Respiration and Organic Matter Field Study of the Soils at Wissahickon Valley Park

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Abstract
The field work done at the Wissahickon was aimed at collecting soil biochemical health indicators. The indicator data collected were soil respiration and soil organic matter content. Soil respiration is defined as the production of carbon dioxide as a result of the aerobic or anaerobic decomposition of organic matter by microbes (Das et al., 2014). Soil organic matter is defined as biologically derived plant tissue such as leaf litter and root material. The data were collected at two separate study areas within the park (Figure 1). The first study area at the park is heavily forested with moderate human disturbance. The second is a grass field which has been developed and disrupted by human activity (figure 10).

These two study areas with varying levels of impact, allowed for investigation into the following research questions. First, is soil respiration correlated with soil organic matter? Secondly, will the two sites, with varying levels of impact, show differing biochemical indicator values? The research hypothesis is therefore composed of two parts. First, there will be a significant positive correlation between respiration and organic matter content. Secondly, site 2 (heavily impacted) will show lower levels of both respiration and organic matter content compared to site 1 (moderately impacted). The reason soil respiration and organic matter content have been selected to analyze the soils is for their common use as biochemical indicators of soil health in published soil biochemical research. While researching potential correlations between organic matter pools and respiration rates, the two study area’s soil health, according to these biochemical indicators, can also be assessed.

The main sources of data collection were soil basal respiration—collected using a field respirometer—and organic matter content, collected using laboratory techniques provided by Penn State’s Agricultural Services Laboratory. Regional geologic data, as well as open source regional soils data, have also been included in the research in order to better understand the building blocks of the research site soil. Knowing the geologic building blocks of the soil, as well as the specific soil type being studied, will allow for more detailed observations relating to the biochemical indicators. All of the mentioned data were then used in combination with several software packages including ArcGIS, and Excel. These programs were chosen to represent data and observations both statistically and geospatially.

After statistical analysis was performed, it was concluded that the first hypothesis cannot be confidently accepted. The correlation coefficients (R-values) between the respiration and organic matter values at both sites were less than 0.50, indicating a weak relationship. Site 1 had an R value of -0.26, meaning there was a weak negatively correlated relationship between the organic matter and respiration data. Site 2 had an R value of 0.47, meaning there was a weak positively correlated relationship between the organic matter and respiration data.

On the other hand, the second hypothesis was accepted. The statistical data shows strong differences in mean respiration rates between sites 1 and 2, as well as strong differences in mean organic matter content between sites 1 and 2. Also, site 2 consistently showed much lower levels of both respiration and organic matter in comparison to site 1.

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RESPIRATION AND ORGANIC MATTER FIELD STUDY OF THE SOILS AT WISSAHICKON VALLEY PARK

EARTH & ENVIRONMENTAL SCIENCE MASTERS STUDENT

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Hydrogeology

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(1.0) Preface

The Wissahickon Valley Park, located Northwest of Center City Philadelphia, is grounds to over 2,000 acres of preserved land, made up of deciduous forest with extensive hiking, biking, and horse riding trails. This park is one of Philadelphia’s largest preserved forests, helping to protect the water supply of over 350,000 Philadelphian’s and fostering invaluable recreational resources. Important ongoing preservation and management of the park is being conducted by the Friends of the Wissahickon (FOW); a non-profit organization founded in 1924 to work in partnership with the Philadelphia Parks & Recreation. FOW is currently working with the Academy of Natural Sciences in developing a comprehensive habitat management plan to be implemented at Wissahickon. The data presented in this paper has been organized with the hope that the FOW may find some portions helpful in developing their management strategies.

(2.0) Abstract

The field work done at the Wissahickon was aimed at collecting soil biochemical health indicators. The indicator data collected were soil respiration and soil organic matter content. Soil respiration is defined as the production of carbon dioxide as a result of the aerobic or anaerobic decomposition of organic matter by microbes (Das et al., 2014). Soil organic matter is defined as biologically derived plant tissue such as leaf litter and root material. The data were collected at two separate study areas within the park (Figure 1). The first study area at the park is heavily forested with moderate human disturbance. The second is a grass field which has been developed and disrupted by human activity (figure 10).

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potential correlations between organic matter pools and respiration rates, the two study area’s soil health, according to these biochemical indicators, can also be assessed.

The main sources of data collection were soil basal respiration—collected using a field respirometer—and organic matter content, collected using laboratory techniques provided by Penn State’s Agricultural Services Laboratory. Regional geologic data, as well as open source regional soils data, have also been included in the research in order to better understand the building blocks of the research site soil. Knowing the geologic building blocks of the soil, as well as the specific soil type being studied, will allow for more detailed observations relating to the biochemical indicators. All of the mentioned data were then used in combination with several software packages including ArcGIS, and Excel. These programs were chosen to represent data and observations both statistically and geospatially.

After statistical analysis was performed, it was concluded that the first hypothesis cannot be confidently accepted. The correlation coefficients (R-values) between the respiration and organic matter values at both sites were less than 0.50, indicating a weak relationship. Site 1 had an R value of -0.26, meaning there was a weak negatively correlated relationship between the organic matter and respiration data. Site 2 had an R value of 0.47, meaning there was a weak positively correlated relationship between the organic matter and respiration data.

On the other hand, the second hypothesis was accepted. The statistical data shows strong differences in mean respiration rates between sites 1 and 2, as well as strong differences in mean organic matter content between sites 1 and 2. Also, site 2 consistently showed much lower levels of both respiration and organic matter in comparison to site 1.

(3.0) Background

3.1 Respiration and Organic Matter

Soil respiration is defined as the production of carbon dioxide within the soil as a result of microbial decomposition of organic matter. Respiration can be used as a biochemical soil health indicator due to the implications that come along with the varying rates of respiration. For example, the rate at which a soil is releasing carbon dioxide can give an estimate to the rate at which beneficial biochemical reactions
are occurring in the soil. This biological activity has significant influence on the physical and chemical properties of a soil, and this biological activity can be constrained by preexisting physical and chemical properties (Moebius-Clune et al., 2016). In addition, soil organic matter data will not only be useful in analyzing links with respiration, but will also allow for making observations regarding soil nutrient reserves and overall soil health. Assessing soil respiration, along with soil organic matter, may provide useful data that can be incorporated into long-term forest management.

The process of organic matter decomposition by microbes is a critical process in an ecosystem. The decomposition under the soil surface helps to shape the biodiversity within the forest itself. While microbes are decomposing and using the organic material for their own growth and energy; they are also releasing usable soil nutrients. Approximately 58% of organic matter is composed of organic carbon (Pribyl et al., 2010) while the rest is mainly composed of elemental nitrogen and phosphorous. Soil microorganisms decompose the organic matter to allow for the absorption of carbon and other elements, but while doing this the microbes can oxidize the elemental nutrients, turning the previously unusable soil nutrients into usable forms. This process of nutrient transformation by way of microbial decomposition is known as nutrient mineralization and is the main process by which a forest obtains its nutrient reserves. Carbon dioxide is released (respiration) as a byproduct of this biochemical reaction (figure 11). Soil biological activity, thus soil respiration, tends to increase with fewer environmental stressors such as compaction, tilling and pH swings (Moebius-Clune et al., 2016).

Soil organic matter acts as the source of a slow release of soil nutrients through mineralization, and also acts as a large store of global carbon. As plants grow, they strip carbon dioxide from the atmosphere during photosynthesis and store this carbon in their cellular tissue. When these plants die, they fall to the forest floor where some of this organic material is decomposed by microbes, but some is also stored in the soil for long periods of time. Partially decomposed organic material can adsorb to soil particles, thus being protected from further decomposition at that time. Organic matter can also be stored within soil aggregates where microbes are unable to interact with the particles. This long-term storage of organic matter is critical for the sustainability of a soil because stored organic matter can slowly feed soil microbial communities, thus slowly releasing essential forest minerals over extensive periods of time. Some researchers argue that managing the organic matter content in an ecosystem is managing a soil’s health. Figure 16 shows a soil organic matter health ranking system provided by Cornell University’s soil health system (Moebius-Clune et al., 2016).
If a soil has been disturbed by anthropogenic or natural causes, soil microorganisms such as bacteria or fungi will react in response to this activity, thus affecting the cycling of soil organic carbon and nutrients (Janssens et al., 2010). This cycling of soil compounds is crucial in maintaining a healthy soil. Anthropogenic disturbance may lead to a decrease in vegetation, leading to a decrease in organic matter content, which in turn may affect the microbial communities which rely upon the available organic content.

Study area 1 has been moderately affected by human activity and will therefore act as the control site. Study area 2 has been heavily affected by human activity and will be designated the test site. These sites are close in proximity, but may show different levels of respiration and organic matter due to varying degrees of anthropogenic impacts. Having two sites with varying levels of impact also allows for deeper investigation into the research questions and hypotheses.

### 3.2 Soil Microorganisms

Organisms within the soil are generally classified under two main groups; autotrophic or heterotrophic. Heterotrophs generally dominate the autotrophs in most soils systems. Heterotrophic organisms, like all other organisms, need carbon to build cellular components. Heterotrophs obtain their carbon from the breakdown of organic matter such as detritus; dead plant material, while autotrophs obtain their carbon from fixing carbon dioxide out of the atmosphere or soil. Since these more abundant heterotrophic microbes are consuming plant material on the forest soil, they are termed primary consumers and are the group of organisms responsible for the measured soil respiration. When a leaf falls from the canopy to the understory, it is immediately subject to microbial decomposition through aerobic processes.

Though these microbes can be highly abundant in a deciduous forest floor like the Wissahickon; there can be limiting factors that control microbial population numbers and activity. The primary influence is available food sources, especially carbon and nitrogen containing sources. The largest store of carbon and nitrogen containing materials are the tree, shrub and plant species which will be mentioned in the *Flora Taxonomy* section. In general, more than half of this organic matter’s chemical makeup is organic carbon, while the rest is composed of oxygen, hydrogen, nitrogen, phosphorous and other elements in trace amounts (Weil, 2016). If the functioning and growth of soil microbial populations rely heavily on available organic matter content, it may be seen that there is a change in respiration with a change in
organic matter content. The total biomass of microbes in the soil may also affect respiration rates, but soil respiration is more significantly correlated with soil organic matter than microbial biomass (Fan et al., 2015). Therefore, soil respiration in a forest may fluctuate with the amount of biologically available substrate (Wang et al., 2003).

In general, fungi are the primary decomposers on the surface of the forest floor, while bacteria are the primary decomposers under the surface (Weil, 2016). Also, fungi are capable of breaking down more complex organic matter content due to their mycelia networks and greater mobility compared with bacteria. Respiration levels may change with vertical distribution in a soil column due to relative availability of soil organic carbon at these depth intervals (Fan et al., 2015), but the respiration measurements are being taken at the soil surface which accounts for the entire microbial community within the measured area.

3.3 Biochemical Soil Health Indicators

Soil biochemistry is a branch of soil science that deals largely with biomass and their chemical interactions with the surrounding soil environment. The biochemistry of a soil can lead one to make observations about the overall health of a soil, and may help with soil management. Biochemical measurements tend to increase in less disturbed or more organically managed soils (Moebius-Clune et al., 2016). Of the biochemical indicators that constantly show up in research, microbial soil respiration and organic matter content are consistently used. So why is it beneficial to analyze organic matter and carbon concentrations alongside respiration? The rate at which soil respiration is occurring is highly dependent upon organic matter which acts as the common substrate for these biochemical mechanisms (Walmsley et al., 2017).

Other factors that influence the biochemical transformation of soil organic matter to carbon dioxide are root biomass composition, soil temperature, soil water content, and the current physical and chemical properties of the soil such as pH, and macronutrient concentrations (Veum et al., 2014). The oxygen level within the soil can also be a limiting factor since the evolution of carbon dioxide by microbes is an aerobic chemical reaction. The complexity of biochemical interactions within the soil matrix quickly becomes complicated when dealing with all of the many parameters that can be included into these
analyses. Furthermore, it has been said that the soil environment is one of the most biologically diverse environments on the planet (Dance, 2008).

There is growing research that indicates anthropogenic causes can influence the soil microbial community, thus exacting change to the natural biochemical cycle; specifically land use and its potential impact on microbial structure and ecosystem functioning (Gupta et al., 2017). Furthermore, research has indicated that land use has indirect effects on the microbial communities by altering some of the critical soil properties that are mentioned above (Jesus et al., 2009). Of the chemical properties mentioned above, pH may be the most notable in terms of its effects on not only the microbial community, but also on the availability of certain nutrients. A low pH could cause toxic forms of some compounds, such as aluminum and iron, to become more soluble which would cause adverse health effects on the entire ecosystem. It has been stated that pH is considered the “master variable” in that its effect can cause changes, and sometimes drastic changes, to many other soil biological and chemical properties (McBride, 1994), though the data presented in the research focuses only on the two biochemical indicators of organic carbon and soil respiration.

3.4 Flora Taxonomy

Study area 1 has an ecosystem consisting mostly of deciduous forest, with patches of evergreen forests and woody wetlands. Much of the canopy in study area 1 are dominated by several tree species including, but not limited to, tulip poplar (*Liriodendron*), American beech (*Fagus grandifolia*) sycamore (*Platanus occidentalis*), and Norway maple (*Acer platanoides*). The under story is limited in the areas surrounding the main study areas, but can become thick in certain areas with a majority being obtuse-leaved privet (*Ligustrum obtusifolium*), spicebush (*Lindera benzoin*), and wineberry (Academy of Natural Sciences). On the other hand, study area 2 is a heavily disturbed portion of the park. It consists of an open field with compacted soils. Vegetation is limited to several types of grasses, along with areas of overgrown weeds. This lack of consistent vegetation at site 1 may certainly affect organic matter content within the soil. As a result, microbial communities may be affected and this may be observed through the respiration values found at site 2.
3.5 Site Geology

Assessing the geologic components of the soil at Wissahickon will allow for insight into the soil’s ability to retain organic matter which will have a potential impact on the rate of respiration. Geological controls on the storage of soil organic matter and carbon are important and are not generally well represented in soil carbon dynamics (Bradley-Cook, 2016). One way to assess for a soil’s potential to store organic matter is by investigating the soil particle size distribution. The particle size of interest for the purposes of this research is the clay sized soil particles. These particles are less than 0.0002 millimeters in diameter (Sheard et al., 1991) and are commonly referred to as soil colloids. What makes these soil colloids important is that they have a large surface area relative to their volume which allows for a beneficial degree of electrical charges to form on their surfaces. These charges on colloids can interact and bond with organic compounds, allowing for long-term storage of organic material. A geologic investigation will allow soil parent material to be identified which in turn will allow for further soil parameter assessment.

(4.0) Methods

4.1 Respiration of Soils using PP System’s EGM-4

Respiration data was collected using an EGM-4 infrared gas analyzer with a soil flux chamber attachment (figure 3). The EGM-4 measures basal respiration. Basal respiration is defined as the steady rate of carbon dioxide (CO2) emitted from the soils due to the microbial decomposition of organic matter, as previously discussed. The EGM-4 device calculates CO2 levels using an infrared gas analyzer. This process is done by passing the gases being emitted from the soil surface through a ray of light emitting infrared rays at a particular wavelength between 700 nanometers and 1 mm. CO2 absorbs light at these infrared wavelengths. A sensor sensitive to infrared light is on the other side of where the CO2 is being passed and thus senses the amount of infrared light making it through the gas. Lower levels of infrared light being sensed will correlate to higher levels of CO2 being detected (PP EGM-4 Systems Manual).

In order to maintain consistent data collection across the many data point’s locations, the respiration chamber was pressed against the soil for approximately two minutes. During these two minutes, the instrument continuously takes readings. These readings are not cumulative, but from these measured
values a slope can be determined by taking the last value recorded, minus the ambient value. 370 ppm was used as the ambient CO₂ value. This value is then divided by the 2 minutes of measurement time, leading to units of part per million (ppm)/minute over a certain area which was 1 m². These units were converted into a more useful form of mgCO₂/cm²s.

Using GoogleMaps, latitude and longitude coordinates were recorded at each measurement location. These coordinates were later placed into ArcMap for spatial data analysis and statistical analysis purposes.

4.2 Soil Organic Matter Data Collection (Penn State Ag. Lab)

18 locations were determined for soil sampling of organic matter; 10 locations at site 1 and 8 locations at site 2. The locations were selected so that there were at least three respiration samples within a few meters of the organic matter sampling points. The top 15 centimeters of soil was sampled. The sampled soil was sent to Penn State’s Agricultural Services Laboratory to be analyzed for organic matter content by way of Loss-On-Ignition procedures designated by Recommended Soil Organic Matter Tests by E.E. Schulte and Bruce Hoskins.

A small amount of each sample is ground and meshed to approximately 2 millimeters in size. The sample is then transferred into tared soil crucibles. The samples are then dried for two hours at 105°C. This allows hygroscopic water to evaporate, but the organic matter to stay intact. The weight of the sample is then measured with +/-0.0001 grams of accuracy. The samples are then heated again for another two hours at 360°C. This then allows for the organic matter to be oxidized into mainly CO₂ and its mass lost. Samples are cooled at 150°C and then weighed one last time in a draft-free environment, again to +/-0.001 grams of accuracy. Loss of weight on ignition (LOI) is calculated by the following equation: LOI (%) = Weight at 105°C - Weight at 360°C x 100 Weight at 105°C. Finally, estimation of organic matter from LOI is done by applying a correction factor where OM, % = (0.8*LOI, %) - 0.23. This correction factor is known as the Walkley-Black method (chromic acid oxidation).

The soil organic matter data was then converted over to % carbon. It is generally accepted in most soils that the % organic carbon is on average, composed of 58% carbon. This conversion has been well researched and documented by Pribyl (Pribyl et al., 2010).

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4.3 Particle Size via Hand Texturing and Geologic Assessment

Determining the soils percent particles size (clay, silt, sand) is useful in many aspects of this research. It not only helps to classify the specific type of soil that is being dealt with, but it also helps with verifying or potentially determining soil quality parameters. It may give an idea to how well the soil can hold onto the soil substrate needed for microbial respiration. A small soil sample was collected during the first respiration data collection field day at both sites 1 and 2. These samples were hand textured to estimate percent particle sizes. This technique involved wetting a small amount of the collected soil. The wet sample of soil was then rolled around and carefully felt for larger sand sized particles. The wet ball of soil was then stretched out to its breaking point. This specific process is known as ribboning and is used to help determine the soils adhesive properties which can be linked to clay and silt content. While hand texturing isn’t a perfect system for measuring the exact percent sand, silt, clay; it can be helpful in estimating the overall textural class of a soil.

A geologic investigation of the Wissahickon Valley Park has been included into this research report. The data and observations collected during this field evaluation has been added to examine parent material found at Wissahickon and to make better observations regarding the soil building blocks. In addition, Web Soil Survey, provided by the USDA, has been implemented to understand the basics soil types found at both sites 1 and 2.

4.4 Statistical Analysis

Analysis of relationships between soil respiration and soil organic matter were processed using Excel. A correlation coefficient (respiration vs organic matter) was calculated using Pearson’s R-test for both sites 1 and 2 (figure 18). The amount of data points evaluated in the R-test depended on the amount of organic matter samples at either site. For site 1, there were 10 organic matter samples, thus 10 respiration values were selected. For site 2, there were 8 organic matter samples, thus 8 respiration values were selected. The respiration values used for regression analysis were calculated by finding the average respiration value of the three closest field respiration values to each organic matter sample.

A z-test (difference between means) was also performed to analyze any potential differences between the respiration values and the organic matter content between sites one and two. The null hypothesis
(H₀) and the alternative hypothesis (Hₐ) are shown below where the null hypothesis indicates that there is no difference between the biochemical parameters (respiration and organic matter) of sites 1 and 2 and the alternative hypothesis indicates that site 1 will have greater biochemical parameters than site 1.

\[
\begin{align*}
H₀ & : \bar{x}_1 = \bar{x}_2 \\
Hₐ & : \bar{x}_1 > \bar{x}_2
\end{align*}
\]

If the null hypothesis is rejected, we would accept the alternative hypothesis stating that site 1 values are greater than site 2 values. If the null hypothesis is accepted, the means are equal and there is no significant difference. For this calculation, \( \alpha \) was set to 0.05. The z-test is two-tailed; therefore the critical values will be located at \( Z_{0.025} \). Using the z-test critical values chart, the critical values are found to be -1.96 and 1.96. That is, if the calculated z-score is \( \leq -1.96 \) or \( \geq 1.96 \), we reject the null hypothesis and conclude site 1 has values of respiration and organic matter greater than site 2.

(5.0) Results

5.1 Soil Classification

Both study areas were mapped on the online Web Soil Survey and the respective soil types are evident (Figure 4). According to this survey, the soils within study area 1 are Typic Dystrudepts. The soil map unit name is “Manor extremely stony loam, with 25 to 50% slopes”. This soil type is generally deep, well drained, of course-loamy texture, consisting of mostly sand, with some silt and less clay. According to the survey, the Wissahickon’s upper most organic soil horizon is at most, 2% organic material. That is, a predicted value of soil organic matter is at least 2% according to the soil survey. This data, along with other selected soil quality parameters, have been displayed in graphical form in figures 7-10.

The soils at site 2 are also Typic Dystrudepts. The soil map unit name is “Chester silt loam, 3 to 8 percent slope”. Though site 1 and 2 has different soil map unit names according the Web Soil Survey, the soils themselves are similar in terms of their contents and particle size distribution. The main difference between the two soil map unit’s names is that site 1 soil has relatively steeper slopes compared with site 2 slopes.
Hand texturing of soil was done at each site in order to potentially confirm web soil survey data and to attempt to further understand the particle distribution of percent sand, silt and clay. After hand texturing, it was concluded that both sites 1 and 2 seemed to have similar texture and they both seemed to fit within the sandy loam texture range. Sandy loams range from 50-70% sand, 30-50% silt, and 0-20% clay. A several inch long ribbon was able to be formed out of the wetted soil samples at both sites. This may provide evidence that there is at least a degree of clay particles in the Wissahickon soil. The ribboning effect could have been supplemented by silt particles as well. A more accurate way of calculating percent sand, silt, and clay would be soil texturing by hydrometer. Also, the soil color code was found to be 10YR with a value of 4 and a chroma of 4. This data was found using Munsell’s soil color chart (Figure 5).

5.2 Respiration Data

Respiration was initially recorded in parts per million (ppm), but has since been converted to mgCO₂/cm²s. At site 1, 42 respiration values were collected. The level of respiration ranged from 0.0059 to 0.0093 mgCO₂/cm²s, with a mean value of 0.0077 mgCO₂/cm²s. At site 2, 24 values were collected. Values ranged from 0.0056 to 0.008 mgCO₂/cm²s, with a mean value of 0.0065 mgCO₂/cm²s. The standard deviation at site 1 was 0.008 mgCO₂/cm²s while the standard deviation at site 2 was 0.006 mgCO₂/cm²s. Further statistical analysis of the respiration data is located in section 5.5. Site 2 is approximately half the size of site 1; therefore approximately half the amounts of respiration measurements were taken.

According to the Cornell soil respiration health ranking graph (figure 17), site 1 has a mean respiration score of approximately 30/100 while site 2 has a respiration score of approximately 20/100. Since the ranking chart is in units of mgCO₂/g dry soil, the previously discussed respiration units were converted to these units so the chart values could be analyzed.

5.3 Soil Organic Matter/ Organic Carbon Data

Organic matter data was recorded by Penn State in % organic matter. At site 1, 10 organic matter samples were run. The values ranged from 3.98 to 26.09 %, with a mean value of 13.015 %. At site 2, 8 organic matter samples were run with values ranging from 4.28 to 6.17 %, with a mean value of 5.5%.
The standard deviation at site 1 was 7.6 % while the deviation at site 2 was 0.6 %. These % organic matter values can and were converted into organic carbon values by multiplying the % organic matter by 58% (Pribyl et al., 2010). Further analysis of this data is presented in section 5.5.

According to the Cornell soil organic matter health ranking graph (figure 16), site 1 has a score well over 100/100, and site 2 has a score of about 80/100, assuming both sites 1 and 2 have a soil texture of approximately medium grained.

5.4 Geologic Analysis

Wissahickon Valley Park is located in the piedmont physiographic province. This province generally features small foothills and complex geology. Most bedrock found at the park is of metamorphic origin. Metamorphic rocks are originally sedimentary rocks that have been induced with high heat and pressure under the earth’s surface. During tectonic uplift, these deep metamorphic rocks can be thrust upward towards the earth’s surface. One rock type found on site is schist, whose parent sedimentary material is shale. Shale is a cemented mud like sedimentary silicate rock. This schist is notably high in the mineral mica, making it micaceous schist. The mica mineral gives the park’s soil an elevated magnesium concentration. Throughout the park, the ground glimmers. This is due to the reflection of these mica crystals.

Another rock type identified at both sites is quartzite. This rock’s strength is attributable to its high composition of the highly resistant mineral quartz. Quartz is highly resistant due to its strongly bonded crystalline structure. Quartzite has the parent material of sandstone, and is also formed through the metamorphic processes of intense heat and pressure. Depending upon the length of cooling, quartzite can have large quartz crystals from slow cooling, or very small crystals from fast cooling. Both small and large quartz crystals were observed within the study areas.

The final rock type present within the Wissahickon Valley Park is gneiss. The parent material for gneiss is much harder to identify than the schist and quartzite, but gneiss is easily identified by the foliation of dark and light bands within the rock. This banding is caused by relative differences in the densities of minerals found within the gneiss rock during exposure to high heat and pressure. Minerals of similar densities will line up in horizontal layers corresponding to their specific gravities.
Weathering of the above mentioned rocks, over millions of years, is what formed the soil found on the research sites. Due to the abundance of quartzite and schist found on site, much of the soil is composed of sand sized particles from the weathering of quartzite while the smaller grained particles may have accumulated due to the weathering of the schist and gneiss.

5.5 Statistic Analysis

The respiration and organic matter correlation R-value at site 1 was found to be approximately -0.26. This value implies a weak negative linear correlation between the two variables. The R-value at site 2 was found to be 0.47, which implies a weak positive linear correlation. The respective R-values have been plotted in figures 13 and 14.

The respiration z-score was found to be 6.69. The organic matter z-score was found to be 3.26. These values are both ≥ 1.96, therefore the null hypothesis is rejected. Rejecting the null hypothesis implies that site 1 has a greater respiration and organic matter mean value than site 2. Since α was set to 0.05, there is a 95% confidence interval that we can accept the alternative hypothesis in which site 1 has greater biochemical values than site 2.

6.0 Discussion

The first research question asked if there exists a correlation between soil respiration and organic matter content. The hypothesis stated there may be a strong, positive, linear correlation. After statistical analysis, it can be concluded that the data presented in this research does not support a strong correlation between the two soil parameters. Both sites 1 and 2 had R-values less than 0.5 which implies a weak linear correlation according to Pearson’s R-test. The statistically weak correlation may be due to several factors. First, organic matter sampling was limited by budget which in turn limited the amount of inputs into the statistical R-test equation. Generally, higher volumes of data support more confident statistical outputs. Also, the respiration samples were taken a small distance away from where the organic matter samples were taken. The respiration measurements should have been taken directly overtop where the organic matter samples would be taken. This may have allowed the correlation to be more accurate and more representative of the area in which the soil was sampled for organic matter testing.
Future research of this nature should employ more organic matter sampling, and also include other forms of biochemical parameters. Other biochemical data that would have benefited this research are in the form of microbial biomass and enzymes, total organic carbon, and total nitrogen. The microbial biomass data would have provided a picture of how dense and active the microbial populations are. This data would have paired well with basal respiration, as the amount of soil respiration deals largely with the microbial communities and their activity. Total organic carbon and nitrogen data would have provided insight into the mineralization activity present at both sites while supplying useful information regarding important nutrient reserves in the soil.

The second research question asked if there are significant differences in respiration values between sites 1 and 2, and also if there are significant differences in organic matter between sites 1 and 2. The hypothesis stated that site 2 would have lower levels of both respiration and organic matter than site 1. The z-test results showed that both respiration and organic matter show significant differences between the two sites. Both z-values were greater than the critical value, thus, with 95% confidence (α=0.05), it can be concluded that there exists significant differences in both respiration and organic matter between both sites 1 and 2. This may be attributed to the human impact that site 2 has been subject to. It seemed most of the site’s soils were compacted and highly managed by heavy vehicles. Knowing that site 2 shows visual signs of soil compaction and deforestation, and also has lower mean biochemical indicators than site 1; it can be confidently said that this research has shown respiration and organic matter content do change with varying levels of soil and environmental conditions. Furthermore, this research has shown that land use will change soil organic matter content which will in turn decrease the soil respiration.

The geologic and Web Soil Survey assessment showed that both sites have the same soil makeup and consist of the same geologic material; therefore the different biochemical values found between the two sites cannot be attributed to a different soil type. Since the two sites show signs of having the same soil type, the soil contained within sites 1 and 2 shouldn’t have a changing impact on the biochemical indicators. If the soil was different between the two sites, then the changing levels in respiration and organic matter could be partially attributed to the soil type.

These geologic and soil type factors certainly have an effect on cycling of organic matter in the soil, and the subsequent transformation of this material to carbon dioxide (Bradley-Cook et al., 2015). The schist
found on site may contribute to the clay content that the soil survey stated is present within the site soil. Clay particles help retain organic matter and also can aid in the long-term storage of partially decomposed organic matter. Site 1 tested for quite high levels of organic matter which may indicate a well aggregated soil which locks in this organic matter, whereas site 2 showed much lower levels of organic matter. This could indicate that site 2 soils have potentially been compacted, or tilled, which in turn damages the aggregation and thus decreases the soils ability to retain organic content. The low organic content can also certainly be a result of the deforestation, which decreases the available inputs of organic matter over time.

(7.0) Conclusion

Decomposition processes in an ecosystem are responsible for major contributions of plant available carbon and essential nutrients in the soil. Terrestrial environments rely upon fluxes of mineralized nutrients for forest growth and health. Organic matter decomposition and thus nutrient fluxes are moderated most notably by the quality of biologically active substrate in the soil (Robertson et al., 1991). Collecting biochemical data, such as soil respiration and soil organic matter values, can be used to help develop forest management plans, and more broadly, can be used to help determine soil health (Wang et al., 2003). Soil basal respiration measurements, as well as organic content analysis, are now being utilized to classify the extent of a contaminated or polluted site (Veum et. al., 2014). As seen in site 2, compaction and deforestation have an impact on the abundance of organic material and have adverse effects on the microbial community. Pollution will also cause a change in the microbial community as well, thus changing the rate of respiration. Assessing a polluted sight using soil respiration can be difficult though since many types of pollutants contain organic compounds which can actually increase the microbial activity.

The broader implications of this research were to examine the feasibility of using these biochemical indicators to potentially assess the health of the soil at an impacted site. The statistical data shows strong differences in mean respiration rates between sites 1 and 2, as well as strong differences in mean organic matter content between sites 1 and 2. The human impacted site 2 consistently showed much lower levels of both respiration and organic matter in comparison to site 1. Implications for site soil assessment using these biochemical indicators, of soil organic matter and soil respiration, are evident in this research.
(8.0) Acknowledgments

I would like to thank Dr. Plante and the Department of Earth and Environmental Sciences for supplying the equipment necessary to make the research possible. Additionally, Dr. Plante supplied invaluable advice that directed the research down the right path. I would also like to thank Mitch Cron for taking the role of the secondary reader for this paper in which he supplied critical input.

(9.0) References

Academy of Natural Sciences. Wissahickon Valley Park Master Plan. Fairmount Park System Natural Lands Restoration Master Plan, Volume II Chapter VI


(10.0) Figures

Figure 1. Map of the study area locations along with respiration and organic matter data points.

Legend
- Respiration Samples: Site 1
- Respiration Samples: Site 2
- Organic Matter Samples: Site 1
- Organic Matter Samples: Site 2
Figure 2. EGM-4 and soil respiration chamber used to collect soil respiration data.

Figure 3. Wissahickon outcrop examined as part of geologic assessment.
Figure 4. Web Soil Survey map of study area used to help collect study area soil classification, provided by the USDA.

Figure 5. Munsell's color chart used to classify Wissahickon soil color.
**Figure 6.** % Sand vs depth (Web Soil Survey).

**Figure 7.** % clay vs depth (Web Soil Survey).

**Figure 8.** % Organic matter vs depth (Web Soil Survey).

**Figure 9.** pH vs depth (Web Soil Survey).
Figure 10. Vegetation map with relative disturbance levels provided by the Academy of Natural Sciences. Study area 1 is within “disturbance class 2” while study area 2 is within “disturbance class 3”.

Study Area 1

Study Area 2
CH$_2$O (Organic Matter) + O$_2$ $\rightarrow$ CO$_2$ (Respiration) + H$_2$O + Nutrients (Mineralization, P$_{O_4}$, N$_{O_3}$)

**Figure 11.** Chemical reaction that leads to respiration and mineralization.

**Figure 12.** Site 1 correlation coefficient plot.

**Figure 13.** Site 2 correlation coefficient plot.
Figure 14. Site 1 vs site 2 mean respiration values.

Figure 15. Site 1 vs site 2 mean organic carbon values.
Figure 16. Cornell soil health ranking chart for (organic matter %).

Figure 17. Cornell soil health ranking chart for (respiration mgCO₂/g).
Figure 18. Pearson’s R-Test equation used for the statistical analysis of correlations between organic carbon and respiration.

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r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}
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