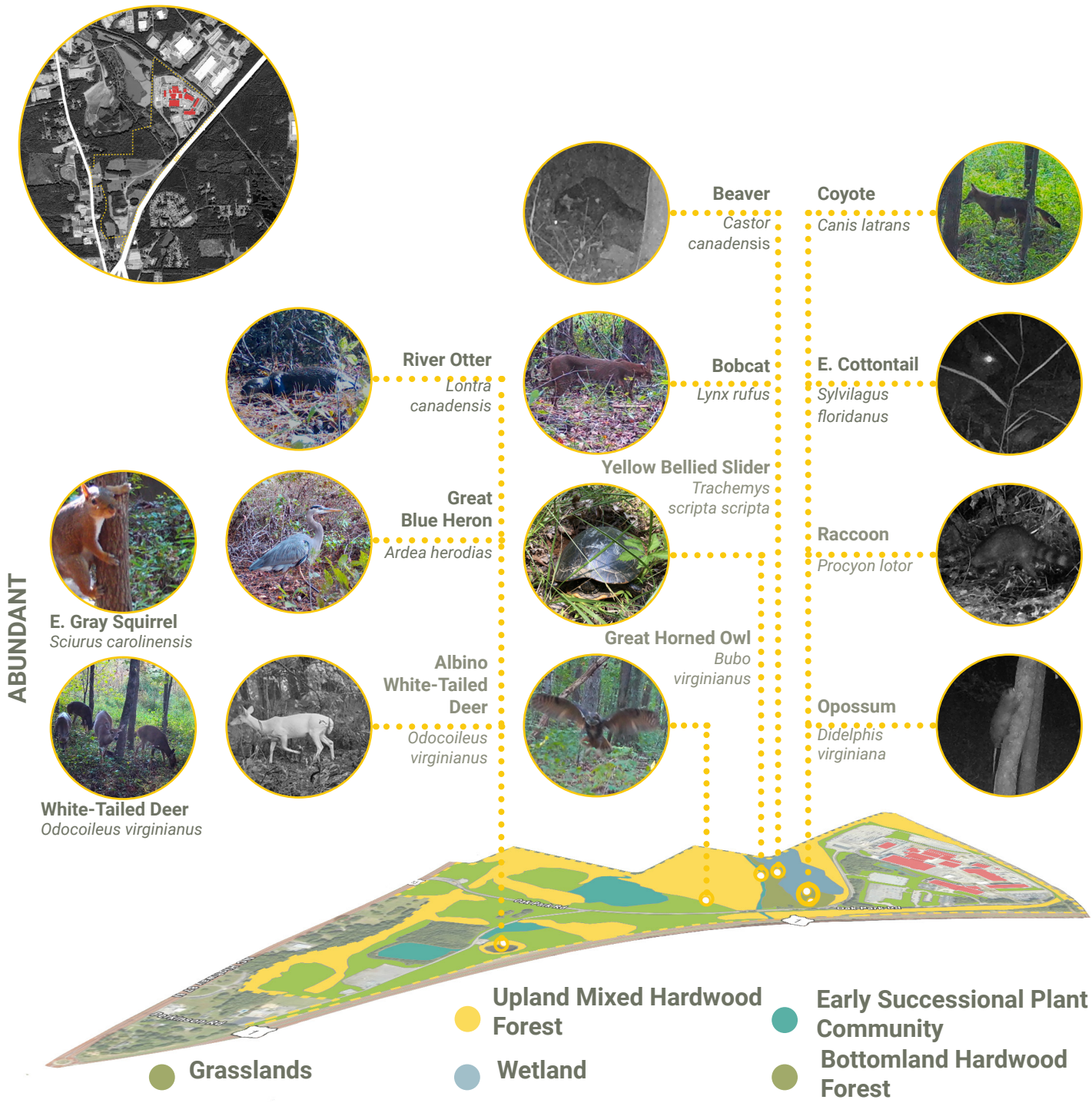


Figure 10. Trail Camera captures of wildlife on the Pfizer Sanford campus

the cameras—specifically a great horned owl and a great blue heron—and we did observe a yellow-bellied slider turtle while conducting our assessments. The Pfizer-Sanford campus is located along a key bird migration pathway, and likely serves a valuable role in providing resources for multiple migrating birds as well as non-migratory species (Figure 11.).

Additionally, presence of apex predators on the property (coyote and bobcat) indicates a highly healthy ecosystem and functioning foodweb system (Figure 12.). Predators are not only an indicator of a highly functioning ecosystem, as a complete food web must be present to support these species, but also help to maintain high functioning systems through their top-down food web control. There are multiple cases studies where the reintroduction of a predator has dramatically altered ecosystems and hastened ecosystem recovery (the reintroduction of wolves to Yellowstone park is a prime example). The presence of bobcat and coyote here, therefore, is an extremely promising sign about the health of the natural areas on the property.

Finally, we captured the highest diversity of species in the bottomland hardwood forest around the wetland. In addition to the high-quality habitat created by this forest type, the wetland is the only place on the Pfizer Sanford campus where there is a gap in the chain link fence that surrounds the rest of the property. This area appears to be a high-traffic pathway for animals with large ranges to connect with the broader landscape, and so maintaining this

A fence surrounds most of the Pfizer Sanford campus, with only one gap in the wetland.

Adult female bobcat with cub captured in the bottomland hardwood forest at night.

Adult bobcat in daytime in the transition between the bottomland hardwood forest and the wetland.

North Carolina is a significant stopover along the Atlantic Flyway and NC natural resources are integral to the survival of migratory bird species. **Lee county** is located within this flyway and its water bodies and plant species provide critical support to about 500 species of migratory birds.

On the night of September 30, 2023, Birdcast reported that an estimated 1,663,900 birds crossed the skies of Lee County within which the **Pfizer Sanford Campus** is located.

The existing diversity of vegetation in the forested and early successional areas, and water access at the pond and the wetland, on the campus play a strong role in supporting the native and migratory bird populations. One service the campus can provide to these migratory birds is to make a commitment to reduce or eliminate light pollution from the skies.

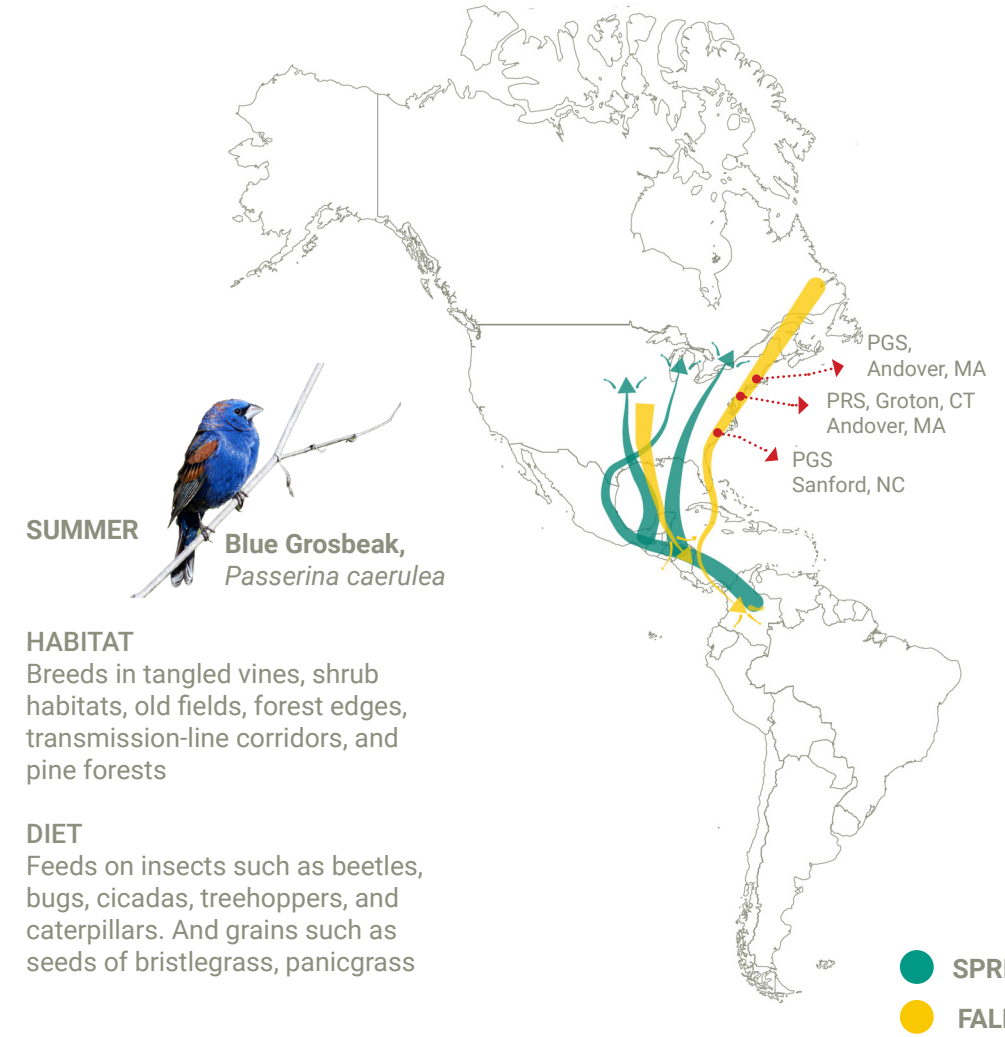
In the Eastern United States, at least 3 Pfizer sites are along the Atlantic Flyway.

SPRING

Yellow Throated Warbler,
Setophaga dominica

HABITAT
Breeds in areas of tall trees and open understory especially pine forests

DIET
Eats insects such as beetles, caterpillars, flies, and scale insects



SUMMER

Blue Grosbeak,
Passerina caerulea

HABITAT
Breeds in tangled vines, shrub habitats, old fields, forest edges, transmission-line corridors, and pine forests

DIET
Feeds on insects such as beetles, bugs, cicadas, treehoppers, and caterpillars. And grains such as seeds of bristlegrass, panicgrass

FALL

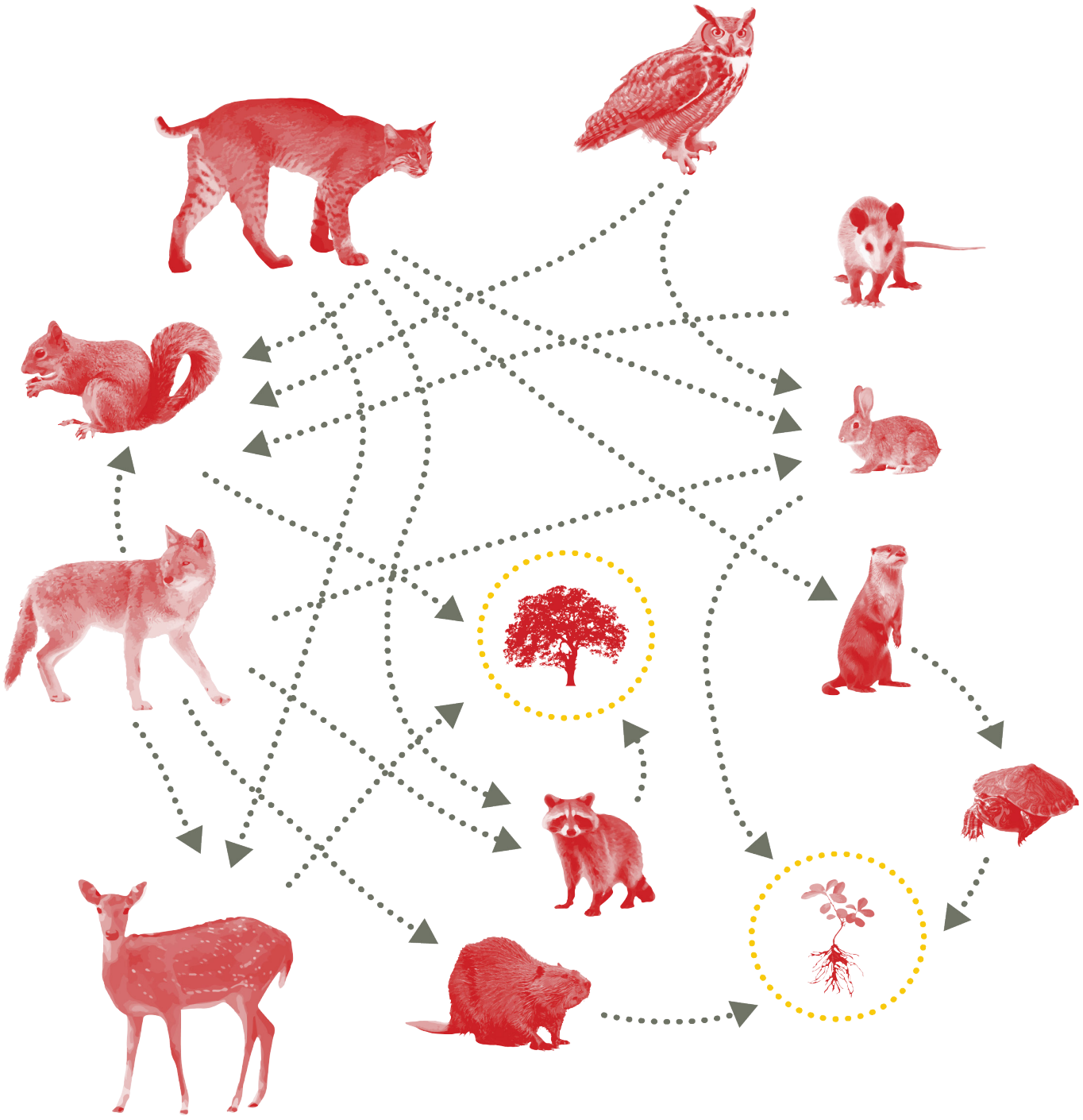
American Redstart,
Setophaga ruticilla

HABITAT
Breeds in deciduous wooded habitats

DIET
feeds on insects, American service berry, magnolia, barberry, willow and alder thickets

Figure 11. Migratory Birds in Lee County

www.Allaboutbirds.org
www.fws.gov/media/migration-mapjpg-0
https://dashboard.birdcast.info/region/US-NC-105?night=2023-09-30



opening in the fence is key to protecting wildlife habitat connectivity for many of these species.

Over the next few pages, we highlight some of the species captured by the cameras and give some greater detail on their ecology and habitat requirements.

Bobcat (Lynx rufa)

We captured a bobcat mother and kitten in our trail cameras. Bobcats are solitary and territorial animals. The home range of a male bobcat overlaps that of several females, and males will mate with more than one female. Female

Figure 12. A highly functioning food web system on the Pfizer Sanford campus

bobcats (such as the one seen on the Pfizer campus) generally have a range of roughly five square miles, while male ranges can be much larger (up to 30 square miles). For context, the Pfizer Sanford campus is less than half a square mile in size, meaning that these animals are traversing the broader landscape successfully, and that the Pfizer property is forming a key part of their home range. Bobcats have a sophisticated form of land tenure and usually respect each other's territory. They mark their specific territories to minimize confrontations with other bobcats.

Bobcats are most active at dawn and dusk, and tend to be more nocturnal when in close proximity to human populations. They are opportunistic hunters and will take advantage of opportunities to eat almost anything of a reasonable size; mammals are their most common prey but they will also eat fish, birds, amphibians and reptiles. Eastern gray squirrels and eastern cottontails make up the bulk of their diet in this region, both of which were also captured by the cameras on the Pfizer campus.

Bobcats can live in a wide variety of ecosystems, and range from boreal forests in Canada to arid landscapes in Mexico. In the southern United States, they are common in bottomland and hardwood forests and coastal swamps, and on the Pfizer campus they were primarily captured in the bottomland forest and wetland areas. For more information on bobcats, see the following summary sources: https://nationalzoo.si.edu/animals/bobcat

The bobcat cub gets close to the camera in the bottomland hardwood forest.

An adult coyote hunts in the evening on the border between the bottomland hardwood forest and the wetland.

An adult coyote pauses in the bottomland hardwood forest during a nighttime hunt.

A beaver dam blocks a section of Little Buffalo Creek. Image taken in November 2023 of reference for changes as building continues.

A beaver travels through the bottomland hardwood forest at night.

An adult opossum climbs a tree in the bottomland hardwood forest.

https://ielc.libguides.com/sdzg/factsheets/bobcat/summary

Coyote *(Canis latrans)*

Coyotes are common throughout North America. Coyotes can live in almost any landscape as long as their prey populations are present. They are opportunistic and omnivorous, though they primarily consume animals, including deer, rabbits, mice, voles, ground-nesting birds, fish, and amphibians.

Like bobcats, coyotes occupy large ranges much greater in size than the area of the Pfizer Sanford campus. On the Pfizer property, coyotes were captured in the cameras in the bottomland forest, but likely rove around much of the natural areas. Coyotes need cover for dens and resting during the day, but they hunt in open or semi-open areas, like fields or woodlands.

Although coyotes are often vilified by farmers, they provide valuable ecosystem services through their impacts on the food web. Coyote presence has actually been correlated with increases in bird diversity and abundance due to their impacts in limiting smaller mesocarnivore populations (i.e. foxes, raccoons, skunks, which often prey on ground nesting birds and songbirds). For more information about the benefits of maintaining coyote populations, see the Project Coyote web resources: https://projectcoyote.org/carnivores/coyote/.

North American Beaver
(Castor canadensis)

North American Beavers are suited to a variety of landscapes but they require a permanent body of water. They are semi-aquatic herbivores and eat bark, twigs, shoots, and aquatic vegetation. Beavers often live in colonies, consisting of a breeding pair and their recent offspring. They are the largest rodents in North America and can live up to twelve years. Predators include wolves, coyotes, bobcats and bears.

Beavers are often considered keystone species and ecosystem engineers due to the dramatic changes they make to the landscape. Beavers build dams that create new ponds, fundamentally altering the hydrology, soil conditions, and vegetation on a site. Although beavers can cause property damage when their dams flood the built environment or roads, they also produce significant ecosystem services on the landscape (Fig 13.). Research suggests that the presence of beavers can significantly increase plant biodiversity (Wright et al. 2002) and can provide ecosystem services ranging from water purification, nutrient cycling, carbon sequestration, and more worth millions of dollars annual across the landscape (Thompson et al. 2020).

We documented the presence of two beavers (a breeding pair) currently residing on the Pfizer Sanford campus. There is significant beaver activity in the bottomland hardwood forest and wetland in the form of cut logs, and the beavers are currently building a dam on the Little Creek River. The location of the dam is certainly far enough away from any of the Pfizer buildings or parking lots to have any flooding impacts on those structures, and appears to be far enough away from the roads as well.

Opossum *(Didelphis virginiana)*

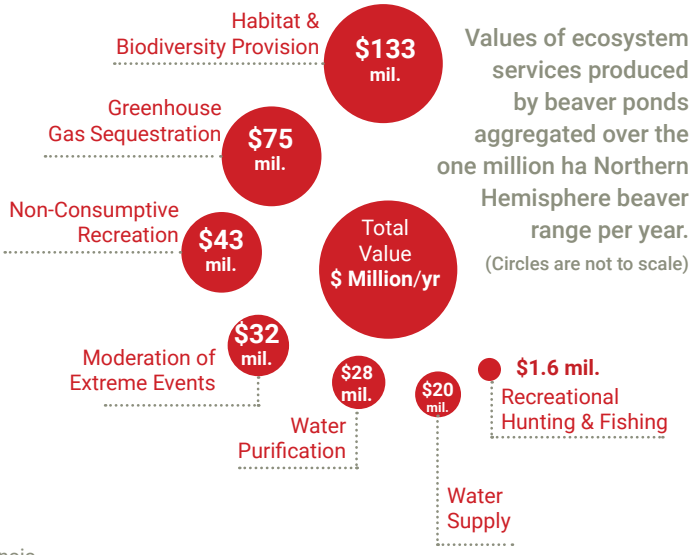
Opossums are highly adaptable and are found in most landscapes in the southern United States. They are often found near water in forests and suburban neighborhoods, and on the Pfizer property they were primarily seen in the bottomland hardwood forest. They nest in stumps, hollow trees, brush piles, or the abandoned dens of other animals. Opossums are nocturnal, and are also North America's only marsupial. Opossums are resourceful and will eat almost anything, ranging from fruits to insects to carrion.

North American River Otter *(Lontra canadensis)*

North American river otters are relatively common along the east coast of the United States and can live in a variety of water-adjacent plant communities, though they are rare in more developed regions due to habitat destruction. They thrive in areas that have abundant fish, slowing moving water and plenty of cover. North American river otters are primarily nocturnal and remain active throughout winter. Their diet largely consists of fish but they also eat amphibians, crustaceans, insects, birds, and plants. Predators include bobcats and coyotes,

Services produced by beaver activity include water purification, moderation of extreme events, habitat and biodiversity provision, nutrient cycling, greenhouse gas sequestration, recreational hunting and fishing, water supply, and non-consumptive recreation.

Beaver
Castor canadensis



Values of ecosystem services produced by beaver ponds aggregated over the one million ha Northern Hemisphere beaver range per year.
(Circles are not to scale)

Thompson, S., Vehkaoja, M., Pellikka, J., & Nummi, P. (2021). Ecosystem services provided by beavers Castor spp. Mammal Review, 51(1), 25

VEGETARIAN DIET

AQUATIC PLANTS

LEAVES

TWIGS

BARK

Preferred species include Alder, Aspen, Birch, Cottonwood, Maple, Poplar and Willow.

HABITAT & BIODIVERSITY PROVISIONS
Since 2000, beavers have globally created 9500–42000 km2 of new wetlands, compensating for 5–16% of United States wetland loss.

WATER SUPPLY
Beaver dams raise groundwater levels both upstream and downstream of the dam, increase groundwater storage capacity, water table level, and aquifer recharge.

THE LODGE

NUTRIENT CYCLING
Beaver ponds cause reductions in total nitrogen, total phosphorus, and dissolved silicate levels.

Figure 13. Ecosystem services provided by beavers *(Castor canadensis)* in the Northern hemisphere

both of which are also present on the Pfizer Sanford campus, as well as wolves and bears.

We captured a photograph of a river otter near the pond on the Pfizer campus, which was somewhat surprising considering the small size of the pond. If the beavers successfully dam Little Buffalo Creek near the wetland, this flooded area will also create additional habitat for the river otters.

A river otter leaves the pond (center), while a great blue heron hunts (bottom right).

White-tailed deer *(Odocoileus virginianus)*

White-tailed deer are a highly adaptable species that thrive in a variety of habitats—including hardwood forests, brushlands, grasslands, and suburban areas. White-tailed deer eat a variety of green-leaved plants (often preferring young leaves and buds), but one of their most important food sources is actually acorns, which are plentiful on the Pfizer Sanford property. Deer (including an albino deer) were captured by cameras in every location they were placed, and seem to roam freely around the entire landscape. Unlike some of the other species, white-tailed deer movement may not be as impacted by the fence around the property, as they are known to easily jump seven feet or higher.

A large buck (male deer) takes a drink of water from the pond (first photo). In the second photo, the albino deer makes a ghostly appearance.

.

Table 1. List of plant species identified on the Pfizer Sanford campus

Scientific Name	Common Name	Status	Form
Acer negundo	boxelder	native	tree
Acer rubrum	red maple	native	tree
Alternanthera philoxeroides	alligator weed	invasive	herbaceous
Athyrium asplenioides	southern lady fern	native	herbaceous
Asplenium platyneuron	ebony spleenwort	native	herbaceous
Baccharis halimifolia	sea-myrtle	native	shrub
Benthamidia florida	flowering dogwood	native	tree
Bidens aristosa	bearded beggartick	native	herbaceous
Bignonia capreolata	crossvine	native	vine
Boehmeria cylindrica	false nettle	native	herbaceous
Campsis radicans	cow-itch	native	vine
Carex sp.	sedges	native	herbaceous
Carpinus caroliniana	musclewood	native	tree
Carya illinoinensis	pecan	native	tree
Carya tomentosa	mockernut hickory	native	tree
Cephalanthus occidentalis	buttonbush	native	shrub
Chamaecyparis thyoides	Atlantic white cedar	native	tree
Conoclinium coelestinum	mistflower	native	herbaceous
Dichanthelium sp.	panicgrass	native	herbaceous
Elaeagnus pungens	thorny olive	invasive	shrub
Erechtites hieraciifolius	American burnweed	native	herbaceous
Erigeron acris	fleabane	native	herbaceous
Euonymus americanus	strawberrybush	native	shrub
Eupatorium capillifolium	dogfennel	native	herbaceous
Fraxinus pennsylvanica	green ash	native	tree
Galactica regularis	milk pea	native	herbaceous
Hamamelis virginiana	witch hazel	native	shrub
Hamelia patens	firebush	native	shrub
Hexastylis arifolia	little brown jug	native	herbaceous
Hypericum sp.	St. John's wort	native	herbaceous
Ilex opaca	American holly	native	tree
Juncus sp.	rushes	native	herbaceous
Juniperus virginiana	eastern red cedar	native	tree
Lespedeza cuneata	lespedeza	invasive	shrub
Ligustrum sinense	Chinese privet	invasive	shrub
Liquidambar styraciflua	sweetgum	native	tree
Liriodendron tulipifera	tulip poplar	native	tree
Lobelia cardinalis	cardinal flower	native	herbaceous
Lonicera japonica	Japanese honeysuckle	invasive	vine
Microstegium vimineum	Japanese stiltgrass	invasive	herbaceous
Mikania scandens	climbing hempvine	native	vine
Monarda punctata	spotted bee balm	native	herbaceous
Morella cerifera	wax myrtle	native	shrub
Muscadinia rotundifolia	muscadine grape	native	vine

Table 1. *continued*

Scientific Name	Common Name	Status	Form
Nyssa sylvatica	black tupelo	native	tree
Onoclea sensibilis	sensitive fern	native	herbaceous
Osmunda cinnamomea	cinnamon fern	native	herbaceous
Osmunda regalis	royal fern	natie	herbaceous
Oxydendrum arboreum	sourwood	native	tree
Paspalum urvillei	Vasey's grass	invasive	herbaceous
Parthenocissus quinquefolia	Virginia creeper	native	vine
Phyllostachys aurea	fishpole bamboo	invasive	herbaceous
Phytolacca americana	pokeweed	native	herbaceous
Pinus echinata	shortleaf pine	native	tree
Pinus palustris	longleaf pine	native	tree
Pinus rigida	pitch pine	native	tree
Pinus taeda	loblolly pine	native	tree
Polygonum sp.	knotweed	invasive	herbaceous
Prunus serotina	black cherry	native	tree
Pteridium aquilinum	bracken fern	invasive	herbaceous
Pyrus calleryana	Callery pear	invasive	tree
Quercus alba	white oak	native	tree
Quercus falcata	southern red oak	native	tree
Quercus nigra	water oak	native	tree
Quercus phellos	willow oak	native	tree
Quercus rubra	northern red oak	native	tree
Quercus velutina	black oak	native	tree
Rhus copallinum	shining sumac	native	shrub
Rubus sp.	brambles	native	shrub
Sambucus canadensis	elderberry	native	shrub
Sassafras albidum	sassafras	native	tree
Schizachyrium scoparium	little bluestem	native	herbaceous
Scutellaria incana	downy skullcap	native	herbaceous
Setaria parviflora	marsh bristlegrass	native	herbaceous
Smilax rotundifolia	greenbrier	native	vine
Solidago sp.	goldenrod	native	herbaceous
Symplocos tinctoria	horsesugar	native	shrub
Symphyotrichum lateriflorum	calico aster	native	herbaceous
Toxicodendron radicans	poison ivy	native	vine
Ulmus americana	American elm	native	tree
Ulmus rubra	slippery elm	native	tree
Urtica dioica	common nettle	native	herbaceous
Uvularia sp.	bellwort	native	herbaceous
Vaccinium arboreum	farkleberry	native	shrub
Vaccinium pallidum	hillside blueberry	native	shrub
Verbena hastata	blue vervain	native	herbaceous
Viburnum dentatum	arrowwood viburnum	native	shrub

Table 2. List of plant species identified in the upland hardwood plant communities on the Pfizer Sanford campus

Scientific Name	Common Name	Status	Habit	Hosts*
Athyrium asplenioides	southern lady fern	native	fern	n/a
Asplenium platyneuron	ebony spleenwort	native	fern	n/a
Acer rubrum	red maple	native	deciduous tree	imperial moth
Benthamidia florida	flowering dogwood	native	deciduous tree	spring azure, fragile mining bee, short-haired dogwood mining bee, plated miner bee
Bignonia capreolata	crossvine	native	woody vine	n/a
Campsis radicans	cow-itch	native	woody vine	trumpet vine moth, white-marked tussock moth, greater red dart, waved sphinx
Carpinus caroliniana	musclewood	native	deciduous tree	eastern tiger swallowtail, red-spotted purple
Carya tomentosa	mockernut hickory	native	deciduous tree	banded hairstreak, regal moth, luna moth
Cephalanthus occidentalis	buttonbush	native	shrub	titan sphinx, hydrangea sphinx
Chamaecyparis thyoides	Atlantic white cedar	native	needled evergreen tree	Hessel's hairstreak
Euonymus americanus	strawberry bush	native	shrub	American ermine moth
Hamelia patens	firebush	native	shrub	pluto sphinx
Hexastylis arifolia	little brown jug	native	evergreen perennial herb	n/a
Ilex opaca	American holly	native	broadleaf evergreen tree	Henry's elfin
Juniperus virginiana	eastern red cedar	native	coniferous tree	juniper hairstreak
Liquidambar styraciflua	sweet gum	native	deciduous tree	imperial moth, luna moth
Liriodendron tulipifera	tulip poplar/yellow poplar	native	deciduous tree	eastern tiger swallowtail, viceroy, spicebush swallowtail, tuliptree silkmoth
Morella cerifera	wax myrtle	native	shrub	red-banded hairstreak
Muscadinia rotundifolia	muscadine grape	native	woody vine	nessus sphinx, mournful sphinx
Nyssa sylvatica	black tupelo	native	deciduous tree	tupelo leafminer
Osmunda cinnamomea	cinnamon fern	native	fern	n/a
Osmunda spectabilis	royal fern	native	fern	n/a
Oxydendrum arboreum	sourwood	native	deciduous tree	lettered sphinx
Parthenocissus quinquefolia	Virginia creeper	native	woody vine	lettered sphinx, nessus sphinx, hog sphinx, Abbot's sphinx, grapeleaf skeletonizer
Pinus echinata	shortleaf pine	native	coniferous tree	eastern pine elfin, imperial moth
Pinus palustris	longleaf pine	native	coniferous tree	imperial moth
Pinus taeda	loblolly pine	native	coniferous tree	eastern pine elfin, imperial moth
Prunus serotina	black cherry	native	deciduous tree	coral hairstreak, eastern tiger swallowtail, viceroy, red-spotted purple, spring azure
Pteridium aquilinum	bracken fern	invasive	fern	n/a
Quercus alba	white oak	native	deciduous tree	Many lepidopterans, including banded hairstreak, imperial moth, gray hairstreak, Edward's hairstreak, white-m hairstreak, Juvenal's duskywing, Horace's duskywing
Quercus falcata	southern red oak	native	deciduous tree	Many lepidopterans, including banded hairstreak, imperial moth, gray hairstreak, Edward's hairstreak, white-m hairstreak, Juvenal's duskywing, Horace's duskywing
Quercus phellos	willow oak	native	deciduous tree	Many lepidopterans, including banded hairstreak, imperial moth, gray hairstreak, Edward's hairstreak, white-m hairstreak, Juvenal's duskywing, Horace's duskywing
Quercus rubra	northern red oak	native	deciduous tree	Many lepidopterans, including banded hairstreak, imperial moth, gray hairstreak, Edward's hairstreak, white-m hairstreak, Juvenal's duskywing, Horace's duskywing
Quercus velutina	black oak	native	deciduous tree	Many lepidopterans, including banded hairstreak, imperial moth, gray hairstreak, Edward's hairstreak, white-m hairstreak, Juvenal's duskywing, Horace's duskywing
Rhus copallinum	winged sumac	native	shrub	luna moth, red-banded hairstreak
Sassafras albidum	sassafras	native	deciduous tree	Cecropia moth, spicebush swallowtail, imperial moth
Smilax rotundifolia	greenbrier	native	woody vine	n/a

** Hosts column includes a partial list of insect species the plant is known to host to demonstrate their interconnected role as the base of the food web.*

Table 2. *continued*

Scientific Name	Common Name	Status	Habit	Hosts*
Symplocos tinctoria	horsesugar	native	shrub	King's hairstreak
Toxicodendron radicans	poison ivy	native	woody vine	dark marathyssa moth, poison ivy sawfly
Uvularia sp.	bellwort	native	erect clumping perennial herb	mining bees
Vaccinium arboreum	farkleberry	native	shrub	brown elfin butterfly, Carolina miner bee, southeastern blueberry bee, twig mason bee, Bradley's miner bee
Vaccinium pallidum	hillside blueberry	native	shrub	brown elfin butterfly, Carolina miner bee, southeastern blueberry bee, twig mason bee, Bradley's miner bee

Table 3. List of plant species identified in the bottomland hardwood plant communities on the Pfizer Sanford campus

Scientific Name	Common Name	Status	Habit	Hosts*
Acer rubrum	red maple	native	deciduous tree	imperial moth
Baccharis halimifolia	sea-myrtle	native	shrub	n/a
Benthamidia florida	flowering dogwood	native	deciduous tree	spring azure, fragile mining bee, short-haired dogwood mining bee, plated miner bee
Campsis radicans	cow-itch	native	woody vine	trumpet vine moth, white-marked tussock moth, greater red dart, waved sphinx
Carpinus caroliniana	musclewood	native	deciduous tree	eastern tiger swallowtail, red-spotted purple
Carya tomentosa	mockernut hickory	native	deciduous tree	banded hairstreak, regal moth, luna moth
Dichanthelium sp.	panicgrass	native	grass	n/a
Hamamelis virginiana	witch-hazel	native	shrub to small multi-stemmed tree	Many lepidopterans, including the unicorn caterpillar moth, witch-hazel dagger moth, alien probole
Hexastylis arifolia	little brown jug	native	evergreen perennial groundcover	n/a
Ilex opaca	American holly	native	broadleaf evergreen tree	Henry's elfin
Liriodendron tulipifera	tulip poplar/yellow poplar	native	deciduous tree	eastern tiger swallowtail, viceroy, spicebush swallowtail, tuliptree silkmoth
Liquidambar styraciflua	sweet gum	native	deciduous tree	imperial moth
Microstegium vimineum	Japanese stiltgrass	invasive	grass	n/a
Muscadinia rotundifolia	muscadine grape	native	woody vine	nessus sphinx, mournful sphinx
Oxydendrum arboreum	sourwood	native	deciduous tree	lettered sphinx
Pinus taeda	loblolly pine	native	coniferous tree	eastern pine elfin, imperial moth
Quercus alba	white oak	native	deciduous tree	Many lepidopterans, banded hairstreak, imperial moth, gray hairstreak, Edward's hairstreak, white-m hairstreak, Juvenal's duskywing, Horace's duskywing
Quercus nigra	water oak	native	deciduous tree	Many lepidopterans, including banded hairstreak, imperial moth, gray hairstreak, Edward's hairstreak, white-m hairstreak, Juvenal's duskywing, Horace's duskywing
Quercus phellos	willow oak	native	deciduous tree	Many lepidopterans, including banded hairstreak, imperial moth, gray hairstreak, Edward's hairstreak, white-m hairstreak, Juvenal's duskywing, Horace's duskywing
Quercus rubra	northern red oak	native	deciduous tree	Many lepidopterans, including banded hairstreak, imperial moth, gray hairstreak, Edward's hairstreak, white-m hairstreak, Juvenal's duskywing, Horace's duskywing
Sassafras albidum	sassafras	native	deciduous tree	spicebush swallowtail, imperial moth, Cecropia moth
Smilax sp.	greenbrier	native	woody vine	n/a
Solidago sp.	goldenrod	native	erect perennial herb	Many lepidopterans, including the wavy-lined emerald moth
Toxicodendron radicans	poison ivy	native	woody vine	dark marathyssa moth, poison ivy sawfly
Vaccinium pallidum	hillside blueberry	native	shrub	brown elfin butterfly, Carolina miner bee, southeastern blueberry bee, twig mason bee, Bradley's miner bee

** Hosts column includes a partial list of insect species the plant is known to host to demonstrate their interconnected role as the base of the food web.*

Table 4. List of plant species identified in wetland plant communities on the Pfizer Sanford campus

Scientific Name	Common Name	Status	Habit	Hosts*
Acer negundo	boxelder	native	deciduous tree	imperial moth
Alternanthera philoxeroides	alligator weed	invasive	creeping perennial herb	n/a
Baccharis halimifolia	sea-myrtle	native	shrub	n/a
Bidens aristosa	bearded beggartick	native	annual or biennial herb	n/a
Bignonia capreolata	crossvine	native	climbing vine	n/a
Boehmeria cylindrica	false nettle	native	multi-stemmed erect perennial herb	eastern comma, red admiral, question mark butterfly
Campsis radicans	cow-itch	native	climbing woody vine	trumpet vine moth, white-marked tussock moth, greater red dart, waved sphinx
Carex ssp.	sedge	native	grass	n/a
Carpinus caroliniana	musclewood	native	deciduous tree	eastern tiger swallowtail, red-spotted purple
Conoclinium coelestinum	blue mistflower	native	erect perennial herb	clymene moth, three-lined flower moth
Erechtites hieraciifolius	American burnweed	native	multi-stemmed annual	tarnished plant bug
Erigeron acris	fleabane	native	erect perennial herb	n/a
Euonymus americanus	strawberry bush	native	shrub	American ermine moth
Fraxinus pennsylvanica	green ash	native	deciduous tree	eastern tiger swallowtail, orange sulphur, mourning cloak
Galactia regularis	milk pea	native	climbing perennial wildflower	n/a
Hexastylis arifolia	little brown jug	native	evergreen perennial	n/a
Hypericum sp.	St. John's wort	native	erect perennial herb	n/a
Lespedeza cuneata	lespedeza	invasive	shrub	n/a
Liquidambar styraciflua	sweet gum	native	tree	imperial moth
Lobelia cardinalis	cardinal flower	native	erect herbaceous perennial	n/a
Lonicera japonica	Japanese honeysuckle	invasive	woody vine	n/a
Microstegium vimineum	Japanese stiltgrass	invasive	grass	n/a
Mikania scandens	climbing hempvine	native	herbaceous perennial vine	little metalmark
Muscadinia rotundifolia	muscadine grape	native	woody vine	nessus sphinx, mournful sphinx
Onoclea sensibilis	sensitive fern	native	fern	n/a
Parthenocissus quinquefolia	Virginia creeper	native	woody vine	lettered sphinx, nessus sphinx, hog sphinx, Abbot's sphinx, grapeleaf
Phytolacca americana	pokeweed	native	erect herbaceous perennial	n/a
Pinus taeda	loblolly pine	native	coniferous tree	eastern pine elfin, imperial moth
Polygonum sp.	knotweed	invasive	herbaceous annual	n/a
Quercus nigra	water oak	native	deciduous tree	Many lepidopterans, including banded hairstreak, imperial moth, gray hairstreak, Edward's hairstreak, white-m hairstreak, Juvenal's duskywing, Horace's duskywing

** Hosts column includes a partial list of insect species the plant is known to host to demonstrate their interconnected role as the base of the food web.*

Table 4. *continued*

Scientific Name	Common Name	Status	Habit	Hosts*
Quercus phellos	willow oak	native	deciduous tree	Many lepidopterans, including banded hairstreak, imperial moth, gray hairstreak, Edward's hairstreak, white-m hairstreak, Juvenal's duskywing, Horace's duskywing
Rubus sp.	brambles	native	perennial shrub	n/a
Sambucus canadensis	elderberry	native	deciduous shrub	Cecropia moth,
Smilax rotundifolia	greenbrier	native	woody vine	n/a
Solidago sp.	goldenrod	native	erect herbaceous perennial	Many lepidopterans, including the wavy-lined emerald moth
Symphyotrichum lateriflorum	calico aster	native	erect herbaceous perennial	aster miner bee, hairy-banded mining bee, cloudy-winged miner bee, peaceful miner bee, simple miner bee, spine-shouldered cellophane bee
Toxicodendron radicans	poison ivy	native	woody vine	dark marathyssa moth, poison ivy sawfly
Ulmus americana	American elm	native	deciduous tree	white-lined sphinx
Ulmus rubra	slippery elm	native	deciduous tree	white-lined sphinx
Urtica dioica	common nettle	native	erect herbaceous perennial	eastern comma, mourning cloak, question mark butterfly
Viburnum dentatum	arrowwood viburnum	native	shrub	spring azure

Table 5. List of plant species identified in the early successional plant communities on the Pfizer Sanford campus

Scientific Name	Common Name	Status	Habit	Hosts*
Baccharis halimifolia	sea-myrtle	native	shrub	n/a
Bidens aristosa	bearded-beggartick	native	multi-stemmed annual or biennial herb	n/a
Campsis radicans	cow-itch, trumpet flower	native	climbing woody vine	trumpet vine moth, white-marked tussock moth, greater red dart, waved sphinx
Carya illinoinensis	pecan	native	deciduous tree	luna moth
Carya tomentosa	mockernut hickory	native	deciduous tree	banded hairstreak, regal moth, luna moth
Conoclinium coelestinum	blue mistflower, wild ageratum	native	erect herbaceous perennial	clymene moth, three-lined flower moth
Elaeagnus pungens	thorny olive	invasive	shrub	n/a
Erechtites hieraciifolius	American burnweed	native	herbaceous annual	tarnished plant bug
Erigeron acris	Philadelphia fleabane	native	erect herbaceous perennial	n/a
Eupatorium capillifolium	dogfennel	native	erect herbaceous perennial	n/a
Juncus sp.	rush	native	erect perennial	n/a
Lespedeza cuneata	lespedeza	invasive	multi-stemmed herbaceous perennial	n/a
Ligustrum sinense	Chinese privet	invasive	multi-stemmed shrub	n/a
Liquidambar styraciflua	sweetgum	native	tree	imperial moth, regal moth
Lobelia cardinalis	cardinal flower	native	erect herbaceous perennial	n/a
Lonicera japonica	Japanese honeysuckle	invasive	woody vine	n/a
Microstegium vimineum	Japanese stiltgrass	invasive	grass	n/a

** Hosts column includes a partial list of insect species the plant is known to host to demonstrate their interconnected role as the base of the food web.*

Table 5. *continued*

Scientific Name	Common Name	Status	Habit	Hosts*
Monarda punctata	spotted bee balm	native	erect herbaceous perennial	beebalm shortface bee
Muscadinia rotundifolia	muscadine grape	native	woody vine	nessus sphinx, mournful sphinx
Parthenocissus quinquefolia	Virginia creeper	native	woody vine	lettered sphinx, nessus sphinx, hog sphinx, Abbot's sphinx, grapeleaf skeletonizer
Paspalum urvillei	Vasey's grass	invasive	grass	n/a
Pinus rigida	pitch pine	native	coniferous tree	imperial moth
Pinus taeda	loblolly pine	native	coniferous tree	eastern pine elfin, imperial moth
Pyrus calleryana	Callery pear	invasive	deciduous tree	n/a
Quercus phellos	willow oak	native	deciduous tree	Many lepidopterans, including banded hairstreak, imperial moth, gray hairstreak, Edward's hairstreak, white-m hairstreak, Juvenal's duskywing, Horace's duskywing
Quercus rubra	northern red oak	native	deciduous tree	Many lepidopterans, including banded hairstreak, imperial moth, gray hairstreak, Edward's hairstreak, white-m hairstreak, Juvenal's duskywing, Horace's duskywing
Quercus velutina	black oak	native	deciduous tree	Many lepidopterans, including banded hairstreak, imperial moth, gray hairstreak, Edward's hairstreak, white-m hairstreak, Juvenal's duskywing, Horace's duskywing
Rubus sp.	brambles	native	perennial shrub	n/a
Schizachyrium scoparium	little bluestem	native	grass	common wood-nymph
Scutellaria incana	downy skullcap	native	erect herbaceous perennial	skullcap caloptilia, skullcap skeletonizer
Setaria parviflora	marsh bristlegrass	native	grass	n/a
Solidago sp.	goldenrod	native	erect herbaceous perennial	Many lepidopterans, including the wavy-lined emerald moth, and goldenrod gall flies
Symphyotrichum lateriflorum	calico aster	native	erect herbaceous perennial	n/a
Verbena hastata	blue vervain	native	erect herbaceous perennial	verbena moth, common buckeye butterfly

Table 6. List of wildlife species identified on the Pfizer Sanford campus

Scientific Name	Common Name	Desired Habitat	Sightings
Bubo virginianus	great horned owl	Deciduous, coniferous or mixed forests or woodlands	Upland Forest
Canis latrans	coyote	Forests or woodlands near open fields	Bottomland Forest, Wetland
Castor canadensis	North American beaver	Ponds, rivers or lakes with adjacent deciduous forest	Bottomland Forest, Wetland
Didelphis virginiana	opossum	Forests, woodlands, developed neighborhoods near water	Bottomland Forest, Wetland
Lontra canadensis	North American river otter	Streams, rivers, lakes and ponds within deciduous, coniferous or mixed forests	Pond
Lynx rufa	bobcat	Bottomland hardwood forest, coastal swamps	Bottomland Forest, Wetland
Procyon lotor	raccoon	Forest, swamps, or farmland near water	Pond, Wetland
Odocoileus virginianus	white-tailed deer	Mature woodlands	Bottomland Forest, Upland Forest, Wetland
Sciurus carolinensis	eastern gray squirrel	Mature deciduous woodland or forest	Bottomland Forest, Upland Forest, Wetland
Sylvilagus floridanus	eastern cottontail	Early successional plant communities and fields with adequate cover	Bottomland Forest, Wetland
Trachemys scripta scripta	yellow-bellied slider	Freshwater ponds, lakes, streams, rivers, and swamps	Wetland
Ardea herodias	great blue heron	Open water and wetlands	Pond

** Hosts column includes a partial list of insect species the plant is known to host to demonstrate their interconnected role as the base of the food web.*

POND

MIXED UPLAND HARDWOOD FOREST (LESS MATURE)

DIRECT SERVICES

- Timber
- Fuel
- Keystone value: support 897 caterpillar species in the United States which in turn provide food for a variety of birds and mammals.

INDIRECT SERVICES

- Air quality
- Water quality
- Carbon sequestration: can store 14,400 pounds of CO_2.
- Soil protection

CULTURAL SERVICES

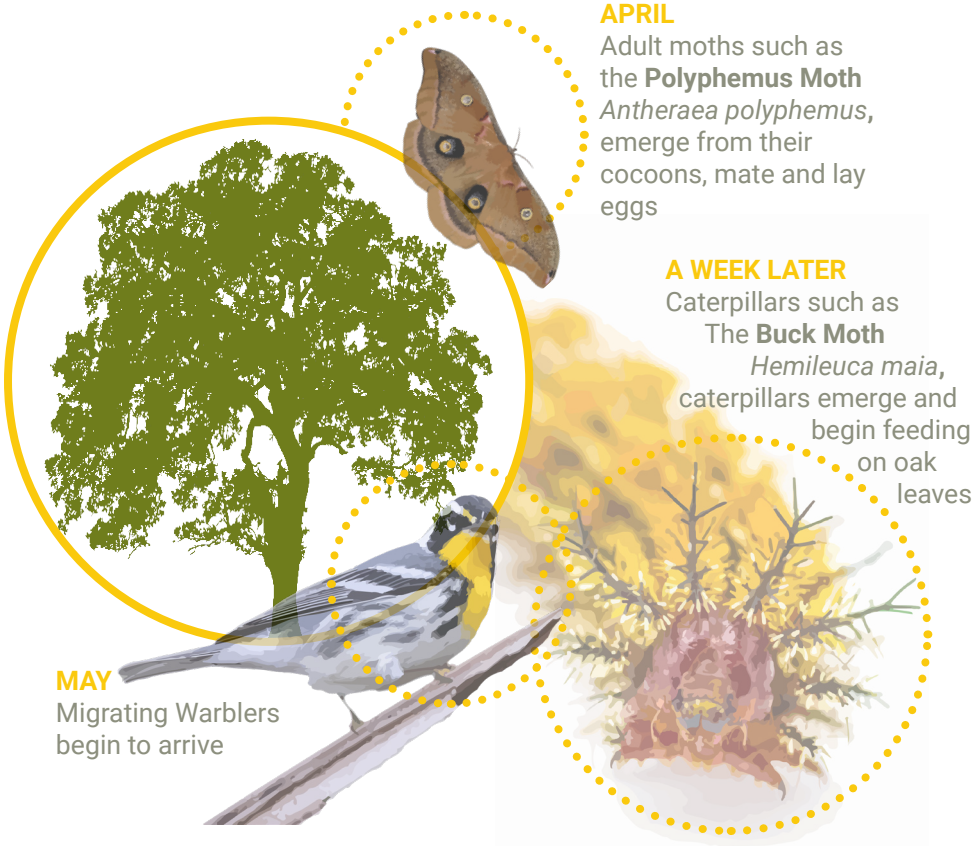
- Recreation
- Aesthetic
- Landscape
- Historic Values
- Cultural Values

WHITE OAK

Quercus alba

HEALTH FUNCTIONS

"White Oaks are the best at supporting caterpillars. In the mid Atlantic States, oaks support 557 species of moths which are an index of a healthy food web. Their caterpillars transfer more energy from plants to other animals than any other plant eater. 96% of birds are insectivores and most of them eat caterpillars. Chickadees, as an example, need 6000-9000 caterpillars to rear one clutch".
Dr. Douglas Tallamy,
The Nature of Oaks



APRIL
Adult moths such as the **Polyphemus Moth** *Antheraea polyphemus*, emerge from their cocoons, mate and lay eggs

A WEEK LATER
Caterpillars such as The **Buck Moth** *Hemileuca maia*, caterpillars emerge and begin feeding on oak leaves

MAY
Migrating Warblers begin to arrive

Tallamy, D. W. (2021). The nature of Oaks: the rich ecology of our most essential native trees. Timber Press.

WETLAND

BOTTOMLAND HARDWOOD FOREST

DIRECT SERVICES

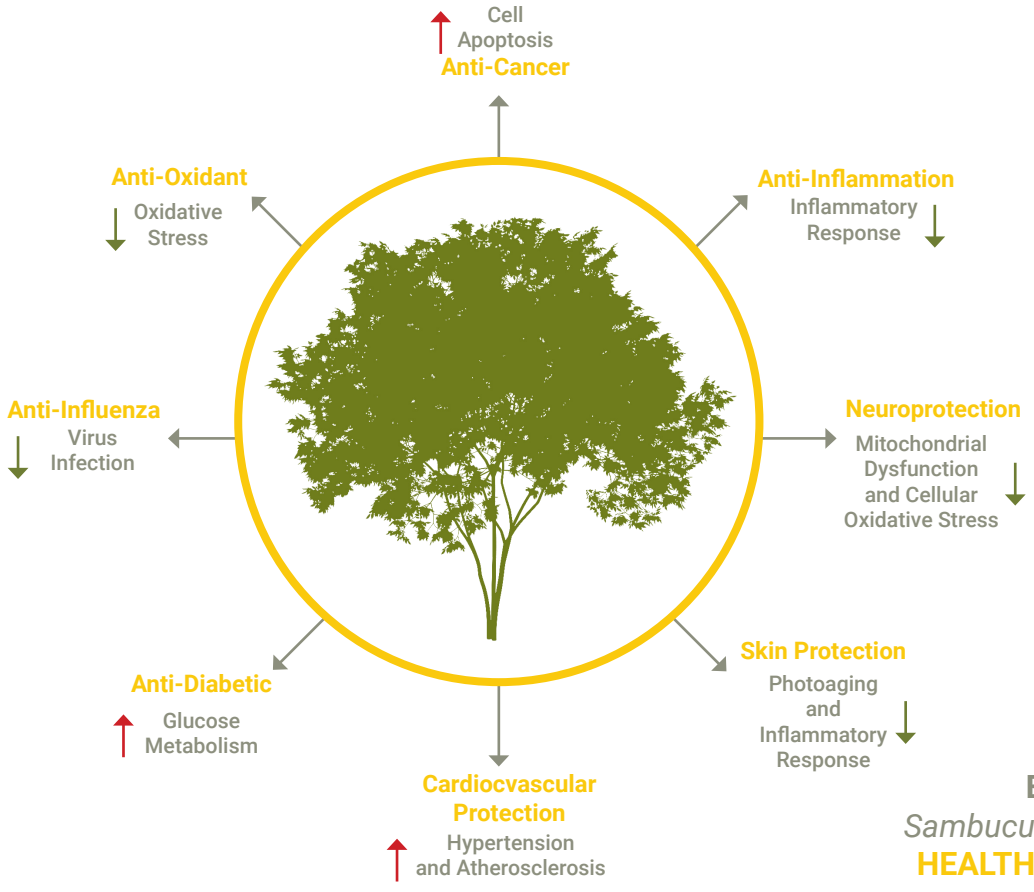
- Shading: keeps water cool and discourages algal blooms
- Sustenance: provides critical food for birds and wildlife

INDIRECT SERVICES

- Root stabilization of banks
- Filtration and treatment of polluted runoff

CULTURAL SERVICES

- Aesthetic
- Landscape
- Historic Values
- Cultural Values: Medicinal



AMERICAN ELDERBERRY

Sambucus canadensis

HEALTH FUNCTIONS

Liu, D., He, X. Q., Wu, D. T., Li, H. B., Feng, Y. B., Zou, L., & Gan, R. Y. (2022). Elderberry (Sambucus nigra L.): Bioactive compounds, health functions, & applications. Journal of Agricultural and Food Chemistry, 70(14), 4202-4220.

EARLY SUCCESSIONAL PLANT COMMUNITY

UPLAND MIXED HARDWOOD FOREST

DIRECT SERVICES

- Drought tolerance
- Root compounds active against crop pathogenic fungi
- Food for seed eating and insectivorous birds

INDIRECT SERVICES

- Significantly attracts beneficial insects that provide pollination services, decomposition, natural pest suppression and form the food base for higher trophic levels
- Highly attractive to native bees

CULTURAL SERVICES

- Aesthetic
- Historic Values
- Cultural Values

MIGRATORY

Dark-Eyed Junco
Junco hyemalis

White-Throated Sparrow
Zonotrichia albicollis

Pine Siskin
Spinus pinus

Indigo Bunting
Passerina cyanea

RESIDENT

American Goldfinch
Spinus tristis

Black-Capped Chickadee
Poecile atricapillus

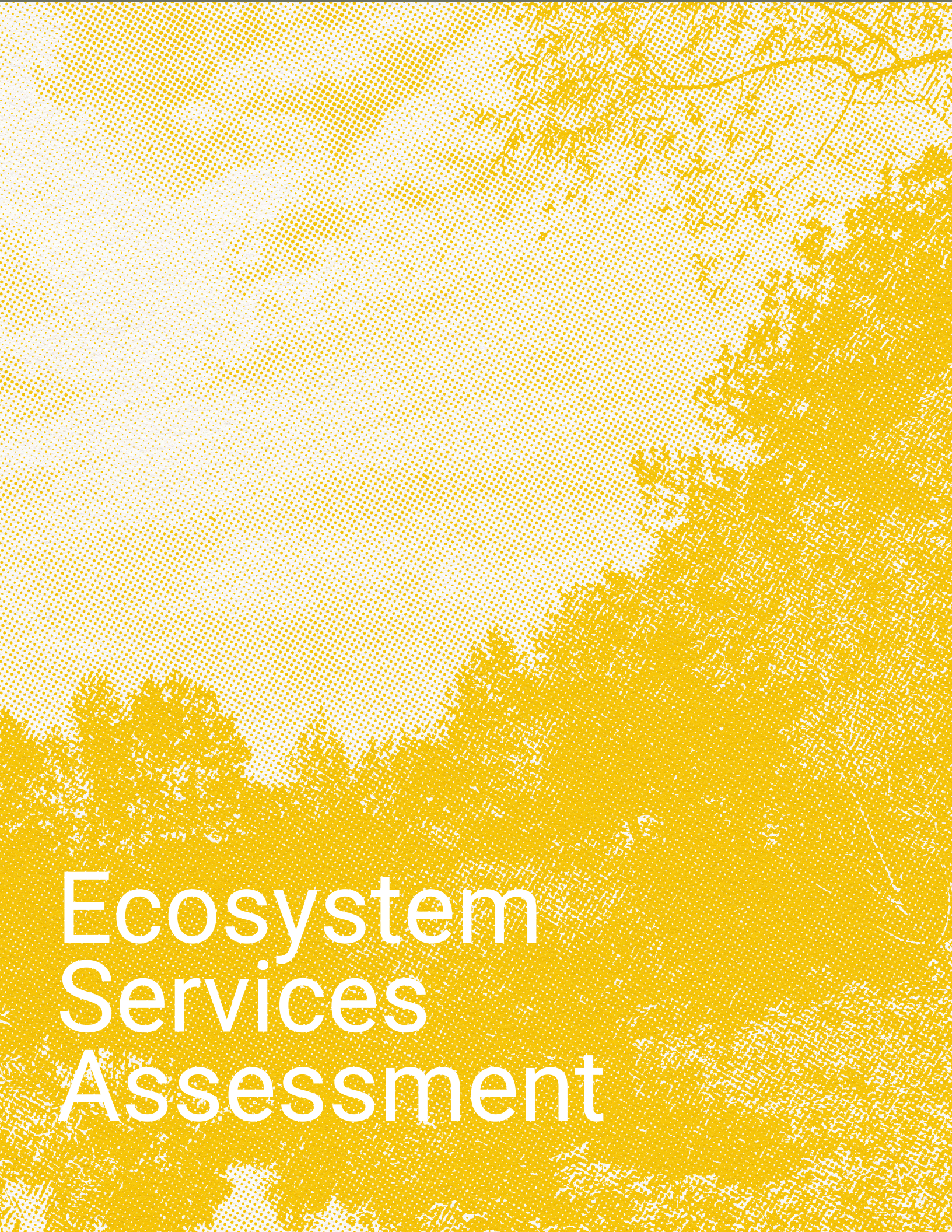
Carolina Wren
Thryothorus ludovicianus

Northern Cardinal
Cardinalis cardinalis

Tufted Titmouse
Baeolophus bicolor

GOLDENROD
Solidago sp.
SUPPORTS SEED EATING BIRDS

https://www.exploringbirds.com/posts/birds-attracted-to-goldenrod



Ecosystem Services Assessment

METHODS: ECOSYSTEMS INTELLIGENCE TOOL

We performed an ecosystem service assessment of the Pfizer Sanford campus using the Ecosystem Intelligence tool provided by the consulting company EcoMetrix Solutions Group. Utilizing a bottom-up perspective, the Ecosystem Intelligence (EI) software provides quantitative data to support site selection and land use decisions that balance the trade-offs between project delivery objectives, community commitments, and the need to conserve and restore the landscape in conjunction with site development. EI includes a Screening and a Design module to help with high-level performance estimating and detailed design analysis by using a common unit of measure across diverse metrics (including climate, biodiversity, water, soil, and wellbeing services). Using the same units (service acres) for multiple different ecosystem services allows the EI platform to provide a uniquely integrated ecosystem perspective instead of the typical siloed approach that does not account for the inter-relationships found in natural systems.

We used the EI Design module for this assessment, which requires the input of site-specific data for modeling baseline site performance, quantifying the impacts and benefits expected to result from design scenarios, and for generating location-specific reference site performance values for benchmarking and target setting purposes. The Design module uses a combination of remotely sensed and on-the-ground, field collected data to provide a comprehensive understanding of site performance conditions. We collected field data using the field data collection App, including information about topography, soil characteristics, vegetation (diversity and structure), canopy cover, coarse woody debris, hydrology, anthropogenic impacts, and more. The EI tool also uses reference data specific to geographic location for comparison the ecosystem services provided by a comparable highly functioning biome.

The Pfizer Sanford campus consists of a developed area and a largely undeveloped area comprised of forest, fields, and water features. For the ecosystem assessment, we analyzed the property as a whole and also analyzed the undeveloped section of the property separately in order to assess ways that management of the natural areas could improve ecosystem service provisioning.

RESULTS

The total property as mapped using the EI tool consisted of 242 acres, yet provides an estimated total of 1210.64 service acres when all ecosystem services are combined (Figure 1.,Table 1.). Thus each acre of the property is providing a mean of 5.00 service acres per acre (Table 2.). This concept of stacked service acres is fairly abstract, but is designed to demonstrate the fact that a single acre of wetland or forest or meadow is providing multiple ecosystem services at the same time in a way that a human

engineered structure cannot. While an acre of solar panels might provide climate ecosystem services, it would not provide any other services. On the other hand, a single acre of the upland forest on the Pfizer campus provides air quality services through plant photosynthesis, water quality and quantity services through natural filtration processes of soil and vegetation, carbon sequestration and storage through the growth of trees, biodiversity services for multiple birds and animals, temperature regulation through tree canopy shade, visual and noise barriers from vegetation for human wellbeing, and more, all at the same time and from the same acreage. For this reason, we can say that a single acre of upland hardwood forest provides multiple acres worth of ecosystem services, although it may not provide the maximum possible service in any given category.

The service acre values for the entire property are lower than the estimates for a well-functioning reference biome scenario at 8.07 service acres per acre, and are particularly lower in the categories of water quality, water quantity and biodiversity services. The lower provisioning of service acres for the campus partially due to the much lower ecosystem functioning of the developed areas, as buildings, parking lots and roads form impervious services with little to no

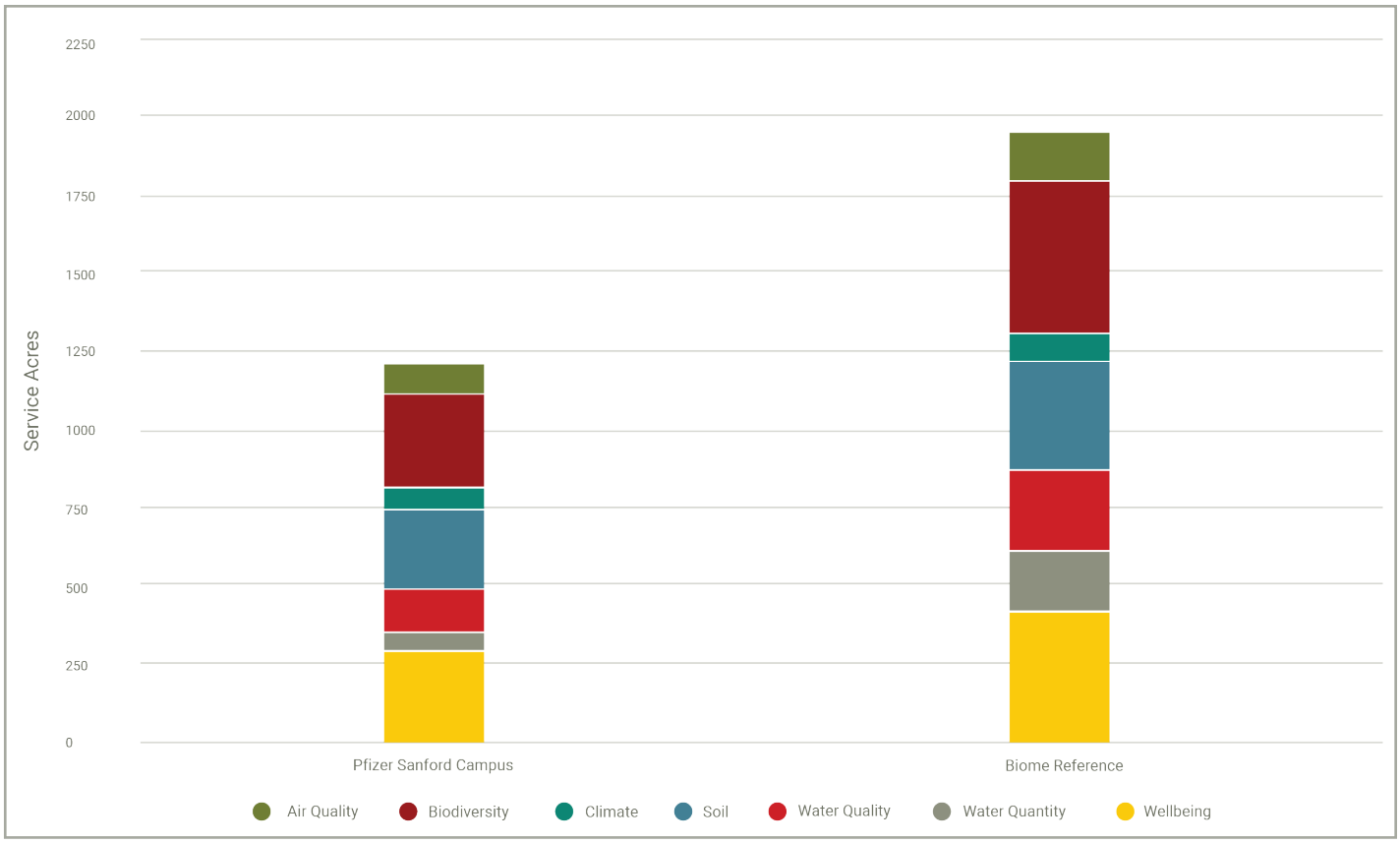


Figure 1. Barcharts showing the stacked service acre values for each ecosystem service category. The Pfizer Sanford camps (on the left) provides fewer ecosystem services compared to a highly functioning reference ecosystem, in part due to the fact that the developed areas on campus provided few ecosystem services.

vegetation that do not provide many services in any of these ecosystem categories.

When analyzing only the undeveloped portion of the property, we mapped approximately 176 acres which provides an estimated total of 1074.24 service acres. This is a smaller number of total service acres compared to the property as a whole because of the smaller size, but the mean service acres per acre value for the natural areas is higher at 6.10 service acres per acre (Figure 2.).

These per acre service value are much closer to those estimated for a biome reference site, as would be expected for these natural areas. The percent performance of the total property and the undeveloped portion of the property (Figure 3.) similarly demonstrate how the natural areas (in darker green in Figure 3) are much closer to the reference line for a highly functioning ecosystem. We note that even the reference biome does not provide 100% of the possible performance in any given ecosystem

Table 1. EA Summary Data: Biome "Temperate Broadleaf and Mixed Forests (TBMF)"

Category	Pfizer Sanford Campus	Pfizer Sanford - undeveloped campus	Biome Reference
Air Quality	102.9	93.55	157.3
Biodiversity	260.15	234.39	487.48
Climate	79.01	70.09	90.21
Soil	284.84	249.44	347.87
Water Quality	127.67	111.19	261.56
Water Quantity	58.21	46.6	191.98
Wellbeing	297.86	268.98	417.75
PER PROPERTY TOTAL:	1210.64	1074.24	1954.15

Table 2. EA Summary Data: Biome "Temperate Broadleaf and Mixed Forests (TBMF)"

Category	Pfizer Sanford Campus	Pfizer Sanford - undeveloped campus	Biome Reference
Air Quality	0.4252066116	0.5315340909	0.65
Biodiversity	1.075	1.331761364	2.014380165
Climate	0.3264876033	0.3982386364	0.372768595
Soil	1.177024793	1.417272727	1.437479339
Water Quality	0.5275619835	0.6317613636	1.080826446
Water Quantity	0.2405371901	0.2647727273	0.7933057851
Wellbeing	1.230826446	1.528295455	1.726239669
PER ACRE TOTAL:	5.002644628	6.103636364	8.075

service category, in part because many of these services represent trade-offs with each other. For example, an intensively managed pine plantation might provide greater carbon sequestration rates compared to a wetland, but the plantation would not provide nearly the same levels of water related services or biodiversity related services as the wetland would. It would be biologically and physically impossible to maximize all services at the same time, but natural areas, including both the reference biome and the natural areas on the Pfizer property are remarkable for their ability to provide high quality services across multiple categories at the same time.

Finally, the EI tool also generates ecosystem service values in the commonly used engineering units for ease of comparison with other programs (Table 3.). These values are for the property as a whole, and include metrics for air quality, temperature regulation, and water quality and quantity.

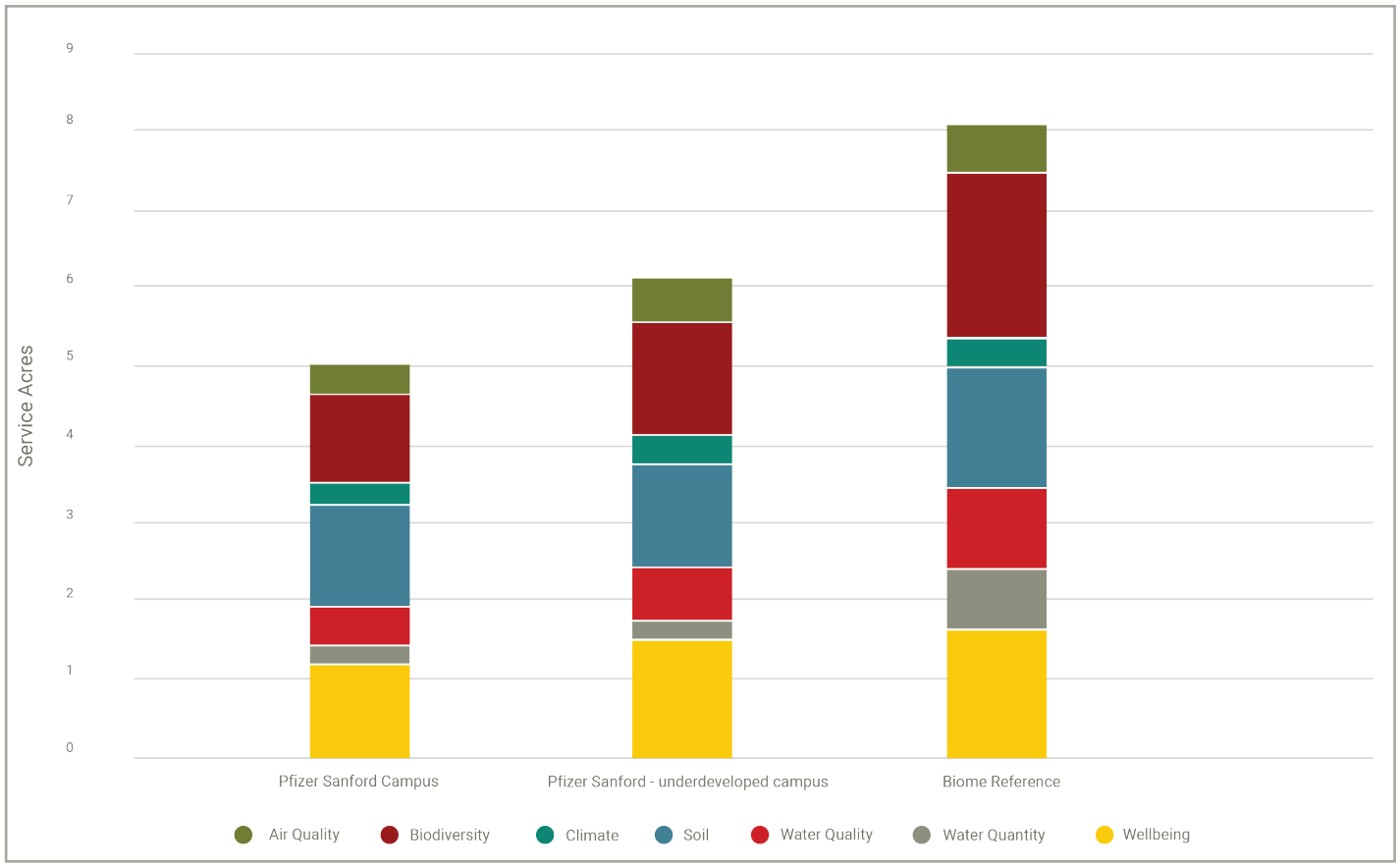


Figure 2. Bar charts showing stacked per acre service acres for the Pfizer campus as a whole (left), the undeveloped portion of the campus (middle), and the reference biome (right). The undeveloped areas still show lower values compared to the reference site, primarily due lower water quality and quantity services from the high clay content in the soils, but are much closer to those of a highly functioning ecosystem.

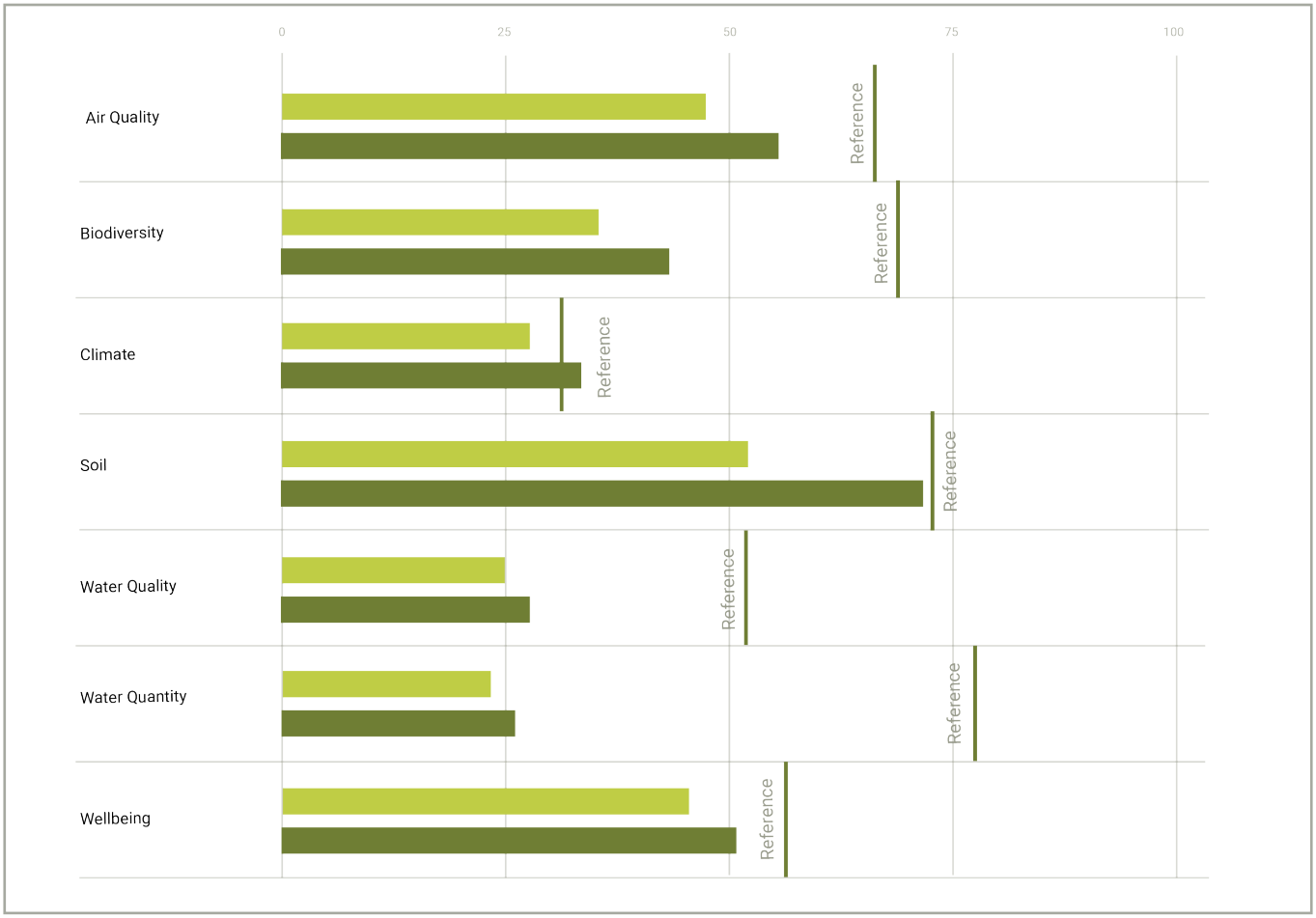


Figure 3. Percent performance in each ecosystem service category for the Pfizer Sanford campus as a whole (light green) and the undeveloped portion (dark green) compared to the highly functioning reference biome (dark green line).

Table 3. EI tool generated ecosystem service values in engineering units for the entire Pfizer Sanford campus

Engineering Units	Pfizer Sanford Campus
Air NOx Removal (lbs/year)	676.12
Air PM Removal (lbs/year)	1707.6
BTU Reduction Shade (BTU/hr)	193730742.7
BTU Reduction Shade (BTU/ft2/hr)	18.37
Max Water Quality NOx Removal (mg/l)	0.34
Max Water Quality TSS Removal (mg/l)	49.57
Water Provisioning (gallons)	2532875.86
Water Provisioning (gallons/ft2)	0.24
Water Quality NOx Removal (mg/l)	0.26
Water Quality TSS Removal (mg/l))	39.51
Water Quantity Runoff (gal)	18083558.73
Water Quantity Runoff (Inches of runoff across site)	2.75

NATIVE POLLINATOR PLANTS

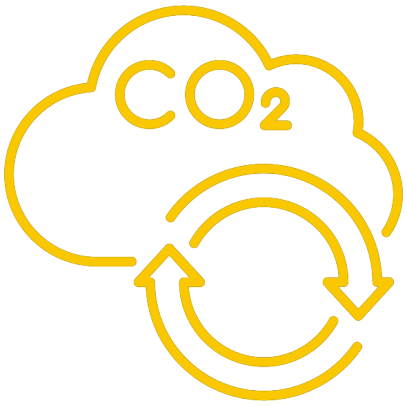
SOFT & HARD MAST

ACCESS TO WATER/ WATER QUALITY

SOIL EROSION PREVENTION/QUALITY

SNAGS

DOWNED WOOD



CARBON SEQUESTRATION

NOISE MITIGATION & VISUAL SCREENING

Water Quality and Quantity

The water quality and water quantity service values on the Pfizer property show the greatest difference from those of the reference biome. While some of this difference is due the presence of impervious surface in the developed area, there remain differences even between the natural areas and the reference biome (Figure 4). These differences are largely due to the fact that the Pfizer site has very clay dominated soils relative to other areas in this biome. The high proportion of clay in the soils explains why brick factories historically were (and still are) located in the area. However, the high clay content also negatively impacts the ability of soil to absorb and filter water. Clay is a very small particle relative to other soil components of sand or silt, and therefore clay-dominated soils are very dense and difficult for water to infiltrate. These properties mean that water tends to run across the land surface rather than draining down through the soil and into the groundwater as quickly, which means less water filtration for the water quality and quantity service metrics relative to a more balanced soil composition. The underlying soil type is not something that can be altered by management, and so these lower values in the natural areas are, to a certain extent, simply intrinsic to the location of the property.

Looking across the campus, the wetland clearly provides extremely valuable water quality and quantity services, while the impervious surfaces in the developed areas provided the fewest water related services. Wetland systems are extremely efficient at filtering water for quality, as well as absorbing and holding water for consistent water provisioning services. Maintaining a healthy and high functioning wetland on the property therefore should continue as a priority in the natural areas management efforts

Soil

Although the clay-based soils are impact water services, the soil services provided by the property are quite high in all vegetated areas. These services include erosion regulation, soil stability, nitrogen storage, and organic matter production, all of which are high when vegetation cover is present to protect soils. The only area on the property where soil condition is more of a concern is the spoils pile (in dark orange on the map in Figure 5). The soils here are composed of unsorted gravel, sand, and clays covered with sparse grasses. The amount of exposed soil here means that rain will continue to wash soils away, leading to erosion and water quality impacts (the area is also red/orange in the water quality map in Figure 4.). The soils here are degraded enough that natural regeneration will likely be very slow and so more active management would be required to improve the vegetation cover here.

Climate

The climate service values provided by the undeveloped portion of the Pfizer property

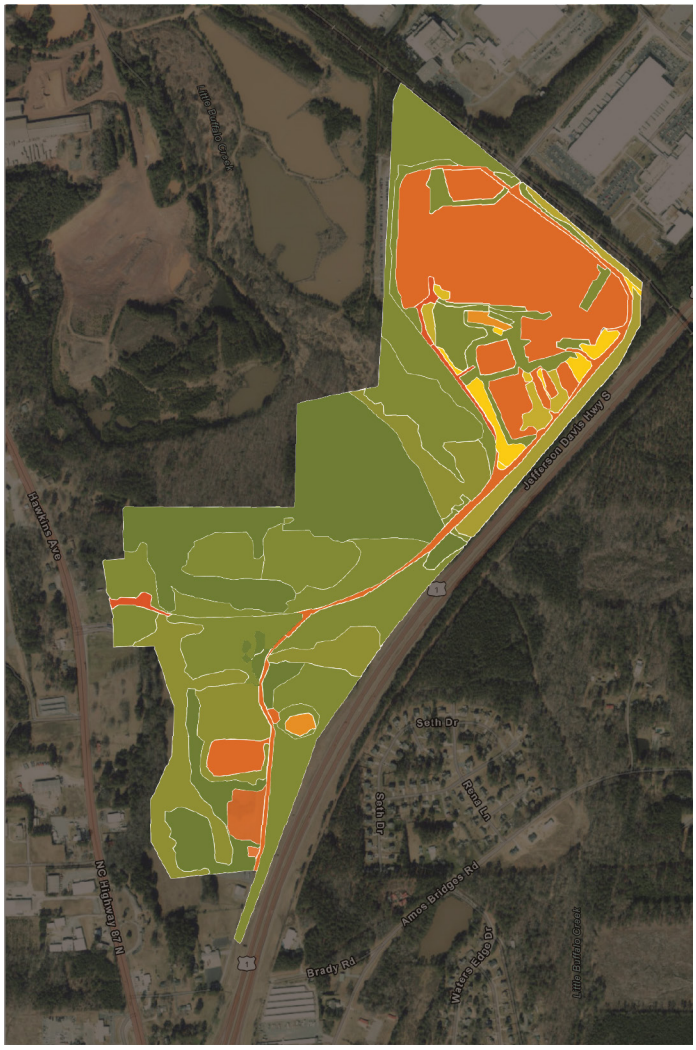


Figure 5. Heat map showing the soil quality services, including erosion regulation, provided by the Pfizer Sanford campus with green showing areas providing high levels of services and red showing areas performing poorly. All vegetated portions of the property provide high quality soil services, as shown by the large amount of green on the map, with the upland forest areas providing the highest proportion. The lowest soil service values are again provided by the developed areas (in red), with spoils pile (dark orange) also highlighted as an area of concern for soil quality and erosion potential.

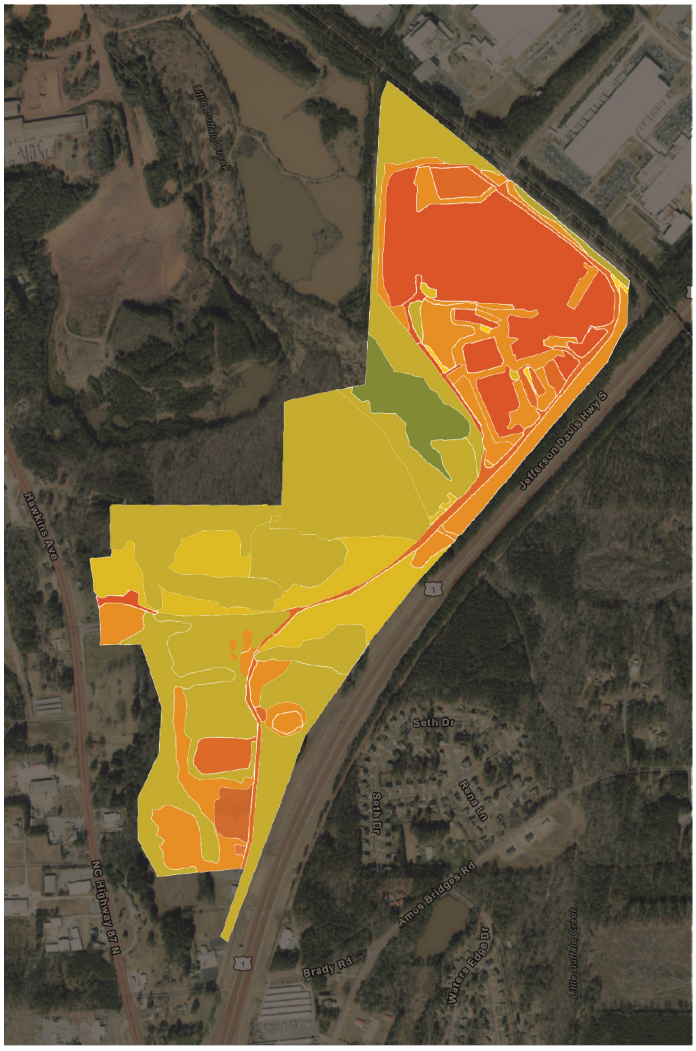


Figure 4. Heat map showing the water quality services provided by the Pfizer Sanford campus with green showing areas providing high levels of services and red showing areas performing poorly. The lowest service values are provided by the developed areas (in red), while the highest values are provided by the wetland (in green). The campus as a whole shows lower values (mostly yellows) due to the high clay content in the soil.

are equivalent to those of a highly functioning reference ecosystem (see Figure 3). The per acre values provided by the property as a whole are slightly lower due to the fact that the developed areas have been cleared of the trees and vegetation that store and sequester carbon. Climate services here are composed of both carbon uptake (i.e. the active capture of carbon into the ecosystem) and carbon storage, which are combined for overall carbon sequestration. Both uptake and storage are key to successful climate mitigation via natural climate solutions. Carbon storage values are highest in upland forest areas (darker green in Figure 6a) because of the high number of large trees, especially pines and oaks, in this area. Carbon uptake values are highest in the young forest around the spoils pile and in the bottomland forest (darker green in Figure 6b) due to differences in forest structure. Young forests and trees grow faster than older, larger trees, and so carbon sequestration rates can be higher in these systems while carbon storage is much higher in the large trees in older forests. The grassland areas sequester less carbon compared to the forests, while the developed areas show the lowest climate service values. The spoils pile also shows low climate service values due to the sparse amount of vegetation growing on the poor quality soils there. As we will discuss further in our recommendations, climate values on the property could be increased by allowing some of the fields to return to forests, as trees generally store and sequester much more carbon compared to grasses.

Air quality

Air quality services on the property are also close to those that would be provided by a highly functioning reference biome, particularly when looking solely at the undeveloped portion of the property. These services are provided at a higher level where there is more vegetation to conduct photosynthesis and air pollution filtration, and so the forested areas are again providing higher values (darker green) compared to the developed areas (red) and the fields (orange and yellow) (Figure 7.). To improve air quality values, we would similarly suggest allowing some of the mowed fields to return to forest.

Biodiversity

The Ecosystem Intelligence software estimates that the Pfizer property provides slightly lower biodiversity services compared to a reference ecosystem, although the program does find that the forested and wetland areas provide high value biodiversity habitat and high value vegetation support services (Figure 8). These estimates are based on the number of species identified and other ecosystem features such as the density of snags and downed wood. Biodiversity habitat can be difficult to assess using these proxies, however, as different animals can have very different habitat requirements, and our biodiversity assessment above indicates that the Pfizer property serves as a healthy habitat to a surprisingly high diversity of wildlife.
We also note that although the meadows and

Figure 6. Heat map showing (a) carbon storage (b) carbon sequestration on the Pfizer Sanford campus with green showing areas providing high levels of services and red showing areas performing poorly. The forest areas show highest levels of both carbon storage and carbon sequestration due to the high photosynthetic rates of trees and the their capacity to store carbon as wood. The grassland areas sequester less carbon compared to the forests, while the developed areas (in red) show the lowest climate service values.

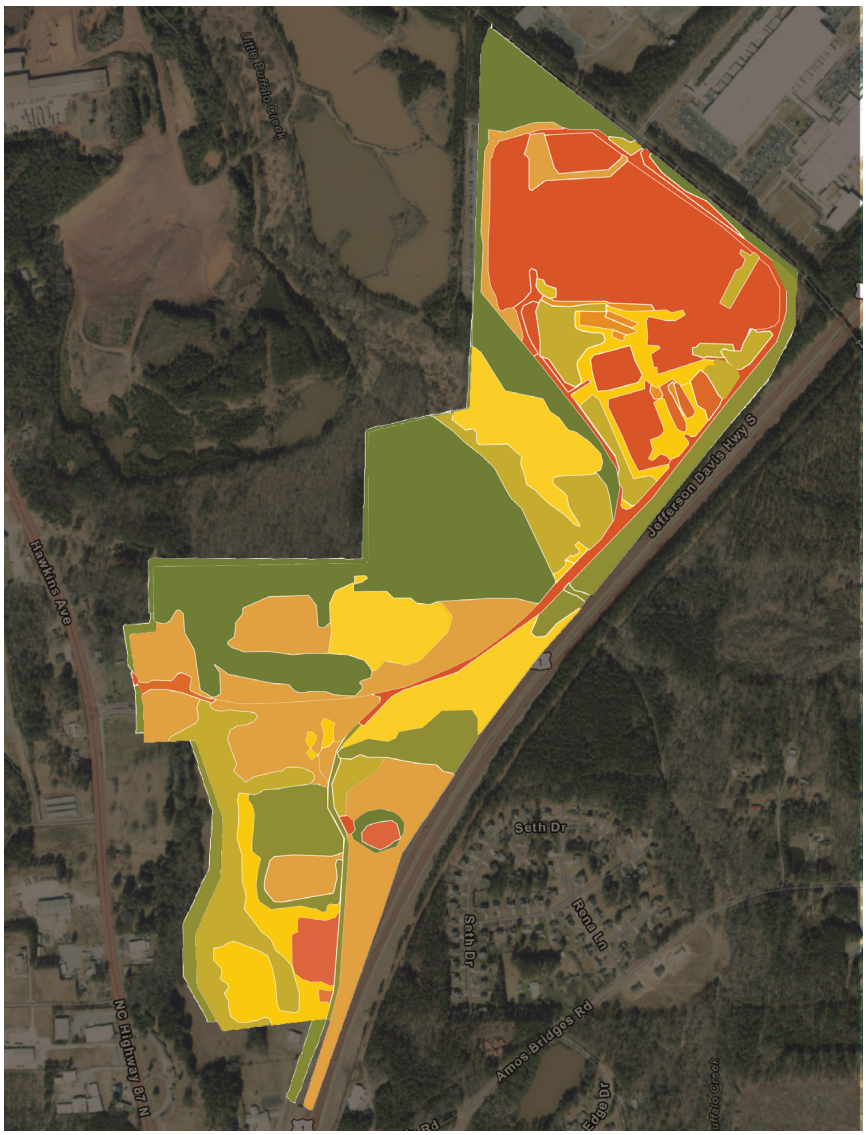


Figure 7. Heat map of air quality services on the Pfizer Sanford campus with green showing areas providing high levels of services and red showing areas performing poorly. Air quality services are largely correlated with the presence of vegetation, and so are higher in the forested areas, followed by the early successional meadows and grasslands, and lowest in the developed areas lacking vegetation.

early successional areas appear to provide fewer biodiversity service acres compared to the forests and wetlands in the heat maps, there is great value in maintaining a diversity of ecosystem types on the property from a biodiversity and climate resilience perspective. The Ecosystem Intelligence software examines each survey unit independently of the others, and so does not take into consideration the value provided by maintaining a heterogeneous matrix of vegetation types. Maintaining a mosaic of vegetation types can create a higher diversity of plants and animals on the property as a whole, even if some of the individual areas contain fewer species than others. Therefore while converting all undeveloped land to mature forest might lead to a high species richness within each individual area when assessed separately, across the property as a whole there would be a loss of total diversity if the many wildflowers, perennial forbs, grasses disappeared, and with them the insects, birds, and animals that rely on early successional habitat types.

Wellbeing

The wellbeing service values provided by the Pfizer property, and especially the undeveloped portions of the property are similar to those estimated for a highly functioning reference site. Wellbeing values represent a combination of noise and visual screening effects as well as air temperature regulation, and are primarily correlated with areas that have dense and tall vegetation capable of blocking noise and visual disturbance from surrounding highways and developed areas and able to provide shade and temperature moderation effects in the hot summers of North Carolina. In the map in Figure 9, the forested areas present much higher per acre values (in green) compared to the fields (dark orange and red). This figure provides a good demonstration of the increase in service values that could be gained by converting some of these fields to forest—particularly for those areas that border the highway, where greater vegetation cover would provide valuable screening from the noise, air pollution, heat, and visual disturbance created by the cars and trucks speeding past.

Ecosystem service trade-offs: importance of landscape diversity

The diversity of ecosystems and vegetation types is one of the great strengths of the current Pfizer Sanford property. Although each of these areas may not provide the maximum amount of a given ecosystem service, the diversity of ecosystems creates a diversity of service provisioning. For example, the wetland performs extremely well in providing water and soil-related ecosystem services, but does not maximize climate-related services because the soils are too wet for many trees to grow and therefore less carbon is being stored and sequestered in above ground biomass. If the property were all forest, we would have higher carbon values, but would lose water and wildlife value.

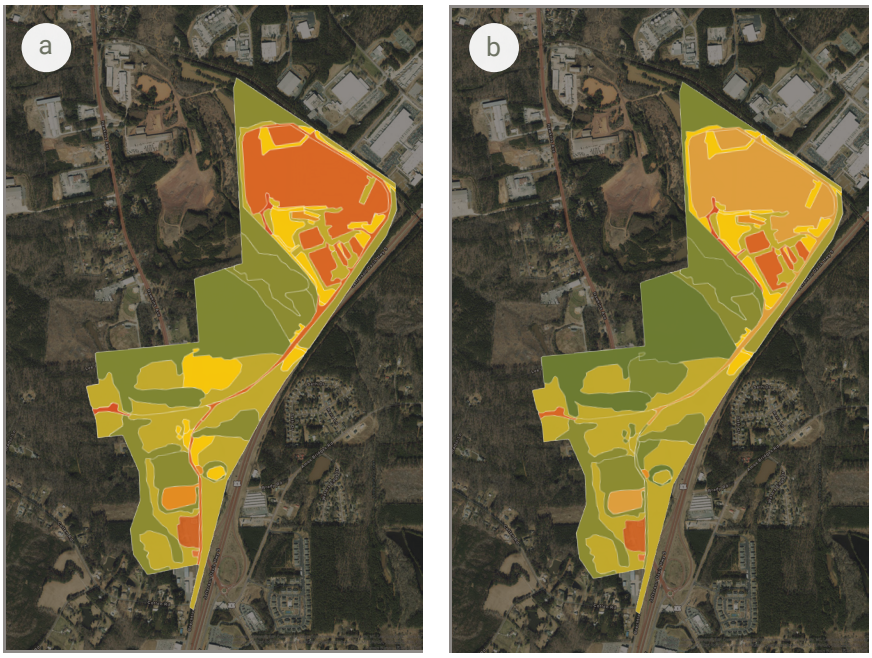


Figure 8. Heat map of (a) biodiversity support services and (b) vegetation support services on the Pfizer Sanford campus with green showing areas providing high levels of services and red showing areas performing poorly.

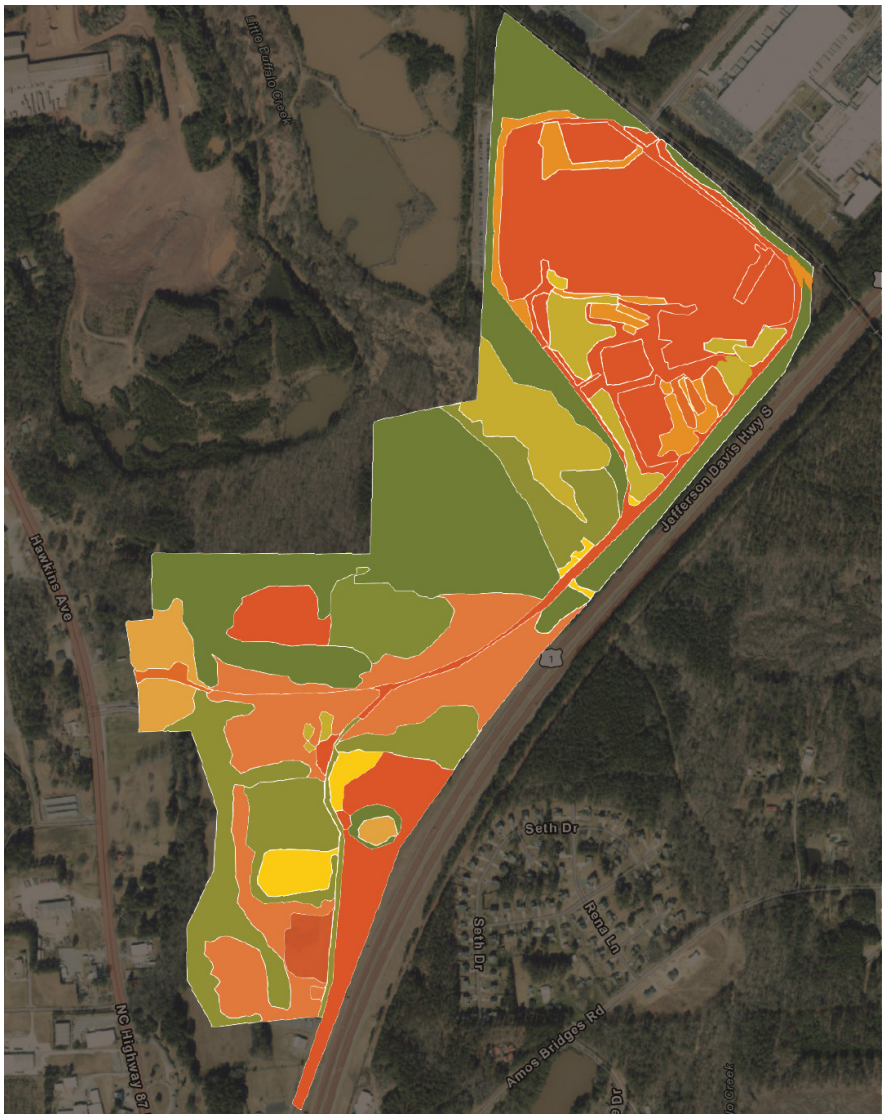


Figure 9. Heat map of noise moderation services on the Pfizer Sanford campus with green showing areas providing high levels of services and red showing areas performing poorly.

MANAGEMENT RECOMMENDATIONS FOR THE NATURAL AREAS

While all ecosystems will inherently present trade-offs in ecosystem services, there are ways to enhance these multiple co-benefits though management. The Pfizer Sanford campus currently provides high value wildlife habitat as well as a suite of ecosystem services through a combination of forest types, wetland, and early successional meadows and grasslands. Our recommendations work to support the existing strengths of the property, and to target areas where a small change in management could provide a valuable increase in ecosystem benefits. We recommend management targeting the following categories: (1) invasive species management, (2) natural reforestation in some areas, (3) wildlife connectivity and habitat management, (4) wetland management, and (5) restoration of the degraded spoils pile. For each of these categories, we highlight which management activities would be a priority, which would be simplest to implement, and which activities would require greater investment.

Invasive species management

While invasive species can provide some of the same ecosystem services that native plants do in terms of water filtration or carbon sequestration, they can have negative impacts on biodiversity and wildlife. The Pfizer Sanford campus currently houses a number of non-native or invasive species—some of which would be relatively simple to target, and others of which are already firmly established and would be much more challenging to eradicate. We recommend targeting efforts towards removing the non-native bamboo stand near the road and the Bradford (Callery) pear located in some of the fields. The invasive Japanese stilt grass in the wetland and in the mowed powerline areas are already too firmly established to remove.

Non-native bamboo stand

The bamboo cluster located off the main road does not currently appear to be spreading at a fast rate, but bamboos in the area are considered invasive, and since this species is currently contained to a small area, it would be wise to eradicate it before it becomes a larger problem. The easily accessible location would also made eradication efforts slightly simpler, although care should be taken to protect the water behind the bamboo. This stand of bamboo does provide some carbon sequestration, carbon storage, and other ecosystem services, but the high shade cast by the dense growth impedes any native species establishment and creates very poor-quality wildlife habitat. The bamboo also stores less carbon compared to a forest of trees. Finally, this cluster is located on the edge of a small pool of water and a small stream area which would have quite high wildlife value if native vegetation could be restored there. Fully eradicating bamboo can take a few years of effort if done mechanically, but combining cutting with herbicides can be more effective. Repeated cutting, or cutting followed by repeated mowing, are two ways to slowly

eradicate bamboo. Glyphosate (Roundup) is an effective herbicide against bamboo, and, if used, should be applied immediately after cutting and then again to any new shoots that emerge. Treatment should continue until no new shoots emerge, as it can quickly re-colonize if left to re-grow before it has been completely eradicated. More information on managing bamboo can be found here: https://extension.umd.edu/resource/containing-and-removing-bamboo/

Bradford (Callery) pear management

Bradford pear is commonly planted as an ornamental tree because of its pretty white flowers in early spring, but it can be an aggressive invasive species that spreads in native forests. Bradford pear does not serve any wildlife value, and in fact none of the native caterpillar species will feed on it, for example, and so when this invasive out competes native trees we see a loss in biodiversity services.

There are Bradford pears planted as ornamentals on some parts of the Pfizer Sanford campus, and the tree is also spreading in a few places. We strongly recommend removing these trees where possible and replacing them with native ornamental trees. Several planted trees are located around the visitor parking lot, and there are a few planted in the field by the main road. There are some young Bradford pear trees and Chinese privet trees (another invasive) located in the young forest near the pond and near the maintenance shed that could also be removed without a great deal of effort. To remove these invasive trees, they should be cut and either re-visited the next year to cut back any re-sprouting or the stump should be sprayed with a small amount of herbicide.

The NC State Extension service has teamed up with the NC Forest Service, NC Urban Forest Council, and NC Wildlife Federation to run a “bounty” program for replacing Bradford pear trees with native species. You can find more about this free program here: https://forestry.ces.ncsu.edu/2023/02/nc-bradford-pear-bounty/. We also recommend that the landscaping crew plant only native tree species going forward to avoid any further unintentional introduction of invasive trees. A list of potential native alternatives can be found here: https://www.missouribotanicalgarden.org/gardens-gardening/your-garden/help-for-the-home-gardener/advice-tips-resources/visual-guides/native-alternatives-for-bradford-pear

Japanese stiltgrass

Unfortunately the Japanese stiltgrass in the wetland and other areas is already too firmly established. Japanese stiltgrass seeds can stay viable in the soil for up to five years, each individual stiltgrass plant can produce up to 1,000 seeds per year, and the seeds float and are easily dispersed in wet environments, making eradication difficult and reintroduction common. While there are some herbicides that are effective against stilt grass (imazapyr or imazapic), these types of herbicides are water soluble, active in soil, and can easily move into

other areas of the landscape. We therefore strongly recommend against using these in the wetland area or near any of the other hydrological features. As such, the stiltgrass is likely here to stay on the campus, and efforts toward invasive species management would be better directed towards other species.

Natural reforestation for improved climate and wellbeing

Maintaining multiple different successional stages across the property creates natural resilience to disturbance and enhances diversity and wildlife habitat. The campus already has multiple different successional stages present in the form of the later successional upland and bottomland forests, the younger pine forests, and the many early successional meadows and fields. While maintaining some early successional meadows creates wildlife habitat and aesthetic and recreational value, there are currently more mowed fields than are necessary for these purposes. We highly recommend allowing some of these fields to return to forest through natural successional processes. This natural forest restoration would lower maintenance costs and enhance other ecosystem services on the property such as carbon sequestration and water filtration features while not negatively impacting wildlife or aesthetic/recreation values.

There are several fields currently being mowed where natural regeneration would create much higher ecosystem services at little to no cost

Close-up of Bradford/Callery pear on the Pfizer Sanford campus.

to aesthetics or recreation. Two of these fields extend beyond existing forest, and are both difficult to access and not visible from the road. The other two areas that we highlight are fields that abut the property fence. In these cases, we recommend maintaining the portion of the field close to the road as a mowed meadow for the aesthetic value along the road, but allowing the back portion of these fields to naturally regenerate. These portions abutting the fence would then create a much stronger noise and aesthetic barrier between the Pfizer Sanford campus and the traffic on Highway 1. In addition, any natural reforestation will increase climate ecosystem services through carbon sequestration and storage, and will also improve water quality, vegetation, and air quality services.

While we recommend natural regeneration as

the most cost efficient and ecologically sound restoration practice for these mowed areas, we do recommend occasional monitoring of these areas for targeted removal of invasive species. While the natural regrowth is still small, invasive Bradford (Callery) pear, Chinese privet, thorny olive, and other invasive tree species can be easily cut back with gardening clippers, and so this could be a community "clean-up" type of event that would not require special equipment or chemicals. Controlling invasives is much easier when there is monitoring to remove them in early stages rather than waiting until they have become firmly established. For more information on common invasive species, see these resources:
https://content.ces.ncsu.edu/invasive-plants-and-your-forests
https://www.fs.usda.gov/research/treesearch/35292
https://www.fs.usda.gov/research/treesearch/36915

Management of early successional meadow habitat

The remaining grasslands that are kept as early successional habitat should be mowed to maintain their open habitat on a high-mow regime. Mowing too frequently will keep these grasslands as less diverse systems dominated by grasses, while more infrequent mowing will prevent the establishment of young forest but will allow a more diverse group of plant species grow. The season of mowing is especially important here—mowing to maintain diverse meadows should occur in the dormant winter months and not during the active growing seasons in spring or summer. Mowing can be as infrequently as once every three years, or as frequently as once a year as long as mowing occurs during the winter. Mowing in the winter also avoids disturbing any ground nesting birds during spring or summer.

Wildlife connectivity and habitat management

The Pfizer Sanford campus currently provides high quality habitat to a number of different wildlife species, including apex predators such as coyotes and bobcats. As such, our recommendations for wildlife management are largely to continue many of the current practices to support existing habitat features.

Many of these species have large range requirements—for example, bobcats may have home ranges that extend from 5 to 30 square miles (generally smaller for females and larger for males) while coyotes can have 4 to 15 square mile ranges—and so the Pfizer Sanford campus, which is less than half a square mile in area, comprises only a small part of their territories. To ensure that these animals are able to access their full habitat requirements, it is essential that the gap in the fence in the wetland area remain open. This small gap seems to currently create enough connectivity with the broader landscape, and so maintaining this access is critical.

We found a surprisingly high diversity of wildlife species using the small pond on the

Pfizer campus, but connectivity between the pond and the other natural forest areas could be improved. We suggest that increasing the connectivity between the pond and the other forest areas would make this water resource more accessible to even more species. This could be accomplished by increasing the size of the forest buffer around the pond, and allowing some of the connecting fields to either return to young forest through natural succession or be maintained as early successional shrubland/ meadows through infrequent dormant season mowing.

The high quantity of downed woody debris and standing dead trees (snags) is also valuable wildlife habitat feature on the Pfizer Sanford campus. While snags close to trails or parking lots should be felled for safety purposes, leaving these trees in the forests and wetlands is an important practice for supporting a healthy food web and nutrient cycling in the soil and vegetation. If trees need to be removed near trails for safety purposes, leaving them in the forest is not only simpler for maintenance, but will also allow for nutrients to recycle into the soil, and creates habitat for insects and amphibians, which in turn are food for birds and larger predators. Standing dead trees provide nesting habitat for raptors and other birds of prey, habitat for insects, and food for woodpeckers and other insect-eating animals.

In a similar vein, the Pfizer Sanford campus is also home to a diverse suite of plants. Maintaining a diversity of successional stages, as discussed above, will contribute to the conservation of both later successional plants as well as meadow species. As noted above, some of these mowed areas would provide better habitat and services if left to naturally regenerate, but it is important to maintain some open areas as well. Addressing some of the invasive species issues discussed in the section above will also support native plant diversity, which in turn supports wildlife diversity.

Wetland management

Current Pfizer Sanford campus management includes an annual wetland trash clean up day. We encourage the continued use of these community days to collect plastics and other trash that gets swept into the wetland from outside of the property. On our field days we found plastic bottles and other bits of pollution along the water ways, and so regular removal will certainly aid the health of this wetland system. We recommend exerting caution when working near the many standing dead trees in the wetland, but recommend leaving these snags standing as much as possible for the bird habitat that they provide.

Although removing the invasive Japanese stiltgrass from the wetland area is likely impossible, it might be feasible to include some invasive species management with the trash pick up days. If so, we recommend ignoring the stiltgrass and instead focusing on any invasive shrubs or trees such as the Bradford (Callery) pear, Chinese privet, or thorny olive.

However, there are several valuable native shrub species also colonizing the wetland, including elderberry, which are a valuable soft mast/food source for wildlife, and so if identification of natives compared to invasives is an issue, we recommend narrowing the focus to one or two easily identifiable species.

Beaver management

The pair of beavers now residing in the wetland pose a unique management consideration. As discussed in the wildlife section, beavers are ecosystem engineers that can dramatically alter their environments through the building of dams and resulting increase in water levels and flooding. The beavers on the Pfizer Sanford campus are currently building a dam in the stream channel. While beavers are notorious for causing flooding damage, the location of the dam is quite far from any Pfizer facilities, buildings, parking lots, or other build structures. While it is possible that the road might be affected, the distance from road and the incline in slope between the wetland and slope make it unlikely that the beaver dam would impact any Pfizer infrastructure. Beavers provide extremely valuable ecosystem services, and their presence on the property could be considered a benefit to the health of the wetland ecosystem.

However, we do recommend monitoring the beaver progress and dam location. Should the beaver activity appear to become an issue, the Beaver Management Assistance Program (BMAP) in North Carolina offers assistance on private and public properties. These specialists work to provide non-lethal solutions to beaver management for a small cost-share fee. For more information on the BMAP program, see this resource: https://www.ncwildlife.org/Portals/0/Learning/documents/Profiles/Mammals/BMAP-Obtaining-Services.pdf

Active restoration of the abandoned fill mound

Aside from the developed facilities and paved sections of the property, the abandoned fill mound is the most degraded area of the Pfizer Sanford campus and provides the fewest ecosystem services. This site shows significant soil degradation, which aligns with its origin as a spoils pile. The mound is surrounded by vegetation, which likely limits the impacts of soil erosion and water run-off from entering the water systems. Increasing the vegetative cover would provide greater erosion protection for the sparsely covered earth and also increase other ecosystem services. Unfortunately, relying on natural regeneration alone in this area will likely be an extremely long process due to the poor soil fertility. If a more active management approach is desired here, we would recommend planting native species to increase the vegetative cover and speed up successional processes. If active planting is selected, care should be taken to avoid invasive species. Furthermore, greater investment may be needed in preparing the site in order to help the planted vegetation survive. Some possible species could be native grasses, shrubs, or even trees, but again, care should be taken to choose species

that will be drought tolerant in these poor soils. A resource for some planting options is here: https://henderson.ces.ncsu.edu/2021/02/stabilizing-slopes/

Active restoration is a more costly management investment, and therefore at a minimum the landscaping crew should avoid mowing this area to prevent any further soil compaction or erosion and to allow existing grasses a greater chance to spread through a passive restoration approach.

SUMMARY OF RECOMMENDATIONS

1. Increase carbon sequestration, water services, and aesthetic noise barriers by allowing several fields to undergo natural forest succession through the cessation of mowing, especially in areas immediately bordering the fence or hidden from site.
2. Maintain early successional habitat in the remaining fields through dormant season (winter) mowing every one to three years.
3. Increase ecological integrity of natural areas through targeted invasive species management in the bamboo stand and in areas where Bradford pear is present. Shift landscaping to native species in order to prevent re-introduction of Bradford pear or the introduction of other invasives.
4. Maintain current wildlife habitat by ensuring landscape connectivity through the fence opening in the wetland.
5. Increase connectivity between the pond and the forest areas by allowing some connecting fields to return to either young forest or to early successional shrubland habitat.
6. Continue current wetland clean-up efforts, with the option to expand these community events into invasive species management.
7. Monitor the beaver dam and consult a specialist if needed for a nonlethal solution that maintains ecological integrity.
8. Continue to maintain a mosaic of vegetation and successional stages to maximize biodiversity and ecological resilience on the property as a whole.
9. Work to restore the abandoned fill mound through either passive or active restoration efforts.

Landscape Management Assessment

Pfizer has committed to invest in no/low carbon technologies at their global campuses and in programs that enable sourcing of clean energy from renewable sources as part of its goal of Net Zero by 2040. In the past 20 years, Pfizer has been building on efforts to reduce greenhouse gas emissions by 95% and value chain emissions by 90% by 2040. To achieve this, Pfizer has taken strong steps to accelerate their transition away from fossil fuels throughout their value chain.[1]

"Constraining the climate crisis requires urgent action to reduce anthropogenic emissions while simultaneously removing carbon dioxide from the atmosphere."[2]

Pfizer's commitment tackles supply chain emissions but does not address the carbon footprint of landscape management practices on its campus in Sanford, North Carolina. With its net zero goals, Pfizer has an opportunity to harness the land-based carbon storage potential.

In tune with Pfizer's commitment towards achieving the Paris Agreement 2 °C goal, Pfizer's EHS department requested that our team provide a Landscape Management Assessment toward a better understanding of stewardship of the landscape on the Pfizer Campus.

PUBLIC HEALTH

ECOLOGICAL HEALTH

COST REDUCTION

PFIZER GOALS

WHAT IS A LANDSCAPE MANAGEMENT ASSESSMENT?

Landscape management is the process of managing the use and development of land resources, which includes but is not limited to the care and maintenance of turf and ornamental plantings. The Initiative for Community Growth and Development at North Carolina State University has been contracted to specifically assess the care and maintenance practices of Ruppert Landscape, the landscape maintenance company hired by Pfizer at the Sanford campus. This includes an evaluation of the equipment used for landscape maintenance practices such as the type of equipment and number of hours spent by Ruppert in mowing, edging, and blowing leaves.

In this Landscape Management Assessment, we evaluate the environmental impact of landscape management practices such as irrigation, fertilization, insecticide, and herbicide use, as well as plant selection on the Pfizer Campus. This report evaluates the chemical use and the carbon footprint of landscape management practices on the Pfizer campus.

THE LANDSCAPE MANAGEMENT TEAM

In October 2022, Pfizer terminated its landscape management contract with Brightview Landscape and signed a new contract with Ruppert Landscape, a firm based in Laytonsville,

1 https://www.pfizer.com/news/articles/net_zero_by_2040_how_pfizer_is_fighting_climate_change_with_ambitious_science_based_goals
2 Walker WS, Gorelik SR, Cook-Patton SC, Baccini A, Farina MK, Solvik KK, Ellis PW, Sanderman J, Houghton RA, Leavitt SM, Schwalm CR, Griscom BW. The global potential for increased storage of carbon on land. Proc Natl Acad Sci U S A. 2022 Jun 7;119(23):e2111312119. doi: 10.1073/pnas.2111312119.

Maryland with offices in Garner and Raleigh with a team of 117 employees. As part of Ruppert Landscape's green initiatives they've produced Educational Sustainability Modules and their construction branch is focused on Green Infrastructure. The research team at North Carolina State University interviewed Mr. William Charping, Area Manager, to better understand current practices and maintenance strategies at Ruppert.

Five Ruppert Landscape team members are on the Pfizer Campus five days a week. For the purpose of efficiency, The Ruppert Landscape team uses the app GoiLawn[1] to script its daily operations on the site.

LANDSCAPE MAINTENANCE AND EQUIPMENT

Approximately 35 gallons of gasoline is used to power the equipment each week, with the riding mower using the most fuel. All landscape maintenance equipment used on site is stored on the Pfizer Campus, which minimizes the number of miles the crew would have to travel to access equipment and reduces their carbon footprint.

Mowing

47 acres of turf are mowed on the Pfizer campus per week. During the period between April and August, turf on the Pfizer campus is mowed 4 times a month with 1 full cutting a week. One Exmark zero-turn 72-inch (19015 Watts, Fuel type = Gas) riding mower and three Exmark Turf TracerX series (17284 Watts, Fuel Type = Gas) walk-behind mowers are used by the Ruppert Landscape team on the Pfizer campus. The Ruppert crew mows the grounds 8 hours per day (40 hours per week). The areas mowed are referenced in (Figure 1). This figure and calculations exclude the areas managed by the landscape crew west of the node at Oak Park Road.

Leaf Blowing

Every day, and for 1 hour a day, 1 member of the Ruppert Landscape team will use a leaf blower to clear sidewalks and any other walking paths of debris such as leaves to ensure the safety of pedestrians on the campus. Equipment on campus includes one Stihl BGA 57 electric leaf blower (59 db(A)), and two gas-powered ECHO Backpack Blower 770 (3104 Watts, 2-stroke 63.3 cc) Engine Displacement, 234 mph Max. Air Speed, 765 cfm Max. Air Flow, 73 db(A)).

Edging

During peak growing season (March to May), a string trimmer is used daily for 1.5-2 hours at most to keep edges in order using an Echo SRM-2620T Line Trimmer (1243 Watts, High Torque, 25.4 cc professional-grade, 2-stroke engine).

1 GoiLawn combines aerial imagery, precision measuring and design tools, pricing and labor rate data, property data, customer data, and automated data insights in one easy-to-use application. https://goilawn.com/

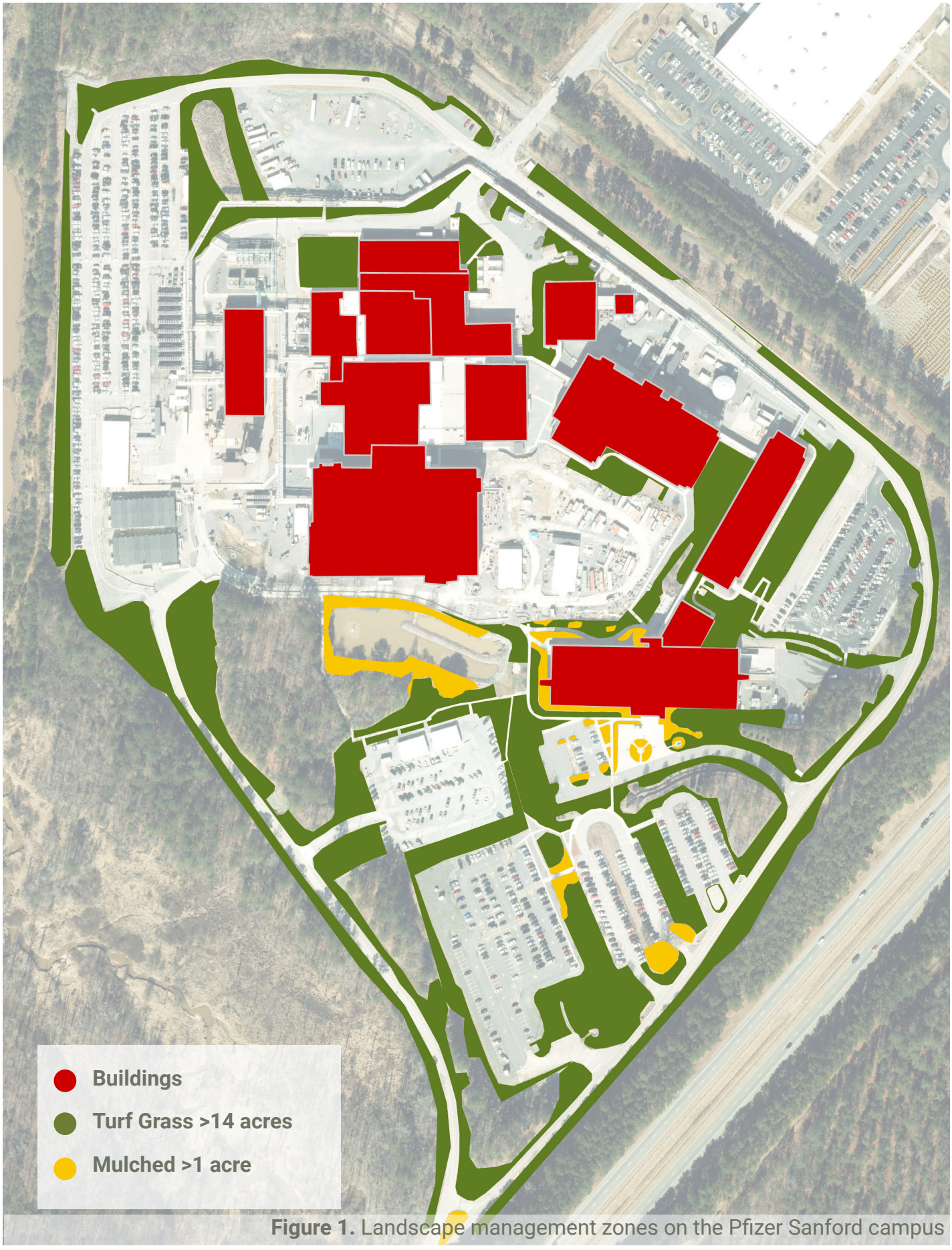


Figure 1. Landscape management zones on the Pfizer Sanford campus

* Areas estimated using Google Earth and exclude turf areas on the main drive

Summary of the environmental impact of equipment used on campus

According to the California Air Resources Board[1], weekly leaf-blowing practices on the Pfizer campus produce emissions equal to the emissions produced while driving 5,500 miles with a new compact car, and weekly mowing practices on the Pfizer campus produce emissions equal to the emissions produced while driving 60,000 miles with a new compact car (Figure 2.).

Using the Pathfinder Carbon Calculator (Figure 3.), the total operation impact on the Pfizer Campus is estimated at 370,375 kg CO2-eq emitted. On the other hand, approximately 25,844,317 kg CO2-eq is sequestered by the forested areas on the Pfizer Campus. The Pfizer EHS department reported that the six-year average greenhouse gas emissions of Pfizer's building operations is 24,591,000 kg GHG (Figure 4.).

5 hrs/week = Emissions while driving 5,500 miles

1 https://ww2.arb.ca.gov/resources/fact-sheets/sore-small-engine-fact-sheet

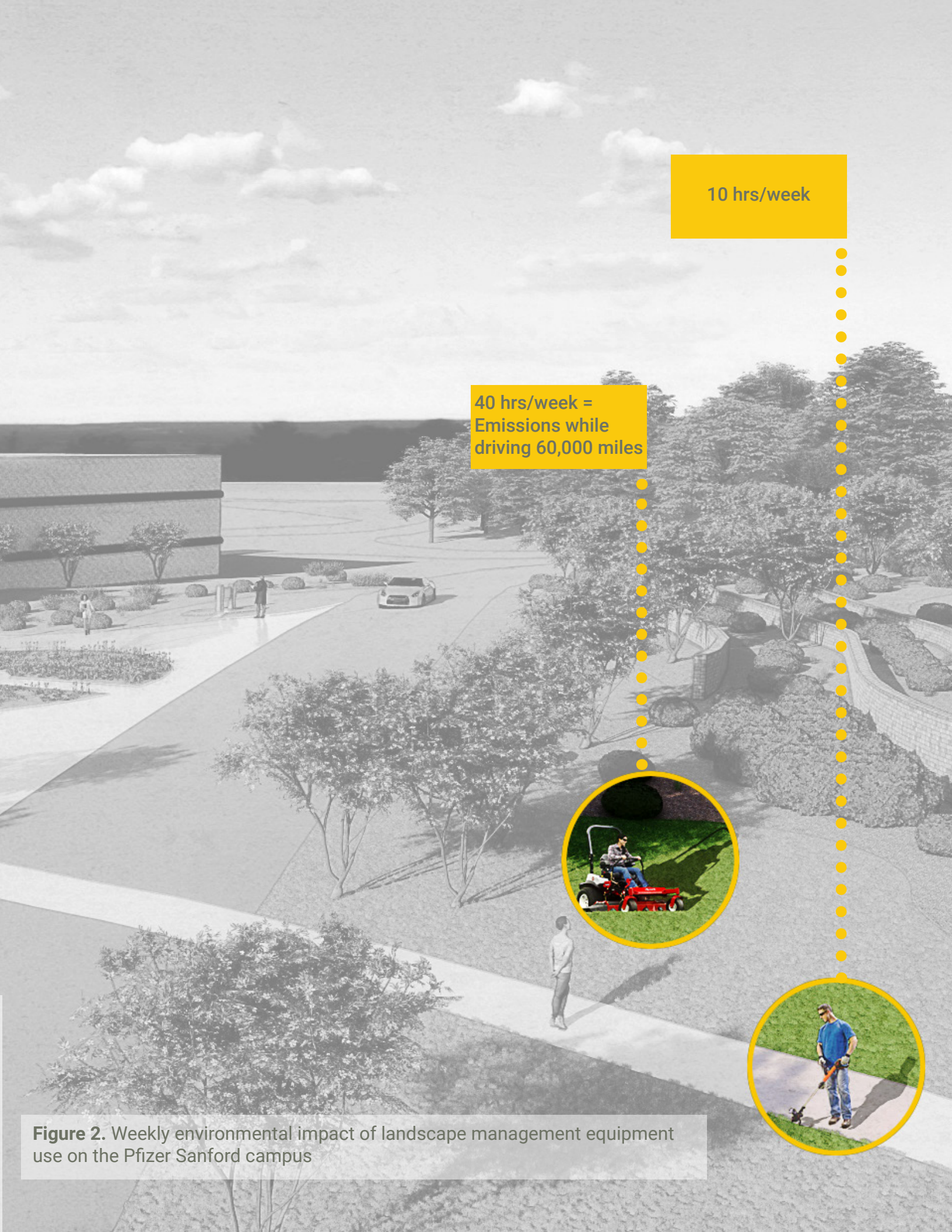


Figure 2. Weekly environmental impact of landscape management equipment use on the Pfizer Sanford campus

gasoline-powered passenger vehicles driven / year	39.5	35.9	6	1.1
miles driven by an average gasoline-powered passenger vehicle	454,925	413,503	68,747	12,300
homes' electricity use for one year	34.5	31.4	5.2	0.934

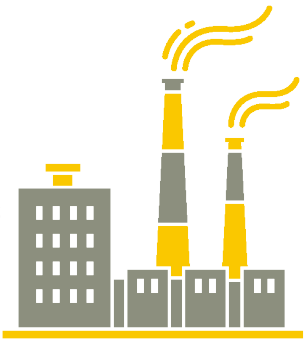
THIS IS EQUIVALENT TO CARBON SEQUESTERED BY:

acres of U.S. forests in one year	212	192	32	5.7

Figure 3. Yearly total operation impact of landscape maintenance equipment on the Pfizer Sanford Campus with contextual comparisons.

https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator#results
https://app.climatepositivedesign.com/

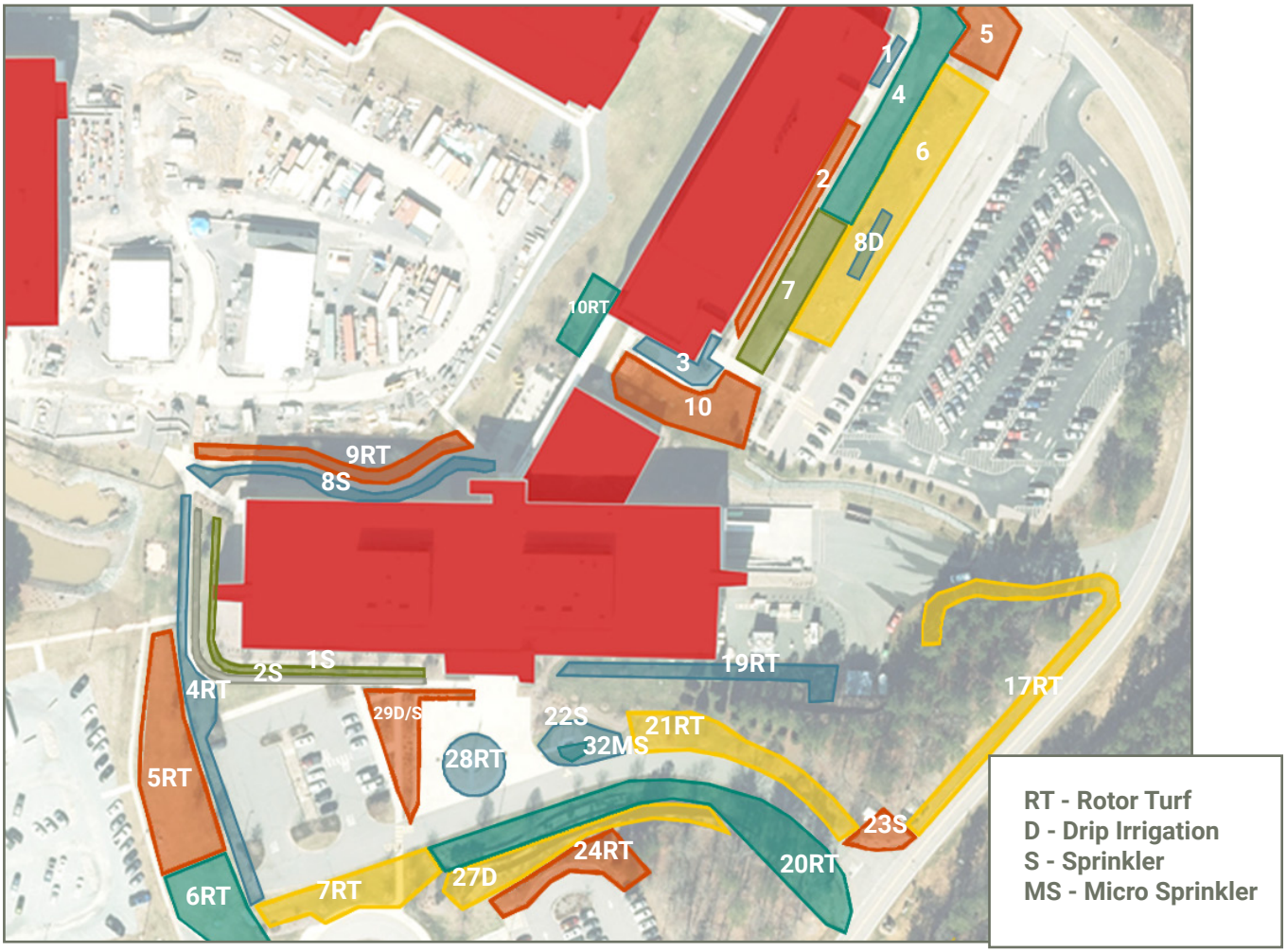
6 Year Average Green House Gas
Emissions of Pfizer's Building Operations
= 24,591,000 kg GHG



Yearly Total Carbon Sequestration
of The Pfizer Forest
= 25,844,317 kg CO_2-eq

Figure 4. Comparison between the estimated carbon sequestration of the forested areas and manufacturing operations green house gas emissions of the Pfizer Sanford campus

https://app.climatepositivedesign.com/



- Notes: Need access to enter the building to get to both the controllers and back flows. The back flows are not tied together.
- Controller location(s): Controllers are located inside the building in 2 different locations.
- Back flow location(s): Back flows are located with the controllers.
- Emergency shut off location(s): Ball valves on the back flows.
- DC remote valve location(s): None

Figure 5. Irrigation zone map (10.14.22) With permission from Mckenna Rowles at Ruppert Landscape

IRRIGATION - WATER USE

Two-thirds of the 40 acres (Figure 5.) maintained by Ruppert Landscape are irrigated. The mulched areas, which are sparsely planted with ornamental trees and shrubs, are drip irrigated once soil moisture levels are low.

In May 2023, Ruppert Landscape installed a smart irrigation system[1] adjacent to buildings 114 and 116. Data has not been collected since its installation and due to limitations in the Sanford metering and water billing system, it might be difficult to assess the financial and environmental benefits of the system. Water usage indoors in Pfizer manufacturing operations far exceeds what is used in the landscape.

Since the system's installation, Pfizer and Ruppert were able to identify an ongoing water leak on the campus and have been able to fix the damaged pipe.

1 The WeatherTRAK® ET Pro3® system can tune irrigation to a unique landscape and site characteristics, the system's controller reduces water waste by only irrigating when it is necessary – saving time, resources, and money. https://www.hydropoint.com/weathertrak/products/weathertrak-et-pro3/

PLANT, SOIL HEALTH, AND FERTILIZER USE

Ruppert Landscape aims to conduct one soil analysis, 6” inches into the ground, every 3 years. A pH test is set to be performed regularly.

Two soil samples from lawn areas were tested by the NCDA & CS Agronomic Division in July 2023, using the Mehlich 3 Soil Test Method. This test is calculated per 1000 sq ft and is based only on the need of the vegetation.

Soil pH on the Pfizer is within the recommended limits. Most ornamental plants and turf grass grow well in a pH range of 6.0 to 7.0.

Phosphorus (P) and Potassium (K) levels are significantly above the recommended levels and are indicative of over-fertilization prior to the employment of the Ruppert Landscape team. An overabundance of Phosphorus (P) can cause chlorosis, stunting, and yellow or bleached foliage. An overabundance of Potassium (K) is sometimes indicative of compacted soil and can cause interveinal chlorosis (leaf tissues turning yellow between the veins), and brownish spots. Nitrogen-only fertilizer (21-0-0) was recommended at a rate of 5 lbs. The Ruppert Landscape Team reports that twice a year, in spring and summer, Encapsulated Urea 18-0-2 (N-P-K) is applied at a rate of ¾ lbs/1000 sq ft to all areas, as phosphorus application is not needed after the initial planting and application of fertilizer.

Humic matter (HM) is the largest constituent of organic matter in the soil. The results indicate that %HM is well within the recommended range (less than 0.04 -10%). %HM is inversely correlated to the soil weight/volume (W/V) which is used to determine the soil class. Soils high in sand have high W/V, while soils high in organic matter have low W/V.

It is relevant to note that compost is produced by the Ruppert Branch in Raleigh using annual plant residues, and their team on the Pfizer Campus has indicated an interest in using compost. Environmental factors such as rainfall, moisture, and temperature impact organic matter content and it is difficult to increase organic matter in sandy soil.

The results show two types of soil: sandy soil and clay-rich soil. Soils with low capacity (CEC)

	Area	pH	P-I	K-I	HM%	W/V (g/cm3)	CEC (meq/100 cm3)		Mn-I	Zn-I	Cu-I	S-I
TURF	116	6.2	103	59	0.32	1.09	SANDY	6.4	236	202	82	38
	114	6.4	118	79	0.32	1.11		8.5	269	310	98	36
FLOWERS	Front	6.2	595	94	0.41	0.61	CLAY	17	192	916	230	65
	116	6.1	468	102	0.51	0.73		14.7	286	663	179	54
	Pfizer Sign	6.3	323	82	0.36	0.65		14.1	194	507	180	37
	116 Walkway	6.2	142	57	0.41	0.73		14.2	236	239	111	27
	Main Drive	7	202	73	0.46	0.76		16.6	430	212	155	26

EXTREMELY HIGH HIGH

Table1. NCDA & CS agronomic division Mehlich 3 soil test on the Pfizer Sanford campus (July, 2023)

such as sandy soils, hold less water than soils with higher CEC such as clay soils. Sandy soils need quick but regular irrigation, while clay-rich soils need slow irrigation less often. Furthermore, soils with high CEC retain more nutrients than low-CEC soils. No lime application was recommended as indicated by the soil test report. Mineral content indices in the soil of the Pfizer landscape are well within what is recommended.[1]

PEST MANAGEMENT - PESTICIDE USE

Pest management on the campus is limited to chemical control but only when the number of pests or level of damage is high enough that pesticide is needed - when the action threshold is reached. An integrated pest management approach that employs biological control, habitat manipulation, change of cultural practices, and uses resistant plant varieties, is an alternative that would reduce chemical use on campus.

In the past year since Ruppert Landscape was contracted by Pfizer, pesticide use has been limited to:

Horticultural Oils- These are non-toxic petroleum or plant-based oils that are water soluble with the addition of an emulsifier. These oils kill soft-bodied insects such as scales, mites, and aphids by suffocation, plugging up the insect's breathing spiracles. Technically, these oils are considered a physical method of control and not a chemical one and need to be sprayed directly on the insect to be effective.

Insecticidal Soaps- are non-toxic insecticides made of Potassium salts of fatty acids which cause soft-bodied insects to dehydrate by physically breaking down the insect's protective cuticle. Insecticidal soaps break down in the soil within a week.

Acelepryn®- is a chlorantraniliprole which is in a class of pesticides called anthranilic diamides used on the campus to control grubs of beetles in turf and caterpillars on flowers and ornamental shrubs and trees. This pesticide is reported to be not harmful to pollinators. The manufacturer recommends a rate of application of 1.15 to 2.3 lbs. of product per 1,000 sq. ft.

Zylam®- a liquid systemic insecticide, Dinotefuran, which is in a class of pesticides called neonicotinoid, is a systemic insecticide that is injected evenly around the trunk no more than 12 inches out from the base and is absorbed internally by the trees. It is used on the campus to control scale infestations.

WEED MANAGEMENT - HERBICIDE USE

Herbicides are only applied in the main focal areas, at the main drive, applied twice a year on about 10 total acres.

Specticle® G- is a selective, preemergence alkylazine herbicide. At Pfizer, it is applied at a rate of 150 lbs/Acre which is below the recommended application rate specified by the manufacturer per year. This herbicide controls weeds by inhibiting the root development of weeds that occur in the mulched areas.

Scythe®- is a non-selective contact herbicide-chemicals that are designed to kill or damage all plants that it comes into contact with. This

1 For more information please visit: https://content.ces.ncsu.edu/a-gardeners-guide-to-soil-testing

herbicide is applied at a rate of 3.5 lbs/Acre.

Tenacity®- is a selective pre-emergence and post-emergence herbicide used for the control of weeds in turfgrasses. The active ingredient, Mesotrione, inhibits a plant enzyme called 4-Hydroxyphenylpyruvate dioxygenase (HPPD) that breaks down the amino acid tyrosine into molecules that are then used by plants to create other molecules that plants need. The typical application rate is between 4-8 fluid ounces per 30 gallons of water per acre. This herbicide is used as a pre-emergence herbicide on the Pfizer campus.

Prodiamine 65 WDG- Pre-Emergent Herbicide is also applied at a rate of 5.2g mixed in water per 1000 sq ft in early spring and 13g per 1000 sq ft in early fall but is getting phased out due to herbicide resistance.

SUMMARY OF CHEMICAL USE

Although chemical pest management and weed management practices on the Pfizer campus are well within the manufacturers' recommendations, a consultation by an NC Extension Service Specialist could further reduce the chemical footprint on the campus (Figure 6.).

PLANT SELECTION

Although annuals are planted on the Pfizer campus, mostly in planters, the Ruppert Landscape team has expressed strong interest in using the NC State Extension Service native plant lists to guide their selection of plants cultivated in the Pfizer landscape. Ruppert Landscape operates its own nursery for trees and shrubs and relies on a local farm, Weigel Farms[1] in Gibsonville, NC for its annuals and perennials.

The overall viewpoint of the Ruppert Landscape team is to support pollinators and increase the number of native plants on the campus. Some of the native plants already on campus include Butterfly Bush, Cone Flower, and Rudbeckia.

Currently, the shrub and tree areas are mulched using pine mulch, but the intention was expressed to switch to walnut-colored designer mulch.

The three types of turf on the grounds are Bermudagrass, St. Augustine, and Zoysiagrass, which are perennial warm-season grasses. In the cooler weather in late fall and winter, these grasses go dormant, turn brown, and won't green up until warmer weather returns in spring. This dormancy conserves energy and water.

To assess the plant variety on the campus; whether native, non-native, or invasive, our team requested a list of ornamental plants present in the vicinity of buildings and parking lots on the Pfizer Campus. Unfortunately, a list was not available, although the Ruppert Landscape team expressed interest in using a plant list developed by Ms. Debbie Roos[2] who is the Extension Agent of Agriculture, Sustainable and Organic Production in the Chatham County Center. The list includes plants that are native to NC, to the US, and the Southwest, as well as plants that are exotic but non-invasive.

1 https://www.manta.com/c/mmlqgd2/weigel-farms
2 https://growingsmallfarms.ces.ncsu.edu/wp-content/uploads/2023/04/2023-Plant-List-for-Web.pdf?fwd=no

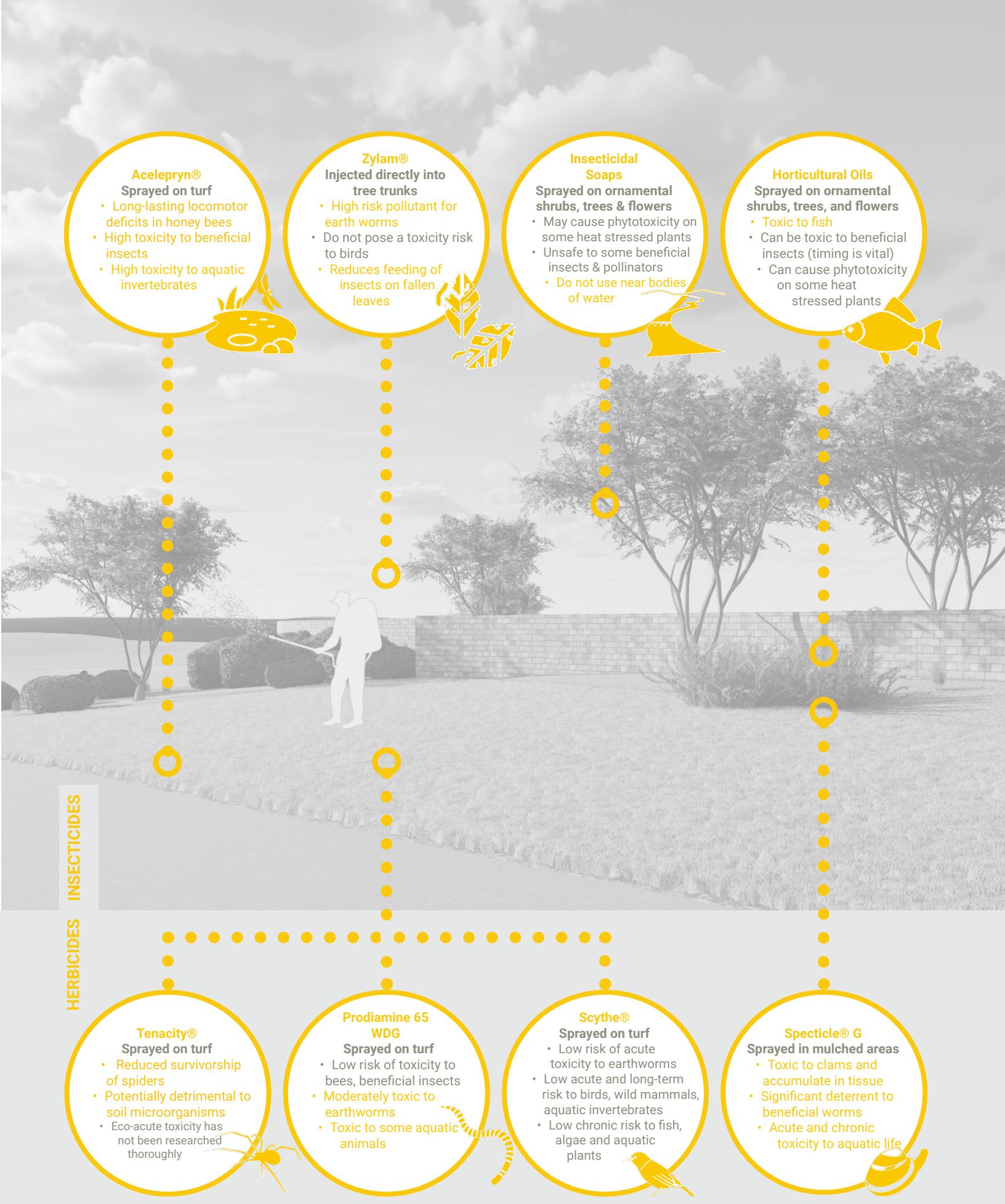


Figure 6. Environmental impact of chemical use on the Pfizer Sanford campus

CONCLUSION AND RECOMMENDATIONS

Corporate campuses across the United States are challenging the status quo of lawn-dominant campus design, reducing their carbon footprint, and increasing the carbon sequestration capabilities of the campus landscape. Interest in sustainable landscape design has increased on corporate campuses, especially when the positive impacts of an engaging landscape are evident in employee health and productivity.

Edwards Lifesciences, an industry-leading medical device manufacturer's redesign of its Irvine, California campus, added A 1,200-stall parking structure, which includes a 4,500-square-foot green wall; the largest of its kind in North America. The parking garage's "green wall created a biophilic backdrop for the site and photovoltaic panels on the canopy system that supplies energy to the growing campus". New outdoor spaces combine a palette of native, drought-tolerant plant species and a stormwater management system that treats 100% of stormwater runoff from buildings, roads, parking lots, and paths across the campus.[1]

Seeking to create a sustainable campus that connects its employees to nature, the Charles Schwab Corporate Campus is an example of a "campus within a park". Its 50 acres in Austin, Texas were converted into a landscape that boasts innovative water management and science-based planting design.[2]

These two examples also illustrate a shift in how landscapes are maintained by landscape crews. While typical corporate campuses are regularly mechanically and chemically managed to produce a certain aesthetic with no regard to the environmental impacts of these practices, a sustainable approach can aid corporations in reaching their net zero goals.

During conversations with the Ruppert Landscape Area Manager, Mr. William Charping, our team realized that the company is leaning towards more sustainable practices. Our findings indicate that lawn management is the biggest contributor to Carbon Dioxide emissions in the Pfizer landscape. A reduction in lawn acreage would significantly reduce the negative impacts of irrigation, equipment, and chemical use. Lawns provide a space for activity and congregation, but what we've observed at the Pfizer campus is an unmethodical spread of lawns as space fillers.

Eliminating portions of the lawn and replacing it with nature-based design solutions, including green infrastructure, would improve the carbon sequestration capability of the campus, improve the aesthetics, and increase biodiversity on the site.

1 https://lpadesignstudios.com/catalyst/the-sustainable-corporate-campus
2 https://www.designworkshop.com/projects/charles-schwab.html

REFERENCES

Insecticides

Acelepryn® (Chlorantraniliprole)

Nakanishi, K., Usio, N., Yokomizo, H., Takashima, T., & Hayashi, T. I. (2022). Chlorantraniliprole application differentially affects adult emergence of sympetrum dragonflies in rice paddy fields. Paddy and Water Environment, 20(1), 177-183. https://doi.org/10.1007/s10333-021-00880-5

Kadala, A., Charreton, M., Charnet, P., & Collet, C. (2019). Honey bees long-lasting locomotor deficits after exposure to the diamide chlorantraniliprole are accompanied by brain and muscular calcium channels alterations. Scientific Reports, 9(1), 2153. https://doi.org/10.1038/s41598-019-39193-3

SDS: https://assets.syngenta-us.com/pdf/msds/Acelepryn_28980_en_SDS.pdf

Zylam® (Dinotefuran)

Liu, T., Wang, X., Xu, J., You, X., Chen, D., Wang, F., & Li, Y. (2017). Biochemical and genetic toxicity of dinotefuran on earthworms (eisenia fetida). Chemosphere (Oxford), 176, 156-164. https://doi.org/10.1016/j.chemosphere.2017.02.113

Hahn, J. et al. (2011). Frequently Asked Questions Regarding Potential Side Effects of Systemic Insecticides Used To Control Emerald Ash Borer. http://emeraldashborer.info/documents/Potential_Side_Effects_of_EAB_Insecticides_FAQ.pdf

SDS https://www.domyown.com/msds/Zylam_Liquid_Systemic_Insecticide_SDS_2020.pdf

Insecticidal Soaps (Potassium salt of fatty acids)

Mizell, R. (1991). Phytotoxicity of sunspray ultra-fine spray oil and safer insecticidal concentrate soap on selected ornamental plants in summer in north florida and south georgia. Arboriculture & Urban Forestry, 17(8), 208-210. https://doi.org/10.48044/jauf.1991.050

Hall, D. G., & Richardson, M. L. (2013). Toxicity of insecticidal soaps to the asian citrus psyllid and two of its natural enemies. Journal of Applied Entomology (1986), 137(5), 347-354. https://doi.org/10.1111/j.1439-0418.2012.01749.x

Pundt L. Uconn Extension Services Fact Sheet. https://homegarden.cahnr.uconn.edu/wp-content/uploads/sites/3479/2022/08/Insecticidal-Soap-1.pdf

Horticultural Oils (Petroleum-based products, plant-based horticultural oils)

Penn State Fact Sheet (2003): Horticultural Oils An alternative to chemicals. http://ento.psu.edu

Kreuser, W. C., & Rossi, F. S. (2014). The horticultural spray oil, civitas™, causes chronic phytotoxicity on cool-season golf turf. Hortscience, 49(9), 1217-1224. https://doi.org/10.21273/HORTSCI.49.9.1217

Baudoin, A., McDonald, S. F., & Wolf, T. K. (2006). Factors affecting reductions in photosynthesis caused by applying horticultural oil to grapevine leaves. Hortscience, 41(2), 346-351. https://doi.org/10.21273/hortsci.41.2.346

HERBICIDES

Tenacity® (Mesotrione)

Ward, W., Heinly, B., Preston, J., Johnson, C., Sweger, A., & Persons, M. (2022). Lethal and sublethal effects of five common herbicides on the wolf spider, pardosa milvina (araneae: Lycosidae). Ecotoxicology (London), 31(10), 1565-1582. https://doi.org/10.1007/s10646-022-02610-x

Pose-Juan, E., Sánchez-Martín, M. J., Herrero-Hernández, E., & Rodríguez-Cruz, M. S. (2015). Application of mesotrione at different doses in an amended soil: Dissipation and effect on the soil microbial biomass and activity. The Science of the Total Environment, 536, 31-38. https://doi.org/10.1016/j.scitotenv.2015.07.039

SDS
https://www.cdms.net/ldat/mp8D9000.pdf

Prodiamine 65 WDG (Prodiamine)

National Pesticide Information Center Fact Sheet
http://npic.orst.edu/factsheets/prodiamine.html#:~:text=Prodiamine%20in%20Brief&text=It%20breaks%20down%20slowly%20in,toxic%20to%20some%20aquatic%20animals.

SDS
https://s3-us-west-1.amazonaws.com/agrian-cg-fs1-production/pdfs/PrimeraOne_Prodiamine_65WDG_MSDS.pdf

Scythe® (Pelargonic Acid)

Alvarez, F., Arena, M., Auteri, D., Borroto, J., Brancato, A., Carrasco Cabrera, L., Castoldi, A. F., Chiusolo, A., Colagiorgi, A., Colas, M., Crivellente, F., De Lentdecker, C., Egsmose, M., Fait, G., Gouliarmou, V., Ferilli, F., Greco, L., Ippolito, A., Istace, F., . . . European Food Safety Authority (EFSA). (2021). Peer review of the pesticide risk assessment of the active substance pelargonic acid (nonanoic acid). EFSA Journal, 19(8), e06813-n/a. https://doi.org/10.2903/j.efsa.2021.6813

SDS
https://www.gowanco.com/sites/default/files/gowanco_com/_attachments/product/resource/sds/sd549_-_scythe_herbicide_us_110419_0.pdf

Specticle® G (Indaziflam)

Schedenffeldt, B. F., Monquero, P. A., da Silva, R. O., & Siqueira, B. B. R. Evaluation of Clomazone, Indaziflam, and Sulfentrazone Toxicity to Eisenia Andrei (Bouché, 1972) in Oxisols. Indaziflam, and Sulfentrazone Toxicity to Eisenia Andrei (Bouché, 1972) in Oxisols.

Tissot, A. G., Granek, E. F., Thompson, A. W.,

Hladik, M. L., Moran, P. W., & Scully-Engelmeyer, K. (2022). The silence of the clams: Forestry registered pesticides as multiple stressors on soft-shell clams. The Science of the Total Environment, 819, 152053-152053. https://doi.org/10.1016/j.scitotenv.2021.152053

SDS
https://gilbasolutions.com/wp-content/uploads/2022/03/Specticle%C2%AE-Herbicide-SDS-GHS-0616-1.pdf

ICONS FROM THE NOUN PROJECT

Page 77 Icons:
Edited Pfizer: noun-carbon-cycle-4441716
Cost Reduction: noun-reduction-5928948
Public Health: noun-public-health-6013225
Ecological Health: noun-ecosystem-5832519 and noun-public-health-6013225

Page 4 Icons:
Car edited: Cars: noun-cars-4303699
Push Mower: noun-mower-3999371
Leaf Blower: noun-leaf-blower-4946419

Page 80 Icons:
Leaf Blower: noun-leaf-blower-4946419
Ride on Mower: noun-ride-on-lawnmower-5742029
Edger: noun-lawn-edger-1974981
Push Mower: noun-mower-3999371
Car sideview: noun-car-216910
Forest: noun-forest-4288884
Cars: noun-cars-4303699
Energy House: noun-energy-house-5281445

Page 77 Icon:
Facility emissions: noun-factory-1437617

Page 87 Icons:
Bird: noun-bird-4208372
Earthworm: noun-earthworm-5048637
Caterpillars: noun-caterpillars-727965
Dragonfly: noun-dragonfly-6217331
Leaves: noun-leaves-6280754
Fish: noun-fish-1007308
Spider: noun-spider-205410
Pond: noun-pond-4968194
River: noun-river-4901830

Action Items, Current BMPs + Plants of Interest

ACTION ITEM LIST

1. **Remove key invasive species: Bradford pear (pg. 63), bamboo (pg. 20; pg. 62), Chinese and glossy privet**
   (Pg. 28 for section on invasives, pg. 62-63 for recommendations)

2. **Formalize plan to transition selected fields to young forests through natural succession following the cessation of mowing and invasive species management**
   (Pgs. 25-26 for section on succession; pg. 64 for recommendations.)

3. **Formalize plan for seasonal winter mowing in selected fields every one-three years to create meadow habitats**
   (Pg. 65)

4. **Formalize plan to plant only native or known non-invasive ornamental species in landscaping**
   (Pg. 63 for discussion of Bradford pear)

5. **Formalize wildlife connectivity plan, including maintaining the open fence in the wetland area**
   (Pg. 65 for recommendations)

6. **Align on beaver management plan**
   (Pg. 36 for details on beaver, pg. 67 for recommendations)

7. **Plan active restoration of abandoned fill mound site.**
   (Pg. 67 for recommendations)

8. **Lawn**

   a. Eliminating portions of the lawn and replacing it with nature-based design solutions, including green infrastructure, would improve the carbon sequestration capability of the campus, improve the aesthetics, and increase biodiversity on the site. The maximum acreage of lawn space needed can be determined by assessing use and activity.

   b. Replacing turf along roadsides with native grasses and other native plants will provide significant ecosystem services such as carbon sequestration, and will not require a high carbon footprint maintenance regimen.

   c. Replacing turf and mulched areas in parking lot islands with stormwater control devices such as vegetated bioretention cells (rain gardens) will mitigate the impacts of runoff from the parking lot. Page 9 of the Rain Garden Manual specifies a list of species suited for rain gardens: https://www.bae.ncsu.edu/workshops-conferences/wp-content/uploads/sites/3/2021/09/Rain-Garden-Manual-2018_Plant-List-Updated-2021.pdf

   Below is a suggested list of urban trees that can withstand the harsh conditions in a parking lot. https://ncforestservice.gov/Urban/pdf/NCStreetTreeSuggestions.pdf Please contact Mitch Woodward

(mdwoodwa@ncsu.edu), Area Specialized Agent, Watersheds and Water Quality for more information on planting in bioretention cells.

9. **Leaf Blowers** (pages 72-76)

Reducing the daily use of leaf blowers and replacing all gas-operated leaf blowers with battery-operated alternatives can significantly reduce the greenhouse gas emissions in the campus landscape. Increasing the number of evergreen trees and shrubs can also reduce the need for blowing leaves on the sidewalks of the campus

10. **Plants** (page 81)

a. Avoid annuals and other plants that provide no ecosystem services, and consider plant communities when selecting plants. https://gardening.ces.ncsu.edu/gardening-plants/native-plant-resources/

b. Increasing the number of plants that attract parasitoids can reduce the need for insecticides on the campus. Plants such as native asters, yarrows, and goldenrods provide excellent biocontrol services.

c. Reducing the need for mulch by planting ground covers that increase the carbon sequestration potential of the campus, and reduce the carbon emissions resulting from the periodic transport of mulch to the campus. https://chatham.ces.ncsu.edu/groundcovers

d. Increasing the number of native evergreens will attract pollinators and reduce the need for leaf blowing on sidewalks. Ex: Hypericum frondosum, Ilex glabra, Vaccinium arboreum. https://plants.ces.ncsu.edu/find_a_plant/

e. Delaying the deadheading and harvesting of plants until early spring supports biodiversity in the campus landscape. By allowing plants to set seed and leaving seed heads and stems in place during the winter, you provide birds with food, and enable insect eggs and pupae to survive in the landscape. The winter plant structure also provides shelter and nesting sites for birds and wildlife.

11. **Chemical Use** (pages 79-81)

a. Continue soil testing and adjust fertilizer use accordingly. Although the rule of thumb is to test the soil every 3 years, we recommended annual testing to ensure that current high phosphorus levels in the soil diminish and determine the correct fertilizer formulation needed.

b. Please contact Lee county Extension Services for guidance on pest control of turf, and ornamental trees and shrubs. The agent below will be able to guide the maintenance crew on cultural control strategies such as

pruning, and biocontrol strategies that can reduce insecticide use and the chemical pressure on the campus landscape.
Amanda Wilkins (amwilkin@ncsu.edu), N.C. Cooperative Extension, Lee County Extension Agent, Agriculture - Horticulture and Colby Lambert (colby_lambert@ncsu.edu) Area Specialized Agent, Forestry

c. Reducing the acreage of the lawn will reduce the use of herbicides.

d. Encouraging the landscape management crew to increase the production and use of compost in planting beds would reduce the cost and the ecological impact of applying chemical fertilizers and benefit soil microorganisms and health.

12. Water Use (page 78)

a. Keeping records of water use and comparing usage over time before and after any recommendations (reducing lawn, adding groundcovers) have been implemented to get a better understanding of the potential of landscape management strategies.

b. Consider using drip irrigation in all ornamental plant beds.

13. The Human Factor

Research shows that corporate campuses that provide employees with sustainably designed spaces and engaging opportunities for physical activity have increased employee productivity and retention.
A campus that is designed so that landscape management practices do not negatively impact the human experience would instead encourage employees to increase time spent outdoors, and improve human health and employee satisfaction and productivity.

Excessive and daily use of landscape maintenance equipment degrades the human experience by negatively impacting the soundscape and air quality in the landscape.

Research shows that air and noise pollution directly impact human health and ecological health.

Amendments to the campus landscape maintenance plan would significantly reduce these impacts on human and ecological health.

Improving the trails and adding wayfinding signage and environmental education opportunities such as hands-on activities and citizen science projects would further engage employees in the landscape and what it offers in relation to human health.

CURRENT BMPs

1. **Wetland clean-up days maintain ecological integrity of key wildlife habitat and ecosystem services.**
   (Wetland description on pg. 17)

2. **Open fence at wetland creates wildlife habitat connectivity for larger mammals.**
   (Wetland connectivity on pg. 31 and 65)

3. **Forest buffer around the pond protects water quality and improves wildlife habitat valueof the water feature.**
   (Pg 20-21)

4. **Presence of multiple successional stages and ecosystem types (mowed fields, open shrubby meadows, young pine forest, mature hardwood forests, and wetland) maintains high biodiversity of flora and fauna and greater resilience to disturbance.**
   (Pgs 9 for description of vegetation types, pg. 11 for figure of vegetation types, pg.64 for recommendations.)

5. **Presence of mature upland and bottomland forest provides complex structure for wildlife habitat, including dead wood snags and logs and a variety of hard and soft mast food sources.**
   (Pg. 10-16)

PLANTS OF INTEREST FACTSHEET

Muscadine grape, Muscadinia rotundifolia (or Vitis rotundifolia)

On the Sanford Pfizer campus, muscadine grape vines can be found in all forested areas, early successional plant communities and the wetland. It is hardy and will grow in full sun to part shade. The vines grow on trees for support, but where options are limited they will grow on smaller shrubs.

Muscadine grape is the state fruit of North Carolina. Another common name for muscadine grape is Scuppernong grape, after the Scuppernong River in eastern North Carolina. The grapes are ripe in early fall and can be eaten right off of the vine or used to make wine. Bees drink nectar from the flowers in the spring, and birds and mammals enjoy the grapes in the fall.

Learn more about Muscadinia rotundifolia at NC State's Plant Toolbox: https://plants.ces.ncsu.edu/plants/vitis-rotundifolia/

Characteristics for identification:

- Woody (brown) climbing vine
- Leaves are toothed and moderately heart-shaped
- Green tendrils
- Grapes are purple and gold (late summer and fall only)

Hillside blueberry, Vaccinium pallidum

Hillside blueberry is a deciduous shrub that is abundant throughout the understory of forests on the Sanford Pfizer campus. Hillside blueberry shrubs can be found in large thickets or as individual plants. They prefer full sun but will tolerate shade. Ripe blueberries can be picked around June and July. The blueberries are typically extremely palatable and are valuable to wildlife.

Learn more about Vaccinium pallidum at NC State's Plant Toolbox: https://plants.ces.ncsu.edu/plants/vaccinium-pallidum/

Characteristics for identification:

- Shrubs are round and typically about 2 feet tall and 2 feet wide
- Leaves are oval shaped and 1 to 2 inches in length. They are deciduous and turn dark orange or red in fall
- Tips of twigs are green, but turn brown at the base of the plant
- Small, white, bell-shaped flowers (spring only)
- Clusters of blueberries (summer only)

Elderberry, Sambucus canadensis

American elderberry is a large shrub. It can be easily spotted around the wetland when its showy white flowers bloom in late spring and early summer. Fruits appear in late summer and can be used for jellies, syrups, wine and desserts. The berries, leaves and flowers are commonly used in homeopathic remedies. However, elderberry can be toxic to humans if not processed properly before ingestion. Birds enjoy the fruit and nesting in the branches.

Learn more about Vaccinium pallidum at NC State's Plant Toolbox: https://plants.ces.ncsu.edu/plants/sambucus-canadensis/

Characteristics for identification:

- Shrubs are 5 to 12 feet tall and 6 to 10 feet wide
- Many stems on one plant
- Showy white aromatic flowers (spring and summer only)
- Leaves are compound (many leaflets on one stem) and sprout opposite each other on each branch
- Berries grow in clusters and are dark purple to black (late summer and fall only)

ID tool: Seek

Seek is an application that uses image recognition technology to identify plants, wildlife and fungi in real time. It is free to download and observations can be tracked in the app. Previously taken images can also be uploaded for identification.

https://www.inaturalist.org/pages/seek_app

STUDY TEAM

Initiative's Team

Adam Walters, PLA, ASLA,
ISA Certified Arborist
Associate Director of the Initiative
Co-Principal Investigator

Elizabeth Gabriel, MFA
Designer at the Initiative
Designer

College of Design

Carla Delcambre, ASLA, PLA
Associate Professor of
Landscape Architecture and
Environmental Planning
Principal Investigator

Luma Kennedy, MS, MLA
Research Associate

College of Natural Resources

Meredith Martin, Ph.D
Assistant Professor in the College
of Natural Resources
Co-Principal Investigator

Valerie Friedmann
Undergraduate Student
Research Associate

Alejandra Betancourt Rial, MS
Research Assistant, Ph.D Student
Research Associate

An Initiative for Community Growth and Development Publication

Printed in the USA

NC STATE | Initiative for Community
Growth + Development