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Microclimatic factors and soil characteristics of Arroceros Forest Park in the City of Manila, Philippines

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Abstract. *Berame JS, Elazegui EP, Arenas MC, Orozco JA. 2021. 2021. Microclimatic factors and soil characteristics of Arroceros Forest Park in the City of Manila, Philippines. Biodiversitas 22: 4956-4962.* Microclimatic factors affect many ecosystem functions. However, the challenge of acquiring consistent data has impeded the quantitative assessment of the spatial heterogeneity of soil-climate in Arroceros Forest Park as an artificial urban forest park known as the last lung of the City of Manila. With this unassisted urban forest park, this study aims to determine the microclimatic factors such as light intensity, air temperature, air humidity, wind speed and direction, soil temperature, soil pH, percent organic matter, percent soil moisture and soil texture by using a sieve analysis and textural triangle method to know the status of the forest park. These procedures reveal the soil type available in the park to be clay and loam suitable for growing plants abundantly. Results showed that four microclimate factors viz. air temperature, air humidity, percent organic matter, and soil texture, were highly significant (p<0.000). Additionally, it further revealed that microclimatic factors such as light intensity, wind speed, and soil pH are essential in an ecosystem. It also found that soil size is a significant parameter for soil characterizations in this kind of study. Finally, the division of soil microsites into different positions based on prevailing light or shade conditions helped assess the significant variations of soil characteristics and conditions within the study area.

Keywords: Dynamics, sieve analysis, soil, textural triangle, urban ecosystem, urban forest.

INTRODUCTION

The Arroceros Forest Park is situated in Ermita, Manila with a total land area of 2.2-hectares. The forest park is famously known as “Manila’s last lung,” as it is the city’s only natural park. During last 2017, the City of Manila was included in the top 10 stressed cities globally due to air pollution and other factors, according to a study conducted by a UK-based firm called Zipjet (Philstar.com 2017). The rapid urbanization in Metro Manila caused the city to have fewer green spaces, which reduced air quality. An additional reason why pollution is present in Metro Manila is massive population growth, infrastructure development, and increased economic activities, which led to the environmental deterioration of Metro Manila (Gorme et al. 2010). The focus is now to provide conservational support to this precious green urban landscape. The relevant study for the determination of the current microclimatic situation of the Arroceros Forest Park has revealed soil moisture and temperature patterns, which affect a wide variety of processes and interactions in the near-surface (Melillo et al. 2002; Seneviratne et al. 2010). Soil moisture plays a vital role in sustaining terrestrial ecosystems, water cycling, erosion, and landscape evolution (Burnett et al. 2008; Penna et al. 2013; Troch et al. 2013; He et al. 2019). Soil moisture significantly controls the atmospheric climate by regulating energy and water balances (Guo and Lin 2018). It also functions as a primary source of moisture for the formation of clouds and precipitation and affects air temperature and boundary-layer stability (Koster et al. 2004). Soil heat provides thermal inertia to the atmospheric climate system (Hauser et al. 2017), mediates land-atmosphere gas exchange, determines the coupling between soil moisture and evapotranspiration (ET) (Seneviratne et al. 2010), and influences many biogeochemical and hydropedological processes (Seyfried et al. 2016).

Subsequently, microclimatic factors are reported to significantly impact the different interactions, processes, and disturbances in the entire terrestrial ecosystem (Berame et al. 2021). For example, temperature and pH level are microclimatic factors that influence the interaction of organisms as temperature varies with climate, topography, location, and other physical characteristics. On the other hand, the soil's pH level depends on the parent material and geologic time scale but can also react to the vegetation composition. Additional microclimatic factors include light intensity, air temperature, air humidity, wind speed and direction, soil temperature, and soil pH level. In addition, it can influence the rate of ecosystem processes, disturbance systems, and the biotic community (Chapin III et al. 2016).

The impact of topographic attributes on soil microclimate distribution is dependent on the time of the year. In some cases, vegetation type and coverage can be distinct between contrasting aspects, which influence rainfall infiltration into the soil and the degree of tree shade and associated soil microclimates and erosion (Gutiérrez and Vivoni 2013). Hence, the temporal dynamics of vegetation cover regulate the actual influence of topographic factors on soil microclimates (Gutiérrez and Vivoni 2013; Ivanov et al. 2018). In addition, the relationship between the spatial variability of soil moisture and topography varies at different spatial scales.

Consequently, identifying the forest park factors that influence soil climate is key to the development of accurate soil analysis (Hlavinka et al. 2011). With this, studies have signified that topographic relief is dynamic to soil microclimates (Gutiérrez and Vivoni 2013). It is also recognized that topography and land use determine slope insolation and the differentiation in microclimate's influence rainfall infiltration and subsurface flow, resulting in localized soil microclimate management (Liu et al. 2011; Corrao et al. 2017).

On the other hand, soil differs in terms of appearance, forms, functions and uses. Soil types can be clay, silt, and sand (Odum 1994) which varies by particle size and texture. According to size, the soil is composed of particles of sand (2.0-0.05 mm in diameter), silt (0.05-0.002 mm) and clay (less than 0.002 mm) particles (King 2003), while soil texture is divided into three groups such as coarse (sandy soil with 70-100% sand-sized particles), medium (even distribution of clay and sand particles), and fine (35-40% clay-sized particles) (Ritchey et al. 2015). Soil texture influences the use of soil in agriculture and the natural ecosystem (Havlicek and Mitchell 2014). It is considered the most vital soil property to influence soil and water relationships (Oli and Subedi 2015). The variations in the soil texture proportions can affect the textural class that determines the features of the soil (Campbell 2014)

Thus, this study aims to utilize the common instruments used to determine the microclimatic factors in the study area and to determine the soil particle size distribution using the sieve method and textural triangle to relate the particle size to the specific surface area in the current status of the Arroceros Forest Park in the City of Manila, Philippines.

MATERIALS AND METHODS

Study area and sampling

The Arroceros Forest Park is a protected forest park in the City of Manila located at 14.5942° N, 120.9817° E with a total land area of 2.2 ha. This forest is an essential urban greenscape and a hub for active research due to its rich biodiversity supported by an ambient microclimate. The area's climate is humid with annual mean precipitation of 610 mm and a mean annual air temperature of 7.5 °C. Loam, clay, and silt were predominant as the most prevailing soil particle fractions. The determination of microclimatic factors and soil textures was conducted through the identification of four quadrants.

To cover a varied range in soil characteristics, sampled soils were analyzed using the sieve method and textural triangle method, including ribbon, grittiness, and smoothness tests to determine the soil sample's textural class. It was noted that different quadrats with soil samples were conducted at the site of the study. In January 2020, the study was performed using the four quadrants to determine the microclimatic factors. In soil characterization sampling, the soil texture class identification has used textural triangle and the determination of the particle size has used sieve analysis.

Microclimatic factors

Light intensity: A light meter was used to collect the light intensity for each quadrant accurately. The light meter was positioned at arm level, pointing the sensor plate towards the light source. The measurement was recorded once the reading had stabilized.

Air temperature, air humidity, wind speed, and wind direction: A pocket weather meter was used to determine the air temperature, air humidity, wind speed, and wind direction.

x 

Figure1. Map of Arroceros Forest Park in the heart of the City of Manila, Philippines

Soil temperature: A soil temperature thermometer was used to determine the temperature of the soil by inserting the metal rod of the soil thermometer in the ground. The soil samples were collected from quadrants 1 to 4 to measure the soil pH. The soil samples were placed on a black plastic bag to avoid light penetration and maintain the dark condition. In the laboratory, the pH level of the soil samples was determined using CPR/BCG/CPR pH indicator dyes. The soil samples from four quadrants were placed in separate test tubes. Seven drops of CPR pH indicator dye were added to each test tube, gently swirled 20 times, repeated twice, and set aside for 5 minutes. Afterward, the pH of the soil was determined using the corresponding color chart of the pH indicator.

Percent soil organic matter: 25 g dry weight soil sample from each quadrant was placed in a separate crucible with cover. The soil sample in crucibles was a furnace for 168 hours. The percent soil organic matter was obtained by subtracting initial dry weight from ignited weight and multiplying it to 100.

Percent soil moisture: 25g fresh weight soil sample was placed in a white paper bag. The soil sample was oven dried for 56 hours at 900 0C and measured to determine the dry weight. The final weight was obtained to determine the percent moisture content of the soil by getting the difference between the fresh and dry weight and multiplied to 100.

Particle size analysis

Textural triangle was used to determine the soil textural class by identifying the percentages of silt, sand, and clay (Lekaj et al. 2016).

Sieve analysis was used with **s**oil samples weighing 100 g. At first, soil samples were oven-dried to pass through sieve #35, sieve #40, and sieve #45. Next, the sieve was agitated in the sample rolls on irregular motion over the sieve. Finally, the material retained on the sieve was rubbed using mortar and pestle. The collected materials from each sieve were placed on pre-weigh paper boxes and weighed. The percentage of soil retained on each sieve was calculated based on the total mass of the sample to determine the soil textural class.

Statistical analysis

The study performed statistical analysis such as mean, standard deviation, and f-test to determine differences after testing data to meet conditions of normality and homogeneity. Probability values of $p < 0.05$ were considered significant. Data analysis was conducted through PAST statistical data analysis software.

RESULTS AND DISCUSSION

Microclimatic factors

The results of a study conducted on some of the microclimatic variables are summarized in Table 1. From the study, the wind speed and wind direction and soil pH were constant variables that were not significant.

As presented in Table 1, there was no significant difference in the light intensity in the four quadrants identified in Arroceros Forest Park with a p-value = 0.066. This suggests that the light intensity in the area is almost the same because of the tall trees present and the wind speed. During the data collection, the wind speed was constant due to the surrounding of the area by trees. The other continuous variable, such as soil pH, was not significant, possibly due to rain, temperature, and dissolved minerals in the area.

In addition, the air temperature was significant (p-value = 0.00), possibly due to the location of the forest park, which is situated beside the Pasig River, Quiapo Bridge, LRT 1 Station, nearby condominiums, and establishments. Furthermore, air humidity was significant with a p-value = 0.00 due to the plant diversity in the forest park (trees, shrubs, herbs, grass), cars passing nearby the park, and air temperature. More so, soil temperature (p-value = 0.00) is possibly affected by plant vegetation, soil moisture, and slope of forest park. Similarly, the percent organic matter was significant (p-value = 0.00). This is possibly an expected fact that the forest park receives the same amount of rain, soil moisture, and climate. Lastly, soil moisture was also significant with a p-value = 0.00 because it was directly affected by the topography, water supply, and soil humidity.

Soil characteristics

As presented in Table 2, the composition of sand, silt, and clay for the textural class is more profound from one texture to another. As assumed in the study, soil texture may contribute to each microbial group (Lauber et al. 2008). It further reported that sand was responsible for general bacteria variability according to Johnson et al. (2003), soil type and physical properties could influence microbial community composition and soil texture had a more substantial effect than plant species.

Table 1. Summary table of microclimatic factors of Arroceros Forest Park, City of Manila, Philippines

Factors	Mean	SD	F-Test	*p*-value	Remarks
Light intensity	20.468	0.048	3.117	0.066	Not Significant
Air temperature	31.433	0.048	35.933	0.000	Significant
Air humidity	68.525	0.068	2426.500	0.000	Significant
Wind speed and direction	20.000	0.000	Constant variable		Not Significant
Soil temperature	28.140	0.191	36.461	0.000	Significant
Soil pH	5.000	0.000	Constant variable		Not Significant
Percent organic matter	5.690	0.046	76.634	0.000	Significant
Soil moisture	6.655	0.022	3936.684	0.000	Significant

Using the textural triangle, Table 3 contains the textural classes of the soil samples. For example, the proportion of sand, silt, and clay from soil sample S1 intersected at the area of clay loam, similarly, sample S2 crossed at the area of loam; soil sample S3 intersected at the area of sandy loam; soil sample S4 intersected at the area of silt loam; soil sample S5 intersected at the area of clay; soil sample S6 intersected at the area of sandy clay, and soil sample S7 crossed at the area loam (King 2003; Hewitt 2015).

Meanwhile, Table 4 displays the textural quality of soil samples that were determined using the feel method. Based on the findings, the three soil samples A to C formed a ball, produced ribbons longer than 5 cm, were predominated by wet texture. Therefore, considering these characteristics of these three soil samples were classified as clay loam.

Soil-landscape attributes indexes

Environmental factors such as soil-landscape, parent material, climate, and vegetation cover substantially influence the variability of sub-factors like moisture availability, temperature (soil and air), and nutrient availability that regulate the forest ecosystem's variability (Tamai 2010; He et al. 2016). Various studies emphasized that soil-landscape had good potential to explain a large part of the variability in soil properties within a given environment (Ayoubi et al. 2012; Zeraatpisheh et al. 2019). Rodrigo-Comino et al. (2016) showed that soil erosion could affect the distribution of the surface soil components.

Table 2. Particle size conversion table

Sieve designation		Nominal sieve opening
Standard	Mesh	Inches
0.500 mm	No. 35	0.0197
0.420 mm	No. 40	0.0165
0.354 mm	No. 45	0.0139

Table 3. Summary table of the % composition of sand, silt, and clay for textural class

Soil sample	% Sand	% Silt	% Clay	Textural class
S1	33	33	34	Clay loam
S2	50	30	20	Loam
S3	80	5	15	Sandy loam
S4	25	60	15	Silt loam
S5	30	20	50	Clay
S6	60	10	30	Sandy clay loam
S7	40	40	20	Loam

Table 4. Unknown soil samples describing the textural class using feel method analysis

Soil sample	Does it make a ball?	Does it make a Ribbon?	Ribbon length	Pre-dominate wet feel	Textural class
A	Yes	Yes	> 5 cm	Yes	Clay loam
B	Yes	Yes	> 5 cm	Yes	Clay loam
C	Yes	Yes	> 5 cm	Yes	Clay loam

Although the interpretations of ecosystem interactions are complex, some novel insights between soil and topographic attributes have been found. The feel method analysis and sensitivity results showed that soil parameters were influenced by soil-landscape and microclimatic conditions (Bramer et al. 2018; Naiman and Likens, 2018).

Succeedingly, quantitative landscape attributes in the area were supposedly affected through the surface and elevation of the forest had a significant contribution to soil variability. It has been understood that elevation slope, height, and aspect attributes have considerable effects on soil temperature, water content, and soil redistribution rate (Liu et al. 2011). Some studies have indicated those landscape attributes, including gradients of elevation, latitudinal variation, and soil moisture index, play an essential role in the soil variability (Coblentz and Riitters 2004). The mentioned influences on soil-landscape and received sunlight intensity (short wave and long wave) and the resultant soil temperature are major causes of spatial variation of soil surface energy, water balance, which ultimately affect forest ground ecosystem (Florinsky et al. 2002; Bohner and Antonic 2009). Land elevation, forest shading, mid-slope, and landscape are closely related to solar radiation and soil temperature, affecting organic matter decomposition (He et al. 2016).

Therefore, a substantial variation in soil within the study area might be ascribed to variation in topographic attributes that regulate soil availability and redistribution. As trees covered in the study are considerable, it could control the amount of sunlight reaching the forest ground and the soil surface temperature. Moreover, in the forest ecosystems, differences in litter leaf quality of tree species (Bardgett and van der Putten 2014) and root exudates (Eisenhauer and Reich 2012) could lead to variability in soil. Vegetation indexes can indirectly and directly affect soil properties (Bishop and Minasny 2005).

Effects of soil size variability's and characteristics

Division of soil microsites into different positions based on the prevailing light or shade conditions helped assess the significant variations of soil conditions

In addition, results support the comments on the importance of soil characterizations and soil position effects on the variations of the forest conditions in different soil sizes (Latif and Blackburn 2010; Čater et al. 2014; Vilhar et al. 2015). Higher penetration levels of solar radiation in significant gaps were responsible for the lowest soil moisture content measured at the center. The center being the most exposed position to light (solar radiation), the anticipation of fast evaporation conditions leading to lower moisture content was expected.

Interestingly, the variability of soil temperature was explainable within the study area and size factors. This result confirms that in the different sizes, soil temperature across other areas of the forest differs. The coverage of the relatively dense herbaceous layer at the forest floor blocked soil surfaces from the direct heating-up effect of the incoming solar radiation. This, therefore, led to the observation of low soil temperature across the forest area. Contrarily, quadrant four had low coverage of herbaceous layer enabled heating-up of the soil surfaces by penetrative solar radiation, resulting in high soil temperature across the forest locations. Further, the heavy shading conditions have caused comparable soil temperature readings across studied forest areas. In general, findings suggest that soil temperature variations under different forest positions and locations of various sizes are closely connected to the complex interaction of shading and insulating effects of undergrowth vegetation. Nonetheless, this recommendation is subjective to further future studies (Ritter et al. 2005).

Soil and microorganisms influence in the forest ecosystem

It was noticed in the study that organic carbon, pH, and soil particle distribution were the most important factors among the soil properties. Studies have demonstrated that soil properties could regulate the activity in the floor ecosystem (Wang et al. 2017). Findings showed that organic carbon had a strong direct effect and showed a strong indirect effect on soil. Various studies have confirmed direct and indirect interaction between organic carbon and microorganisms an essential part of the carbon and nitrogen cycle in the ecosystems (Aislabie and Deslippe 2013). Also, through their associated enzymes, they regulate the amount of carbon and nitrogen in soil (Cusack et al. 2011). In addition, soil microorganisms play an essential role in soil structure through binding soil particles and organic matter (Six et al. 2000; McMahon et al. 2005; Williams et al. 2006).

Basically, the intracellular pH of nearly all microorganisms in an ecosystem is usually within 1 pH unit from neutral, thus soil pH may be an unbiased driver of microbe diversity (Madigan et al. 2006). More so, it has been shown that soil pH is one of the main factors in soil bacteria distribution and can be used as an only predictor variable in large (Fierer and Jackson 2006). Further, Lauber et al. (2008) confirmed that soil bacteria were related to soil pH, which was the top predictor of soil bacteria across the landscape or soil surface. On the contrary, Wang et al. (2013) has stated that pH has no significant direct effect on soil microorganisms and Brocket et al. (2012) have shown that soil pH was not the explanatory variable for microbial community function.

Soil microorganisms are primarily attached to soil particles. In this regard, findings showed that different soil particle fractions had varying effects on other microbial groups. Silt and sand were directly correlated. However, the indirect analysis was affected by particle size fractions. Various studies (Bach et al. 2010) informed that there is higher microbial biomass and more diversity in silt and clay fractions. One possible explanation for these results is that finer size particles provide small pore sizes of soil particles. In addition, silt and clay particles have more water holding capability and impact water and nutrient availability (Bach et al. 2010).

This study revealed that microclimatic factors such as light intensity, wind speed, and soil pH are significant factors in an ecosystem. Wind speed and soil pH for all the quadrants were at a constant value. Air temperature, air humidity, soil temperature, percent organic matter, and soil moisture were found highly significant among the four quadrants, as shown in the study. The value of these microclimatic factors from four quadrants differed significantly. On the other hand, the use of a textural triangle was helpful to determine the point area where the percentage of sand, silt, and clay intersected. Results showed that the mass of retained soil per sieve level and its percentages were essential to determine which soil particles could be clay, silt, and sand in sieve analysis. This was done by comparing the weight per level to the standard sizes of the particle. The soil size was found to be a significant parameter for soil characterizations and further investigation in this regard is advised. Finally, soil sensitivity analysis indicated that soil-landscape attributes and vegetation indexes were influential parameters and could indicate soil microorganisms for soil quality assessment and analysis in forest soils.

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