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SOIL PRODUCTIVE QUALITY THROUGH PHYSICAL, CHEMICAL AND BIOLOGICAL INDICATORS AT THE BOTANICAL PARK OF SUCUA CANTON, 2022

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ABSTRACT

The soil preservation takes a priority approach for all sectors of society since its damage adversely affects the components of nature and the life of the human being. Therefore, the objective was to determine the soil quality at the Botanical Park in the Sucúa canton through the analysis of physical, chemical, and biological indicators in the forest soils of the Botanical Park, in addition to the application of the Soil Quality Index and the Diversity Index. Methodology: The investigation was carried out with a mixed approach, randomly sampling 30 soil samples, and using a GPS to determine the sampling points of the botanical park area. These samples were collected at a depth of 20 cm, to be analyzed in the Science laboratory of the Escuela Superior Politécnica de Chimborazo where physical-chemical parameters such as humidity, bulk density, electrical conductivity, organic matter, and for the biological processes, the edaphic macrofauna of the place was identified. Results: The Soil Quality Index was evaluated presenting a class 2, which means high quality, evidenced by a high organic matter content, good water drainage and an optimal pH for plant growth and development. The biological analysis recognized that the haplotaxide family formed by a majority of earthworms was of greater importance in relation to the other organisms (detritivores/non-detritivores), which is an indicator of a high-quality soil. Implications: In order to maintain good quality soils in this place, it is recommended to study the soil considering the parameters already analyzed and making comparisons to identify if there are variations that disturb the quality of the soil. Conclusions: this evaluation responds to a cyclical

process that integrates different physical, chemical, biological and biodiversity evaluation parameters, giving a value of 0.64 corresponding to a high-quality soil.
Keywords: soil; forestry; physical indicator; chemical indicator; biological indicator; soil quality index; diversity index

RESUMEN

La preservación del suelo toma enfoque prioritario para todos los sectores de la sociedad, porque su daño repercute adversamente sobre los otros componentes de la naturaleza y de la vida en si del ser humano por lo cual se planteó como Objetivo: determinar la calidad del suelo del Parque Botánico del cantón Sucúa, mediante el análisis de indicadores físicos, químicos y biológicos en los suelos forestales del Parque Botánico además de la aplicación del Índice de Calidad del Suelo y los Índices de Diversidad. Metodología: La investigación se lo realizo con enfoque mixto, muestreando aleatoriamente 30 muestras de suelo, usando un GPS para la determinación de los puntos muestrales del área del parque botánico, estas muestras se recolectaron a una profundidad de 20 cm de profundidad, para ser analizadas en el laboratorio de Ciencias de la Escuela Superior Politécnica de Chimborazo donde se determinó parámetros físicos-químicos como humedad, densidad aparente, conductividad eléctrica, materia orgánica y para los procesos biológicos se identificó la macrofauna edáfica del lugar. Resultados: se evaluó el Índice de Calidad de Suelo, presentando una clase 2 que corresponde una alta calidad, evidenciado por un alto contenido de materia orgánica, buen drenaje del agua y un pH óptimo para el crecimiento y desarrollo de las plantas. El análisis biológico reconoció que la familia haplotaxida formada por su mayoría de lombrices fue de mayor importancia con relación de los demás organismos (detritívoros/No detritíviros) el cual es indicador de un suelo de alta calidad. Implicaciones: Para mantener una buena calidad en los suelos del lugar se recomienda estudiar el suelo considerando los parámetros ya analizados y realizando comparaciones para identificar si existen variaciones que perturben la calidad de suelo. Conclusiones: esta evaluación responde a un proceso cíclico que integra diferentes parámetros de evaluación físicos, químicos, biológicos y de biodiversidad dando un valor de 0,64 correspondiente a un suelo de alta calidad
Palabras clave: suelo; forestal; indicador físico; indicador químico; indicador biológico; índice de calidad del suelo; índice de diversidad

INTRODUCTION

Forest soils are essential and considered as a support for plants and other organisms, for this reason, their quality is critical to regulating the climate, preventing water and air pollution by damping possible contaminants, and protecting hydrographic basins by normalizing the rainfall infiltration and distribution (Gomez Ávila & Hoyos Rojas, 2020). (Cantú, 2007) expresses that carrying out a soil quality evaluation through physical, chemical, and biological indicators is important to determine the natural and anthropic alterations that alter the parameters of the soil.

Worldwide, according to the Food and Agriculture Organization of the United Nations, FAO (2011), 33% of the land is degraded thanks to erosion, salinization, and soil compaction. This is due to the increase in the population, as well as the water and food demand causing greater interventions on the soil whose situation is in an acceptable condition.

In Ecuador, there has been a soil loss rate of between 30 and 50 t ha-1 year-1, the main cause being global warming, deforestation with an average of 3000 km2/year, and mining projects (Vargas et al., 2016); these anthropogenic activities are currently controlled.

The municipal government of the Sucúa canton (2011) states that the Botanical Park is an ecological reserve located in the community "El Kiim" to the South-East of the Sucúa canton. It has an area of 28.06 ha and has a high diversity, which enables the balanced conservation of the environment, which is maintained by the action of factors such as climate, vegetation, structure, as well as soil and relief quality(Gobierno municipal del cantón Sucúa, 2014). From the point of view of López (2022), activities such as tourism, destruction and modification of the forest area alter the properties of the soil, leading to irreversible losses for conservation.

Haro (2022) expresses that the management and application of indicators facilitates the understanding of the dynamics and functioning of the productive systems of the soil. Therefore, carrying out an integral evaluation measured in a certain time scale, systematically contributes to the evaluation of the behavior of the soils (Toro et al. 2010). This evaluation of the soils is based on methodological frameworks that facilitate the selection of appropriate indicators in the integration and transformation of the information to have a clearer picture of the current state of the soils and to be able to present sustainable alternatives in terms of production systems. (Rodríguez et al., 2010).

Based on the above, the objectives were to determine the quality of the soil through physical, chemical and biological indicators in the botanical park, with the purpose of recommending correct alternatives for sustainable soil management. The scope of the project is to collaborate with scientific research and relevant information on the state of the soil in the Botanical Park so that, through the results obtained, the authorities in charge have a starting point to act in the management, conservation, and remediation of the case

METHODOLOGY

Research Focus: This research has a mixed approach; qualitative due to the data collection and analysis process to establish results with high reliability in order to answer questions and verify the hypothesis established in the research by (Haro, 2022). Thus identifying the characteristics of the soil in the Botanical Park in addition to analyzing the macrofauna of the place to determine the quality through the biological method. Regarding the quantitative approach, the obtained data analysis method was used to describe the current state of the soil in the Botanical Park. Keeping in mind that the research phases were carried out from the sample collection to the analysis of each one.

Research Level: It was established as a descriptive investigation because, through the analyzes carried out on the soils of the study area, observation of the forest area and elaboration of maps corresponding to the study area, it was possible to analyze the soil parameters and thus be able to determine the soil quality in the study area (Haro, 2022).

Type of study: It was defined as a bibliographic, documentary, and field research, according to the methodology exposed by Priego et al (2009). This is considered as bibliographical research because it was prepared by reviewing literature in books, technical guides, information on the development plan of the Sucúa canton, websites, and by reviewing previous studies on this type of research. The field study was carried out by sampling in the study area, exploration and reconnaissance tours of the area, and obtaining geographical coordinates of the Botanical Park.

Study area: The study was carried out in forest soils of the Botanical Park belonging to the "El Kiim" community of the Sucúa canton, Morona Santiago province. For the delimitation of the study area, the ArcMap version 10.5 software was used. The location map of the study area and monitoring points was plotted.

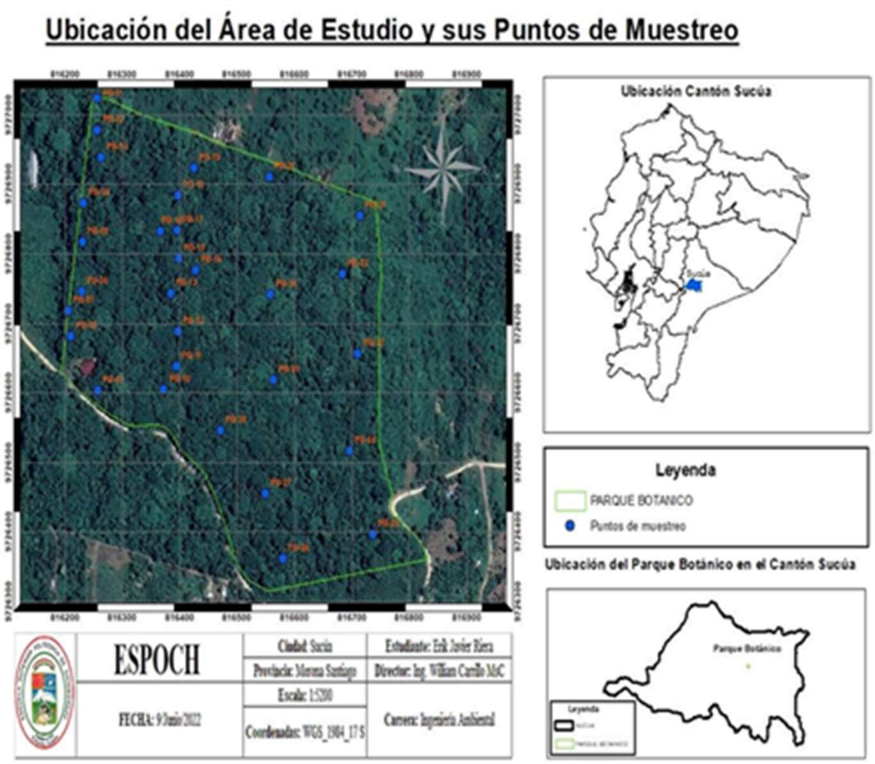

Figure 1-2: Location map of the study area and its sampling points

Simple Random Sampling: In the study area, a simple random sampling was carried out and a cartography of the study area was used with a Geographic Information System (GIS) in which the sampling points for the corresponding analyzes were delimited.

Sampling points: 30 representative sampling points were established in the 28.06 hectares that correspond to the Botanical Park because it is a protected area, therefore the alteration of its resources is restricted when carrying out the sampling.
Sample size: A total of 30 simple samples were obtained, where each sample represented about one hectare of the study area. The established extraction weight for the analysis was 2 lb for each sample.

Data Collection Techniques: The research was carried out in 2 stages: collection and analysis stage. The collection of soil samples was carried out following the sampling guide described in (Vidal, 2014). (Vidal, 2014) in order to correctly collect and preserve the soil

Materials and Equipment used for Soil Sampling

Table 1: Field materials used in soil sampling

Field materials	
Shovel	Jars
Auger	Knife
Bucket	Flexometer
Trolley	Ziploc Bags
Machete	Plastic garbage bags

Source: Own making

Table 2: Equipment used in soil sampling

Sampling Equipment
GPS
Camera
Sample container

Source: Own making

Table 3: Office supplies used in soil sampling

Office supplies
Markers
Tags
Tweezers
Brushes
Pair of scissors

Source: own making

Tabla 4: Reagents for conserving the macrofauna

Reagents
70% alcohol
Formaldehyde

Source: own making

Soil sample collection

1. A georeferencing of the 28.06 Botanical Park hectares was established using the ArcGIS 10.5 software.
2. The 30 representative sampling points in the Botanical Park were determined with the help of a Garmin Etrex 10 GPS.
3. The extractions of the soil samples were carried out at a depth of 20 cm with an auger for the physical-chemical analysis.
4. Each sample was collected in a hermetic plastic bag and labeled with its respective code. Subsequently, it was placed in a container to transport the sample to its analysis in the laboratory.
5. For the sampling of edaphic macrofauna, a pit with a dimension of 25 x 25 cm was dug in the walls and 20 cm deep.
6. All the litter and soil were removed and placed in a white bag, and all visible organisms were collected using brushes and small tweezers.
7. Insects and other arthropods were placed in flasks with 70% alcohol and labeled.
8. The worms were placed in 3% formaldehyde.
9. Once all the macrofauna had been collected, the soil was returned to the pit.
10. The samples for the physical chemical analyzes were taken to the Science research laboratory of the Escuela Superior Politécnica de Chimborazo in Riobamba, and for the identification of the macrofauna it was taken to the laboratory of ESPOCH in Morona Santiago.

Macrofauna Identification

Once the macrofauna samples were taken to the laboratory, the identification was carried out at an Order and Family level using dichotomous keys and counting macrofauna populations. A photographic record was made, and it was verified with databases on the Internet in order to identify all the species and later determine the diversity indices.

Biological evaluation of soil quality

In a simple way, the determination of soil quality is defined in two categories and using the following equations taken from (Cabrera, 2014):

$$Cs = \frac{\#Total\ detritus\ eaters}{\#Total\ non-detritivorous\ individuals} \quad [1]$$

Equation 1: Equation to determine soil quality

$$\text{Cs} = \frac{\#Earthworms}{\#ant\ individuals} \quad [2]$$

Equation 2: Equation to determine soil quality

Where:

Cs = Soil quality

-High quality: Soils with a greater quantity of organisms where the result is a value >1.

-Low quality: Soils with fewer organisms where the result is a value <1.

Once the results of the counting and identification of the macrofauna of the Botanical Park's Forest soils were obtained, the calculations of the diversity indices were made using the formulas presented below obtained in (Aguirre & Z, 2013).

Relative Abundance Index

$$AR = \frac{\#Number\ of\ individuals\ of\ a\ species}{\#Total\ individuals\ of\ all\ species} \quad [3]$$

Equation 3: Equation to determine the Relative Abundance

Where:

AR: Relative abundance

Simpson's Diversity Index

$$Ds = 1 - \frac{\Sigma \text{n}(\text{n}-1)}{\text{N}(\text{N}-1)} \quad [4]$$

Equation 4: Equation to determine the Simpson Diversity

Where:

Ds: Simpson Diversity

n: number of individuals of the species

N: Total individuals

Shannon-Wiener Diversity Index

$$SH' = -\sum pi\ Ln\ pi \quad [5]$$

i=1

Equation 5: Equation to determine the Shannon-Wiener Diversity

Where:

H´: Shannon Wiener Index

S: number of species

pi: proportion of individuals of species i with respect to the total number of individuals (relative abundance of species i).

Soil Physical-Chemical Characterization

The physicochemical analyzes were carried out in the science laboratory of the Escuela Superior Politécnica de Chimborazo following the procedures described in(Luters & Salazar, 1999), (Fernández, 2006), (Chambers, Beilman, & Yu, 2011)

Bulk Density

To calculate the bulk density, the cylinder method was used, which consisted of:

1. Drive a 2-inch diameter ring, 15 cm deep into the ground until it is full of soil and then carefully remove the ring, avoiding soil loss.
2. Remove excess soil from the sample with a broad-bladed knife.
3. Place the sample in a bag and label it.
4. Dry the sample in an oven for 24 hours at 105 ºC.
5. Weigh the dried soil sample.

Determine the volume in cm3

$vsuel = \pi r2h$

Equation 6: Equation to determine soil volume

Determine bulk density (g/cm3)

$$Dap = \frac{\text{Pss}}{\text{Vs}} \qquad [6]$$

Process to determine Bulk Density

Where:

Dap: Bulk Density

Pss: dry soil weight

Vs: soil volume

Electric conductivity

The method used was by means of an ORION VERSASTAR PRO conductivity meter on a soil extract and was carried out as follows:

1. Extract a 25g subsample of soil and place it in a container.
2. Add 30 ml of distilled water to the subsample container.
3. Shake the subsample container with a rod 25 times.
4. Calibrate the conductivity meter with the 100 dS/m calibration buffer.
5. Insert the conductivity meter into the soil-water mixture.
6. Record the CE when the value stabilizes.

pH

The pH was measured using an XL150 acumen pH meter following the following procedure:

1. Extract a 25 g subsample of soil and place it in a container.
2. Add 30 ml of distilled water to the container with the subsample.
3. Shake the subsample container with a rod 25 times.
4. Calibrate the pH meter with the buffer solutions of 4, 7 and 10.
5. Carry out the pH measurement by inserting the meter in the upper sector of the solution.
6. Wait 0 to 30 seconds until it stabilizes and record the pH value

$$\%Soil\ humidity = \left(\frac{\mathrm{Pi} - \mathrm{Ps}}{\mathrm{Pss} - \mathrm{Pcrisol}}\right) x\ 100 \qquad [7]$$

Equation 7: Equation to determine humidity

Where:

Pi: initial sample weight

Pss: sample dry weight

Organic matter

The organic matter content was determined by the Lost-Ignition method following the methodology described in (Chambers, Beilman, & Yu, 2011) which is detailed below:

1. The sample should be dried at room temperature for 1 day; then sieve to 2mm.
2. 5g of soil was weighed in a crucible and placed in an oven at 105ºC for 24 hours. Take data on the weight of the crucible.
3. The samples were placed in a desiccator and weighed again.
4. The sample was placed in a muffle at 550ºC for 4 hours.
5. Placed in a desiccator until the sample cools.
6. The sample weight was recorded.

The calculation of organic matter was made using the following Equation:

$$\%MO = \left(\frac{\mathrm{Pss}105° - \mathrm{Pss}550°}{\mathrm{Pss}105°}\right) x\ 100 \qquad [8]$$

Equation 8: Equation to determine Organic Matter

Where:

Pss: Dry soil weight

Phosphorus and Potassium

The determination of the phosphorus and potassium content was carried out by spectrometry following the Olsen methodology, for which the following dissolutions were first made:

Solutions and Reagents

- Dissolution of 42g of Sodium Bicarbonate in 50ml of distilled water and makeup to 1000ml in a flask.
- Dissolve 4g of Ammonium Molybdate in 50ml of distilled water and make up to 100ml.

- Dissolve 0.275g of Potassium Antimony Tartrate in 50ml of distilled water and make up to 100ml.
- Dissolve 1.75g of Ascorbic Acid in 50ml of distilled water and make up to 100ml.
- Add 56ml of concentrated Sulfuric Acid to 150ml of distilled water, shake, cool and makeup to 250ml.
- For the standard solution. Take 2ml of Phosphorus 1000ppm and makeup to 50ml.
- Take 4 aliquots of 1, 3, 4, and 5ml from the standard solution and makeup to 100ml.
- Mix the solutions made: 200 ml of distilled water, 50 ml of Sulfuric Acid, 15 ml of Ammonium Molybdate, 30 ml of Ascorbic Acid and 5 ml of Antimony and Potassium Tartrate.

Procedure

1. Add 2g of each 2mm sieved dry soil sample into a tube and add 40ml of the prepared sodium bicarbonate solution.
2. Shake the samples at 350 rpm for 30 minutes.
3. Filter the samples into beakers using filter paper.
4. Place a tablespoon (0.5g) of activated carbon in a test tube, add 3ml of the filtered sample and 3ml of distilled water.
5. Shake the samples at 350 rpm for 15 minutes.
6. Place the samples in a centrifuge for 5 minutes.
7. Pipette 3ml of the clear sample into a test tube.
8. Add 1ml of the mixed reagents to each sample.
9. Let the samples rest for 1 hour until they obtain a blue color.

Potassium determination

Transfer the samples to an atomic absorption spectrometer and record the data.
Perform the calculations using the following Equation

$$\mathrm{meq/100gK} = \frac{\mathrm{(C)X\ V}}{\mathrm{W\ X\ 10000}} x\ PmolK \qquad [9]$$

Equation 9: Equation to determine the potassium

Where:
Value obtained in the spectrophotometer V: Volume of the extract
W: Weight of the soil sample PmolK: Molecular weight of Potassium

For the determination of phosphorus

1. Take the calibration standards prepared at 1,3,4, 5ml and read in the spectrophotometer to build the calibration curve.
2. Take each sample and insert into the spectrophotometer to determine the value.
3. Carry out the calculations using the following Equation.

$$\frac{mgP}{Kg} = \frac{(C)X\,V}{W} \qquad [10]$$

Equation 10: Equation to determine Phosphorus

Where:

[C]: Value obtained in the spectrophotometer

V: Extract volume

W: Soil sample weight

Determination of the Soil Quality Index (ICS)

To evaluate the soil quality, important properties for the soil were established.

Table 5: Parameters considered for the evaluation of the soil in the Botanical Park

Indicator	Measurement unit	Maximum value	Minimum value
pH		7	5,5
Electric conductivity	dS/m	1	0,01
Bulk Density	mg/cm3	1,5	1,15
Organic matter	%	Higher than 5	2
Humidity	%	50	5
Available phosphorus	ppm	Higher than 30	4,09
Available potassium	meq/100g	Higher than 0,8	0,2

In order to obtain a unique value of each parameter, an average of all the samples analyzed was made in representation of the total area. Afterwards, the indicators were normalized on a scale of 0 - 1, which represents the worst and best condition in terms of quality.

The following Equation is used when the soil presents stable situations (Vn=1).

$$Vn = \frac{(Lm - Lmin)}{(Lmáx - Lmin)} \qquad [11]$$

Equation 11: Equation to normalize (Vn=1)

Equation used for the worst soil quality situation (Soil instability Vn=0)

$$Vn = 1 - \frac{(Lm - Lmin)}{(Lmáx - Lmin)} \qquad [12]$$

Equation 11: Equation to normalize (Vn=0)

Where:

Vn: Normalized value

Im: Indicator measurement

Imáx: Maximum value of the indicator

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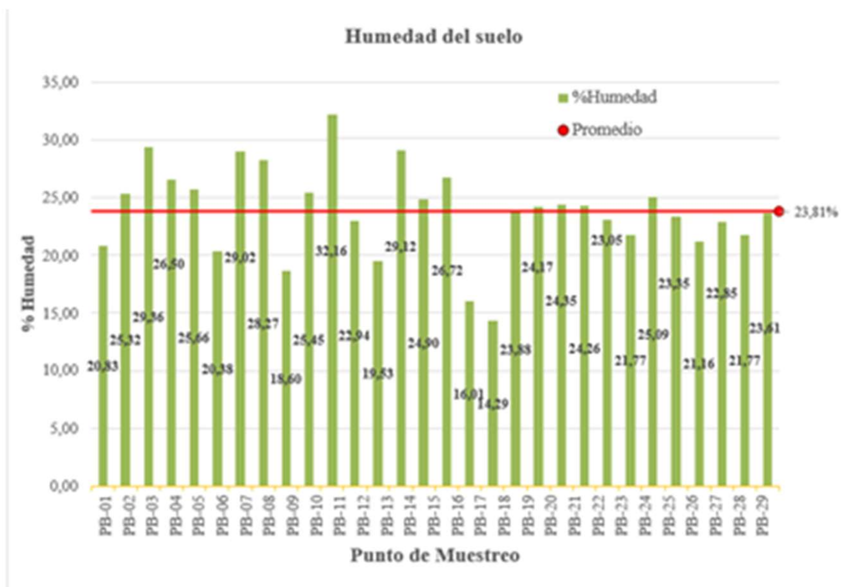
Lmin: Minimum value of the indicator

The maximum and minimum values were established for each indicator taking into account the optimal conditions of some parameters and others defined by theoretical criteria. For organic matter, the minimum requirement to meet the mollic condition was taken as a reference, and the maximum value was the average of the values measured in the soils of the study area. The pH minimum value was established according to the toxicity point for the development of fauna and the maximum value was defined at neutral pH. For the value of the minimum bulk density, the average of the values measured in the soils of the study area was determined and the maximum value was 1.5 g/cm3 in which aeration, and water infiltration problems in the soils occur. The moisture content in the soils is generally in the range of 5 to 50%, which represents the maximum and minimum values respectively. The Electrical Conductivity value was taken as a reference to the optimal values for the crop considering that values less than 0.5 dS/m maintain a good development and values greater than 1dS/m present difficulties in many crops. For the available Phosphorus, the maximum and minimum values of the results obtained in the laboratory analyzes were taken as a reference. The maximum value of Potassium was taken as the highest obtained in the analyzes while the minimum value was considered the minimum requirement that can be assimilated by the plants. After having obtained all the values of each indicator, a soil quality index (ICS) was established by averaging each indicator. Therefore, for the ICS interpretation, the resulting value in Table 2 was compared.

RESULTS AND DISCUSSION

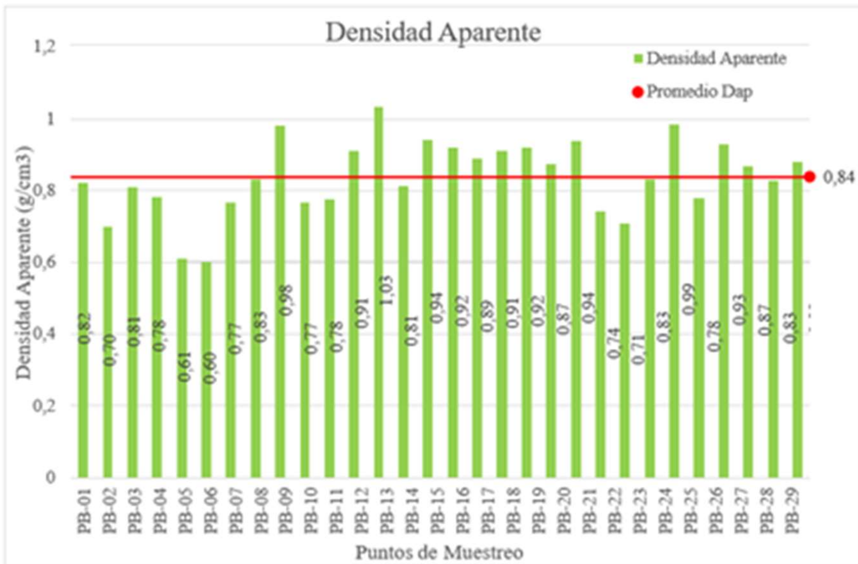


Graph 1: Measurement and average value of soil humidity

Humidity Parameter

The results of humidity in the Botanical Park area are shown in graph 1. Slight changes are recorded at each sampling point. The humidity values obtained are in an intermediate range between the established maximum and minimum limits. Therefore, the average value of humidity corresponds to 23.81%, which indicates an acceptable and important value for the physical, chemical and biological activities in the soil. (Quichimbo et al., 2016)

Bulk Density Parameter



Graph 2 Bulk Density Measurements and Average Soil Value

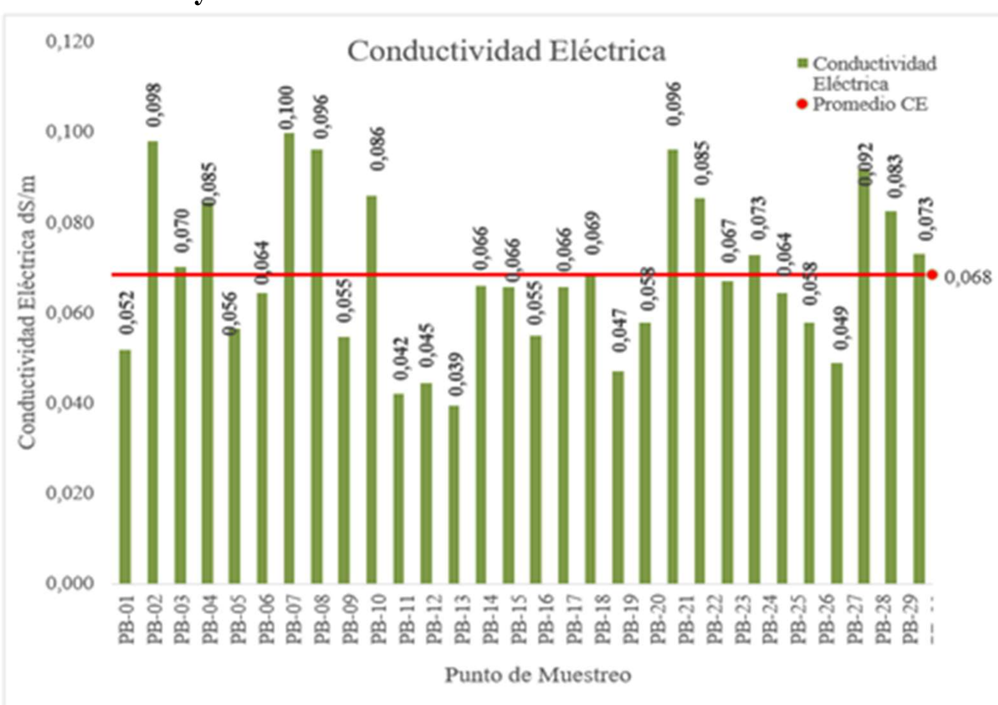
The results of the Bulk Density in the Botanical Park soils indicated in Graph 2-4 register slight changes in each one of the sampled points. With an average value of Dap= 0.84 g/cm3 which, being below 1.5 g/cm3, establishes a good porous, aerated condition, with good drainage and excellent root penetration, thus facilitating root development.

Chemical analysis
pH parameter

Graph 3: pH measurements and average value of the soil

Graph 3 shows the pH values measured in the soils of the Botanical Park in which the total average value of the study area is given by pH=6.49 According to Table 4, it represents a slightly acidic soil and an optimal range for plant growth. (Porta, 2008) (Barbaro, 2005)

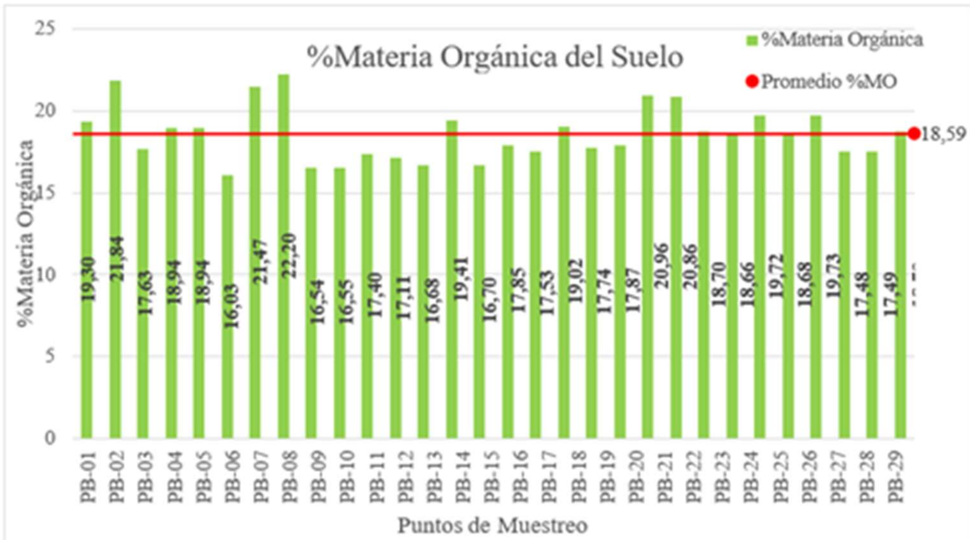
Electrical Conductivity Parameter



Graph 4: Electrical Conductivity Measurements and the average value of the Soil

Graph 4 shows the CE values obtained at the sampling points in the study area. Therefore, the average value of the parameter corresponds to 0.068 dS/m. Table 5-2 indicates a non-saline soil that is very favorable for controlled fertilization management, which avoids problems due to phytotoxicity in crops. (Gallart Martínez , 2017)

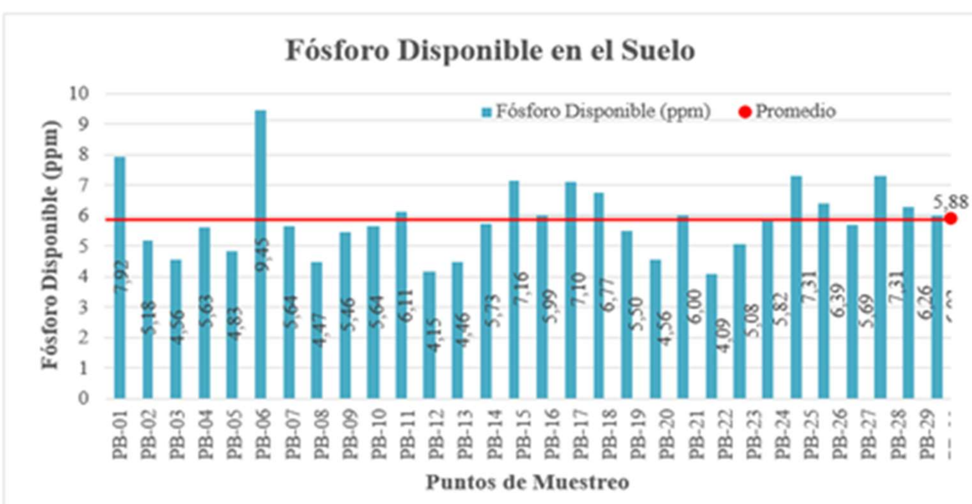
Organic matter parameter



Graph 5: Measurement of soil organic matter and its average value

The Organic Matter analyzed in the soil samples from the study area did not vary significantly, there was a range of 16.03% to 22.20% with an average value of 18.59% as indicated in Graph 5. The average value obtained indicates a high organic matter content, which allows reducing the effects of climate change since the earth's surface forms a stable carbon reservoir. (Molina, 1978)

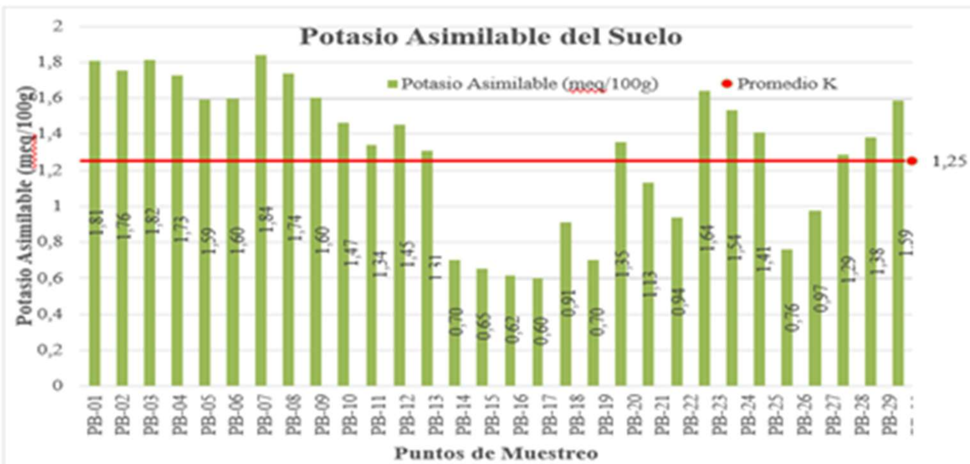
Available Phosphorus Parameter



Graph 6: measurement of available phosphorus in the soil and its average value

Graph 6 indicates the available P values obtained in the samplings carried out in the Botanical Park soils, ranging from a range of 4.09 to 9.45 ppm; being 5.88ppm the average soil value of the place and according to Table 6-2 the available P value is classified as POOR. The reason for the low Phosphorus content is the result of the abundant vegetation with a large root system that exists in the Botanical Park, especially the Tindiuky Neida species, which has the greatest presence in the place. According to (Guencaimburu et al., 2019) the available P value corresponds to a dynamic variable, which increases as the trees form mycorrhizal associations where the elements released in the process accelerate weathering to mineralize the availability of Phosphorus.

Assimilable Potassium Parameter



Graph 7: Soil Potassium Measurement and its average value

The Potassium values analyzed in the soil samples from the Botanical Park have little variance between them, in which a range ranging from 0.60 to 1.84 meq/100g was obtained; where 1.25 meq/100g constitutes the average potassium value in the study place and according to the interpretation scale described in Table 7-2, the soil of the Botanical Park has a HIGH Potassium content. Therefore, it indicates that the soils maintain large reserves of this element in all its forms, which is important to maintain the vegetation of the place.

Soil Quality Index

The Soil Quality Index is represented in 5 classes as indicated in Table 6

Table 6: Indicators and Soil Quality Index

Indicator	Indicator Value
Organic matter	0,82
pH	0,66

Electric conductivity	0,94
Humidity	0,42
Bulk Density	0,66
Available Phosphorus	0,33
Assimilable Potassium	0,64
Soil Quality Index	0,64

Table 6 shows the Vn (Normalized Values) of each calculated indicator and the resulting Soil Quality Index with a value of 0.64. Additionally, Table 2-2 belongs to Class 2 and represents a High-Quality corresponding to a range of 0.60 – 0.79.

Table 7: Soil Quality Indicators for each parameter

Indicator	ICS
Organic Matter	very high quality
pH	High quality
Electric conductivity	very high quality
Humidity	Moderate Quality
Bulk density	High quality
Available Phosphorus	Low quality
Available Potassium	High quality

The indicator that presented the lowest value was the phosphorus with a Class 4 ICS belonging to a Low Quality, followed by humidity with ICS of Class 3 of Moderate Quality, while the indicators of pH, Potassium and Bulk Density presented a High Quality. The remaining indicators obtained maximum quality values as indicated in Table 7. The ICS value obtained corresponding to the High-Quality class is strongly influenced by the Organic Matter indicator, which represents an influence on many of the soil properties.

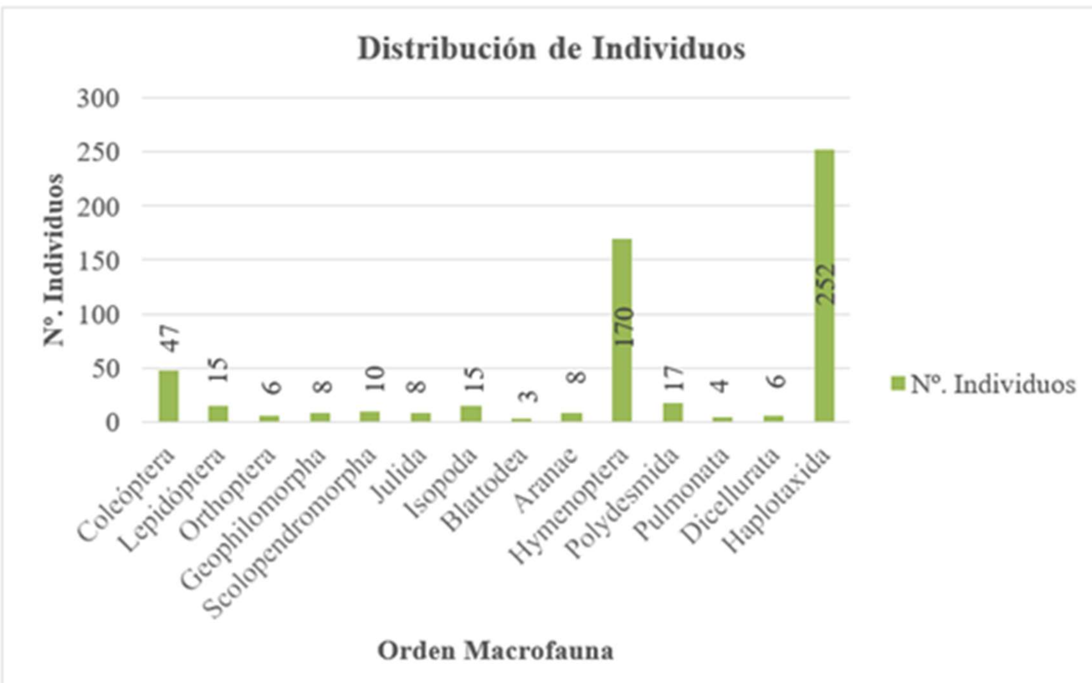
Analysis of the Edaphic Macrofauna

A total of 569 individuals corresponding to 14 orders and 23 families of edaphic macrofauna were collected. The most diverse order was Coleoptera with 7 families. Table 8 shows the distribution of families and order of the individuals found in the soils of the Botanical Park.

Table 8: Richness and Abundance of the Edaphic Macrofauna

ORDER	FAMILIES	No. Individuals
Coleoptera	7	47
Lepidoptera	1	15

Orthoptera	2	6
Geophilomorpha	1	8
Scolopendromorpha	1	10
Julida	1	8
Isopod	1	15
Blattodea	1	3
Araneae	1	8
Hymenoptera	2	170
Polydesmide	1	17
Pulmonata	2	4
Dicellurata	1	6
Haplotaxida	1	252
Total of Individuals	**23**	**569**



Graph 8 shows the total distribution of individuals in the soils of the Botanical Park, where the Haplotaxida order is the one that contains the most individuals (252) followed by the Hymenoptera order with 170 individuals.

Each organism found was classified into functional groups according to their way of life and their food source as indicated in Table 8.

Table 9: Functional Groups of the Edaphic Macrofauna in the Botanical Park

Families/Functional Groups	Total
Detritivores	
Haplotaxida	252
Armadillidae	15
Paradoxosomatidae	17
Scolopendridae	10
Tenebrionidae	12
Total Detritivores	306
Predators	
Geophilidae	8
Staphylinidae	10
Clubionidae	8
Julida	8
Dermestidae	6
Total Predators	40
Herbivores	
Pulmonata	4
Lepidóptera	15
Scarabaeidae	6
Formicidae	170
Gryllidae	6
Total herbivores	201
Omnivores	
Blattellidae	3
Anthicidae	7
Canthon	3
Total Omnivores	13
Unidentified Organisms	
Elateridae	3
Japygidae	6
Total Unidentified Organisms	9

The total number of detritivore organisms that exist in the soils of the Botanical Park are 306, and the organisms that make up the non-detritivore group contain 263 individuals. When applying Equation 1-3 (Detritivores/Non-Detritivores) and Equation 2-3 (Earthworms/Ants) according to the methodology described in Cabrera (2014, p. 30), the resulting values were 1.16 and 1.48 respectively.; As these results are greater than 1, they indicate that the soil contains a High Quality.

Diversity Index and its relationship with the biological quality of the soil
Relative Abundance Index
The Relative Abundance Index refers to how common a species may be compared to other species in a community. According to the data presented in Table 6-4, it is evident that the order of highest proportion is Haplotaxide with 44.29% belonging to earthworms. This representativeness indicates that this species has a good distribution in the soil with a good detritivore function and a high degree of decomposition of organic matter (Aguirre, 2013).

Table 10 Relative Abundance of Edaphic Macrofauna

ORDER	No. Individuals	Abundancia Relativa (%)
Coleoptera	47	8,26
Lepidoptera	15	2,64
Orthoptera	6	1,05
Geophilomorpha	8	1,41
Scolopendromorpha	10	1,76
Julida	8	1,41
Isopod	15	2,64
Blattodea	3	0,53
Araneae	8	1,41
Hymenoptera	170	29,88
Polydesmida	17	2,99
Pulmonata	4	0,70
Dicellurata	6	1,05
Haplotaxida	252	44,29
Total Individuals	569	100,00

Simpson Diversity Index

ORDER	No. Individuals	Simpson Diversity
Coleoptera	47	0,0067
Lepidóptera	15	0,0006
Orthoptera	6	0,0001
Geophilomorpha	8	0,0002
Scolopendromorpha	10	0,0003
Julida	8	0,0002
Isopoda	15	0,000650
Blattodea	3	0,0000186
Araneae	8	0,00017
Hymenoptera	170	0,0889
Polydesmida	17	0,00084
Pulmonata	4	0,000037
Dicellurata	6	0,00009
Haplotaxida	252	0,1957
Total Individuals	569	0,29
Simpson Diversity Index		0,71

According to Moreno (2015, p. 41), the value obtained in the Simpson Diversity Index indicates that the sampled soils reflect an abundant richness of species in which most of the forest soil has not been intervened by anthropic actions and environmental disturbances. In addition, it is important to highlight that large macrofauna populations have been formed on the site due to the balance of the ecosystem free of actions that disturb the soil.

Shannon-Wiener Diversity Index

This Index measures biodiversity without taking into account its distribution in space. In the study area, the value of 1.63 was obtained, which indicates that the diversity in the ecosystem studied is average table 11.

Table 11: Shannon-Wiener diversity

ORDER	FAMILIES	S–W diversity
Coleoptera	7	-0,21
Lepidoptera	1	-0,10
Orthoptera	2	-0,05
Geophilomorpha	1	-0,06
Scolopendromorpha	1	-0,07
Julida	1	-0,06
Isopoda	1	-0,10
Blattodea	1	-0,03
Araneae	1	-0,06
Hymenoptera	2	-0,36
Polydesmida	1	-0,10
Pulmonata	2	-0,03
Dicellurata	1	-0,05
Haplotaxida	1	-0,36
Shannon-Wiener Index		***1,63***

According to the Shannon - Wiener Diversity Index, the study area presented medium diversity; This is due to the intensity of trees and shrubs that exist in the place, which guarantees abundant input of organic matter whose action is favorable for the establishment of macroinvertebrates. (Pashanasi, 2006) .

Soil quality evaluation through biological indicators

The edaphic macrofauna is an indicator of the soil quality state due to its sensitivity to significant disturbances suffered by the soil by natural or anthropic actions; This is reflected in the loss, variation and intensity of families and individuals that make up the macrofauna. The qualitative and quantitative analysis allowed an evaluation of the quality of the edaphic environment in which the dominance of the Haplotaxida family was evident. Thus, table 12 corresponding to the individuals of worms whose detritivorous function is favorable to maintain the quality of the soil in good conditions, contributing large amounts of organic material.

Table 12: Dominance of Biological Diversity Indices

ORDER	No. Individuals	Relative Abundance (%)	Simpsons diversity	Shannon–Wiener diversity
Coleoptera	47	8,26	0,0067	-0,21
Lepidoptera	15	2,64	0,0006	-0,10
Orthoptera	6	1,05	0,0001	-0,05
Geophilomorpha	8	1,41	0,0002	-0,06
Scolopendromorpha	10	1,76	0,0003	-0,07
Julida	8	1,41	0,0002	-0,06
Isopode	15	2,64	0,000650	-0,10
Blattodea	3	0,53	0,0000186	-0,03
Aranaea	8	1,41	0,00017	-0,06
Hymenoptera	170	29,88	0,0889	-0,36
Polydesmida	17	2,99	0,00084	-0,10
Pulmonata	4	0,70	0,000037	-0,03
Dicellurata	6	1,05	0,00009	-0,05
Haplotaxida	252	44,29	0,1957	-0,36
Total Individuals	**569**	**100,00**	**0,71**	**1,63**

Conclusions

• The physical, chemical, and biological characteristics of the forest soil in the Sucúa Canton Botanical Park were determined by means of 30 simple random soil samples distributed over 28.06 hectares. For the Soil Quality Index (ICS), the physical-chemical analysis was carried out considering the parameters of pH, electrical conductivity, bulk density, organic matter, available Phosphorus, assimilable Potassium and humidity; whose resulting value was 0.64 corresponding to Class 2, which represents a HIGH-QUALITY soil. According to the biological method (edaphic macrofauna) a total of 569 individuals were found distributed in different functional groups (detritivores, predators, herbivores and omnivores). The most abundant group in the study area was detritivores organisms (306 individuals) compared to non-detritivores organisms (263 individuals) and by means of the detritivores/non-detritivores ratio, a value greater than 1 was obtained, which indicates a HIGH-QUALITY soil.

• A total of 23 families of macrofauna were found, among the most representative: Coleoptera composed mainly of beetles whose work facilitates the decomposition of organic matter that comes from plants and animals, which guarantees the recycling of nutrients in the area.

• Through the ICS and the edaphic macrofauna, the soil state in the Botanical Park was determined, in which a HIGH soil quality level was reported. In addition, with the results obtained it was possible to establish that biological organisms maintain the physical conditions of the soil and adapt to the chemical parameters, which is why to determine the quality of the soil any method can be executed, being physical, chemical, or biological.

• According to the biodiversity indices application, the analysis of both the populations and their species was allowed, these being important tools that allow observing if there are environmental disturbances in the study place. In addition, through the Simpson and Shannon - Wiener indices, it was shown that the soils contain HIGH and MEDIUM diversity respectively; This is reflected in the organisms found, since the greatest diversity of macrofauna found is a reference to important soil organisms that allow stability.

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