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Watch It! I'm Growing Here: Inventory, Assessment, and Recommendations of the University of Pennsylvania's Street Tree Surface Treatments

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An independent study project report by The Martha S. and Rusty Miller Endowed Urban Forestry Intern (2018-2019)

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Abstract
Street trees are a multi-beneficial green infrastructure that are under substantial environmental stress, which many take for granted. On the University of Pennsylvania's campus, the maintenance for these trees grows as more trees are added and cared for, from canopy to surface material choice. Cataloging and assessing Penn's trees and recommendations for potential surface treatments are provided to determine the most effective and low-maintenance surface material while also not negatively impacting the tree.

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GLOSSARY

Terms:

Street tree--any tree within the pubic or vehicular right of way according to the City of Philadelphia's guidelines

Stormwater mitigation--active management of stormwater runoff from buildings, roads, sidewalks, and driveways via green infrastructure or plantings such as rain gardens, stormwater retention basins, or tree plantings

Surface treatment--the top most material of a pit or trench such as mulch, metal grates, or bricks

Impervious surface--a surface which does not allow for water or air movement through it

Pit--a space for a single tree in a streetscape

Trench--a space designed for more than one tree with continuous soil

Tree vacancies--sites where tree could be planted but no trees were present

Treatment types:

Metal fencing--a metal fence that goes around the parameter of the tree space

Metal grate--a metal fitting that is placed on top of the tree's soil that usually has circular metal rings that can be removed as the tree grows

Plastic grate--a plastic fitting that is placed on top of the tree's soil that usually has circular metal rings that can be removed as the tree grows

Organic mulch--wood, leaves, or bark material that is spread around or over a plant to provide insulation to the soil

Inorganic mulch--inorganic material, such as rock or ground up rubber tires that can be spread around or over a plant to provide insulation to the soil

Cobblestone treatment--rounded blocks, also known as Belgian block pavers, which are loosely placed together on a subbase of sand or gravel with finestone aggregate between the blocks

Brick treatment--bricks that are tightly placed together on a subbase of sand or gravel

Paver treatment--moderately or interlocking blocks placed together on a subbase of sand or gravel with finestone aggregate sometimes placed between the blocks Resin bound pavement

INTRODUCTION AND BACKGROUND

The University of Pennsylvania (Penn) has a 300 acre campus with 21,000 students, 17,000 faculty and staff, and 6,500 woody plants accessioned (University of Pennsylvania, 2019) of which, there are about 800 **street trees (**note: all bold text are words that are defined in the glossary).

Street trees provide a beautiful setting, improve mental health (Manchester City of Trees, 2016), help students retain information (Galliger, 2016), and provide important green infrastructure by providing shade, decreasing building energy use, and **stormwater mitigation** (EPA, 2017).

Philadelphia and Penn have a long history with street trees and streetscapes. "In 1683, William Penn and Thomas Holme envisioned trees and green spaces as important components of the city plan" (Igoe, 2013). This mentality of how important trees are carried over to how the University of Pennsylvania designs and manages its street trees. The first tree trench application was in 1979 on the north side of the intersection of 36th Street Walk and has continued since that time (Lundgren, 2019). This includes using new building construction as an opportunity to improve streetscapes by improving the design and tree species through campus landscape standards. The campus landscape standards, established in the late 1970's, aim to create areas of "proven durable, well-designed, ecologically sensitive and maintainable materials for a more cohesive approach to site development on campus" (Lundgren, 2019). Ecological performance blossomed at Penn with their Climate Action Plan starting in 2009, aiming to improve their sustainability in areas such as the physical environment, utilities, and operations (Penn Sustainability, 2014). New standards have been made, including the decision to use cobblestone and fine stones for street trees.

Surface treatments, such as brick and cobblestone, can help trees survive in an urban setting by reducing soil compaction, a major tree-limiting feature that can lead to tree health decline, poor water absorption, and tree failure (Coder, 2000). Furthermore, using well-designed surface treatments can also make tree areas pedestrian and vehicle friendly. For campuses, reducing risk of tree failure and increasing safety is a primary goal (Kenyon College, 2019; Western Michigan University, 2019), but stormwater mitigation is important as well (Princeton University, 2019; Thomas Jefferson University, 2017).

Stormwater has evolved from a minor concern to a large scale issue that cities are aiming to ameliorate. In a natural, undeveloped setting, rain falls onto the soil and either evaporates or percolates into the ground water; this is different in cities due to **impervious** surfaces, such as sidewalks, buildings, and streets that block water migration to the groundwater or soil and causing it to go into our combined sewer system (Philadelphia Water Department, 2018).

Philadelphia County is 54% impervious (Philadelphia Water Department, 2018), meaning that of the 142.71 square miles there are 77.06 square miles of impervious infrastructure like streets, sidewalks, roofs, and parking lots. Therefore, when it rains, large amounts of water flow into the combined sewer system, which can overflow and lead to contamination of local watersheds. It only takes 0.1 inches of rain to overflow the combined sewer system in Philadelphia (Chelser, 2015), leading to untreated raw sewage going directly into the water systems. Due to local watershed contamination from stormwater runoff, Philadelphia established a stormwater billing method where "property owners pay for the cost of treating stormwater runoff on their monthly water bill" (Philadelphia Water Department, 2019). To acquire tax credits toward this billing, landowners can install green infrastructure on their property to reduce their runoff (Philadelphia Water Department, 2019). Currently, Penn's water bill prior to discount is $5.4 million, with the discount rate being $4 million (Schuh, 2019). Installing the most effective stormwater mitigation design for street trees may increase this discount, making new standard treatments a high economic priority.

This project aims to determine the best surface treatment for Penn's campus with stormwater mitigation, aesthetics, tree health impacts, maintenance requirements, and lifespan of the product. Additionally, the Penn Student Eco-Rep's report "Infiltrating the Question of Stormwater Retention" (Frankil and Viney, 2019) goes with this report to provide a well-rounded recommendation for future streetscape standards for more effective tree health care, maintenance, and stormwater mitigation.

METHODOLOGY

The study site included street trees from 33rd to 40th Streets and Chestnut to Spruce Streets. Data collected from each street tree planting area were: if it was a **pit** or **trench**, treatment types, number of trees, planted area length and width, sidewalk width, if sidewalk drains towards the pit or trench, tree health, and accession number(s) for tree tree(s) present. Data was collected in October, 2018 after a wet summer, with September, 2018 reaching the annual precipitation total of 41.58 inches just at the start of fall (Wood, 2018).

After cataloguing what is present on site, the "Surface materials around trees in hard landscapes" by the London Tree Officers Associate was used as a guide for researching potential surface treatment types (2017). The surface treatment types selected to research for Penn's campus were: metal fencing/guard, metal and plastic grills, organic and inorganic (rubber and gravel) mulch, cobblestone, bricks, pavers, and **resin bound** pavement. To gather information about the installation process, three vendors of each surface treatment type were contacted with survey questions about their product's material cost and recommended maintenance.

RESULTS AND DISCUSSION

In the study site, there are 342 street tree planted areas for pits and trenches. Out of the 342 street tree areas, there were 237 pit spaces and 105 trenches with 436 total potential tree spaces (Figure 1).

Fourteen different surface treatments were documented on Penn's campus in the study site. In the tree pits, the gravel surface treatment was the most numerous, and in trenches, cobblestone surface treatments were the most numerous (Figure 2). Listed in the "trench-other" category is also "trench-planted" at 0.6%, "trench-gravel" at 1.8%, and "trench-paver" at 2.3%. In the other category for pits, there is 0.3% pits with pavers, 1.5% planted pits, and 2.9% pits with metal grates.

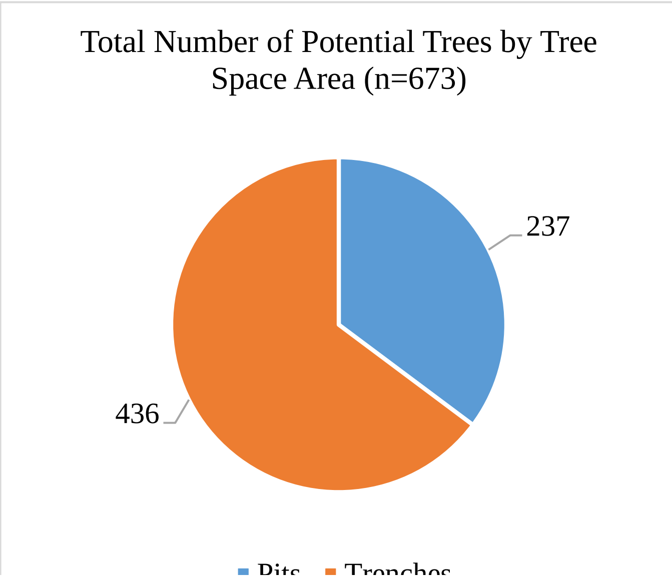

Figure 2 Total number of potential trees by tree space area. Potential tree spaces includes present trees and vacancies, highlighting the tree holding capacity of tree spaces.

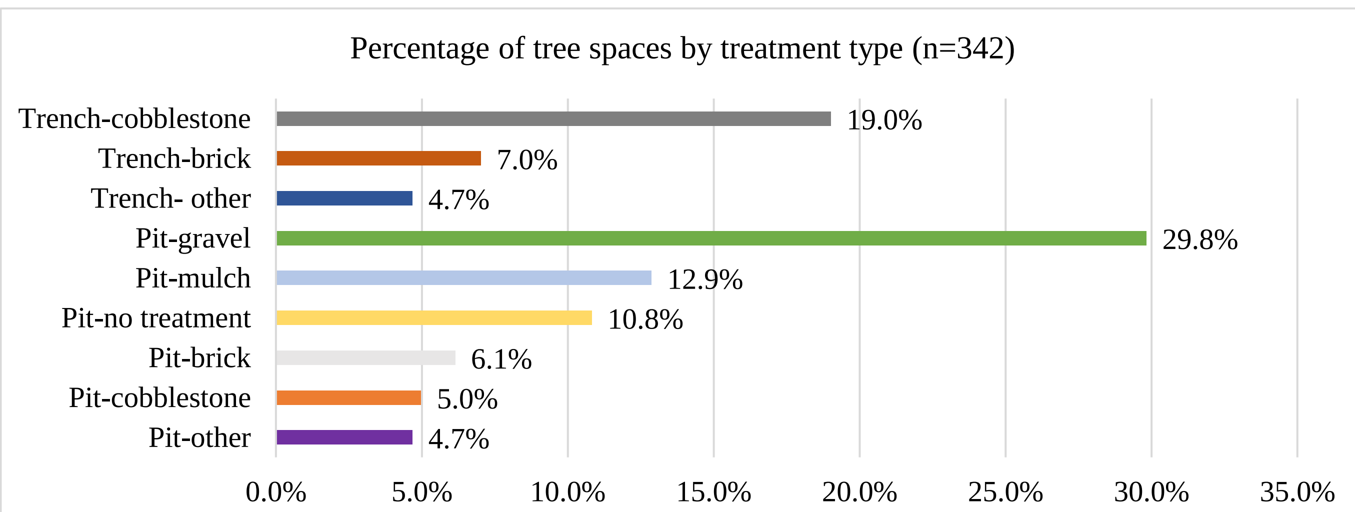

Figure 1 Percentage of tree spaces by treatment types. Also includes tree vacancies.

Of the trench surface treatment types, cobblestone is the highest due to the University of Pennsylvania's Facilities and Real Estate's (FRES) adoption of a cobblestone standard surface treatment. Pits with gravel treatment were almost evenly distributed while trenches with cobblestone were mostly focused on Walnut Street, near the Inn at Penn, and 33rd Street (Figure 3).

During data collection, **tree vacancies** were observed in both pits and trenches. Of the vacancies there were 50 observed pit vacancies out of 270 spaces. For trenches there were 26 trees removed out of 436 total trees (Figures 4 and 5).

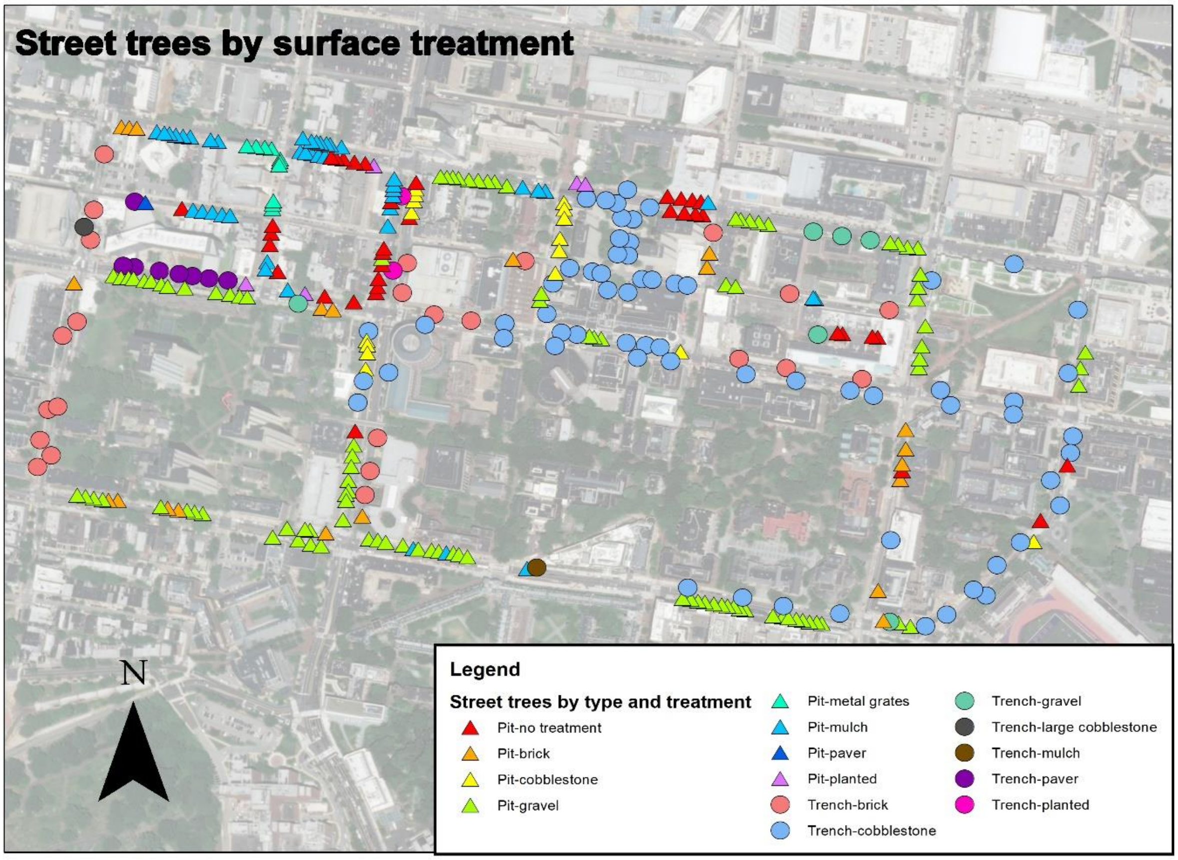

Figure 3 Street tree areas by surface treatment on Penn's campus

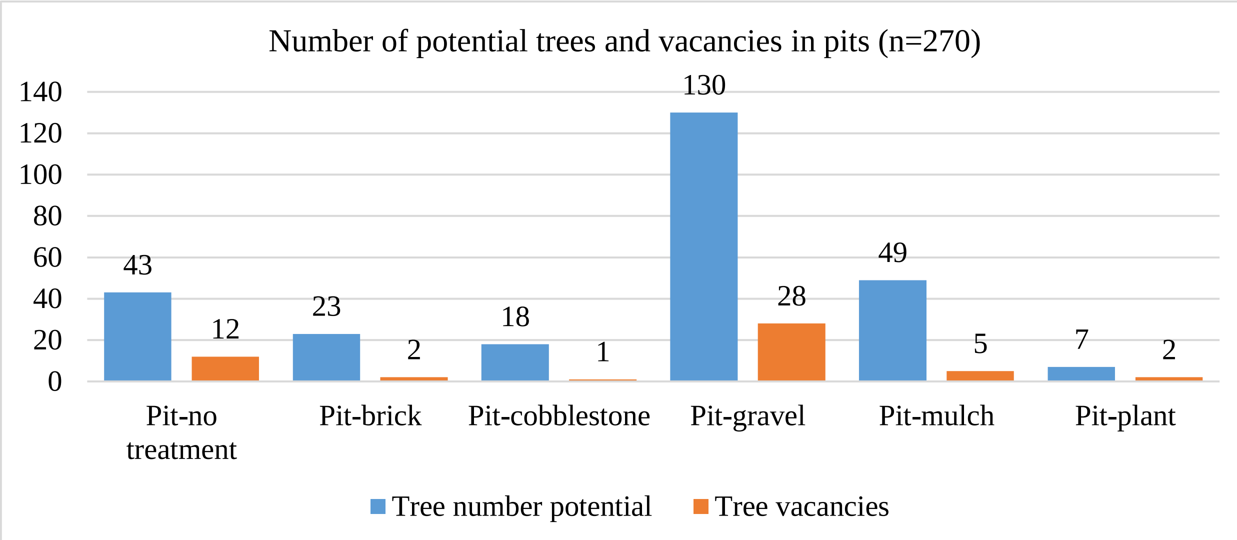

Figure 5 Number of potential trees and vacancies in pits (n=270)

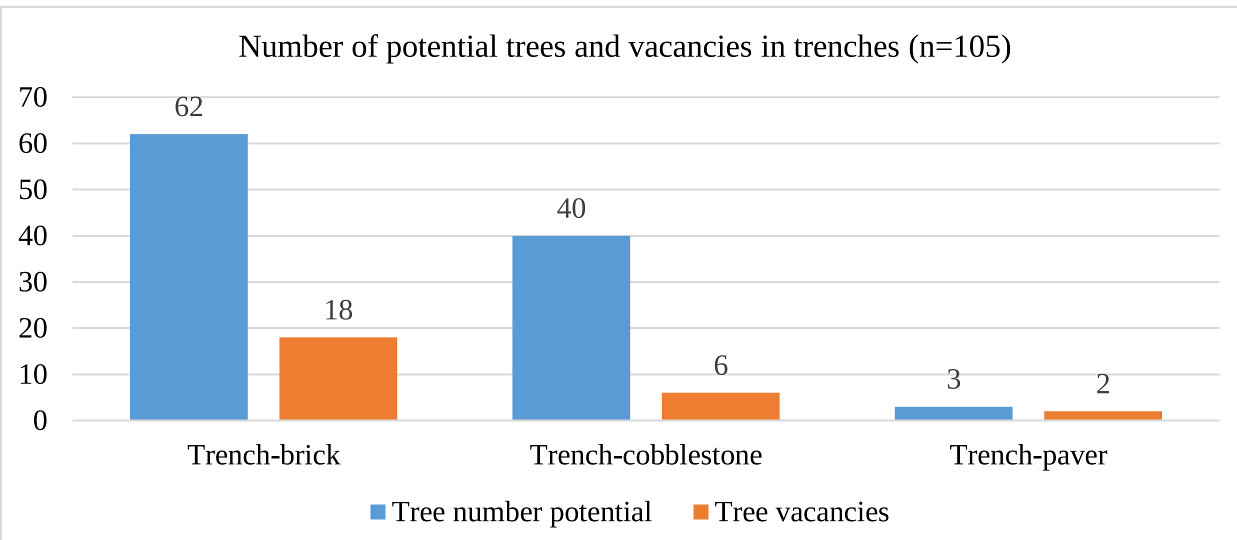

Figure 4 Number of Potential trees and vacancies in trenches (n=105)

For tree vacancies in pit areas, there was a higher number of trees missing in planted pits (28.6%), but there was a smaller sample size of that surface treatment. The second highest vacancy rate was in pits with no treatment, at 27.9%. In trenches, there was only one trench with pavers, making it an outlier. Between trenches with brick treatment and cobblestone treatment, brick-treated trenches had a higher vacancy rate (29.0%) than cobblestone treated trenches (15.0%). This is most likely due to the cobblestone trenches being the newer standard and are planted with newer trees. These trees are usually under a two-year warranty, allowing for a higher likelihood that dead trees would be replaced more readily than trees in the brick surface treatment.

In addition, streetscape design was also considered while looking at stormwater draining potential into the pit or trenches. Sixty-one percent of the pits and trenches do not drain toward the tree space. Draining the surfaces towards the tree pit, along with the ideal street tree surface treatment could potentially help Penn reduce their stormwater runoff and increase their stormwater water tax credit.

The ideal street tree surface treatment is low maintenance, long-term, locally sourced, allows for high air and water exchange, is pedestrian and vehicle friendly, robust, and easy to replace. This ideal surface treatment along with vendor and stakeholder responses were used to create a guide based on aesthetics, installation impacts, maintenance, cost, lifespan, and stormwater mitigation (See Appendix).

Highlighting some of the anecdotal maintenance and installation concerns, Craig Roncace, Penn's Urban Parks Manager, mentioned that skateboarders will frequently lift up metal grates, creating negative tree health impacts, maintenance issues, and pedestrian risk. As for resin bound materials, Frances Piller, the Operations District Manager for Philadelphia Parks and Recreation, noted that other resin bound material installations in Philadelphia have led to street tree failure. The applications led to "sinking, water ponding on top of it, lifting at the edges, and most importantly many of the trees died" (Piller, 2018).

RECOMMENDATIONS AND CONCLUSION

Considering the different surface treatments researched, it is recommended that a short term tree health impact and maintenance study be performed for metal fencing, resin bound material, and paver surface treatments. This study should last from three to five years in moderately trafficked areas with maintenance being recorded for comparison to current practice standards. The study can be done on newly planted trees in gravel pits areas with no current trees or on replacement trees for current poor performing trees. It would be beneficial to also do the performance study on established, healthy trees to provide a comparison on installation, maintenance requirements, and tree health impacts on newly planted trees versus established, mature trees.

While metal fencing is expensive per tree (estimated $1000 for materials and shipping/handling), the tree's soil is less likely to be compacted allowing for better tree establishment and growth and stormwater mitigation. While there are some concerns with installation and maintenance (i.e. poured concrete impacting tree health and trash inside fenced area), "installing a perimeter tree pit guard prevents vandalism and vehicular damage, prevents animal waste deposition, and is visually representative of a tree that is being cared for by someone" (Lu et al., 2010). It would not only prevent soil compaction but show the public that Penn is actively maintaining its street trees.

As for resin bound material, it can be beneficial to trees if installed and maintained correctly. Porous pavement has been shown to improve tree establishment rates and growth (de la Mota Daniel et al., 2018), allowing for trees to recover more quickly from transplant shock. A negative attribute is that resin bound material promotes shallower root systems (de la Mota Daniel et al., 2018). Shallower root systems may displace nearby sidewalks and pose potential pedestrian tripping hazards. Negative attributes can be avoided with proper pit maintenance, which can drastically improve the lifespan of the trees and product. Previous studies have proven that the lifespan of unmaintained porous pavement is one to five years (Burlotos, 2015), which doubles when properly maintained and can last more than 10 to 15 more years according to surveyed vendors.

Finally, pavers are a logical choice for low maintenance and high stormwater mitigation on campus. While there are few paver sites on campus, using a product such as PaveDrain® with smaller gaps and no aggregate between the stones can lower maintenance needs by not requiring frequent sweeping and reducing pedestrian trip hazard. Furthermore, it has a high percolating rate of 27.33 inches per minute when properly maintained (PaveDrain, 2019). This may be preferred over cobblestone, which has larger space between stones and requires more consistent maintenance to keep fine stones from littering the sidewalks.

Overall, Penn has a diverse number of surface treatments that require a different management style for each type. In order to create a contiguous spatial experience for pedestrians and ease of maintenance, streamlining the surface treatment will help reduce the complexity of requiring different management styles and different time schedules for maintenance. By implementing a performance study on Penn's campus with the recommended treatments including metal fencing, resin bound material, and pavers, FRES can determine if their current standard is more effective or if there is a more effective option on the market best suited for the University. For the campus's 800 street trees to thrive, they must receive the best care possible while also not becoming too much of a maintenance burden. Until everyone learns to not step or drive on tree roots, having efficient maintenance to keep these multi-beneficial organisms alive is the best way to reduce risk for all students, staff, and pedestrians, and to increase stormwater infiltration in Penn's highly urban area.

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APPENDIX

Guide of surface treatments

Why surface treatments matter for street trees

Street trees are constantly under stress, from trucks driving over their roots to dogs using them as bathrooms. Surface treatments (the material on top of their roots) can help mitigate that stress and reduce stormwater runoff. The ideal surface treatment is: low maintenance, long term, locally sourced, allows for high air and water exchange, pedestrian and vehicle friendly, robust, and easy to replace.

This guide aims to help provide an informed decision of what treatment more environmentally and maintenance friendly based on a price range per tree.

$ <499

Rubber mulch	
Installation time	G
Installation impact	F
Maintenance time	G
Lifespan	P
Tree health benefit s	F
Aesthetics	F
Stormwater mitigation	F

Gravel mulch	
Installation time	G
Installation impact	F
Maintenance time	G
Lifespan	P
Tree health benefits	F
Aesthetics	F
Stormwater mitigation	F

Wood mulch	
Installation time	G
Installation impact	F
Maintenance time	G
Lifespan	P
Tree health benefits	G
Aesthetics	F
Stormwater mitigation	F

Plastic grates	
Installation time	F
Installation impact	F
Maintenance time	F
Lifespan	G
Tree health benefits	P
Aesthetics	G
Stormwater mitigation	F

$ $ 500-999

Pavers	
Installation time	F
Installation impact	F
Maintenance time	G
Lifespan	G
Tree health benefits	F
Aesthetics	G
Stormwater mitigation	G

Brick	
Installation time	F
Installation impact	F
Maintenance time	F
Lifespan	G
Tree health benefits	F
Aesthetics	F
Stormwater mitigation	G

Metal grates	
Installation time	P
Installation impact	P
Maintenance time	F
Lifespan	G
Tree health benefits	P
Aesthetics	G
Stormwater mitigation	F

$ $ $ >1000

Cobblestone	
Installation time	F
Installation impact	F
Maintenance time	G
Lifespan	G
Tree health benefits	F
Aesthetics	F
Stormwater mitigation	G

Metal fencing	
Installation time	P
Installation impact	P
Maintenance time	F
Lifespan	G
Tree health benefits	F
Aesthetics	G
Stormwater mitigation	G

Resin bound material	
Installation time	F
Installation impact	P
Maintenance time	F
Lifespan	G
Tree health benefits	F
Aesthetics	G
Stormwater mitigation	G

The rating system for this :

- Good (G)
- Fair (F)
- Poor (P)

and is based off of literature reviews, vendor responses, stakeholder responses, and Eco-Rep report. Further information can be found in "Watch it! I'm growing here: Inventory, assessment, and recommendations of Penn's street tree surface treat-ment report" by A. Wood