COMPARATIVE PROPERTIES IN RIPARIAN FOREST BUFFER ZONES AND ADJACENT AGRICULTURAL AREAS: INFILTRATION AND TOTAL CARBON

by

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ABSTRACT

Addressing nonpoint source nutrient pollution to improve the health of degrading aquatic ecosystems is becoming increasingly important with growing anthropogenic stresses. Soil water infiltration and total organic carbon help determine a soil's ability to reduce runoff and improve water quality through denitrification. This study surveyed the infiltration rates and organic carbon content of soil samples from 30 different paired riparian and agricultural sites around three counties in western Maryland. Infiltration rates in riparian forest buffer zones were found to be significantly higher than those of their adjacent agricultural areas. Total organic carbon concentrations were not different between the two land uses, indicating that the buffers, having been established between five and fifteen years ago, are improving soil infiltration rates. More time may be needed to develop soil carbon that will, together, improve the functionality of these zones in addressing nonpoint source pollution from farmland.

ACKNOWLEDGEMENT

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The Chesapeake Bay is the largest estuary in the United States with a drainage basin of approximately 165,760 km^2 including over 150 rivers, streams, and creeks covering portions of six states and the District of Columbia (U.S. Environmental Protection Agency 1983). The Bay has supported some of the most productive fisheries in the world, is a center of recreational and tourist activities, and has two of the most productive ports in the United States, Hampton Roads and Baltimore (Kemp et al., 2005). Even though the benefits of a clean bay are paramount, environmental conditions in the Chesapeake Bay continue to deteriorate significantly as they have over the past 70 years (Friedrichs et al., 2017). There is a 14:1 land-to-water surface area ratio within the Chesapeake Bay Watershed and it is because of this high ratio that nutrient and sediment loading pressures are so high on the Bay's ecosystem, causing poor water quality (Mulkey et al., 2017). This poor water quality has resulted in declines in submerged aquatic vegetation, fish, and shellfish (Dauer et al., 2000) and threatens the future health and economic productivity of the Bay.

Coastal seas, bays, lagoons, and estuaries that are found around the Chesapeake Bay have become increasingly degraded due to anthropogenic stresses. Development within the watershed is one of the largest anthropogenic stresses (Kemp et al., 2005). This development causes the reduction and removal of vegetation and an increase in road density and other impervious surfaces (Kovealenko et al., 2014). Agricultural activities, such as crop cultivation and livestock production, are major factors that also contribute to water pollution via increased nutrient loading in both freshwater and coastal watersheds (Dauer et al., 2000). If uncontained, the pollution from these anthropogenic activities on the landscape, including agriculture, has the potential to directly impact adjacent waterways.

One of the major problems with the environment is nutrient pollution and it is a costly widespread challenge across all of America (Kemp et al., 2005). Nutrient pollution is caused by excess nitrogen and phosphorus in the water. Both of these nutrients are a crucial and necessary component of the natural aquatic ecosystem because they support the growth of algae and aquatic plants which provide food and habitat for other organisms. However, too much of either nutrient can be considered pollution. Human activities on the landscape, such as agriculture, result in runoff of too much of these nutrients into the water, which can cause algal blooms that impact both environmental and human health as well as the economy (Dodds and Smith 2016).

The states around the Chesapeake Bay have agreed to reduce their states' nitrogen and phosphorous loadings, as well as sediment runoff to the Chesapeake Bay by 2025 (Reckhow 2011). One way in which the agricultural sector plans to meet these goals is to implement best management practices (BMPs) that aim to reduce nutrient and sediment runoff from farmland. Riparian forest buffers are one type of BMP: they are the vegetated region adjacent to streams and wetlands that act as interfaces between terrestrial and aquatic ecosystems (Surasinghe and Baldwin 2015). They are ecotones and as such they encompass sharp gradients of environmental factors, ecological processes, and plant communities (Gregory et al., 1991). Riparian buffer zones are most well known as being effective at mitigating nonpoint source pollution and they are one of the most commonly recommended BMPs (Lowrance et al., 2000). At smaller spatial scales, riparian forests and wetlands are thought to be effective at intercepting and reducing nitrogen loads entering water bodies from agricultural and urban land use (Surasinghe and Baldwin 2015). Thus, the installation of riparian buffers along streams that border farmland is expected to be an effective way to mitigate nonpoint source nutrient pollution from farmland.

Water movement and storage, through infiltration into the soil, is part of the hydrological process of a successful riparian zone. Infiltration is the process of water flowing through the soil due to gravity and capillary forces (Tan et al. 2018). Riparian forest buffer zones will typically be able to absorb the total incoming upland runoff and throughfall. The buffers protect the water quality by reducing or even at times eliminating non-point source pollution (Medina et al., 2016). It is only during storms of high intensity that is it possible that these runoff and throughfall rates will exceed the infiltration capacity of the riparian zone (Lowrance et al., 2000). In forested watersheds, very little surface runoff occurs unless it is near streams and there are zones of saturated soil. Natural riparian forest studies indicate that forests are particularly effective in filtering fine sediments, promoting decomposition, and reducing nutrient pollution as water infiltrates the soil (Lowrance et al., 1997; Fortier et al., 2015).

Soil nitrogen is strongly influenced by the amount of organic carbon present in the soil (Flite et al., 2001). Soil and litter carbon are divided into two different major organic groups: residue and humus (Wershaw 1993). Residue is woody debris, leaf litter, and roots; humus, is soil organic matter. They are related in that the litter from leaves, stems, branches, coarse roots, and fine roots is readily decomposable and these residues are turned into soil organic matter over time, resulting in a continuum of organic carbon in the soil that is characterized by different degrees of physical and chemical stabilization. This humus, or soil organic matter, is divided into active, passive and slow pools that describe the rate of decomposition. Organic nitrogen pools correspond to those of the organic carbon pools in the soil; the stoichiometric relationship assumed between carbon and nitrogen show that corresponding amounts of nitrogen will be transformed as carbon is transformed (Lowrance et al., 2000).

Denitrification of runoff is an important process that converts soluble nitrate to dinitrogen gas under anaerobic conditions. This process has major consequences for nitrogen retention as well as plant growth (Yoon et al., 2015). In order for this process to occur, the soil conditions must be right; there must be a high or perched water table, alternating periods of aerobic and anaerobic conditions, a healthy population of bacteria that denitrifies, and sufficient amounts of available organic carbon. The permanent removal of excess nitrogen from the riparian area is an important benefit of denitrification (Klapproth and Johnson 2009). When it comes to the health of streams and other adjacent waterways, denitrification is one of the major mechanisms responsible for changes in nitrogen concentrations in shallow groundwater as subsurface flow passes from agricultural fields to the stream (Schnabel et al., 1995).

Grass and forest buffers reduce levels of nutrients and sediments from surface runoff as well as reduce the levels of nitrates from subsurface flows. Previous studies have shown that riparian buffers of various types are effective at reducing nitrogen in riparian zones, particularly via denitrification if nitrogen is flowing in the subsurface (Mayer et al., 2007). Grassed riparian sites tend to achieve lower denitrification rates than wooded ones, most likely because of lesser availability of organic carbon and fewer interactions between the vegetation and the soil in relation to surface area (Correll 1997). Denitrification rates in riparian buffer zones may be carbon-limited (Schnabel et al., 1995). The more carbon that is found within these riparian buffer zones, the more denitrification can take place. Denitrification is one of two major ways in which a riparian buffer can remove nitrogen that is passing through the soil; the other is through uptake, or assimilation, by the vegetation. If the flow of water through the buffer is shallow and is able to pass through the root zone of the plants, vegetative uptake can be significant (Wagner 1999). Vegetative assimilation is a temporary storage of the nitrogen while denitrification by bacteria is a permanent loss of nitrogen from the system; both of these removal methods are critical to a healthy ecosystem (Payne et al. 2014). While grass buffers can be established more quickly, forested buffers offer the additional advantage of woody debris and offer greater resistance to erosion during heavy floods (Flanagan et al., 2017). Woody debris is important to the ecosystem because it conserves moisture, improves habitat, benefits wildlife, reverses soil compaction, and provides nutrients (Manning et al., 2013).

The Appalachian Ridge and Valley physiographic province makes up one of the largest portions of the eastern United States and Chesapeake Bay drainage basin. This study includes sample sites in Carroll and Frederick Counties, which are in the Piedmont physiographic province, as well as sites in Washington County in the Appalachian Ridge and Valley physiographic province (Figure 1).

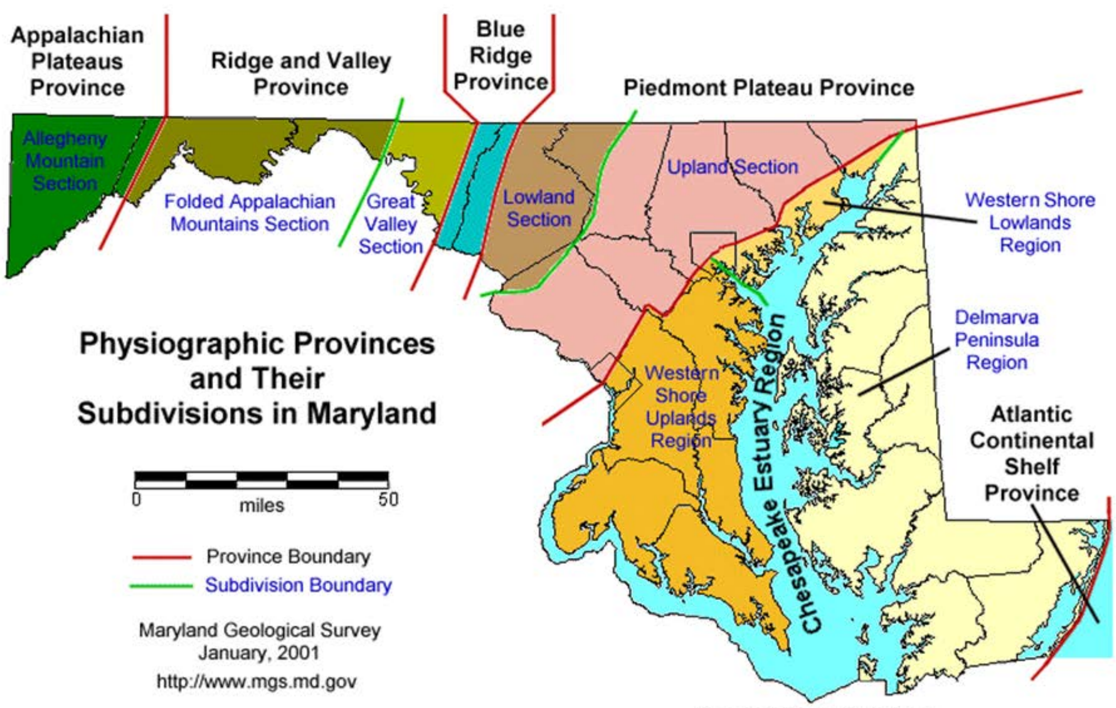

Figure 1. A map of the physiographic provinces and their subdivisions in the state of Maryland. The sites selected for experimentation in this project fall within the piedmont and the ridge and valley province.

OBJECTIVES AND HYPOTHESIS

There has been an overall lack of research done to investigate the anthropogenic impacts within the Appalachian Ridge and Valley province even though it has a large expanse of streams that impact the quality of waterways, including the Chesapeake Bay. There have been even fewer studies looking at physical soil properties. There is a need to expand upon the monitoring efforts of the riparian forest buffer sites in this area to include water infiltration ability and carbon storage because of their importance to the process of nitrogen removal from soil by denitrification.

The Maryland Forest Service established riparian forest buffer zones on many private agricultural sites in an attempt to get local farmers to use a land management practice that was expected to improve the water quality and decrease pollution runoff from their land. Despite their wide use, there are not many field studies that have quantified riparian buffer function over time, particularly as it relates to long-term nitrogen removal via denitrification. In an attempt for the Forest Service to formulate long-term forest management strategies, 33 restored riparian forest buffer sites up to 15 years old will be evaluated for many parameters. Parameters include stream cross sections, vegetative diversity and density, tree planting survival, and soil infiltration and organic carbon. Soil is the foundation for the success of vegetation, as defined by growth and diversity, which supports both terrestrial and aquatic organisms within the riparian forest buffer zone. Thus, it is important to incorporate a soil study into the overall project. These sites are located in Carroll County, Frederick County, and Washington County in the state of Maryland. The sites and their locations are shown in Figure 2. There are many organizations working together to accomplish this assessment and evaluate the effectiveness and success of the riparian forest buffers.

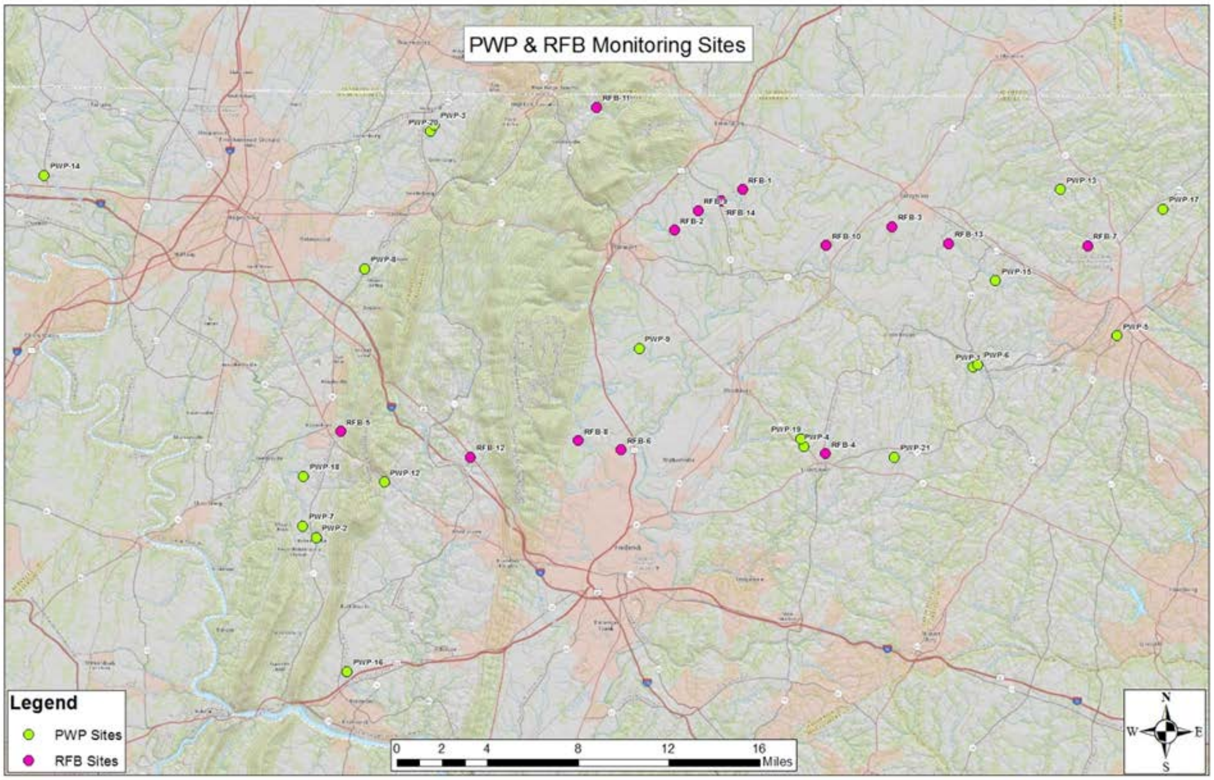

Figure 2. The locations of all of the sampling locations surveyed for the project with the Maryland Forest Service. The different color points indicate which program that riparian buffer restoration was started within. The PWP (Potomac Watershed Partnership) sites were established at a later date than the RFB (Riparian Forest Buffer) sites. The RFB pilot was run in 1999 but both programs were up and running by 2001.

At the conclusion of the project, we hope to have a more complete understanding of how infiltration and total carbon, as an indication of denitrification, differ between riparian buffer zones and adjacent agricultural areas in the Piedmont and Appalachian Ridge and Valley physiographic provinces of Maryland. The riparian buffer zones being analyzed vary in location, date of establishment, width, soil type, and vegetative growth and diversity.

Based on the literature review, it is hypothesized that the riparian forest buffer zones have significantly greater rates of infiltration when compared to adjacent agricultural areas. It is also hypothesized that riparian forest buffer zones have significantly greater levels of total organic carbon content when compared to adjacent agricultural areas (Klapproth and Johnson 2009, Bharati et al., 2002).

METHODS

Selection of the sampling sites was done by the Maryland Forest Service. The MD Forest Service planted trees to restore riparian areas on private agricultural properties over the past 15 years. These sites were either considered PWP (Potomac Watershed Partnership) sites or RFB (Riparian Forest Buffer) sites, based on their date of establishment. PWP sites were established more recently (approximately five years ago) and the RFB sites were those that were established 10 to 15 years previous to this study. All of these sites are shown on Figure 3 and the site's locations are further specified in Figures 4, 5, and 6.

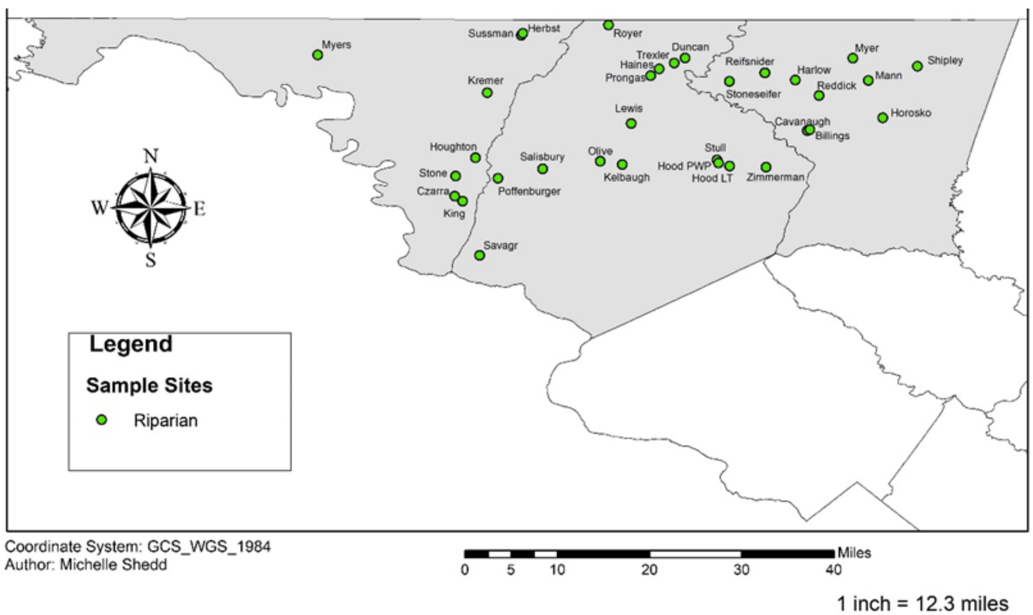

Figure 3. This map shows all of the riparian forest buffer zones that the Maryland Forest Service surveyed and requested soil analysis be done.

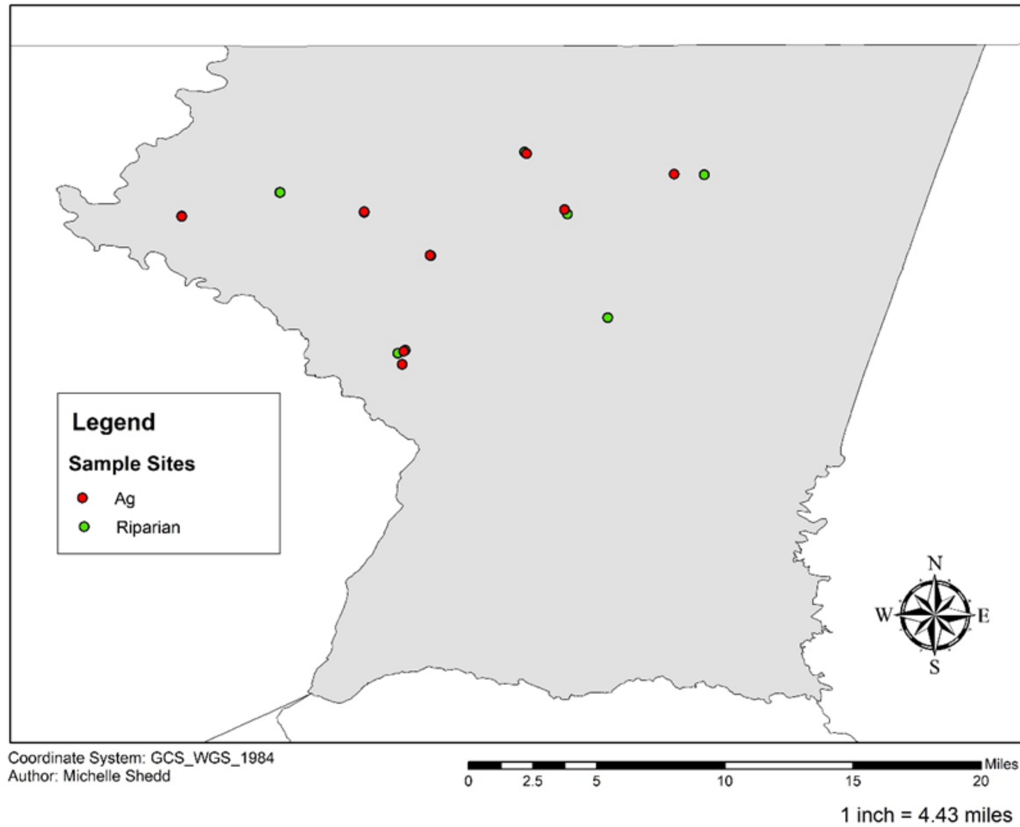

Figure 4. The locations of agricultural areas (red points) and riparian buffer zones (green points) sampled from and within Carroll County, Maryland. There are some locations that look as though there were only agricultural data or riparian data taken, but that is just due to the scale of the map and how closely those samples were taken from each other and thus these sites overlap on the map.

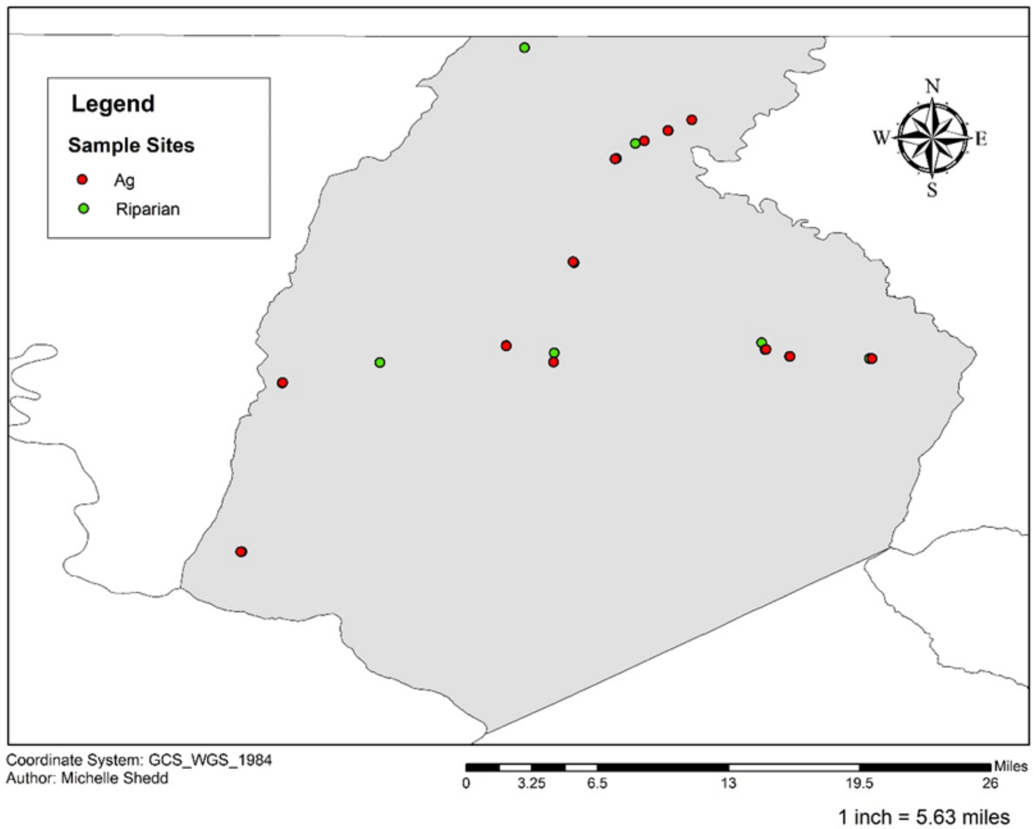

Figure 5. The locations of agricultural area (red points) and riparian buffer zones (green points) sampled within Frederick County, Maryland. There are some locations that look as though there was only agricultural data or riparian data taken, but that is just due to the scale of the map and how closely those samples were taken from each other and thus these sites overlap on the map.

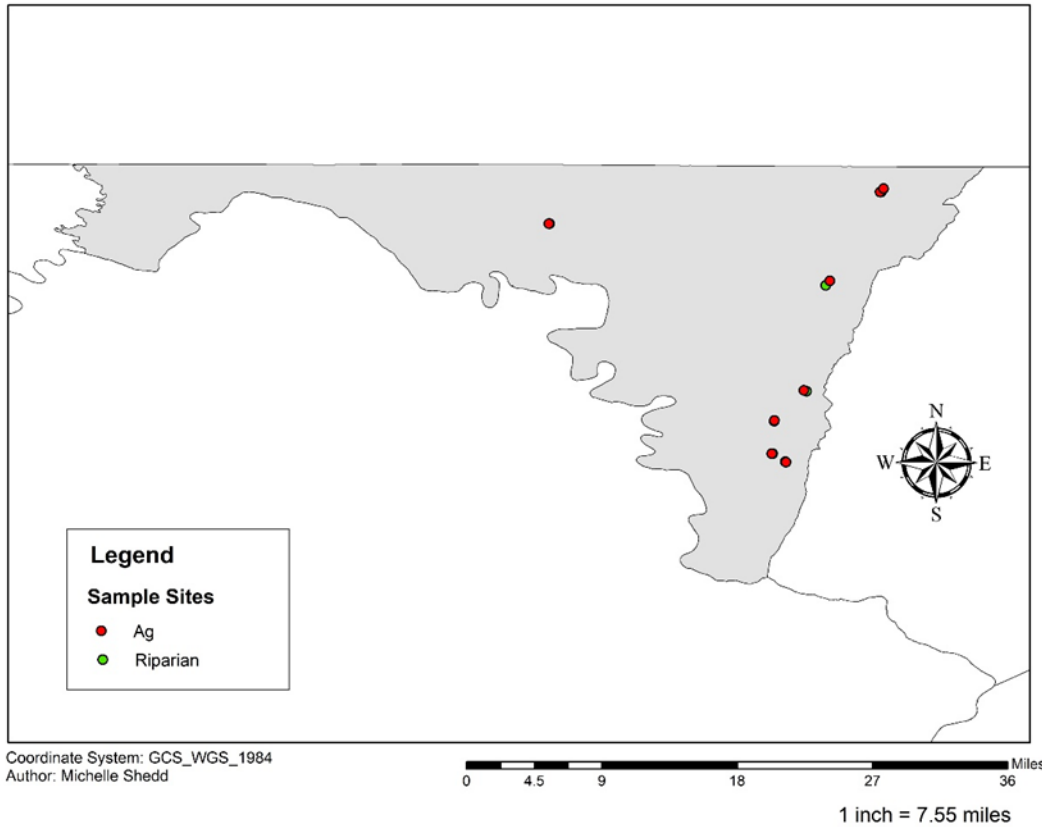

Figure 6. The locations of agricultural areas (red points) and riparian buffer zones (green points) sampled within Washington County, Maryland. There are some locations that look as though there was only agricultural data or riparian data taken, but that is just due to the scale of the map and how closely those samples were taken from each other and thus these sites overlap on the map.

Field Testing for Infiltration

Thirty-three different sites were tested for infiltration. Each site included a location within a well-forested area of the riparian forest buffer zone and an adjacent normal agricultural area. A well forested area has trees higher than five meters and a tree canopy cover of more than 10%. An adjacent normal agricultural area in this study was either a pasture or crop field. Within the area selected for the well-forested area, three separate infiltration cylinders were installed and ran simultaneously. The cylinders were six inches by twelve inches and included a marker for the 6” mark in height to indicate target depth (Figure 7). The cylinders were lined up next to each other, approximately half a meter apart, parallel to the stream. Keeping the sides of the infiltrometer ring vertical was critical. This was important so that there was no undue disturbance of the soil surface from driving of the ring in at an angle (Trickler 1978). Following Johnson's method (1991), with modifications, the ring was driven 4 to 6 inches into the soil using a centered driving cap (wooden block) onto the infiltration ring. A sledge was used to hammer the ring into the soil with medium force so that unnecessary soil fracturing and compaction was avoided. Unfortunately, slight compaction of the soil core is almost an inevitable consequence of sampling (Ankeny et al., 1991) but an attempt was made to limit the extent to which the soil was altered, as described. The driving cap was moved around the ring instead of just hammering in one place so that the cylinder was uniformly penetrated into the soil. If the cylinder was not uniformly penetrated into the soil (such as when a rock was hit), the cylinder had to be removed and a different location had to be tried. The disturbed soil adjacent to the ring on the inside was tamped firm; though if the soil was disturbed more than 1/8 of an inch on the surface from the ring, the infiltrometer was reset with less disturbance.

After the cylinders were properly put into the ground, water was poured into the cylinders using a 2000 mL container. To prevent disturbing the soil surface, water was poured into the side of the ring. A volume of 1400 mL of water was poured from a container and a note was made of the start time at which the initial water was poured into the cylinders. At this point, stopwatches were started and watched at each of the different cylinders (three separate stop watches). A ruler was placed into the center of the cylinder perpendicular to the ground and the initial water level was recorded. The water level was measured in inches because inches per hour is the industry standard (Bureau of Environmental Services 2008).

While these tests were running, a one-inch diameter gator corer was used to take a sample of the soil, approximately four to six-inches deep, around the testing site. Two cores were taken from around the testing site for this sample so that a composite could be made in the field, and this sample was then taken back to the Hood College lab in a plastic bag for further moisture analysis.

The infiltration cylinders were watched to record the rate at which the water level dropped and then the time on the stopwatch was recorded at the point when the water had completely saturated the soil and none was left pooled on the surface. In the event that the infiltration readings were taking an extended period of time (in excess of one hour), water level measurements were taken at fifteen-minute intervals. If the water still had not fully infiltrated into the soil after one hour, the ruler was used to record the ending water level at this time. The infiltration rate for these soils was calculated based on the volume of water that infiltrated the soil over the one-hour period. Upon completion of the infiltration test, the infiltrometer ring was removed from the soil by placing a piece of rebar through two holes in the top of the cylinder (Figure 7) and hoisting up until the cylinder came free. Once the cylinder was free, there was likely soil stuck in the cylinder that had to be removed and repacked into the ground before moving onto the next step of the assessment.

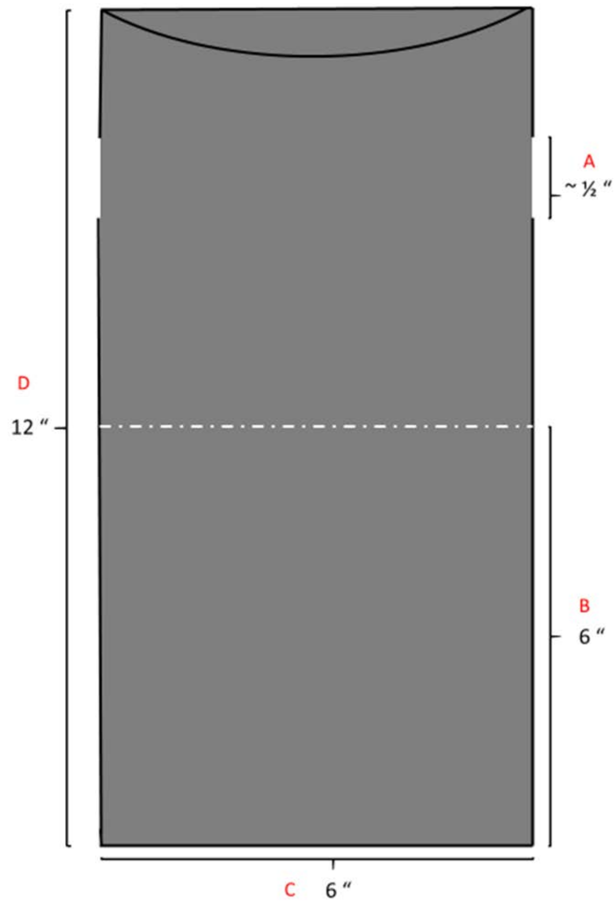

Figure 7. Diagram of the infiltration cylinder. Label A indicates the holes that the rebar goes into to remove the cylinder from the soil; label B indicates the distance to the line showing ideal soil depth; label C indicates the diameter of the ring; and label D indicates the height of the cylinder.

On that same field site, an infiltration test was performed using the same method on a location from an adjacent agricultural area. This area was normally within a few meters of the riparian zone but on certain occasions it was as far away as a kilometer due to topography and access constraints. This site was picked at the experimenter's discretion and was usually at the very edge of an agricultural area, away from the transitional boundary between riparian zone and agricultural area, so that the soil had clearly been impacted by agricultural practices (whether crop or pasture land) but the private owner's land was not unduly disturbed.

Field Testing for Organic Matter

At each site, a location from a well-forested area of the riparian forest buffer zone was selected. This was the same area that was picked to do the infiltration tests so that there was consistency in location. The riparian buffer zone sampling site was in the forested area within a few meters of the stream. From that area selected, a core sample was taken using the AMS Gator Probe without removing surface organic material from the core site (Schumacher 2002). The probe was pushed into the ground about three inches deep. The probe was removed from the soil, opened up, and the entire soil core was then taken and placed into a plastic bag for future storage; four more cores were taken from this selected area (for a total of five) and placed into this same plastic bag to be mixed into a composite sample later in the lab. The bags were returned to the lab and frozen to await further analysis.

Organic matter testing was also completed on the adjacent normal adjacent agricultural areas where infiltration testing had been completed. Five sample cores were taken from these areas, following the same method as previously described for the riparian zone.

Lab Testing for Soil Moisture

The moisture samples that were stored in plastic bags from the riparian buffer zones and the adjacent agricultural area were brought back to Hood College for further analysis. Once back at Hood College, the soil moisture samples were taken and weighed inside two pre-measured aluminum weigh boats. The samples were then dried at 35°C (Boone et al., 1999). After 24 hours, those samples were taken out of the oven and weighed again. This weight minus the initial weight gave the moisture content of the soil. These data were reported as percent moisture content of the sample so that an easier comparison could be made.

Lab Testing for Organic Matter

The samples were brought back to Hood College and mixed together into composites separately for each riparian and agricultural site (Boone et al., 1999) and then stored in a -20°C freezer for later processing. Once it was time to evaluate the soil, the CoorsTek 60107 High-Form Crucible porcelain containers were meticulously cleaned. The weight of each individual clean crucible without any sample in it was taken and then the desired sample was put into the crucible and weighed. The sample that was put into the crucible was a subsample of the total composite sample, so that the crucible was almost filled to the top with sample. This determined the initial weight of the soil sample gathered. The sample in the crucible was put into a drying oven, with the temperature set at approximately 120° C (Hoskins 2002).

The samples were considered dry after being in the oven for at least 24 hours. The samples were then removed from the oven, weighed, and taken to the furnace. From this point forward, the samples were not touched without gloves so that any possible added moisture from my hands would be avoided. A compact benchtop muffle furnace was used, and six crucibles were placed into the furnace at once to be heated. The crucibles were not allowed to touch the side of the furnace or any of the adjacent crucibles in the furnace. The temperature of the furnace was set to 550° C for four hours. After four hours, the carbon matter in the sample had been incinerated (Schumacher 2002) and, the furnace was turned off and allowed to cool. The samples were carefully removed from the furnace and allowed to cool in a desiccator. Once the sample in the crucible was cool, the weight of the sample was measured again. By subtracting the weight of the sample after the furnace from the initial dry weight of the sample, the amount of organic matter was determined.

Statistical tests were performed using the R statistical program to test if the following null hypotheses were supported:

1. Riparian forest buffer zones have no difference in rates of infiltration when compared to adjacent agricultural areas.
2. Riparian forest buffer zones have no difference in the levels of total organic carbon content when compared to adjacent agricultural areas.

Further analysis was done to make sure differences in original moisture found in the soil on site did not significantly impact the rate of infiltration or total carbon by running a correlation in R.

RESULTS

Riparian and agricultural soils that were sampled in the summer and fall of 2017 were analyzed for infiltration rate, total organic carbon, and moisture content (Figures 8, 9, and 10). Three sites that were sampled (PWP-19, RFB-12, and RFB-11) were left out of the final data analysis because of the absence of a paired adjacent agricultural area to the riparian forest buffer zones.

Riparian forest buffer zones have an average infiltration rate greater than that of the adjacent agricultural areas (Figure 8). An unpaired two-tailed t-test confirmed that this difference is significant (Figure 8; $t(172)=4.105$, $p<0.0001$), meaning that the null hypothesis can be rejected.

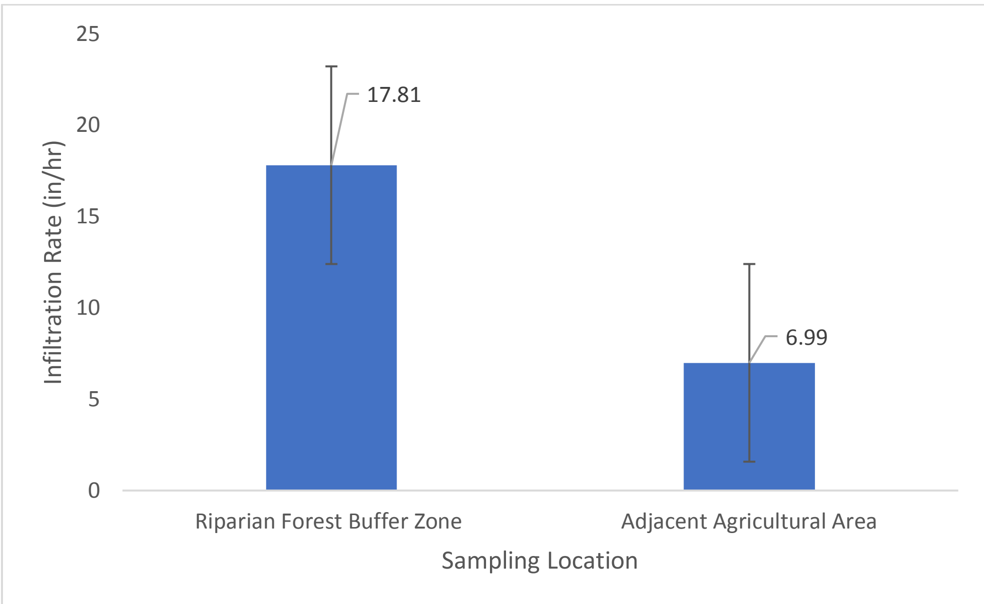

Figure 8. The comparative average infiltration rates (in/hr) of the riparian forest buffer zones and their adjacent agricultural areas. Th error bars represent standard deviation.

Riparian forest buffer zones have an average organic carbon concentration that is not significantly greater than that of the adjacent agricultural area (Figure 9). An unpaired two-tailed t-test confirmed that this difference is not significantly greater than the concentration of their adjacent agricultural area (Figure 9; t(56)=0.3849, P=0.7018), meaning that the null hypothesis is not rejected.

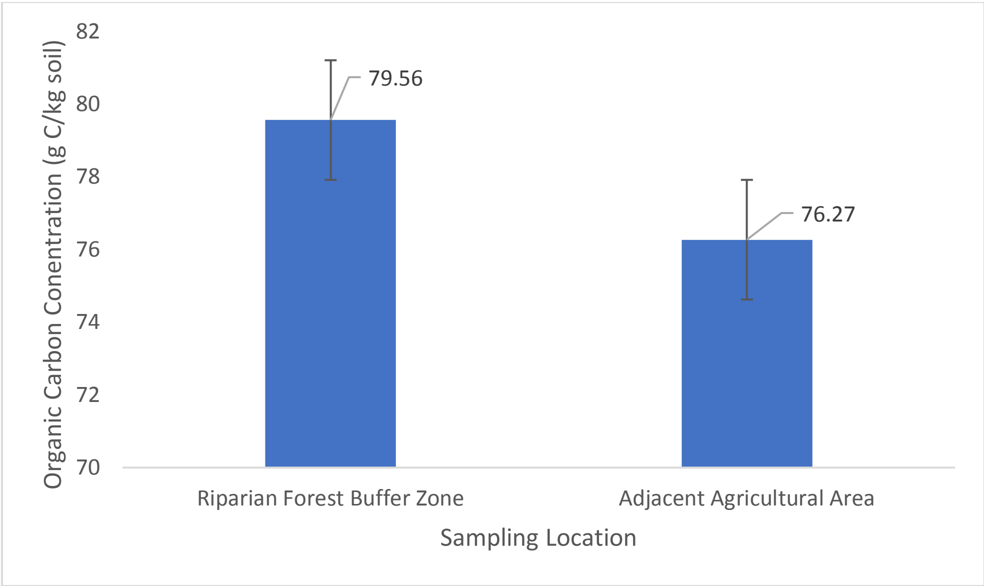

Figure 9. The comparative average organic carbon concentrations (g C/kg soil) of the riparian forest buffer zones and their adjacent agricultural areas. The error bars represent standard deviation.

The relationships between infiltration and total carbon in both the riparian forest buffer zones and adjacent agricultural areas are shown on Figures 10, 11, and 12. They visually show the lack of correlation between these two sets of data according to this study. Figure 10 shows the same data as Figure 11, except for one removed datum from RFB-14, which seemed like an outlier when plotted against the other data (infiltration average of 24.75 in hr^{-1} and a total organic carbon concentration of 273.01 g carbon kg^{-1} soil). The removal of the outlier did not result in a significant correlation.

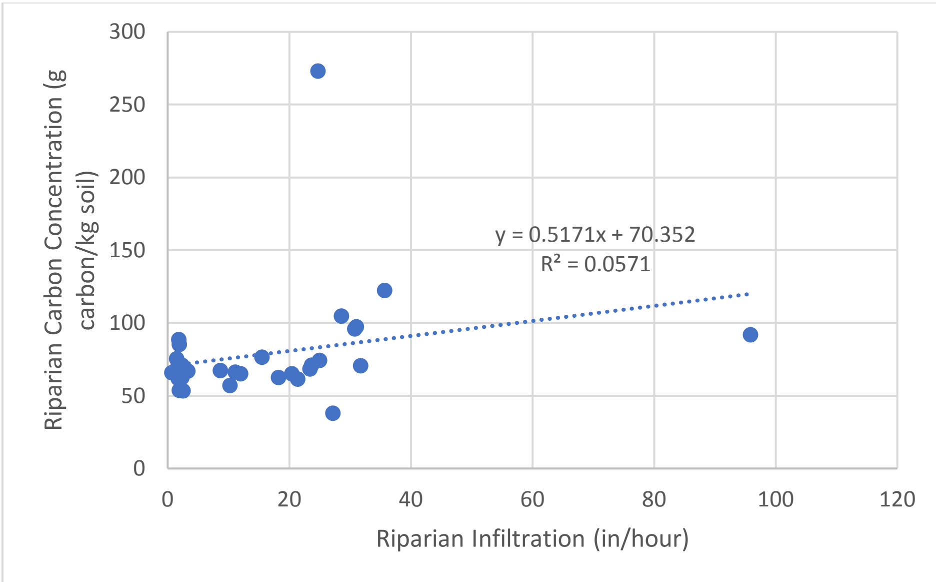

Figure 10. The relationship between infiltration and total carbon concentration in the riparian forest buffer zones.

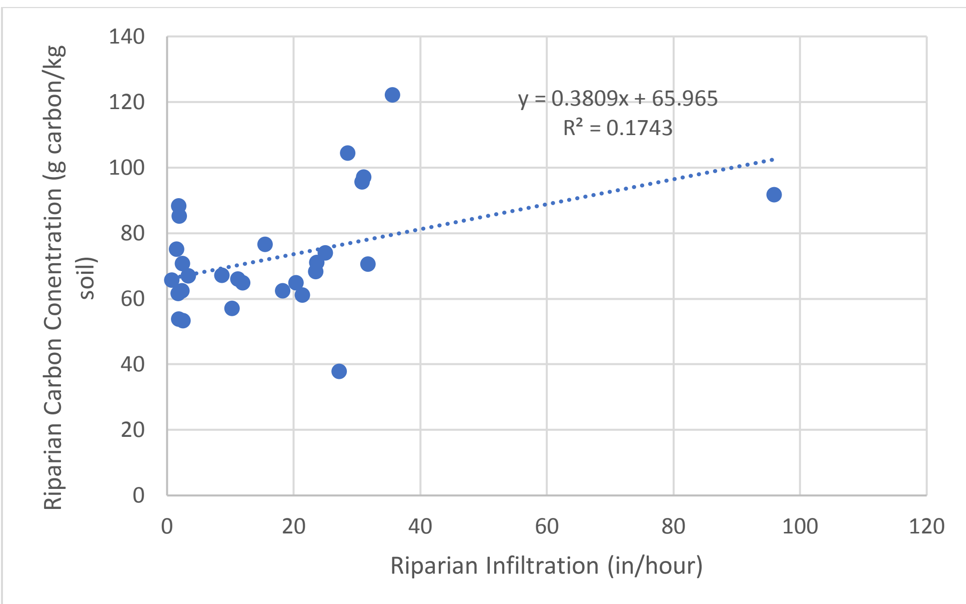

Figure 11. The relationship between infiltration and total carbon concentration in the riparian forest buffer zones without an outlier site to see if the removal of that datum would significantly impact the model.

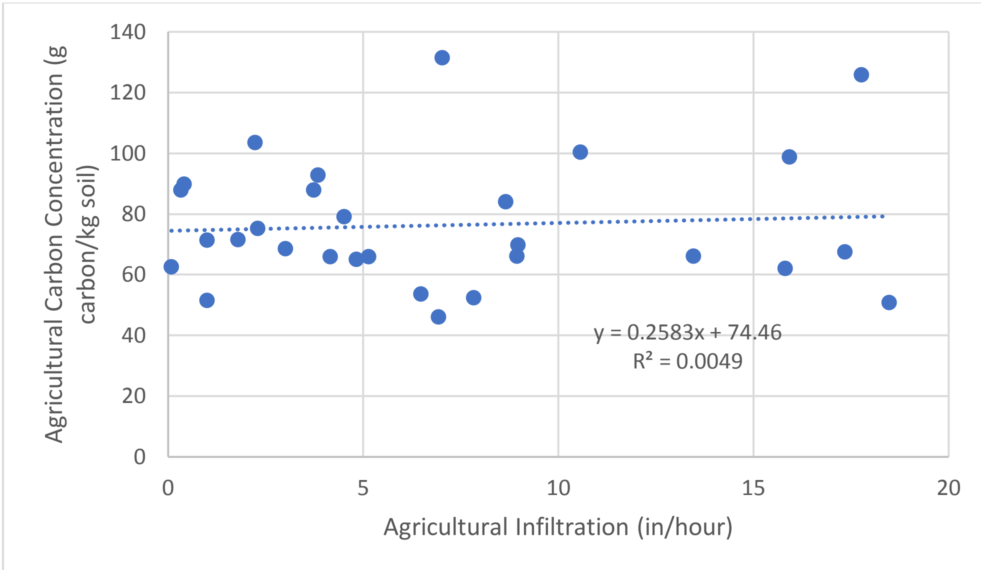

Figure 12. The relationship between infiltration and total carbon concentration in the adjacent agricultural areas.

Correlation tests were run in the R statistical program for the infiltration rates, total organic carbon, and soil moisture for both the riparian forest buffer zones and the adjacent agricultural areas. The rate of infiltration, total organic carbon, and soil moisture are not significantly correlated according to the test (Table 1).

Table 1. The correlation coefficients showing the relationship between infiltration rates, total organic carbon, and soil moisture across all sites.

	Infiltration Rates	Total Organic Carbon	Soil Moisture
Infiltration Rates	1.00	0.24	0.11
Total Organic Carbon	0.24	1.00	0.12
Soil Moisture	0.11	0.12	1.00

DISCUSSION

The analysis showed that there was a significant difference in infiltration between the riparian forest buffer zones and their adjacent agricultural areas. The average rate of infiltration was 17.81 in hr^{-1} in riparian zones and 6.99 in hr^{-1} in agricultural areas, indicating that riparian forest buffer zones showed higher infiltration rates overall in comparison to their adjacent agricultural counterparts. Literature indicates that the average rate of infiltration in a forested riparian area is similar to these findings between 11.81 in hr^{-1} and 17.72 in hr^{-1} (Bharati et al., 2002). At 6.99 in hr^{-1} the adjacent agricultural area has higher than expected average infiltration rates, which Bharati and colleagues (2002) measured between 1.18 in hr^{-1} and 1.96 in hr^{-1}. The higher-than-expected infiltration rates in the agricultural soils may be due to farmers' use of the soil which could have included crop rotation, cover cropping, and no-till farming. However, data on these practices were not collected. The higher infiltration rates in the riparian forest buffer zone is an important finding when it comes to our understanding of the restoration of a healthy ecosystem. High infiltration rates indicate an increased ability for root water uptake, plant growth, and habitat for soil (Fischer et al., 2015; Jackson et al., 2015). The riparian forest buffer zones that were tested used to be under the same influences as the adjacent agricultural zones to which they were compared. This means that in the 5-15 years of riparian forest buffer zone establishment, an impact on infiltration improvement takes place.

Our analysis showed that for total organic carbon content there was not a significant difference in the organic carbon concentrations between the riparian forest buffer zones and the adjacent agricultural areas. The average organic carbon content was 79.6 g C kg $soil^{-1}$ in the riparian buffer zones and 76.3 g C kg $soil^{-1}$ in the agricultural areas. This lack of statistical difference could be due to the age of the riparian buffer zones; the oldest sites were established

15 years ago, and this may not be enough time for differences in soil organic matter to develop. Soil organic matter is a mixture of different components that are all at different stages of development. There are fresh plants that are decomposing alongside highly decomposed material (Ontl and Schulte 2012). The latter may not be fully developed in the systems studied. Most soil scientists agree that it takes up to 100 years to develop substantial organic matter in the soil and it is dependent on factors such as climate and vegetation. (United States Department of Agriculture). Soil organic carbon is important because it impacts many ecosystem services such as nitrogen cycling and soil physical properties (Palmer et al., 2017). Organic carbon is the fuel for many different microbial processes including denitrification (Barnes et al., 2012; Bowles et al., 2014; Mooshammer et al., 2014) which is crucial to the health of the stream, especially with increasing nutrient pollution resulting from anthropogenic stressors on the ecosystem.

Infiltration rates and total carbon within both the riparian buffer zones and the adjacent agricultural area were not correlated (Figure 11, Figure 13). A datum that looked like it was an outlier (Figure 8; riparian carbon concentration of 273 g C kg^{-1} soil and infiltration rate of 24 in hr^{-1}) was removed to see if there was a significant difference in the model but there was not. There were no particular unique qualities to this riparian forest buffer site that would cause such a distinct organic carbon concentration difference, though this site was particularly marshy and did not have as much woody vegetation as some of the other sites. Many studies suggest that infiltration and total carbon are linked since increased organic carbon in the soil causes increased aggregation as well as improved soil structure. As a result, there are improved infiltration rates. (Franzluebbers, 2002; Li et al., 2015). This study may have found a different result due to the methods of surveying. The place of testing was not cleared of above ground biomass before taking the soil cores for the organic carbon samples. The organic litter on top of the soil was included in both the riparian forest buffer zone and the adjacent agricultural areas and homogenized into the soil sample within the lab. This differs from other methods for testing soil organic matter content that say to remove these larger above-ground biomass particles before examination (Schumacher 2002). My procedure differed from other methods per request of the Maryland Forest Service when we first began the study.

This study is limited by there not being any previous soil surveys done on these specific sites, so there is no particular baseline to which to compare. Now that there have been data gathered on the infiltration and total organic carbon at each of the sites, future surveyors could use these data to track changes and possible further improvements over time. This study is a good first step in showing the importance of riparian forest buffer zones along streams, but additional data are needed in future years to show at what point restored riparian areas can be considered fully functional with respect to improving the quality of water that reaches streams.

Addressing nonpoint source nutrient pollution to improve the health of degrading aquatic ecosystems is becoming increasingly important with growing anthropogenic stresses. Problems associated with aquatic ecosystems in western Maryland include runoff and the nutrient loading from agricultural areas. Soil water infiltration and total organic carbon are indicators of soil health because they determine a soil's ability to reduce runoff and improve water quality through denitrification (Morgan and Connolly 2013). Riparian forest buffer zones have long been believed to increase the infiltration rates and total organic carbon concentration found in soil (Kuglerova et al., 2014), and so the Maryland Forest Service planted riparian forest buffer zones along streams on certain private agricultural properties to improve stream water quality. This study surveyed the infiltration rates and organic carbon content of soil samples from 30 different paired riparian and agricultural sites around three counties in western Maryland. While infiltration rates in riparian forest buffer zones were found to be significantly higher than those of their adjacent agricultural areas, the total organic carbon concentrations were not different between the two land uses. These results indicate that the buffers, having been established between five and fifteen years ago, are improving soil infiltration rates but need more time to develop soil carbon that will, together, improve the functionality of these zones in addressing nonpoint source pollution from farmland.

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