Trees improve soil health and biodiversity on a golf course

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Abstract

Currently, golf courses often remove trees and use unnatural methods to maintain turfgrass, such as using pesticides. Previous research has primarily focused on the benefits of trees in areas other than the golf course and has shown that trees are important for maintaining soil health and biodiversity. In order to determine the impact of trees on soil nutrients, soil structure, and biodiversity on a golf course, soil cores were collected from 1m, 5m, and 10m from the base of five mature trees on a golf course in Princeton, New Jersey, U.S. The soil samples were tested for pH, nitrogen/potassium/phosphorus content, water stable aggregates, and soil color. The percentage of weeds at each distance was also recorded in a 1m x 1m plot. It was found that as the distance from the tree increased, water-stable aggregates and the percentage of weeds decreased. Soil brightness tended to increase as the distance from the tree increased. Soil nutrients (N/P/K) and soil pH did not change significantly across the different distances from the trees. In summary, this study found that, consistent with previous research, trees on the golf course did improve the overall health of the soil by increasing the amount of water stable aggregates and organic matter, accommodating a higher biodiversity belowground and aboveground. Based on the results, it is recommended that trees are planted and maintained on golf courses to keep the soil healthy longer so that less unnatural maintenance is required.

Keywords

Golf course, soil structure, trees, pesticides, organic matter, biodiversity.

Introduction

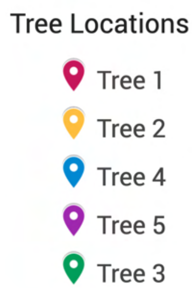
There are many management practices that are used to keep a golf course in the best shape possible. However, while pesticide use, green rolling, and irrigation keep the turfgrass looking healthy, some environmental consequences should be considered. An increased amount of pesticide use leads to heightened environmental problems. Birds, beneficial insects, and fish are a few species that are negatively impacted by the toxicity of pesticides. Furthermore, excess irrigation can create runoff into nearby ecosystems, further creating an environmental threat. It was found in 2018 that golf courses use around 50,000 pounds of pesticides annually, a number 4-7 times greater than the amount used for agriculture purposes (Garris, 2018).

Trees naturally help keep the soil healthy by providing more organic matter for the soil microbes to feed on. They also promote biodiversity in the soil, such as fungi, bacteria, and soil microbes, which are essential for cycling ecosystem nutrients to plants (NSW, 2023). However, many courses are removing their trees in order to reduce competition with the turfgrass, to take away shade on the course, and even to prevent injuries or appease the members (Sens, 2020). The consequences of removing trees could greatly affect the long term health of the soil by improving soil structure. They do this by increasing organic matter and water stable aggregates in the soil (Tisdall, 1982). If trees can serve as a natural aid for soil health, golf courses can reduce the amount of maintenance they need to do. Thus, this experiment was designed to determine the impact of trees on soil pH, nitrogen, phosphate, and potassium content, water aggregate stability, soil color, and percentage of weeds in the turfgrass of a golf course.

For this study, I predict that as the distance from the tree increases, there would be an increase in nitrogen, phosphorus, and potassium levels because pesticides contain N, P, and K and they are used more farther away from the trees by the fairways (interview with superintendent). As the distance from the tree increases, I also expect that there would be a decrease in the percent weed because the pesticides used on the golf course target certain weeds (USDA, 2019). Finally, as the distance from the tree increases, I expect that there would be a decrease in water stable aggregate ability and lighter soil color because there is more organic matter at the base of the tree, which can help generate darker soil and maintain a higher amount of water stable aggregate (Myers, 2020).

Methods

The data was collected from Springdale Golf Club in Princeton, NJ over the course of 3 ½ weeks in the summer of 2023. This golf course 5 large trees were selected in different sections of the golf course. The tree species are: tree 1 Pinus spp. (pine tree), tree 2 Rosaceae family, tree 3 Liriodendron tulipifera (tulip tree), tree 4 Pinus spp. (pine tree),, and tree 5 Acer platanoides (Norway maple). The DBH (diameter at breast height) of the trees range from 45 cm to 90 cm. The tree height ranges from 5 m to 20 m. The species of each tree was identified. Then, plastic ziploc bags were labeled with the tree number, distance from the tree, and replicate number: for example, Tree3_1m_rep1. At the site of data collection, a 1m x 1m square was placed 1m, 5m, and 10m from each tree. A picture was taken to determine the percent weed per 1m of turfgrass. Afterwards, a 12-inch (0.49-inch radius) soil probe was used to extract soil cores from each distance and each soil core was placed in a corresponding ziploc bag. The days of collection were 1-3 days after it had rained. The weather conditions and time the sample was taken were marked down. This procedure was performed twice for each tree, resulting in a total of 30 soil samples (5 trees x 3 distance x 2 replicates).



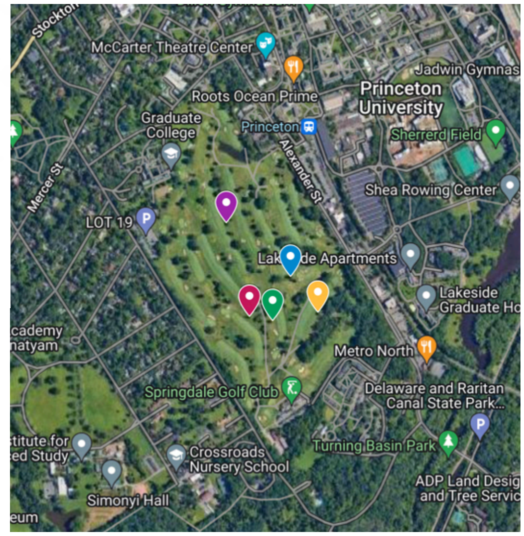


Fig. 1 Location of sampled trees

Fig. 2 Example of one of the trees and 1m x 1m plot (Tree 3)

The soil samples were taken home for testing within the same day. Luster Leaf 1601 Rapitest Test Kits were used to test soil pH, nitrogen, phosphorus, and potassium levels (Fig 3). All tests sat out for 10 minutes before they were photographed and analyzed following the instructions of the test kits. All tests were photographed on white paper to ensure there were no inconsistencies with color. Additionally, soil color was measured using a Land-Potential Knowledge System (LandPKS) and 3M yellow post-its to provide the most accurate color reads. Soil was placed on a post-it alongside an empty post-it. A photograph was then taken and the soil color was compared to the post-it color. The LandPKS algorithm determined the soil color using the munsell color system, including information on soil brightness, soil hue, and soil chroma. The last test performed was the water stable aggregates test (USDA, 2021). About 3 inches of the soil core was used for this test. The soil was put in a drainer and then submerged in a bowl of water for 1 minute. Then, the soil was put on parchment to prevent any water absorption. Each soil sample was determined to have a great, good, decent, or poor water stable aggregate ranking based on how much percentage of solids remained in the soil (Fig 4).

Fig. 3 Example of pH and K/P/N tests

All of the data was compiled into an excel sheet (Golf_course_data_final.xlsx). RStudio was used to analyze the data. Nutrient levels and water stable aggregates were transformed from descriptive text to ranking, following Table 1. The first test was the ANOVA permutational (AOVP) tests using the aovp function from R package lmPerm: Permutation Tests for Linear Models (Wheeler, 2016) to see how the distance from the tree and tree number affected the data. The second test was a post hoc pairwise analysis permutational test, whichused the pairwisePermutationMatrix function from R package rcompanion: Functions to Support Extension Education Program Evaluation (Mangiafico, 2023). This test was only run if the AVOP test was significant (see Table 1). This test determined where the significant differences between the treatments were–for example, between 1m and 5m but not between 5m and 10m. Box plots were used to visualize the significant tests.

Table 1 Ranking system for water stable aggregates and soil nutrient level.

Water stable aggregates	4 - great	3 - good	2 - decent	1 - poor	
Nutrient level (P, K, N)	5 - surplus	4 - sufficient	3 - adequate	2 - deficient	1 - depleted

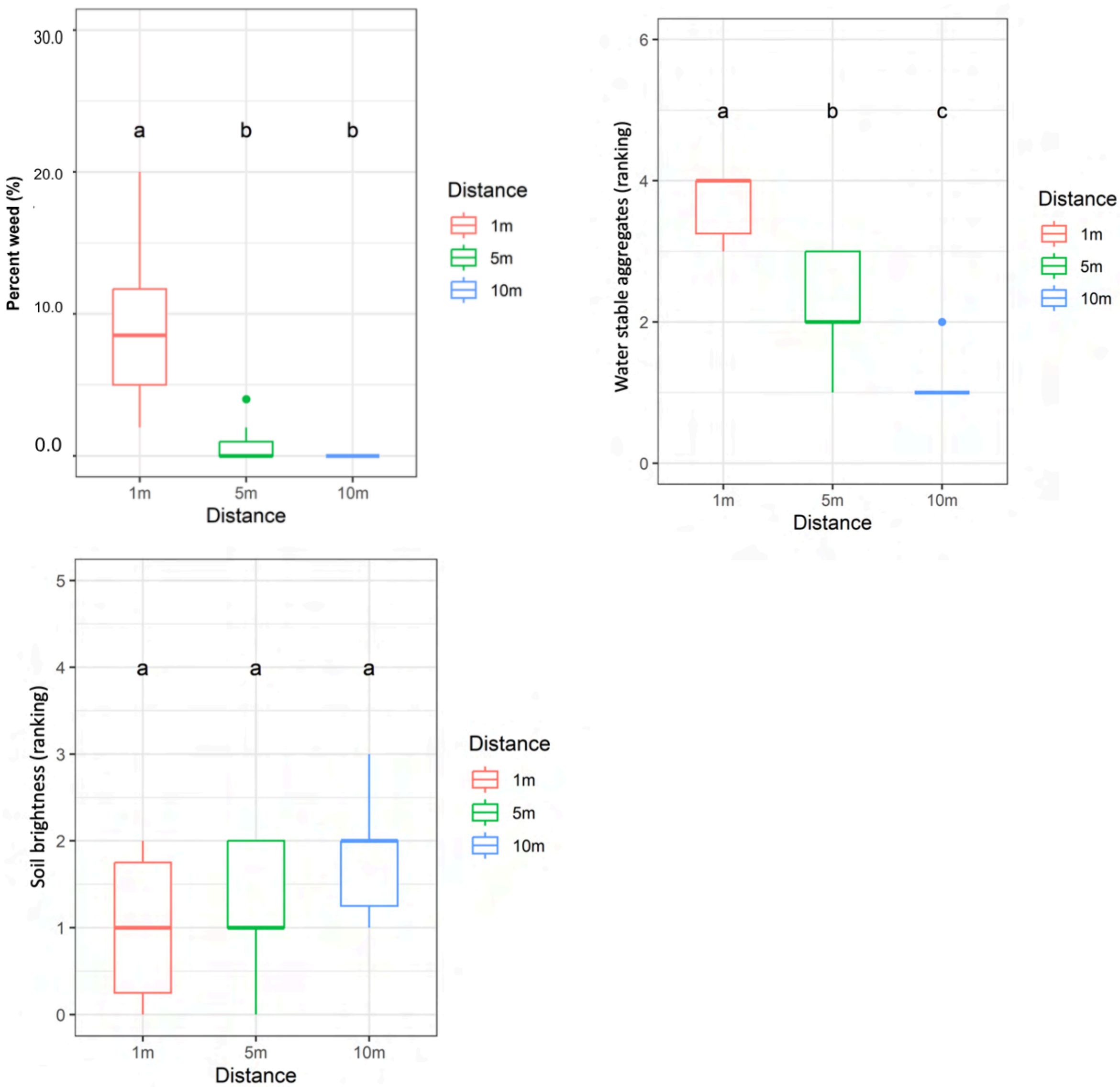


Fig. 4 Percent weed, water stable aggregates, and soil brightness variation between 3 different distances from the base of 5 different trees. Soil brightness is derived from the munsell color system. Soil brightness ranged from 0 (darkest) to 10 (brightest). The letters represent the significant differences between the treatments (distance from tree). Data marked with the same letter had no significant difference. Colored dots are data outliers. The lower and upper boundaries of each box specify the 25% and 75% quartiles within the group, and the whiskers specify the 95% confidence intervals. The bolded line is the median value. Water stable aggregates: 4 - great, 3 - good, 2 - decent, 1 - poor.

Table 2 AOV permutation tests of all data collected. Numbers less than 0.05 in the Pr(prob) columns mark that there are significant differences between the data collected. See Fig 1 for the data with a Pr(prob) number less than 0.05.

Postassium					
	Df	R Sum Sq	R Mean Sq	Iter	Pr(Prob)
Distance	2	0.2	0.1	61	0.93442623
Tree_number	1	10.41666667	10.41666667	5000	0.0032
Residuals	26	28.08333333	1.080128205	NA	NA
Nitrogen					
	Df	R Sum Sq	R Mean Sq	Iter	Pr(Prob)
Distance	2	0.466666667	0.233333333	170	0.547058824
Tree_number	1	0.016666667	0.016666667	51	0.921568627
Residuals	26	14.98333333	0.576282051	NA	NA
Phosphorus					
	Df	R Sum Sq	R Mean Sq	Iter	Pr(Prob)
Distance	2	0.466666667	0.233333333	152	0.710526316
Tree_number	1	1.77E-30	1.77E-30	51	1
Residuals	26	14.9	0.573076923	NA	NA
Water stable aggregates					
	Df	R Sum Sq	R Mean Sq	Iter	Pr(Prob)
Distance	2	31.66666667	15.83333333	5000	0
Tree_number	1	0.816666667	0.816666667	825	0.109090909
Residuals	26	8.483333333	0.326282051	NA	NA
pH					
	Df	R Sum Sq	R Mean Sq	Iter	Pr(Prob)
Distance	2	0.216666667	0.108333333	235	0.510638298
Tree_number	1	0.016666667	0.016666667	51	0.823529412
Residuals	26	4.133333333	0.158974359	NA	NA
Percent weed					
	Df	R Sum Sq	R Mean Sq	Iter	Pr(Prob)
Distance	2	0.049626667	0.024813333	5000	0
Tree_number	1	0.000735	0.000735	121	0.454545455
Residuals	26	0.029625	0.001139423	NA	NA
Soil brightness					
	Df	R Sum Sq	R Mean Sq	Iter	Pr(Prob)
Distance	2	3.266666667	1.633333333	4806	0.036412817
Tree_number	1	2.016666667	2.016666667	2766	0.035068691
Residuals	26	11.68333333	0.449358974	NA	NA
Soil chroma					
	Df	R Sum Sq	R Mean Sq	Iter	Pr(Prob)
Distance	2	3.266666667	1.633333333	4806	0.036412817
Tree_number	1	2.016666667	2.016666667	2766	0.035068691
Residuals	26	11.68333333	0.449358974	NA	NA
Soil hue					
	Df	R Sum Sq	R Mean Sq	Iter	Pr(Prob)
Distance1	2	6.066666667	3.033333333	759	0.239789196
Tree_number	1	0.15	0.15	51	0.921568627
Residuals	26	79.65	3.063461538	NA	NA

Results and Discussion

The data suggests that different distances from trees on a golf course does affect how many weeds are present in the turfgrass, how good the water stable aggregates are, and how bright the soil color is. The farther the distance from the tree, the lower the percentage of weeds and water stable aggregates. In contrast, the soil brightness increases as the distance from the tree increases. The data does not show that different distances from trees on a golf course affects soil pH, potassium, nitrogen, and phosphorus levels, along with soil chroma and hue.

There are a few mechanisms that can explain the results of the percentage of weeds in different distance gradients from target trees. In Figure 3, the percentage of weeds at 1m from the tree is significantly higher than 5m and 10m. The use of herbicides and fungicides on the golf course heavily reduces the amount of weeds that grow on the turf grass (Monaco, 2002). Also, the herbicides at Springdale Golf Club are not sprayed right up to the tree trunks (personal communication with golf-course superintendent). Since the 1m square is the closest to the base of the tree, it has the least amount of pesticides used and therefore the highest amount of weeds. Therefore, it can be concluded that the reason for a higher percentage of weeds closer to the tree trunks is because of a lower use of pesticides. Another explanation for this is how the environmental conditions directly under the tree differ from further away. Some weeds thrive in shaded areas (Marble, 2023). The branches and leaves of the trees provide ample shade for the turf underneath, allowing certain species of weeds to flourish. The turfgrass cannot grow as much with the limited sunlight which explains the increased amount of bare soil that shows up at the 1m distance from the tree. The weeds then have less competition and can thrive. Another environmental difference that can encourage weed growth is the moisture of the soil. All soil samples were taken 1-3 days after it had rained. Trees help to store rainfall by absorbing water from the soil through its roots (Myers, 2020). This makes the soil drier closer to the base of the tree where there's the highest concentration of roots. Furthermore, the golf course has a sprinkler system that doesn't reach the bases of the trees, resulting in drier soil closer to trees. Turf grass cannot thrive as well in dry soil, which creates less competition for weed species. This allows weed species to grow more easily (Marble, 2023). Both reasons support why there is a higher percentage of weeds at 1m compared to 5m and 10m. In summary, the higher amount of weeds under trees could be explained by the usage of pesticides on the fairways and ruff, as well as more shade and higher soil moisture under trees; all of these factors can contribute to the germination, survival, as well as the growth of the weeds. To confirm the mechanism and causes, a manipulative experiment that controls the variation of these variables (pesticides, sunlight, soil moisture) should be carried out in future.

Also in Figure 3, the difference of the soil brightness is statistically significant in the first test (AOVP) but not in the second test (post-hoc permutational test). This could be due to the varying level of sensitivity of these tests. Regardless, soil brightness tends to be higher at 10m >5m >1m. There are multiple factors that can influence the brightness of soil, some of which are

soil moisture and the content of organic matter (Sin, 2023). As it was previously mentioned, a closer distance to the tree can affect how moist the soil is. However, based on my observation in the field, soil was drier closer to the tree; this contradicts the data collected about the soil brightness, since the soil tended to be the lightest in color at 10m, and darkest at 1 m. If the soil brightness was completely based on soil moisture, the soil would be the lightest in color at 1m. However, that is not the case. Instead, the amount of organic matter in the soil can serve as a possible explanation for why the soil was the brightest shade at 10m. When the roots of the old tree die, they decompose in the soil and create more organic matter. Leaves that fall from the tree are also sources of organic matter. A larger amount of organic matter decreases the lightness of the soil (Vodyanitskii, 2017). Thus, an explanation for why the soil appears to be darkest at 1m is because it has the highest amount of organic matter under trees. Organic matter is key for maximizing biological activity and improving soil structure. Bacteria and fungi feed on organic matter and in turn release beneficial nutrients, such as nitrogen, phosphorus, and potassium. This leads to better plant root growth and healthier microbial populations. Organic matter also increases soil water holding capacity by improving soil structure (Kalwar, 2017). The findings support the hypothesis that trees can maintain darker soil and potentially higher organic matter in the golf course, which indicates their ecological importance in providing natural habitats and nutrients for a diverse range of belowground microorganisms.
Soil water holding capacity is also determined by the amount of water stable aggregates. There is a significant difference of water stable aggregates between 1m, 5m, and 10m as seen in Fig 4. 1m had the highest ranking, 10m had the lowest ranking, and 5m was in between. This result suggests that soil at 1 m away from the trees has the highest content of water stable aggregates. This relates back to the amount of organic matter in the soil closer to the tree. As previously mentioned, there is more organic matter closer to the tree, and the increased amount of organic matter increases soil water holding capacity. The microorganisms feeding on the organic matter in the soil promote more aggregation in the soil particles (Kalwar, 2017). Since there is less organic matter farther away from the tree, the 10m soil had a low ranking of water stable aggregates. The organic matter can be removed due to foot traffic and turf maintenance, such as mowing (Myers, 2020). There are more people walking along the areas that are farther away from the trees on the golf course, and there is more maintenance done on the fairways and greens, areas that are both far away from the base of the trees. Consequently, the soil's ability to hold water declines.

A possible reason for why there was no significant difference in the pH at different distances from the trees could be that the rainwater from a couple days before the soil samples were taken had broken down the pesticide molecules, diluting the efficiency of the pesticides (Esticon, 2021). This would make the differences in pH of soil samples from any distance from the tree less significant. The same reason could apply to the concentrations of nitrogen, phosphorus, and potassium. The pesticides can be diluted by the rainwater and therefore during the nitrogen, phosphorus, and potassium tests, there wasn't enough of a difference between the 1m distance with the least amount of pesticides sprayed and the 10m distance with the most pesticides sprayed (Esticon, 2021).

This experiment was relevant to real life for several reasons. The data collected highlights the importance of keeping healthy trees on golf courses in order to maintain better soil health. Better soil health can lead to a positive feedback loop where less pesticides are needed to maintain the turf in good condition for golfers (Geison, 2019). The data also highlights areas of improvement for golf course soil health, such as focusing on increasing soil water holding capacity rather than changing the amount of phosphorus, nitrogen, and potassium being added to the soil.

Conclusions

The findings indicate that trees on a golf course are essential for maintaining soil biodiversity, soil structure, and overall soil health. Pesticides and other turf management techniques can threaten the health of soil as well as natural species that live in the soil. It is important to keep in mind the benefits of having trees on golf courses in order to create the best, lasting conditions of the turfgrass. Trees may add an additional challenge for golfers, but they are advantageous for the soil and overall biodiversity.

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