LANDSCAPE PLANT SELECTION AND MANAGEMENT FOR SLOPE RESTORATION ON URBAN FREEWAYS

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Horticulture–Master of Science

2021

ABSTRACT

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Roadsides can be difficult environments for plant establishment, but with proper site preparation techniques and plant selection, roadside plantings can flourish. To improve roadside plantings in the state of Michigan, we investigated the impacts of site preparation and evaluated plant selections in collaboration with the Michigan Department of Transportation. We conducted a large-scale field study at two locations (Warren, MI, and Roseville, MI) along I-696 near Detroit, MI. The objective of the site preparation study was to evaluate the effect of site preparation (tillage and addition of compost) on the establishment of roadside plantings. 16 selections of shrubs, perennials, and grasses were planted in four site preparation treatments. In a supplemental plant evaluation study, the establishment and survival of 16 additional plant selections. In the site preparation experiment, compost application had positive effects on plant growth and ground cover in 2019 and 2020, however, compost did not affect plant survival in either year. Possible aspect effects were observed as well. Overall, shrubs had increased rates of survival and groundcover when compared to perennial plants. Plant selections that had no mortality in 2020 were Hemerocallis 'Happy Returns', Hemerocallis 'Stella De Oro', Amsonia hubrichtii 'Halfway to Arkansas', Diervilla sessilifolia 'Butterfly', and Cephalanthus occidentalis 'SMCOSS'.

ACKNOWLEDGEMENTS

I would like to thank Dr. Bert Cregg for the opportunity to work on this project, the opportunity to further my education, and all the support along the way during a world-wide pandemic. I wish to thank Dr. Robert Schutzki for his guidance and support with the MDOT plant selection manual. My sincere thanks to Dr. Jeffery Andersen for sitting on my advisory committee and providing climatological expertise. I would like to thank Steve Marquie and the MSU EnviroWeather team for providing equipment and technical support. I wish to thank Riley Rouse, Dana Ellison-Smith, Deborah Trelstad, and all other members of the Cregg lab for powering through data collection in Detroit. I could not have finished this project without you. Thank you to Nanette Alton for helping me navigate MDOT's resources and processes. Special thanks to Jonathan Faasse and Kristen Faasse of Elements Studio for creating roadside planting details for the MDOT plant selection manual. I would also like to thank Paul Siciliano for awakening my passion for ornamental horticulture and encouraging me to further my education. Finally, thank you to all my friends and family for their love and support.

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CHAPTER 1

INTRODUCTION

In the fall of 2013, the Michigan Department of Transportation (MDOT) installed 21 linear miles of roadside landscapes along Interstate 696 near Detroit Michigan. This project was intended to reduce erosion, reduce runoff, and reduce maintenance along the interstate. Establishment of these plantings were variable. As a result, MDOT wished to investigate the factors that affect plant establishment along urban roadsides. This led to MDOT collaborating with Michigan State University to create a study that examined MDOT's current site preparation specifications, compared the effect of compost and tillage on roadside plant establishment, and evaluated the success of 32 plant selections in the roadside environment.

The next chapter of this thesis contains a literature review that explores the benefits of roadside plantings, challenges to plant establishment on the roadside, and techniques to improve roadside plant establishment. Chapter three contains a research article that examines the effects of compost application and soil surface tillage on roadside plant establishment and survival, and compares the success of 32 commonly available plants in Michigan. The results of this study have been used to update MDOT's planting specifications and helped to create a new plant selection manual for use throughout the state. This manual makes up chapters four and five of this thesis. In addition to this, a database of plants that are well suited for roadside plantings in Michigan is included as a supplemental excel spreadsheet that can be downloaded with the electronic version of this thesis. Descriptions for each category within the database can be found on page 219.

CHAPTER TWO

LITERATURE REVIEW

Establishing Vegetation Along Urban Highways: Benefits, Challenges and Opportunities

As the public grows more concerned about climate change and sustainability, many municipalities have been looking for practical and cost-effective ways to reduce their environmental impact. One way they can meet their goals is establishing roadside plantings along major roadways. Roadside plantings not only provide aesthetic benefits to an area, but also benefit the surrounding ecosystems (Singh et al., 1995). Unfortunately, roadside environments present several challenges to plant establishment, such as pollution, poor soil quality and other environmental stresses (Mills et al., 2020). These barriers to establishment may discourage municipalities from dedicating funding to roadside planting projects. However, proper plant selection and site preparation can improve plant establishment and the longevity of roadside plantings (Barwise and Kumar, 2020; Bochet and García-Fayos, 2015). The requirements for plant selection and site preparation will vary by region, therefore many departments of transportation have created manuals that outline proper installation and design and maintenance for a given region. In this review I will examine the benefits roadside plantings provide, discuss the challenges to the establishment roadside plantings, and discuss approaches to overcoming those challenges. This review will largely focus on examples from North America and Europe.

Benefits of Roadside Plants

Roadside plantings can improve biodiversity and provision of ecosystem services for humans who are present in an area. Pollinators and other urban wildlife benefit from the additional habitat and food sources that roadside plantings can provide (Hopwood, 2008; Way, 1977). The health of humans and wildlife also benefit from the reduction of polluted runoff and particulate matter that roadside plantings can provide. Finally, roadside plantings can require less maintenance than turf covered areas, saving both money and time (Bretzel et al., 2009; O'Sullivan et al., 2017). When compared to urban areas with shade trees, turf by itself required large amounts of water, and provided very little cooling benefit (Shashua-Bar et al., 2009).

Reduction of the Urban Heat Island Effect

Due to the large heat capacity and conductivity of common construction materials, like concrete or asphalt, urban areas are unable to dissipate heat effectively overnight. The poor heat dissipation combined with the effects of increased CO_2 and other human activity results in an urban heat island effect where urban areas have warmer surface temperatures than surrounding rural areas (Bornstein, 1968). The urban heat island has implications for human health, such as increased frequency and severity of heat waves that can result in heat stress (Tan et al., 2010). Fortunately, the urban heat island effect can be reduced by planting trees and shrubs in urban areas. In a study in Leicester UK, soil surface temperatures beneath urban tree and shrub plantings were 5.7 degrees cooler on average than areas with no plantings (Edmondson et al., 2016). Moderate canopy coverage over urban streets can also offset the heating effects of heavy vehicle traffic (Shashua-Bar and Hoffman, 2000).

Benefits to Wildlife

Urban plantings and urban roadside plantings can make developed areas more hospitable not only to humans, but also provide habitat for urban wildlife. Increased species and floral abundance led to increased bee abundance and species richness in urban plantings (Hopwood, 2008). In general, plants with large and abundant flowers were the most beneficial to generalist pollinators. However, many pollinators prefer specific flower structures and species. For example, hummingbirds prefer tubular shaped flowers like those found on *Salvia* (Wojcik and Buchmann, 2012). Butterflies, in contrast, need different plants depending on what part of their lifecycle they are in. Adult butterflies need various sources of nectar, while larvae need foliage to shelter from predators and for food (Wojcik and Buchmann, 2012). Because of this, plantings designed to increase pollinator populations should use a diverse selection of plants in order to appeal to as many pollinator species as possible.

Programs to increase pollinators along highways have been popular in various states in the US. In the late 1990's the Indiana Department of Transportation (INDOT) started their Hoosier Roadside Heritage Program, which incorporates native wildflowers into roadside plantings. This benefitted INDOT not only by reducing maintenance costs and time, but also by reducing the amount of herbicide applied to roadsides. Additionally, the wildflowers provided both food and habitat for pollinators and other wildlife (INDOT, n.d.). Reducing mowing and practicing passive habitat restoration creates useable habitat for wildlife (Wigginton and Meyerson, 2018). The Virginia Department of Transportation (VaDOT) began a similar program in 2015 called the Pollinator Habitat Program. This program focuses on creating "Pollinator Waystations" in rest areas and parking lots. Through this program, VaDOT aims to reduce both mowing and erosion, while also providing habitat for wildlife (VaDOT, n.d.).

Pollution reduction

Ecosystems and humans alike can also benefit from the ability of roadside plantings to reduce or sequester pollutants from the surrounding environment. Urban and roadside plants have the potential to filter pollutants, especially those that are found in car exhaust. Both lead and sulfur dioxide are common pollutants from car exhaust that can be effectively mitigated by roadside plants (Singh et al., 1995). Morphological structures such as leaf hairs and foliage density affect the amount of particulate matter that leaves of various trees species can collect (Dzierzanowski and Gawronski, 2011). Dzierzanowski and Gawronski (2011) compared five tree species and found that silver birch (*Betula pendula*) had the highest level of particulate removal, removing 80 percent of particulates from the air. This mirrors the conclusions reached in a related study that focused on herbaceous plants, which found that particulate matter immobilization is dependent on both plant height and leaf trait (Weber et al., 2014). Plants that had a greater number of leaf hairs were the most effective at particulate matter immobilization, and the authors suggest that plants that are structurally diverse and have large leaf area would be the most effective in trapping pollutants (Weber et al., 2014). Weber et al. (2014) also postulate that because herbaceous vegetation is often closer to roadway than trees or shrubs it can maximize particulate matter absorption by a roadside planting.

Based on numerous studies confirming that roadside plantings can improve the surrounding air quality, the Environmental Protection Agency (EPA) released a publication in 2016 recommending the creation of roadside plantings that improve air quality. The EPA recommends plants with hairy leaf surfaces and increased surface area. However, the EPA goes further and considers both seasonal effects and a plant's tolerance for urban conditions. For maximum air quality improvement, the EPA recommends planting coniferous or evergreen plants that are tolerant of urban environments (Balduf, 2016). This bulletin also recognizes that roadside plantings can benefit an area by reducing noise and mitigating runoff.

Roadside Plantings Increase Safety

As stated before, many DOTs have been replacing turf covered areas with more diverse plantings to reduce maintenance costs and time. Reducing the amount of time an employee is mowing along roadsides may also reduce related accidents and traffic. In addition, roadside plantings may help to encourage safer driving. Varied landscapes help keep drivers alert compared to more homogeneous ones (AASHTO, 1991; Antonson et al., 2009; Nelson, 1997). Antonson et al. (2009) found that semi-forested areas have a positive effect on drivers' safety, and postulate that roadside plantings could help make roads safer by influencing drivers to steer in a certain direction. Using plants to signal a change in road direction is a technique that is endorsed by the American Association of Highway and Transportation Officials (AASHTO, 1991). AASHTO (1991) also recommends the use of dense roadside plants to reduce headlight glare and drift from snow or sand, mitigating those hazards from roadways.

Furthermore, Mok et al. (2006) found that while there is no clear cause, sites with managed roadside landscapes had significantly reduced crash rates when compared to sites that did not have managed landscapes. It is possible that the improved landscapes decreased stress of those driving by the site as viewing greenery and natural features can calm the viewer and reduce stress (Parsons et al., 1998). Parsons et al. (1998) exposed subjects to a mild stressor and then showed videos of different driving routes from the perspective of a car passenger, all with varying roadside environments. Subjects that viewed the videos from more vegetated environments had lower blood pressure, and other somatic factors that indicated these subjects were significantly more relaxed than those who viewed the videos of other environments (Parsons et al., 1998).

Challenges to establishing roadside vegetation

While roadside plantings provide ecosystem services and improve aesthetics and driver well-being and safety, roadsides are not ideal environments for plants to grow. As a result, the use of diverse plantings along urban highways and roadways is still relatively rare. Roadside plantings are subjected to pollution, compacted and degraded soils, and reflected heat; all of which negatively affect establishment and growth of plants.

<u>Roadside and Urban Climates</u>

The water and energy balances of urban areas are different than natural environments due to the presence of built terrain and other human activity (Gebert et al., 2019; Oke, 1982). Although roadside plantings help to mitigate this urban heat island effect, these altered microclimates are a source of stress for plants (Czaja et al., 2020; Gillner et al., 2014; Kjelgren and Clark, 1992a). The presence of buildings and other built features along roadways create urban canyons, which cause altered wind and airflow patterns (Hunter et al., 1990; Nakamura and Oke, 1988). Wind that skims over the top of a canyon perpendicular to the roadway can cause air to form a vortex within the canyon, pulling air from the ground to the top of the buildings (Hunter et al., 1990; Oke, 1988). The orientation of these canyons influences the microclimate within the canyon. Urban canyons that run in a North-South or Northeast-Southwest direction are have been observed to be cooler than those that run East-West or Northwest-Southeast (Zaki et al., 2020). Plants in these canyons, particularly those that run north to south, often receive limited amounts of solar radiation throughout the day due to shadows from buildings (Gebert et al., 2019; Kjelgren and Clark, 1992a). This limited sunlight results in shade acclimation responses in street trees planted in these urban canyons (Kjelgren and Clark, 1992a). Shade intolerant plants such as *Liquidambar styraciflua* can become chronically stressed from this limitation of sunlight (Kjelgren and Clark, 1992b). Increased temperatures and evaporative demand has also been observed in urban canyons when compared to other urban and rural sites (Gebert et al., 2019).

As discussed before, the urban heat island effect causes urban areas to be warmer than more rural areas (Bornstein, 1968). When compared to a vegetated lawn, soil temperatures beneath asphalt can be up to 16 ^{o}C higher (Celestian and Martin, 2004). Consistent high soil temperatures negatively affect a plant's photosynthetic process and the water content in leaves (Nóia Júnior et al., 2018). Higher air temperatures and decreased relative humidity that result from the urban heat island effect affect plants as well. Elevated temperatures increase the rate of respiration in plants and can be linked with higher carbon dioxide emissions (Czaja et al., 2020; Reich et al., 2016). The urban heat island effect also results in a lower relative humidity in the affected areas and therefore an increased vapor pressure deficit (Wang et al., 2011). This vapor pressure deficit causes an increase in transpiration rate and negative effects on plant growth (Wang et al., 2020). Micro-climatic factors can also interact with pollutants in urban areas, causing more deleterious effects on plant growth (Wang et al., 2011, 2020).

Deicing Salt

One of the most common pollutants that roadside plants encounter in northern climates are deicing salts. In this discussion I will focus primarily on sodium chloride (NaCl), which is by far the most common deicer used in the Midwest and northeastern U.S.(Minnesota Pollution Control Agency, 2020). This is often because chloride based deicers are the least expensive deicer available(Minnesota Pollution Control Agency, 2020). Salt applications during winter months are imperative for safety as it helps prevent ice formation on roadways, but chloride based salts can have adverse effects on plants at high concentrations (Bryson and Barker, 2002). Salt can become aerosolized from vehicle traffic, resulting in acute plant exposure and build up in soils adjacent to the road (Cunningham et al., 2008; Davison, 1971; Patykowski et al., 2018). Salt can also accumulate in soils via runoff and this build up can negatively affect soil properties and chronically expose plants to salt (Cunningham et al., 2008; Davison, 1971).

Increasing salt levels in soil is negatively correlated with vegetation cover along roadsides (Hopkinson et al., 2016). Chronic exposure to deicing salt can result in plant uptake and altering pH of the soil which changes the availability of key nutrients (Cunningham et al., 2008; Davison, 1971). Plant uptake can cause reduced drought tolerance and reduced cold tolerance because of the buildup of chlorine and sodium ions in plant tissue (Maas, 1985; Sucoff et al., 1976). Damage as a result of these effects is usually seen in deciduous plants, and becomes more obvious during the growing season (Patykowski et al., 2018; Sucoff et al., 1976). The reduction in cold tolerance can cause bud kill, which will affect the future growth and flowering of plants (Sucoff et al., 1976). When chronically exposed to salt via growing media, silver maple (*Acer saccharinum*) seedlings had reduced dry plant tissue weights when compared to those with no salt exposure (Patykowski et al., 2018).

The most visually obvious salt damage is often a result of direct contact between salt and plant tissue. Direct or acute exposure often results in desiccation injury, especially in evergreen plants (Bryson and Barker, 2002). Most direct exposure of plants to deicing salt is a result of salt spray, which can reach plants up to 10 meters from the roadside (Bryson and

Barker, 2002). Bryson and Barker (2002) observed increased incidence of diplodia disease on Austrian pines (*Pinus nigra*) near their study site and speculated that foliar damage that resulted from salt exposure increased disease susceptibility of those trees. Acute salt damage on trees can be significantly reduced by installing a square box made of straw mats around the trunk (Pedersen et al., 2000). However, because salt concentrations are higher closer to the roadway, planting trees two or more meters from the roadway is the most effective preventative measure against salt damage (Pedersen et al., 2000).

Due to the potential phytotoxicity of NaCl, road maintenance agencies sometimes apply alternative deicing agents, which may have reduced effects on soil and plants. Akbar et al. (2006) compared standard deicing salt to Calcium Magnesium Acetate (CMA), which is another common deicing treatment. Acetate based deicers can be used in colder temperatures than chloride based agents, but are less common due to increased cost and decreased availability (Minnesota Pollution Control Agency, 2020). Plants exposed to increased concentrations of NaCl via soil and aerosol exposure had lower shoot dry weights to than those with no exposure to a deicing agent (Akbar et al., 2006). Plants exposed to CMA had less visual injury than those exposed to NaCl, and CMA had no effect on plant dry weights when aerosolized (Akbar et al., 2006). The results of this study imply that using alternative deicers on roadways could result in healthier and more vigorous roadside plants.

<u>Heavy Metals and Particulate Matter</u>

Salt and deicers are not the only contaminants that can accumulate in roadside environments. Vehicle emissions and wear on vehicle components can release heavy metals and particulate matter in the surrounding environment (Thorpe and Harrison, 2008; Thorpe et al., 2007). Particulate matter released from vehicle wear accumulates in roadside environments, and can become re-suspended in the air in high traffic areas (Handler et al., 2008; Thorpe and Harrison, 2008). Vehicle emissions can contain heavy metals such as cadmium, chromium, copper, lead, and zinc, which can build up in soil near roadways and on the surface of plant tissue (Handler et al., 2008; Ndiokwere, 1984; Thorpe and Harrison, 2008). Vehicle emissions also contain sulfates, ammonium, and nitrates (Fraser et al., 1998). Pollutants from vehicle wear usually come from brakes and tires in the form of particulate matter (Thorpe and Harrison, 2008). This particulate matter also contains heavy metals and also can contain man-made materials such as rubber (Thorpe and Harrison, 2008). Accumulation of these pollutants in roadside environments can have negative effects on roadside plantings.

While some heavy metals, like iron or copper, are essential for plant life, excessive concentrations are damaging to plants. Other heavy metals, such as lead, only have negative effects on plant life (Nagajyoti et al., 2010). Heavy metal concentrations in plants are highest when plants are close to the source of contamination, such as roadsides (Khalid et al., 2018; Nagajyoti et al., 2010; Ndiokwere, 1984). Vegetables grown in high traffic areas of Berlin had higher concentrations of trace metals, such as cadmium, lead, nickel and chromium than vegetables grown in other areas (Säumel et al., 2012). Säumel et al. (2012) also found that stem and root vegetables had the highest metal concentrations compared to other types of vegetables. Over 50% of the produce sampled by Säumel et al. exceeded the EU standards for lead concentration in food crops, meaning the vegetables were not considered safe for consumption. Certain concentrations of heavy metals can prevent nutrient uptake by damaging root tips, as well as interrupt metabolic processes and growth (Balsberg-Påhlsson, 1989; Sanità Di Toppi and Gabbrielli, 1999).

In addition to pollutants in the soil, roadside plantings can be affected by particulate matter that is distributed through the air. As discussed before, roadside plants have been shown to be effective in collecting particulate matter that could be hazardous to human health. However, the process of intercepting particulate matter can result in deleterious effects on plants like abrasion and radiative heating (Grantz et al., 2003). In addition, particulate matter can negatively affect photosynthetic rates by clogging the stomata on leaves (Popek et al., 2018). Because of this issue, Popek et al. (2018) recommend that species that are sensitive to particulates should be planted further from emission sources (Popek et al., 2018). In practice, this would result in the use of plants that are tolerant of air pollution and other urban conditions.

Urban Soils

Degradation of urban soil can impede establishment of roadside plantings in urban areas. Human activity is the primary cause of the degradation of urban soils (Craul, 1985). During urbanization and construction, topsoil is often removed and stockpiled, and different soils or layers of the soils can be mixed together causing soil structure to be lost or modified (Craul, 1985; Scharenbroch et al., 2005). The loss of soil structure can lead to compaction and erosion (Craul, 1985). Because of this degradation, urban soils can contribute to the urban heat island effect, and decreased storm water mitigation (Craul, 1985; Pavao-Zuckerman, 2008; Scharenbroch et al., 2005). Increased soil bulk density, decreased organic matter, and exposed sub-soil layers that result from urbanization can promote the establishment of invasive species, which can make ecological restoration difficult (Pavao-Zuckerman, 2008). Haan et al. (2012) examined survival of native plants along roadsides near Ann Arbor, Michigan. When examining the factors that caused mortality, they found that some clay soils at their study sites had bulk densities 1.5 g/cm^3 (Haan et al., 2012). Bulk densities between 1.40 and 1.65 g/cm^3 restrict the root growth of woody plants (Alberty et al., 1984; McGrath and Henry, 2015). Soil compaction also reduces soil porosity, which decrease the amount of available water and air (Jim and Ng, 2018).

Haan et al. (2012) and Mills et al. (2020) reported that soils on their study sites were much more alkaline than non-roadside soils in the region. Craul and Klein (1980) found that soil samples taken from roadsides had pH values that were at the upper limit of the pH range of undisturbed soils in Syracuse, NY. Urban soils commonly have higher pH values than their undeveloped counterparts, most likely because the release of calcium from construction materials and deicing agents (Craul, 1985; Craul and Klein, 1980). Soil pH values of 7 or greater cause soil nutrients such as nitrogen, phosphorus, manganese and iron to be less available to plants, which could cause nutrient deficiencies (Fernández and Hoeft, 2009).

Creating Successful Roadside Plantings

Hopkinson et al. (2016) suggests that challenges related to establishment are mainly related to site preparation. The combination of particulate matter pollution, poor soil quality and salt accumulation can result in poor survival and establishment of roadside plantings. The proper establishment of plants is critical to the long term success of a roadside plantings (AASHTO, 1991). To mitigate the effects of urban roadside environments and improve plant establishment, the principal tools available to designers and contractors include site preparation, irrigation and plant selection. Appropriate plant selection, plant handling, site preparation, and maintenance can improve establishment of trees and shrubs along roadsides (Kuhns et al. 2004; McGrath, 2016). Because of varying climates and conditions across the country, there is a need for regionally specific guidelines for the creation of roadside plantings.

Site Preparation via Tillage

In order to improve the establishments of root systems of roadside plants, the soil at the site must be loose enough to allow for root penetration (Alberty et al., 1984; Kuhns et al., 2004; McGrath and Henry, 2015). Because of the prevalence of compacted soils in urban and roadside environments, loosening the soil in roadside plantings site via tillage has become a prevalent site preparation technique. A bulletin from Penn State University concerning tree and shrub plantings along roadsides recommends that the soil at a site be loosened as deeply and in as large of an area as possible (Kuhns et al., 2004). If only small areas are tilled, root growth could stop at the untilled areas, leading to plants becoming root bound (Jim and Ng, 2018). The water infiltration rate of urban soil is significantly increased by tillage (Mohammadshirazi et al., 2017). Tilling the soil also has the benefit of incorporating organic matter or other amendments to the soil, further improving the quality of soils at the site.

Although tillage is often recommended for roadside plantings, as noted above, the effects of tillage are not consistent. Rivers et al. (2021) reported that tillage alone did not increase infiltration rate, and that tillage did not reduce stormwater runoff from roadsides. Additionally, vegetation cover was negatively affected by tillage (Rivers et al., 2021). Bary et al. (2016) observed that incorporating organic amendments into the soil did not improve plant survival or growth, implying that surface application of organic material was sufficient.

Site Preparation via Compost

One of the most common site preparation techniques is the addition of organic material to urban soils. Urban soils often have decreased organic matter content because the surface layers are often removed during construction (Craul, 1985; Pavao-Zuckerman, 2008). The amount of organic matter is often correlated with the amount of vegetation coverage in roadside plantings (Hopkinson et al., 2016). Low quality topsoil can be amended with organic materials to create a more ideal soil for most plants (AASHTO, 1991). Increasing soil organic matter can improve plant performance in several ways including reducing soil bulk density, increasing soil cation exchange capacity (CEC), increasing soil water holding capacity, and providing plant nutrients. The addition of compost significantly improved the growth of roadside trees in Ontario, Canada (McGrath and Henry, 2016). Improved tree growth was attributed to decreased soil bulk density in the treatments with compost amendments (McGrath and Henry, 2016). Incorporation of organic matter via tillage has been shown to reduce the bulk density and improve the water holding capacity within urban soils (Sax et al., 2017). However, incorporating compost into urban soil showed no significant plant growth benefit when compared to surface application of compost, suggesting a top dressing of compost is sufficient for plant success (Bary et al., 2016).

In addition to compost, amending soils with biosolids and biochar have been shown to increase tree growth and tree biomass (Scharenbroch et al., 2013). Organic amendments can also improve both soil and plant nutrition in roadside plantings. A turf-based study tested the effectiveness of using yard compost and biosolids as soil amendments in roadside environments. Sites treated with both organic amendments had increased amounts of soil nitrogen and phosphorus than those without (Brown and Gorres, 2011). Brown and Gorres also observed that overall, the turf in those same treatments had increased ground cover and height compared to the control treatment (Brown and Gorres, 2011). The authors inferred that the turf responded positively to the increased amount of nutrients in the soil. The Minnesota Department of Transportation (MnDOT) recommends the use of compost in roadside plantings citing benefits such as salt alleviation, enhanced growing environment and wildlife mitigation (Johnson, 2008). The benefits associated with organic amendments are often dependent on the amount organic material added to urban soils. Recommended application rates vary between crops and location (Cogger, 2005). Exaggerated application of compost could result in a soil becoming waterlogged, settling significantly, and accumulating salt (Cogger, 2005). McGrath et al. (2020) found that roadside trees had the greatest increase in height when the topsoil at the planting site contained 25% compost by volume and trees did not benefit from higher additions.

Organic amendments come in many different forms and can have different plant available nutrients. Simply adding straw can greatly increase the amount of available carbon, and add some available nitrogen to the soil (Siedt et al., 2021). Like straw, biochar can add some plant available nitrogen to the soil, but has a very low amount of available carbon (Siedt et al., 2021). Compost adds both nitrogen and carbon to a soil, but the nitrogen is released slowly over time (Nelson, 1997; Siedt et al., 2021). While the nutrient availability of compost can be lower than other fertilizers, it can release nutrients over a long period of time (Cogger, 2005). To know more about the quality of a compost, Bary et al. (2002) recommends that the carbon to nitrogen ratio, electrical conductivity, NH_4 content, NO_3 content, moisture content, and organic matter content be analyzed. These factors give insight into a compost's stability, nutrition content and nutrient availability (Bary et al., 2002). Stable compost is often thought of as compost with low amounts of plant available organic matter, which slows microbial activity and therefore slows the decomposition of compost (Hue and Liu, 1995). Compost age or maturity often determines its suitability for use and is often closely related to stability (Cooperband et al., 2003; Hue and Liu, 1995). While there is no specific measure to determine what makes a compost mature, older composts generally released lower amounts of carbon and nitrogen into stormwater runoff, implying that these nutrients were immobilized (Al-Bataina et al., 2016). Cooperband et al (2003) determined that individual measures of compost stability or maturity were not correlated with plant growth, however pH changes over time and NO_3-N/CO_2-C ratios could be. Higher ratios were associated with nitrogen and carbon mineralization and plant nutrient uptake (Cooperband et al., 2003).

Compost quality can be an important consideration in municipal projects as many state agencies have specific quality specifications for compost (Brinton, 2000). European countries have more comprehensive guidelines and certifications related to compost quality than the U.S. (Brinton, 2000). These guidelines often contain specifications related to a compost's composition, heavy metal content, maturity, and concentration of other potentially hazardous materials(Brinton, 2000). Potentially hazardous materials that could be contained in compost are weeds or weed seeds, pesticides or herbicides and salt (Brinton, 2000; Cogger and Sullivan, 2009). All of these materials could have an effect on plant growth (Brinton, 2000).

Irrigation Considerations

In addition to organic amendments and tillage, installing irrigation can be a consideration during the creation of roadside plantings. In a Florida study, irrigating palm trees via a permanent drip system improved tree establishment, however the presence of irrigation had no significant effect on the establishment of other types of trees (Blair et al., 2019). Relatively few studies have considered the effectiveness of long-term irrigation on roadside plant establishment, possibly because of the added installation and maintenance expenses irrigation would bring to a project. While proper irrigation is important during initial establishment, temporary irrigation techniques, like irrigation bags, are often sufficient (Kuhns et al., 2004). If permanent irrigation systems are necessary, they should be designed to be easily maintained and minimize water spraying on the roadway (AASHTO, 1991).

Plant Selection

Even with improvements to the site, plants selected for roadsides need to be tolerant of urban conditions, adapted to the local climate, and fit in with municipal maintenance plans. Because of the varied climates across the United States, the best way to determine what plants are appropriate for a site is to examine the plant life in natural areas that have similar topography, soils, and climate (AASHTO, 1991). While the plant selection process is complex, landscape architects are mainly influenced by cost of plants, the amount of maintenance a plant requires, and the overall structure of a plant when selecting plants for roadsides (Guneroglu et al., 2019). In their recent roadside planting manuals, the Florida Department of Transportation has begun to implement a “right plant in right place” philosophy (FDOT, 2014). The manuals of several other states, such as Minnesota, Washington and Texas mirror this

(Jones et al., 2007). Other states, like New York and Massachusetts, have goals to improve their sustainability by designing low input and low maintenance roadside plantings (Jones et al., 2007). These goals affect the plant selections for projects in these areas.

Selecting Plants Based on Urban Stressors

Many roadside planting manuals have begun incorporating “natural landscaping”, which can refer to the practice of using native plants or natural materials into the designs of roadside plantings, and minimizing the amount of fertilizing, watering, weeding and mowing done after planting (Jones et al., 2007). Reducing the number of inputs to roadside landscapes often results in increased exposure to adverse environmental conditions, such as drought and low nutrient availability. Selecting plants that are tolerant of these stresses can improve the success of a roadside planting project.

A plant’s native habitat can be indicative of its tolerances and success on roadsides. A study in Freising, Germany evaluated the growth of six different tree species under drought conditions designed to resemble roadside conditions. Some of the trees selected were considered to be “low-resource” because they originate from drier climates, including *Acer campestre*, *Ostrya carpinifolia,* and *Tilia tomentosa* ‘Brabant’. These “low resource” species used water more conservatively in drought conditions, and had higher growth rates than plants from wetter climates (Stratópoulos et al., 2018). Salt tolerance in plants often varies by plant type. Bryson and Barker (2002) observed that spruce, sumac and mountain laurel selections near their study area had considerable salt damage, while fern, oak, grass and yarrow selections in the area did not show any signs of damage. In general, deciduous plants are more salt tolerant than evergreen plants, as deciduous trees do not retain their foliage during the winter (Bryson and Barker, 2002). Native habitats of plants are indicative of salt tolerance, as plants that are native to coastal or seaside regions are often more salt tolerant (Ishikawa and Kachi, 2000).

Plant selection Based on Project Goals

Certain plant morphological structures can be selected based on the goals of a roadside planting project. If reduced maintenance is desired, plant architecture and morphology that is conducive to covering and shading the ground, such as dense foliage or creeping habit, helps to reduce the need for weed control and reduces the amount of weeds in an area overtime (Eom et al., 2005; Weston and Eom, 2008). *Alchemilla mollis, Nepeta* x *faassenii*, *Phlox subulata*, and *Solidago sphacelate* suppressed weed growth in managed and un-managed plots (Eom et al., 2005). Some groundcovers, like *Nepeta* x *faassenii* emit allelopathic chemicals that inhibit weed growth (Weston and Eom, 2008).

Some projects may be more focused on the cooling effects roadside plantings provide, which can be dependent on plant morphology and the location of plantings (Morakinyo et al., 2020; Tan et al., 2010). Dense plantings of trees that produce large amounts of shade are often the most effective in cooling urban areas (Tan et al., 2010). However, this effect may be dependent on the surrounding environment. Urban canyons with low amounts of shading from buildings received the most cooling benefit from trees that had high foliage density and shorter trunks (Morakinyo et al., 2020). In contrast, sites that received greater amounts of shade from surrounding buildings received the most cooling benefit from taller trees with moderate foliage density (Morakinyo et al., 2020). Projects that focus on cooling need to also consider the availability of water at their proposed site. Plants that have better water use efficiency and drought tolerance may have less of a cooling effect due to lower transpiration rates (Stratópoulos et al., 2018).

Other projects may be more focused on pollution mitigation. Plants with thick epicuticular wax, dense foliage and leaf hairs are often more efficient in capturing airborne particulate matter (Dzierzanowski and Gawronski, 2011). Having a diverse plant pallet that contains a variety of species, plant architectures and morphologies allows for a wide range of particulate matter to be captured (Weber et al., 2014). Stormwater treatment can be another possible project focus, which relies heavily on selecting resilient plants that are efficient in removing nitrogen and phosphorus from runoff (Read et al., 2009). Plants that have high biomass, extensive root systems and rapid growth rate are the most effective in removing nutrients from runoff (Payne et al., 2018).

Conclusions

Roadside plantings have numerous benefits to the urban landscape, including filtering out airborne particulate matter, providing habitat to urban wildlife, and dissipation of the urban heat island effect. There is even evidence that well landscaped roadsides can reduce crash rates, possibly due to reduced driver stress. Incorporating low maintenance plantings can also reduce maintenance costs when compared to turf plantings due to the reduced need for mowing. Unfortunately, establishing roadside plants can be challenging because of the effects of poor urban soils and pollution, which can cause municipalities to be hesitant to fund these projects. Proper site preparation and plant selection can drastically improve the success of these roadside plantings. The addition of compost can improve soil nutrition and reduce the bulk density of urban soils, which allows for better root growth and improved plant nutrition.

The bulk density of urban soils can further be reduced by tillage. When selecting plants for roadside sites one should not only consider the local climate, but also a plant's tolerance for urban conditions and pollution. Incorporating proper plant selection and site preparation into municipal planting manuals may result in better outcomes for future roadside planting projects.

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CHAPTER THREE

LANDSCAPE PLANT SELECTION AND MANAGEMENT FOR SLOPE RESTORATION ON URBAN FREEWAYS

Introduction

Roadside plantings that include woody plants and perennials can provide a myriad of benefits (AASHTO, 1991; Baldauf, 2017). When designed appropriately, roadside plantings can reduce road noise (Balduf, 2016), reduce the urban heat island effect (Edmondson et al., 2016; Shashua-Bar and Hoffman, 2000) and improve the aesthetic quality of an area. Roadside plantings can improve the safety around a site as well. For example, sites that have well managed landscapes have significantly reduced crash rates when compared to areas with poorly managed or no landscapes (Mok et al., 2006). Biodiverse roadside plantings not only benefit humans, but also provide habitat for pollinators and urban wildlife, which can aid restoration efforts (Hopwood, 2008; Wigginton and Meyerson, 2018). In addition, urban and roadside plants benefit the surrounding environment because they have the potential to improve air quality by filtering and sequestering pollutants from the surrounding environment (Baldauf, 2017; Dzierzanowski and Gawronski, 2011; Weber et al., 2014). Lead and sulfur dioxide, common pollutants from car exhaust, as well as particulate matter from wear of tires and brakes can be effectively filtered from the air by plants (Singh et al., 1995). The efficacy of particulate matter collection is dependent on plant morphological features such as foliage density, leaf hairs, leaf area and height (Balduf, 2016; Dzierzanowski and Gawronski, 2011; Weber et al., 2014).

While the benefits of roadside plantings are of interest to many communities and transportation agencies, highway roadsides are difficult environments to establish plantings (Bary et al., 2016). Human activity often degrades urban soils, which leads to increased bulk density, low organic matter content and loss of soil structure (Craul, 1985; Scharenbroch et al., 2005). These factors can restrict root growth of woody plants (Alberty et al., 1984), reduce the amount of available water and air in the soil (Jim and Ng, 2018), and reduce the amount of nutrients in the soil (Craul, 1985). Roadside soils are also subject to pollution from heavy metals (Khalid et al., 2018; Nagajyoti et al., 2010; Ndiokwere, 1984), which can affect the development and growth of plants when they accumulate in the soil (Balsberg-Påhlsson, 1989; Nagajyoti et al., 2010; Sanità Di Toppi and Gabbrielli, 1999). Accumulation of deicing salt in roadside soils can also cause plants to uptake sodium and chloride ions, causing damage to roadside plants, affecting development and reducing cold tolerance (Maas, 1985; Patykowski et al., 2018; Sucoff et al., 1976). Additionally, roadside plants face challenges not related to soil conditions. Although roadside plants have been shown to benefit the surrounding environment by sequestering aerial pollutants, excessive buildup on of particulate matter on leaves can result in plant damage (Grantz et al., 2003) or reduce photosynthetic efficiency (Popek et al., 2018). During the winter, deicing salt exposure can cause damage to plant tissue up to 10 meters from the roadside due to spray from vehicle traffic (Bryson and Barker, 2002).

In order to address the challenges of the roadside environment, proper site preparation is important to the establishment of roadside plantings and can mitigate some of the factors that make establishment difficult. During construction, grading and other activities often remove of topsoil leaving subsoils with little organic matter (Craul, 1985). A popular way to resolve this problem is amending soil with compost or other commonly available organic materials. The addition of organic amendments can significantly increase tree growth and tree biomass of roadside plantings (McGrath and Henry, 2016; Scharenbroch et al., 2013). McGrath and Henry (2016) attributed the improved growth of roadside trees associated with compost addition to improved soil physical properties, particularly bulk density. Incorporation of organic matter via tillage also decreases soil bulk density and can result in increased water holding capacity (Sax et al., 2017). Organic amendments also can improve soil nutrition. Soil amended with organic matter had increased amounts of phosphorus and nitrogen, which was associated with increased ground cover and height of turfgrass (Brown and Gorres, 2011). When compared to trees grown in greater amounts of compost, roadside trees grown in topsoil that contained twenty five percent compost by volume had the greatest increase in height (McGrath et al., 2020), suggesting that compost additions should be optimized for site conditions and desired plant species. Excessive application of compost can result in significant settling, waterlogging and salt accumulation in the soil (Cogger, 2005).

In addition to reducing organic matter, construction activities can increase compaction and reduce soil structure of urban soils (Alberty et al., 1984; Craul, 1985). Compacted soils can restrict root growth of woody plants at bulk densities between 1.40 and 1.65 g/cm or above (Alberty et al., 1984). For plants to have successful root systems, the soil must be loose enough for root penetration (Alberty et al., 1984; Kuhns et al., 2004). Guidelines from Pennsylvania State University recommend that soils on roadside planting sites be loosened as deeply and in as large of an area as possible (Kuhns et al., 2004). Tillage of compacted soil increased infiltration rates of water by 3 to 4 times compared to soils that were not tilled (Mohammadshirazi et al., 2017). Increased infiltration rates reduce runoff, increase plant available water, and improve growth of plants (Mohammadshirazi et al., 2017). Tillage also allows for increased incorporation of amendments into the soil and can make plant installation easier for planters. Incorporation of compost via tillage mitigates re-compaction from mower traffic (Mohammadshirazi et al., 2017). Furthermore, incorporation of compost via soil tillage can improve water infiltration rates and reduce stormwater runoff (Rivers et al., 2021). However, improved soil physical properties associated with the incorporation of organic amendments into soil via tillage does not always translate into improved plant growth (Bary et al., 2016; Rivers et al., 2021).

Along with site preparation, appropriate plant selections are essential to the success of roadside plantings. The effects of pollution, poor soil quality, and the urban heat island effect cause roadside plantings to require plants that are both adapted to the local climate and resilient to extreme conditions. The American Association of Highway Transportation recommends that plant selection be based on the climate, soils, and topography in natural areas close to the planting site (AASHTO, 1991). Many municipalities have created updated guidelines for roadside plantings that both maximize establishment and the benefits that roadside plantings provide (Jones et al., 2007).

In this study we investigated the effect of site preparation practices and plant selection on the establishment of roadside plantings along Interstate-696 (I-696), a major interstate highway near Detroit, MI USA. In 2013 the Michigan Department of Transportation (MDOT) installed 21 linear miles of landscaping along I-696 in the metro Detroit area (Lawrence, 2015). The purpose of the project was to reduce erosion along the sloped roadsides, reduce mowing frequency, and improve the aesthetics of the area (MDOT, 2021). However, MDOT became concerned about poor planting survival in certain areas of the plantings and wished to investigate factors that contribute to roadside plant survival and success. Poor plant survival of plants along roadsides may be due to range of factors, some of which highway departments and their contractors can control and some which are beyond their control. As noted earlier, two key factors in roadside planting success are site preparation and plant selection. Existing MDOT planting specifications require top-dressing sites with 8 cm of compost prior to planting. The last set of guidelines that MDOT has on file are from the 1970s and need to be updated (Nanette Alton, MDOT, personal communication). This experiment had two main objectives. The first objective was to evaluate the current MDOT site preparation specification's effect on plant establishment and compared to other site preparation methods. The second objective was to evaluate the performance of several different selections of plants. In particular, we evaluated shrubs, ornamental grasses and herbaceous perennials, which can add contribute aesthetic, structural and biological diversity to roadside plantings. To accomplish this, we evaluated plant establishment as percent ground cover, plant survival and growth. To understand the mechanisms by which the site preparation treatments affected plant establishment and survival, we evaluated plant physiological responses and environmental parameters for each site preparation treatment.

Materials and Methods

<u>Location</u>

Site description

The study was installed on two sites along Interstate 696 (I-696), also known as the Walter P. Reuther Freeway, an east-west running highway located near Detroit, Michigan, USA. Two sloped roadsides along I-696 were selected for this experiment (Figure 1). The first site was located in Roseville, Michigan, near I-696 exit 28 and a residential neighborhood (Figure 2). The research blocks at this site are on a south facing slope situated between westbound I-696 and westbound East Eleven Mile Road and were installed in October of 2018. In 2020, the annual average daily traffic (AADT) at this site was 41,022 vehicles travelling west (lanes closest to study site). In 2019, the westbound AADT was 51,324 vehicles. The second site was located in Warren, Michigan near I-696 exit 24, retail shops, and other commercial buildings (Figure 3). The research blocks at this site are on a north facing slope situated between westbound I-696 and westbound East Eleven Mile Road were installed in June 2018. In 2020, the AADT at this location was 52,582 vehicles travelling east. In 2019, the eastbound AADT was 62,227 vehicles. These two locations are approximately 5 km apart and both locations were the sites of failed plantings from the initial I-696 project. On average, the soil within 15 cm of the surface at these sites consisted of 33.10% sand, 31.35% silt and 38.27% clay (clay loam texture). The average soil pH was 8.2, and the average soil bulk density was 1.58 g/cm^3. Each block had a slope between 30 to 40%.

Climate

The study area is within USDA plant hardiness zone 6B (mean annual minimum temperature –26.6 to –17.8 C). The metro Detroit area has warm summers and cool winters, but extreme heat or cold weather is uncommon due to the proximity of the Great Lakes. The mean daily maximum temperature at the Coleman A. Young airport (located approximately 9.4 km from the Warren site) between 1981 and 2010 was 14.4 ^oC, the mean daily minimum temperature during this period was 6 ^oC (Table 2.1). The average yearly precipitation between 1981 and 2010 was 795.8 mm. In this area, precipitation occurs in all months, but is often heaviest in the warm season. 65% of the annual total precipitation occurs between April and October.

Experimental Design

This study was installed as a split-plot in a randomized complete block design with site preparation treatment (site prep) as the main plot factor and plant selection as the sub-plot factor (Figure 1.4).

Main plot: Site Prep

We installed three complete blocks with four main plots within each block at each location. Each main plot measured 6 meters wide and 17 meters long. We randomly assigned one of four site preparation treatments to each main plot: control, compost only, tillage only, and compost + tillage. Before construction of each block, existing plant material, mulch and compost were cleared from the site down to mineral soil. Plots assigned to the *compost only* treatment were top-dressed with a 10 cm deep layer of compost. Plots assigned the *tillage only* treatment were mechanically tilled to a 20 cm depth using a rotary tiller attached to a skid-steer tractor. Plots assigned the *compost + tillage* had a 10 cm deep layer of compost applied, which was then mechanically tilled into the soil to a 20 cm depth. All plots were subsequently top-dressed with a top layer of 8 cm of twice-ground hardwood mulch (TDE Enterprises Inc., Commerce Township, Michigan). Compost consisted of composted municipal yard waste (C:N ratio = 8:1, %K=0.88, %P=0.2) (Advanced Disposal, Northville, Michigan).

Sub-plot: Plant Selection

Each main plot was divided into 16 sub-plots (Figure 5). The subplots were arranged in two rows with larger sub-plots located at the top of the slope measuring 2.4 meters wide and 3.7 meters long, and contained 6 individual plants each (Figure 6). Smaller sub-plots were located at the bottom of each main plot and measured 2.4 meters by 1.8 meters, and contained 9 plants (Figure 6).

Within each sub-plot, contract crews planted one of 16 selections of ornamental plants; these included 7 shrubs, 5 herbaceous perennials and 4 ornamental grasses (Table 2). All plants were obtained from commercial nurseries in the area and arrived in #3 (11.4 L) or #1 (3.8 L) nursery containers. The *Baptisia*, *Cephalanthus*, *Cornus, Diervilla*, and *Physocarpus* selections were planted in the larger 2.4m by 3.7m sub-plots. All other plant selections were planted in the smaller 2.4m by 1.8m subplots

Supplemental Plant Evaluation Study

Proximate to each block, one additional plant evaluation plot was constructed to allow evaluation of additional plant selections without replicating the entire site preparation study. These evaluation plots were the same size and layout of the main plots, and contain different plant selections. Within each evaluation plot, contract crews planted 16 additional selections of ornamental plants; this included 7 shrubs, 6 herbaceous perennials and 3 ornamental grasses (Table 3). All plants were obtained from commercial nurseries in the area and arrived in #3 (11.4 L) and #1 (3.8 L) nursery containers. The *Baptisia*, *Cotoneaster*, *Deutzia* 'NCDX2'*, Diervilla*, and *Physocarpus* selections were planted in the larger 2.4m by 3.7. sub-plots. All other plant selections were planted in the smaller 2.4m by 1.8m subplots

Site Management

Weed Control

To reduce competition from weeds, each planting site was treated with a pre-emergent herbicide (Snapshot 2.5 TG Dow Agrosciences, Indianapolis, IN) at 7.5 ml m^{-2} after compost application and before mulching according to MDOT 2012 Standard Specifications for Construction. This application was repeated in the spring of 2019. We were unable to apply pre-emergent herbicide in spring 2020 due Covid-19 travel restrictions. During the growing seasons, weeds were removed from each site by hand or by spray application of glyphosate (Prosecutor, Lesco, INC. Cleveland, OH) as a 2% a.i. solution.

Environmental Monitoring

Initial monitoring

After initial construction, a rain gauge (All-Weather Rain Gauge, Productive Alternatives, Fergus Falls, Mn) was installed on a 2 m tall post on the top of the slope in block five at the Warren location. We also installed a tipping bucket rain gauge and temperature sensor (Hobo RG3, Onset, Inc. Bourne MA) in this location. Near the roadside, a weatherproof temperature and relative humidity data logger (HOBO Pro V2, Onset, Inc., Bourne, MA) was installed.

MSU Enviroweather Station

During the summer of 2020 we installed two weather stations with the assistance of the MSU Enviroweather Team. One station was installed close to block one at the Roseville location approximately 4.5 meters from the roadside. The other station was installed between blocks five and six at the Warren location approximately 4.5 meters from the roadside. Each station was outfitted with a wind sentry set (model 03002-L, Campbell Scientific, Logan, UT), solar radiation sensor (model LI200x, LI-COR INC. 4647 Lincoln, NE), HygroVUE10 Temp/Rh sensor (model HygroVUE10, Campbell Scientific, Logan, UT), metric rain gauge (model TE525MM-L, Campbell Scientific, Logan, UT) and datalogger (model CR1000, Campbell Scientific, Logan, UT). In addition, each station was outfitted with four soil moisture sensors (model CS616, Campbell Scientific, Logan, UT) and four thermocouple probes (model 105T, Campbell Scientific, Logan, UT). At each location, soil moisture sensors and thermocouples were installed at 15 cm and 30 cm depths at locations within a research block and under the weather station. Soil temperature, soil moisture, solar radiation, air temperature, relative humidity, and total precipitation were logged every hour. Wind speed and temperature were logged every five seconds.

<u>Plant Evaluation</u>

Growth and Mortality

In 2019 we measured plant heights and plant widths in two perpendicular directions on all plants in June, July and October with a meter stick. Plant survival was also noted during this time. In August 2020 we measured plant height only as the crown of many plants had begun to overlap, making width determination impractical. We also assessed mortality and plant cover at this time. Plant cover was evaluated by visual estimation of percentage of plant cover within each sub-plot. Within a block, the same observer estimated plant cover.

Plant Nutrition

Foliar nutrition samples were collected from mature leaves on the upper third of each plant in a subsample of plant selections in the 2019 and 2020 growing seasons between June and July of each year. Within each main plot we collected foliar samples from Artic Sun® Red Twig Dogwood, Summer Wine® Ninebark, Show Off® Starlet Forsythia, Kodiak® Black Diervilla, Red Switch Grass, 'Happy Returns' Daylily, Bronze Veil Tufted Hair Grass. Due to resource limitations foliar samples were collected on a subsample of block 2 and 5 only for Six Hills Giant Nepeta, Halfway to Arkansas Narrow Leaf Blue Star, Slender Deutzia, Little Blue Stem, Sugar Shack® Buttonbush, Dwarf Bush Honeysuckle. All foliar samples were dried in an oven and sent to a commercial analytical laboratory (Waters Agricultural Lab, Camilla, GA) and were analyzed for nitrogen, phosphorus, potassium, magnesium, calcium, sulfur, boron, zinc, manganese, iron and copper concentration via inductively coupled plasma analysis.

Photosynthetic Gas Exchange

We measured photosynthesis and stomatal conductance on a sub-sample of selections in the Site Prep plots (Artic Sun® Red Twig Dogwood, Summer Wine® Ninebark , Sugar Shack® Buttonbush, 'Happy Returns' Daylily, and Red Switch Grass) using a portable photosynthesis system (LI-6400XT LI-COR INC, Lincoln, Nebraska USA). Four plants per sub-plot were measured in July and August of 2019 and 2020. We measured one fully expanded leaf in the upper third of the crown from each plant. These measurements were taken between 10 am and 2 pm. The settings for the portable photosynthesis system included 400 ppm CO_2 as the reference CO_2 and 1500 µmol PPFD. The measurements in 2019 occurred between 3 July and 11 July, and between 8 August and 20 August. In 2020 these measurements occurred between 7 July and July 14, and 5 August and 12 August. Stability of gas exchange readings was assessed by tracking photosynthetic rate, stomatal conductance and total CV using the Li-6400's real-time graphing feature. Readings were logged when net photosynthesis and conductance appeared stable and total CV was less than 5%, which was usually achieved within 1.0–1.5 min of placing leaves in the chamber.

Chlorophyll Content Index

Chlorophyll content index of Artic Sun® Red Twig Dogwood, Show Off® Starlet Forsythia, Summer Wine® Ninebark, Kodiak® Black Diervilla, Red Switch Grass, Halfway to Arkansas Narrow Leaf Blue Star, 'Happy Returns' Daylily and Bronze Veil Tufted Hair Grass were measured with a Chlorophyll meter (SPAD-502, Konica Minolta Sensing Americas, Inc, Ramsey, NJ). Six plants per subplot were measured in July and August of 2019, and in July of 2020. One fully expanded leaf from the upper crown of each was measured.

Leaf Water Potential

Mid-day Leaf water potential (Ψ_l) of Summer Wine® Ninebark and Sugar Shack® Buttonbush was measured using a portable pressure chamber (Model 1000, PMS Instrument Company, Albany, OR). The measurements in 2019 occurred between 3 July and 11 July, and between 8 August 8 and 20 August. In 2020 these measurements occurred between 7 July and 14 July, and 5 August and 12 August. This data was collected between 10:00 and 14:00 h. Within each sub-plot, three mature leaves were selected randomly from three different plants. Water potential sampling was limited to two selections due to time and logistical constraints. We did not collect pre-dawn water potential readings due to safety considerations of working in darkness on steep slopes near the freeway roadside.

Soil Evaluation

During each growing season soil samples were collected in each main plot and evaluation plot. Before collection, mulch and compost top-dressing were removed from each sampling area. Using a soil sample probe we took 5 to 7 samples from various locations within each plot at approximately 15 cm depth. Samples from each plot were combined, dried in an oven to a constant weight, and sent to a commercial analytical laboratory for nutrient analysis (Waters Agricultural Lab, Camilla, GA). Samples were analyzed for available Phosphorus, exchangeable potassium, magnesium, calcium, zinc, manganese, iron, copper, and boron, soil pH, Cation Exchange Capacity (CEC), and Percent Base Saturation of cation elements. Elements were extracted by the Mehlich-3 extraction method and analyzed via inductively coupled plasma analysis. In addition to this, bulk density samples were taken in both 2019 and 2020 using a 143 cm^3 bulk density ring. Before sampling, any mulch was removed from the soil surface. In July of both years, one bulk density sample was collected from the soil surface of each main plot. In 2019 an additional sample was taken from each main plot 15 cm below the soil surface. All bulk density samples were then dried in an oven and weighed.

Statistical Analysis

Data were analyzed using SAS version 9.4 software. PROC MIXED was used to conduct an analysis of variance (ANOVA) for all variables, and tested the effects of site location, compost, tillage. The main plot factors (compost and tillage) were analyzed as 2 × 2 factorial. Block, and subplot effects were treated as random factors. Soil nutrition and bulk density were analyzed for main effects only. Plant coverage, and foliar nutrition were analyzed as sub-plot means. Plant growth, photosynthetic rate, chlorophyll content, and water potential were analyzed at the individual plant level. Means separation using Tukey's HSD was performed in the LSMEANS prompt of PROC MIXED.

Results

Site Prep Experiment

Plant Coverage

Among main plot effects, compost affected plant coverage more than tillage. Compost treatments increased plant coverage for shrub ($p \leq 0.05$) and perennial ($p \leq 0.001$) groups (Table 1.3), whereas tillage did not affect cover for either plant group. Species x Compost interaction reflected increased coverage for *Cornus*, *Forsythia*, and *Diervilla* selections (Figure 1.9) and *Amsonia*, *Chleone*, *Hemerocallis* and *Nepeta* selections in response to compost. (Figure 1.10). All other species had no observable effects that could be attributed to compost treatment. Differences in coverage between locations were observed in certain shrub ($p \leq 0.05$) and perennial ($p \leq 0.001$) species (Table 1.3). The *Cephalanthus*, *Cornus*, *Physocarpus,* and *Diervilla* selections all had greater plot coverage at the Warren site (Figure 1.10). Tillage had no effect on plant cover of most species, and did not have any interaction effects (Table 1.3). Sub-plots with *Diervilla lonicera* had less coverage in tilled treatments. Increases in coverage were observed for the *Deschampsia* and *Carex* selections in tillage treatments ($P \leq 0.05$). *Cephalanthus*, *Physocarpus*, *Diervilla rivularis*, *Diervilla lonicera*, *Amsonia, Hemerocallis, Nepeta*, and *Panicum* had over 50% average plot cover in composted treatments.

Plant Growth

Compost increased overall plant height of both groups of plants in both 2020 (P≤0.05) and 2019 (P≤0.001), however effects varied between species and years (Table 1.3). In both years, compost addtition resulted in increased growth of *Cornus, Forsythia,* and both *Diervilla* selections that were grown in a compost treatment (P≤0.05) (figure 1.11). Tillage did not increase average plant height or have any overall effect for most species in the shrub group in both years. The only observable effects tillage had on plant growth was decreased average height of *Baptisia* in 2019 (P≤0.05) and increased average height in *Diervilla lonicera* in 2020 (P≤0.05). As with the shrubs, compost increased overall plant height of grasses and perennials in both 2019 (P≤0.001) and 2020 (P≤0.05). Compost increased mean plant height of *Panicum*, *Nepeta*, *Hemerocallis* and *Chleone* in 2020 (P≤0.05) when compared to those planted in non-compost treatments (Figure 13). Compost treatments increased the average heights of *Panicum*, *Schizachrium*, and *Chelone* in 2019 (P≤0.05). Tillage did not affect the overall growth of shrubs, perennials or grasses in either year. However, the average height of *Carex* in tillage treatments was greater in 2019 (P≤0.05). Location did not affect overall plant height in either year. The only plant selection affected by location was *Carex* which was taller at the Warren location (p≤0.05) in both years (Figure 1.12).

Plant Survival

Location affected survival of shrubs in 2019 (≤0.05), but not in 2020 (Table 1.3). In general, shrubs in Roseville had a higher rate of survival than those in Warren. Compost by itself had no overall effects on the survival of shrubs in 2019, but in increased rates of survival (p≤0.05) of shrubs in 2020 (Figure 1.13). Compost and location interactions were observed

($p \leq 0.05$) in 2019 and 2020 (Table 1.3). However there does not seem to be a clear trend. *Baptisia* in Roseville had increased survival with no compost but decreased survival with compost in Warren (Figure 1.13). Similarly, *Forsythia* in non-composted treatments located in Warren had lower rates of survival ($p \leq 0.05$) than those in either treatment in Roseville or those in composted treatments in Warren (Figure 1.13). Tillage negatively affected survival of *Baptisia* and *D. Lonicera*, but positively affected *Forsythia*.

Compost generally had a positive effect on survival of perennials in 2019 ($p \leq 0.001$), but did not affect survival in 2020 (Table 1.3). *Chelone* survival was greater in composted treatments in both years ($p \leq 0.05$) (Figure 1.14). *Panicum* and *Deutzia* did not benefit from compost treatments, as their survival rates in compost treatments were lower in 2020 ($p \leq 0.05$) (Figure 1.14). Plant survival in response to compost varied by location ($p \leq 0.05$). In Warren, the first year survival of *Nepeta* and *Chleone* in composted treatments was higher ($p \leq 0.05$) than those without compost. *Carex* in non-composted treatments in Roseville had lower survival ($p \leq 0.05$) than all other groups. Tillage had no overall effect by itself in perennial survival rates, but Deutzia in treatments with soil tillage had reduced ($p \leq 0.05$) survival in 2019. Tillage and location interactions existed in 2019. When in tilled treatments, *Carex* had a much lower survival rate ($p \leq 0.05$) in Roseville than in Warren in both years. *Carex* in untilled treatments had similar survival rates in both years. Location effects in 2019 were also seen in the perennial group ($p \leq 0.001$) (Table 1.13). However, different species had higher rates of survival at different locations. *Carex* and *Deutzia* had increased overall survival in Warren ($p \leq 0.05$), *Panicum, Chleone,* and *Schizachrium* had increased survival in Roseville ($p \leq 0.05$) (Figure 1.15).

Foliar Nutrition

In both years, compost application increased foliar nitrogen, phosphorus, potassium, calcium and magnesium, regardless of tillage (Tables 1.7 and 1.8). In general, compost did not influence any other micronutrient concentrations. The only observed differences in micronutrients concentrations were for *Amsonia, Forsythia* and *Diervilla* selections. In 2019, compost treatments increased foliar Cu concentrations in *Forsythia* and *Diervilla* (Table 1.6). *Amsonia* in compost treatments had decreased levels of Zn in 2020. Tillage decreased overall foliar iron content in 2020, these differences were significant ($p \leq 0.05$) in *Hemerocallis* (Table 1.8).

Chlorophyll Content

Overall, compost increased SPAD chlorophyll index (≤ 0.001) in both years. In 2019, SPAD values from *Amsonia*, *Diervilla*, *Hemerocallis*, and *Panicum* were higher in compost treatments ($p \leq 0.05$). There was an overall compost and tillage interaction in 2019. The addition of tillage treatment decreased chlorophyll content in *Diervilla* and *Hemerocallis* selections ($p \leq 0.05$) even if these plants were treated with compost. Tillage and location effects were not significant in either year. In 2020, compost treatments increased the SPAD values of *Cornus*, *Diervilla*, *Hemerocallis*, *Forsythia*, *Panicum*, and *Physocarpus* ($P \leq .05$).

Photosynthesis and Conductance

Site preparation treatments did not affect the photosynthetic rate of the *Cornus, Cephalanthus, Hemerocallis,* and *Physocarpus* selections in 2019. In July of 2020, *Cornus* and *Cephalanthus* selections showed lower rates of photosynthesis when in compost treatments. The photosynthetic rates of these two species were also affected by location, but exact effects varied by species. *Cephalanthus* plants in Warren had higher photosynthetic rates in August of 2020 while *Cornus* plants in Roseville had higher rates in July of 2020.

Water Potential

Compost and tillage did not affect ($p \leq 0.05$) water potential (Ψ_l) in *Cephalanthus* plants. Compost treatment decreased midday Ψ_l in *Physocarpus*, however compost treatment did not have any other negative effects for this species (Figure 1.16). Location also affected midday Ψ_l of both species as plants in Warren had higher midday Ψ_l than plants in Roseville in both years ($P \leq 0.05$) (Figure 1.17).

Soil Properties

Soils in the composted treatments had improved soil nutrition. Soils treated with compost had increased phosphorus and potassium in both 2019 ($P \leq 0.001$) and 2020 when compared to those that were not treated with compost (Table 1.4). In addition to this, compost reduced soil pH in both 2019 ($P \leq 0.001$) and 2020 ($P \leq 0.001$). Application of compost also increased other soil nutrients such as magnesium, boron, zinc, manganese, iron and copper (Tables 1.4). Site preparation treatments did not affect calcium content of the soils at either site. Tillage had no effect on soil nutrient content.

Soil bulk density taken at the soil surface (0-15 cm) in 2019 was decreased in composted treatments and was not affected by tillage or location. Tillage, compost and location did not affect soil bulk density taken 15 cm below the soil surface. Soil bulk density taken at the surface decreased in all treatments in 2020, but was unaffected by compost, tillage or location (Table 10). Compost application resulted in lower soil pH values in both years ($P \leq 0.001$) (Figure 1.18).

All site preparation treatments had lower pH in 2020 than in 2019 (Figure 20). Tillage had no effect on soil pH in either year. Compost treatments increased soil CEC in 2019 ($P \leq 0.05$) and 2020 ($P \leq 0.001$) (Figure 1.18). In 2020, tillage treatments decreased CEC when compared to untilled treatments ($P \leq 0.05$), this effect was not seen in 2019.

<u>Supplemental Plant Evaluation Experiment</u>

Growth and Coverage

Data from the supplemental plant evaluation blocks were combined with those from the comparable treatment in the site preparation study (Compost + Tillage) in order to develop an overall evaluation of all selections studied. Survival of all eight ornamental grass species was lower in 2020 than in 2019 (table 1.5). Only one grass species, *Panicum virgatum* 'Rostrahlbush', had greater than 60 percent plot coverage (Figure 1.19). Survival of perennials remained relatively steady between the two years (table 1.5). The exception was *Deutzia gracilis* 'Nikko' as the average survival rate decelined from 83 percent to 28 percent (Table 1.5). Perennials with 60% average coverage were Nepeta, *Amsonia hubrichtii*, *Hemerocallis* 'Stella de Oro' and *Hemerocallis* 'Happy Returns' (Figure 1.19). Shrub survival rates were high overall and similar between both years (Table 1.5). The shrub group had the most selections with 60% or greater coverage. These include *Diervilla sessilfolia* 'Butterfly', *Diervilla rivularis* 'Kodiak Black', *Diervilla rivularis* 'Kodiak Orange', *Physocarpus opulifoluis* 'Summer Wine', *Cephalanthus* and *Cotoneaster* (Figure 1.19).

The Urban Microclimate

Comparing North and South Aspects

Site differences soil moisture, soil temperature, solar radiation, and relative humidity between the two sites between August 2020 and February 2021 were relatively small. For most of this period, monthly precipitation totals were similar between the two sites. Between October and December 2020, the Warren site had warmer average air temperatures than Roseville.

Roadside climates vs non roadside climates

Monthly average and maximum temperatures at the Warren site were most often higher than those at the Detroit city airport between July 2018 and February 2021 (Tables 15, and 16). During the summer months, maximum extreme temperatures at the roadside were often higher than those observed at the airport.

Distance from the roadside

Temperatures at the top of the roadside slope and the roadside in Warren showed differences in temperature extremes during the fall and winter months. Minimum temperatures at the top of the slope were much cooler than those by the roadside. Maximum temperatures by the roadside remained consistently higher than temperatures at the top of the slope between September 2019 and February 2020.

Discussion

Proper site preparation and plant selection are two factors that are critical to a successful plant establishment in roadside environments (Brown and Gorres, 2011;

Mohammadshirazi et al., 2017; Weston and Eom, 2008). Often, urban soils are compacted and have little plant available nutrients (Craul, 1985). Past studies suggest application of compost improves soil nutrition, and can improve overall soil quality when incorporated into the soil which improves plant establishment and results in increased plant growth (Brown and Gorres, 2011; McGrath et al., 2020; Mohammadshirazi et al., 2017). Tilling roadside soils reduces soil bulk density, allowing more water infiltration, increased stormwater capture and increased root growth (Alberty et al., 1984; Mohammadshirazi et al., 2017; Rivers et al., 2021). In our study, we hypothesized that both tillage and compost would improve plant establishment, and that when these two treatments were combined their effects would be additive. However, we observed that compost was the main factor that affected plant establishment and growth. Tillage and the interaction of compost and tillage had little to no effect on plant performance.

Effects of Compost

Compost was beneficial to overall plant growth and plant coverage for both shrubs and perennials. We observed that plants that covered over 50% of the subplot often had little to no issues with weed competition. Increased ground coverage and dense canopies allows plants to out-compete weed species, which can reduce costs associated with weed control (Eom et al., 2005; Weston and Eom, 2008). McGrath and Henry (2016) attributed the success of plants in compost-amended soil to lowered soil bulk density. In 2019, we observed decreased soil surface bulk density in both the compost only, and compost and tillage treatments. However, compost application did not affect surface bulk density from 2020. Based on previous work, we hypothesized that compost would improve plant establishment by reducing plant moisture stressed and improving soil nutrition. While we observed some increases in water stress in

Physocarpus opulifolius ‘Seward’ that were planted in the compost treatments, this did not affect overall plant establishment, growth, or aesthetics. Increases in plant growth and plant coverage can most likely be attributed to the increased soil nutrition that resulted from compost application. Soils with compost contained more phosphorus, potassium, magnesium, boron, zinc, manganese, iron and copper than soils without compost. These increases in nutrients were reflected in foliar nutrition in both years. In addition, compost application resulted in lower soil pH, which allows more nutrients contained in the soil to become available to the plants (Fernández and Hoeft, 2009). The chlorophyll content analysis also provides evidence for improved foliar nutrition. Plants in compost treatments had higher SPAD values than those without.

While compost benefit was seen in this study, it is possible that the benefits can be maximized with proper application levels, techniques, and quality. The type and quality of organic amendments used in roadside plantings can also influence the nutritional benefit compost provides. Brown and Gorres (2011) found that turfgrass treated with biosolids created from treated sewage had increased ground coverage than turfgrass treated with compost made from municipal yard waste.

Effects of Tillage

Tillage did not influence overall plant survival, plant coverage or plant growth. When tillage effects existed in certain species, it was often negative. For example, Diervilla *lonicera* ‘Michigan Sunset’, *Duetzia gracillis* ‘Nikko’ and *Baptisia australis* had lower rates of survival when planted in tillage treatments than those in untilled treatments. *Carex pensylvanica* was the only species that benefited from tillage treatment. Incorporating compost into the soil via compost did not change any soil properties. Since there is no overall benefit, soil tillage cannot be recommended at this site at this time. Similar to our study, Bary et al. (2016) observed that while incroporating organic material into the soil reduced soil bulk density below the surface, there were not any signifigant benefits to plant survival.

While we did not see any benefit to incorporating compost with tillage, others have concluded that incorporation of compost into the soil via tillage reduces soil bulk density and reduces future soil compaction (Mohammadshirazi et al., 2017). Similar to our study, Mohammadshirazi et al. incorporated compost created from municipal yard waste with a rotary tiller. Mohammadshirazi et al (2017) observed that in roadside sites with sandy clay or clay loam soil, plots that were tilled to a 30 cm depth and had compost incorporated into the soil had reduced bulk densities when compared to the plots that had received the tillage only or control treatments. These differences were observed for over two years. Different tillage methods have also produced long term benefits for soil and plant health. Siedt et al. (2021) observed long term improvements to urban soils using the scoop and dump method, where top 45 cm of the soils were fractured and amended with compost using a backhoe. McGrath et al. (2020) tilled soil by deep ripping to a depth of 0.9 m, which resulted in varying levels of benefits to plants depending on the amount of compost added. In that study, amending the soil with 25% compost by volume resulted in the most benefit for tree establishment and growth (McGrath et al., 2020). It is possible that a deeper tillage depth, alternate techniques, or incorporating greater amounts of compost could benefit our study site.

Soil type may also be a factor in the magnitude of tillage effects. The sites used in the study by Bary et al. (2016) had a gravelly sand texture, and bulk density reduction was observed with the tillage depth was only 15 cm. Mohammadshirazi et al (2017) did not see any differences between the soil bulk density of tilled an untilled treatments at their mountain site after 30 months. The mountain site had soil that was a silty clay loam texture.

Location Effects

Several shrub selections planted in the Warren site had greater ground coverage than those in Roseville. *Physocarpus opulifolus* also planted in Warren had decreased water stress. In addtion, *Carex pensylvanica* planted in Warren were taller on average than those planted in Roseville. There are a few reasons that could explain this phenomenon. Plants in Warren were located on a north aspect, where as plants in Roseville were on a south aspect. The Warren location had warmer monthly average temperatures than the Roseville location between October 2020 and December 2020. It is likely the differences in plant performance between the two sites are at least in part a result of different planting times and any location effects seen in this study are confounded with planting date. The research blocks in Warren were planted in June of 2018. Plants for the Roseville site remained in a temporary nursery site due to construction delays and were not planted until October of 2018. It is possible that since the Warren plants were planted earlier, they had more time to establish roots before the winter. The plants reserved for the Roseville may have been subjected to more stress while in the containers than if they had been planted immediately.

Plant Selection

We evalauted plant coverage and survival for 32 plant selections in this study. Fifteen species had both high average rates of survival and high amounts of average plant coverage. Shrubs that were most successful in this study based on plant coverage and survival were

Physocarpus opulifolius ‘Seward’, *Physocarpus opulifolius* ‘SMPOTW’, *Diervilla lonicera* ‘Copper’, Diervilla rivularis ’SMNDRSF’, *Diervilla* ‘G2X885411’, *Diervilla* ‘G2X88544’, *Diervilla sessilifolia* ‘Butterfly’, *Cotoneaster dammeri* 'Coral Beauty' and *Cephalanthus occidentalis* ‘SMCOSS’. Perennials that were successful in this study were *Nepeta* x *faassenii* ‘Six Hills Giant’, *Hemerocallis* ‘Happy Returns’, *Hemerocallis* ‘Stella De Oro’, *Amsonia hubrichtii* ‘Halfway to Arkansas’, *Panicum virgatum* ‘Rotstrahlbush’, *Allium tanguticum* ‘Noneuq’, *Allium tanguticum* ‘Summer Beauty’. All the mentioned plant selections would be good choices for roadside plantings in Michigan.

Conclusion

Diverse roadside plantings improve air quality, provide habitat for pollinators and reduce the urban heat island effect (Baldauf, 2017; Barwise and Kumar, 2020; Hopwood, 2008; Shashua-Bar et al., 2009). The results of this study indicate that compost is more beneficial to plant establishment and growth than tillage. Based on these results, the optimum site preparation treatment is to apply a 10 cm top-dress of compost, which is the current MDOT specification. For benefits to be observed, compost needs to be applied in proper amounts. Inspections of the original I-696 plantings revealed that compost had been applied to depths up to 30 cm. Because of this observation, it is important that these plantings are inspected during and after construction to ensure that all plantings are meeting the standards set by the client. Plant selection is another important factor in the success of roadside plantings. We observed that most of the shrubs in this study had high rates of survival and ground coverage. Perennials and ornamental grasses with dense foliage and a spreading habit were successful as well.

The results of this study open more research questions. Since most of the compost benefit appears to be a result of increased nutrition, it is possible that simply adding chemical fertilizer could provide similar benefits. Additionally, application different organic amendments, like biosolids or biochar, could influence plant growth and establishment. The effect of slope aspect is also another topic that warrants further study. We did observe some location effects on plant ground cover, water stress, and air temperature, but since slope aspect was confounded with location and planting date, formal conclusions about slope aspect cannot be made.

APPENDICIES

APPENDIX A

Table 1.1: Plant selections planted in the site preparation experiment near Detroit, MI.

Scientific name	Common name	Plant Type	Plants per subplot	Container size
Cephalanthus occidentalis 'SMCOSS'	Sugar Shack® Buttonbush	Shrub	6	#3
Cornus sanguinea 'Cato'	Artic Sun® Red Twig Dogwood	Shrub	6	#3
Deutzia gracilis 'Nikko'	Slender Deutzia	Shrub	9	#3
Diervilla lonicera 'Michigan Sunset'	Dwarf Bush Honeysuckle	Shrub	6	#3
Diervilla rivularis 'SMNDRF'	Kodiak® Black Diervilla	Shrub	6	#3
Forsythia x 'Minfor6'	Show Off® Starlet Forsythia	Shrub	6	#3
Physocarpus opulifolius 'Seward'	Summer Wine® Ninebark	Shrub	6	#3
Carex pensylvanica	Pennsylvania Sedge	Grass	9	#1
Deschampsia cespitosa 'Bronzeschleier'	Bronze Veil Tufted Hair Grass	Grass	9	#1
Panicum virgatum 'Rotstrahlbush'	Red Switch Grass	Grass	9	#1
Schizachyrium scoparium 'The Blues'	Little Blue Stem	Grass	9	#1
Baptisia australis	Blue False Indigo	Perennial	6	#1
Chelone lyonii 'Hotlips'	Hot Lips Turtle Head	Perennial	9	#1
Hemerocallis 'Happy Returns'	Happy Returns Daylily	Perennial	9	#1
Nepeta x *faassenii* 'Six Hills Giant'	Six Hills Giant Nepeta	Perennial	9	#1
Amsonia hubrichtii 'Halfway to Arkansas'	Halfway to Arkansas Narrow Leaf Blue Star	Perennial	9	#1

Table 1.2: Plant selections planted in the supplemental plant evaluation experiment near Detroit, MI.

Scientific name	Common name	Plant Type	Plants per subplot	Container size
Cotoneaster dammeri 'Coral Beauty'	Bearberry Cotoneaster	Shrub	6	#3
Deutzia gracilis 'Duncan'	Chardonnay Pearls® Deutzia	Shrub	6	#3
Deutzia 'NCDX2'	Yuki Cherry Blossom® Deutzia	Shrub	6	#3
Diervilla sessilifolia 'Butterfly'	Southern Bush-honeysuckle	Shrub	9	#3
Diervilla 'G288544'	Kodiak® Orange Diervilla	Shrub	6	#3
Diervilla 'G2X885411'	Kodiak® Red Diervilla	Shrub	6	#3
Physocarpus opulifolius 'SMPOTW'	Tiny Wine® Ninebark	Shrub	6	#3
Carex vulpinoidea	Fox Sedge	Grass	9	#1
Deschampsia cespitosa 'Goldstaub'	Goldstaub Tufted Hair Grass	Grass	9	#1
Panicum virgatum 'Shenandoah'	Shenandoah Switch Grass	Grass	9	#1
Schizachyrium scoparium 'Jazz'	Jazz® Little Blue Stem	Grass	9	#1
Allium tanguticum 'Balloon Bouquet'	Balloon Bouquet Ornamental Chive	Perennial	9	#1
Allium tanguticum 'Summer Beauty'	Summer Beauty Ornamental Chive	Perennial	9	#1
Baptisia 'Solar Flare'	Solar Flare Prairieblues™ Indigo	Perennial	6	#1
Hemerocallis 'Stella de Oro'	Stella de Oro Daylily	Perennial	9	#1
Amsonia tabemontana	Blue Star	Perennial	9	#1

Table 1.3: Summary of analysis of variance (p values) for plant cover, survival and plant growth of shrubs, herbaceous perennials and grasses planted at two locations along an urban freeway near Detroit, MI.

Shrubs

		Cover	Plant survival		Total height	
Source	df	2020	2019	2020	2019	2020
Location (L)	1	≤0.05	≤0.05	ns	≤0.05	≤0.05
Compost (C)	1	≤0.05	ns	≤0.05	≤0.001	≤0.05
Tillage (T)	1	ns	ns	ns	ns	ns
C x T	1	ns	ns	ns	≤0.05	ns
L x C	1	ns	≤0.05	≤0.05	ns	ns
L x C x T	1	ns	ns	ns	ns	ns
Species (S)	6	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001
S x C	6	≤0.05	ns	ns	≤0.001	≤0.001
S x T	6	ns	ns	≤0.05	≤0.05	≤0.001
L x S	6	≤0.05	ns	ns	≤0.001	≤0.001
S x C x T	6	ns	ns	ns	ns	ns
L x C x S	6	ns	ns	ns	≤0.05	ns
L x T x S	6	ns	ns	ns	ns	ns
L x T x C x S	6	ns	ns	ns	ns	≤0.05

Grasses and herbaceous perennials

		Cover	Plant survival		Total height	
Source	df	2020	2019	2020	2019	2020
Location (L)	1	ns	ns	ns	≤0.05	ns
Compost (C)	1	≤0.05	≤0.001	ns	≤0.001	≤0.05
Tillage (T)	1	ns	ns	ns	ns	ns
C x T	1	ns	ns	ns	≤0.01	ns
L x C	1	0.05	ns	ns	ns	ns
L x T	1	ns	ns	ns	ns	ns
L x C x T	1	ns	ns	ns	≤0.05	ns
Species (S)	8	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001
S x C	8	≤0.001	ns	≤0.001	≤0.05	≤0.001
S x T	8	≤0.05	≤0.05	ns	≤0.05	ns
L x S	8	≤0.001	≤0.001	≤0.001	≤0.001	ns
S x C x T	8	ns	ns	ns	ns	ns
L x C x S	8	≤0.05	≤0.05	ns	ns	≤0.05
L x T x S	8	ns	≤0.05	≤0.05	≤0.05	ns
L x C x T x S	8	ns	ns	ns	ns	ns

Table 1.4: Mean soil nutrient concentrations from 2019. Means within the same column that are followed by the same letter are not significantly different at P≤0.05 level.

	2019 Soil Nutrients								
Site prep trt	P (Kg ha-1)	K (Kg ha-1)	Mg (Kg ha-1)	Ca (Kg ha-1)	B (Kg ha-1)	Zn (Kg ha-1)	Mn (Kg ha-1)	Fe (Kg ha-1)	Cu (Kg ha-1)
Control	33.44 b	424.11 b	876.06 b	12517.84 a	2.72 b	21.83 b	179.92 a	505.01 a	17.24 a
Tillage only	42.78 b	418.13 b	782.83 b	11864.85 a	3.06 b	24.02 b	163.3 a	530.42 a	16.89 ab
Compost only	384.87 a	1248.79 a	1623.77 a	12397.14 a	6.13 a	48.6 a	107.62 b	503.89 a	12.61 ab
Compost and tillage	283.8 a	1384.63 a	1503.63 a	12566.04 a	6.13 a	43.75 a	118.83 b	524.07 a	10.09 b
	2020 Soil Nutrients								
Site prep trt	P (Kg ha-1)	K (Kg ha-1)	Mg (Kg ha-1)	Ca (Kg ha-1)	B (Kg ha-1)	Zn (Kg ha-1)	Mn (Kg ha-1)	Fe (Kg ha-1)	Cu (Kg ha-1)
Control	36.62 c	322.66 b	733.32 c	11327.71 a	3.39 b	23.06 b	200.10 a	469.89 a	6.87 a
Tillage only	36.24 c	391.04 b	626.27c	11056.61 a	3.06 b	21.94 b	185.53 a	450.45 a	9.55 a
Compost only	506.32 a	964.43 a	1719.80 a	12641.15 a	6.93 a	47.62 a	116.02 b	495.48 a	14.26 b
Compost and tillage	309.03 b	982.19 a	1304.84 b	11227.75 a	5.77 a	41.01 a	119.02 b	494.17 a	16.23 ab

Means separation done by Tukey’s HSD at the P≤0.05 level

Table 1.5: A comparison of the survival rates of perennial selections from the site preparation experiment, and the supplemental plant evaluation experiment. Survival rates of selections from the site preparation experiment were calculated from the compost and tillage treatment only.

	Survival Rate		
Species	Experiment group	2019	2020
Amsonia hubrichtii 'Halfway to Arkansas'	Site Preparation	100.0	100.0
H. 'Stella de Oro'	Plant Evaluation	100.0	100.0
Hemerocallis 'Happy Returns'	Site Preparation	100.0	100.0
Deschampsia cespitosa 'Bronzeschleier'	Site Preparation	100.0	98.2
Chelone lyonii 'Hotlips'	Site Preparation	94.4	92.6
Panicum virgatum 'Rotstrahlbush'	Site Preparation	100.0	90.7
Allium tanguticum 'Summer Beauty'	Plant Evaluation	94.4	88.9
Nepeta x *faassenii* 'Six Hills Giant'	Site Preparation	87.0	88.9
Amsonia tabemontana	Plant Evaluation	94.4	87.0
Deutzia gracilis 'Duncan'	Plant Evaluation	100.0	79.6
Allium tanguticum 'Balloon Bouquet'	Plant Evaluation	87.0	77.8
Panicum virgatum 'Shenandoah'	Plant Evaluation	100.0	68.5
Schizachyrium scoparium 'The Blues'	Site Preparation	83.3	68.5
Deschampsia cespitosa 'Goldstaub'	Plant Evaluation	100.0	61.1
Carex vulpinoidea	Plant Evaluation	81.5	53.7
Carex pensylvanica	Site Preparation	59.3	44.4
Deutzia gracilis 'Nikko'	Site Preparation	83.3	27.7
Schizachyrium scoparium 'Jazz’	Plant Evaluation	40.7	24.1

Table 1.6: A comparison of the survival rates of shrub selections from the site preparation experiment, and the supplemental plant evaluation experiment. Survival rates of selections from the site preparation experiment were calculated from the compost and tillage treatment only.

		Survival Rate	
Species	Experiment group	2019	2020
Diervilla sessilifolia 'Butterfly'	Plant Evaluation	100.0	100.0
Cotoneaster dammeri 'Coral Beauty'	Plant Evaluation	100.0	100.0
Diervilla rivularis 'SMNDRF'	Site Preparation	97.2	97.2
Physocarpus opulifolius 'SMPOTW'	Plant Evaluation	97.2	97.2
Physocarpus opulifolius 'Seward'	Site Preparation	97.2	97.2
Cephalanthus occidentalis 'SMCOSS'	Site Preparation	97.2	97.2
Cornus sanguinea 'Cato'	Site Preparation	100.0	97.2
Forsythia x 'Minfor6'	Site Preparation	97.2	97.2
Diervilla 'G288544'	Plant Evaluation	100.0	93.1
Deutzia 'NCDX2'	Plant Evaluation	100.0	91.7
Diervilla 'G2X885411'	Plant Evaluation	100.0	90.0
Diervilla lonicera 'Michigan Sunset'	Site Preparation	88.9	80.6
Baptisia 'Solar Flare'	Plant Evaluation	97.2	75.0
Baptisia australis	Site Preparation	72.2	58.3

Table 1.7: Foliar nutrition results of plants in compost treatments and plants in treatments without compost in 2019. "*" indicates that means are significantly different at P≤0.05.

		2019									
Species	Compost	N (%)	P (%)	K (%)	Mg (%)	Ca (%)	B (ppm)	Mn (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)
Amsonia	N	1.51*	0.14	1.10*	0.35	1.31*	98.64*	409.55*	232.18*	300.45	6.45
	Y	2.03	0.19	1.45	0.33	0.99	167.83	345.25	164.83	252.50	5.92
Cornus	N	2.13*	0.33	1.04*	0.64*	3.11*	38.33*	24.58	19.25	99.83	6.50
	Y	2.41	0.32	1.39	0.73	2.63	61.42	19.92	18.75	103.92	7.08
Deschampsia	N	1.97*	0.24	1.83*	0.26	0.69	13.83	96.67*	38.75	189.17	7.58
	Y	2.24	0.31	2.07	0.26	0.63	19.75	48.17	39.83	161.50	8.50
Diervilla	N	1.58*	0.51*	1.10*	0.34	1.40*	54.17*	35.33	71.92*	133.67	3.75*
	Y	2.03	0.63	1.70	0.33	1.09	92.67	32.67	96.92	124.83	5.33
Forsythia	N	1.44*	0.23*	1.27*	0.25	1.00*	34.73	124.00*	22.27	85.64	5.36*
	Y	2.07	0.33	1.76	0.27	0.78	41.27	84.45	27.09	93.45	12.91
Hemerocallis	N	1.61*	0.19	1.86*	0.39*	1.82*	32.25	50.17	37.92*	379.42	4.75
	Y	2.29	0.37	2.77	0.44	1.50	38.17	42.92	57.00	404.17	5.17
Physocarpus	N	1.41*	0.23	0.90*	0.35	1.34*	24.67	28.33	23.92	188.67	5.42
	Y	1.71	0.24	1.16	0.35	1.06	24.25	19.67	26.25	185.25	5.83
Panicum	N	1.49*	0.12*	1.20	0.14	0.50	10.27	20.45	16.55	145.45	5.91
	Y	1.82	0.16	1.38	0.17	0.45	16.00	18.82	18.73	134.55	6.91

Table 1.8: Foliar nutrition results of plants in compost treatments and plants in treatments without compost in 2020. “*” indicates that means are significantly different at P≤0.05.

		2020									
Species	Compost	N (%)	P (%)	K (%)	Mg (%)	Ca (%)	B (ppm)	Mn (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)
Amsonia	N	1.58*	0.14	1.33*	0.29	1.02*	80.45*	226.09*	142.18*	156.45	4.82
	Y	1.95	0.20	1.26	0.30	0.85	92.50	108.42	90.83	173.00	5.50
Cornus	N	1.99*	0.29	1.32	0.57	2.68*	38.55	23.55	20.18	83.27	6.82
	Y	2.37	0.31	1.31	0.59	2.26	42.58	21.33	19.25	82.58	6.92
Deschampsia	N	1.69*	0.34	1.50	0.31	1.08	31.92	35.67	50.17	176.83	7.42
	Y	1.90	0.39	1.56	0.32	1.03	41.33	26.42	53.08	189.83	8.25
Diervilla	N	1.64*	0.37	1.28	0.37	1.22	56.36	29.00	78.18	128.09	4.64
	Y	2.15	0.41	1.26	0.34	1.07	63.83	23.83	73.42	138.83	6.08
Forsythia	N	1.83*	0.24	1.60	0.25	0.88	39.33	66.83*	32.25	81.50	15.08*
	Y	2.07	0.27	1.55	0.28	0.76	40.00	42.67	33.42	90.67	17.50
Hemerocallis	N	1.74*	0.24*	2.15*	0.32*	1.53	62.42	32.17	42.42	383.42*	6.17
	Y	2.23	0.35	2.19	0.38	1.50	65.00	34.58	39.08	268.67	6.00
Physocarpus	N	1.75*	0.21*	1.20	0.33	1.19	42.67	24.25	27.33	147.67	8.83
	Y	2.20	0.27	1.20	0.36	1.07	40.33	25.50	29.58	164.50	9.75
Panicum	N	1.57*	0.20*	1.72*	0.19*	0.78	24.50*	18.42	25.50	180.58	6.25
	Y	1.98	0.29	1.68	0.26	0.80	45.11	19.67	28.89	138.11	6.56

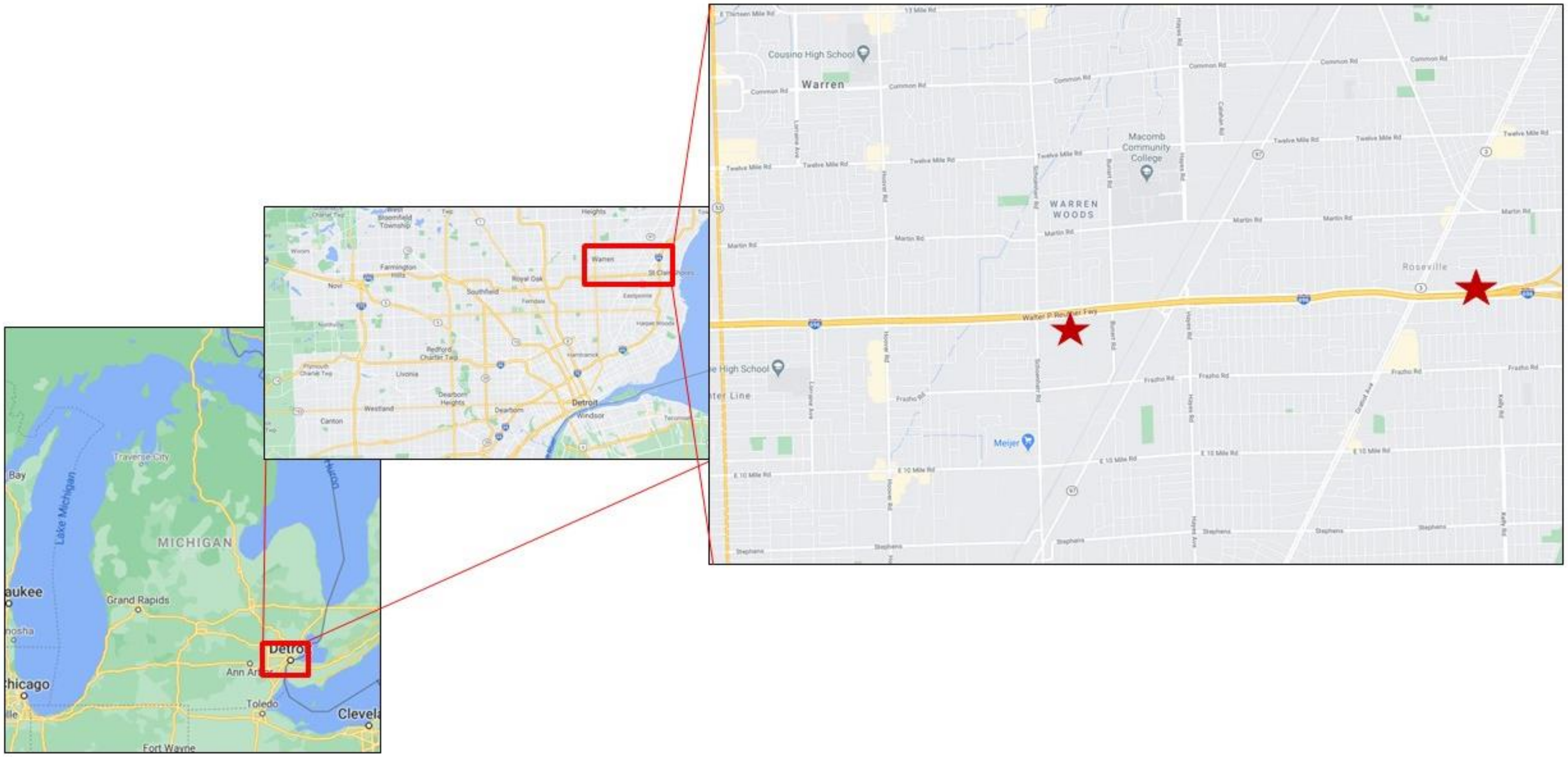


Figure 1.1: Inset maps depicting the locations of the two study sites in the greater Detroit, MI metropolitan area.

Figure 1.2: Photo indicating location of blocks at the Roseville site along I-696. Blocks with an “A” are the plant evaluation plots.

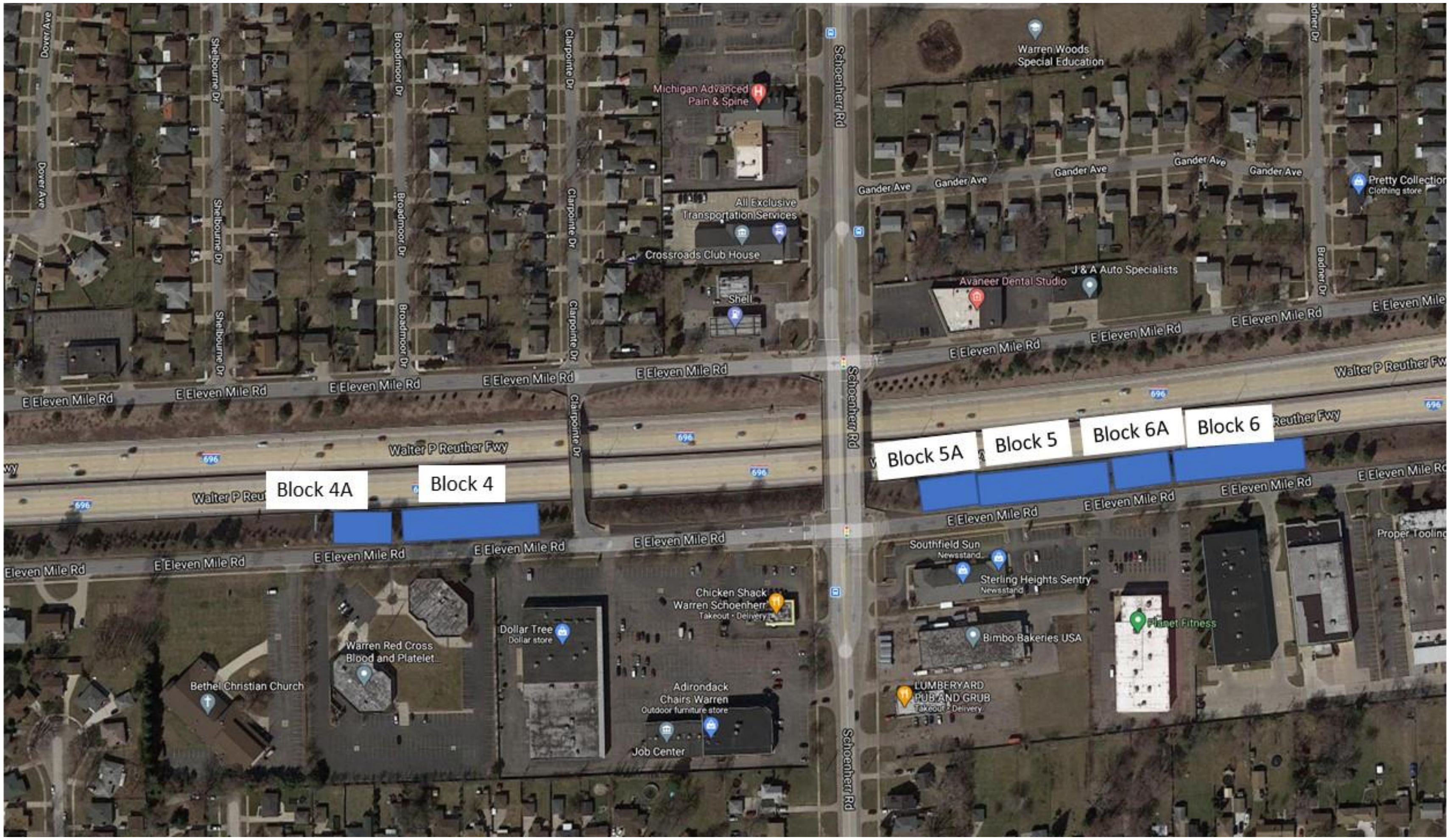


Figure 1.3: Photo indicating location of blocks at the Warren site along I-696. Blocks with an “A” are the plant evaluation plots

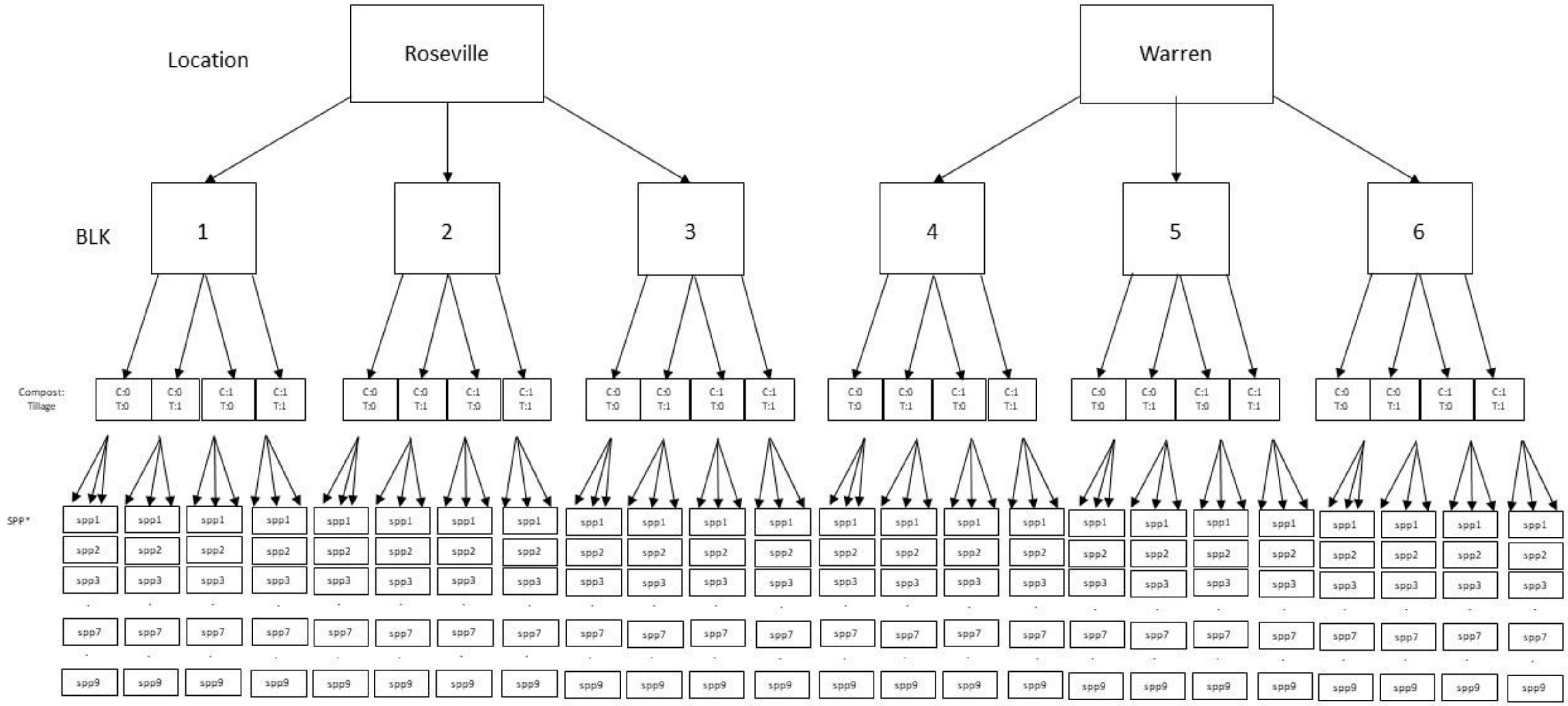


Figure 1.4: Schematic illustration of the study design indicating main plots (compost:tillage) and subplots (SPP).

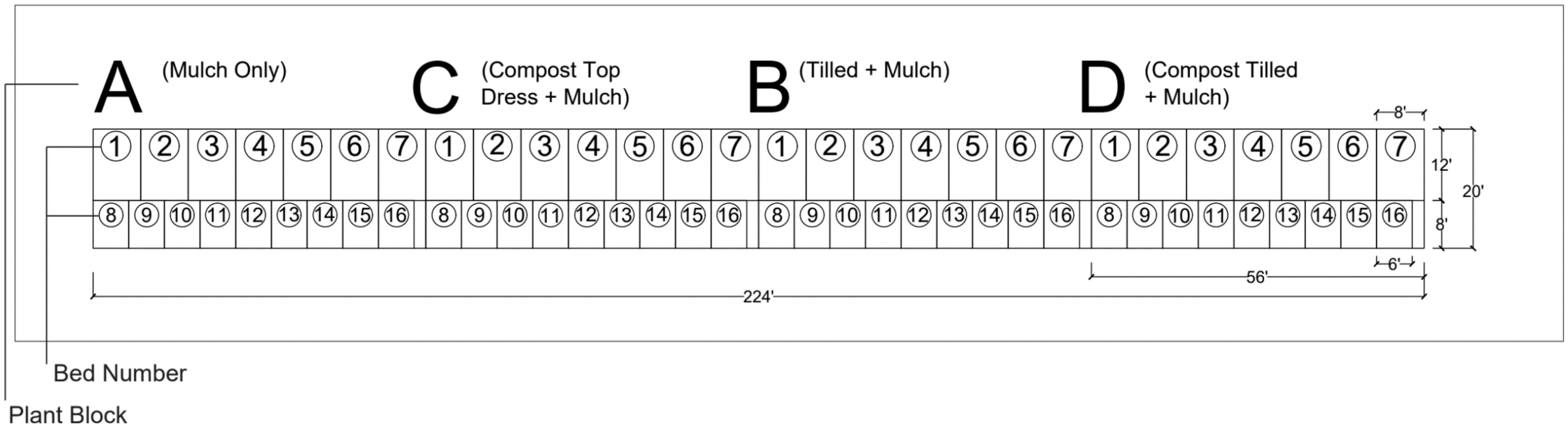


Figure 1.5: Schematic illustration of a single block indicating layout of main plots and subplot

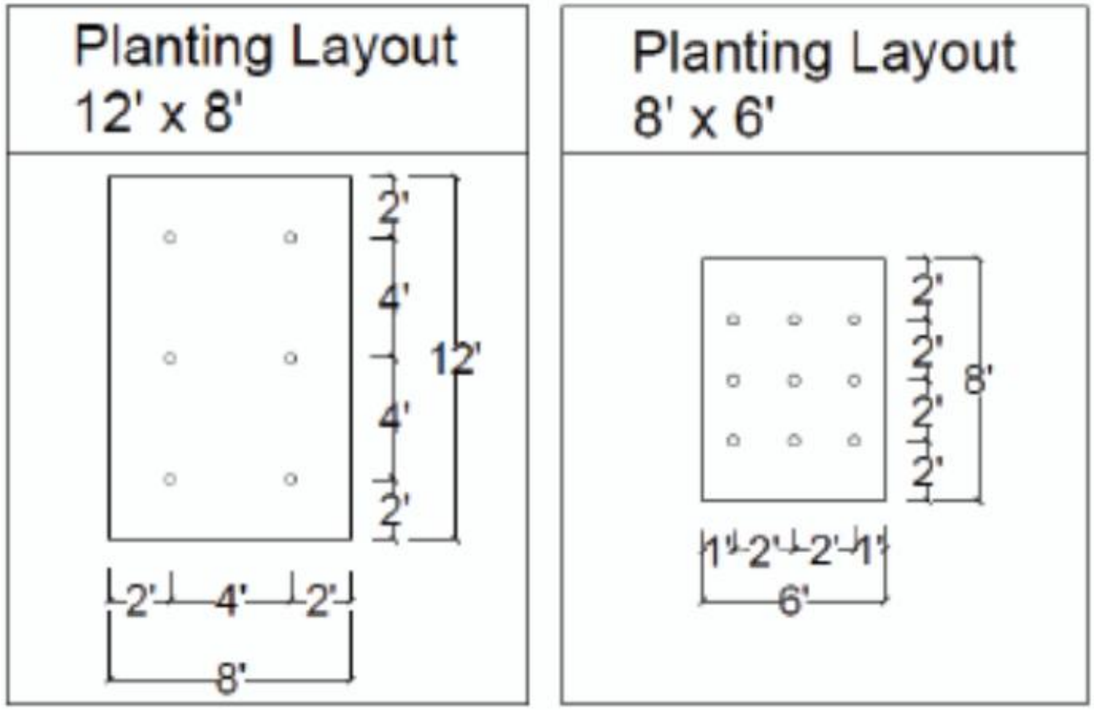


Figure 1.6: Schematic illustration of the two subplot sizes within each treatment plot

Figure 1.7: Photo depicting the four treatments (Control, Tilled Only, Compost only, and Compost and Tilled) within a block before plant installation.

Figure 1.8: A photo depicting a single treatment plot after plant installation.

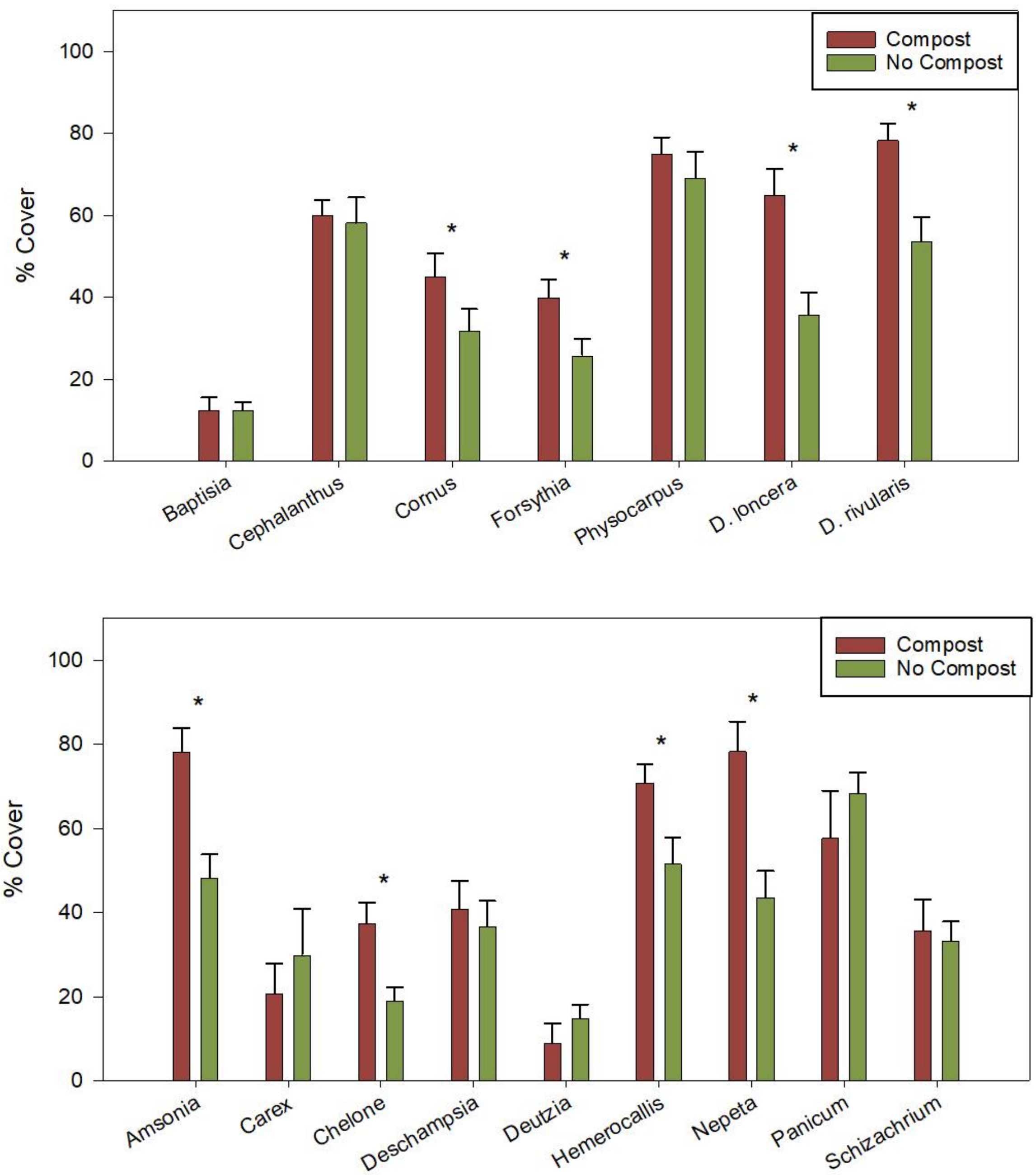


Figure 1.9: Mean (± SE) subplot coverage (%) of plants species at each study location subjected to compost treatment and no compost treatment along roadsides near Detroit, MI. "*" indicates that means are significantly different at P≤0.05.

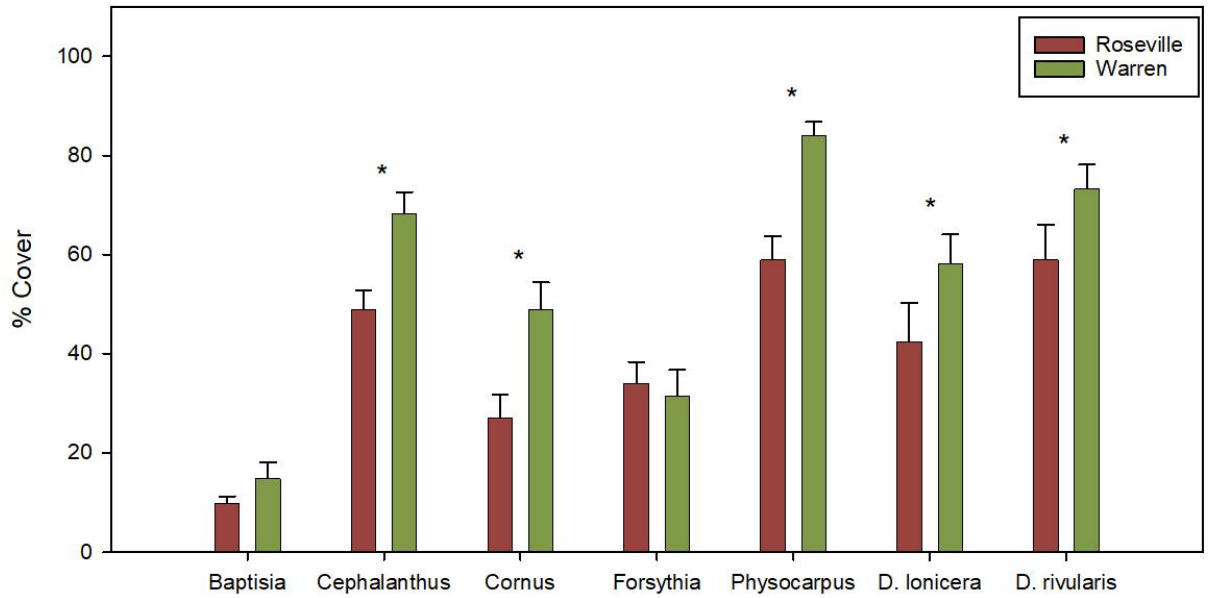


Figure 1.10: Mean (± SE) subplot coverage (%) of plants of 7 species separated by location along roadsides near Detroit, MI. "*" indicates that means are significantly different at P>0.05.

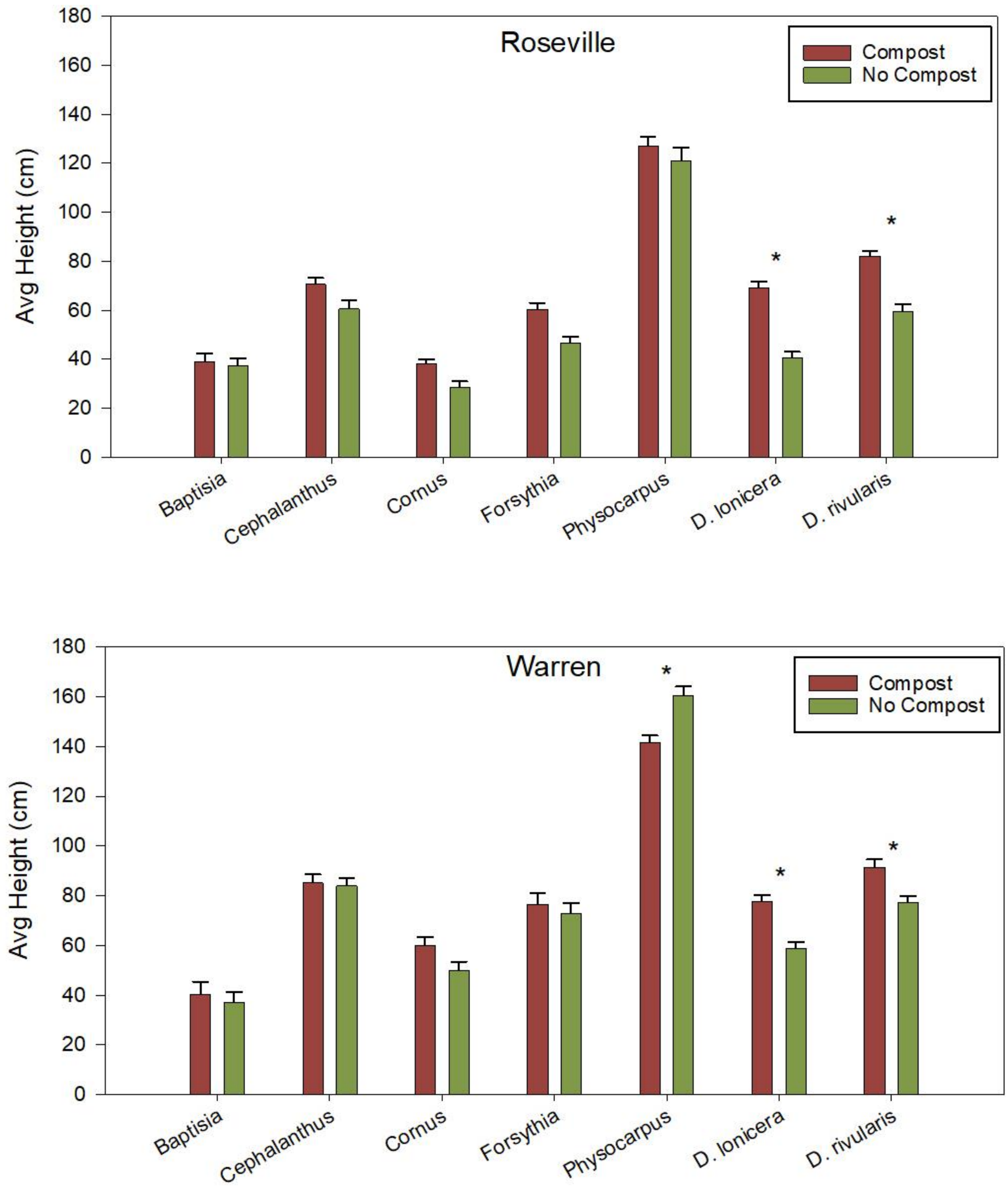


Figure 1.11: Mean (± SE) end of the 2020 season height of plants of 7 shrub species at each study location subjected to compost treatment and no compost treatment along roadsides near Detroit, MI. "*" indicates that means are significantly different at P≤0.05.

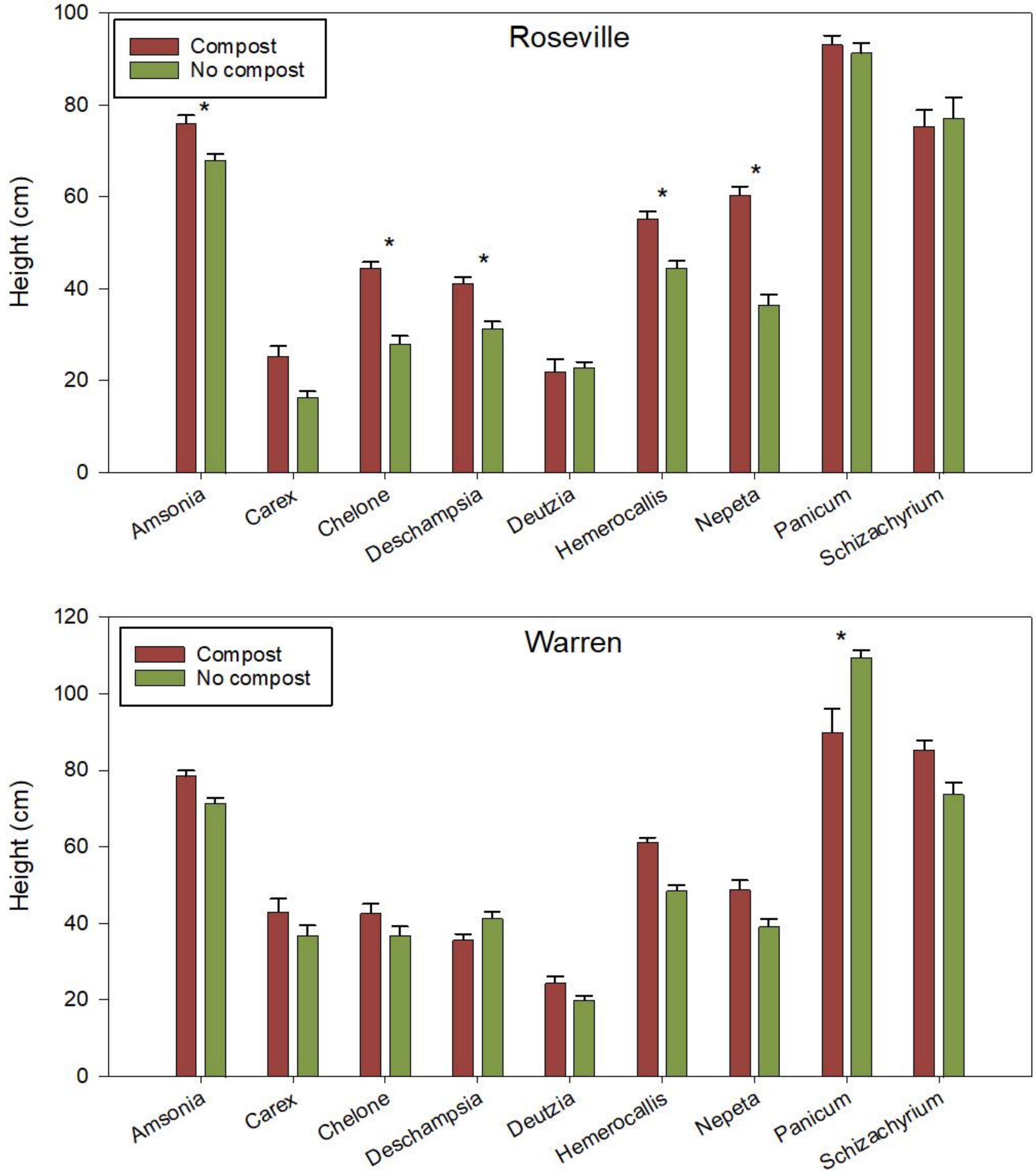


Figure 1.12: Mean (± SE) end of the 2020 season height of plants of 9 species at each study location subjected to compost treatment and no compost treatment along roadsides near Detroit, MI. "*" indicates that means are significantly different at P≤0.05.

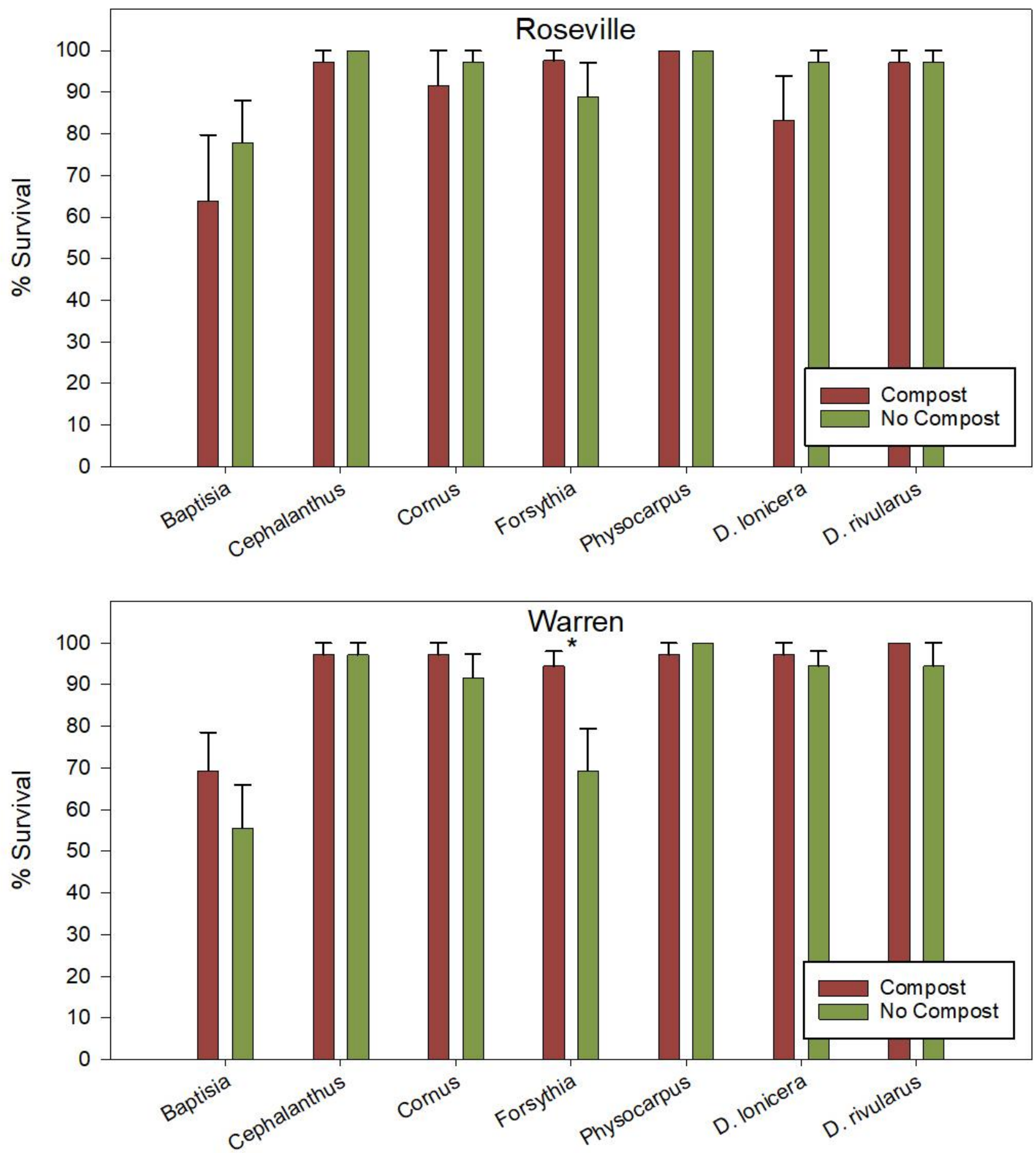


Figure 1.13: Mean (± SE) survival (%) of plants of 7 shrubs species at the Warren and Roseville locations subjected to compost treatment and no compost treatment along roadsides near Detroit, MI. “*” indicates that means are significantly different at P≤0.05.

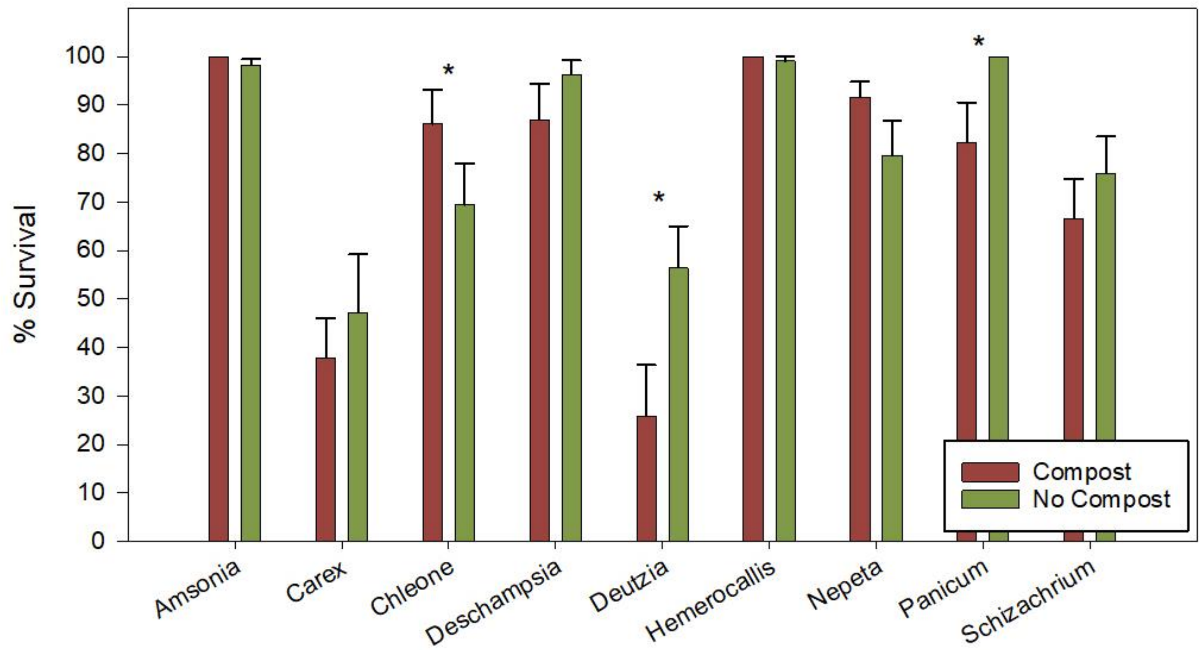


Figure 1.14: Mean (± SE) survival (%) of plants of 9 perennial species at the Roseville site subjected to compost treatment and no compost treatment along roadsides near Detroit, MI. “*” indicates that means are significantly different at P≤0.05.

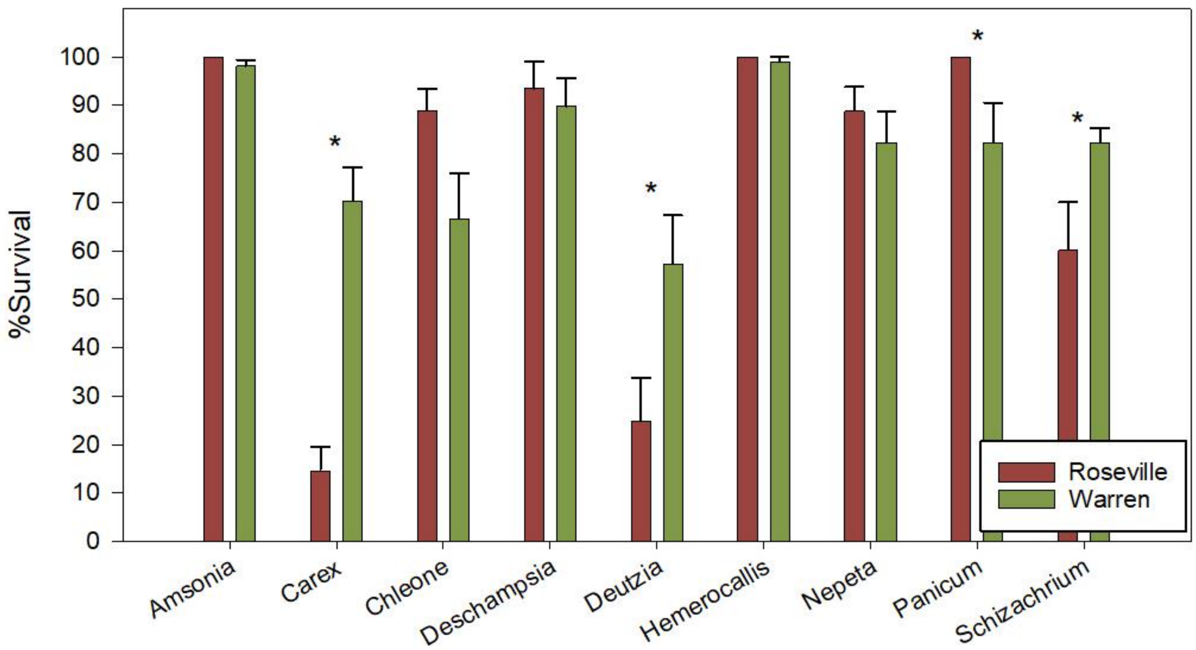


Figure 1.15: Mean (± SE) survival (%) of plants of 9 perennial species in the Roseville and Warren locations along roadsides near Detroit, MI. “*” indicates that means are significantly different at P≤0.05.

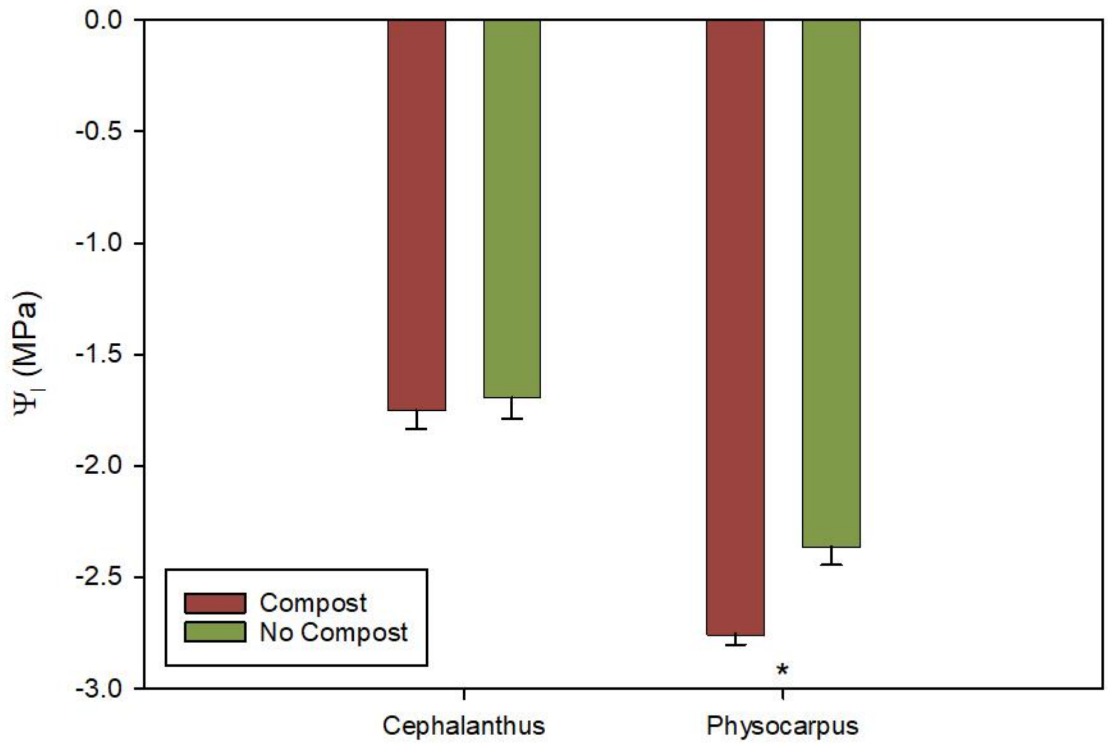


Figure 1.16: Mean (± SE) midday Ψl of Summer Wine® Ninebark and Sugar Shack® Buttonbush in July of 2020 subjected to compost treatment and no compost treatment along roadsides near Detroit, MI. "*" indicates that means are significantly different at P≤0.05.

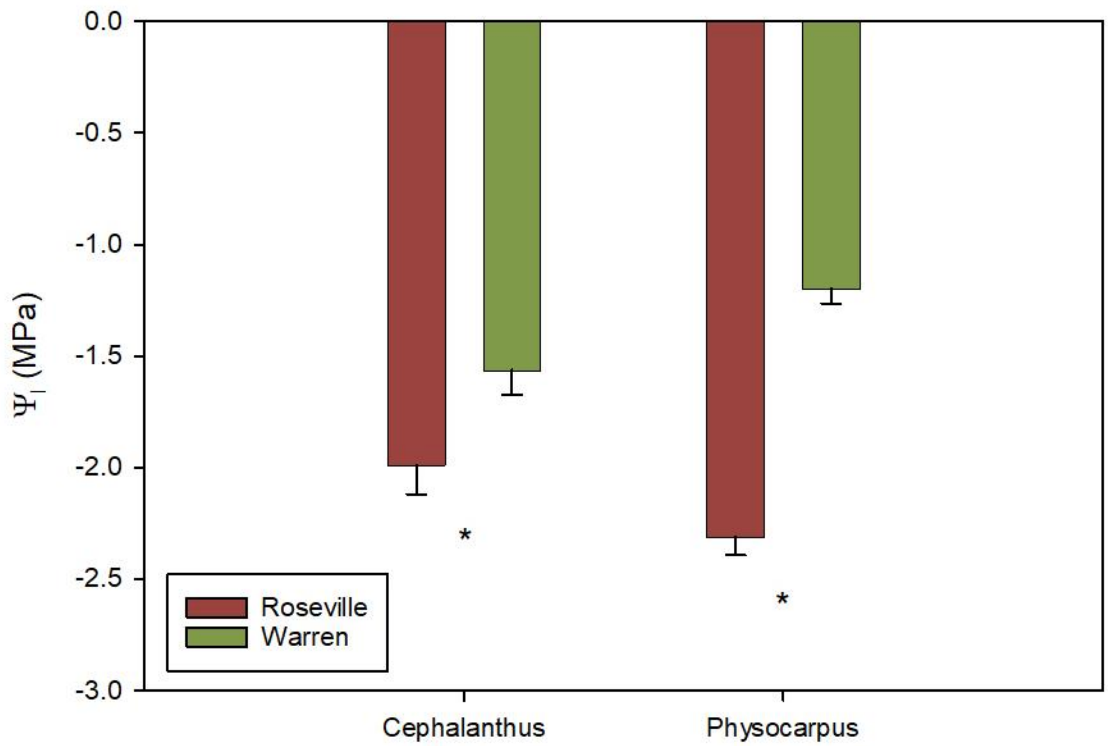
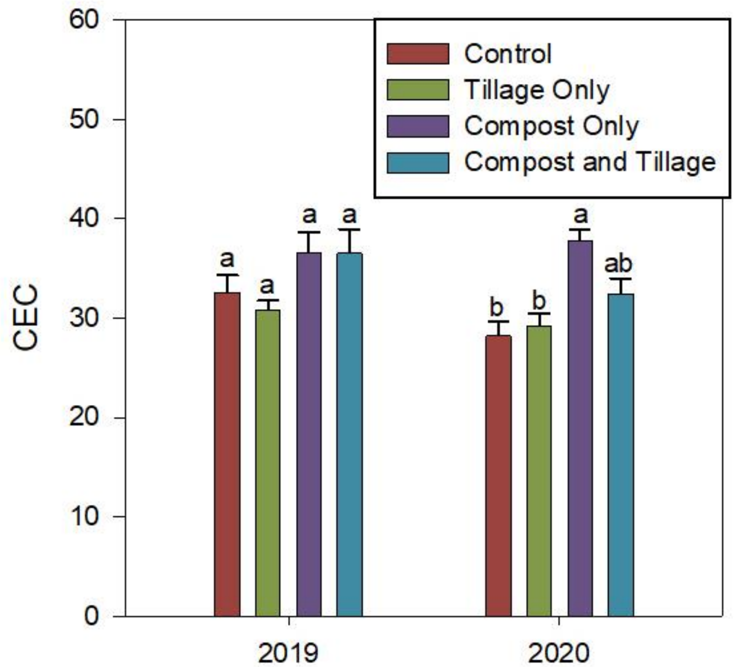


Figure 1.17: Mean (± SE) midday Ψl of Summer Wine® Ninebark and Sugar Shack® Buttonbush in August 2019 along roadsides near Detroit, MI. "*" indicates that means are significantly different at P≤0.05.



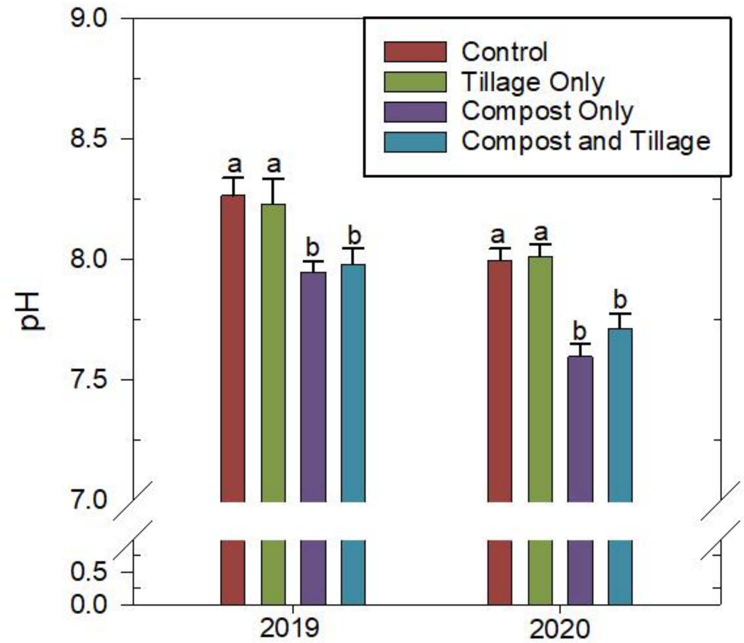


Figure 1.18: Mean (± SE) soil pH and CEC of the control, tillage only, compost only and compost and tillage treatments in 2019 and 2020 along roadsides near Detroit, MI. Letters indicate significant differences at $p \leq 0.05$.

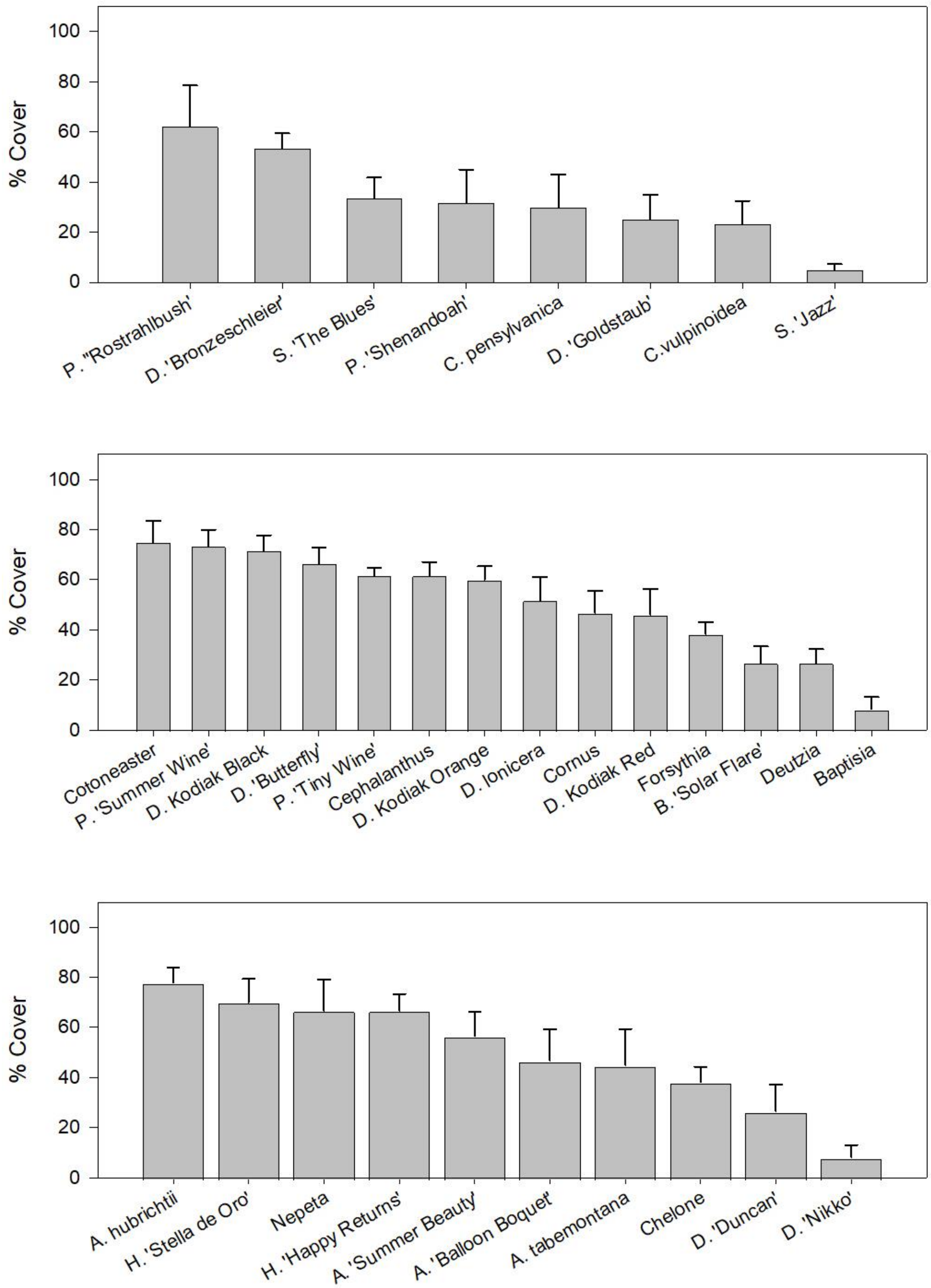


Figure 1.19: Mean (±SE) ground cover (%) of plants of all selection in the site preparation and supplemental plant evaluation studies. Means of selections from the site preparation study were taken from plants in the compost and tillage treatment.

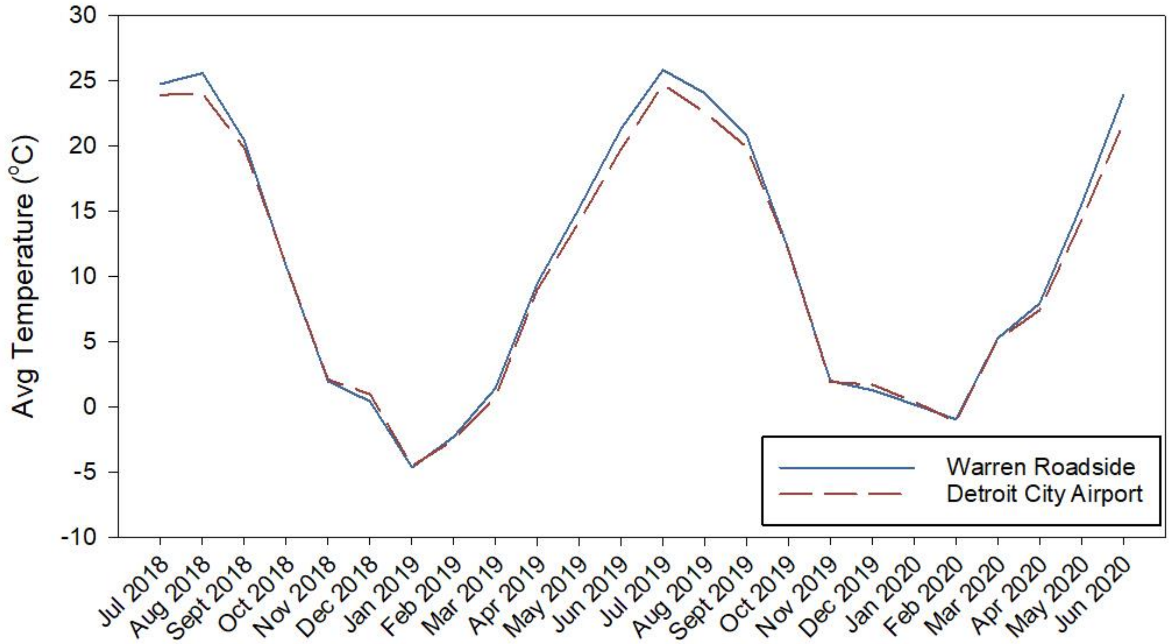


Figure 1.20: Mean monthly temperatures at the Warren roadside and the Detroit City (Coleman A. Young) airport.

APPENDIX B
Supplemental Information

Table 2.1: 1981-2010 climate normals at Coleman A. Young International Airport Detroit, MI. Data from National Weather Service station at Detroit City (Coleman A. Young) Airport and compiled by the Michigan State Climatologist's office.

	Max Temp (^oC)	Min Temp (^oC)	Precipitation (mm)	Mean Temp (^oC)
Jan	-0.33	-6.50	35.56	-3.42
Feb	1.33	-5.50	43.18	-2.08
Mar	6.78	-1.72	51.31	2.53
Apr	14.11	4.22	70.61	9.17
May	20.39	10.06	77.98	15.22
Jun	25.72	15.72	82.55	20.72
Jul	28.11	18.44	76.96	23.28
Aug	26.89	17.78	80.26	22.33
Sep	22.78	13.39	86.11	18.08
Oct	15.67	7.11	69.09	11.39
Nov	8.72	1.89	72.14	5.31
Dec	1.94	-9.04	50.04	-0.92
Annual	14.39	6.00	795.78	10.19

Table 2.2: Summary of analysis of variance (p values) for foliar macronutrient content of shrubs, herbaceous perennials, and grasses planted at two locations along an urban freeway near Detroit, MI Sampled selections included Artic Sun® Red Twig Dogwood, Summer Wine® Ninebark, Show Off® Starlet Forsythia, Kodiak® Black Diervilla, Red Switch Grass, 'Happy Returns' Daylily, Bronze Veil Tufted Hair Grass.

		Foliar Macronutrients											
		N		P		K		Mg		Ca		S	
Source	Df	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Location (L)	1	ns	ns	ns	≤0.05	ns	ns	ns	ns	≤0.05	ns	ns	ns
Compost (C)	1	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.05	≤0.001	≤0.05
Tillage (T)	1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
C x T	1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
L x C	1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
L x C x T	1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Species (S)	7	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001
S x C	7	≤0.05	ns	≤0.001	ns	≤0.001	ns	ns	≤0.001	≤0.05	≤0.05	≤0.05	≤0.001
S x T	7	ns	ns	ns	ns	≤0.05	≤0.05	ns	≤0.05	ns	ns	ns	ns
L x S	7	≤0.001	ns	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	ns	≤0.05
S x C x T	7	ns	ns	ns	ns	ns	ns	≤0.05	ns	ns	ns	ns	ns
L x C x S	7	ns	ns	≤0.05	≤0.05	ns	ns	ns	ns	ns	ns	ns	ns
L x T x S	7	ns	ns	ns	ns	≤0.05	≤0.001	ns	≤0.05	ns	ns	ns	ns
L x T x C x S	7	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Table 2.3: Summary of analysis of variance (p values) for foliar micronutrient content of shrubs, herbaceous perennials, and grasses planted at two locations along an urban freeway near Detroit, MI. Sampled selections included Artic Sun® Red Twig Dogwood, Summer Wine® Ninebark, Show Off® Starlet Forsythia, Kodiak® Black Diervilla, Red Switch Grass, 'Happy Returns' Daylily, Bronze Veil Tufted Hair Grass.

		Foliar Micronutrients									
		B		Zn		Mn		Fe		Cu	
Source	Df	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Location (L)	1	ns	≤0.001	ns	ns	ns	≤0.05	ns	ns	ns	ns
Compost (C)	1	≤0.001	≤0.05	ns	≤0.05	≤0.001	≤0.001	ns	ns	≤0.001	ns
Tillage (T)	1	≤0.05	ns	ns	ns	ns	ns	ns	≤0.05	ns	ns
C x T	1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
L x C	1	ns	ns	ns	ns	ns	≤0.05	ns	ns	ns	ns
L x C x T	1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Species (S)	7	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001
S x C	7	≤0.001	≤0.001	≤0.001	≤0.001	≤0.05	≤0.001	ns	≤0.05	≤0.001	ns
S x T	7	≤0.05	ns	ns	ns	ns	≤0.05	ns	ns	ns	ns
L x S	7	≤0.001	ns	≤0.001	ns	≤0.05	≤0.001	≤0.001	≤0.001	≤0.001	ns
S x C x T	7	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
L x C x S	7	ns	ns	≤0.001	ns	≤0.001	≤0.05	ns	ns	ns	≤0.001
L x T x S	7	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
L x T x C x S	7	ns	ns	ns	≤0.05	≤0.05	≤0.05	ns	ns	ns	ns

Table 2.4: Summary of analysis of variance (p values) for SPAD Index of shrubs, herbaceous perennials and grasses planted at two locations along an urban freeway near Detroit, MI appendix. Selections measured were Artic Sun® Red Twig Dogwood, Show Off® Starlet Forsythia, Summer Wine® Ninebark, Kodiak® Black Diervilla, Red Switch Grass, Halfway to Arkansas Narrow Leaf Blue Star, 'Happy Returns' Daylily and Bronze Veil Tufted Hair Grass.

		SPAD	
Source	df	2019	2020
Location (L)	1	ns	ns
Compost (C)	1	≤0.001	≤0.001
Tillage (T)	1	ns	ns
C x T	1	≤0.05	ns
L x C	1	ns	ns
Species (S)	7	≤0.001	≤0.001
S x C	7	≤0.05	≤0.05
S x T	7	ns	ns
S x C x T	7	ns	ns
L x C x S	7	ns	ns
L x T x S	7	ns	ns
L x T x C x S	7	ns	ns

Table 2.5: Summary of analysis of variance (p values) for photosynthesis and conductance of shrubs, herbaceous perennials and grasses planted at two locations along an urban freeway near Detroit, MI. Selections measured were Artic Sun® Red Twig Dogwood, Summer Wine® Ninebark , Sugar Shack® Buttonbush, 'Happy Returns' Daylily, and Red Switch Grass.

Shrubs									
		Photosynthesis				Conductance			
Source	df	July '19	Aug '19	July '20	Aug '20	July '19	Aug '19	July '20	Aug '20
Location (L)	1	ns	ns	ns	ns	ns	ns	ns	ns
Compost (C)	1	ns	ns	≤0.05	≤0.05	ns	ns	≤0.001	≤0.05
Tillage (T)	1	ns	ns	ns	ns	ns	ns	ns	ns
C x T	1	ns	ns	ns	ns	ns	ns	ns	ns
L x C	1	≤0.05	ns	ns	ns	ns	ns	ns	ns
L x C x T	1	ns	ns	ns	ns	ns	ns	ns	ns
Species (S)	2	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001
S x C	2	ns	ns	ns	ns	ns	≤0.05	≤0.05	ns
S x T	2	ns	ns	ns	ns	ns	ns	ns	ns
L x S	2	ns	ns	≤0.001	≤0.001	ns	ns	≤0.05	ns
S x C x T	2	ns	ns	ns	ns	ns	ns	ns	ns
L x C x S	2	ns	ns	ns	ns	ns	ns	ns	≤0.05
L x T x S	2	ns	ns	ns	ns	ns	ns	ns	ns
L x T x C x S	2	ns	ns	ns	ns	ns	ns	ns	ns

Grasses and herbaceous perennials									
		Photosynthesis				Conductance			
Source	df	July '19	Aug '19	July '20	Aug '20	July '19	Aug '19	July '20	Aug '20
Location (L)	1	ns	ns	ns	ns	ns	ns	ns	ns
Compost (C)	1	ns	≤0.001	ns	ns	ns	≤0.05	≤0.05	≤0.05
Tillage (T)	1	ns	ns	ns	ns	ns	ns	ns	ns
C x T	1	ns	≤0.05	ns	ns	ns	ns	ns	ns
L x C	1	ns	≤0.05	ns	ns	ns	ns	ns	ns
L x T	1	ns	ns	ns	ns	ns	ns	ns	ns
L x C x T	1	ns	ns	ns	ns	ns	ns	ns	ns
Species (S)	1	≤0.001	≤0.001	≤0.001	≤0.001	≤0.05	≤0.05	ns	ns
S x C	1	ns	≤0.001	ns	ns	ns	ns	ns	≤0.05
S x T	1	ns	ns	ns	ns	ns	ns	ns	ns
L x S	1	ns	≤0.001	ns	ns	ns	≤0.05	ns	ns
S x C x T	1	ns	ns	ns	ns	ns	ns	ns	ns
L x C x S	1	ns	≤0.05	ns	ns	ns	ns	ns	ns
L x T x S	1	ns	ns	ns	ns	ns	ns	ns	ns
L x C x T x S	1	ns	ns	ns	ns	ns	ns	ns	ns

Table 2.6: Summary of analysis of variance (p values) for water potential of shrubs planted at two locations along an urban freeway near Detroit, MI appendix. Plants selections measures were Summer Wine® Ninebark and Sugar Shack® Buttonbush.

		Water Potential			
Source	df	July '19	Aug '19	July '20	Aug '20
Location (L)	1	≤0.05	ns	ns	ns
Compost (C)	1	ns	ns	≤0.05	ns
Tillage (T)	1	ns	ns	ns	ns
C x T	1	ns	ns	≤0.05	ns
L x C	1	ns	ns	ns	ns
Species (S)	1	≤0.001	≤0.001	≤0.001	≤0.001
S x C	1	ns	ns	ns	ns
S x T	1	ns	ns	ns	ns
S x C x T	1	ns	ns	ns	ns
L x C x S	1	ns	ns	ns	ns
L x T x S	1	ns	ns	ns	ns
L x T x C x S	1	ns	ns	ns	ns

Table 2.7: Summary of analysis of variance (p values) for soil macronutrient content at two locations along an urban freeway near Detroit, MI.

		Soil Macronutrients							
		P		K		Mg		Ca	
Source	Df	2019	2020	2019	2020	2019	2020	2019	2020
Location (L)	1	ns	ns	ns	ns	ns	ns	ns	ns
Compost (C)	1	≤0.001	≤0.001	≤0.001	ns	≤0.001	≤0.001	ns	ns
Tillage (T)	1	ns	≤0.05	ns	≤0.001	ns	≤0.05	ns	ns
C x T	1	ns	≤0.05	ns	ns	ns	ns	ns	ns
L x C	1	ns	ns	ns	ns	ns	ns	ns	ns
L x C x T	1	ns	≤0.05	ns	ns	ns	ns	ns	ns

Table 2.8: Summary of analysis of variance (p values) for soil micronutrient content at two locations along an urban freeway near Detroit, MI.

		Soil Micronutrients									
		B		Zn		Mn		Fe		Cu	
Source	Df	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Location (L)	1	Ns	≤0.05	≤0.05	≤0.05	≤0.05	≤0.05	≤0.05	≤0.05	≤0.05	≤0.05
Compost (C)	1	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	ns	ns	≤0.05	≤0.05
Tillage (T)	1	Ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
C x T	1	Ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
L x C	1	Ns	ns	ns	ns	ns	ns	≤0.05	ns	≤0.05	≤0.05
L x C x T	1	Ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Table 2.9: Monthly average temperatures (^oC) recorded at the Detroit City (Coleman A Young) Airport, Roseville site, and Warren site between August 2020 and February 2021 compared with the 1981-2010 climate normal from the Detroit City (Coleman A Young) Airport.

Location	Aug 2020	Sept 2020	Oct 2020	Nov 2020	Dec 2020	Jan 2021	Feb 2021
Roseville	23.6	18.1	11.1	8.2	1.0	-1.1	-4.1
Warren	25.6	23.6	17.9	10.8	7.9	-1.3	-4.1
Detroit Airport	23.4	17.8	10.9	7.9	0.9	-1.2	-4.0
	Aug	Sept	Oct	Nov	Dec	Jan	Feb
Climate Normals	22.3	18.1	11.4	5.3	-0.9	-3.4	-2.1

Table 2.10: Monthly average temperatures (C) at Coleman A Young Airport and the roadside at the Warren site between January 2018 and June 2020.

Warren roadside average maximum temperatures												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018							31.8	34.2	27.6	16.5	4.8	3.7
2019	-0.4	2.6	7.6	15.9	22.3	28.3	34.1	32.7	28.0	18.5	6.0	5.0
2020	3.4	3.9	11.3	15.3	23.0	32.5						
Airport average maximum temperatures												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018							29.0	28.6	24.2	15.3	4.7	4.1
2019	-0.4	1.6	5.3	13.6	19.7	24.9	30.1	27.6	24.6	16.8	5.4	5.3
2020	3.3	2.3	9.8	12.4	19.3	27.8						
Warren roadside average minimum temperatures												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018							18.7	19.1	14.9	5.7	-0.9	-2.7
2019	**-8.5**	-6.4	-4.0	4.2	8.9	14.2	18.7	16.8	15.0	7.0	-1.7	-2.2
2020	**-2.7**	-4.9	0.2	1.3	8.5	15.1						
Airport average minimum temperatures												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018							18.8	19.5	15.4	6.4	-0.5	1.0
2019	-8.6	-6.6	-3.8	4.4	8.8	14.6	19.3	17.6	15.2	7.2	-1.4	1.7
2020	-2.4	-4.5	0.6	2.4	9.3	15.7	20.4					

Table 2.11: Monthly average temperatures (C) at Coleman A Young Airport and the roadside at the Warren site between January 2018 and June 2020.

Warren site extreme maximum temperatures												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018							39.0	39.9	41.1	31.3	14.0	13.9
2019	10.7	12.3	21.7	25.3	32.8	36.5	39.7	37.0	35.2	31.7	12.3	15.0
2020	12.3	15.1	19.9	24.7	37.8	38.0						
Airport extreme maximum temperatures												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018								32.8	33.9	28.9	13.9	14.4
2019	11.7	12.8	19.4	22.2	30.0	32.2	35.6	31.7	31.1	30.6	13.3	14.4
2020	13.9	11.7	18.9	21.7	31.1	33.3						
Warren Site Extreme minimum temperatures												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018							14.5	11.8	5.0	-3.2	-9.8	-10.8
2019	-26.0	-20.3	-14.5	-6.0	3.1	6.6	13.4	11.3	7.9	-0.2	-14.1	-12.4
2020	-10.7	-15.6	-8.6	-5.3	-3.6	6.3						
Airport extreme minimum temperatures												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018								13.9	7.2	-1.7	-6.7	-8.9
2019	-24.4	-18.3	-13.3	-4.4	3.9	7.8	14.4	12.2	10.6	0.6	-12.8	-10.6
2020	-10.0	-15.6	-6.7	-3.3	-1.1	8.3						

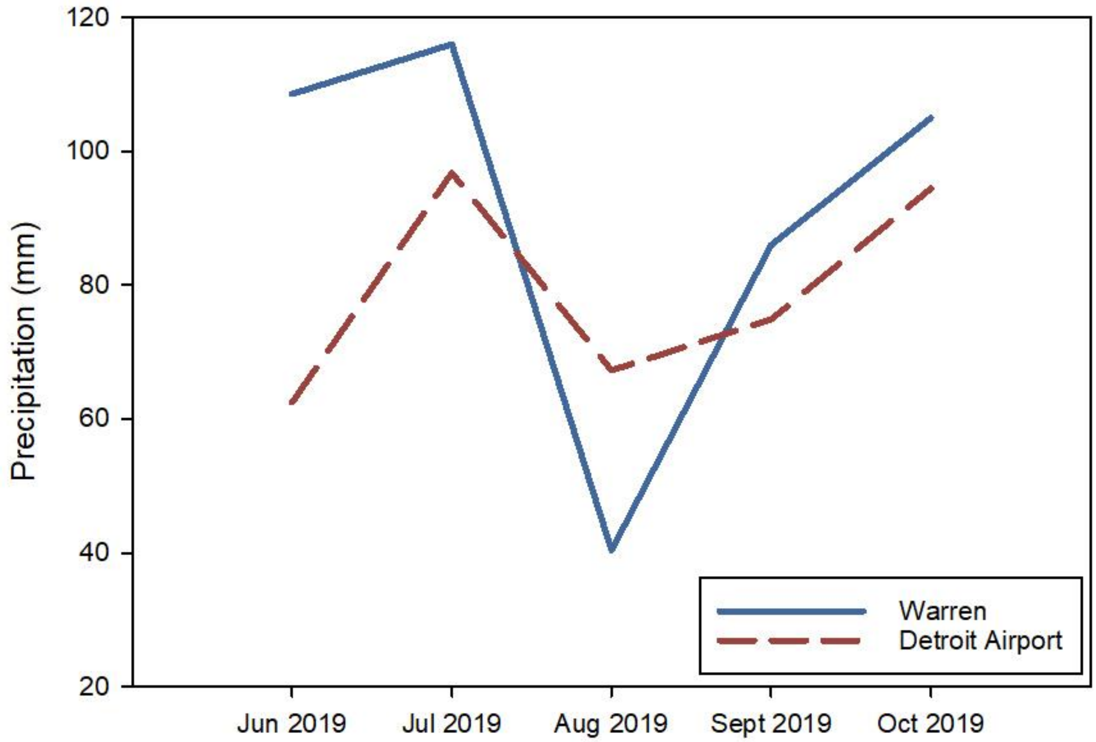


Figure 2.1: Monthly average temperatures (C) and precipitation at Coleman A Young Airport and the roadside at the Warren site between January 2018 and June 2020.

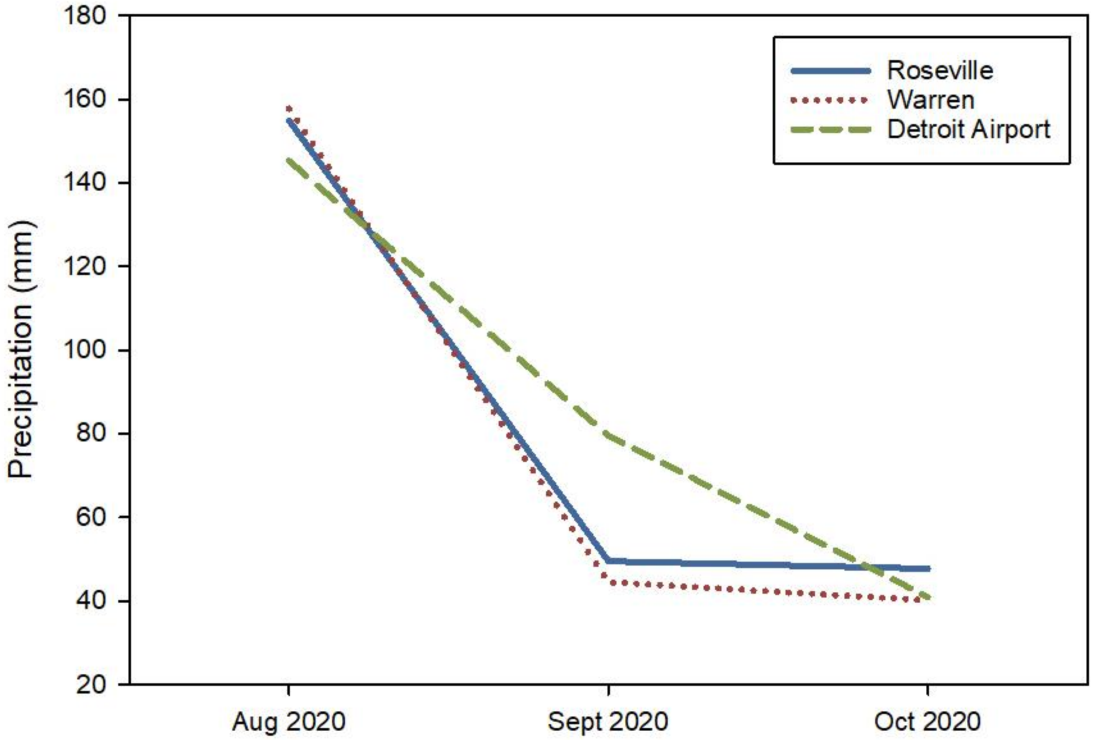


Figure 2.2: Monthly precipitation totals (mm) between August 2020 and October 2020 at the Warren location, Roseville location and the Detroit City (Coleman A. Young) airport.

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WORKS CITED

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CHAPTER 4

MICHIGAN DEPARTMENT OF TRANSPORTATION PLANT SELECTION MANUAL:

SECTION 1

MDOT Mission

Providing the highest quality integrated transportation services for economic benefit and improved quality of life.

MDOT Vision

MDOT will be recognized as a progressive and innovative agency with an exceptional workforce that inspires public confidence.

MDOT Values

- Quality: Achieving our best within our resources.
- Teamwork: Effective involvement of people.
- Customer Orientation: Knowing our customers and understanding their needs.
- Integrity: Doing the right thing.
- Pride: In MDOT and the importance of our work.

Introduction

The Michigan Department of Transportation (MDOT) has direct jurisdiction over Michigan's nearly 10,000-mile state highway system, comprised of all I, US, and M-numbered routes. It is the backbone of Michigan's 120,000-mile highway, road and street network. The state also owns:

- 4,775 highway, railroad, and pedestrian bridges
- 665 miles of railroad track (which is managed by private operators)
- 2,754 miles of nonmotorized trails
- Four airports

Additionally, MDOT administers other state and federal transportation programs for aviation, intercity passenger services, rail freight, local public transit services, the Transportation Economic Development Fund (TEDF), the Transportation Alternatives Program (TAP), and others. The department is responsible for developing and implementing a comprehensive, statewide transportation plan that includes all modes of transportation.

Landscapes associated with the MDOT systems are as diverse as its operation and a basic understanding of the landscape ecosystems aids in planning, constructing, and maintaining this critical infrastructure.

Section One of the manual provides the foundational information about Michigan's ecosystems and their environmental characteristics.

Ecoregions of North America

Ecoregions denote areas of general similarity in ecosystems along with the type, quality, and quantity of environmental resources. They are designed to serve as a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components. These general-purpose regions are critical for structuring and implementing ecosystem management strategies across federal agencies, state agencies, and non-governmental organizations that are responsible for different types of resources within the same geographical areas. The approach used to compile the following map (*Figure 1*), is based on the premise that ecological regions can be identified through the analysis of patterns of biotic and abiotic phenomena, including geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology. The relative importance of each characteristic varies from one ecological region to another regardless of the hierarchical level. The Ecoregions of Michigan map was compiled at a scale of 1:250,000, as part of the US EPA framework of ecological regions. Although there have been differences in conceptual approaches and mapping methodologies used by the USDA–Forest Service, USDA–NRCS, and US EPA to develop the most common ecoregion-type frameworks, collaboration on refinement of these frameworks is a step toward attaining consensus and consistency in ecoregion frameworks for the entire nation. Comments regarding this map should be addressed to James Omernik, U.S. Geological Survey, 200 SW 35th Street, Corvallis, OR 97333, (541) 754-4458, omernik.james@epa.gov; or Sandy Bryce, Dynamac Corp., c/o US EPA, 200 SW 35th Street, Corvallis, OR 97333, (541) 754-4788, bryce.sandy@epa.gov.

North American ecological regions are categorized as follows and shown in Figure 1:

- 15 broad, level I ecological regions
- 50 level II ecological regions intended to provide a more detailed description of the large ecological areas nested within the level I regions
- 182 Level III ecoregions, which are smaller ecological areas nested within level II regions.

North America *level I* ecological regions highlight major ecological areas and provide the broad backdrop to the ecological mosaic of the continent, putting it in context at global or intercontinental scales. Viewing the ecological hierarchy at this scale provides a context for seeing global or intercontinental patterns.

The 50 *level II* ecological regions delineated are intended to provide a detailed description of the large ecological areas nested within the level I regions. *Level II ecological regions* are useful for national and subcontinental overviews of ecological patterns.

Level III mapping describes smaller ecological areas nested within *level II* regions. At *level III*, the continent currently contains 182 ecological regions. These smaller divisions enhance regional environmental monitoring, assessment, and reporting, as well as decision-making. Because *level III* regions are smaller, they allow locally defining characteristics to be identified, and more specifically oriented management strategies to be formulated (*CEC 1997*).

<u>Michigan Level III and IV Ecoregion</u>

Level III and IV Ecoregion Descriptions / Mapping Issues

Descriptions for each of the *level III* and *level IV* ecoregions of Michigan are listed below. They are presented in bullet format to facilitate regional comparisons and discussion of boundaries. In this EPA version of the Ecoregions of Michigan, we have considered the boundaries of existing frameworks of Michigan ecological regions, such as the several iterations of *Albert et al., U. S. Forest Service*, and *NRCS* Common Resource Areas. This framework may differ from the others in some areas in the combination of geographic attributes that characterize a region. This Michigan framework is consistent with the national EPA framework in terms of level of resolution and line generalization. For this reason, some of the smaller polygons and regions from other frameworks may have been aggregated to create regions of a more consistent size.

50 Northern Lakes and Forests

The Northern Lakes and Forests (50) ecoregion contains relatively nutrient-poor glacial soils, coniferous and northern hardwoods forests, morainal hills, broad lake basins, and areas of extensive sandy outwash plains. Soils are formed primarily from sandy and loamy glacial drift material and generally lack the arability of those in adjacent ecoregions to the south. Ecoregion 50 also has lower annual temperatures and a frost-free period that is considerably shorter than ecoregions to the south. These conditions generally hinder agriculture; as a result, forest is the predominant land use/land cover. The numerous lakes that dot the landscape are clearer, at a lower trophic state (mostly oligotrophic to mesotrophic with few eutrophic lakes), and less productive than those in ecoregions to the south. Some lakes in the region are of low alkalinity and sensitive to acidic deposition.

Mapping issues

The Level III boundary between Ecoregions 50 and 56 is a broad transition zone in central Lower Michigan. Of major federal agency frameworks, the *NRCS* boundary is further north reflecting the frigid/mesic soil break. The USFS boundary is like *Albert*'s, reflecting physiography and vegetation. *Omernik's* 1987 boundary was revised in 1998 in an interagency effort to delineate common ecological regions, and it was closer to matching the *NRCS* boundary. In this version, to better correspond with landforms, historical vegetation, and land use capability, the draft boundary with Ecoregion 56 is moved to the south, closer to *Albert*'s Section boundary and the USFS Division boundary.

50a Lake Superior Clay Plain

The Lake Superior Clay Plain is a flat, clayey, lake plain marking the former extent of Glacial Lake Algonquin, Glacial Lake Ontonagon, Glacial Lake Agassiz, or Glacial Lake Duluth. The ecoregion is distinguished by its soils, topography, and climate.

Soils

The soils of 50a are generally calcareous red clays that range from well- to poorly drained. Few wetland soils occur in the Michigan portion of the ecoregion; the poorly drained soils that are present are seasonally wet. Soil types are fairly homogeneous within each of the two ecoregion areas that flank eastern and western sides of the central Keweenaw basalt ridge: the western lakeshore section—MI208 Watton-Alstad Variant-Bohemian; the more inland section—MI181 Ontonagon-Bergland-Pickford. Pickford and Bergland are deep, poorly drained to somewhat poorly drained, silt clay loams with a seasonal high water table. Well-drained silt loams like Ontonagon, Bohemian, and Watton, have less cultivated area and are left mostly in forest. There is more cultivation in this ecoregion closer to the lake.

Topography

The clay lake plains are flatter near Lake Superior and more sloping inland; both are dissected by stream and river channels giving them a somewhat corrugated surface. Larger streams and rivers are deeply incised (as much as 250 feet) in the clay substrate. There are few lakes or wetlands in this ecoregion.

Climate

The climate is lake moderated. Areas in closer proximity to the lake shore have a somewhat longer growing season (105-125 days) than interior areas. However, lake effect snows can be heavy, as much as 200 inches near the Lake Superior shore.

Presettlement Vegetation

The hardwood-conifer forest included white pine, hemlock, northern white-cedar, black ash, basswood, and sugar maple; it also included some boreal species such as balsam fir and black and white spruce. Beech is absent in the west. Most tree species are tolerant of seasonally wet soils. Today second growth forest is often managed for aspen pulpwood.

Land Use Capability

The clay plains of Ecoregion 50a differ from the Rudyard Clay Plain (50z) to the east in having sandstone, shale, and volcanic bedrock as soil parent material rather than limestone. As a result, the western clay plains (50a) are not as suited to agriculture as the Rudyard Clay Plain, and both sections of Ecoregion 50a are mostly forested. In contrast, the Rudyard Clay Plain (50z) is mostly cleared for dairy pasture and hay.

Boundaries

The lake plains are distinguished from surrounding hilly or sandy lake shore features by topography, and distinctive soil and surficial geology.

Mapping Issues

Albert & USFS extend the region to the Portage Lake Ship Canal, while *NRCS* and this version follow the lacustrine sediments to map the boundaries. We have also included *Albert's* Ewen lake plain (VI 6.2) in this ecoregion. Both lake plain areas share clay soils, some lake moderation in climate, lake effect snowfall, pre-settlement vegetation, eroded stream valleys, and a low capability for agriculture.

50d Superior Mineral Ranges

Modified description from the Ecoregions of Wisconsin

The rolling to hilly moraines of loamy till, much of it shallow over igneous and metamorphic rock, distinguish the Superior Mineral Ranges ecoregion from surrounding regions. The Precambrian volcanic basalt and conglomerates form steep ridges that rise several hundred feet above adjacent regions. Rock outcrops increase in number to the north. Perennial streams are common, and there are more lakes than in adjacent ecoregion 50a. The potential natural vegetation of 50d is a mosaic of hemlock/sugar-maple/white pine forests, swamp conifers, and cedar/hemlock forests. Red pine, white pine, red oak, and paper birch grew on the thin soils of the bedrock ridges, while northern hardwood forests of hemlock, sugar maple, basswood, and yellow birch occurred on areas of till. Historic mining of iron and copper occurred in this region.

Mapping issues

Omernik et al in Wisconsin revised this region from an earlier version, bringing it further east in Iron County, Wisconsin, and including some flatter moraine area. In this version for Michigan, the region was extended into the Porcupine Mountains and up the central ridge of the Keweenaw Peninsula. *Albert* divides the area into 3 separate regions. *NRCS* has combined the three regions. The southwestern area has gentler topography with bedrock not as close to the surface; it also has somewhat less lake moderation than the portion of the region further north on the Keweenaw Peninsula, although the climate characteristics for the two areas are very similar in growing season length and amount of lake effect snowfall.

<u>50d Superior Mineral Ranges (Isle Royale)</u>

Though Isle Royale is part of Michigan, it is located across Lake Superior from the Upper Peninsula fifteen miles from the north shore of Minnesota.

Bedrock Geology

Isle Royale is composed of Precambrian Keweenawan basaltic lavas and conglomerates. The island is an exposed portion of the north end of the Lake Superior syncline; the matching south end is the Keweenaw Peninsula. Copper has been mined on the island both by Native Americans and during early settlement times.

Climate

The island is strongly influenced by Lake Superior. The lake effect is stronger on Isle Royale than it is either on the Minnesota shore or the Keweenaw Peninsula, but it would be closer to the Keweenaw in that regard.

Soils

Soils are thin, and bedrock is at or near the surface over most of the island. Topsoil also burned off on the ridges when extensive fires swept the island in the 1930's. Some glacial till occurs in the southwest part of the island.

Vegetation

Aspen, birch, white spruce, and balsam poplar grow on thin soils over bedrock. Sugar maple, yellow birch, and balsam fir grow in the southwest portion of the island where the glacial till is thicker. Linear wetlands (conifer swamps, sphagnum bogs) fill the depressions between the parallel ridges. The vegetation pattern is consistent with that in the Upper Peninsula.

Mapping issues

Albert et al. separate Isle Royale as its own region, but within the Keweenaw subsection. *NRCS CRA 93B.2* lumps Isle Royale with the northern Keweenaw Peninsula and the Iron Ranges. The attributes listed above, geology, climate, soils, and vegetation, are consistent with Keweenawan characteristics.

<u>50i Northern Wisconsin Highlands Lakes Country</u>

Modified description from Wisconsin ecoregion map

The Northern Highlands Lakes Country (50i) occurs primarily in Wisconsin and is distinguished from surrounding ecoregions by pitted outwash, extensive glacial lakes (many of which are shallow), and wetlands. Ecoregion 50i contains a high density of lakes of generally lower trophic state and lower alkalinity values (hence, greater sensitivity to acidification). Deep drift, 100-300 feet thick covers the Precambrian bedrock. The region's soils developed in deep, acidic drift are gravelly, sandy, and well to excessively drained. Unlike the predominantly hardwood forests of surrounding ecoregions, 50i supports a potential natural vegetation of white and red pine forests, some pine barrens, and jack pine to the south. Heavy historical logging of pine has converted many stands to aspen and paper birch, although there is potential for restoration of the pine forests.

Mapping issues

Albert (IX.5), USFS (212Xb), and *NRCS (94D)* close most of this region off in Wisconsin with only small areas extending into Michigan. *Omernik et al*., in Wisconsin extended the region's boundaries across the Wisconsin/Michigan border to include a high density area of lakes on the coarse end moraines just north of the border. (The pre-settlement vegetation on the end moraines included more northern hardwoods and hemlock rather than pine). All landscape attributes were reconsidered in the border area, and it was decided that, for the EPA framework, the portion of the Winegar moraine that has the densest distribution of lakes will be left in ecoregion 50i. Ecologically, the density of lakes, the habitats they provide, their trophic state, and their sensitivity to acidification, outweigh the changes in surficial geology (from outwash to end moraine) and vegetation (pine on the outwash and northern hardwood on the end moraines).

50j Brule and Paint Rivers Drumlins

Modified description of the Brule and Paint River Drumlins from Ecoregions of Wisconsin:

The Brule and Paint Rivers Drumlins (50j) ecoregion has extensive eskers and drumlinized ground moraines, wetlands, and a lower density of lakes than in adjacent Northern Wisconsin Highlands Lake Country (50i). Lake trophic state is low, with a high percentage of oligotrophic and mesotrophic lakes.

The Brule and Paint Rivers Drumlins ecoregion is characterized by its landforms, soils, and pre-settlement vegetation.

Landforms

The landscape character is marked by the repetitive pattern of drumlin ridges, oriented northeast-southwest, alternating with wetland depressions.

Soils

Soils in this region commonly have a silt cap. They differ from the sandy, more acidic soils in adjacent ecoregions. MI157 Champion-Wabeno-Monico is a widespread soil association in this region: Champion and Wabeno are cobbly silt loams on drumlins and Monico is a somewhat poorly drained silt loam found in inter-drumlin depressions.

Pre-settlement Vegetation

The finer-textured, loamy soils create conditions more favorable to northern hardwoods and a diverse woodland groundcover. American elm, basswood, white ash, and yellow birch are more common than in adjacent regions. The northern hardwoods forest type contrasts with the more coniferous forests of the Northern Wisconsin Highland Lakes Country (50i) to the west and the pine and oak barrens of the Wisconsin/Michigan Pine Barrens (50k) to the east.

Climate

The region's climate is continental because of its inland location and lack of lake moderation. The growing season is short at around 87 days.

Boundaries

The western boundary is marked by the change from the loamy soil of this ecoregion to sandy outwash soil and a high lake density characteristic of the Northern Wisconsin Highlands Lake Country (50i). The northern boundary is delineated along the transition from the drumlin topography to the end moraines and kettle lakes of the Winegar Dead Ice Moraine (50v). The eastern boundary meets the thin soil over bedrock and exposed bedrock knobs of the Wisconsin-Michigan Pine Barrens (50k).

Mapping issues

This region is similar to *Albert's* IX.3.1 Iron River (called Brule and Paint Rivers region online).

<u>50k Wisconsin-Michigan Pine Barrens</u>

The Wisconsin-Michigan Pine Barrens ecoregion is characterized by its bedrock geology, pre-settlement vegetation, and soils.

Bedrock geology

Precambrian bedrock lies close to the surface or exposed as knobs protruding 200-300 ft from the surrounding moraines and outwash plain. Surrounding low sandy ridges have a bedrock core. The bedrock is granite, quartzite, and iron- bearing formations. The region is one of the Upper Peninsula iron ranges, and mining was a major activity in the early 20th century.

Pre-settlement Vegetation

White and red pine, hemlock, and sugar maple grew on thin soils over bedrock. Where soils were deep and loamy enough on flanking moraines, they supported northern hardwoods. The region is transitional for northern hardwood forest species. Beech declines in the northern portion, and southern species such as bitternut hickory, white oak, and rock elm occur in the southern portion. More characteristically, red and jack pine, and some white oak and white pine grew on thin soils over bedrock and on sandy outwash. Today, most forest cover is composed of aspen and birch with some jack pine. Fire suppression has created closed canopy forest where open pine barrens once occurred.

Soils

The region's soils vary between deeper loamy soils on moraines, deep excessively-drained sands, and shallow sandy soils over bedrock: MI182 Pemene-Emmet-Carbondale; MI207 Sayner-Rubicon-Omega; MI171 Mancelona-Pemene-Rubicon; MI204 Cathro-Emmet-Onaway. Emmet, Onaway, and Pemene are deep, well-drained, fine to coarse sandy loams on ground moraines and end moraines. Rubicon, Omega, Sayner, and Mancelona are excessively-drained sands on end moraines and outwash plains that mainly support pines. Though some of the soil series are cultivated in other ecoregions, there is little agriculture in Ecoregion 50k.

Boundaries

Ecoregion 50k differs from the drumlins and more loamy soils of the adjacent Brule and Paint Rivers Drumlins (50j) in having more exposed bedrock and thinner, excessively drained soils. In the west, the boundary is marked where the outwash plains meet the drumlins of Ecoregion 50j. To the north and east, the area of thin soils and bedrock exposure meets the deeper ground moraines and till of the Menominee Drumlins and Ground Moraine (50l). Most of the region's area extends into Wisconsin.

Mapping Issues

This ecoregion differs somewhat from Albert's two versions. Albert's1995 version of the IX.1 Norway region (Spread Eagle-Dunbar Barrens online) has an added area of outwash in the west. We have included the lower portion of this outwash. In the eastern half *Albert's* boundaries extend farther northward to include some of the same soil series (MI204) that makes up the bulk of the Menominee Drumlins and Ground Moraine ecoregion (50l). We drew the northeastern boundary farther south near the southern edge of the MI204 STATSGO polygon. The overall regional boundary is like the *NRCS* Common Resource Area boundary.

The disjunct portion of 50k in Wisconsin along Green Bay should probably be placed in Ecoregion 50aa, the Menominee-Drummond Lakeshore.

<u>50l Menominee Drumlins and Ground Moraine</u>

Bedrock geology, associated soils, and landforms characterize the Menominee Drumlins and Ground Moraine ecoregion.

Bedrock geology

Over much of the region limestone and dolomite lie within 40 feet of the surface.

Soils

The region's soil, having limestone as parent material, is more neutral and higher in nutrients than that in surrounding ecoregions. Soils are better-drained loams on drumlin mounds and more poorly drained between drumlins: MI204 Cathro-Emmet-Onaway; MI209 Carbondale-Cathro-Zimmerman; MI146 Charlevoix-Onaway-Trenary; MI179 Emmet-Tawas-Nadeau. Cathro, Carbondale, and Tawas muck and mucky peat occur in depressions. Emmet, Onaway, Trenary, and Charlevoix sandy loams are better drained and support northern hardwood forest.

Landforms

The flat to gently rolling ground moraine is generally poorly drained. Better-drained drumlin mounds are distributed across the ground moraine in a northeast-southwest orientation.

Pre-settlement Vegetation

Historical vegetation on the loamy uplands consisted of northern hardwood forests of sugar maple, beech, hemlock, northern white-cedar, and yellow birch (particularly in the west). Northern white-cedar swamps on peats and mucks occupied the flat lowland plains between the drumlins.

Land Use Capability

The region has experienced significant agricultural clearing, with areas of pasture and forage crops.

Boundaries

On the north and east the boundaries are marked by the transition from ground moraine to the lower and flatter lake plain regions to the east (Grand Marais Lakeshore 50x, Seney-Tahquamenon Sand Plain 50y, and Menominee-Drummond Lakeshore 50aa). The southern and western boundaries are delineated near the transition to the more exposed granitic and iron-rich bedrock, drier outwash soils, and drought-tolerant vegetation of the Wisconsin-Michigan Pine Barrens (50k).

Mapping issues

Ecoregion 50l is generally similar to Albert's Region VIII.3.1 Hermansville. The EPA framework differs somewhat by including the lower half of Albert's Gwinn region, which has broad wetlands and organic soils, with the Menominee Drumlins and Ground Moraine ecoregion. Though they are on outwash rather than ground moraine, the poorly-drained soils of that portion of the Gwinn region are consistent with the poorly-drained soils of the Menominee Drumlins and Ground Moraine. However, the Gwinn wetlands are more acidic than the inter-drumlin wetlands; as a result, they will have spruce and tamarack dominating rather than northern white-cedar. We have also broadened the arm of this ecoregion that protrudes to the west, taking in part of the northern Wisconsin-Michigan Pine Barrens ecoregion (50k) (Albert's Norway region IX.1) that has soils and drumlin topography similar to the Menominee Drumlins and Ground Moraine.

<u>50u Keweenaw-Baraga Moraines</u>

The Keweenaw-Baraga Moraines ecoregion is distinguished by its climate, landforms, and pre-settlement vegetation.

Climate

The climate of the Keweenaw-Baraga Moraines is lake-moderated. The growing season is moderately long at 110-130 days, but it is cool. Lake effect snow is heavy, up to 200 inches.

Landforms

The Keweenaw-Baraga Moraines are steep, coarse textured end and ground moraines that range as high as 500 ft. There is also some poorly drained lake plain along Keweenaw Bay and a sand plain at the Baraga Plains.

Pre-settlement Vegetation

Hemlock, sugar maple, and yellow birch were common on the deep, loamy soils. Yellow birch increases toward the north end of the Keweenaw Peninsula. Mixed conifer swamps with white-cedar, black spruce, tamarack, and alder occurred in riparian areas and in poorly drained areas on the clay lake plain. Red pine and jack pine grew on the fire-prone Baraga Plains.

Soils

The region's soils, mostly sands and sandy loams, are derived from Keweenaw sandstone and shale bedrock. Soils north of Houghton Channel are more sandstone-based and south of the channel they are more basalt-based: MI174 Munising-Yalmer-Keweenaw; MI176 Ontonagon-Nunica-Froberg; MI164 Graveraet-Misery-Skanee; MI200 Munising-Skanee-Gay. Munising, Keweenaw, and Yalmer are well-drained and moderately well-drained loamy sands that support sugar maple, yellow birch, and hemlock as well as hay and potatoes when cultivated. Graveraet and Misery are finer silt loams that are also mostly in hardwood forest. Ontonagon, Nunica, and Froberg are silty loams found on the lake plain.

Boundaries

The western boundary is marked where the end and ground moraines of this ecoregion meet the basalt and conglomerate ridges of the bedrock spine of the Keweenaw Peninsula (Superior Mineral Ranges, 50d). The southern boundary meets the end moraines of the Winegar Dead Ice Moraine (50v). This ecoregion differs from the Winegar Dead Ice Moraine in its proximity to Lake Superior, which moderates its climate. The Winegar ecoregion has a more continental climate and a much shorter growing season. In the east, this ecoregion meets the rocky ridges of the Michigamme Highland (50w).

Mapping issues

*USFS, NRC*S, and *Albert* are in some agreement on this region. We have combined Albert's Baraga IX 6.3 and Gay IX 7.1 as both contain high end and ground moraine, sandy soils, similar vegetation, and lake effect climate.

50v Winegar Dead Ice Moraine

The Winegar Dead Ice Moraine is characterized by its climate, topography, and coarse-textured sandy soils.

Climate

The region's inland location reduces any lake effect from the Great Lakes. The growing season is short at about 87 days. Lake effect snow is less than it is closer to Lake Superior, and winters are very cold.

Topography

The region has sections of ground moraine and glacial outwash, but the characteristic topography is one of steep end moraine ridges containing a high distribution of deep kettle lakes. The kettle lakes are acidic and low in nutrients. As is true of other ice stagnation areas, the stream drainage system is undeveloped.

Soils

Red sands and sandy loams are widespread across Ecoregion 50v: MI156 Gogebic-Dinkey-Champion; MI144 Champion-Tacoosh-Carbondale; MI192 Rubicon-Grayling-Rock Outcrop; MI155 Gogebic-Sarona-Witbeck; MI143 Champion-Lupton-Carbondale. Gogebic and Champion are sandy loams with silty eolian deposits on end moraines that support northern hardwoods. Witbeck, Carbondale, and Tacoosh are poorly-drained, sometimes stony, mucky soils in depressional areas on outwash plains or end moraines; they support water tolerant trees such as black ash, black spruce, and red maple. Rubicon and Grayling are excessively-drained sands on outwash plains that serve as habitat for red and jack pine.

Pre-settlement Vegetation

Historically, northern hardwood forests of sugar maple, yellow birch, hemlock, and basswood grew on the uplands. Hemlock and white pine covered more fire prone areas on south and west slopes. Bogs and black spruce/tamarack swamps fill or surround kettle depressions. Today, after logging, sugar maple and red maple dominate and the representation of conifers is much lower.

Boundaries

Ecoregion 50v is distinguished from surrounding ecoregions based on differences in landform, bedrock exposure, and climate.

Mapping issues

Other agency frameworks show this ecoregion crossing the state line into Wisconsin. In the EPA framework, a portion of the Winegar Moraine is included in the Northern Wisconsin Highlands Lakes Country (50i), which continues north across the Michigan/Wisconsin border. Though landform and forest tree species differ between the Winegar moraine and Ecoregion 50i, the density of lakes and lake phosphorus levels were important attributes in the delineation of Ecoregion 50i in Wisconsin. As a result the portion of the Winegar moraine north of the MI/WI border with the densest distribution of lakes was included in the Northern Wisconsin Highlands Lakes Country (50i).

We included two areas of outwash in Ecoregion 50v that Albert had placed in other regions: the northern part of Albert's Gwinn region (VIII 3.2), and the upper arm of a portion of outwash that was placed in his Norway region (IX 1).

50w Michigamme Highland

The Michigamme Highland is distinguished by its bedrock geology, variable within-region climate, and pre-settlement vegetation.

Bedrock Geology

The Michigamme Highland is an outcrop of complex Precambrian bedrock, including sandstone, slate, shale, gneiss, quartzite, and iron formations. Elevations range from 600 feet at the lakeshore to almost 2000 feet at Mt. Curwood, the highest point in Michigan. There are several bedrock lake basins; the lakes are mostly acidic and low in nutrients.

Climate

Because of its elevation and geographic position, this region experiences a minimal amount of lake moderation, except near the lakeshore. There is a strong climatic gradient; the growing season ranges from 100 days near the lake shore to just 75 days in the interior. Snow increases with elevation to almost 200 in.

Pre-settlement vegetation

Variable depths of acidic, sandy soils over bedrock determine vegetation patterns. White pine, red oak, red pine, and aspen grew on exposed bedrock with little or no soil. Balsam fir and white spruce occurred on thin soils over bedrock. Any areas with greater depths of well-drained soil and a silty loess cap supported northern hardwoods forest minus beech, which grew only in more moderate lakeshore areas. Better water retaining soils supported hemlock and yellow birch.

Soils

Michigamme Highland soils include thin to discontinuous till over bedrock with variable amounts of loess on the surface: MI145 Michigamme-Champion-Tacoosh; MI193 Rubicon-Rock Outcrop-Kalkaska; MI159 Champion-Rubicon-Greenwood. Michigamme and Champion are deep, cobbly silt loams on moraines or glacial till with an eolian cap over igneous or metamorphic bedrock; they are forested with hemlock, sugar maple and yellow birch. Rubicon and Kalkaska sand, on outwash plains, support white, red, and jack pine. Tacoosh and Greenwood are mucky peats found in the limited bogs and marshes in the region.

Land use

The region has experienced logging and iron mining. However, there are some roadless areas remaining and a section of old growth forest preserved in the Huron Mountains.

Boundaries

The western boundary is delineated where the highlands and exposed bedrock meet the glacial drift of the Keweenaw-Baraga Till Plain. The boundary is not as abrupt in the south and southeast where the highlands meet the end moraines and outwash of the Winegar Dead Ice Moraine (50v) and the Menominee Drumlins and Ground Moraine (50l). This ecoregion differs from surrounding ecoregions in its elevation, more severe climate, general lack of human habitation, and low road densities.

Mapping issues

This delineation is like Albert's, though it extends a bit more to the east to include some of the lower ridges transitional to the Grand Marais Lakeshore (50x).

50x Grand Marais Lakeshore

The Grand Marais Lakeshore is distinguished by its climate, landforms, soils, and pre-settlement vegetation.

Climate

The climate of Ecoregion 50x is lake-moderated in that its growing season is somewhat longer (110-130 days) than that of inland regions. The region also experiences cool summers and heavy lake effect snows that are almost as heavy as they are on the Keweenaw Peninsula to the west. Winter temperatures just inland from the lake are some of the lowest in the state.

Landforms

The Grand Marais Lakeshore is a mix of steep-sided, sandy end moraines and pitted outwash with kettle lakes and inter-ridge swamps, droughty outwash plain, and poorly drained peaty wetlands. Sandstone bedrock is near the surface in the western end of the region (Albert's Deerton subdistrict).

Soils

Soils in this ecoregion are not quite as diverse as those in the Menominee -Drummond Lakeshore to the south. They are characteristic of dry outwash plains, sandy moraines, and poorly drained wetland depressions: MI191 Rubicon-Rousseau-Ocqueoc; MI117 Kalkaska-Rubicon-Duel; MI173 Munising-Onota-Deerton; MI165 Karlin-Kalkaska-Blue Lake; MI162 Rubicon-Rousseau-Guardlake. Kalkaska, Karlin, and Rubicon sand are somewhat excessively drained and found on moraines, dunes, or outwash plains. Well-drained sands and sandy loams like Rousseau, Duel, Blue Lake, and Guardlake are found on sandy moraines, dunes, or outwash covered with northern hardwoods mixed with balsam fir.

Pre-settlement Vegetation

Jack pine, red pine, and white pine grew on the dune complexes and dry lake plain. Northern hardwood forest occurred with hemlock and white pine on sandy moraines in areas that seldom burned. Clay lake plain and poorly drained areas with bedrock near the surface supported spruce, tamarack, and white-cedar swamps.

Boundaries

The southern boundary is marked by the broad extent of Seney-Tahquamenon Sand Plain (50y) lowlands and swamps. In the west the boundary of the lake plain meets the ridges of the Michigamme Highland (50w).

Mapping issues

This region is like Albert's VIII.2.2 Grand Marais subdistrict except that it also includes Albert's Deerton subdistrict VIII 3.3, which has similar topography, but bedrock closer to the surface.

<u>50y Seney-Tahquamenon Sand Plain</u>

The Seney-Tahquamenon Sand Plain is characterized by its topography, hydrology, and soils.

Topography

Ecoregion 50y is a flat sand lake plain once filled by Glacial Lake Algonquin. The flat landscape is broken by occasional low beach ridges or sand dunes.

Hydrology

A permanently high-water table and poor drainage result in broad areas of wetlands. The wetlands serve as the source for several eastern Upper Peninsula rivers.

Soils

The region contains sandy soils and mucky organic soils: MI131 Lupton-Carbondale-Tawas; MI203 Dawson-Markey-Carbondale ; MI163 Tawas-Kalkaska-Carbondale. Carbondale, Lupton, Markey and Tawas are very poorly drained, acidic muck or mucky peat soils that support conifer swamp and birch, aspen, and red maple. An area with a particularly high-water table may have a peaty soil like Dawson; tree vegetation is sparse in such areas with stunted black spruce and tamarack comprising the major species. Boggy ground cover in all cases is composed of bog rosemary, cranberries, laurel, sphagnum mosses, and blueberries. The excessively drained Kalkaska soils are on the drier sand ridges, mostly found in the west end of the region; they support red pine and jack pine on dry exposures, and northern hardwoods in lake-moderated areas.

Pre-settlement Vegetation

Conifers such as tamarack, black spruce, northern white-cedar, balsam fir, and white pine dominated the swamps and peat bogs. Today, after widespread logging in the wetlands, there are more hardwoods mixed with second growth conifers. Dry sand ridges supported jack and red pine, northern hardwoods, hemlock, and white pine.

Climate

Because of its location between the two lakeshore regions (50x and 50aa), the Seney-Tahquamenon Sand Plain ecoregion experiences somewhat less lake moderation in climate and less lake effect snow than the Grand Marais Lakeshore (50x) directly to the north. The region also shares with the Grand Marais Lakeshore some of the coldest winter temperatures in Michigan.

Boundaries

The flat lake plain marks the former presence of Glacial Lake Algonquin. The region is distinguished from other Lake Algonquin embayments, such as the Rudyard Clay Plain (50z), by its sandy and organic soils and its uniformly high-water table. It lacks the diversity of landforms (e.g., outwash or moraines) and bedrock exposure of either of the lakeshore regions to the north and south.

Mapping issues

This framework agrees with Albert's boundaries for VIII.2.1 Seney.

<u>50z Rudyard Clay Plain</u>

The Rudyard Clay Plain is distinguished by its bedrock geology, topography, and soils.

Bedrock Geology

Limestone and dolomite underlie the Rudyard Clay Plain.

Topography

The topography of the Rudyard Clay Plain is nearly level with a few sandy beach ridges and low moraines. No lakes occur in this region.

Soils

Ecoregion 50z is covered by lacustrine clays. A common soil association is MI185 Pickford-Rudyard-Ontonagon.

Pre-settlement Vegetation

Historical vegetation included a hardwood-conifer forest of balsam fir, balsam poplar, hemlock, northern white-cedar, tamarack, trembling aspen, white pine, and spruce. On slightly better drained sites, hardwoods of sugar maple, beech, American elm, basswood, and yellow birch occurred. Some areas of shallow peatlands were also found here.

Mapping Issues

The Rudyard Clay Plain has a slightly longer growing season, more neutral limestone-based soils, and more clearing for agriculture than the Lake Superior Clay Plains in the west (50a). The clay plains of Ecoregion 50a have sandstone, shale, and volcanic bedrock as soil parent material rather than limestone. As a result, the western clay plains (50a) are not as suited to agriculture as the Rudyard Clay Plain, and they are mostly forested. The agricultural land in the Rudyard Clay Plain is used for feed grains and dairy cattle.

<u>50aa Menominee-Drummond Lakeshore</u>

The Menominee-Drummond Lakeshore is characterized by its landforms, sandy soils, associated pre-settlement vegetation, and climate.

Landforms

This ecoregion has typical lake plain characteristics such as flat sand plain, beach ridges, dunes, and poorly drained depressions. It differs from some of the other lake plain regions in having limestone bedrock of the Niagara escarpment either close to the surface or exposed as bedrock shores, cliffs, or cobble beaches.

Soils

The soils of Ecoregion 50aa reflect the diversity of landforms: MI188 Roscommon-Finch-Wallace; MI131 Lupton-Carbondale-Tawas; MI117 Kalkaska-Rubicon-Duel; MI170 Longrie-Carbondale-Ruse; MI203 Dawson-Markee-Carbondale; MI175 Cathro-Tacoosh-Nahma. Roscommon, Carbondale, Nahma, Cathro, and Ruse mucky sands may be deep but poorly drained on outwash and lake plains or shallow over bedrock; they support balsam fir, black spruce, and northern white-cedar swamps. Kalkaska and Rubicon sand are somewhat excessively drained and found on moraines, dunes, or outwash plains. Well-drained sandy loams like Duel and Longrie are found on sandy moraines covered with northern hardwoods mixed with balsam fir.

Pre-settlement Vegetation

Portions of the region have thin soils over bedrock. Forest types varied on these soils depending on drainage: better drained soils supported northern hardwoods and poorly drained sites had balsam fir, spruce, and white cedar. Northern hardwoods also grew on dunes closer to the lakeshore where there was less moisture stress; farther inland red and jack pine occurred in dune habitats. Cedar swamps and tamarack swamps filled poorly drained depressions.

Climate

This ecoregion has the warmest climate in the Upper Peninsula. The growing season of about 125 days is similar to the Cheboygan Lake Plain ecoregion to the south across Lakes Michigan and Huron. There is some lake effect snowfall, but it is less than that on the western and northern Superior lake shore.

Boundaries

The northern boundary in the east meets the homogeneous soils and flat topography of the Rudyard Clay Plain (50z). The central portion is bounded by the Seney-Tahquamenon Sand Plain (50y) to the north, a region with many wetlands and organic soils. In the southwest the ecoregion boundary is delineated at the rolling Menominee Drumlins and Ground Moraine (50l).

Mapping issues

NRCS CRA 94B.2 uses one unit similar to this one. *USFS* and *Albert* split the region into two sections near Manistique. Albert suggests there is a climate difference from west to east, but we felt that the similarities between the two sections were greater than the climatic differences.

<u>50ab Cheboygan Lake Plain</u>

The Cheboygan Lake Plain is characterized by its surficial and bedrock geology, sandy soils, a predominance of poorly drained soils and wetlands, and pre-settlement vegetation.

Surficial and Bedrock Geology

The covering of glacial drift is thinner along the lake shores. Limestone, dolomite, and gypsum lie just beneath the surface or are locally exposed and mined. The rest of the ecoregion is covered by sand, expressed as sand dunes, beach ridges, and flat sand plain. The dunes and beach ridges are excessively drained and the interdune swales and flat sand plain are poorly drained.

Soils: The regions soils are mainly sand, cobbly sand, and gravelly sand: MI108 Krakow-Onaway-Detour; MI129 Summerville-St. Ignace-Alpena; MI121 Roscommon-Tawas-Au Gres; MI130 Detour-Hessel-Nadeau; MI112 Pinconning-Ingalls-Hettinger. Detour, Hessel, and Au Gres are somewhat poorly drained cobbly loams and loamy sands that support white cedar, black spruce, aspen, and birch. St. Ignace is a fine, shallow silt loam over bedrock, supporting northern hardwoods, white cedar, and balsam fir. Nadeau and Alpena represent the coarser-textured, well-drained to excessively-drained sandy soils on beach ridges. Wetland species are found on poorly-drained Hettinger and Roscommon mucky sand.

Pre-settlement Vegetation

The broad areas of wetland were dominated by northern white-cedar and tamarack. Various moisture and drainage conditions supported balsam fir, black spruce, hemlock, white pine, aspen, birch, and willow. Red pine and jack pine grew on dry outwash sands, and white pine and red pine occurred on beach ridges.

Boundaries

The Cheboygan Lake Plain is clearly distinguished from inland regions to the south, like the Onaway Moraines, Vanderbilt Moraines, and Mio Plateau, by its flat topography, longer growing season, increased incidence of wetlands, reduced occurrence of northern hardwood forest, and thinner glacial drift, with limestone bedrock near or at the surface. It differs from other lake plain regions to the south in its more severe climate, the addition of northern species in wetland habitats, and bedrock near the surface, sometimes forming cobble beaches.

<u>50ac Onaway Moraines</u>

The Onaway Moraines ecoregion is characterized by climate, heterogeneity of landforms, and pre-settlement vegetation.

Climate

The Onaway Moraines span an area that experiences a lake effect from Lakes Michigan and Huron in the north portion, and further south near the steep moraines ascending the Mio Plateau, the growing season is shorter (about 108 days) and the winter is more severe. A combination of the northern location and a profusion of cold air pockets produces habitats suitable for forests with a boreal character.

Landforms

The region's landforms are heterogeneous: they include rolling as well as steeper ground moraine, drumlins, and outwash deposits, both excessively drained and poorly drained. Glacial drift is very thick, up to 500 feet, in the south at the edge of the Vanderbilt moraines, but it declines steadily in depth to the north. Closer to the lakes there are areas of karst topography and bedrock exposure.

Pre-settlement Vegetation

The variety of landforms and soils supported similarly diverse forest types and soil moisture regimes. Red oak and red, jack, and white pine grew in dry outwash soils; beech-sugar maple and associated northern hardwoods occurred on rolling ground moraines and drumlins; and white cedar, tamarack, black spruce, and black ash grew in wetlands and swamps. As mentioned above, a combination of northern location, heavy lake effect snows, shorter growing season, and cold air drainage combine to create habitats suitable for boreal forest species such as white- cedar, spruce, and balsam fir.

Land Use Capability

Though the soils are very rocky, much of the terrain once covered in northern hardwood forest has been cleared for pasture, potatoes, and row crops.

Boundaries

The southern boundary is marked where the more gently rolling ground moraines and drumlins meet the steep end moraines of the Vanderbilt Moraines ecoregion (50ad). The northern boundary is at the meeting of the rolling moraines and the flat Cheboygan Lake Plain.

Mapping Issues

The ecoregion as delineated here also includes Albert's VII 6.2 Stutsmanville sand ridges in the far northwest corner, which share the region's distinguishing features: sandy ground moraines, thick drift (up to 500 ft.), northern hardwoods forest, wetland vegetation in poorly drained outwash, and geographic position just above the Cheboygan Lake Plain (50ab).

50ad Vanderbilt Moraines

The distinguishing features of the Vanderbilt Moraines ecoregion are very similar to those of the Mio Plateau to the south. The two areas share similar climate, soils, depth of till, pre-settlement vegetation, and fire regime patterns. In addition, both regions have "blue ribbon" trout stream habitats. The major difference lies in their landforms, the steep end moraines of the Vanderbilt Moraines contrast with the flat Mio Plateau. Elevations decline 200-400 feet along the escarpment. Streams in the Vanderbilt Moraines ecoregion have steeper gradients; strong winds are channeled down the narrow valleys, and cold air drainage off the high plateau pools in white cedar dominated wetlands below.

Boundaries

The southern boundary is delineated at the edge of the Mio Plateau (50ad). The base of the toe slopes of the end moraines forms the northern boundary, where the Vanderbilt Moraines meet the Onaway Moraines ecoregion.

Mapping Issues

Attendees at the meeting in Lansing decided that the differences between the Mio Plateau and the Vanderbilt Moraines were enough to separate them into two separate regions.

50ae Mio Plateau

The Mio Plateau is characterized by its climate, landforms, soil, pre-settlement vegetation, and fire regime.

Climate

The Mio Plateau, with its inland location and higher elevations, has the most continental climate in the Lower Peninsula. There is a chance for frost at any time of the year. The growing season is the shortest in the LP at 80-130 days. Snow amounts are like those in the Cadillac Hummocky Moraines, up to 140 inches in the west and 60 in the east.

Landforms

A broad apron of outwash plain extends in a southwesterly direction from high end moraines in the north. Glacial drift is extremely deep, as much as 800 ft. thick. The water table is far beneath the surface of the thick glacial drift; as a result, there are fewer wetlands and lakes on end moraines and outwash than in some other ecoregions (e.g., 56h). However, there are areas of lakes and wetlands where lenses of clay lie beneath the surface. Depressions in the outwash plain serve as frost pockets that limit the growth of deciduous forest species, but they are better suited to jack pine.

Soils

The region contains mostly well-drained to excessively drained sandy soil associations like the frigid soils in the northern Cadillac Hummocky Moraines ecoregion (50ae). Soil associations: MI126 Rubicon-Grayling-Croswell; MI119 Grayling-Graycalm-Au Gres; MI116 Kalkaska-Leelanau-Emmet; MI124 Rubicon-Graycalm-Montcalm MI131 Lupton-Carbondale-Tawas; MI115 Graycalm-Kalkaska-Montcalm. Grayling, Rubicon, and Graycalm sands are excessively drained and generally left in jack pine and pin oak forest. The well-drained Montcalm, Emmet, and Kalkaska sandy loams support a more diverse hardwood forest, with sugar maple, red pine, and some white and jack pine. The somewhat poorly drained Au Gres soil supported moist habitat forest species such as northern white-cedar, balsam fir, red maple, and hemlock, and it may be cleared for pasture. The Lupton, Carbondale, and Tawas soils comprise the mucky wetland soils found near Houghton and Higgins Lakes as well as Dead Stream Swamp.

Pre-settlement Vegetation

Most of the region is forested. Jack and red pines, white and pin oak grew on the more excessively drained outwash plains. Wetter outwash supported white pine, hemlock, aspen, and red maple. Fire created a mosaic of vegetation types on the drier outwash plains. The most frequently burned areas contained open grassland, jack pine savanna, or closed forests of jack and red pine. The fire-prone jack pine forest remains an important nesting habitat for the endangered Kirtland's warbler. Beech-sugar maple and other hardwoods species grew on the finer-textured soils. This was particularly true in the northwestern part of the region where a long end moraine creates a fire break; in the northwest there is also higher humidity and some lake effect snow. Conifer hardwood swamps, mixed conifer swamp, and bogs occur near Higgins and Houghton Lakes and Dead Stream Swamp.

Boundaries

The northern boundary is delineated at the edge of the high plateau where it drops off toward the northern Lake Michigan and Lake Huron shorelines. The western boundary marks a similar drop in elevation to the Manistee-Leelanau Shore. The southwestern boundary is drawn where the flat outwash plain meets the Cadillac Hummocky Moraines. Finally, the transition to the finer- textured soils of the Tawas Lake Plain forms the eastern boundary.

Mapping issues

Ecoregion 50ad generally matches the outline of Albert's Grayling Subdistrict.

<u>50af Cadillac Hummocky Moraines</u>

The Cadillac Hummocky Moraines ecoregion is distinguished by its landforms, climate, soils, and land use capability.

Landforms

The end moraines that comprise the Cadillac Hummocky Moraines are composed of exceptionally deep sandy and gravelly drift. Some of the moraines are 200-500 ft high, and the region also contains the highest point in the Lower Peninsula (1725 ft.). Because of the depth of the drift and the desiccation of outwash soils, the moraines do not alternate with wet depressions as they do in other moraine-based ecoregions.

Climate

The region's inland location makes it one of the colder Lower Peninsula ecoregions, with a growing season that ranges between 90 and 140 days. However, the climate is variable across the region. Snowfall declines from 100 to 50 inches west to east and the mildest temperatures are found in the southeast portion near the Saginaw Basin.

Soil

The region has mostly very deep sandy soils; there are some sandy loams in the southern portion. Mesic soils: MI076 Remus-Spinks-Coloma; MI011 Coloma-Spinks-Oshtemo; MI014 Spinks-Houghton-Boyer; MI058 Perrinton-Ithaca-Coloma. Boyer and Spinks soils are associated on outwash plains and valley trains. The well-drained Spinks soils have an eolian origin and are mostly in pasture to reduce wind erosion from tillage. Soils like Coloma are excessively drained and often left to second growth oak woodland. Perrinton and Ithaca soils are somewhat finer textured and less permeable; they supported beech-sugar maple forest, and with cultivation, they are in forage crops and pasture. Frigid soils: 124 Rubicon-Graycalm-Montcalm; 117 Kalkaska-Rubicon-Duel; 107 Emmet-Montcalm-Kalkaska. Rubicon and Graycalm sand are excessively drained and generally left in jack pine and pin oak forest. The well-drained Montcalm, Emmet, and Kalkaska sandy loams support a more diverse hardwood forest, with sugar maple, red pine, hemlock, and some white and jack pine.

Land Use Capability

Though some of the soils listed above are farmed more intensively in other ecoregions, they are mainly used for pasture in the Cadillac Hummocky Moraines.

Pre-settlement Vegetation

In this cooler, more northerly ecoregion, even sandy, coarse-textured end moraines were dominated by beech-sugar maple and red oak, with some hemlock and white pine. Outwash areas and moraines that burned frequently had a more xeric forest cover, with white and black oak, red and jack pine. The Cadillac Hummocky Moraines straddle a transition zone where southern hardwood species such as such as black walnut, tulip poplar, and the hickories begin to drop out and are replaced by eastern hemlock, white pine, and yellow birch.

Boundaries

The high, steep end moraines of the Cadillac Hummocky Moraines contrast with the flat outwash plains to the west (50ag Newaygo Barrens) and northeast (the Mio Plateau 50ae). This ecoregion's more northerly location, steep topography, and droughty soils distinguish it from the rolling ground moraines on the cultivated Lansing Loamy Plain (56g) to the south. Also, the Cadillac moraines do not alternate with wetland depressions as do the moraines on the Lansing Loamy Plain. Differences in climate, vegetation, soils, and land use capability between the Cadillac Hummocky Moraines and the Lansing Loamy Plain form the basis for the boundary between Level III ecoregions 50 and 56. The end moraines in this ecoregion are not studded with kettle lakes as are those in the Interlobate Dead Ice Moraines (56h). The region is like the Mio Plateau (50ae) in the thickness of the drift and in its elevated position.

Mapping issues

The region is like *Albert's* VII.2.1. Because the Cadillac Hummocky Moraines are evenly divided into frigid soils in the north and mesic in the south, the *NRCS* framework divides it into two separate Common Resource Areas.

<u>50ag Newaygo Barrens</u>

The Newaygo Barrens is characterized by its sandy soils, pre-settlement vegetation, and climate.

Soils: Most of the soils are well-drained or excessively drained. MI119 Grayling-Graycalm-Au Gres; MI080 Plainfield-Kingsville-Pipestone; MI050 Grattan-Pipestone-Granby. MI124 Rubicon-Graycalm-Montcalm. Grayling, Rubicon, and Graycalm sand are excessively drained and generally left in jack pine and pin oak forest. The well-drained Montcalm sandy loam supported a more diverse hardwood forest, with sugar maple, red pine, and some white and jack pine. The somewhat poorly drained Au Gres soil supported moist habitat forest species such as northern white-cedar, balsam fir, red maple and hemlock, and it may be cleared for pasture. The somewhat poorly drained Pipestone soil in the southern half of the region is cultivated for pasture or specialty crops. Some of these soils, like Plainfield and Grattan were once cultivated for grain, corn, and specialty crops, but are now reverting to second growth forest or pine plantations in some areas.

Pre-settlement Vegetation

The sandy soils of the Newaygo Barrens were once the location for broad areas of tallgrass prairie and oak and white pine savanna. Frequent fire perpetuated these habitats; ground fires likely burned the grassy understory and retained larger trees within the savanna intact. Jack pine and northern pin oak also grew on the fire-prone outwash plain. Because of the proximity to Lake Michigan, beech and sugar maple were able to grow in areas that did not experience frequent fire.

Climate

Ecoregion 50ag is close enough to Lake Michigan to experience some moderation in climate and some lake effect precipitation. Lake effect snow varies from 140 inches on the west side to 70 inches on the eastern boundary. The length of the growing season is intermediate between the lake front ecoregions (56d, 56f, 51m) and the interior Mio Plateau (50ae. The region experiences cold air drainage from the Mio Plateau as well, which raises the risk for late spring frosts.

Land Use Capability

The droughty sandy soils, leaching of nutrients, and erosion risk limit the capability of Newaygo soils for agriculture. In some areas, farmland has been abandoned and has reverted to forests of white oak, black oak, and jack pine.

Boundaries

The western boundary is delineated where the flat outwash plain meets the more diverse topography of the Lake Michigan Lake Plain (56d) and the Manistee-Leelanau Shore (51m). The flat outwash meets the hilly topography of the Cadillac Hummocky Moraines (50af) in the east. The northern boundary is discussed below in Mapping Issues. The Newaygo Outwash ecoregion differs from the Battle Creek Outwash (56b) in its cooler climate and in the addition of conifers to the forest vegetation there. It differs from the Mio Plateau (50ae) outwash in its lower elevation, more moderate climate, and greater capability for (limited) agricultural production

Mapping Issues

The boundaries of this ecoregion agree with those of Albert's Newaygo District (VII.3) except in the far northern portion. There, the Platte River outwash has been included in the Manistee-Leelanau Shore ecoregion (51m).

NRCS divides this region based on the mesic/frigid line. The mesic/frigid break integrated well with other attributes on the east and west lake plain ecoregions (56d, 56f, 50ah), but in this ecoregion the soil temperature factor did not dominate other attributes.

<u>50ah Tawas Lake Plain</u>

The Tawas Lake Plain is distinguished from other Huron/Erie Lake Plain ecoregions by its climate, soils, pre-settlement vegetation, and land use capability.

Climate

A major climate change occurs near the southern border of the Tawas Lake Plain where cool northern air masses meet those from the south. The growing season in the Tawas Lake Plain is up to 20 days shorter than that of the Saginaw Lake Plain to the south. Though the proximity of Lake Huron has a modest moderating effect on the climate of the Tawas Lake Plain, there is no lake effect in winter precipitation. Snow amounts are 40-60 inches in this ecoregion compared to 100-140 inches at the same latitude on the west side of the state.

Soils

Though there are some clay and silt-based soils in the southern portion of the ecoregion, more of the lake plain consists of excessively-drained to poorly drained sands:126 Rubicon-Grayling-Croswell;127 Rubicon-Croswell-Au Gres; 122 Roscommon-Au Gres-Iosco; 97 Nester-Kawkawlin-Sims; 99 Kawkawlin-Iosco-Sims; 111 Iosco-Brevort-Gladwin. Rubicon sand is excessively drained and most of it remains in cut-over native forest or pine plantations. A small proportion of the somewhat poorly drained or moderately well-drained sandy loams such as Iosco, Kawkawlin, Croswell, or Au Gres may be used for pasture, grain, hay or specialty crops such as blueberries. Sims is a clay loam; though it is poorly drained, it may be tiled or ditched for conversion to cropland. Roscommon, a poorly drained mucky sand, and Brevort, a poorly drained sandy loam, support balsam fir, black spruce, jack pine, northern white-cedar, and quaking aspen.

Pre-settlement vegetation

Beach ridges supported red oak and white and red pine. Beech-sugar maple, along with hemlock and white pine, occurred on finer-textured loam or clay soils. Poorly-drained areas on the lake plain created a diverse collection of wetland habitats such as cedar, black ash, tamarack, and hemlock/white pine/red maple swamps, old lake embayment shrub swamps, and Great Lakes marsh along the lake shore.

Land use capability

The colder climate combined with the widespread occurrence of nutrient-poor sand and poorly-drained wetlands result in less cropland and a higher proportion of this lake plain's area being devoted to forest or pine plantation than in the lake plain regions to the south (Ecoregions 57a and 57e).

Boundaries

The boundary on the northwest meets the Mio Plateau (50ae) outwash plain and the moraines of the Vanderbilt and Onaway Moraines. The southern boundary is drawn in the vicinity of the transition to a cooler northern climate; the boundary line is delineated along STATSGO polygons marking the transition to soils with a frigid temperature regime.

Mapping Issues

The region closely matches Albert's Arenac District (VII 1.1), except for the southern boundary. The EPA framework also cuts off the arm of the Lansing Moraine that extends north of the Level III Ecoregion 50 line and includes the finer-textured northern Lansing Moraine soils with the finer-textured Tawas Lake Plain soils.

<u>51 North Central Hardwood Forests</u>

Modified description from Wisconsin poster

The North Central Hardwoods Forests (51) is a transitional region between the predominantly forested Northern Lakes and Forests (50) and the warmer, mostly agricultural ecoregions to the south. Though the ecoregion occurs mostly in Minnesota and Wisconsin, a narrow zone follows the Michigan lake shore in northern Lower Michigan. Here, steeply sloping end moraines and drumlins, sand dunes, and outwash plains support a mosaic of forests, wetlands and lakes, commercial fruit production, and pasture. The growing season is generally longer in Ecoregion 51 than in the Northern Lakes and Forests (50). Lake densities are generally lower here than in Ecoregion 50, and lake phosphorus levels tend to be higher.

51m Manistee-Leelanau Shore

The Manistee-Leelanau Shore is distinguished by its climate, sandy soils, land use capability, and pre-settlement vegetation.

Climate

Though the climate is somewhat cooler and the growing season somewhat shorter than that in the Lake Michigan Lake Plain (56d) to the south, lake moderation of the climate in this region is enough to support commercial fruit production for cherries, apples, and grapes. Lake effect snowfall is heavy, about 100-140 inches.

Soils

Lakeside dunes, steep end moraines, and lake plains in the region are composed of sandy soils of varied texture. The soil temperature regime is mesic close to the lakeshore and frigid inland. The dunes consist of excessively drained, coarse sands of eolian origin. The moraines may contain a range of fine- to coarse-textured sands. MI116 Kalkaska-Leewenau-Emmet; MI107 Emmet-Montcalm-Kalkaska; MI106 Emmet-Onaway-Omena. Emmet is a well-drained sandy loam on end moraines and drumlins. It supports fruit orchards in favorable locations, grain, and hay elsewhere. Steep areas are left in beech, maple, aspen, hemlock, and red pine forest. Omena is a sandy loam mostly cultivated to grain, corn, and hay. Leelanau and Montcalm are somewhat sandier, and a larger proportion is kept in forest and pasture. Kalkaska sands are excessively drained and support beech-sugar maple and red and white pine forest.

Pre-settlement vegetation

Because of the lake-moderated climate, beech-sugar maple and other northern hardwoods occurred even on sandy moraines, dunes, and outwash. The difference in this more northern lakeside region is the addition of a larger proportion of conifer species: hemlock and white pine on lake plain and moraines, and hemlock, white, red, and jack pine on the dunes. Poorly drained portions of the lake plain supported elm, ash, tamarack, or cedar swamps, and large areas of marsh surrounded the large coastal lakes near Manistee and Big Sable.

Boundaries

The eastern boundary of the Leelanau Shore is marked where the outwash and steep end moraines of the interior plateau begin (Ecoregion 50ad and 50ae). The southern boundary at its narrowest points south of Manistee.

Mapping Issues

The Manistee-Leelanau Shore ecoregion takes the northern portion of Albert's Manistee region and places it in EPA's Level III region 51 along with Albert's Leelanau District.

<u>51n Platte River Outwash</u>

The Platte River Outwash ecoregion is characterized by its sandy soils, land use capability, climate, and pre-settlement vegetation.

Soils

Most of the outwash soils are excessively drained to well-drained: MI116 Kalkaska-Leewenau-Emmet and MI125 Rubicon-Eastlake-Eastport. Leelanau loamy sand and Rubicon and Kalkaska sands are excessively drained and support beech-sugar maple and red and white pine forest. Eastlake and Eastport sands similarly support mixed hardwoods and pine, but small areas may be under cultivation for small grains and hay.

Land Use Capability

Early attempts at cultivation of the outwash sands led to wind erosion, loss of productivity, and eventual abandonment of farms. Today, many areas are idle, and now support pine plantations or native forest of pines, red and black oak, and aspen.

Climate

The climate of Ecoregion 51n is midway between the mild, lake-moderated climate of the Manistee-Leelanau Shore (51m) and the colder, more continental climate of the interior ecoregions, the Mio Plateau (50ae) and the Cadillac Hummocky Moraines (50af)

Pre-settlement Vegetation

The forest cover of the Platte River Outwash included beech-sugar maple forest even on sandy outwash soils.

Boundaries

The triangular Platte River Outwash has a boundary moraine of the central Mio Plateau as its eastern boundary and the other two boundaries meet the lake plain of the Manistee-Leelanau Shore.

Mapping Issues

The Platte River outwash area is included in the northern portion of Albert's Newaygo Outwash region (VII.3). In the EPA framework, it is separated from the corresponding Newaygo Barrens (Ecoregion 50ag) to the south because of its pre-settlement vegetation (northern hardwoods-beech-sugar maple). The rest of the outwash region to the south contained more oak and pine and experienced frequent fire. The Platte River Outwash may have escaped burning because of its proximity to Lake Michigan.

55 Eastern Corn Belt Plains (OH/IN)

Ecoregion 55 is primarily a rolling till plain with local end moraines. It has loamier and better drained soils than the Huron/Erie Lake Plain (Ecoregion 57). Glacial deposits of Wisconsinan age are extensive; they are not as dissected nor as leached as the pre-Wisconsinan till which is restricted to the southern part of Ecoregion 55. Originally, beech, sugar maple, and basswood forests were common. Today, extensive corn, soybean, and livestock production occurs that has affected stream chemistry and turbidity.

55a Clayey, High-Lime Till Plains

Modified from Indiana/Ohio poster description

Rolling ground moraines and deep, clay loam soils characterize the Clayey, High-Lime Till Plains ecoregion (55a). Though soils in Ecoregion 55a are somewhat less productive than those in the Loamy, High-Lime Till Plains ecoregion (55b) to the south, the land has been under intensive agricultural production since the mid-nineteenth century. The region's corn, soybean, wheat, and livestock farming have replaced the original land cover of beech-sugar maple and oak-hickory forests. Because of the prevalence of row crops and accompanying fine soil erosion, the low gradient streams of Ecoregion 55a are turbid; however, streamside cover strips and no-till agriculture have somewhat reduced sediment inputs to surface waters.

This ecoregion is characterized by its landforms and soils.

Landforms

The arm of 55a that extends north into Michigan is composed of a series of flat ground moraines and more rolling end moraines. There are few lakes in this ecoregion.

Soil

Soils include fine-textured silt and clay loams: MI017 Miami-Conover-Brookston, MI055 Blount-Glynwood-Morley, MI006 Morley-Blount-Pewamo, and MI010 Urbanland-Marlette-Capac. Miami – very deep, fine silt loam with an overlying layer of loess. Brookston – deep, poorly drained silt loam. Conover - deep, somewhat poorly drained fine loam. Blount – very deep, somewhat poorly-drained clay loam. Glynwood – moderately drained fine silt loam, loess component. Morley – very deep, moderately well-drained clay loam with a loess component. Pewamo - very deep, poorly drained clay loam. Marlette – fine sandy loam, moderately well-drained. Capac – fine sandy loam, somewhat poorly drained.

Pre-settlement Vegetation

The historic forest vegetation consisted of oak-hickory on well-drained soils and beech-sugar maple on clay soils. Most of what was once closed-canopy forest has been cleared and half of the region's wetlands have been drained for agriculture. Wetter soils also supported red maple, American elm, white ash, and American basswood. Today small areas of cutover woodland occur on steeper slopes and the landscape is almost entirely devoted to corn, soybeans, oats, wheat, and hay.

Water Resources

In Ecoregion 55a the major water quality problems on rivers and tributaries originate from nutrient loading, high sediment inputs, and agricultural chemicals. Channelization of tributaries has also increased sediment loading. Best management practices such as no-till farming and cover strips near waterways have achieved some progress in reducing sediment and chemical pollution. Wooded river corridors are important for sustaining remaining populations of mammals (fox, mink, muskrat, beaver) and birds, both resident and migrant (Dodge, River Raisin Assessment, 1998).

Boundaries

The eastern boundary is marked where the moraines of the Clayey, High-Lime Till Plains meet the flat Maumee Lake Plain (57a). The transition to lake-studded ice contact topography and sandier soils defines the boundary between this ecoregion and the Interlobate Dead Ice Moraine (56h) to the west. The present boundary in the northeast does not extend as far as does the region outlined by Albert et al. because of the transition to a more lake-rich topography and sandier soils in northern Oakland County that are more typical of ecoregion 56h. Near the Indiana/Michigan border, the northwest boundary is placed at the northwestern boundary of soil series MI017.

Mapping issues

There is general agreement among the agency frameworks on the location and extent of 55a in Indiana and Ohio (*NRCS MLRA 111B, USFS 222Je*) and that an arm of 55a extends into Michigan. The soil types characteristic of 55a appear to end in middle Oakland County at the north end of MI010. North of there MI016 and M014 are soil associations that cover the width of ecoregion 56h, the Interlobate Dead Ice Moraines. Near the Indiana/Michigan border, the northwest boundary of 55a is marked at the northwestern boundary of soil association MI017, Miami-Conover-Brookston. This soil association occurs again in 55a further north and southeast of

Jackson, Michigan. The soils in this association are similar to the other clay loams of 55a in that they are fine-textured, well-drained to somewhat poorly-drained, silt loams and almost entirely cultivated to the same crops grown elsewhere in 55a (corn, soybeans, grains). They and the other silt and clay loams of 55a also share an overlying layer of loess. They are more similar to soils in 55a than they are to the sandy, very well-drained soils in the neighboring ecoregion, the Interlobate Dead Ice Moraines (56h). This evidence indicates a wider ecoregion 55a in the vicinity of the Indiana/Ohio/Michigan state line (the jog in the state lines).

56 Southern Michigan/Northern Indiana Drift Plains

Modified from the Ohio/Indiana poster

Ecoregion 56 is distinguished from adjacent ecoregions by its many lakes and marshes as well as its diverse assortment of landforms, soil types, soil textures, and land uses. Broad till plains with thick drift deposits, moraines, paleobeach ridges, relict dunes, kames, drumlins, meltwater channels, and kettles occur. Feed grain, soybean, and livestock farming as well as woodlots, quarries, recreational development, and urban-industrial areas are common. An assortment of soils developed under oak-hickory forests, northern swamp forests, or beech forests. Bogs and bog soils are also locally common. Low to medium gradient streams occur and often have gravelly substrates and low amounts of suspended sediment.

56b Battle Creek Outwash Plain

The Battle Creek Outwash Plain is characterized by its landforms, soil, and historic vegetation.

Landforms

The Battle Creek Outwash Plain is a broad, flat plain that served as a major drainage way for receding Pleistocene glaciers. Today, streams and rivers occupy some of the main outwash channels. A few low moraines are scattered across the plain.

Soils

The sands and gravels underlying the outwash plain are coarse and permeable and a source of ground water. Associated soils on both outwash plain and low moraines are predominantly well-drained sandy loams that can be droughty or subject to wind erosion. Soil series: Soils in the drainage include well-drained loamy and sandy soils: MI045 Oshtemo-Kalamazoo-Houghton; MI047 Schoolcraft-Kalamazoo-Elston; MI014 Spinks- Houghton-Boyer; MI041 Barry-Locke-Hatmaker; MI011 Coloma-Spinks-Oshtemo; MI034 Riddles-Hillsdale-Gilford. Oshtemo, Boyer, and Kalamazoo are sandy loams, mostly cultivated to corn, soybeans, and grain. The well-drained Spinks soils have an eolian origin and are mostly in pasture to reduce wind erosion from tillage. Houghton, Locke, and Barry represent poorly drained sandy soils in depressions, often drained for corn, soy, and vegetable production. Soils like Coloma are excessively- drained and often left to second growth oak woodland.

Pre-settlement Vegetation

The region's pre-settlement vegetation was diverse. The coarse soils of the outwash plain supported Michigan's largest concentration of dry tallgrass prairies, though wet prairies were also common. Frequent fires maintained the prairie and savanna habitats. Oak savanna grew on gently sloping terrain where fires were more frequent and oak-hickory forest grew in steeper terrain or where moisture conditions did not favor frequent fires.

The outwash deposits provide for stable flows in the region's streams and rivers. Though stream quality is generally better than in lake plain and till plain ecoregions (such as 57a and 55a), channelization and the removal of riparian vegetation have degraded both aquatic and terrestrial stream habitats. Silt-tolerant fish species have increased as sediment is deposited in gravel substrates (Wesley and Duffy, 1999). The distribution of lakes is not as dense as on the end moraine complexes (such as Ecoregion 56h), but they are numerous and they serve as the source of some of the region's streams.

The ecoregion's southerly location gives it a relatively warm climate compared to the rest of the state. However, situated as it is east of the Lake Michigan Moraines (Ecoregion 56f), the region experiences little lake temperature moderation, though the far western portion of the region does receive some lake effect snow.

Boundaries

The Battle Creek Outwash Plain meets the lake-studded end moraines on the north and northeast. The western boundary is marked where the Lake Michigan moraines meet the more level outwash plain. In the southeast the region's boundary is based on soil type, that is, where the sandy outwash soils meet the finer-textured clay loams of the Clayey, High-Lime Till Plains (55a).

Mapping issues

This ecoregion is like Albert's VI 2.1 Battle Creek.

56d Michigan Lake Plain

Modified description from the Ohio/Indiana poster

The Michigan Lake Plain ecoregion is a sandy coastal strip with beaches, high dunes, beach ridges, mucky inter-dune depressions, and swales. Its lake-moderated climate, as well as its beach and dune plant communities, differentiates it from inland ecoregions. Drought tolerant oak and pine grow on stabilized dunes and remnants of beech-sugar maple forest grow on dunes and moraines. The lake-moderated climate makes this region the center for fruit and vegetable farming in Michigan.

The Michigan Lake Plain is characterized by its climate, predominance of sandy soils and lake plain features, pre-settlement vegetation, and present-day land use capability.

Climate

The Michigan Lake Plain has a relatively mild lake-moderated climate. The growing season ranges from 140-157 days north to south. Lake effects, such as cooler summer temperatures, moderate winter temperatures, heavy winter snow, and early last frost date strongly influence the natural vegetation and land use capabilities. Lake effects extend inland eastward to include the flanking moraines adjacent to Ecoregion 56d (Lake Michigan Moraines, Ecoregion 56f).

Soils

Though there are some low moraines in this ecoregion having well-drained clay loam soils, the predominant soil parent material is sand. Sand covers the flat lake plain and it forms dunes as high as 200 ft. Sand over clay creates wetland areas, many of which have been drained for agriculture. Excessively drained sands are generally left in natural cover because of erosion risk. Representative soil associations: MI031 Blount-Pewamo-Glynwood; MI011 Coloma-Spinks-Oshtemo; MI048 Capac-Riddles-Selfridge; MI046 Oakville-Covert-Adrian; MI050 Grattan-Pipestone-Granby. Excessively drained Oakville and Grattan soils are located on dunes and beach ridges; they support oak and white pine vegetation and may be cultivated with grain, hay, or vegetables. Granby, Capac, and Pipestone are poorly drained sandy loams or clay loams between ridges; they support marsh grasses, aspen, silver maple, or if drained, small grain, hay, fruit and veg. The well-drained Spinks and Covert sands are mostly in pasture or hay or in second growth woodland of aspen, cherry, oak, and white pine.

Pre-settlement Vegetation

Higher humidity and soil moisture retention affect forest cover. Pine and hemlock, often found on stabilized dunes, occurred farther south than in inland areas, possibly because of cooler summer daytime temperatures. Beech and sugar maple, normally found on clay soils, grew on sandy soils in this region due to reduced moisture stress. Wetlands were widespread in inter-dune swales and in riparian areas of rivers and streams. The wetlands varied from treeless marshes to lowland hardwood swamps (black ash or silver maple dominant) to tamarack swamp. Most of these wetlands have been drained for blueberry and asparagus farming. Significant floodplain wetlands still exist near the White, Muskegon, and Sable rivers.

Land Use Capability

The focus of present-day land use is in fruit, vegetable, nursery, orchard, and vineyard production.

Boundaries

The eastern boundary of the Michigan Lake Plain lies along the base of the Lake Michigan Moraines (56f). The northern boundary is marked by the transition to a cooler climate at the southern boundary of the Manistee-Leelanau Shore (51m). The Michigan Lake Plain ecoregion is distinguished from the Lake Michigan Moraines (56f) to the east by the transition from flat lake plain to rolling moraines and more diverse soil types.

Mapping issues

This ecoregion includes *Albert's* VI.3.2 Benton Harbor Subdistrict and the southern portion of *Albert's* Manistee District. These two areas were aggregated because of their similarities in climate, pre-settlement vegetation, soils, landforms, and land use. (Soil series MI050 extends into the southern third of the Manistee District.) Temperatures are somewhat cooler, and the growing season is somewhat shorter in the northern part of the Michigan Lake Plain.

<u>56f Lake Michigan Moraines</u>

The Lake Michigan Moraines ecoregion is characterized by its landforms, climate, and pre-settlement vegetation. Landforms: The Lake Michigan Moraines lie inland and parallel to the present-day lake shore. They consist of end and ground moraines left by one of the advances of the Michigan lobe of the Wisconsinan glacier.

Climate

The Lake Michigan Moraines ecoregion experiences a lake-moderated climate. Lake effects, such as cooler summer temperatures, moderate winter temperatures, and early last frost date influence the natural vegetation and land use capabilities, though somewhat less than on the lake plain itself. Lake effect snow can be heavy in the western portion, but it quickly declines to the east of Ecoregion 56f.

Pre-settlement vegetation

Due to the lake effect, beech and sugar maple dominated both clay loams and sandy loams. Further inland, various oak dominated forest types occupy sandy soils. In the northern portion of Ecoregion 56f some hemlock also occurred in somewhat poorly drained soils in depressions. Oak savanna and oak-hickory forest grew on drier ridges and steep slopes.

Soil

MI057 Riddles-Crosier-Oshtemo; MI048 Capac-Riddles-Selfridge; MI058 Perrinton-Ithaca-Coloma; MI011 Coloma-Spinks-Oshtemo; MI007 Wasepi-Gilford-Boyer. Well-drained Riddles, Spinks, Oshtemo, and Boyer are sandy loams, mostly cultivated to rowcrops or orchards; if uncultivated they support oak-hickory-sugar maple forest. Wasepi, Gilford, and Capac, sandy loams or clay loams, on poorly-drained soil between ridges, grew marsh grasses, aspen, and silver maple, and presently, if drained, they produce corn, grain, hay, fruit, or vegetables. Perrinton and Ithaca soils are somewhat finer-textured and less permeable; they supported beech-sugar maple forest, and with cultivation, they are in row crops and pasture. Soils like Coloma are excessively drained and often left to second growth oak woodland unless irrigated.

Land use

Most of Ecoregion 56f is cultivated. As in the Lake Michigan Lake Plain to the west, the climate is amenable to fruit production; however, because of the occurrence of finer-textured soils on the moraines in the north, agricultural production there is less focused on fruit and vegetables, but includes a larger proportion of forage and row crops.

Surface waters

Kettle lakes are present but insignificant compared to ecoregions such as the Interlobate Dead Ice Moraines (56h). There are also few streams originating in this ecoregion.

Boundaries

The ecoregion boundaries trace the point at which the rolling moraines meet the flat lake plain to the west (Ecoregion 56d) and the flat outwash plain to the east (Battle Creek Outwash Plain, 56b). Besides being hillier than either the lake plain or the outwash plain, the Lake Michigan Moraines ecoregion also includes some finer-textured soils with the coarser sands common to the other two regions. This ecoregion shares the lake-moderated climate and land use of the Michigan Lake Plain ecoregion (56d), although there is less fruit and vegetable production and more rowcrop production in the Lake Michigan Moraines.

Mapping issues

Like USFS 222Jb, although they extend it south into Indiana. This ecoregion combines Albert's VI.3.1 and VI.3.3.

56g Lansing Loamy Plain

The Lansing Loamy Plain ecoregion is distinguished by its landforms, pre-settlement vegetation, soils, and climate. Landforms: The region covers a broad area in central Lower Michigan. It consists of mostly gently rolling ground moraine; well-drained hills alternate with poorly drained linear depressions. The moraines are cut by glacial outwash channels.

Pre-settlement Vegetation

The ground moraine supported broad areas of beech-sugar maple forest. Associated species included basswood, black maple, red oak, and white ash. Oak-hickory forests grew on the drier end moraine and outwash habitats. The poorly drained depressions and riparian floodplains contained American elm, red ash, silver maple, tamarack, and swamp white oak as well as areas of wet prairie. Today, the region has been almost entirely converted to rowcrops and pasture, except for farm woodlots and the small number of steeply sloping end moraines that still support patches of oak-hickory forest. In the northwest portion of Ecoregion 56g, northern forest tree species, conifers such as white pine and hemlock, appear in woodland areas as the moraines increase in elevation and yearly temperatures decrease.

Soil

The soils on the ground moraine are medium-textured loamy soils and coarser-textured soils on outwash areas and end moraines. MI035 Marlette-Capac-Parkhill; MI061 Parkhill-Capac-Londo; MI058 Perrinton-Ithaca-Coloma; MI017 Miami-Conover-Brookston; MI036 Marlette-Capac-Spinks. Miami, Marlette, Perrinton and Ithaca soils are medium-textured loams; they supported beech-sugar maple forest, and they have been largely converted to row crops and pasture. On end moraines and outwash channels, sandy soils like Spinks and Coloma are mostly in pasture or hay or in second growth woodland. Parkhill, Brookston, and Capac loams on poorly drained soil between moraines supported marsh grasses, aspen, silver maple, and swamp white oak, and when drained, they produce corn, soybeans, and hay.

Climate

The Lansing Loamy Plain has a continental climate. With its interior location, the ecoregion does not experience a lake effect either as moderated temperatures or increased winter snow. (In the far western portion of the ecoregion there is a longer growing season and more lake effect snow, but these effects decline quickly to the east.) The growing season is140-150 days, somewhat shorter than ecoregions to the west, south, and east.

Surface waters

There are relatively few lakes in this ecoregion. Some kettle lakes occur on end moraines and in pitted outwash channels, especially in the northwest portion. Postglacial stream drainage is not well developed and many of the drainage ways contain poorly drained soils and an accumulation of organic matter. Ditching and channelization to drain poorly drained areas to convert them to pasture or to specialty crops like mint is widespread. Existing rivers and streams occupy glacial outwash channels, the most prominent being the Grand River, which carried huge amounts of glacial runoff during the withdrawal of Pleistocene glaciers.

Boundaries

The rolling ground moraine of Ecoregion 56g is similar topographically to the Lake Michigan Moraines (56f) to the west. The two regions differ climatically, however, because the Lake Michigan Moraines experience a moderating lake effect from the proximity of Lake Michigan. The Lansing Loamy Plain ecoregion differs topographically and in soil types from both the steeper Interlobate Dead Ice Moraines (56h) to the south and the flat Maumee and Saginaw Lake Plains (57a and 57e) to the east.

Mapping issues

Ecoregion 56g is like Albert''s region VI.4.1, the Lansing Subdistrict, except for the addition of the northern portion of Lum Subdistrict VI 5.2, which contains similar medium-textured ground moraine. Another of Albert's areas, the southern portion of Greenville Subdistrict 4.2, was aggregated into the Lansing Ground Moraine ecoregion. The Greenville area is small in area and not distinctive enough to merit a separate ecoregion in the EPA framework—its differences in topography and the addition of northern forest species can be addressed in the description for the Lansing Loamy Plain. The coarse-textured end moraines and oak-hickory forest vegetation found in the eastern portion of the Greenville Transition encompass quite a small area, and there are other coarse-textured moraines and outwash found inside the Lansing Loamy Plain ecoregion (in the southeast).

<u>56h Interlobate Dead Ice Moraines</u>

Landforms and associated water resources, soil, and pre-settlement vegetation characterize the Interlobate Dead Ice Moraines.

Landforms

The Interlobate Dead Ice Moraines ecoregion encompasses a band of coarse-textured end moraines, kames, and outwash sands extending across much of the width of the Lower Peninsula, beginning just east of the Lake Michigan Moraines (56f) and ending above the Saginaw Lake Plain (57e) on the east side of the state. The Interlobate Dead Ice Moraines consists of ice-contact topography or dead-ice moraine; it formed where ice melted in place within a stalled glacier, leaving numerous kettle ponds in its wake. Lakes also occur in pitted outwash channels.

Soil

Soils on the moraines are well- to excessively drained. Outwash may be either very well-drained or poorly drained if it is underlain by finer-textured material. Organic soils occur in and around kettle lakes (e.g., Houghton soils). MI034 Riddles-Hillsdale-Gilford; MI014 Spinks-Houghton-Boyer; MI016 Miami-Marlette-Lapeer; MI091 Oshtemo-Spinks-Marlette; MI036 Marlette-Capac-Spinks; MI045 Oshtemo-Kalamazoo-Houghton. Riddles, Hillsdale, Oshtemo, Boyer, and Kalamazoo are sandy loams, mostly cultivated to corn, soybeans, and grain. Capac and Gilford are poorly drained sandy loams between ridges that support marsh grasses, aspen, silver maple, or if drained, row crops and hay. The well-drained Spinks soils have an eolian origin and are mostly in pasture. All well-drained soils in the region are left in oak-hickory forest if they occur on steep slopes.

Pre-settlement Vegetation

The sandy and gravelly soils supported oak savannas, oak-hickory forest, and both wet and dry tallgrass prairies. Common tree species included white oak, black oak, pignut hickory, and pin oak. Frequent fires kept the open nature of the prairie and woodland. With fire prevention the oak woods have become more close-canopied. Oak-hickory forests on broader end moraines have been cut and the land converted to agricultural production; however, many of the end moraines are too steep for agricultural production and they remain in oak woodland (or beech maple in the far western portion of the region). Poorly drained depressions in the moraines contained wet prairie, tamarack, or willow-buttonbush swamp. Wetland losses due to agricultural drainage are less than in other ecoregions with gentler topography.

Surface waters

Though the Interlobate Dead Ice Moraines serve as the headwaters of major river systems (Grand and Raisin), in some areas drainage patterns are lacking due to the hummocky terrain and coarse underlying material. The many lakes and ponds are relatively low in nutrients compared to those in other ecoregions surrounding this one in southern Lower Michigan, such as Ecoregions 56g and 55a. (Summer Total Phosphorus map, Omernik et al., 1988). However, kettle lakes may undergo rapid eutrophication in the vicinity of agricultural and residential development.

Land use/Land Cover

This ecoregion has a more diverse land cover pattern than more highly cultivated ecoregions, with woodland, pasture, some cropland, and increasing residential development.

Boundaries

In the western portion of the state the western, eastern, and southern boundaries of Ecoregion 56h are defined at the base of the steep-sided moraines where they meet the flat Battle Creek Outwash Plain (56b). In the eastern half of the region, the northern boundary is delineated where the sandy, lake-studded end moraines meet the more gently rolling ground moraine of the Lansing Loamy Plain (56g). Similarly, the interface between the steeper end moraines and the finer-textured ground moraines of the Clayey, High-Lime Till Plain (55a) marks the southeastern boundary of Ecoregion 56h in the eastern half of the state.

Mapping issues

The Interlobate Dead Ice Moraines is an aggregation of Albert's regions VI 2.1 Battle Creek, VI 2.2 Cassopolis, VI 1.3 Jackson Interlobate, and the southern portion of VI 5.2 Lum. All four of these regions have in common sandy and gravelly end moraines, a high density of kettle lakes, sandy outwash deposits, and associated oak forest types. Individually, each region is somewhat small for the scale of level IV ecoregions and they are not distinguishable one from another.

57 Huron/Erie Lake Plains

Modified from the Ohio/Indiana poster

Ecoregion 57 is a broad, fertile, nearly flat plain punctuated by relict sand dunes, beach ridges, and low-end moraines. Originally, soil drainage was typically poorer than in Ecoregion 55, and elm-ash swamp and beech forests were dominant. Oak savanna was typically restricted to sandy, well-drained dunes and beach ridges. Today, most of the area has been cleared and artificially drained and contains highly productive farms producing corn, soybeans, livestock, and vegetables; urban and industrial areas are also extensive. Stream habitat and quality have been degraded by channelization, ditching, and agricultural activities.

Mapping issues

The Level III boundary was modified to join previously disjunct areas and to have a continuous region like *NRCS*, *USFS, Albert* frameworks.

57a Maumee Lake Plain

Modified Ohio poster description of 57a: The Maumee Lake Plain ecoregion is a Pleistocene glacial lake plain that contains clayey lake deposits, poorly drained fertile soils, and water-worked glacial till. Elm-ash swamp forests and beech forests once were widespread and extensive marshland occurred along the coast. Both forests and marshes have been mostly drained and tiled for farmland. Sluggish, low gradient rivers winding through Ecoregion 57a have high suspended sediment loads that threaten the habitats of aquatic species.

The Maumee Lake Plain is characterized by its topography, climate, and pre-settlement vegetation.

Topography

The region's characteristic topography is a flat lacustrine sand and clay plain marking the higher water levels of Pleistocene Lake Maumee that formed about 14,000 years ago. The sand and clay deposits are as much as 100 ft. thick inland and as little as 5 ft. thick near the Lake Erie shore. Climate: Ecoregion 57a is one of the warmest areas of Lower Peninsula of Michigan. Growing season about 160 days. The Maumee Lake Plain's position at the east end of Lake Erie and well east of Lake Michigan means that it has little lake effect snow.

Pre-settlement Vegetation

Pre-settlement forest on the clay lake plain was predominantly closed-canopy forest. Well-drained rises in the clay plain supported beech, sugar maple, hickory, and basswood; less well-drained sites 1-2 feet lower supported American elm, red ash, silver maple, and other deciduous swamp species. Deciduous hardwood swamps, marshes, and wet prairie occurred in poorly drained areas. Mixed hardwood swamps were once extensive on the lake plain (forming a large proportion of over a million acres statewide). Beach ridges were covered with oak-hickory forest, oak savanna, or dry prairies. Lake plain wet prairies containing bluejoint grass, prairie cordgrass, and big bluestem once covered > 380,000 acres of lake plain. The wet prairies had seasonal water level fluctuations. Today, lowland hardwoods (pin oak, silver maple, swamp white oak, black tupelo, and burr oak) have grown in former wet prairies because water tables have dropped with the drainage of wetlands. Extensive Great Lakes marsh occurred along most of Lake Erie and Lake St. Clair shorelines. Marshes extended into 4-5 ft. of water, were 1-2 miles wide in places, and extended for miles up major rivers such as the Huron and Raisin. Upland of marshes, wet prairie or a broad zone of swamp forest occurred. Large areas of Great Lakes marsh were lost with port development in Detroit and Monroe. Total wetland loss in this region is 80-90%. Existing marshes are degraded by silt and wave action.

Land Use Capability

The lake plain was one of the first regions in the state to be farmed by European settlers and is one of the most productive agricultural regions. Most clay lands have been ditched and tiled. The only forest remaining in what was once a forested region is in scattered woodlots. A few areas of lowland hardwoods and black ash swamp remain on the sand lake plain or near waterbodies where drainage for agriculture was ineffective.

Boundaries

Ecoregion 57a is a continuation of the Maumee Lake Plain ecoregion delineated in Ohio. End moraine ridges form the northwestern boundary in Michigan where the lake plain meets Ecoregion 55a, the Clayey, High-Lime Till Plains. Conceptually, the northern boundary of Ecoregion 57a is fuzzy; it represents the gradual transition from the warmer climate of the southern lake plain to the cooler climate of the Saginaw Lake Plain to the north. The mapped delineation is marked just south of the Black River and its major southern tributary so as not to divide this major watershed. In general, the soils of the Maumee Lake Plain are fine-textured silty clays and sand over clay, while those of the Saginaw Lake Plain are loamier.

57b Oak Openings

Ohio/Indiana poster description

The Oak Openings ecoregion is a belt of low, often wooded, sand dunes and Pleistocene beach ridges that are situated among the broad, nearly flat, agricultural plains of Ecoregion 57a. Well-drained, sandy soils are common and originally supported mixed oak forests and oak savanna; poorly drained depressions with wet prairies alternated with the better-drained ridges. Today, farms, residential development, oak woodland, and sand quarries occur.

Mapping issues

Polygons in Ohio were drawn from Gordon's pre-settlement vegetation map of Ohio. In general, the polygons are larger than those in Michigan based on *Comer* and *Albert*'s historical vegetation map.

To get a number of oak polygons of adequate size in Michigan we had to combine these categories from Comer and Albert: A. Black Oak Barrens; B. Mixed Oak Savanna; C. Mixed Oak Forest; D. Oak-Hickory Forest.

Sandy soils Oakville, Tedrow, Ottokkee roughly match oak polygons listed above from *Comer* and *Albert* 1800 vegetation map. Sandy soil polygons MI054: Oakville-Tedrow-Granby; MI089: MI005: Ottokee-Granby-Tedrow; MI083: Granby-Gilford-Thetford.

57e Saginaw Lake Plain

The Saginaw Lake Plain is a continuation of the Pleistocene Maumee glacial lake plain to the south. It contains clayey lake deposits, beach ridges, and dunes of low relief, with mostly poorly- drained soils, like the Maumee Lake Plain (57a). The differences between the two regions are based mainly on climate and pre-settlement vegetation.

Climate

The climate is somewhat cooler and the growing season somewhat shorter (151-153 days) than that of the Maumee Lake Plain ecoregion (57a) to the south. Since the region is east of Lake Huron, it does not experience lake effect snow. Air temperatures are cooler along the lake shore. The western portion of the ecoregion west of Saginaw Bay is somewhat warmer compared to the peninsula, which is exposed to cooler lake shore temperatures.

Pre-settlement Vegetation

Though the Saginaw Lake Plain consists of flat clay and sand deposits similar to those composing the Maumee Lake Plain to the south, the combination of cooler temperatures along with the poorly-drained soil and somewhat lower evapotranspiration rates resulted in a pre-settlement forest that had a significant proportion of hemlock added to beech, sugar maple, and other northern hardwood species. Hemlock and white pine grew on the drier beach ridges. The mix of species on deeper, inland sandy sites included red and white pine, and white and black oak. The addition of pines and hemlock to the drier sandy sites contrasts with the predominance of oaks growing on beach ridges in the Maumee Lake Plain (57a) to the south. Cut-over areas today support aspen, black cherry, tamarack, paper birch, and red maple. A broad band of coastal marshes and wet prairies occurred along Saginaw Bay providing excellent habitat for waterfowl. Much of the region was ditched and tiled to drain the coastal marsh, wet prairies, and depressional wetlands. Little of the wetland acreage remains. Conifer swamps covered poorly drained areas and they contained northern white-cedar, tamarack, and balsam fir in addition to hardwoods tolerant of wetter habitats such as elm, ash, and swamp white oak.

The increasing prevalence of conifer swamps is another difference between the Maumee and Saginaw Lake Plain ecoregions.

Land Use Capability

Cropland is extensive on clay soils, producing corn, soybeans, white beans, sugar beets, dairy, and livestock production. A smaller area of the sand plain and beach ridges has been drained for agriculture due to risk of erosion.

Prominent soil types

Londo-fine loam, poorly drained; Parkhill-loamy, poorly drained; Avoca-sandy over loamy, somewhat poorly drained; Guelph-fine loamy, moderately well-drained; Capac-clay loam, somewhat poorly drained.

Boundaries

As stated earlier, the boundary of Ecoregion 57e with 57a represents the gradual transition from the warmer climate of the southern lake plain (57a) to the cooler climate of the Saginaw Lake Plain to the north. The mapped delineation is fixed just south of the Black River and its main southern tributary so as not to divide this major watershed. In general, the soils of the Maumee Lake Plain are fine-textured silty clays and sand over clay, while those of the Saginaw Lake Plain are somewhat loamier. The border of the Saginaw Lake Plain with the Lansing Loamy Plain (56g) and the Interlobate Dead Ice Moraine (56h) is marked topographically where the flat lake plain meets the base of the ground and end moraines that characterize those ecoregions. Though there are several low moraines in the thumb of the Lower Peninsula, they are consistent in topography and vegetation cover with the rest of the Saginaw Lake Plain. In the far northeastern corner of the Lansing Loamy Plain (56g) there is a change from a more crenulated topography to a smoother topography (near Kingston). The increase in forest land along the northwestern boundary of this easternmost portion of the Lansing Loamy Plain is consistent with the overall increase in woodland in the Saginaw Lake Plain. To the northwest, the boundary with the Tawas Lake Plain (50ah) is based on both climate and soil factors. Northern and southern air masses meet in this area, and the region to the north (50ag) is considerably cooler as a result. In addition, the mapped boundary between the Huron and Tawas Lake Plains approximates the STASGO boundaries between mesic and frigid soils.

Mapping issues

USFS and Albert et al. separate the Saginaw lake plain from the Sandusky lake plain. In contrast, *NRCS* combines these two areas with the Maumee Lake Plain (Ecoregion 57a) as CRA 99.1. We separated the Maumee from Saginaw Lake Plains, but combined Saginaw and Sandusky. Though the Saginaw lake plain region is somewhat warmer than the Sandusky peninsula, the topography (flat lake plain with sand channels and beach ridges), soil (sand and clay soils alternating with wetland depressions), and vegetation cover (beech-sugar maple-hardwoods-hemlock) are quite similar. There are few lakes in either subsection or the streams make a short straight run from the inland moraines to the lake.

Regional Landscape Ecosystems of Michigan, Minnesota, and Wisconsin

The aim of landscape ecosystem classification and mapping is to distinguish appropriately sized ecosystems—useful and functional land units that differ significantly from one another in abiotic characteristics as well as in their related biotic components. The subdivision of a large area into distinctive landscape ecosystems provides a much-needed framework for integrated resource management and planning; for biological conservation; and for comparison of differences in composition, occurrence, interactions, and productivity of plants and animals among ecosystems.

This publication provides such a regional landscape ecosystem classification for Michigan, Wisconsin, and Minnesota. Based on differences in climate, bedrock geology, glacial landform, and soils, this classification delineates and describes map units at the Section, Subsection, and Sub-subsection levels that represent areas with distinctive natural conditions affecting species composition and productivity. Macroclimate and physiography were the major components used to distinguish sections and subsections; differences in local physiography and soil were used primarily to delineate sub-sections. Vegetation was used wherever possible to validate climatic and geomorphological boundaries. Further, by drawing on the expertise of numerous members of the scientific and conservation communities, I have incorporated specific information on rare species distributions, adequacy of existing preserves, and management concerns relative to the ecosystem mapping units delineated. The result is a product that expresses the interactive character of landscape ecosystems and their components of climate, geological parent material, physiography (landform and waterform), soil, plants, and animals that will prove useful for resource management, conservation, and study.

Guide to Descriptions

For each map unit, including sections, subsections, and sub-subsections, descriptions are provided under the following headings: discussion, elevation, area, states, climate, bedrock geology, landforms, lakes and streams, soils, presettlement vegetation, natural disturbance, present vegetation and land use, rare plant communities, rare plants, rare animals, natural areas, public land managers, conservation concerns, and boundaries. A brief explanation of the information included under each of these headings follows:

Discussion:

The discussion section provides a brief, general overview of the map unit, concentrating on the most distinctive characteristics of the map unit. In some cases, no DISCUSSION section is provided.

Elevation:

The elevation is provided in both feet and meters, and is based on 1:24,000 topographic maps in most cases. Elevation can be an important factor for understanding biotic distribution. Elevation can be used to contrast adjacent map units. For example, a sub-subdistrict of lake plain will generally be very flat and poorly drained. A sub-subdistrict of end moraine will have steeper, more irregular topography, characterized by better drainage conditions.

Area:

Area is listed in acres and hectares.

States:

The states in which the section, subsection, or sub-subsection occurs are listed here.

Climate:

Several climatic variables are described, including average annual precipitation, average annual snowfall, average growing season length, and extreme minimum temperature. Other climatic factors may be discussed in certain sections, subsections, or sub-subsections. The influence of specific climatic factors on the biota and land management may also be discussed when appropriate.

Bedrock geology:

Predominant or common bedrock types are described, emphasizing the bedrock types closest to the surface. If bedrock is not exposed within the map unit, the depth of overlying glacial deposits is provided, where known. Important mineral deposits of economic importance are mentioned. The detail of bedrock maps differs greatly across the three States; this is reflected in map-unit descriptions.

Landforms:

Most of the landforms occurring in Michigan, Minnesota, and Wisconsin are glacial landforms. The major landforms are described, with some discussion of the size of the landform features, as well as the spatial relationship of neighboring landforms.

Lakes and streams:

The number, size, and types of lakes and streams are described. Water chemistry and substrate are also discussed where appropriate. Consistently presented data bases for lakes and streams do not exist for all three states, but such data bases are being developed, and may soon allow for more consistent and detailed descriptions of both.

Soils:

Soils descriptions can include parent material, soil texture, slope class, and drainage class. Factors important for understanding forested landscapes often differ from those used for describing agricultural soils. Characteristic soil orders are listed for each mapping unit.

Presettlement vegetation:

Comments on the presettlement vegetation are based on maps by Marschner (1974) in Minnesota, Finley (1976) in Wisconsin, several published studies describing portions of Michigan, and an ongoing statewide mapping project in Michigan. Presettlement mapping provides a brief view of the vegetation at the time of the original land surveys, before intensive logging, farming, industrial development, and settlement in the 19th century by immigrants from outside of North America. Published maps, used for the descriptions of Minnesota and Wisconsin, provide generalized descriptions of the dominant vegetation, including wetlands, forests, and grasslands. The surveyors' notes, used for many of the Michigan descriptions, provide more detailed information on species composition of forests and natural disturbances.

Natural disturbance:

The common natural disturbances that occur across the three-State area are listed and discussed. Many of these were mentioned and mapped by the first land surveyors. Some of the more common disturbances referenced by the surveyors were forest fires, windthrown forests, flooding caused by beaver dams, and alterations of wetlands caused by fluctuations of Great

Lakes water levels. Land use by Native Americans, including game management, foot trails, villages, and farming, were also mapped by the first land surveyors. Other natural disturbances that are critical for maintaining the natural biota of ecosystems were not mentioned by the land surveyors but have been subsequently documented by researchers. Examples of these include widespread disturbance and modification of prairie soils by mammals, such as bison and prairie dogs, and insects, such as ants. Such disturbances are also discussed in this section.

Present vegetation and land use:

The full range of vegetation conditions and land uses will be discussed in this section, but not in great detail; obviously there are many more detailed studies of both present vegetation and land use available to the reader. Present vegetation includes natural vegetation, both in relatively intact and highly modified condition, and agricultural and plantation lands.

Rare plant communities:

This section lists, and in some cases, discusses plant communities that are considered rare, based on scientific literature and the data bases of the Heritage Programs.

Rare plants:

This section contains both the common and scientific names of rare plants listed by the Heritage Programs of all three States. Included within this list are species listed as threatened and endangered by the State and Federal Governments, and as special concern by the states. The status of each of these species is periodically reviewed and revised on the basis of available scientific data.

Rare animals:

This section contains both the common and scientific names of rare animals listed by the Heritage Programs of all three States. Included within this list are species listed as threatened and endangered by the State and Federal Governments, and as of special concern by the States. The status of each of these species is periodically reviewed and revised based on available scientific data.

Natural areas:

These lists include both privately and publicly owned natural areas. All three States name and track their natural areas differently. County- and township-owned natural areas are more thoroughly tracked in Minnesota and Wisconsin than in Michigan.

Public land managers:

Public lands are important areas for natural resource management. In this section, major public land ownerships are listed for each mapping unit. This section is based on information from published maps, Heritage Programs, and government agencies.

Conservation concerns:

Concerns are based on comments from staff of Heritage Programs, conservation groups, university staff, and government agencies. The lists of concerns are often incomplete and may focus on the concerns of a single agency or organization. This document does not attempt to resolve these concerns.

Boundaries:

Boundary interpretations and questions are referenced or discussed here. Alternative interpretations of boundaries typically occur in areas where there has been earlier classification by government agencies. Different interpretations are often the result of mapping and classifying at different scales, especially when previous work has been done at a more local scale or only on lands under a single ownership. It is assumed that further studies may be required to resolve some of the boundary questions discussed here. Different boundaries will often result from studies either based on different data or conducted for different management purposes.

Regional Landscape Ecosystems of Michigan's Lower Peninsula

Go to the Website: Follow a link below to view the ecosystem description. Figure 2 is a map outlining the location of each region.

- Section VI. Southern Lower Michigan
- Subsection VI.1. Washtenaw
- Sub-subsection VI.1.1. Maumee Lake Plain
- Sub-subsection VI.1.2. Ann Arbor Moraines
- Sub-subsection VI.1.3. Jackson Interlobate
- Subsection VI.2. Kalamazoo Interlobate
- Sub-subsection VI.2.1. Battle Creek Outwash Plain
- Sub-subsection VI.2.2. Cassopolis Ice-Contact Ridges
- Subsection VI.3. Allegan
- Sub-subsection VI.3.1. Berrien Springs
- Sub-subsection VI.3.2. Southern Lake Michigan Lake Plain
- Sub-subsection VI.3.3. Jamestown
- Subsection VI.4. Ionia
- Sub-subsection VI.4.1. Lansing
- Sub-subsection VI.4.2. Greenville
- Subsection VI.5. Huron
- Sub-subsection VI.5.1. Sandusky Lake Plain
- Sub-subsection VI.5.2. Lum Interlobate

- Subsection VI.6. Saginaw Bay Lake Plain
- Section VII. Northern Lacustrine-Influenced Lower Michigan
- Subsection VII.1. Arenac
- Sub-subsection VII.1.1. Standish
- Sub-subsection VII.1.2. Wiggins Lake
- Subsection VII.2. Highplains
- Sub-subsection VII.2.1. Cadillac
- Sub-subsection VII.2.2. Grayling Outwash Plain
- Sub-subsection VII.2.3. Vanderbilt Moraines
- Subsection VII.3. Newaygo Outwash Plain
- Subsection VII.4. Manistee
- Subsection VII.5. Leelanau and Grand Traverse Peninsula
- Sub-subsection VII.5.1. Williamsburg
- Sub-subsection VII.5.2. Traverse City
- Subsection VII.6. Presque Isle
- Sub-subsection VII.6.1. Onaway
- Sub-subsection VII.6.2. Stutsmanville
- Sub-subsection VII.6.3. Cheboygan

Regional Landscape Ecosystems of Michigan's Upper Peninsula

Go to the Website: Follow a link below to view the ecosystem description. Figure 2 is a map outlining the location of each region.

- Section VIII. Northern Lacustrine-Influenced Upper Michigan and Wisconsin
- Subsection VIII.1. Niagaran Escarpment and Lake Plain
- Sub-subsection VIII.1.1. St. Ignace
- Sub-subsection VIII.1.2. Rudyard
- Sub-subsection VIII.1.3. Escanaba/Door Peninsula
- Subsection VIII.2. Luce
- Sub-subsection VIII.2.1. Seney Sand Lake Plain
- Sub-subsection VIII.2.2. Grand Marais Sandy End Moraine and Outwash
- Subsection VIII.3. Dickinson
- Sub-subsection VIII.3.1. Northern lake Michigan (Hermanville) Till Plain
- Sub-subsection VIII.3.2. Gwinn
- Sub-subsection VIII.3.3. Deerton
- Section IX. Northern Continental Michigan, Wisconsin, and Minnesota
- Subsection IX.1. Spread Eagle-Dunbar Barrens
- Subsection IX.2. Michigamme Highland
- Subsection IX.3. Upper Wisconsin/Michigan Moraines

USDA Natural Resource Conservation Service

https://www.nrcs.usda.gov/wps/portal/nrcs/mi/soils/surveys/

Soil Surveys

The Soil Survey is a compilation of soils information designed to assist in making land use decisions. In Michigan, soils data is available in a variety of formats ranging from a hard copy of the Soil Survey to digital data for use with Geographic Information Systems (GIS).

Access to soil survey information is provided through maps. All text and tables relate to the map symbols and the areas delineated on these maps. Persons with disabilities who require alternative means for communication of soil survey information should contact the *NRCS* at the USDA Service Center.

Status of Michigan Soil Surveys

Soil surveys are completed and available for all Michigan counties. NRCS is starting to work with cities in southeast Wayne County to develop a GIS level of soil resources for these municipalities. NRCS recently completed soils mapping of Isle Royale National Park and the information is being reviewed for publication.

Obtaining a Soil Survey

Field work is being conducted by the Major Land Resource Area Soil Survey offices to update portions of all soil surveys. The most updated soil survey information is available online from the Web Soil Survey. The Web Soil Survey allows users to display and copy up to 10,000 acres of soils information from the site.

Historical copies of some soil surveys may be available, to check the availability of a specific soil survey in Michigan, view the "Soil Survey Availability" document linked below. Printed soil surveys are no longer available for Alger, Alpena, Benzie, Gogebic, Kalkaska, Keweenaw, Luce, Manistee, Marquette, Ontonagon, Oscoda, Otsego, Roscommon, and Schoolcraft counties.

Local *NRCS* field offices help with obtaining Soil Survey information. *NRCS* offices are listed in local telephone books under U.S. Department of Agriculture, a listing of *NRCS* field offices with contact information is also available online.

Dominant Ecological Communities in Michigan

Major ecological systems found in Michigan include the Northern Great Lakes and Southern Great Lakes. Central Plains communities touch the southwestern corner of the state. The North Great Lakes include upland systems: Northern Hardwoods-Conifer Forest; Great Lakes Spruce-Fir Forest; Great Lakes Pine Forest; and Pine Barrens. Wetland systems include: Conifer Bog; Hardwood-Conifer Swamp; Northern Shrub Swamp; Open Bog; and Northern Wet Meadow.

The Southern Great Lakes upland communities are: Maple-Basswood Forest; Oak-Hickory Forest; Beech-Maple Forest; Oak Barrens; and Mesic Prairie. Wetland systems include: Great Lakes Floodplain Forest; Shrub Swamp; and Wet Meadow.

Each of these upland and wetland systems are composed of dominant/characteristic canopy species, associate canopy species (lesser frequency), woody understory and herbaceous understory. Upland systems include all areas that are typically found on dry land and have soil that is rarely saturated with water or is saturated briefly, such as after prolonged rains. The upland systems are dominated by plants that cannot withstand prolonged flooding or saturated soils (Harker et al, 1993). Wetland systems include freshwater areas that are transitional between upland and aquatic systems. They typically have a high water table with saturated soil or shallow, standing water during all or a significant part of the growing season (Harker et al, 1993).

Lists of specific tree, shrub, and herbaceous plant species from each of these native communities can be found in the United States Golf Association Landscape Restoration Handbook (1993) by D. Harker, S. Evans, M. Evans and K. Harker. Lewis Publishers. Plant names obtained from these lists can be crossed referenced with production nurseries to determine availability.

MDOT Regions – USDA Plant Hardiness Zones:

- Superior
  - USDA : 4a-5a
- North
  - USDA: 4a-6a
- Grand
  - USDA: 4b-6b

- Bay
    - USDA: 5a-6a
- Southwest
    - USDA: 5b-6b
- University
    - USDA: 5b-6a
- Metro
    - USDA: 5b-6b

Michigan Climate Data

In addition to the USDA Hardiness Zone assigned to a location, data on climatic normals can give additional insight into the conditions at a project site. Climate normals are calculated every 10 years using the past 30 years of weather data. Currently, the data used spans from 1981 to 2010. The monthly climate data below includes mean minimum temperatures, mean maximum temperatures, temperature extremes with their year of occurrence, mean precipitation and mean snowfall from the 1981 to 2010 dataset. The data in this manual is found in the appendix and is organized by MDOT region, and then alphabetically by city (Tables 1-21). The MDOT regions are shown in Figure 5. Also included are frost free date probabilities for various cities in Michigan (Table 22).

APPENDIX

Table 3.1: Bergland Dam, MI Climate Normals and Extremes (1981-2010). MDOT Region: Superior.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	21.3	2.2	53 (1981)	-38 (1982)	3.038	42.79
Feb	26.0	2.1	58 (1981)	-39 (1985)	1.960	26.61
Mar	36.4	10.9	70 (2000)	-31 (2003+)	2.491	25.67
Apr	50.6	25.7	87 (1990)	-11 (1982)	2.751	10.82
May	64.7	37.6	93 (2006)	15 (1996)	3.444	6.83
June	73.4	47.7	96 (1995)	27 (1992)	3.846	0
July	77.5	52.0	97 (1999)	35 (1988)	3.839	0
Aug	76.1	50.5	96 (2006)	32 (2009+)	3.541	0
Sept	67.1	43.4	91 (2005)	21 (1991)	4.001	1.60
Oct	53.6	32.5	86 (1992)	13 (1988+)	4.079	6.87
Nov	38.1	22.1	73 (1999)	-10 (2005+)	3.307	25.21
Dec	25.1	8.4	59 (1982)	-30 (1983)	3.544	44.07

Data source: Michigan State Climatologist's Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.2: Marquette, MI Climate Normals and Extremes (1981-2010). MDOT Region: Superior.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	22.3	6.2	49 (2006)	-27 (1996)	2.417	44.13
Feb	26.1	6.8	61 (1981)	-32 (1981)	2.121	36.42
Mar	35.1	14.6	71 (2000)	-30 (2003)	3.022	34.87
Apr	48.1	28.8	89 (1990)	-9 (2003)	3.012	14.47
May	62.2	39.3	93 (2006)	17 (1983)	2.839	3.43
June	71.9	48.9	96 (1995)	28 (1986)	2.835	0
July	76.4	54.9	99 (1988)	36 (2000)	3.052	0
Aug	74.4	52.8	96 (2001)	34 (1992)	3.717	0
Sept	65.8	45.3	93 (2002)	24 (1993)	3.841	0.77
Oct	52.1	34.5	87 (1992)	14 (1984)	3.841	6.92
Nov	37.6	23.6	73 (1999)	-8 (2005)	3.176	23.85
Dec	26.0	11.8	59 (1998)	-28 (1981)	2.562	42.71

Data source: Michigan State Climatologist's Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.3: Sault Ste Marie, MI Climate Normals and Extremes (1981-2010). MDOT Region: Superior.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	22.7	6.6	44 (2006+)	-36 (1982)	2.179	30.31
Feb	25.6	8.4	49 (2004+)	-28 (1981)	1.335	18.51
Mar	34.4	16.9	63 (2010+)	-21 (2003+)	1.941	14.02
Apr	49.1	30.0	85 (1990)	-2 (1982)	2.386	6.54
May	62.4	39.8	89 (2006+)	24 (1988+)	2.572	0.42
June	71.0	47.7	93 (1983)	26 (1982)	2.701	0
July	75.9	53.3	97 (1988)	36 (1992+)	2.859	0
Aug	74.4	53.5	94 (2007)	29 (1982)	3.137	0
Sept	66.2	46.6	90 (2002)	25 (1993+	3.815	0.2
Oct	53.0	36.8	81 (2005)	16 (1981)	3.800	2.30
Nov	39.9	27.1	68 (2008)	-4 (1995)	3.368	14.61
Dec	28.4	14.8	62 (2001)	-31 (1982)	2.789	32.59

Data source: Michigan State Climatologist’s Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.4: Alpena, MI Climate Normals and Extremes (1981-2010). MDOT Region: North.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	27.3	11.4	52 (1998+)	-28 (1994)	1.628	23.08
Feb	29.8	11.3	65 (1984)	-25 (1994+)	1.311	17.68
Mar	38.7	19.0	80 (2000)	-17 (2007+)	1.840	12.09
Apr	52.8	30.9	90 (2002+)	-7 (2003)	2.386	6.48
May	65.0	40.4	93 (2006)	21 (2005)	2.664	0.40
June	75.0	49.6	103 (1995)	29 (1982)	2.617	0
July	79.9	55.3	102 (1983)	37 (1986)	3.025	0
Aug	77.5	53.6	102 (1988)	30 (1982)	3.232	0
Sept	69.4	46.4	94 (1983)	25 (1993+)	2.918	0.4
Oct	56.4	36.3	90 (2007)	16 (1997)	2.606	0.75
Nov	43.5	28.3	75 (1999+)	-6 (1995)	2.094	7.08
Dec	32.1	18.3	65 (2001+)	-18 (1985)	1.721	19.18

Data source: Michigan State Climatologist’s Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.5: Cheboygan, MI Climate Normals and Extremes (1981-2010). MDOT Region: North.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	27.1	10.4	55 (1996)	-27 (1994)	1.705	25.11
Feb	29.3	10.0	62 (2000)	-28 (1985)	1.352	19.19
Mar	37.6	17.8	74 (1990)	-18 (2003)	1.765	12.83
Apr	50.3	30.8	86 (1986)	-2 (2003)	2.428	5.08
May	62.2	40.9	90 (2007)	17 (1999)	2.783	2.00
June	72.	51.3	96 (2006)	32 (1982)	2.823	0
July	77.6	57.5	98 (1988)	41 (2000)	3.072	0
Aug	76.2	56.6	98 (1988)	36 (1982)	3.503	0
Sept	68.9	49.0	92 (2000)	26 (1991+)	3.389	0
Oct	55.9	38.1	88 (2005)	19 (2006+)	3.484	4.50
Nov	43.5	29.2	72 (2008)	8 (2007+)	2.528	7.53
Dec	32.4	18.6	64 (2001+)	-15 (2001+)	2.052	24.30

Data source: Michigan State Climatologist's Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.6: Grayling, MI Climate Normals and Extremes (1981-2010). MDOT Region: North.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	25.8	7.9	53 (2005)	-34 (1994)	1.714	30.09
Feb	28.8	8.0	60 (1984)	-37 (1996)	1.295	20.67
Mar	38.8	15.4	78 (2000)	-25 (1982)	1.721	14.66
Apr	53.4	28.8	87 (1990)	-3 (2003)	2.773	4.57
May	66.0	39.3	92 (2006)	18 (1987+)	3.271	0.78
June	75.8	49.2	98 (2009+)	26 (1982)	3.690	0
July	79.8	53.9	99 (1988+)	33 (1987)	3.578	0
Aug	77.6	51.9	96 (2007+)	26 (1986)	3.679	0
Sept	69.5	43.7	92 (2002)	16 (1989)	3.746	0
Oct	56.0	33.9	87 (2007)	11 (1986)	3.771	3.36
Nov	42.4	25.3	73 (2008)	-4 (2005)	2.613	12.57
Dec	30.5	15.6	64 (2001)	-26 (1983)	1.764	26.46

Data source: Michigan State Climatologist's Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.7:Traverse City, MI Climate Normals and Extremes (1981-2010). MDOT Region: North.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	28.8	16.3	52 (1998)	-20 (1984)	1.866	31.11
Feb	31.3	16.2	65 (2000)	-16 (2003)	1.267	19.22
Mar	40.7	22.3	78 (2010+)	-16 (2003)	1.489	10.60
Apr	54.9	33.1	88 (2002+)	4 (2003)	2.483	3.16
May	66.8	42.5	93 (2010+)	24 (2002+)	2.501	0.63
June	75.7	52.5	97 (1991+)	31 (2003+)	2.921	0
July	80.9	57.3	100 (2006)	37 (1992)	2.697	0
Aug	78.5	50.0	98 (2001+)	32 (1982)	2.990	0
Sept	70.5	39.4	93 (2008)	27 (2000+)	3.489	0
Oct	57.5	31.1	88 (2007)	22 (2008+)	3.081	0.64
Nov	45.1	31.1	75 (1990)	10 (1989)	2.368	8.98
Dec	32.7	21.2	63 (2001+)	-13 (1983)	2.058	26.64

Data source: Michigan State Climatologist's Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.8: Big Rapids, MI Climate Normals and Extremes (1981-2010). MDOT Region: Grand.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	29.4	12.6	58 (2008)	-25 (1994+)	2.103	17.58
Feb	33.1	13.7	64 (2000)	-29 (1996)	1.704	12.44
Mar	43.1	20.6	76 (2007+)	-15 (1982)	2.460	8.25
Apr	56.8	32.2	89 (2002)	1 (1982)	3.271	3.89
May	68.6	42.8	93 (2006)	19 (2002)	3.476	0
June	77.9	52.4	98 (1995)	32 (1989)	3.321	0
July	82.0	56.9	100 (1995+)	37 (2001)	3.214	0
Aug	79.6	55.2	101 (1988)	32 (1982)	3.987	0
Sept	71.6	46.7	92 (2000)	16 (1989)	3.946	0
Oct	58.5	36.2	87 (2007)	10 (2001)	3.414	1.02
Nov	45.0	27.8	75 (1990)	3 (1996)	3.182	5.62
Dec	33.1	18.2	66 (2001)	-15 (1989+)	2.370	16.06

Data source: Michigan State Climatologist's Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.9: Grand Rapids, MI Climate Normals and Extremes (1981-2010). MDOT Region: Grand.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	30.3	17.1	63 (2008)	-22 (1994)	2.080	20.74
Feb	33.3	18.8	69 (1999)	-17 (1996)	1.782	14.79
Mar	43.9	25.9	78 (2010+)	-7 (1996)	2.365	8.16
Apr	57.8	36.7	86 (2004+)	3 (1982)	3.349	2.67
May	69.1	46.8	91 (2006+)	26 (2005)	3.972	0.15
June	78.6	56.7	98 (1995+)	36 (1993)	3.772	0
July	82.5	61.1	100 (1988)	41 (1983)	3.772	0
Aug	80.2	60.0	198 (1988)	41 (1986)	3.588	0
Sept	72.6	51.6	92 (2008+)	27 (1991)	4.272	0
Oct	59.9	40.7	88 (2007)	18 (1988)	3.254	1.70
Nov	46.8	32.0	74 (1999+)	9 (1986)	3.505	7.04
Dec	34.4	39.2	69 (2001)	-18 (1983)	2.471	21.75

Data source: Michigan State Climatologist’s Office
(https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.10: Montague, MI Climate Normals and Extremes (1981-2010). MDOT Region: Grand.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	30.5	17.9	59 (1997+)	-17 (1994)	1.490	25.80
Feb	33.0	18.8	65 (2000)	-27 (1996)	1.450	17.05
Mar	42.7	24.4	78 (1981)	-16 (2005+)	2.230	8.24
Apr	55.9	33.9	83 (1986)	0 (1982)	3.291	3.33
May	66.6	43.0	88 (2010+)	18 (1986)	3.253	0
June	75.4	52.5	96 (1995)	27 (1994)	2.816	0
July	79.6	57.0	95 (1999)	23 (2010)	2.747	0
Aug	78.2	56.8	92 (2001+)	26 (2010)	3.466	0
Sept	71.1	49.9	90 (1999)	24 (1989)	3.698	0
Oct	58.8	40.4	82 (2007)	21 (2001+)	3.588	1.50
Nov	46.0	32.0	70 (2009+)	7 (2008)	3.459	4.73
Dec	34.5	23.0	64 (1984)	-15 (2000)	1.958	20.86

Data source: Michigan State Climatologist’s Office
(https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.11: Flint, MI Climate Normals and Extremes (1981-2010). MDOT Region: Bay.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	30.1	15.7	61 (2008+)	-21 (1994)	1.625	13.16
Feb	33.3	17.3	68 (1999)	-19 (1994)	1.479	10.77
Mar	43.9	25.2	80 (2000)	-11 (2003)	1.908	6.36
Apr	57.7	36.0	87 (2004+)	6 (1982)	2.889	2.93
May	69.0	45.7	93 (1988)	23 (2005)	3.073	0.30
June	78.4	55.6	101 (1988)	33 (1998)	3.066	0
July	82.4	59.6	101 (1995+)	40 (2001)	3.318	0
Aug	80.2	58.4	98 (2001+)	37 (1982)	3.180	0
Sept	72.7	50.3	94 (2002)	26 (1991)	3.744	0
Oct	60.0	39.8	89 (2002)	20 (1988)	2.472	2.10
Nov	47.1	31.4	75 (1990+)	9 (1997)	2.664	2.97
Dec	34.5	21.2	70 (2001)	-13 (2000)	1.909	11.66

Data source: Michigan State Climatologist's Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.12: Harbor Beach, MI Climate Normals and Extremes (1981-2010). MDOT Region: Bay.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	29.2	14.9	55 (2008+)	-19 (1982)	2.459	14.61
Feb	31.2	15.5	68 (1984)	-13 (1994)	2.018	11.38
Mar	38.8	23.3	80 (2000)	-12 (1986)	2.093	7.68
Apr	50.2	33.4	88 (1990)	6 (2003)	2.882	3.56
May	61.3	43.2	92 (1987)	27 (2004+)	3.261	4.30
June	71.3	53.1	97 (1983)	33 (1986)	3.048	0
July	77.0	58.8	100 (1995)	41 (1982)	2.846	0
Aug	76.1	57.9	99 (2001)	35 (1982)	3.456	0
Sept	69.7	50.6	94 (1983)	32 (1991+)	3.967	0
Oct	57.6	40.4	88 (2007)	23 (1981)	2.895	1.60
Nov	45.5	31.2	74 (1990)	11 (2008+)	3.006	3.31
Dec	33.9	21.3	65 (2001+)	-6 (2004)	2.478	10.50

Data source: Michigan State Climatologist's Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.13: Midland, MI Climate Normals and Extremes (1981-2010). MDOT Region: Bay.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	30.2	16.5	60 (2008)	-19 (1994)	1.651	10.37
Feb	33.4	18.2	67 (1999)	-15 (1996)	1.572	7.75
Mar	44.1	25.4	80 (2000)	-8 (2003)	2.071	3.83
Apr	58.1	36.3	88 (2002)	10 (1982)	3.148	2.10
May	69.1	46.8	96 (2006)	27 (1989+)	3.388	0
June	79.2	56.7	99 (1995)	36 (1993)	3.287	0
July	83.3	61.0	100 (1995+)	42 (2001+)	2.521	0
Aug	80.9	59.7	100 (2001)	33 (1982)	3.195	0
Sept	73.6	51.8	93 (1983)	28 (1991+)	3.726	0
Oct	60.7	41.5	89 (2007)	22 (1988+)	3.736	.20
Nov	46.8	32.2	74 (1999)	3 (1995)	2.760	2.33
Dec	34.4	22.3	67 (2001)	-13 (2000)	1.874	8.61

Data source: Michigan State Climatologist’s Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.14: Battle Creek, MI Climate Normals and Extremes (1981-2010). MDOT Region: Southwest.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	32.4	17.1	62 (2008+)	-20 (1994)	1.692	14.40
Feb	35.3	18.1	67 (2000)	-19 (1996)	1.513	12.81
Mar	46.7	26.0	79 (2000+)	-6 (2003)	2.011	6.33
Apr	60.1	36.7	87 (2002+)	5 (1982)	2.901	2.85
May	70.8	46.7	94 (2006)	22 (1989)	4.044	0
June	79.4	55.8	97 (1988)	30 (1993)	3.296	0
July	82.7	59.8	100 (1988)	42 (1995+)	3.461	0
Aug	81.0	58.2	99 (1988)	37 (1986)	3.551	0
Sept	73.3	50.2	95 (1983)	25 (1991+)	3.933	0
Oct	61.2	40.0	87 (2007)	16 (1988)	3.364	2.90
Nov	47.6	30.7	75 (1987)	7 (1986)	3.150	5.64
Dec	35.5	20.8	69 (2001)	-18 (1989)	2.046	16.68

Data source: Michigan State Climatologist’s Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.15: Benton Harbor, MI Climate Normals and Extremes (1981-2010). MDOT Region: Southwest.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	33.1	18.5	66 (2008)	-17 (1994)	2.118	30.89
Feb	36.4	20.7	70 (1999)	-12 (1994)	1.727	22.20
Mar	46.6	27.1	84 (1986)	-3 (1999)	2.141	9.43
Apr	59.0	36.9	89 (2002)	9 (1982)	3.324	2.67
May	69.6	46.3	97 (2006)	24 (1992)	3.566	0
June	79.2	56.3	100 (2005)	31 (1993)	3.348	0
July	83.5	60.9	104 (2002+)	37 (2001)	3.394	0
Aug	81.6	59.4	101 (2006)	37 (1982)	3.837	0
Sept	75.1	51.7	98 (2002)	23 (1989)	3.954	0
Oct	63.3	41.7	92 (2005)	15 (1988)	3.529	2.50
Nov	49.6	33.0	76 (2008+)	8 (1989)	3.402	5.44
Dec	36.7	23.0	69 (1982)	-15 (1989)	2.308	24.38

Data source: Michigan State Climatologist's Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.16: Coldwater, MI Climate Normals and Extremes (1981-2010). MDOT Region: Southwest.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	30.5	15.9	63 (2008)	-23 (1981)	2.120	15.58
Feb	34.5	18.8	67 (1999)	-14 (1994)	2.010	10.45
Mar	44.7	26.2	78 (1998+)	-3 (2003+)	2.326	6.39
Apr	58.2	37.3	86 (1990)	6 (1982)	3.006	2.42
May	69.0	47.2	91 (1991)	26 (2005+)	4.569	0
June	78.4	56.9	102 (1988)	37 (2003+)	3.462	0
July	81.8	60.7	100 (1988)	40 (1988)	4.100	0
Aug	79.6	58.7	101 (1988)	36 (1996)	3.827	0
Sept	72.5	50.9	94 (1990)	30 (1991+)	3.642	0
Oct	60.0	40.2	84 (2010+)	19 (1988+)	3.227	2.67
Nov	47.0	31.5	75 (1987)	5 (1986)	2.918	4.28
Dec	34.3	21.0	67 (2001+)	-15 (1989)	2.448	12.53

Data source: Michigan State Climatologist's Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.17: Adrian, MI Climate Normals and Extremes (1981-2010). MDOT Region: University.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	32.4	16.0	62 (2008+)	-22 (1994)	2.051	9.26
Feb	35.4	18.0	70 (1999)	-16 (1994)	1.960	7.77
Mar	46.3	25.7	80 (2007+)	-6 (2003)	2.416	5.07
Apr	59.7	36.0	88 (1990)	8 (1982)	3.198	2.72
May	70.7	45.6	94 (2006+)	25 (2004+)	3.783	0
June	80.0	55.6	104 (1988)	35 (1994)	3.906	0
July	83.7	59.5	100 (1995+)	41 (2001+)	3.278	0
Aug	81.5	57.9	100 (2001+)	32 (1986)	3.731	0
Sept	74.4	49.8	94 (2002+)	27 (1995+)	3.656	0
Oct	61.8	38.9	88 (2007)	15 (1988)	2.752	2.00
Nov	48.8	30.6	76 (2003+	7 (1986)	2.972	2.76
Dec	36.0	21.1	69 (2001)	-14 (1983)	2.504	7.14

Data source: Michigan State Climatologist's Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.18: Ann Arbor, MI Climate Normals and Extremes (1981-2010). MDOT Region: University.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	31.5	17.8	62 (2008)	-22 (1994)	2.588	16.39
Feb	35.3	19.8	67 (1999)	-13 (1988)	2.403	12.94
Mar	46.2	27.1	80 (1998)	-8 (2003)	2.660	8.79
Apr	60.0	37.9	87 (1990)	7 (1982)	3.248	3.24
May	70.9	48.1	92 (2006)	27 (2005)	3.418	0.10
June	79.9	57.8	101 (1988)	37 (1993+)	3.677	0
July	83.4	62.0	100 (1988)	43 (2001)	3.610	0
Aug	81.4	61.0	98 (2001)	39 (1986)	3.933	0
Sept	74.4	53.3	94 (2002+)	30 (1991)	3.445	0
Oct	61.8	42.3	89 (2007)	21 (1988)	2.832	0.77
Nov	48.1	32.9	75 (1999)	10 (1986)	3.090	3.46
Dec	35.1	22.69	67 (2001+)	-12 (1983)	2.886	13.47

Data source: Michigan State Climatologist's Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.19: Lansing, MI Climate Normals and Extremes (1981-2010). MDOT Region: University.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	30.1	15.3	62 (2008)	-29 (1981)	1.646	14.42
Feb	33.3	17.0	69 (1999)	-25 (1994)	1.469	11.04
Mar	44.1	24.6	79 (2000)	-13 (1999)	2.056	6.69
Apr	57.8	35.5	86 (2002)	-2 (1982)	3.024	2.30
May	6.8	45.2	91 (1988)	23 (1989)	3.361	3.00
June	78.4	55.2	99 (1988)	33 (1998+)	3.508	0
July	82.4	59.1	100 (1988)	38 (2001)	2.836	0
Aug	80.2	58.0	100 (1988)	36 (1986+	3.227	0
Sept	72.2	49.8	93 (2002+)	22 (1991)	3.493	3.00
Oct	59.9	39.2	87 (2002)	19 (1988)	2.524	1.51
Nov	46.7	30.9	74 (1999+)	8 (1996+)	2.772	3.85
Dec	34.3	20.8	69 (2001)	-18 (2002+)	1.868	13.02

Data source: Michigan State Climatologist's Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.20: Detroit, MI Climate Normals and Extremes (1981-2010). MDOT Reigion: Metro.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	32.0	18.4	64 (2008)	-21 (1984)	1.951	12.49
Feb	35.2	20.4	70 (1990)	-15 (1985)	2.013	10.70
Mar	45.8	28.0	81 (2007+)	-4 (2003)	2.276	6.98
Apr	59.1	38.8	87 (1994+)	10 (1982)	2.899	2.42
May	69.9	48.9	93 (1988)	29 (1983)	3.382	0.10
June	79.3	59.0	104 (1988)	40 (2003+)	3.514	0
July	83.4	63.3	102 (1988)	44 (1984)	3.371	0
Aug	81.4	62.2	100 (1988)	38 (1982)	2.996	0
Sept	74.0	54.2	94 (2002+)	33 (1991+)	3.264	0
Oct	61.6	42.7	90 (2007)	21 (1988)	2.521	0.76
Nov	48.8	33.6	75 (2003+)	12 (1984)	2.785	1.86
Dec	36.1	23.5	69 (1998)	-10 (1983)	2.453	9.61

Data source: Michigan State Climatologist's Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.21: Table 21: Pontiac, MI Climate Normals and Extremes (1981-2010). MDOT Region: Metro.

Month	Mean Max (F)	Mean Min (F)	Extreme High (F) (year)	Extreme Low (F) (year)	Mean Precipitation (in)	Mean Snowfall (in)
Jan	30.6	16.8	63 (2008)	-21 (1994)	1.705	10.62
Feb	33.7	17.7	65 (1984)	-11 (1996)	1.803	9.30
Mar	44.7	25.6	80 (2007)	-8 (2003)	2.083	4.63
Apr	58.5	36.9	86 (1990)	8 (1982)	2.632	2.91
May	68.9	47.1	92 (2006+)	28 (1986)	3.073	0
June	78.8	57.2	102 (1988)	38 (1993)	3.315	0
July	82.7	61.7	104 (1988)	45 (1985)	2.869	0
Aug	80.8	60.6	101 (1988)	40 (1986)	2.994	0
Sept	73.4	53.1	93 (2002+)	31 (1991)	3.163	0
Oct	60.5	41.9	90 (2007)	21 (1981)	2.818	0.73
Nov	46.7	32.0	76 (1987)	10 (1986)	2.755	2.03
Dec	34.2	22.1	64 (1982)	-11 (1983)	2.276	7.47

Data source: Michigan State Climatologist’s Office (https://climate.geo.msu.edu/climate_mi/index.html)

Table 3.22: The table below shows the percent probability of an air temperature 32°F or lower occurring on the date listed or after at each weather station.

Station	First	25%	50%	75%	Last
Adrian	April 16	April 27	May 3	May 9	May 23
Allegan	April 15	April 28	May 6	May 14	June 12
Alma	April 18	May 3	May 10	May 17	May 27
Alpena WSO	May 3	May 22	May 31	June 8	June 21
Alpena	April 18	May 1	May 8	May 15	May 29
Ann Arbor	April 10	April 22	April 29	May 6	May 27
Atlanta	May 2	May 24	June 2	June 11	July 6
Bad Axe	April 20	May 8	May 15	May 22	June 8
Battle Creek	April 16	April 28	May 5	May 11	May 27
Bay City	April 13	April 25	May 2	May 9	May 26
Big Rapids	May 2	May 13	May 20	May 26	June 12
Bloomingdale	April 17	May 1	May 10	May 19	June 12
Cadillac	May 19	May 21	June 1	June 12	July 11
Caro	April 23	May 15	May 23	May 31	June 22
Charlotte	April 17	May 5	May 13	May 21	June 12
Chatham	May 17	June 1	June 11	June 21	July 31
Cheboygan	April 26	May 10	May 17	May 24	June 21
Coldwater	April 16	April 29	May 7	May 14	May 27
Detroit city	April 7	April 18	April 24	April 30	May 12
Detroit Metro	April 12	April 25	May 3	May 11	May 29
East Jordan	May 10	May 22	May 30	June 6	June 22
East Tawas	April 29	May 14	May 22	May 30	June 14
Eau Claire	April 8	April 25	May 2	May 9	May 29
Escanaba	April 24	May 5	May 11	May 17	May 30
Fayette	April 26	May 9	May 16	May 23	June 8
Fife Lake	May 9	May 29	June 7	June 17	July 6
Flint	April 18	May 2	May 8	May 15	May 27
Frankfort	April 16	May 10	May 18	May 26	June 23
Gladwin	May 4	May 13	May 20	May 28	June 22
Grand Haven	April 7	April 25	May 1	May 8	May 18
Grand Marais	May 7	May 23	June 4	June 15	July 20
Grand Rapids	April 10	April 24	May 2	May 10	May 27
Grayling	May 2	May 21	May 31	June 10	July 21
Greenville	April 13	May 1	May 9	May 18	June 12
Gull Lake	April 20	May 1	May 7	May 13	May 29
Hale Loud Dam	May 3	May 16	May 23	May 30	June 20
Harbor Beach	April 8	May 2	May 9	May 16	May 26
Harrisville	April 27	May 14	May 23	June 1	June 25
Hart	April 24	May 12	May 20	May 27	June 13
Hastings	April 20	May 6	May 13	May 21	June 12
Hillsdale	April 20	May 4	May 12	May 20	June 12
Holland	April 15	April 29	May 8	May 17	June 12
Houghton	May 8	May 15	May 23	May 31	July 10
Houghton Lake	April 28	May 22	June 2	June 14	June 20
Iron Mountain	May 10	May 23	May 30	June 6	June 22
Ironwood	May 4	May 17	May 24	May 31	June 14

Table 3.22 (cont'd): The table below shows the percent probability of an air temperature 32°F or lower occurring on the date listed or after at each weather station.

Station	First	25%	50%	75%	Last
Ishpeming	May 11	May 21	May 28	June 4	June 18
Jackson	April 17	May 1	May 8	May 15	May 31
Kalamazoo	April 14	April 26	May 3	May 11	May 27
Lake City	May 7	May 19	May 29	June 8	July 11
Lansing	April 13	April 30	May 8	May 17	June 12
Lapeer	April 16	May 5	May 14	May 23	June 8
Ludington	April 17	May 4	May 13	May 22	June 14
Manistee	April 18	May 3	May 11	May 18	May 31
Marquette WSO	April 21	May 7	May 13	May 19	May 29
Midland	April 7	April 30	May 8	May 17	June 12
Milford	April 13	May 1	May 8	May 15	May 30
Mio	May 3	May 24	June 1	June 10	June 21
Monroe	April 8	April 19	April 26	May 2	May 13
Mt. Clemens	April 8	April 19	April 27	May 5	May 23
Mt. Pleasant	April 26	May 8	May 14	May 21	May 30
Munising	May 17	June 2	June 10	June 17	July 4
Muskegon	April 14	April 28	May 6	May 14	June 12
Newaygo	April 24	May 18	May 26	June 3	June 22
Newberry	May 5	May 19	May 26	June 2	June 18
Onaway	May 3	May 17	May 25	June 1	June 15
Owosso	April 19	May 5	May 12	May 19	May 30
Paw Paw	April 20	May 4	May 11	May 19	June 12
Pontiac	April 17	April 30	May 6	May 13	May 25
Port Huron	April 13	April 25	May 3	May 11	June 5
Saginaw	April 10	April 27	May 4	May 11	May 28
Sault Ste. Marie	April 23	May 14	May 22	May 29	June 21
South Haven	April 15	April 26	May 3	May 9	May 23
Three Rivers	April 15	April 30	May 8	May 15	May 29
Traverse City	May 3	May 15	May 23	June 1	July 6
Vanderbilt	May 22	June 10	June 20	June 30	July 31
West Branch	May 7	May 19	May 27	June 4	June 18
Willis	April 19	May 2	May 10	May 17	May 29

Data Source: MSU Extension, Michigan State Climatologist's Office

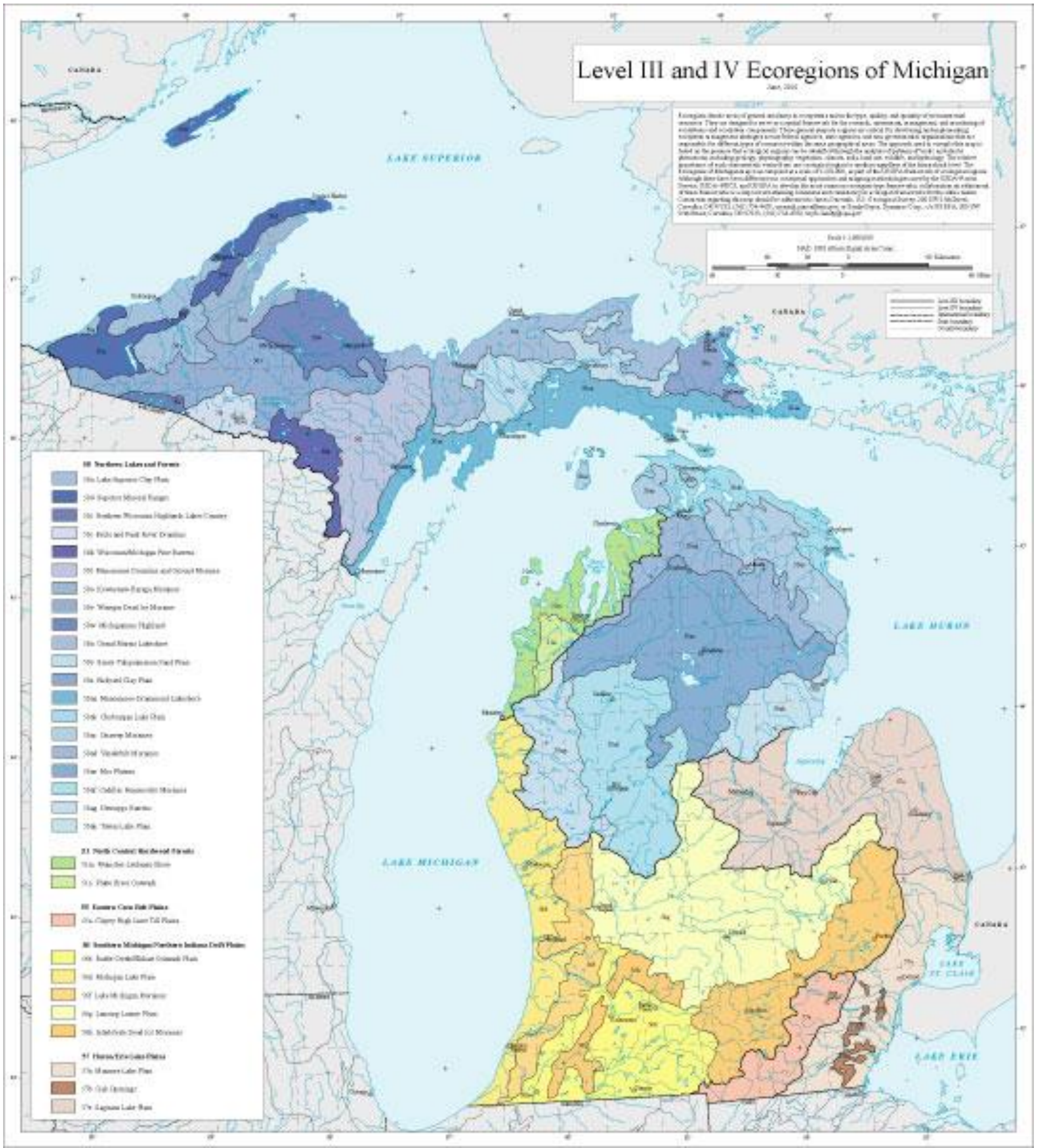

Figure 3.1: A map displaying the ecoregions throughout Michigan. Source: EPA

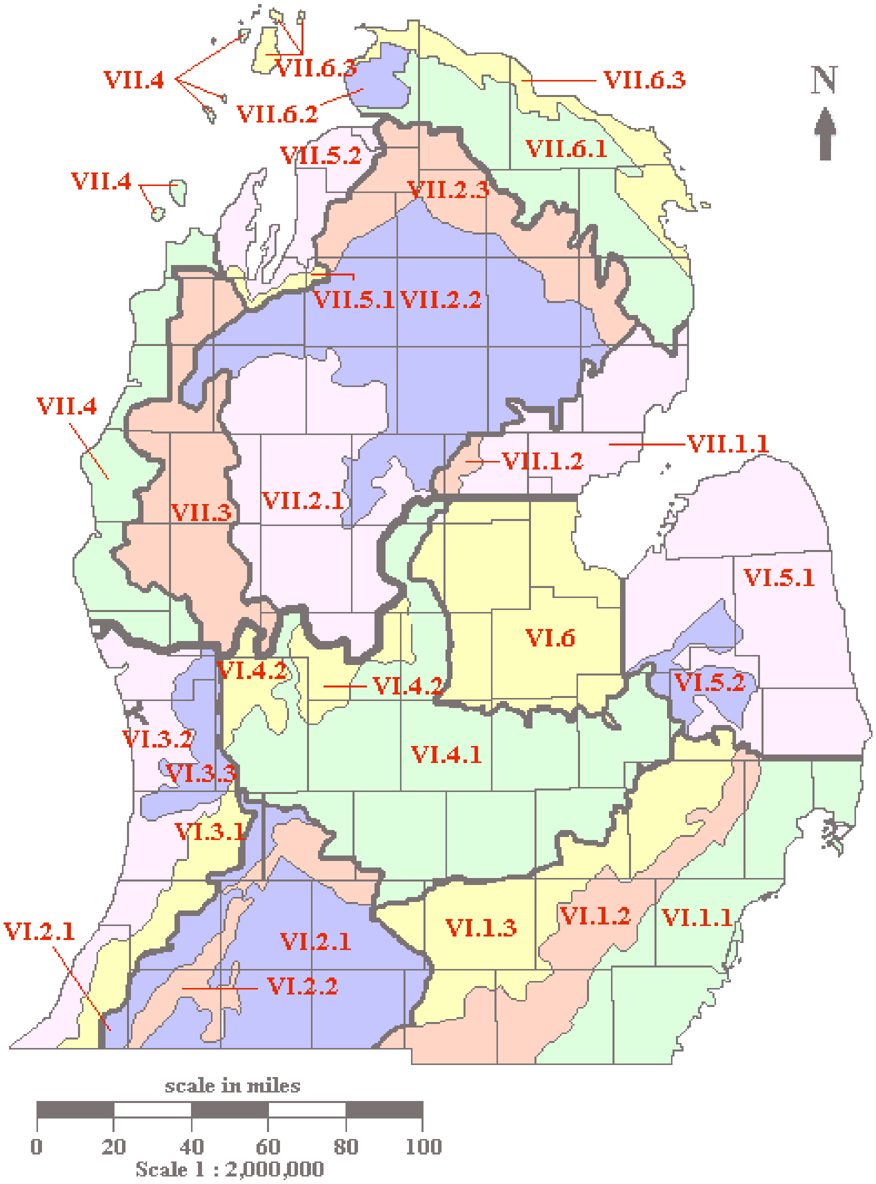

Figure 3.2: A map of Michigan's lower peninsula that highlights the location of each type of ecosystem present.

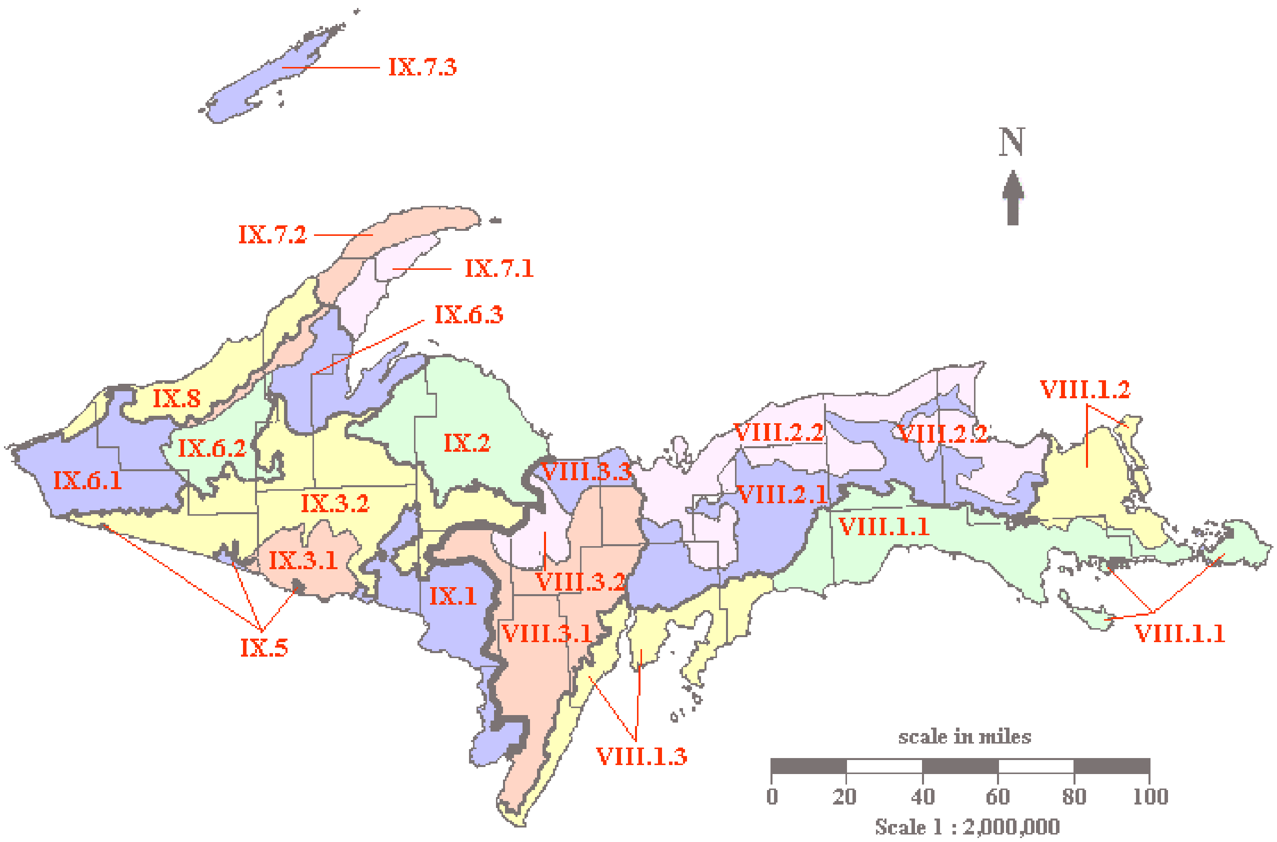

Figure 3.3: Figure 3: A map of Michigan's upper peninsula that highlights the location of each type of ecosystem present.

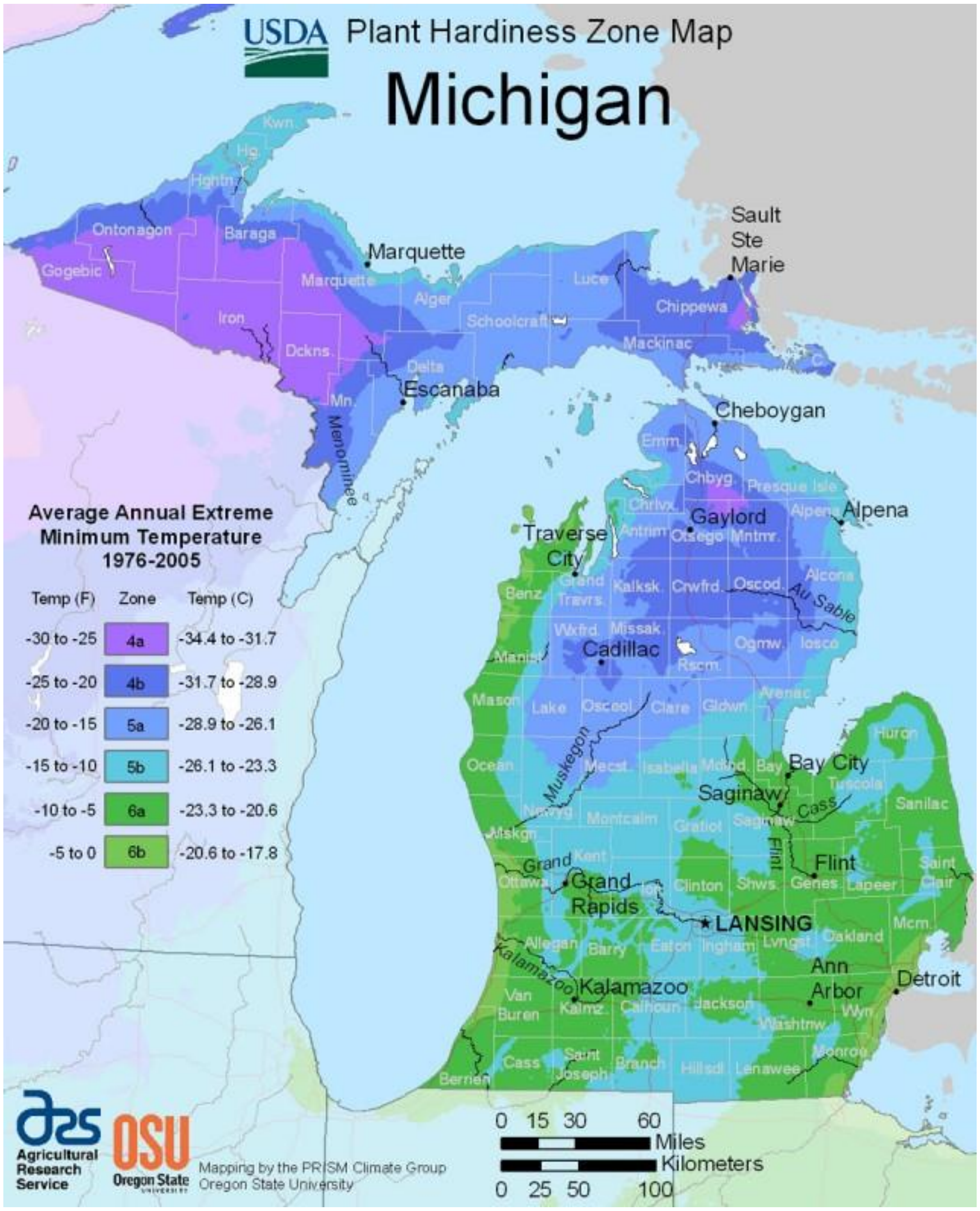

Figure 3.4: A map of the state of Michigan that highlights the USDA Plant Hardiness Zones within the state. Source: USDA ARS

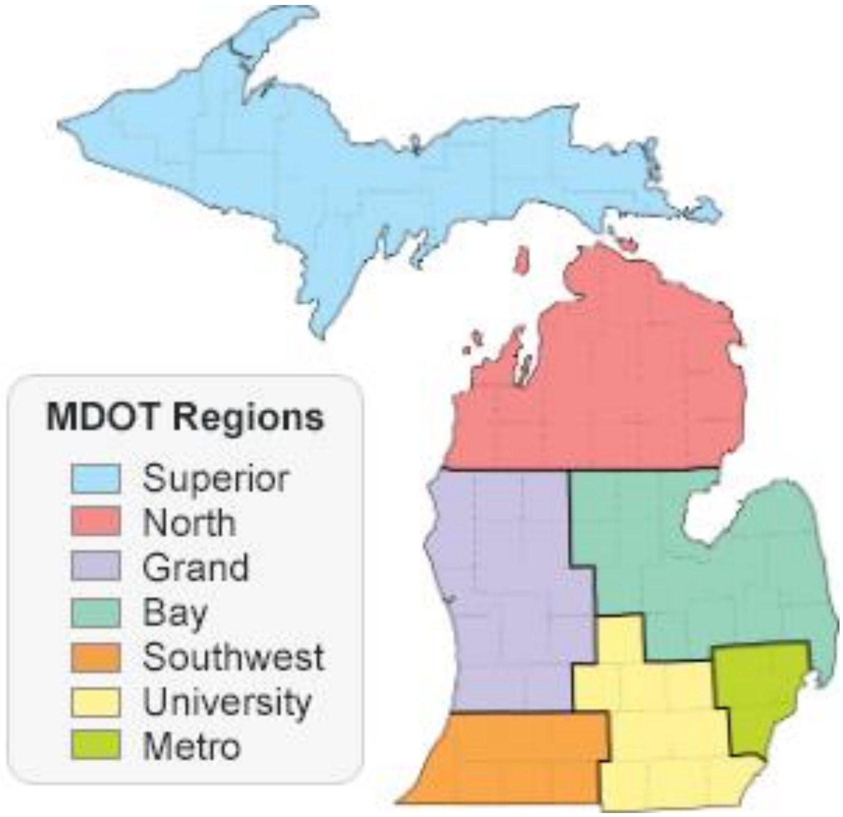

Figure 3.5: A map of the reigons used by the Michigan Department of Transportation (MDOT).

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CHAPTER 5

MICHIGAN DEPARTMENT OF TRANSPORTATION PLANT SELECTION MANUAL: SECTION 2

Plant Selection

Plant selection is an organized process that examines several factors: function, aesthetics, site adaptability and management. The priority placed on each factor varies with the plant's purpose, the designer and ultimately the end use. The freedom to choose from a variety of plants depends on the flexibility or imposed user or site restrictions or in some cases the availability of plant species. Understanding that plant selection is a process can lead to ease in selection and appropriately chosen selections. This is especially true for plants selected for the transportation environment where diverse and difficult conditions often exist.

Function refers to the purpose that the plant serves in the landscape. The shade, screening, or erosion control addresses the specific objectives of the planting. Function guides the selection of a plant type, such as a tree, shrub, or herbaceous perennial. Individually or in concert, plant type is the foundation of the landscape and reinforces the intention of its use in an outdoor space, whether the use is active or passive.

Aesthetics or curb appeal tends to be the most notable and regarded quality of a landscape. The success or failure of a landscape often is judged on the visual appeal of the plants. Aesthetics also considers the relationship between plant types and scale of the designated planting area. Identifying the space that a plant will cover or that we will allow it to cover influences the overall success of the planting.

Site adaptability is the relationship between the needs of the plant and the environmental and soil conditions in the designated planting area and determines whether a plant will perform to expectations. If the plant is unable to establish and maintain vigorous growth after planting, it is not likely to exhibit the aesthetic qualities that led to its selection. "*Don't fight the site*" – let the site conditions either guide selection or be prepared to modify the site (soils, drainage, microclimate) to accommodate the plant introductions. Soil type influences aeration, water retention, drainage, and nutrient-holding capacity. Soil pH is an important parameter, which influences plant growth because it regulates the availability of micronutrients in the soil. Compass orientation refers to exposure to the north, east, south, and west. Orientation may subject plants to prevailing winds or seasonal sun patterns influencing either a positive or a negative result on establishment. Prevailing winds in the winter come from the north-northwest. The wind direction shifts in the summer to south-southwest.

Management practices within the landscape contribute to its overall appeal. The visual quality of the landscape can fail if horticultural practice does not match plant needs. Plant selections must match the level of maintenance available. Maintenance-free landscapes do not exist, but low-maintenance landscapes are possible.

Database Category Descriptions

Light:

Light is an important consideration for creating a roadside planting. Choose plants that fit the site light conditions, inadequate light consideration is detrimental to plants. "*Full sun*" plants should receive at least six hours of light per day. "*Part shade*" should receive 3 to 6 hours of light per day. "Shade" is not complete darkness, plants need a small amount light to thrive, strive for indirect sunlight such as under a filtered light canopy or in the shadow of a building.

Category:

This column identifies the type of plant. Small trees height range is 10-30 feet. Medium trees height range is 40-60 feet. Large trees grow to heights over 60 feet tall. Small shrubs height range is 1-3 ft. Medium shrubs range from 4-8 feet in height and large shrubs are 9 foot or taller. Aquatic plants refer to perennial plants that can be planted in very wet soils or in water.

Bloom time:

Deciduous and herbaceous plants flower, but not all are showy. Bloom time is not only important for aesthetics but is an important consideration for pollinator plantings.

Origin: Plants marked, as "*Native*" are known to be native to the state of Michigan. Plants marked as "*US native*" are not native to Michigan but are native to other areas of the United States.

Soil tolerances:

This plant selection guide provides information on soil tolerances for each plant. In general, plants thrive best in moist, well-drained soil. However, many plants tolerate and even thrive in various conditions. If a column is marked with an "X", the plant will tolerate that condition. To know what specific conditions exist at a given site, the soils should be tested.

USDA Hardiness Zone: The USDA hardiness zone provides an idea of what will thrive in a specific location based on the climate. According to the 2012 hardiness map, the hardiness zones in Michigan range from 4a to 6b.

Erosion prevention:

Plants marked with an “X” in this category are well suited to areas where there is high risk of erosion or slope stabilization is needed.

MSU Proven:

Plants in this category were part of the Urban Slope Restoration study and were successful. Specific cultivars used in the study can be found in the notes section.

Clear Vison:

Plants in this category fit into MDOT “Clear Vision” specifications. These plants are less than 30” tall when mature.

Habit:

Refers to the growing pattern of the plants. Plants may fit into multiple habit categories.

Tree Growth Habits:

- *Upright*: Tree canopy does not have a widespread habit. Branches tend to grow upward. Includes fastigiated and columnar forms.
- *Spreading*: Tree has a wide canopy and spread. Branches tend to grow horizontally.
- *Oval*: Tree canopy is an oval shape.
- *Rounded:* Tree canopy appears circular or rounded.
- *Multi-stemmed*: Tree has multiple, discernable stems that form a cohesive canopy.
- *Pyramidal*: Tree canopy appears loosely or moderately triangular.

- *Weeping*: Branches appear to be drooping towards the ground.
- *Vase*: Tree is narrow at the base, and fans outward towards the top.
- *Irregular*: The canopy does not have a uniform shaped outline.
- *Conical*: Overall shape of the tree is triangular.

Shrub Growth Habits:

- *Spreading*: Plants have a widespread and can slowly spread into other areas.
- *Arching*: Plants stems arch from the plant base toward the ground.
- *Upright*: Plant tends to grow upward and does not significantly increase in width over time.
- *Rounded*: Plant is circular or generally round.
- *Creeping*: Low growing plants that can slowly grow into other areas.

Grass and Perennial growth Habits

- *Clumping*: Plant that tends to grow in clumps that spread slowly.
- *Rhizomatic*: Plant that spreads via rhizomes. Grasses in this category can spread rather quickly.
- *Upright*: Plant has tall erect stems with little to no foliage at the base.
- *Groundcover*: Plant is low growing and spreads quickly.
- *Spreading*: Plant spreads in an area and can easily form colonies.

Planting Techniques

Unlike other construction practices, planting involves a live product, *soil dynamics* and other environmental influences at the planting site. Planting techniques focus on the plant, planting procedures and management with modifications needed to address specific requirements of: stock type (B&B, container, bare root or mechanical spade); species types (trees, shrubs, ground covers, herbaceous perennials, and annuals); transplant method (mechanical tree spade); and site conditions. They must incorporate plant biology, horticulture, soil science, engineering, and economics. The bottom line is that techniques must be scientifically sound, feasible within construction operations and efficient in terms of labor requirements.

<u>Soil Dynamics</u>

The following information is taken from the manuscript "*Working with Urban Soils*" by Phillip J. Craul, Visiting Professor of Landscape Architecture, The Graduate School of Design, Harvard University.

> *"Natural soils are a porous medium made up of mineral materials, organic residues in various degrees of decay and contains air and water in various proportions. It is a dynamic system composed of physical and chemical processes together with biological processes undergoing daily and seasonal changes and fluctuations that give the soil its ability to retain nutrients and water in plant available form and provides mechanical support for plants.*
>
> *Urban soil is one that has been disturbed or manipulated by human activity connected with construction and urbanization. It has one or more horizons, composed of material*

that has undergone one or more of the following actions associated with urban activities: mixing, compaction, pulverization, filling, scraping, and addition of anthropogenic contaminants or toxic substances at levels above those of natural soils (Craul, 1990).

Given the potential differences between natural, disturbed, and disturbed urban soil, it is important that soil characteristics be taken into consideration when preparing project-planting specifications. Soil characteristics to include the examination of the soil profile, physical characteristics (texture, organic matter, porosity) and chemical characteristics (pH, nutrient analysis) should be noted.

Plant Stock Type

Planting techniques begin with addressing the specific requirements of stock type such as *bare root*, *balled and burlapped* and *container*. Every type of nursery is associated with specific production, harvesting or handling techniques that should be considered when detailing planting specifications.

Bare-Root Plants

Bare-root plants, as the name implies, are harvested, processed, stored, shipped, handled, and planted without soils or other media attached to the roots. Each step from harvest to planting can have a potential impact on the plant and its successful establishment. Bare-root plants are harvested while dormant in either fall or early spring. Factors related to bare-root planting stock include *root desiccation* and *damage*, *planting depth*, and stability in the hole.

Root desiccation and damage

The first consideration when planting bare-root stock is root desiccation (drying out). Root exposure from harvest to planting causes plant moisture and fine root loss; the extent of the loss depends on the species and the storage and handling procedures prior to planting. Several practices attempt to re-hydrate bare-root plants prior to planting. They include submerging root systems into water for a brief period; sweating, packing moist materials around the plants and covering the plants with a tarp; and coating the root system with a soil slurry.

Root damage

Harvesting is another artifact of this stock type. Broken or frayed roots should be pruned to facilitate root regeneration. Root regeneration occurs immediately behind severed root ends; clean cuts will enhance their production.

Planting depth and stability in the hole

Planting depth and stability in the hole are also concerns when planting bare-root stock. Bare-root plants should be planted at a level that corresponds to the trunk/root collar. The trunk/root collar is usually identified by the flare at the base of the plant. On budded or grafted plants, the bud/graft union is often mistaken for the trunk/root collar. The trunk/root collar on these plants will be slightly below the bud/graft union on the rootstock.

Plant stability within the hole is addressed through proper backfill procedures. Backfill soil should be worked around and throughout the root system. Failure to do so will result in plant/soil settling and/or shifting of the plant within the planting hole. Staking is usually required for all bare-root trees planted in the landscape.

Balled and Burlapped (B&B) plants.

Factors related to B&B planting stock include soil ball moisture, planting depth, and top of the root system.

Soil ball moisture

B&B harvest plants are usually staged in the field and later shipped to project sites or intermediate sites for holding. Soil ball moisture is lost during the transitional period between harvesting and planting. Moisture loss occurs through evaporation from the ball surface while the plants are dormant and quickly increases at bud break when roots draw moisture for shoot growth, leaf expansion and root initiation. The period between harvest and planting can have a significant influence on soil ball moisture. Watering at planting aids in recharging ball moisture, however, care must be taken to ensure that water infiltrates into the ball and does not run off into the planting backfill. Check soil ball moisture prior to planting and provide its necessary recharge. Also note that an automatic irrigation system does not necessarily ensure that water is penetrating soil balls within the holding yard or at the planting site during establishment.

Planting depth and top of the root system

Another important consideration is planting depth. During production, normal settling or cultural practices might alter the soil level around the root collar and give a false impression of the true level of the root system. Some nurseries remove the “rootless” soil from the top of the ball before finishing off the top laces; others leave this soil intact. The real concern comes at the planting. During planting at the landscape site, it is important to examine the top of the soil ball to determine the true level of the root system and establish planting depth accordingly.

Planting specifications should address this concern as follows:

1. *Remove the twine or other material from the trunk* Natural materials such as sisal will degrade in time, synthetic materials (poly-twine or strapping) will not. Even though natural materials degrade, the multiple wraps used to secure the basket and trunk take several seasons to loosen.

2. *Pull back or remove the burlap and basket loops from the top of the ball.* There may be layers or folds in the burlap that can act as a barrier between the soil ball and planting soils. Bend the top loops of the basket back onto the basket or remove them. The basket does not need to be completely removed; however, loops can work their way to the surface if not removed or bent back properly.

3. *Examine the top of the ball and locate the root system.* Pull away the soil from the trunk and locate the uppermost structural roots of the plant. A few fibrous roots may have worked themselves up into the soil but are usually not in substantial numbers. Once the top of the root is located, the excess soil can be skimmed off the top of the ball revealing the true level at which the root system should be set. This is especially important when planting in a site where soil drainage may be a problem. Soil build-up can vary from 2-4 inches and can be as high as six inches on larger trees. The false top found on balled and burlapped (B&B) trees does not seem to be as prevalent in shrubs, although large field grown shrubs may exhibit an altered soil level. Soil ball moisture can also be an issue on B&B shrubs; watering should focus on the soil ball area.

Container grown plants

Important considerations for container grown nursery stock include *root/backfill, soil contact*, *media moisture levels* and *pot bound root systems*.

Root/backfill soil contact

Regardless of the type of container, the first step is to remove the container. Pressed paper pots and bags may be accompanied with instructions indicating that the pot or bag is degradable and may be planted in the hole. However, these materials cause barriers to lateral water movement and root growth into backfill soils which is counter-productive to the goal of establishing the root system.

In working with container grown plants, the objective is to integrate container media with backfill soil. This allows root/backfill soil contact and lateral soil water movement towards the root system. Backfill soil should be in contact with roots within the core of the container media, not just at the edges. Water in the soil is delivered to the roots by capillarity. The difference in physical characteristics between mineral soil and container media and the lack of soil water movement across the interface has caused death of many container plants. Integrating soils and media help to minimize water stress during the establishment period.

Media moisture levels

The same concerns with moisture in B&B nursery stock holds true for container grown plants. It is important to ensure that adequate moisture is delivered to the plants prior to and immediately after planting. This minimizes any stress that may impact plant quality or delay establishment. Peat and bark mixes are known to repel water as they dry. As a result, it takes more effort to rewet the media, both in time and the volume of water needed to pass through the container root mass. If the plant arrives in the hole with adequate moisture, it requires less time watering following planting and is one more factor in favor of its establishment.

Pot bound root systems

Pot bound root systems are the most common concern in planting container produced plants. Disruption of the root system is required to facilitate root development into backfill soils and promote plant establishment. In the case of plants that are not severely bound it is easy to loosen the root system by hand. Simply massage the root mass, letting media particles fall from the roots. The loosening facilitates for root/backfill soil contact. On dense and tighter masses, the butterfly method is most often used. This involves slicing through the root mass approximately one third up from the bottom of the mass, turning the mass 90 degrees and slicing through it again. This will produce four lobes and open the core of the container root mass to backfill soil. Again, the extent of the disruption depends on the pot bound nature of the root mass. Butterflying may cause water stress to container plants depending on the stage of growth. Focus subsequent watering on the root mass to ensure adequate moisture levels in both the container media and backfill soil.

<u>Mechanical Spade</u>

Mechanical spades are a valuable tool-of-the-trade. They expand the size of plants available for transplanting, extend the planting season, reduce labor, and provide ‘instant’ impact to many landscapes. There are several manufacturers of spades with variations in size, blade configuration, and plug shape. Considerations in transplanting using a mechanical tree spade include the *plant*, *hole*, *transplanted plant plug*, *staking*, *watering*, and *mulching*.

Plant

The first consideration when choosing this transplant method is access to the planting site. The next consideration is the spread and depth of the root system. Most plant root systems are within the upper three feet of soil with the largest amount found in the upper twelve to fifteen inches of the soil horizon. Root growth following transplanting happens through root elongation and root regeneration. Root elongation occurs from existing intact roots within the transplanted plant plug. New root regeneration occurs from behind the cut ends of severed roots near the edge of the transplanted plant plug and is critical for long-term plant establishment. Soil moisture in the root zone is also critical to successful mechanical transplanting because the transplanted plant uses water from within the transplanted soil plug during initial establishment. Water "charging" of the soil around the base of the plant prior to harvest minimizes water stress of root loss when dug, especially during the active growing season.

Hole

At the planting site, procedures focus on extracting the plug, orienting the plant, providing the closest fit between the hole and the incoming plant, and setting the plant plug at the appropriate level for site/soil drainage. As a rule, the spade operator will use the same tire tracks for extracting the plug and returning with the plant. In doing so, the spade blades will be in the same position, thus minimizing the gaps following planting. If there are concerns with drainage at the planting site, the operator can extract a shallower plug or backfill the hole prior to inserting the plant.

In mechanical tree spading, compaction (glazing) occurs on the outside wall of the hole and the outside surface of the plug. It is caused by friction from the penetrating blades. Clay soils tend to aggravate this problem. These compacted layers can extend few inches into each surface and impede new root penetration from the transplanted plant plug into surrounding soils. They also interfere with the lateral movement of soil moisture across the existing site soil and the transplanted plant/soil plug interface. This interference can limit water entering the transplanted plant plug only through surface applications on the plant plug area.

Plant Plug

As mentioned earlier, a majority plant roots reside in upper twelve to fifteen inches of the soil. When a spaded plant is brought to the site, focus on only loosening soil to a depth of 12-15 inches and width of 6 inches wide around the transplanted plant plug and approximately 6 inches wide around the wall of the hole. When placing new soil, allow the soil to filter into the gap between the plug and hole wall. This should be sufficient to make a soil connection to allow lateral moisture movement. Additional soil can be used as necessary to fill remaining voids or to level soil surfaces. The intent is to bridge the gap between the transplanted plant plug and the glazed surface to allow roots room to development into surrounding soils. If the plant plug is elevated due to poor drainage, use additional soil to provide a smooth transition from the plant plug level to the existing grade.

<u>Planting Procedures</u>

Planting procedures include the *planting hole*, *positioning the plant*, *backfilling the hole*, *staking/guying*, *trunk guards* and *mulching*.

Planting hole

The characteristics of the hole include width, depth, bottom, and sides. Width recommendations of planting holes are usually based on plant type and range from 6 to 12 inches from the outside of the soil ball or container mass. For trees, 12 inches from the outside edge of the soil ball/container mass is acceptable to facilitate root development, allow for backfilling and will stabilize the plant within the hole. For shrubs, general recommendations call for approximately 6 inches from the outside edge of the soil ball or container root mass. Large sized shrubs may require wider holes and, in some cases, extend the width recommendation to 12 inches.

Depth of the planting hole relates to root ball or container size and the top of the root system. Align planting depth with the top of the root system; keeping in mind that the final step in backfilling will add a shallow covering of planting soil over the soil ball or container root mass. This is especially true for container stock to avoid moisture loss through media wicking. In heavier soils or where drainage issues are a concern, establish planting depth so that 1/8 to 1/4 of the root mass is positioned above existing grade. Plantings can be elevated higher, however it must be understood that a wider planting circle may be needed to accommodate a smooth transition from the top of the root mass to the surrounding grade. Sides of the hole should be free from glazing or noticeable compaction. This is especially a concern if an auger or other power equipment is used to dig the holes. If a plateau at the bottom of the hole is used to seat the root mass, it should be firm to prevent future settling or shifting of the plant.

Positioning the plant in the hole

Orient the plant in the hole respecting the optimal view and/or alignment with structures or other architectural features on the site. Align individual plants in plant masses so that they complement surrounding plants and contribute to the overall shape of the mass. Plants should be plumb (vertically straight) and set firmly on the bottom of the hole.

Backfilling the Hole

Backfilling is critical in stabilizing the plant and facilitating an optimal rooting zone for establishment. Backfilling should be done in 2-3 layers depending on the stock type and depth of the hole. Backfilling and compacting in layers will minimize or eliminate future soil settling and shifting of the plant. The first step is to place and compact soil around and under the base of the plant to compensate for irregularities in ball shape or container mass and aid in straightening the plant. The next layer should be done with soil sliced from the sides of the hole. Slicing soil at an angle from the sides of the hole provides an expanded zone of loose soil for root penetration without having to excavate a wider hole. Slice soil from the circumference of the hole compacting it around the base of the plant. The final steps consist of finishing the backfill, grading a smooth transition to the surrounding soil grade and constructing the water saucer. The smooth transition of backfill soil into the surrounding grade provides an additional zone for future root development. This is beneficial when elevating the root mass due to poor soil drainage. The water saucer is shaped at the base of the plant, especially on non-irrigated sites. The saucer is shaped out of soil and encircles the soil ball or container mass area prior to mulching. The objective is to place it directly over the root mass and allow collected water to penetrate to the existing roots. Too wide of a saucer will allow water to easily run off the root mass and filter into the backfill.

Amendments

The benefits of amended backfill and special planting mixes on plant establishment depend on existing site soils. Organic amendments can be added to sandy soils to increase water and nutrient holding capacity. Most current specifications call for using a mixture of topsoil and existing site soils for backfill material.

Staking/Guying

Generally, staking is specified to protect trees from mechanical trunk damage, to prevent shifting due to prevailing winds, and to stabilize bare-root and B&B trees with shallow roots or loose soils. Staking specifications may call for 1, 2, or 3 stakes/anchors (metal posts, anchors/guying) evenly distributed around the tree with one stake/anchor on the windward side. Stakes are driven through the backfill into the undisturbed subgrade. Anchors and guy wires are placed in the undisturbed areas beyond the perimeter of the planting hole. Material used to secure the trunk firmly to the stake is usually poly/canvas strapping. Research conducted on the influence of staking on trunk caliper development in nursery liners is often misinterpreted and applied to the landscape. Trees planted in the landscape already have developed significant trunk taper and caliper and there is no evidence to suggest that tight staking for 1-2 seasons in landscape has a significant influence on subsequent trunk development. Stakes should be removed after one year. However, in the case of larger trees, evergreens and trees on exposed/windy sites, stakes may stay in place for two years.

Trunk guards

Trunk wrap and tree guards are often used to minimize potential damage to trunks due to extreme weather (sunscald and frost cracking) and/or physical damage (trimmers, mowers and animals). This may be especially appropriate with thin bark species (Red Maple, American Beech, ornamental cherries) or on sites where animal damage is a concern (esp. deer). All trunk protection should be removed after no more than two growing seasons to prevent moisture decay on the trunk and insect nesting. On sites with heavy deer pressure it may be advisable to include the annual placement and removal of tree guards into the maintenance schedule.

Mulching

Recommendations call for 3 inches of organic mulch evenly applied across the planting area without allowing it to be in contact with the trunk. Excessive wetness on a trunk from prolonged contact with mulch can lead to trunk decay.

Watering

Watering is usually the last step in the process. The best start to watering is to ensure adequate soil ball or container media moisture going into the hole. Newly installed plants rely on soil ball and container moisture for the first growing season. Concentrate watering on the root mass whether it is soil or media and provide water to the backfill/root mass interface. Target future watering to the base of the plant and regulate the frequency based on stock type, available irrigation systems and weather conditions. Remember, an automatic irrigation system does not necessarily ensure that water is penetrating existing root masses during establishment.

Site Preparation and Slope Planting Specifications/Details

The Contractor will notify Digger's Hotline to verify location of underground utilities prior to starting work. The Contractor is responsible for coordination and completion of utility marking. The Contractor is responsible for damages related to failed or neglectful utility marking.

Remove existing vegetation from the planting area. Use a non-selective contact herbicide to kill perennial weeds and undesirable vegetation. Strip plant debris and expose mineral soil. Prepare final slope grade in the planting area. Spread 4” of compost across the entire planting area prior to plant installation.

Prior to mulch application and after compost application and planting, treat each planting site with a pre-emergent herbicide according to MDOT 2012 Standard Specifications for Construction and approve herbicide product and application method.

<u>Deciduous Tree</u>

Prune to remove dead, damages, broken, or weak branches; lightly thin the interior of the crown. Prune to maintain a central leader on appropriate species.

Soil/root ball should have adequate moisture prior to positioning the plant in the hole. Examine the trunk/root crown and inspect the soil/root ball for the true top of the root system. Planting depth is referenced to the top of the root system.

The slope-finished grade on the planting details depicts a varied actual grade at the planting site from 1 vertical: 6 horizontal to 1 vertical: 1 horizontal. Adapt the planting hole excavation as deemed appropriate with MDOT representative.

Dig the planting hole 12" wider than the edge of the soil/root ball. Hole depth is determined by the height of the soil/root ball to the top of the root system. The top of the root system should coincide with existing grade or in the case of poorly drained soils be elevated. The bottom of the hole should be firm and shaped as a plateau for positioning the soil/root ball.

Orient the plant in the hole with respect to optimum viewing; the plant should be set firmly on the base of the hole; align the plant so that it is plumb in the hole. Remove twine, the top rung of the basket wire and burlap from the top of the soil/root ball or fold them back on the soil/root ball; remove excess soil from the top of the soil ball down to the level of the roots.

Describe the backfill soil/mix; for example, backfill with existing soil; backfill with a 50/50 blend of existing soil and topsoil; If an amended backfill mix is required, identify the amendments and the percentages of amendments within the soil mix. Backfill soil/mix should be approved by MDOT representative.

Backfill in three lifts. Begin backfilling by slicing soil at an angle from the edge of the hole and use it to stabilize the soil/root ball and ensure that the plant is plumb in the hole. The second lift is applied and packed around the soil/root ball. The third lift finishes filling the hole to final grade, covers the top of the soil/root ball and shapes a saucer over the soil/root ball area. Note: packing the soil around the soil/root ball stabilizes the plant, removes any air pockets in the backfill, and minimizes or eliminates future soil settling which may cause a shift in plant orientation. A saucer is shaped over the soil/root ball area to collect water and allow its gradual percolation into the soil/root ball. The saucer may remain or be knocked down at some point in the future.

Mulch is applied at a 3 inch depth over the planting area following the soil contour. Do not allow the mulch to come in contact with the tree trunk.

Apply nutrients (based on a soil test) at the appropriate rate and method for the plant.

If staking is required, stake the tree with appropriate stakes (2” x 2” wooden stakes, metal posts, guide wires and anchors, etc.). Staking specifications may call for 1, 2, or 3 stakes per tree. If three stakes are used, position the stakes evenly around the tree with one stake positioned on the windward side. Stakes are driven through the backfill into the undisturbed subgrade. If anchors are used, position the anchors in the undisturbed area beyond the perimeter of the planting hole. When anchors are used, the mulch ring is extended to enclose the anchors within the planting area. Poly/canvas strapping is used to firmly secure the trunk to the stakes. Stakes are typically removed after one year however in the case of larger plants they may stay in place for two years.

Water the soil/root ball area and backfill adequately after planting.

Conifer Tree

Prune to remove dead, damages, broken, or weak branches. Prune to maintain a central leader on appropriate species. Soil/root ball should have adequate moisture prior to positioning the plant in the hole. Examine the trunk/root crown and inspect the soil/root ball for the true top of the root system. Planting depth is referenced to the top of the root system.

The slope-finished grade on the planting details depicts a varied actual grade at the planting site from 1 vertical: 6 horizontal to 1 vertical: 1 horizontal. Adapt the planting hole excavation as deemed appropriate with MDOT representative.

Dig the planting hole 12” wider than the edge of the soil/root ball. Hole depth is determined by the height of the soil/root ball to the top of the root system. The top of the root system should coincide with existing grade or in the case of poorly drained soils be elevated. The bottom of the hole should be firm and shaped as a plateau for positioning the soil/root ball.

Orient the plant in the hole with respect to optimum viewing; the plant should be set firmly on the base of the hole; align the plant so that it is plumb in the hole. Remove twine, the top rung of the basket wire and burlap from the top of the soil/root ball or fold them back on the soil/root ball; remove excess soil from the top of the soil ball down to the level of the roots.

Describe the backfill soil/mix; for example, backfill with existing soil; backfill with a 50/50 blend of existing soil and topsoil; If an amended backfill mix is required, identify the amendments and the percentages of amendments within the soil mix. Backfill soil/mix should be approved by MDOT representative.

Backfill in three lifts. Begin backfilling by slicing soil at an angle from the edge of the hole and use it to stabilize the soil/root ball and ensure that the plant is plumb in the hole. The second lift is applied and packed around the soil/root ball. The third lift finishes filling the hole to final grade, covers the top of the soil/root ball and shapes a saucer over the soil/root ball area. Note: packing the soil around the soil/root ball stabilizes the plant, removes any air pockets in the backfill, and minimizes or eliminates future soil settling which may cause a shift in plant orientation. A saucer is shaped over the soil/root ball area to collect water and allow its gradual percolation into the soil/root ball. The saucer may remain or be knocked down at some point in the future.

Mulch is applied at a 3 inch depth over the planting area following the soil contour. Do not allow the mulch to come in contact with the tree trunk.

Apply nutrients (based on a soil test) at the appropriate rate and method for the plant.

If staking is required, stake the tree with appropriate stakes (2” x 2” wooden stakes, metal posts, guide wires and anchors, etc.). Staking specifications may call for 1, 2, or 3 stakes per tree. If three stakes are used, position the stakes evenly around the tree with one stake positioned on the windward side. Stakes are driven through the backfill into the undisturbed subgrade. If anchors are used, position the anchors in the undisturbed area beyond the perimeter of the planting hole. When anchors are used, the mulch ring is extended to enclose the anchors within the planting area. Poly/canvas strapping is used to firmly secure the trunk to the stakes. Stakes are typically removed after one year however in the case of larger plants they may stay in place for two years.

Water the soil/root ball area and backfill adequately after planting.

<u>Container Shrub</u>

Prune to remove dead, damages, broken, or weak branches; lightly thin the interior of the crown. Prune to maintain the appropriate shape of the plant. Container media/root mass should have adequate moisture prior to positioning the plant in the hole.

Remove the plant from the container; Disrupt the root mass to allow root/backfill soil contact. Butterfly the container/root mass on pot bound plants by slicing through the root mass 1/3rd the distance up from the bottom of the mass in two directions; resulting in four lobes at the bottom of the container/root mass. Butterflying facilitates root development into the backfill and allows for the integration of backfill soil into the core area of the container/root mass. Spread the four lobes for placement in the hole.

The slope-finished grade on the planting details depicts a varied actual grade at the planting site from 1 vertical: 6 horizontal to 1 vertical: 1 horizontal. Adapt the planting hole excavation as deemed appropriate with MDOT representative.

Dig the planting hole 6" wider than the edge of the container/root mass. Hole depth is determined by the height of the container media/root mass. The top of the container/root mass should coincide with existing grade or in the case of poorly drained soils be elevated. The bottom of the hole should be firm and shaped as a plateau for positioning the container/root mass.

Orient the plant in the hole with respect to optimum viewing; spread the four lobes and set the plant firmly on the plateau at the base of the hole; align the plant so that it is plumb in the hole.

Describe the backfill soil/mix; for example, backfill with existing soil; backfill with a 50/50 blend of existing soil and topsoil; If an amended backfill mix is required, identify the amendments and the percentages of amendments within the soil mix. Backfill soil/mix should be approved by MDOT representative.

Backfill in 2-3 layers (depending on the size of the plant). Begin backfilling by slicing soil at an angle from the edge of the hole and use it to stabilize the container/root mass and ensure that the plant is plumb in the hole. If butterflied, integrate backfill soil into the interior core area of the root mass and around each lobe. The final layer is packed around the container/root mass, finishes filling the hole to final grade, covers the top of the container/root mass and shapes a saucer over the container/root mass area. Note: packing backfill soil around the container/root mass stabilizes the plant, removes any air pockets in the backfill, and minimizes or eliminates future soil settling which may cause a shift in plant orientation. A saucer is shaped over the container/root mass area to collect water and allow its gradual percolation into the container/root mass area. The saucer may remain or be knocked down at some point in the future.

Mulch is applied at a 3 inch depth over the planting area following the soil contour. Do not allow the mulch to come in contact with the trunk.

Apply nutrients (based on a soil test) at the appropriate rate and method for the plant.

Water the root mass and backfill soil area adequately after planting.

Annuals, Perennials and Ground Covers

The following specification is recommended when planting plugs, plants from cell packs or quarts on 6”, 8”, 10” or 12” spacing. Larger container sizes such as 1 gallon containers would be planted as described for container shrubs.

Apply uniform layer of compost 4 inches deep to the surface of the planting area. Till the entire area, loosening the soil and incorporating compost to a depth of 6-8 inches.
Level/smooth the soil to finished grade.

Apply mulch (if applicable) evenly over the planting area at a depth of 1 – 1 ½ inches.

Check the plants for plug/cell moisture. If necessary, water the plants in their containers to insure adequate plug/cell moisture prior to planting. Remove the plants from their containers; disrupt, tease or loosen the roots of container bound plants.

With a hand trowel or other appropriate tool, plant through the mulch layer so that the roots are entirely covered with soil. Plants should not planted in the mulch layer.

Alternatively, perform soil preparation and plant preparation as indicated above. Plant the plants into the finished graded soil and apply mulch to a depth of 1 – 1 ½ inches evenly over the planting area.

Water the planting area so that plugs/cells and soil are adequately moist.

APPENDIX

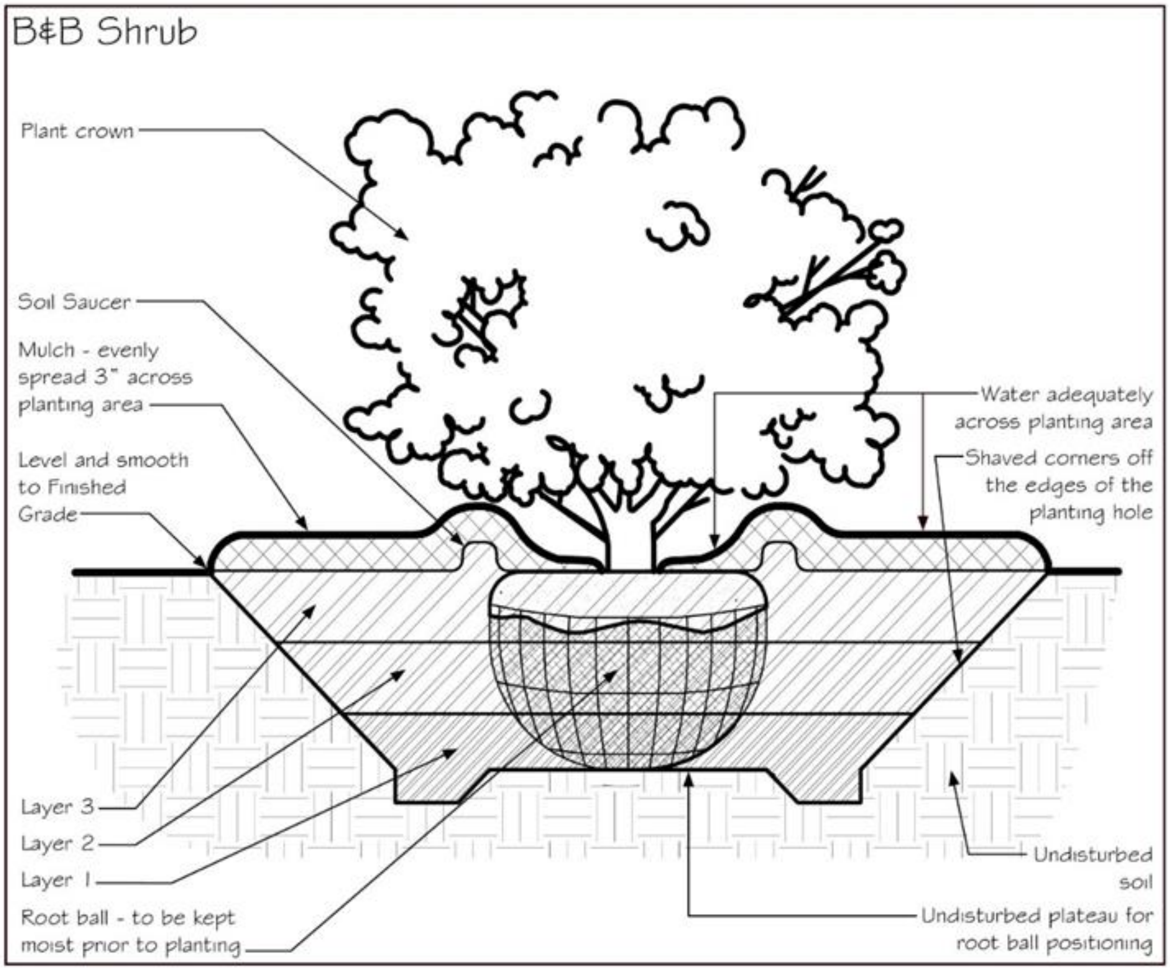

Figure 4.1: Planting detail of a Balled and Burlapped (B&B) shrub developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

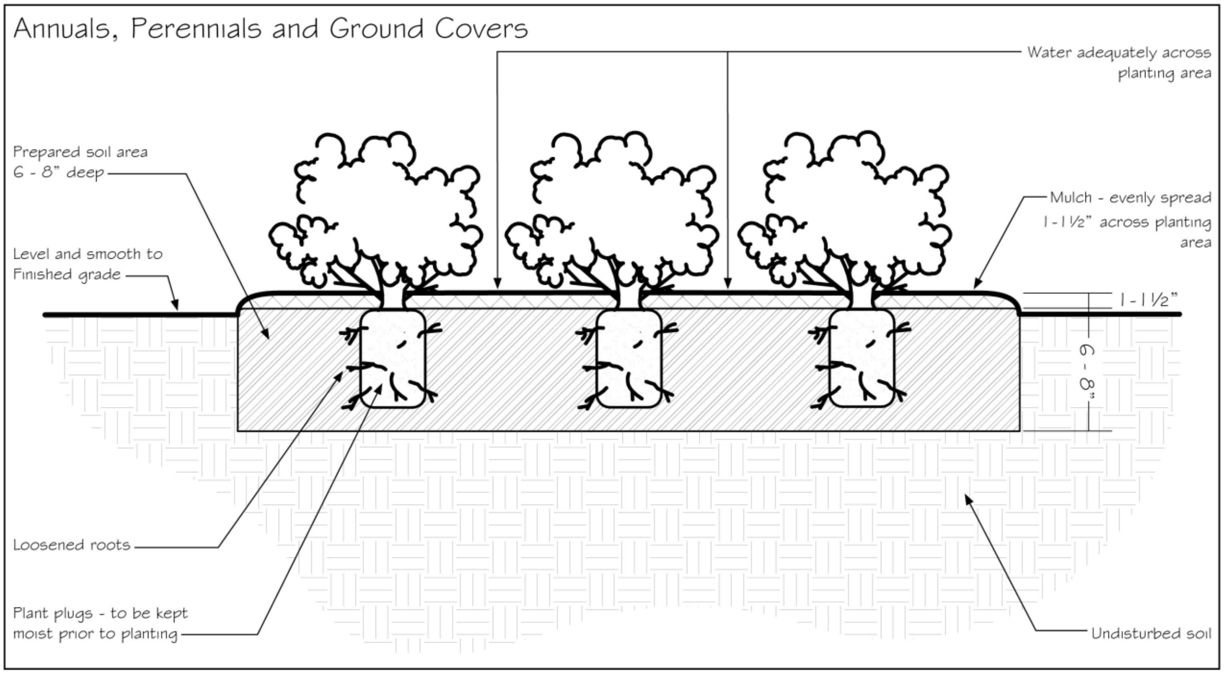

Figure 4.2: Planting detail for annual, perennial and ground cover plants developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

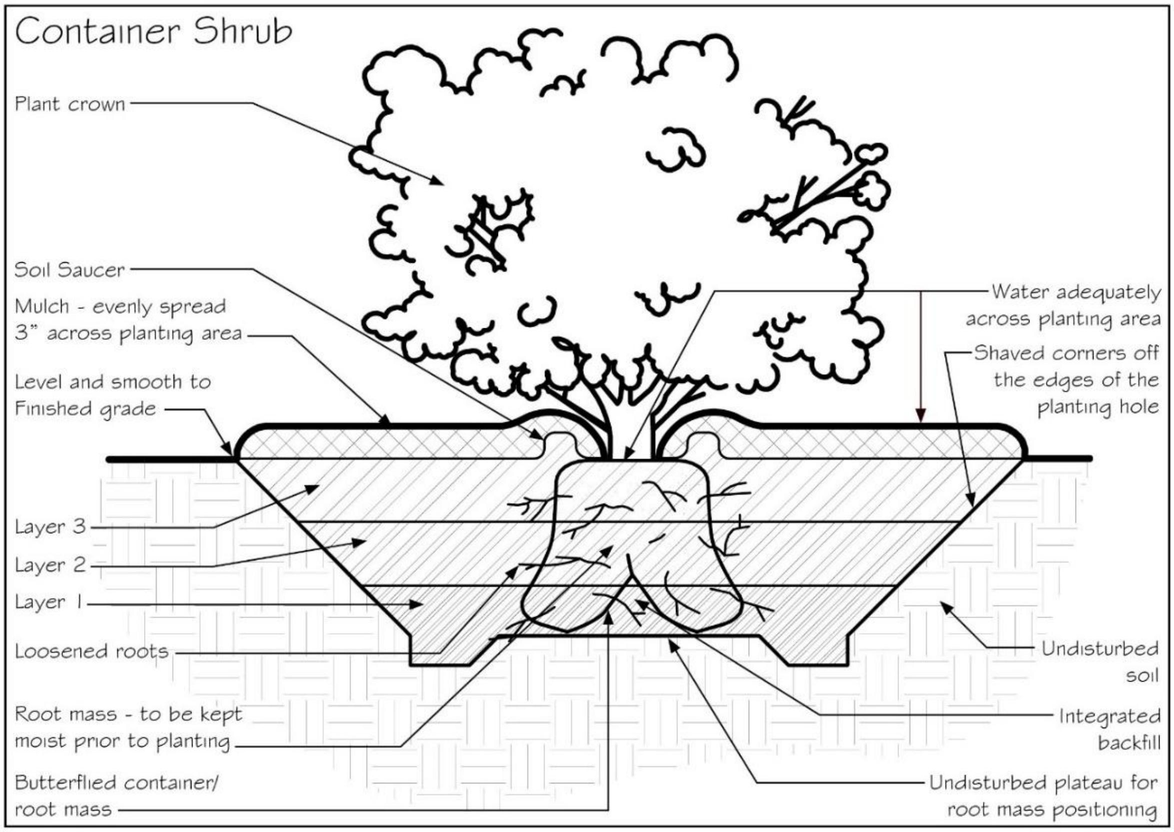

Figure 4.3: Planting detail of a container grown or containerized shrubs developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

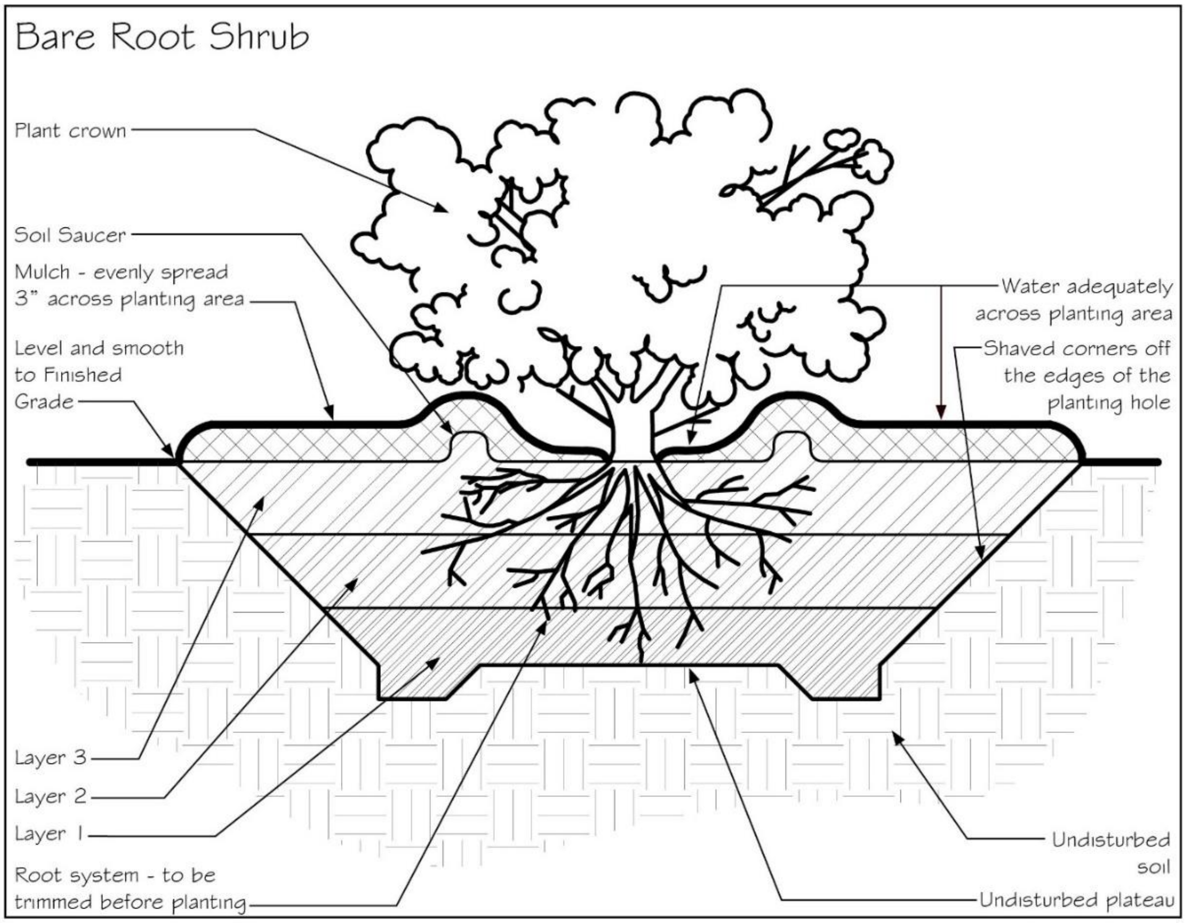

Figure 4.4: Planting detail of a bare root shrub developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

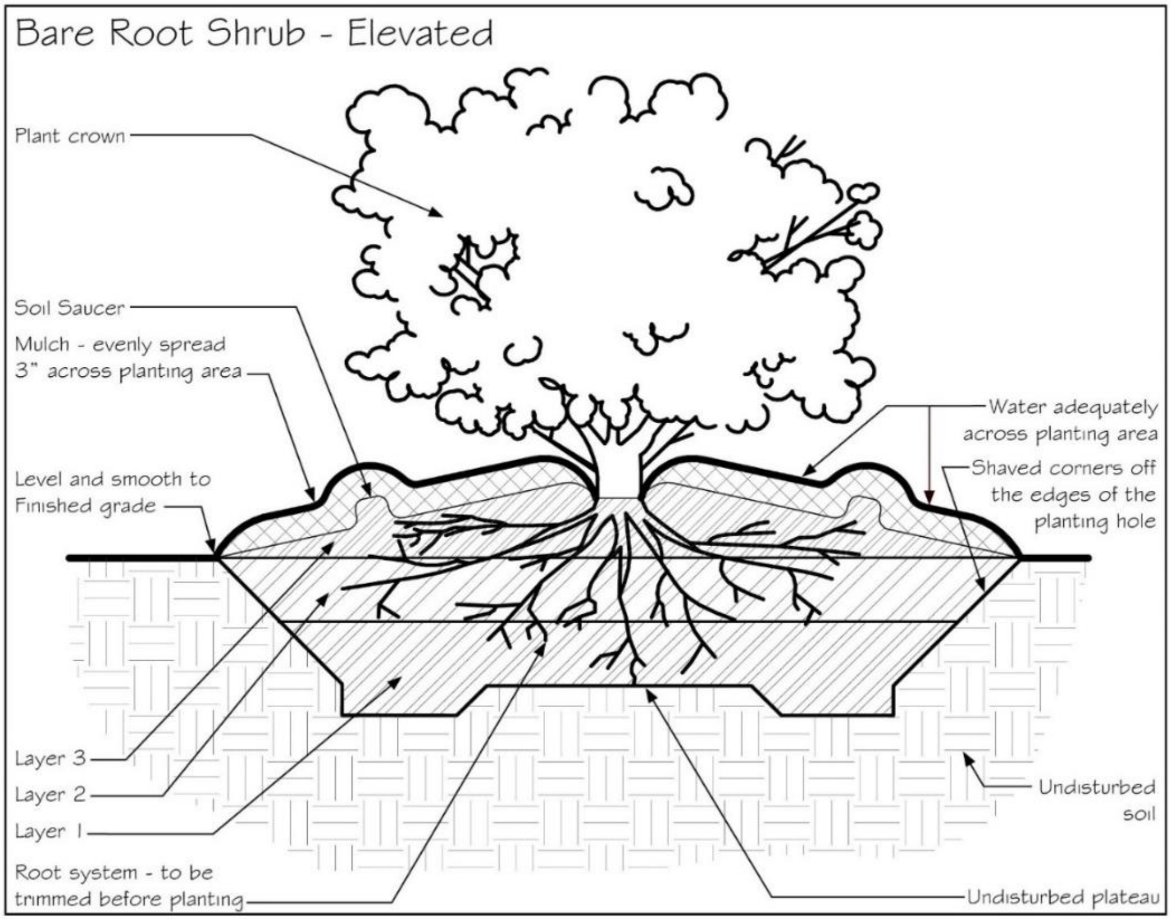

Figure 4.5: Planting detail of an elevated bare root shrub developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

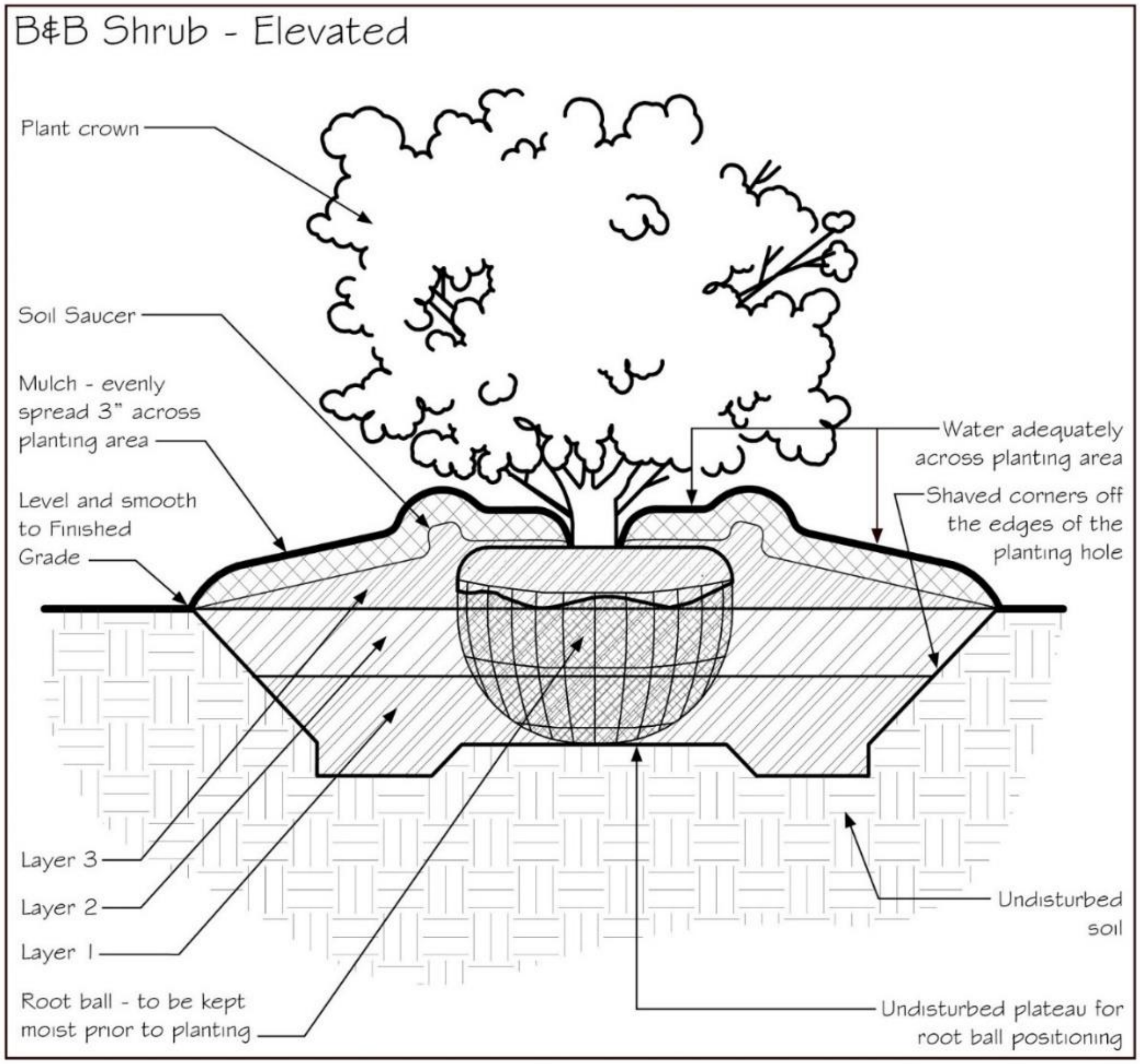

Figure 4.6: Planting detail of an elevated balled and burlapped (B&B) shrub developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

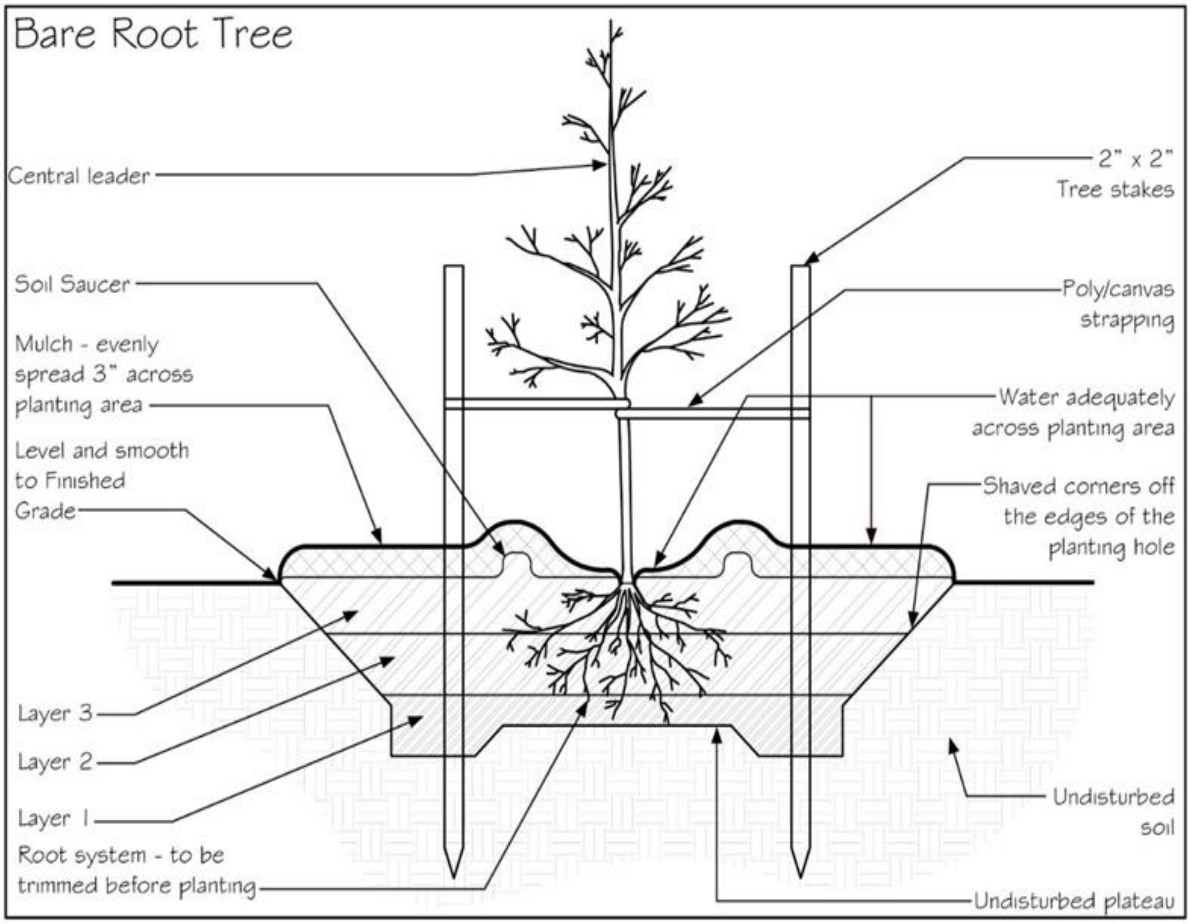

Figure 4.7:Planting detail of bare root tree developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

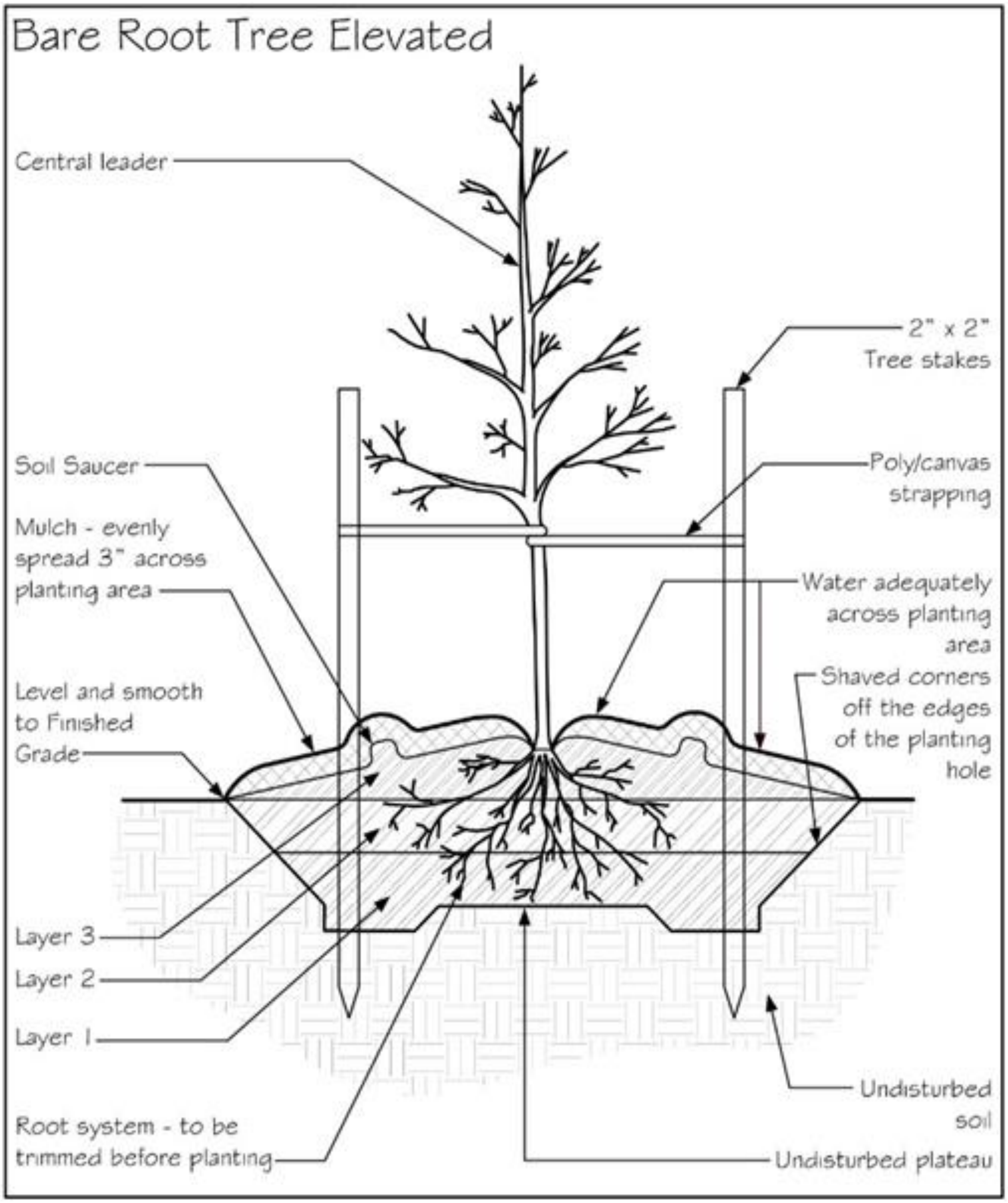

Figure 4.8: Planting detail of an elevated bare root tree developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

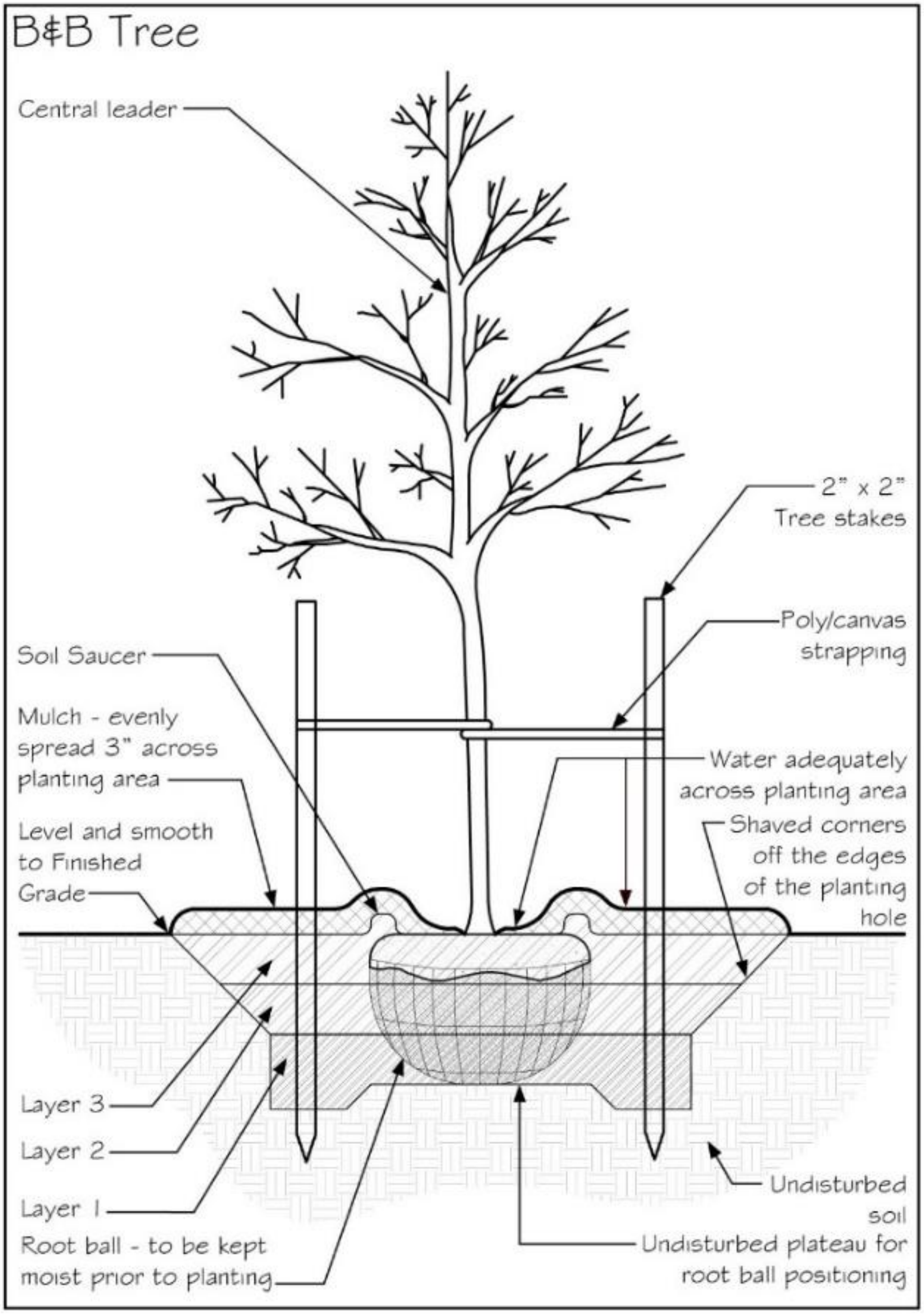

Figure 4.9: Planting detail of a balled and burlapped (B&B) tree developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

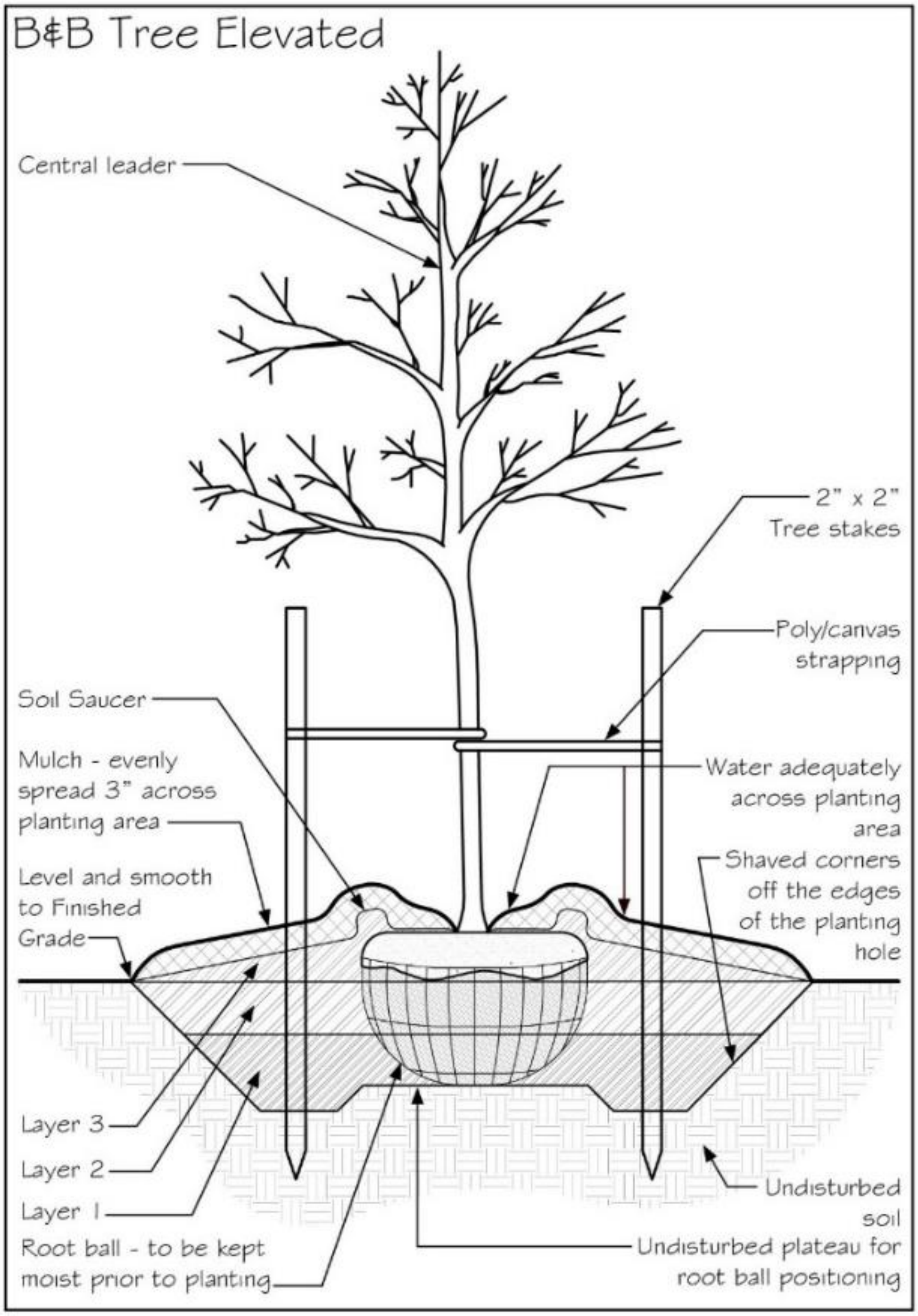

Figure 4.10:Planting detail of an elevated balled and burlapped (B&B) tree developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

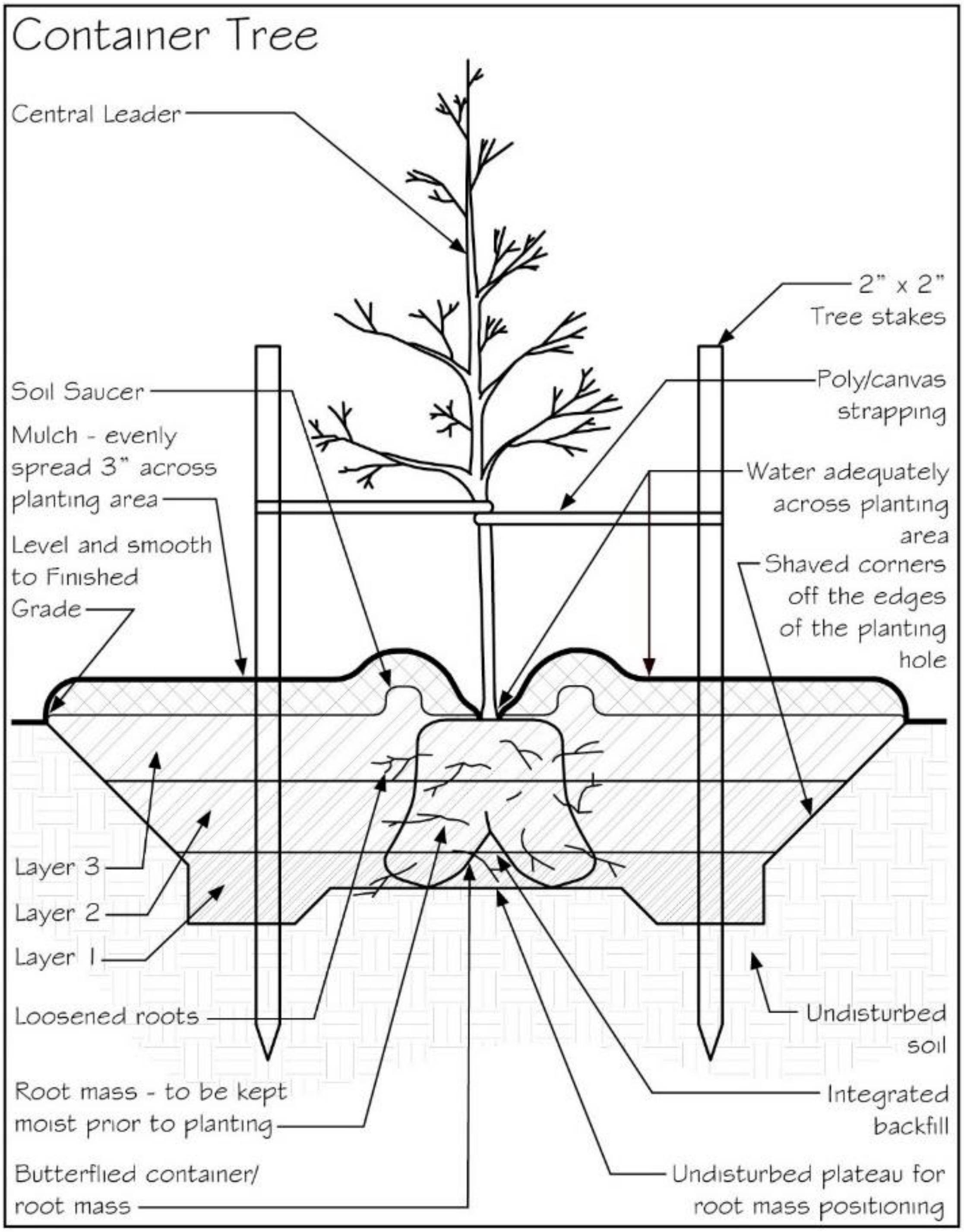

Figure 4.11: Planting detail of a container grown or containerized tree developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

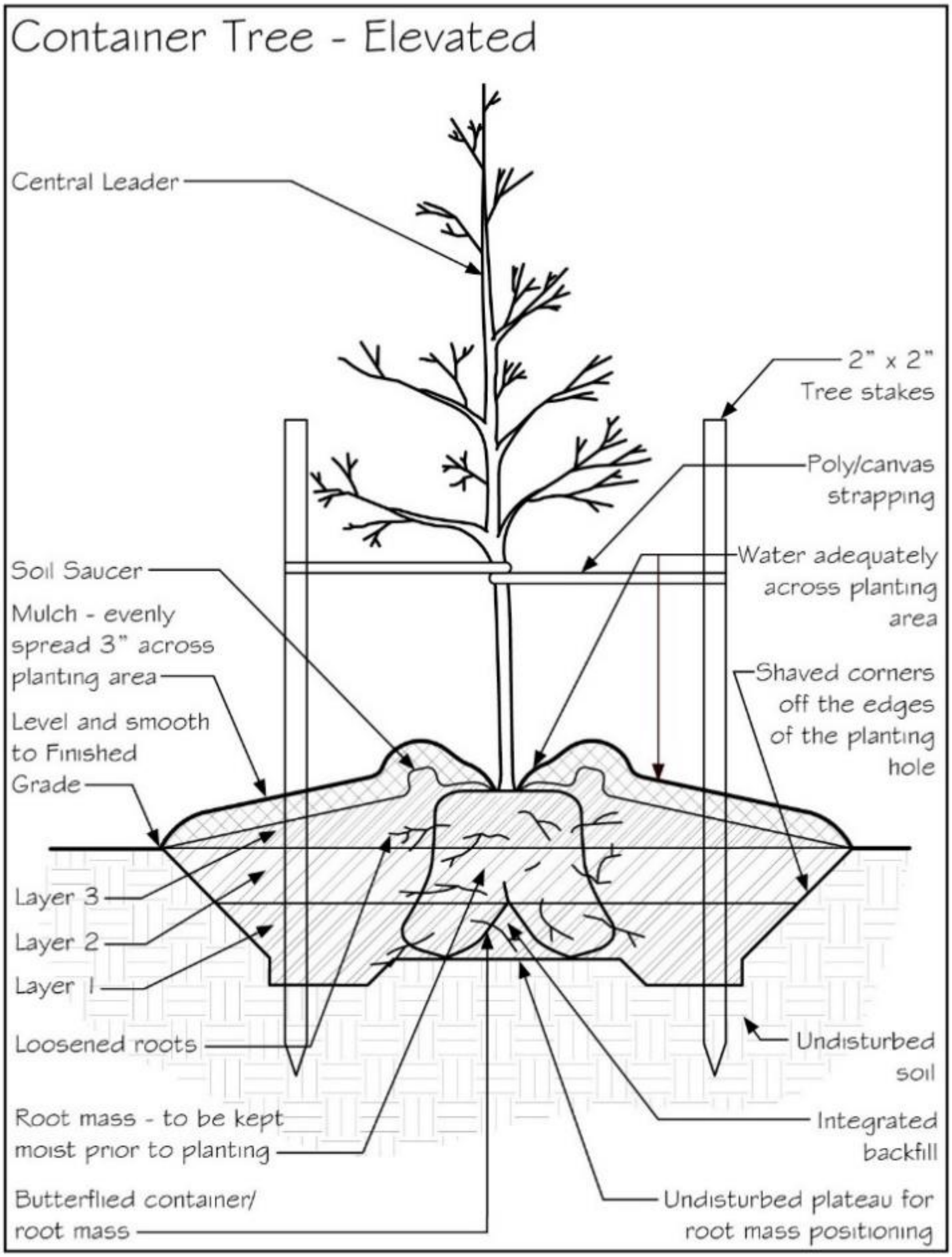

Figure 4.12:Planting detail of an elevated container grown or containerized tree developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

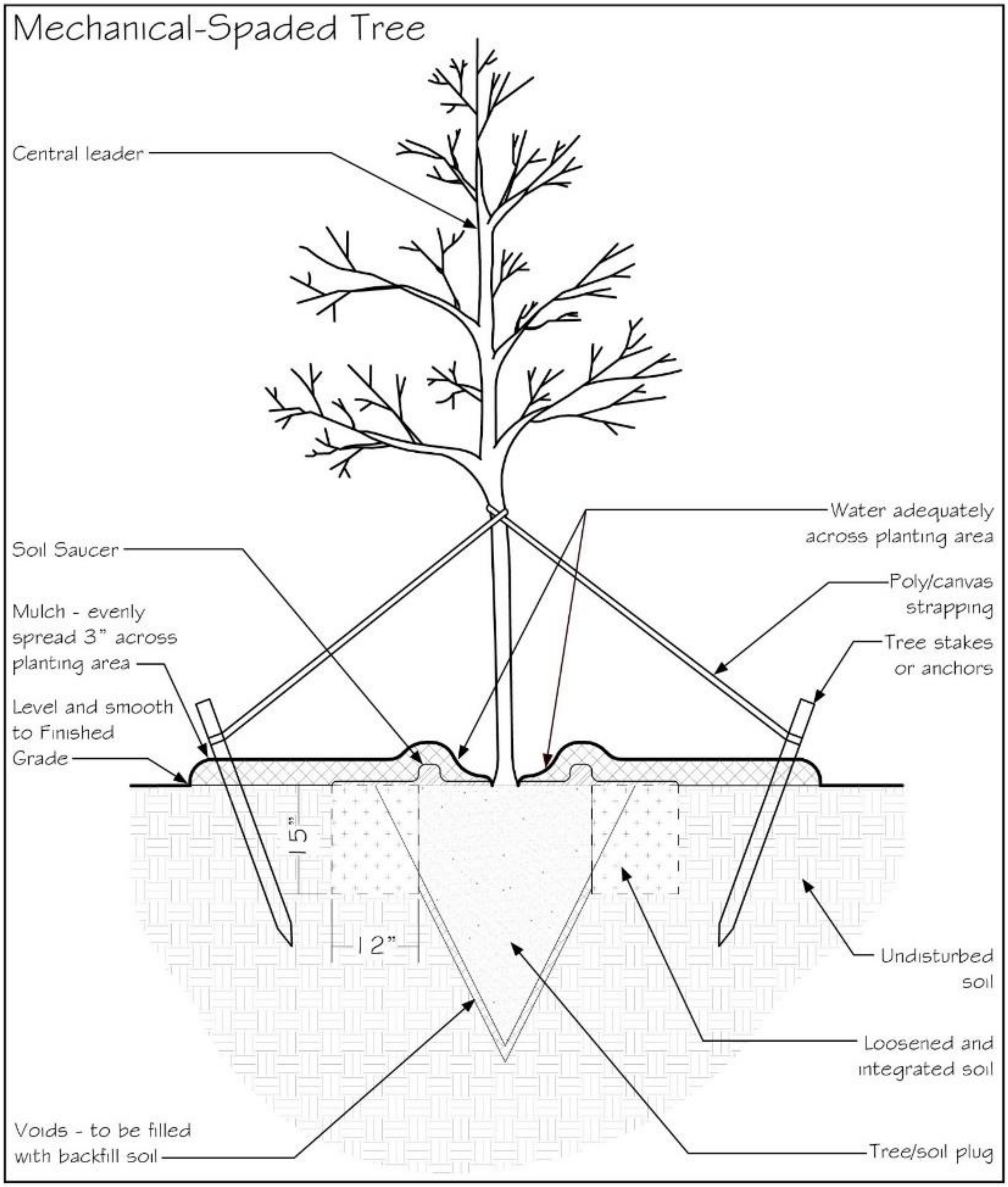

Figure 4.13: Planting detail of mechanically spaded tree developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

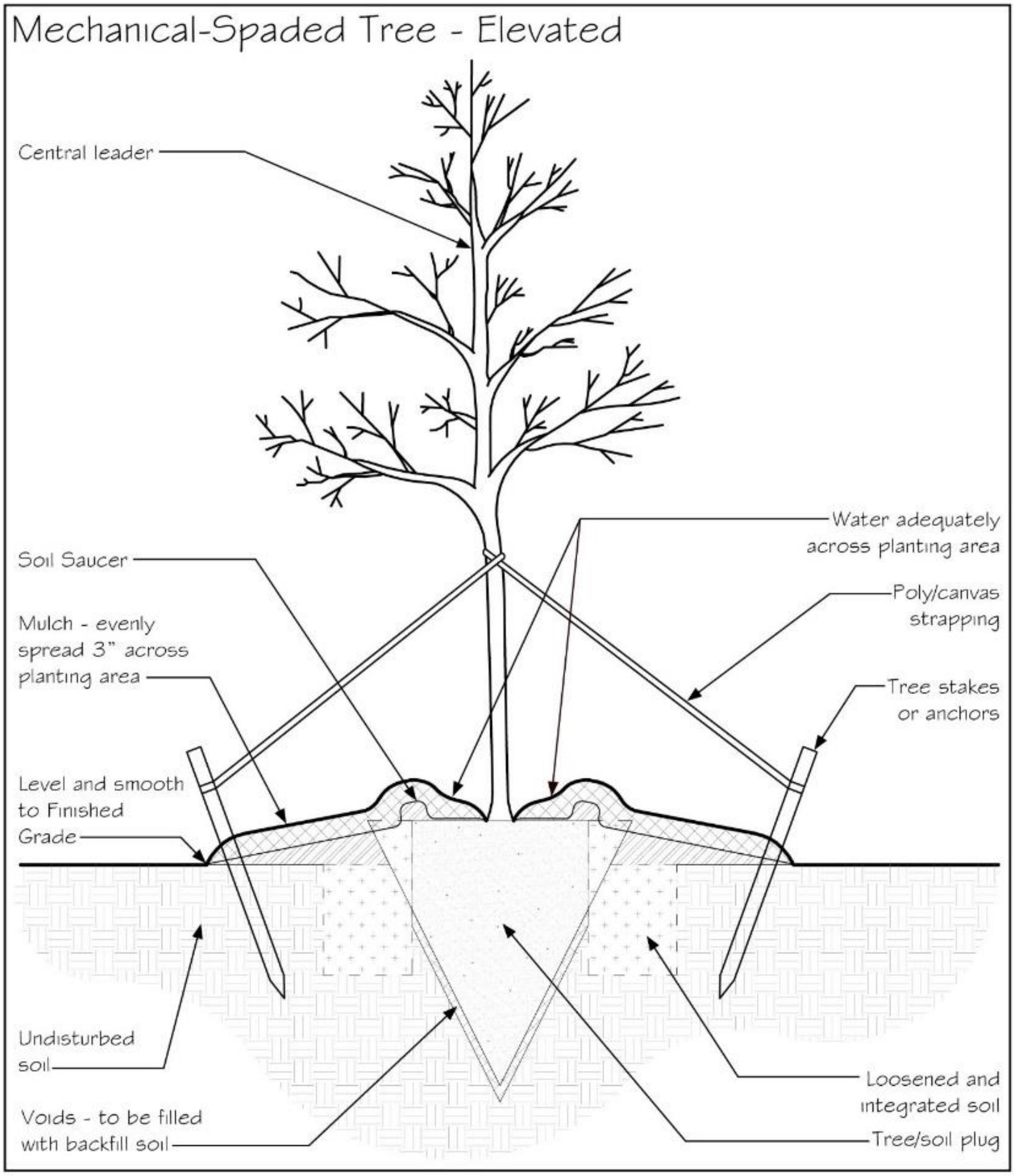

Figure 4.14: Planting detail of an elevated mechanically spaded tree developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

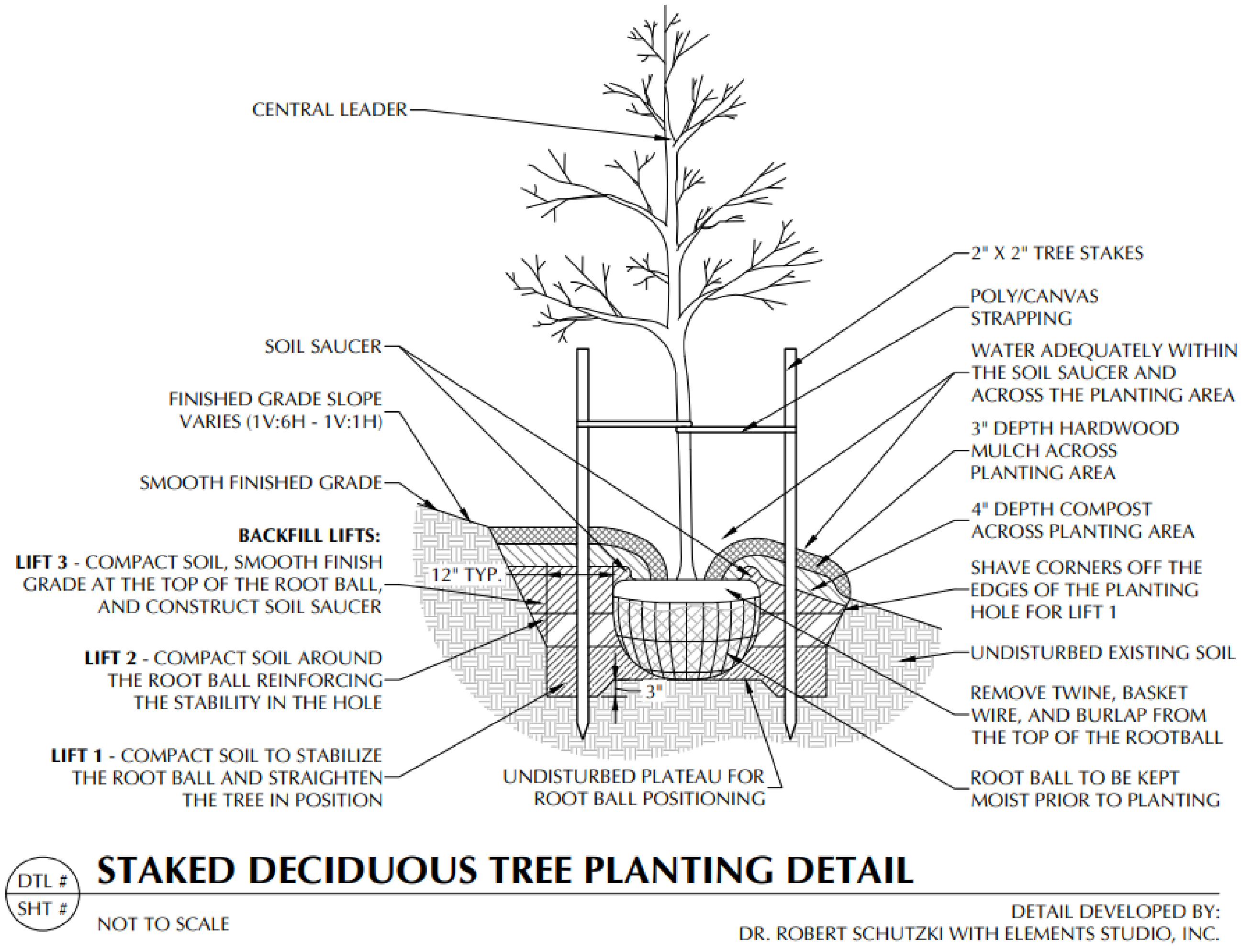

Figure 4.15: Planting detail of a staked deciduous tree on a sloped site developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

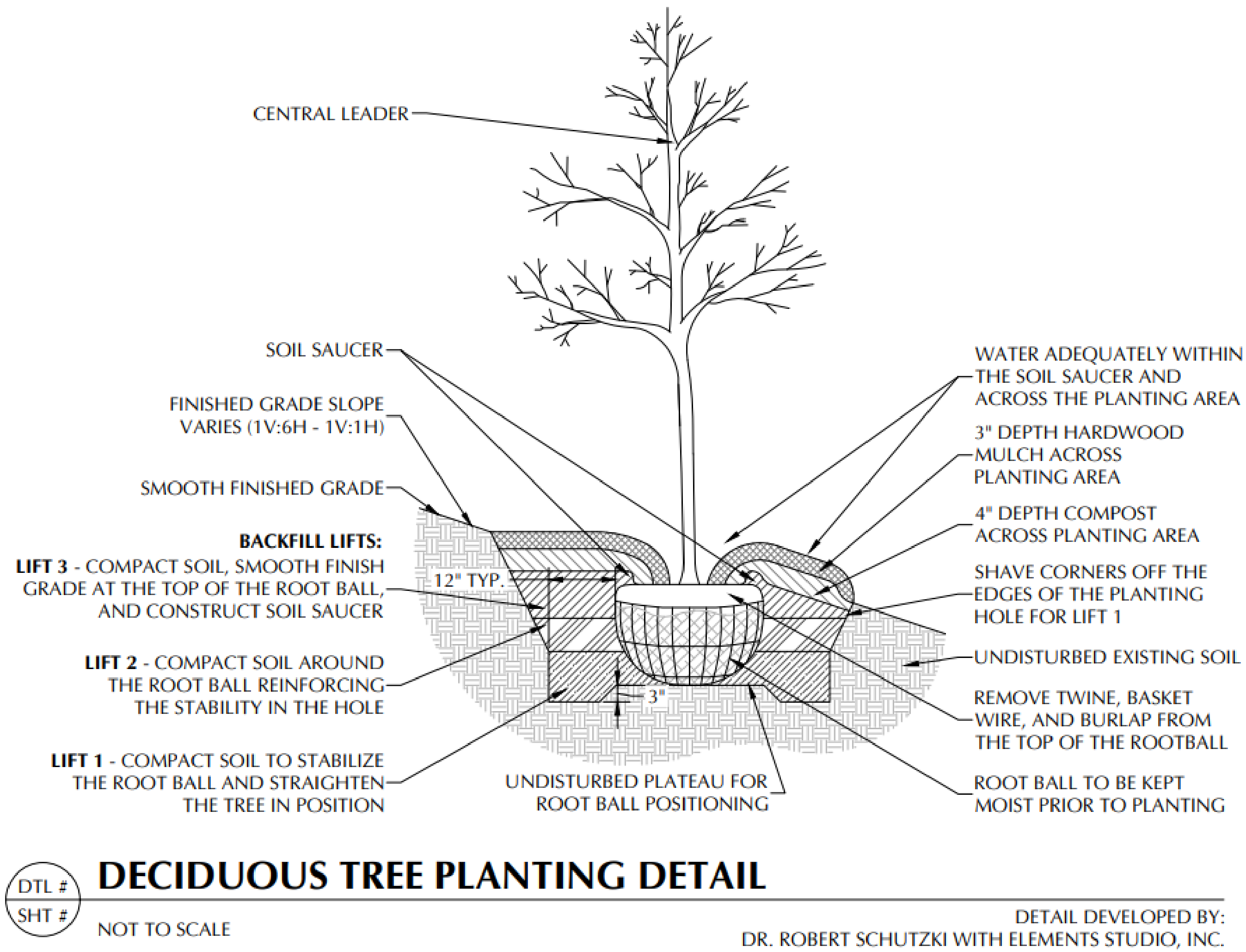

Figure 4.16: Planting detail of a deciduous tree on a sloped site developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

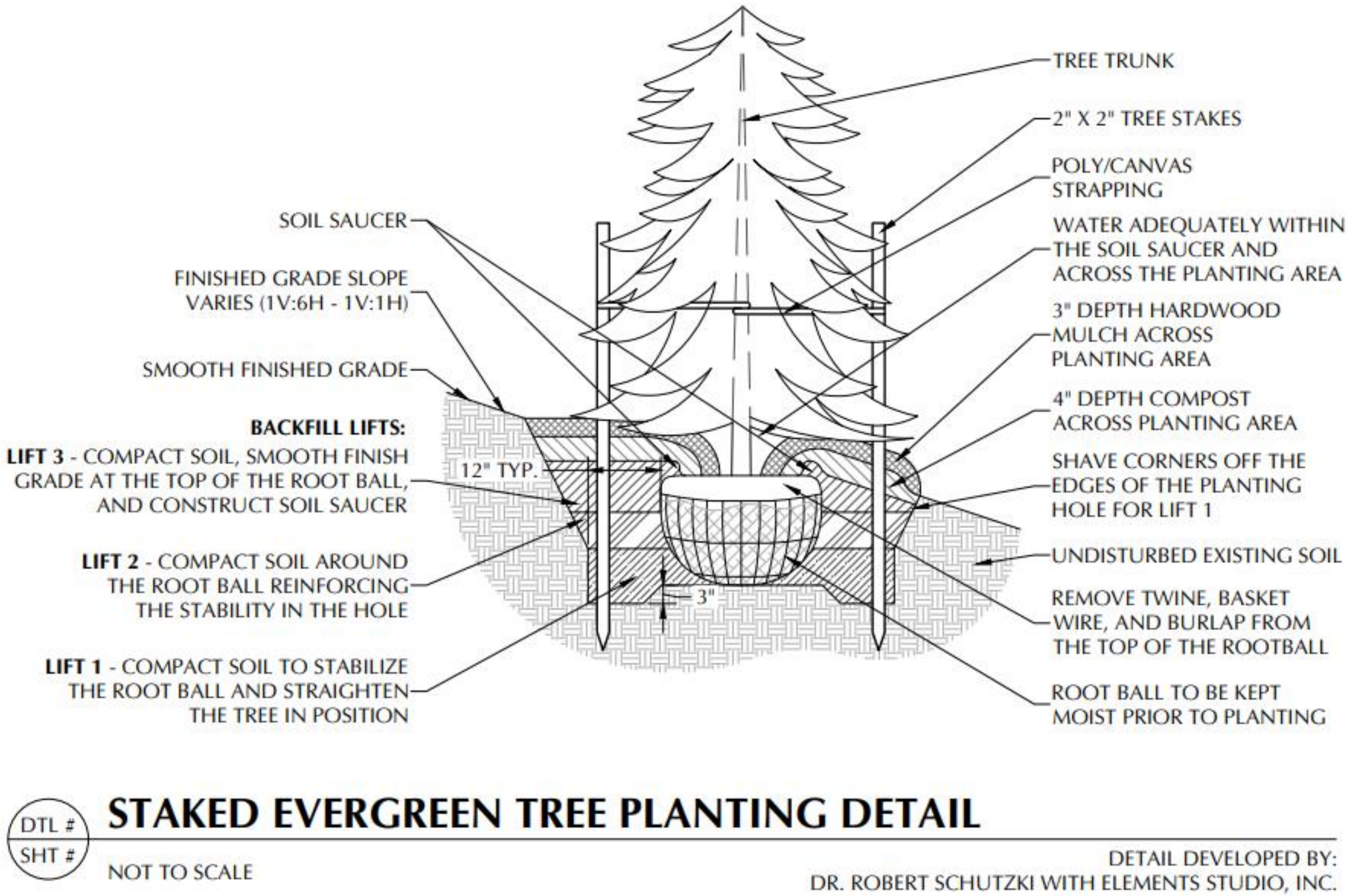

Figure 4.17: Planting detail of a staked evergreen tree on a sloped site developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

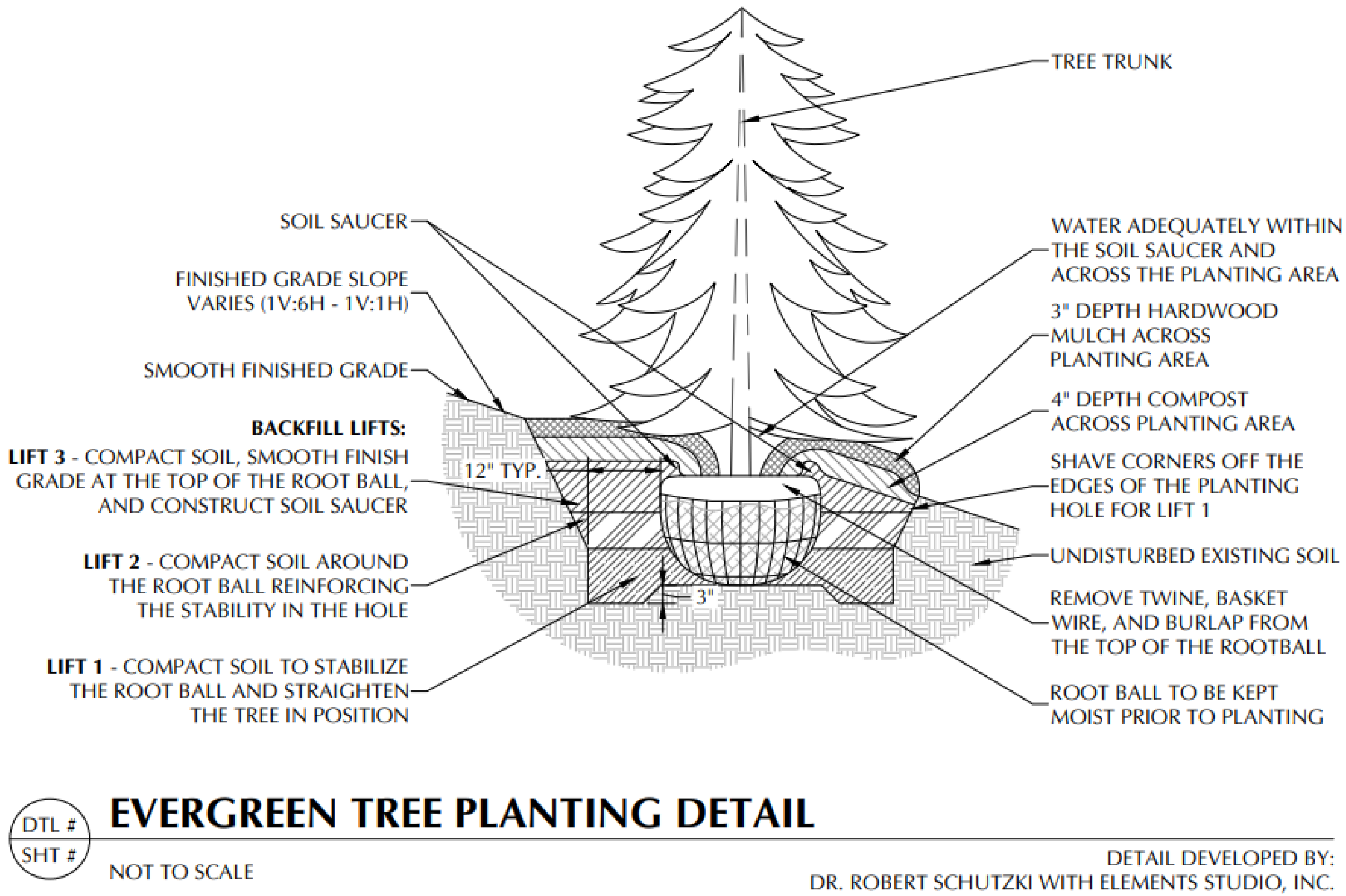

Figure 4.18: Planting detail of an evergreen tree on a sloped site developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

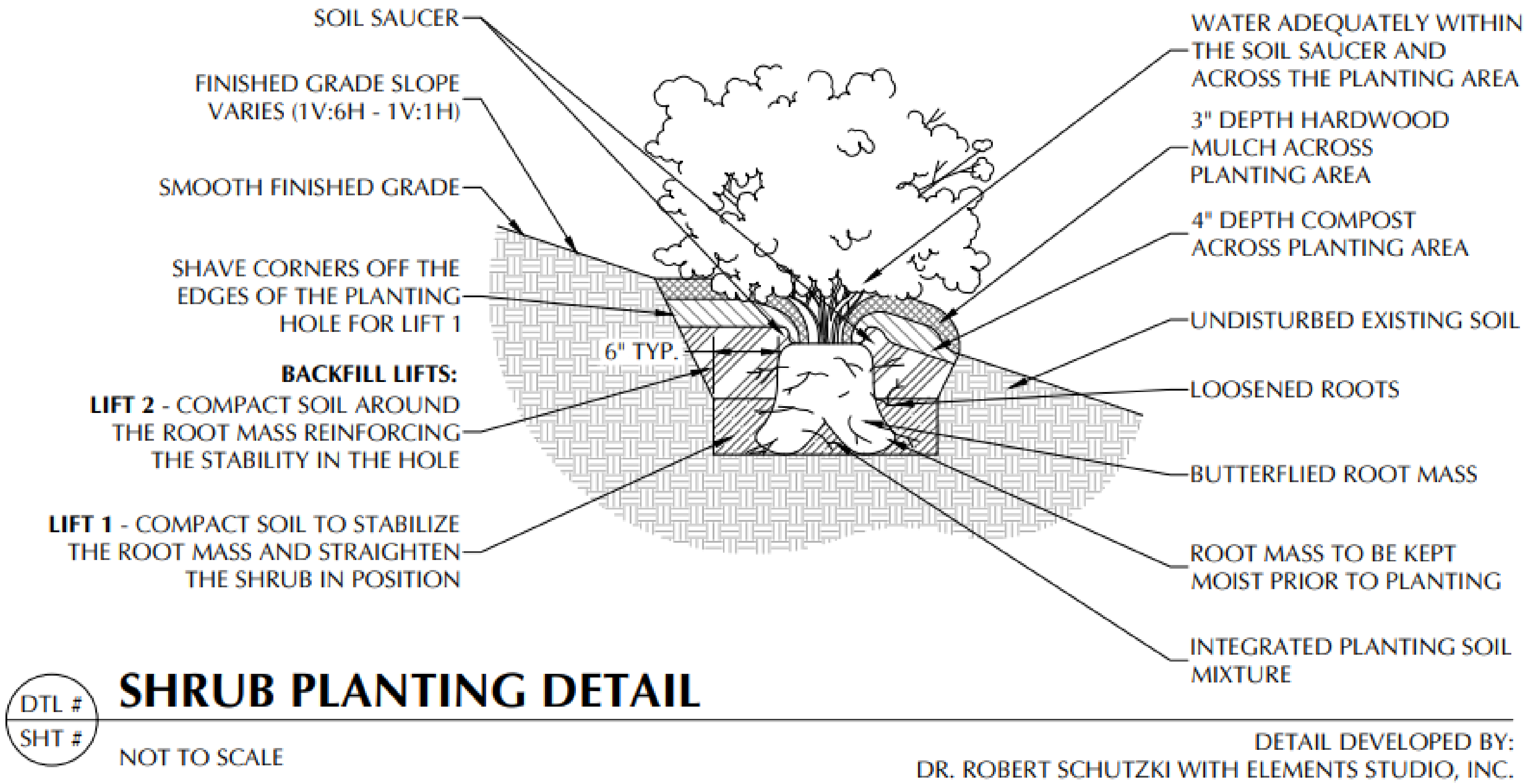

Figure 4.19: Planting detail of a shrub on a sloped site developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

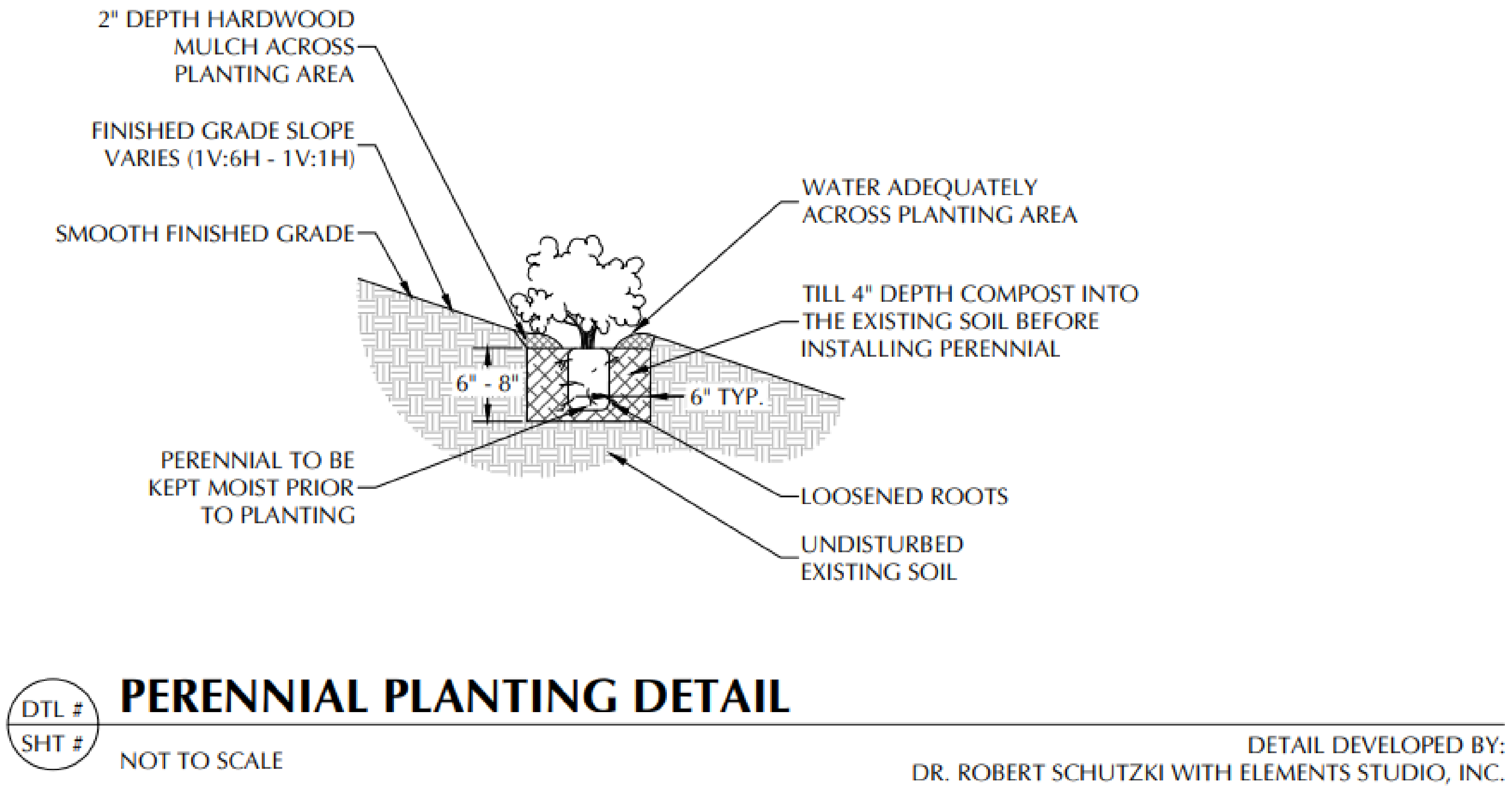

Figure 4.20: Planting detail of a perennial on a sloped site developed by Dr. Robert Schutzki. Rendering done by Jonathan Faasse and Kristen Faasse of Elements Studio, INC, East Lansing, MI.

WORKS CITED

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