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Tree removal analysis of the 2018-2019 Gambles Mill Eco-corridor restoration

Abstract

Trees have been extensively researched, and it has been concluded that they are useful not only useful tools in enhancing biofiltration, as well as managing stormwater and retaining sediment, but they also benefit the health of the ecosystem as a whole. But as the University of Richmond's Gambles Mill Eco-corridor was restored between 2018 and 2019 in order limit to the amount of phosphorus, nitrogen, and other sediment flowing into the Little Westham Creek; many of the trees that combat these problems were removed. The following research intends to analyze the number of trees actually removed throughout the restoration, as well as explore the future of Gambles Mill Eco-corridor in regard it's plant life, and opportunities surrounding it. In order to complete this analysis, drone imagery from before and after the restoration as well as blue prints of the restoration were utilized. These images were used combination with ARCGIS software to complete a visual analysis of the number of trees removed. Through this analysis, it was concluded that 14-16% of the total trees in the Gambles Mill Eco-corridor polygon were removed throughout this restoration and that within roughly 35-40 years, those trees will be replenished with mature native trees. This analysis is especially important, not only given the importance of trees in an ecosystem, but also highlights the disturbance that the restoration entailed, shedding light on the emphasis for the university to maintain the restored eco-corridor and ensure its wellbeing in the future.

Introduction

As of March 2018, the Gambles Mill Eco-corridor on the University of Richmond campus has been under restoration by the company Resource Environmental Solutions (RES). This restoration included significant earthwork, realignment and redevelopment of the Gambles Mill multi-purpose trail, as well as gathering spaces, native landscaping along the trail, and buffer plantings along the neighboring golf course. The goal of this endeavor is to locally limit the amount of phosphorus, nitrogen, and other sediment flowing into the James River and ultimately to restore clean water in the Chesapeake Bay and the region's streams, creeks and rivers. This is sensible, given the fact that prior studies have consistently shown that stormwater runoff, in regard to suspended solids and nutrient concentrations, can be crippling to the ecosystem in which said stormwater runs off into, as well as connecting water bodies (Steinman, Isley, and Thomas, 2015, Lazar, Spahr, Grudzinski, and Fisher, 2019). Also, paired with the increasing effects of climate change, the effects of stormwater runoff are going to become increasingly worse (Steinman et al., 2015). Given stormwater runoff's affect and increasing impact, it seems imperative to study certain aspects of the newly renovated Gambles Mills Eco-corridor in regard to stormwater runoff. Additionally, due to the prevalence of impervious surfaces within urban areas, urban areas are especially susceptible to the negative effects of stormwater runoff (Nagase and Dunnett, 2012). Given the University of Richmond's prevalence of impervious surfaces, as well as the amount of activity occurring within close proximity to the Gambles Mill Eco-corridor, the campus itself can be considered an urban environment making it especially to stormwater runoff.

One noted effective stormwater retention practice is the planting of grasses and other vegetation types (Nagase and Dunnett, 2012, Sanders, 1986). Past studies have tested the stormwater retention of smaller species of plants but came to the consensus; that size and structure of plants significantly influenced the amount of water runoff (Nagase and Dunnett, 2012). It has also been researched that plant species with taller height, larger diameter, and larger shoot and root biomass are in fact more effective in reducing water runoff (Nagase and Dunnett, 2012). In certain cases, it was found that trees in bioswales, or the linear channels designed to concentrate stormwater, accounted for 46 to 72% of total water outputs via transpiration, thereby reducing runoff and discharge from a parking lot in the study site (Scharenbroch et al., 2016). Given this fact, in general, trees and particularly mature trees are very important tools in storm water retention, given their high biomass when compared to shrubs or other understory species. Furthermore, it has been discovered trees in particular are quite effective tools in natural stormwater retention for urban areas (Berland et al., 2017), and as stated before, the University of Richmond campus is an urban environment. Stormwater retention is important in combating the negative effects of flooding events.

Additionally, trees in particular have been noted to increase the runoff retention performance of biofiltration systems (Szota et al., 2018). Biofiltration is a pollution control technique which utilizes living plants to capture and biologically degrade pollutants that would otherwise enter water systems and pollute them. It has been noted that the presence of trees in the biofiltration system have resulted in significant reductions of the soluble nitrogen and phosphorus concentrations of the stormwater (Denman et al., 2016), which is the overarching goal of the restoration. Researchers of biofiltration have found that strong contributors to Nitrogen and Phosphorus removal are the length of the longest root, rooting depth, the total root length, and the root mass of the particular plant (Read et al., 2009). Once again, given trees general biomass being the highest of species within a landscape, trees are the most important factors in biofiltration. Importantly, given the Gambles Mill Eco-corridor's close proximity to The Country Club of Virginia golf course, a major consumer of artificial fertilizers high in phosphorus and nitrogen, incorporating biofiltration systems between the golf course and the Little Westham Creek is imperative to hinder these fertilizers from entering the water system, via stormwater runoff.

As for the suspended sediment or soil present in the water system due to erosion that this restoration is intended to alleviate, trees have been noted being a useful tool in conserving soil in this regard. Historically, a common practice amongst farmers to plant trees in the form of agroforestry to conserve soils, especially in areas with major storm seasons (Young, 1994). Furthermore, in a study conducted in five American cities that implemented trees as a management practice to manage stormwater, mitigating urban-heat-island effect for cleaner air, reducing carbon dioxide to offset emissions, and as an alternative to expensive new power plants, found in these cities that on average, for every dollar invested to management, benefits returned annually ranged from $1.37 to $3.09 (Mcpherson et al., 2006). Conclusively, trees are an identified useful tool in combating the negative effects that come with stormwater runoff, such nutrient filtratration and soil erosion, both of which are the goals of restoring the Gambles Mill Eco-corridor.

Conversely, in order to complete the restoration of the Gambles Mill Eco-corridor on the University of Richmond campus, it seems that much of the plant life present in the corridor was removed. Atheistically, in the weeks leading up to the completion of the restoration the Eco-corridor looks much more barren than it did pre-restoration. But, as the prior research has signified, this type of landscape facilitates stormwater runoff, with little biofiltration, stormwater retention, or sediment retention. Moving forward, I decided to analyze the actual percentage of trees removed throughout the restoration, due to their key role in terms of stormwater management and biofiltration. Additionally, I wanted to consider how long it would be until the Gambles Mill Eco-corridor would be replenished with a population of mature trees.

Given the aesthetics of the eco-corridor in the few months preceding the main aspects of restoration, I hypothesized that more trees then were intended to be removed from the Gambles Mill Eco-corridor polygon were actually removed during the restoration, due to the accessibility of machines, workers, transportation, etc. Overall, I estimated about 25-30% of the trees were removed from the polygon during the restoration. In regard to the future of the restoration, I hypothesized that it would be roughly 50 years until the corridor was stable again with mature trees present.

Methods

In order to carry out the analysis of the loss of plant life, particularly trees, in the Gambles Mill Eco-corridor polygon throughout the restoration, the most feasible procedure given the time frame of this research was a data analysis. Specifically, analyzing drone imagery from before the restoration, and cross-referencing it to drone imagery taken after the restoration had been completed. By doing so, the differences in the orientation of the landscape, and plant life present can be analyzed and noted. Obtaining this data involved contacting professors at the university such as Dr. Todd Lookingbill, Dr. Stephanie Spera, and Dr. Wendy Stout, all of which have class lessons revolving around the Gambles Mill Eco-corridor and its restoration. Once the data was obtained, there were actually three images to be analyzed. Firstly, with the help of Dr. Spera and Dr. Stout, the drone imagery from before and after the restoration were obtained. The first image was taken before the restoration on February 14th, 2019 and the post restoration image was taken on September 5th, 2019.

Additionally, with the help of Dr. Lookingbill, RES's blueprint titled "Invasive species and tree inventory plan", which was essentially a map of the plants present in the eco-corridor polygon, and RES's plan for them in the restoration. Within this blueprint were the locations of all the trees present in the polygon, with certain ones highlighted. The ones highlighted were either green, yellow, or red, correlating to legend that identified the condition of each respective tree (where green= good condition, yellow= average conditioning, and red= poor condition). This condition was based off of the root exposure of the respective tree, the amount of the tree that was covered in invasive species such as English Ivy, and the overall health of the tree in general. In the blueprint there were 291 trees identified present in the Gambles Mill Eco-corridor polygon pre-restoration. Of those 291, there were roughly 40 trees were scheduled to be removed, with a total of 46 highlighted in the blueprint (green-7, yellow-16, red-21).

Equipped with these three images, they needed to be put on the same map in order to be analyzed. In order to do so, utilizing the software ARCGIS, specifically ArcMap was necessary. Using ArcMap, the user is able to georeference, or associate an image with their actual locations in physical space. The first drone image taken before the restoration was already georeferenced, but neither the image taken after the restoration nor the blueprint were georeferenced. Once all three images were georeferenced on the same map, it was on to the analysis.

In order to complete this analysis, the user would have to zoom in on the map on the viewing window within ArcMap, so that only a handful of trees were visible in order to minimize the number of trees that were being taken account for. Then by clicking through the images, or layers in ArcMap, the user would be able to see the changes in trees present from pre-restoration drone images and blueprint, when compared to the post-restoration drone images. Then, the user would move the viewing window to a different cluster of trees and repeat that process until all of the trees were accounted for within the polygon. Additionally, in order to reassure the results, this process was completed and repeated multiple times over the span of a few days.

As indicated through the red polylines in the images below (*Images 1-3)*, this is the process that was carried out through this analysis. By clicking through the georeferenced images on ArcMap, you user is able to see the differences in the orientations of the landscape. As can be seen on the first image (*Image 1)*, the user can vaguely make out the trees present in the landscape before the restoration. Then by referencing it to the second image (*Image 2)*, the georeferenced blueprint, it becomes a bit clearer what trees are actually present in the image.

Finally, by switching to the georeferenced post restoration drone image (*Image 3)*, it is clear which trees were actually left and which were taken out. This process was completed and repeated until all 291 trees within the polygon were accounted for.

Image 1: Pre-restoration drone imagery, georeferenced, and zoomed in for ease of comprehension within ArcMap.

Image 2: RES's blueprint, georeferenced, and zoomed in for ease of comprehension within ArcMap.

Image 3: Post- restoration drone imagery, georeferenced, and zoomed in for ease of comprehension within ArcMap.

Once this part of the analysis was complete, it was important to analyze how long it would be until the Gambles Mill Eco-corridor polygon was replenished with mature trees. It is noted on RES's blueprint utilized for this analysis that "more than 2,000 trees" would be planted through the restoration. So, with the help of Dr. Lookingbill, RES's planting list for the eco-corridor was obtained. As indicated through the planting list, roughly 1926 individual barefoot trees, ranging from 6 species were scheduled to be planted within the polygon. Additionally, the trees were supplemented by 640 individual understory or shrub plants, ranging from 5 species. Equipped with this list, I began researching scholarly articles in regard to the maturity of tree species, specifically; the American Beech, the Red Maple, Tulip Poplar, Willow Oak, the White Oak, and the Northern Red Oak, was made possible. Once the maturity year was obtained for each tree, they were averaged to give a rough estimate for the entire eco-corridor.

Results

After this analysis was completed multiple times, it was concluded that of the 46 trees highlighted in the blueprint for their condition, 10 were left, meaning 36 trees of all the major trees present in the Gambles Mill Eco-corridor were removed during the restoration. Additionally, it was concluded through the analysis that there were roughly 6-12 trees observed that were not highlighted on the blueprint (grey circles) but were removed from the Eco-corridor. Conclusively, through this analysis it was found that that 42-48 trees, or roughly 14 (14.43) - 16 (16.49) % of the total trees in the Gambles Mill Eco-corridor polygon were removed during the restoration (*Figure 1)*.

Then, in regard to the future of the Gambles Mill eco-corridor, scholarly articles identified that it would be roughly 35-40 years until the trees planted generally would be reaching maturity (Hoyt, 2017, Burns and Honkala, 1990, Neal and Whitlow, 1994, Bush, 2018, Bingaman, 2019) (*Figure 2*).

Discussion

Conclusively, through this analysis, it was found that during 2018-2019 restoration of the Gambles Mill eco-corridor, roughly 14-16% of the total trees that were present within the polygon were removed. This finding in regard to my hypothesis proves it wrong, and it seems the RES accurately estimated that roughly 40 trees would be removed through the restoration. Additionally, it was found that in roughly 35-40 years, the eco-corridor will have mature trees present, proving my hypothesis wrong again.

This analysis and its results were at the expense of a few limitations. Given the season and the day that the pre-restoration image was taken, it was very hard to comprehend the actual contents of the image. The image was taken in the late winter (February), with all of the plant life mostly dead and brown and the trees bare, and in amalgam with the image being not the highest resolution, and the eco-corridor being very overgrown before the restoration took place, the image was nearly useless for certain areas of the analysis (*Image 4*). But the blueprint was very useful for the most part in the completion of this analysis. The highlighted trees were much simpler to identify their presence. The trees in grey circles were much tougher to analyze given their groupings, and it seems they may have less accurately depicted on the blueprint (*Image 5*). As you can see in the pictures provided, in the blueprint within the red line polygon, there is a grouping of trees signified by the grey circles. But it is evident in the post restoration imagery that the grouping of trees is not there, but there is a grouping a bit to the left that is not accounted for in the blueprint. Then, in the pre-restoration image, it is apparent that it is very hard to comprehend in general. These discrepancies made it difficult to offer completely confident results and was a limitation. Regardless, the three images in this analysis were enough to give fairly confident results.

Image 4: As can be seen, the pre-restoration drone image was very difficult to comprehend.

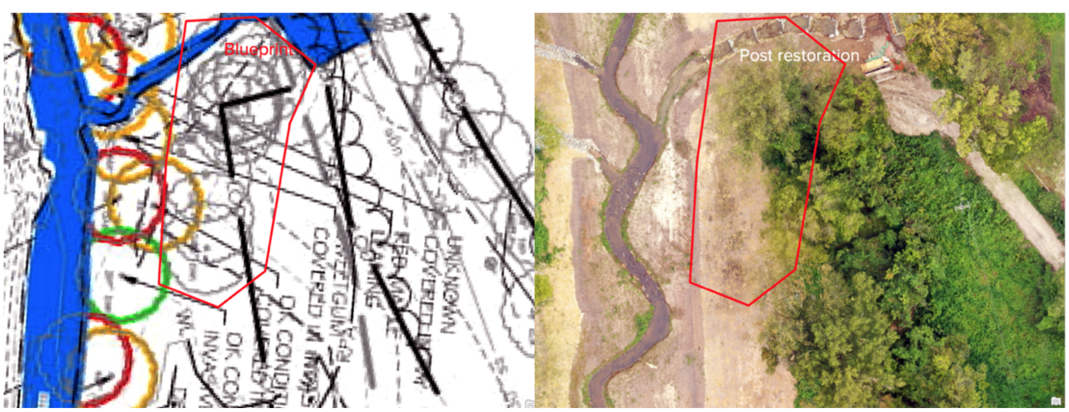

Image 5: As depicted, in the left image (the blueprint), there is a large grouping of trees signified by the grey circles within the red polyline. But in the right image (post-restoration drone imagery), within the same red polyline there is little to no trees. But there is a large grouping present to the right of the polyline in the right image, that is not present in the left image.

As for the second part of this analysis, in regard to the duration to maturity of the newly planted trees, I relied heavily on prior scholarly research. The reason for this part of the analysis was the fact that forests, characterized by a long ecological continuity may be better adapted to global change than recent forest ecosystems (Oheimb et al., 2014). Given the fact that the Gambles Mill Eco-corridor was heavily disturbed at the ecosystemic level throughout the restoration, and globally the Earth is in a climate change crisis, it seemed imperative to research how long it would be until the newly planted trees would grow to a more mature state, inherently building the ecological continuity of the ecosystem as a whole. Firstly, 257 bareroot American Beech trees were scheduled to be planted, and according to (Hoyt, 2017), this species of tree takes roughly 40 years to reach a mature state. Then, through the planting list it was identified that also 257 bareroot Red Maple trees would be planted through the restoration. Red Maple trees, according to (Burns and Honkala, 1990), tend to reach full maturity around roughly 70 to 80 years of age. As for Tulip Poplar trees, 385 bareroot individuals were scheduled to be planted, which have been observed reaching maturity between 15 and 30 years after they have been planted (Hoyt, 2017). In regard to Willow Oak trees, 257 bareroot individuals were scheduled to be planted through the restoration, and this species tends to mature at around 20 years of age (Neal and Whitlow, 1994). Then, 385 individual bareroot White Oak trees were scheduled to be planted, which have been observed to mature between 20 and 50 years after being planted (Bush, 2018). Finally, there were 385 bareroot Northern Red Oak trees scheduled to be planted, which reach maturity roughly around 30 years (Bingaman, 2019). As the restoration comes to an end, the plantings have already been underway, enlisting the help of undergraduate students (*Image 6).* Once it was identified when all six species would roughly reach maturity, the numbers were averaged to conclude that it would be roughly 35-40 years until the Gambles Mill Eco-corridor is replenished with nearly 2,000 mature trees.

Image 6: Planting of native trees in the Gambles Mill Eco-corridor as a part of the restoration.

Of course, this estimate had its limitations. Given the fact that these studies cited are not specific to Richmond, Virginia and its climate and other characteristics, there definitely could be variance in the actual amount of time it takes these trees to reach maturity. On the same note, there are many factors that feed into a trees growth rate on an individual level, so getting an accurate estimate on how long it will take for these tree species to reach maturity is often arbitrary. Regardless, this estimate is useful in roughly depicting the actual magnitude in regard to time of this restoration.

The future of the newly restored Gambles Mill Eco-corridor is full of opportunity and responsibility that mostly falls in the hands of the university. As stated in the contract that RES has with the University of Richmond, through the year 2020 after the restoration, the company will manage the invasive species that show up in the eco-corridor. Once this contract is up, it is up to the university to manage and ensure the wellbeing of the eco-corridor and its inhabitants. For this reason, a great emphasis is put on the university and its facilities to manage aspects of the eco-corridor, such as invasive species. Invasive species have been observed being especially detrimental to the longevity and mortality of juvenile trees (Richardson, 2008). Given the fact that the new plantings previously discussed were all juvenile trees, and the prevalence of invasive English Ivy on campus, it is imperative for the university to deploy an intensive invasive species management plan specific to the Gambles Mill Eco-corridor to ensure the new trees longevity and health, as well as the effectiveness of the restoration as a whole. If the new trees mortality is ensured, the biofiltration, stormwater/ soil retention, and the overall health of the ecosystem that the Gambles Mill Eco-corridor creates as a whole will inherently be ensured too (Szota et al., 2018, Denman et al., 2016, Read et al., 2009).

There are a multitude of ways to go about enlisting the help for this intensive maintenance. Initially and obviously, utilizing the university's Landscape Department, in collaboration with the Office of Sustainability to maintain the health of the eco-corridor is essential. To supplement their efforts, the sustainability office can set up volunteering events, such an invasive species rip-out or native species planting events monthly, which would be beneficial to the ecosystemic health of the eco-corridor, and also build an educated community that is dedicated to the areas well-being. Additionally, required courses for geography and environmental studies majors can incorporate an invasive species lab, supplemented by an invasive species rip-out or a native species planting. There is also an opportunity for a student club to be created, dedicated to maintaining the eco-systemic health of the eco-corridor. Even though this maintenance will be time consuming and intensive, it will be ecologically beneficial and will inherently open many educational, volunteer, and community building opportunities for the university.

Overall, even though this restoration will have beneficial effects the Gambles Mill Eco-corridor in the future, it was still a great disturbance to the plants and animals that inhabit it. As found through this research, 14-16% of the total trees present were removed during the restoration, as well as many other aspects of the polygon were disturbed. Regardless of the fact that these trees were supplemented by nearly 6 times the amount that were originally there, it will still be decades until those trees complete the same functions as the ones removed. Given this fact, it is important for the university to pay close attention to the eco-corridor in future, particularly the few decades preceding the restoration in order to ensure its ecosystemic health. Trees play a key role in many aspects of ecosystem, specifically biofiltration and combatting other negative effects of flooding events, so maintaining the trees health is key to the success of this restoration.

An overarching and final limitation encountered throughout this research was in relation to time constraints as well as the actual subject of my research. When I initially proposed my research, I wanted to analyze the Westhampton Lake under a type of hydrologic model known as the CORINE model. But as my research progressed, I had to abandon this idea due to its complexity, lack of data, and the timeframe of the research. Once I finally decided to switch to my current area of research, I was left with much less time to complete my research and come up with a finished product. Given this limitation, my research may not seem as extensive as my classmates but was extensively worked on and was done to the best of my ability.

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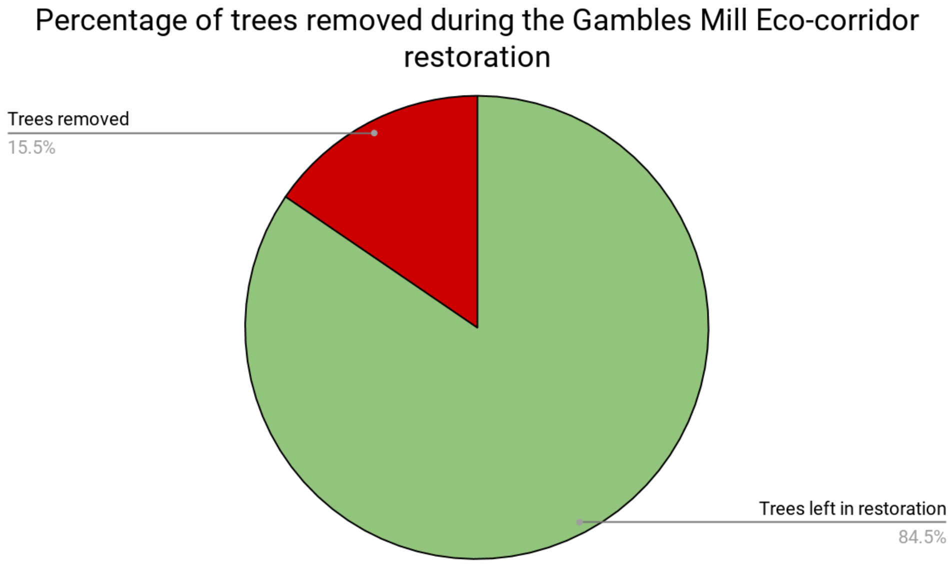

Figure 1: A breakdown of the percentage of trees removed during the 2018-2019 restoration of the Gambles Mill Eco-corridor.

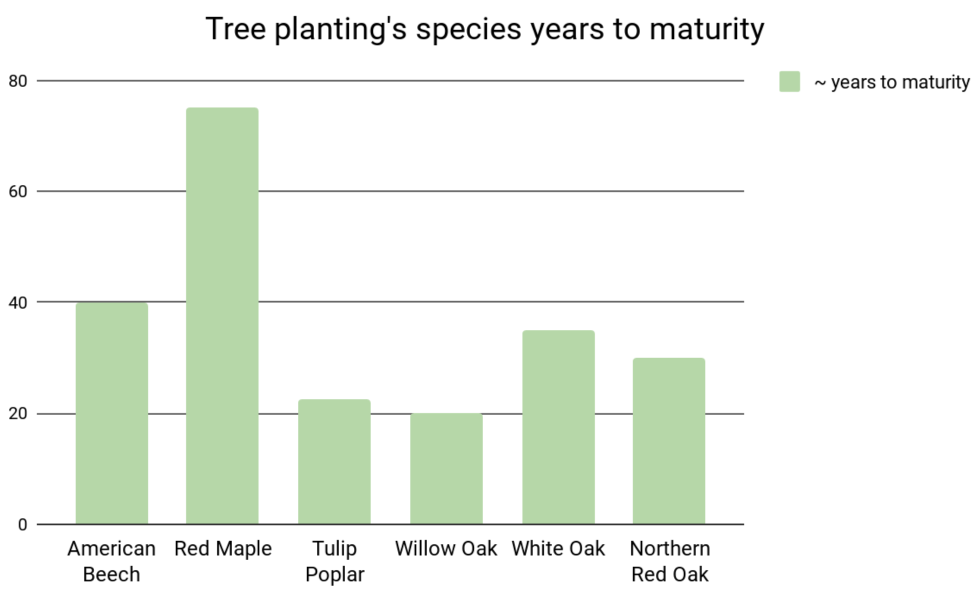

Figure 2: Depicting the rough estimate of the years to maturity for each respective tree species planted through the restoration.