PROJECT LORAX:

TREES IMPACT IN OUR SCHOOL'S CAMPUS

Students:

Patricia Skaf
Sara Crespo
Luciana Logroño
Ana María Clavijo
Rafaela Rodríguez
Mía Falconí
Emilia López
Matias Campaña
Eliana Muñoz
Katherine Riesen

Colegio Británico Internacional

Teachers:

Ana Sofía Miranda

María José Erazo

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“In a very short time it was found that they were things to be unlearned as well as discovered in Ecuador”

Edward Whymper, Travels Amongst the Great Andes of the Equator, 1892

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Abstract

This research project describes a year process of research about trees at Británico International School, the species identification and inventory, later on the interactions with species of animals mostly birds for nesting and feeding, an analysis of tree growth in 5 randomly chosen species of trees located mostly to the south side of the campus and finally the correlation trees have in the air and soil temperature. All of it looking forward to finding a better way to support tree biodiversity and in consequence the fauna around our campus.

Key words: trees, species, growth rate, temperature, biodiversity.

Research Questions and Hypothesis

The seventeen countries with the greatest biological diversity in the world occupy less than 10% of the total surface of the planet; however, they are home to seven out of ten recognized species of flora and fauna. Ecuador is one of the 17 megadiverse countries of the world.

This diversity is due to the location of the country in the neotropics, the presence of the Andes and the influence of the ocean's currents on its coasts. It is divided into 4 well-defined natural geographical zones: coast, mountain range, the Amazon and the Galapagos Islands (CONVENTION ON BIOLOGICAL DIVERSITY & United Nations Environment Programme, n.d.), due to that it turns out to be one of the smallest territories that exceeds the biodiversity of large nations such as Brazil and the United States, which places us as a country in the first places, if not in the first, as the most megabiodiverse per square kilometer in the world.

Despite this, the constant and visible transformation of natural environments, whether due to agriculture, livestock, extraction of natural resources or urbanization, has led to the loss of many natural spaces, such as the protective forest of Quito, that borders the city to the east and west, which in the last 30 to 50 years, has been seriously diminished, specially on its eastern border.

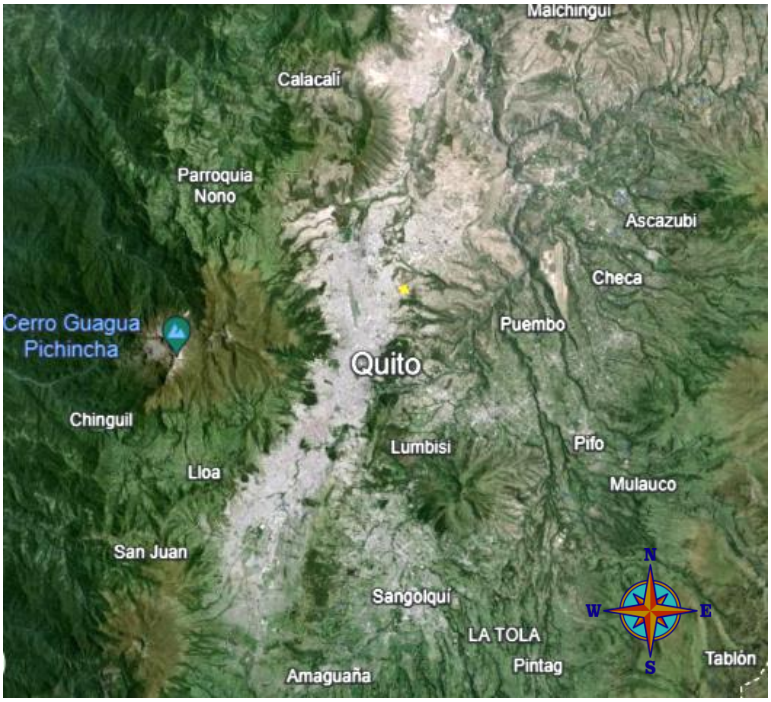


Illustration 1. Map of Quito and its surrounding protective forests.

As seen in the map above, the city has started to grow more towards the eastern side over the east Andes range and down to the valleys. The yellow dot is where our school is located.

Illustration 2. Colegio Britanico Internacional location in relation to the city.

The Británico International School is located in one of these borders, at the east range of the Andes, and at 2800m above sea level. With its 3 hectares of campus, we are luckily surrounded with several species of trees inside the campus and to the northwest side with a Eucalyptus forest over a very steepy downhill known as “Quebrada de Gualo”.

Ilustración 3. Satellite view of the Britanico Internacional campus. Yellow line marks its limit.

RESEARCH QUESTIONS

With this research, we want to answer the following questions:

1. ***Which species of trees can we find on the school campus?***
2. ***What the growth rate of trees in our campus?***
3. ***How do they affect the biodiversity around the school?***
4. ***How are trees related to temperature changes?***

HYPOTHESIS

And we think some of our hypotheses are:

- The school campus has a diverse range of tree species, including native and exotic ones, that reflect the climatic and soil conditions of the area.
- The growth rate of trees on the campus depends on the species, age, size, and health of the trees, as well as the availability of water, nutrients, and sunlight.
- The tree species on the campus influence the biodiversity around the school by providing habitat, food, and shelter for various animals and plants, and by affecting the microclimate and soil quality.
- The temperature changes on the campus are affected by trees, and they may respond by altering their growth, phenology, physiology, and distribution.

To answer these research questions, it is important to review the existing literature on tree species diversity, biodiversity, growth and temperature changes in forest ecosystems.

We all know that forests are critical habitats for biodiversity, and that they provide a wide range of ecosystem features such as biomass production, habitat provisioning services, pollination, seed dispersal, resistance to windstorms, fire regulation and mitigation, pest regulation of native and invading insects, carbon sequestration, and cultural ecosystem services, which are crucial for ecosystem balance and even more for human well-being. According to an investigation published by the Conservation and Biodiversity Magazine, there is increasing evidence that biodiversity contributes to forest ecosystem functioning and the provision of ecosystem services. (Brockerhoff et al., 2017, 3005)

According to an experimental study held in the subtropical forest of China, it has been proven that broad-leaved tree species have a bigger impact on temperature change during seasonal variation or under the impact of global warming, the study mentions that two important factors influencing N2O and NO emissions from forest

soils. These emissions are related to the nitrogen cycle and the greenhouse effect. (Cheng et al., n.d., 617-625)

The response of tree growth to a change in temperature may differ in predictable ways. Trees with conservative growth strategies may have little ability to respond to a changing climate. In addition, high latitude and altitude tree growth may be temperature-limited and thus benefit from some degree of warming, as opposed to warm-adapted species. (Way & Oren, 2010, 670)

Trees that developed at elevated temperatures did not simply accelerate growth but followed different developmental trajectories than unwarmed trees, allocating more biomass to leaves and less to roots and growing taller for a given stem diameter. More carbon may be available to allocate to growth at high temperatures because respiration acclimated more strongly than photosynthesis, increasing carbon assimilation but moderating carbon losses. (Chung et al., 2013, 450)

These studies suggest that tree species diversity, biodiversity, and temperature changes are interrelated and complex topics that require further research and monitoring. They also imply that the tree species found on the school campus depend on the climate, soil, and management practices of the area, and that they may have several effects on the biodiversity and ecosystem services around the school. Therefore, it is important to identify and assess the tree species on the campus and their potential impacts on the environment.

On the Technical Manual for Urban Trees published by the Environmental Secretary of the City Hall of Quito, it is mentioned that special preference should be given to the production and planting of native species since it has been proven that native plants defend themselves better against plagues and diseases, it is also important to consider biodiversity in the plantation for it favors native fauna reproduction, taking into account the following considerations:

IDEAL RATIO	70 native - 30 foreign species
INTERNATIONAL STANDARD	20% of the same genre No more than 20% of the same specie.
SUMMARIZING	No more than 5% of the same planted specie out of the total number of trees.

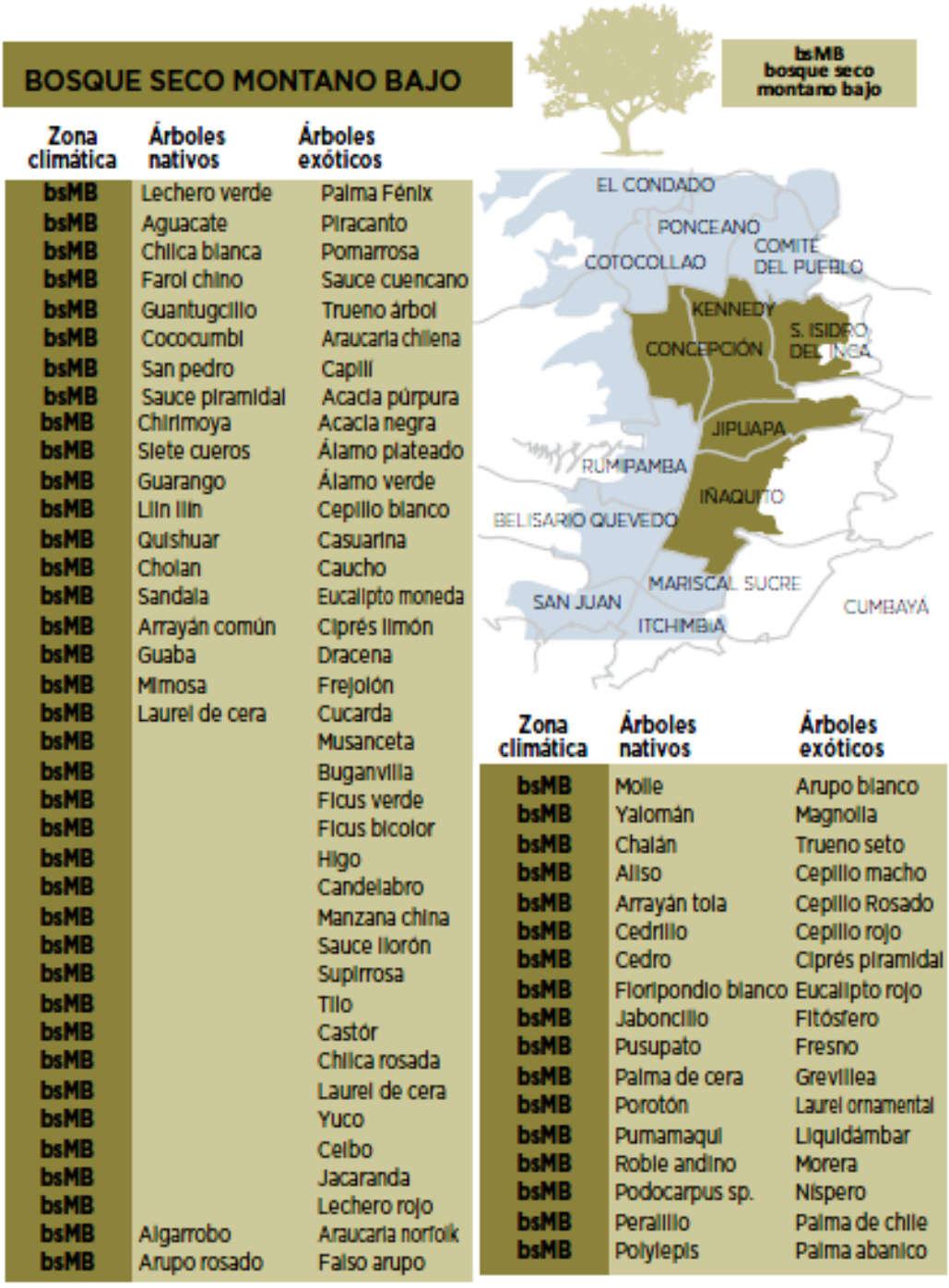
Tabla 1. International Standards for the ideal tree species distribution in an ecosystem.

Furthermore, in the same manual we can find several classifications of trees one of them according to sub climatic zones in Quito, in which is shown their location zone and a list of trees that are expected to be located in that zone. Detail presented in the following diagram.

To be able to calculate growth rate of trees, we could repeatedly measure the height, crown spread, and stem diameter of specific trees over time. You can get an average growth rate by taking the change in size and dividing it by the amount of time it has been growing. This calculation is based on the Average Growth Rate Formula:

AGR: (Final size - Initial size) / lapse of time

Native and exotic trees of Quito according to climate zone



BOSQUE SECO MONTANO BAJO

bsMB
bosque seco
montano bajo

Zona climática	Árboles nativos	Árboles exóticos
bsMB	Lechero verde	Palma Fénix
bsMB	Aguacate	Piracanto
bsMB	Chilca blanca	Pomarrosa
bsMB	Farol chino	Sauce cuencano
bsMB	Guantugcillo	Trueno árbol
bsMB	Cococumbi	Araucaria chilena
bsMB	San pedro	Capili
bsMB	Sauce piramidal	Acacia púrpura
bsMB	Chirimoya	Acacia negra
bsMB	Siete cueros	Álamo plateado
bsMB	Guarango	Álamo verde
bsMB	Lin lin	Cepillo blanco
bsMB	Quishuar	Casuarina
bsMB	Cholan	Caucho
bsMB	Sandala	Eucalipto moneda
bsMB	Arrayán común	Ciprés limón
bsMB	Guaba	Dracena
bsMB	Mimosa	Frejolón
bsMB	Laurel de cera	Cucarda
bsMB		Musanceta
bsMB		Buganvilia
bsMB		Ficus verde
bsMB		Ficus bicolor
bsMB		Higo
bsMB		Candelabro
bsMB		Manzana china
bsMB		Sauce llorón
bsMB		Supirrosa
bsMB		Tilo
bsMB		Castór
bsMB		Chilca rosada
bsMB		Laurel de cera
bsMB		Yuco
bsMB		Ceibo
bsMB		Jacaranda
bsMB		Lechero rojo
bsMB	Algarrobo	Araucaria norfolk
bsMB	Arupo rosado	Falso arupo

Zona climática	Árboles nativos	Árboles exóticos
bsMB	Molle	Arupo blanco
bsMB	Yalomán	Magnolia
bsMB	Chalán	Trueno seto
bsMB	Aliso	Cepillo macho
bsMB	Arrayán tola	Cepillo Rosado
bsMB	Cedrillo	Cepillo rojo
bsMB	Cedro	Ciprés piramidal
bsMB	Floripondio blanco	Eucalipto rojo
bsMB	Jaboncillo	Fitósfero
bsMB	Pusupato	Fresno
bsMB	Palma de cera	Grevillea
bsMB	Porotón	Laurel ornamental
bsMB	Pumamaqui	Liquidámbar
bsMB	Roble andino	Morera
bsMB	Podocarpus sp.	Níspero
bsMB	Perallilo	Palma de chile
bsMB	Polylepis	Palma abanico

Ilustration 4. Native trees of the San Isidro del Inca area. Lower montane forest.

Materials and Method

Materials List:

Table 2. Materials used to collect and register data.

Materials:	**Use:**
● Cell phone	To install the globe app and take pictures
● Globe “trees” app	To observe the height of trees
● Measuring tape	To measure the width of trees
● IRT GP-300	To measure surface temperature
● C02 sensor	To measure the different amounts of CO2 in different tree positions.
● iNaturalist app	To be able to recognize the tree species in our school and make a catalog.
● Digital thermometer “Vernier” model	We used it to measure the temperature of the soil beneath the tree, near the tree, in open areas, and in the shade to be able to compare how the temperature changed in different areas.

Source: Team elaboration.

Protocols used:

Table 3. Protocols applied during the investigation.

Protocol	**Purpose**	**Data:**
• GLOBE Biosphere - Biometry: Tree Heights.	Get data about tree height and tree trunk width.	Tree height Trunk Diameter
• Average Growth Rate Formula:	Measure the rate of growth of some observed trees	AGR: (Final size - Initial size) / lapse of time
• Simpson's index	Estimate the biodiversity index	$D = \frac{\sum n_i(n_i - 1)}{N(N-1)}$
• Vernier - Air Temperature.	To register air temperature measurements related to tree's location.	Air temperature: - 0 meters away - 3 meters away - 6 meters away

During this research, we applied an on-site observation and deductive methodology, in which for every data range we needed to find we went outside to all the school's sections to register the data, then systematize it and finally analyze it.

Procedures:

We decided to answer all 4 questions established by our science club team, by creating small groups to focus on one topic and be able to advance at good pace, having meetings every Wednesday during at least 1 hour and sharing our findings and the next tasks to get done. As follows:

Group A was in charge of answering question #1: ***Which species of trees can we find on the school campus?*** To do it, we followed these steps:

- Downloaded the iNaturalist app and learned how to send observations and determine the species of trees, plants and animals.
- Took photos of all kinds of species of flora and fauna seen in the school.
- At the same time, there was a team that was in charge of the iNaturalist application to recognize tree and register species.
- With all the information gathered, we started creating a catalog to organize the information about these species using the Canva platform.

To answer the second question: ***What is the growth rate of trees in our campus?*** we:

- Downloaded the Globe app and learned how to use the Trees protocol, then practiced several times in group and with the teacher how to send observations about tree height correctly.
- Started using it to measure tree heights by ourselves, at this point we also used the measuring tape to measure the width of the tree trunk.
- We kept a register of these observations to be able to compare tree growth.

Then, to be able to answer Question #3: ***How do they affect the biodiversity around the school?***

- We collected photos of animal species that are constantly seen in our campus.
- We mapped the places they were seen.
- We compared the mapping to the location of trees in campus.

Finally, to answer question #3, ***How are trees related to temperature changes?*** We decided to:

- Select some trees randomly.
- Register data about air temperature with our brand new Vernier devices following this procedure: T1 at 0 meters, T2 at 3 meters distant and T3 at 6 meters distant.
- Then with all this data, we created some charts to visualize and compare these air temperatures and the influence trees have on it.

Data Summary

TREE SPECIES IN THE CAMPUS.

The following table contains all the species of trees found in campus of the CBI school, compared to the Quito Urban Tree Guide to be able to match and detail the common name, scientific name, an image of the individual and the total number of existing trees belonging to that species. They have also been marked with a color code to represent if the species is emblematic (light blue), native (green), exotic (yellow) or toxic (pink).

As a first summary, based on the analysis of the data table (annex 1), we have found out that in our school campus we have:

TYPE OF SPECIE	AMOUNT OF SPECIES	TOTAL NUMBER OF INDIVIDUALS
Emblematic	2	11
Native	5	14
Exotic	8	44
Toxic	1	46

Table 4. Summary of species according to type of specie.

On one hand, we found that the emblematic species are *Ulmus americana* and *Inga insignis that together add up to 11 individuals*, on the other hand we have *Acacia Melanoxylon* as a toxic specie for this area on a number of 46.

We decided to create a species album for these species to be known and seen among our community for it, we planned creating QR tags in our 3D printer to attach to trees for students, teachers and parents to have access to the information of each emblematic specie.

Furthermore, we found out why *Acacia melanoxylon* is considered an invasive and toxic species.

Acacia melanoxylon is native to Australia, it is toxic “The black acacia tree causes various problems to humans, thanks to its high tannin content and the fact that it contains quinones that irritate the skin and other tissues. If ingested, it causes nausea, vomiting, stomach ache” Limiterd, G. L. (n.d.).

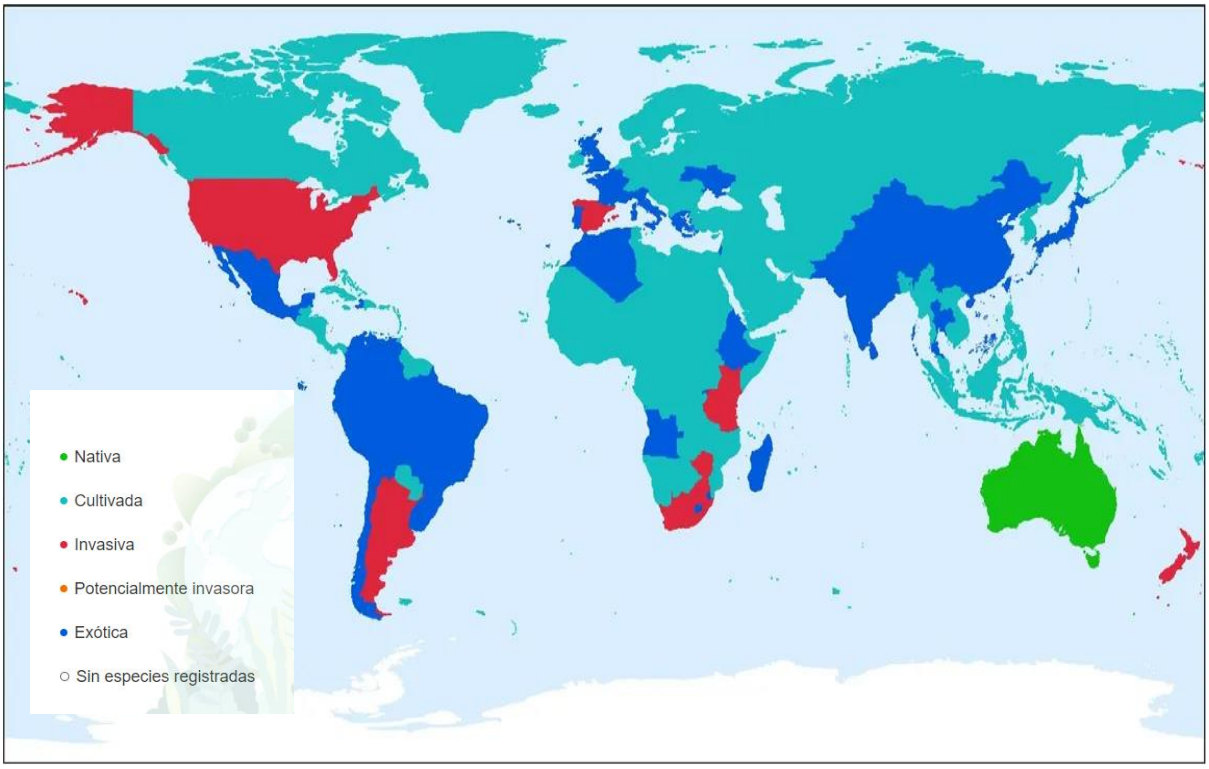


Illustration 5. Mapping of the location of *Acacia melanoxylon around the world. (Limiterd, n.d.-b)*

TREE GROWTH RATE AND FACTORS

For the matter of this research, we will apply this formula

Average Growth Rate Formula

AGR: (Final size - Initial size) / lapse of time

By using the AGR formula with the data collected on the GLOBE DATA VISUALIZATION SYSTEM about tree height measurement (tH) and its trunk diameter (tD), on as detailed on ANNEX 3, we could calculate the rate of growth of some selected trees in our campus, as shown in the following table:

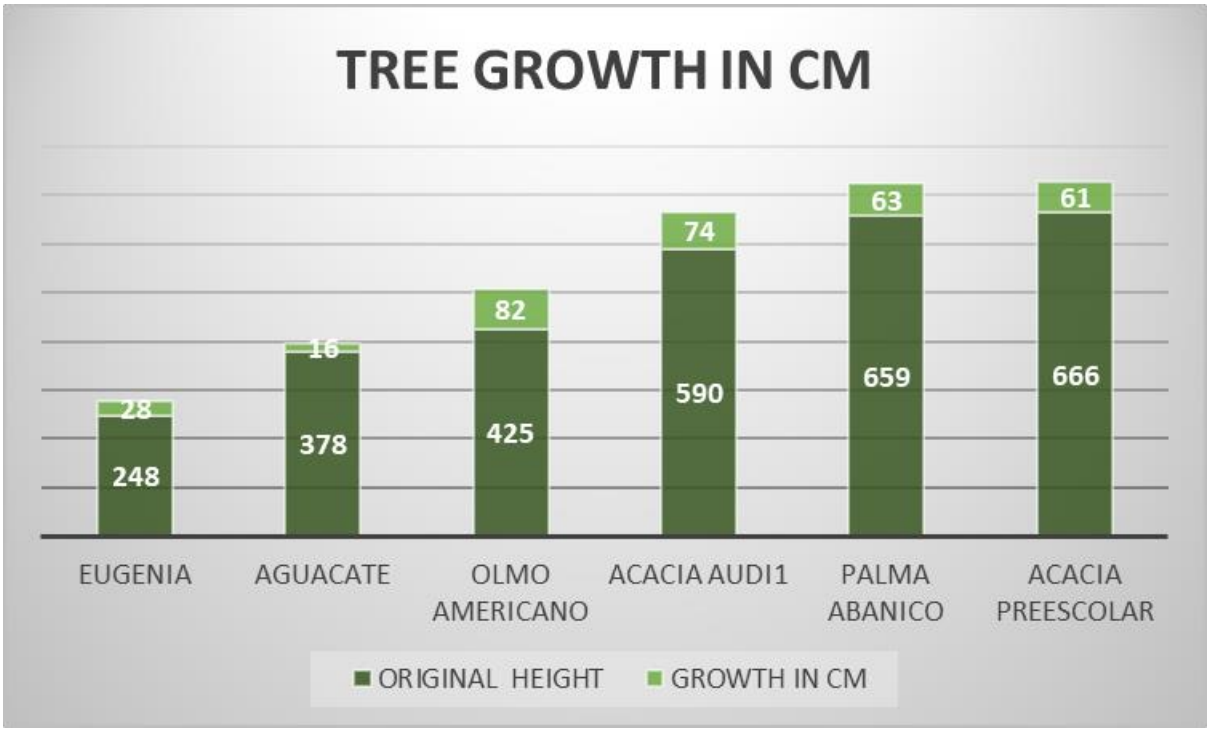


Figure 1. Tree Growth rate in cm. Created by the team

Once data was processed, we could find out that trees had grown on a range of 16cm to 82 cm, being the *Ulmus americana* the one that has grown the most during the measuring period of time.

And the avocado being the least to grow in the time of study with only 16 cm of growth.

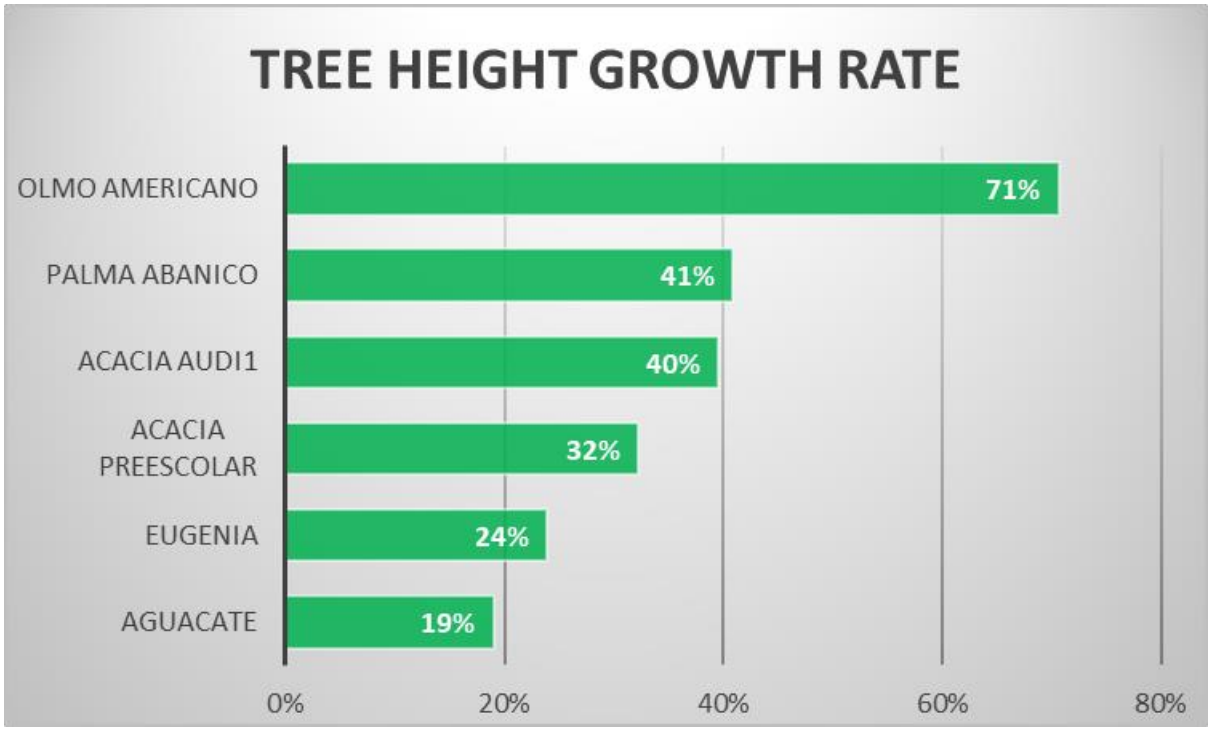


Figure 2. Tree height growth rate in percentages. Made by the Team

As we can see in the chart, the *Ulmus americana* got a growth rate of 71%, which takes us to wonder if it is located in a suitable place in campus to have that fast growth. Data also shows that *Persea Americana* has the least growth rate, with only a 19% compared to the rest of the species analyzed. We wonder if it is due to its fruit production season that seems to be starting.

BIODIVERSITY IN THE SCHOOL

In Ecuador, we can find a variety of native plants that are an important part of its biodiversity. The *Iochroma fuchsioides* stands out for its striking flowers, while the *Schinus molle*, known as "molle," provides shade and small red berries. Guabas, of the *Inga* spp species, are popular for their sweet and refreshing flavor. The *Eugenia myrtifolia*, with its shiny leaves, is common in many Ecuadorian gardens. Finally, the avocado, named *Persea americana*, is appreciated both for its delicious fruit and its nutritious properties. These plants not only beautify the landscape but also play a vital role in the ecosystem and the country's culture.

Besides those mentioned, we can find several fauna species around the gardens and green areas of our campus, in the table and collage below you will be able to see evidence of some of the species we commonly observe during our daily activities.

Local name	**English name**	**Scientific name**
Gorrión	Rufous collared sparrow	*Zonotrichia capensis*
colibrí	Sparkling violetear	*Colibri coruscans*
Colibrí cola larga	Black-tailed trainbearer	*Lesbia victoriae*
jilguero	Saffron finch	*Sicalis flaveola*
gallinazo	Black vulture	*Coragyps atratus*
cucube /sinsonte	Tropical mockingbird	*Mimus gilvus*
mirlo	Great thrush	*Turdus fuscater*
Quilico	American Kestrel	*Falco sparverius*
Tórtolas	Eared dove	*Zenaida auriculata*
Huiracchuro	Golden grosbeak	*Pheucticus chrysogaster*
Carpintero	Crimson-mantled woodpecker	*Pheucticus chrysogaster*

Table 5. Bird species observed in the school campus. Collected by the science team.

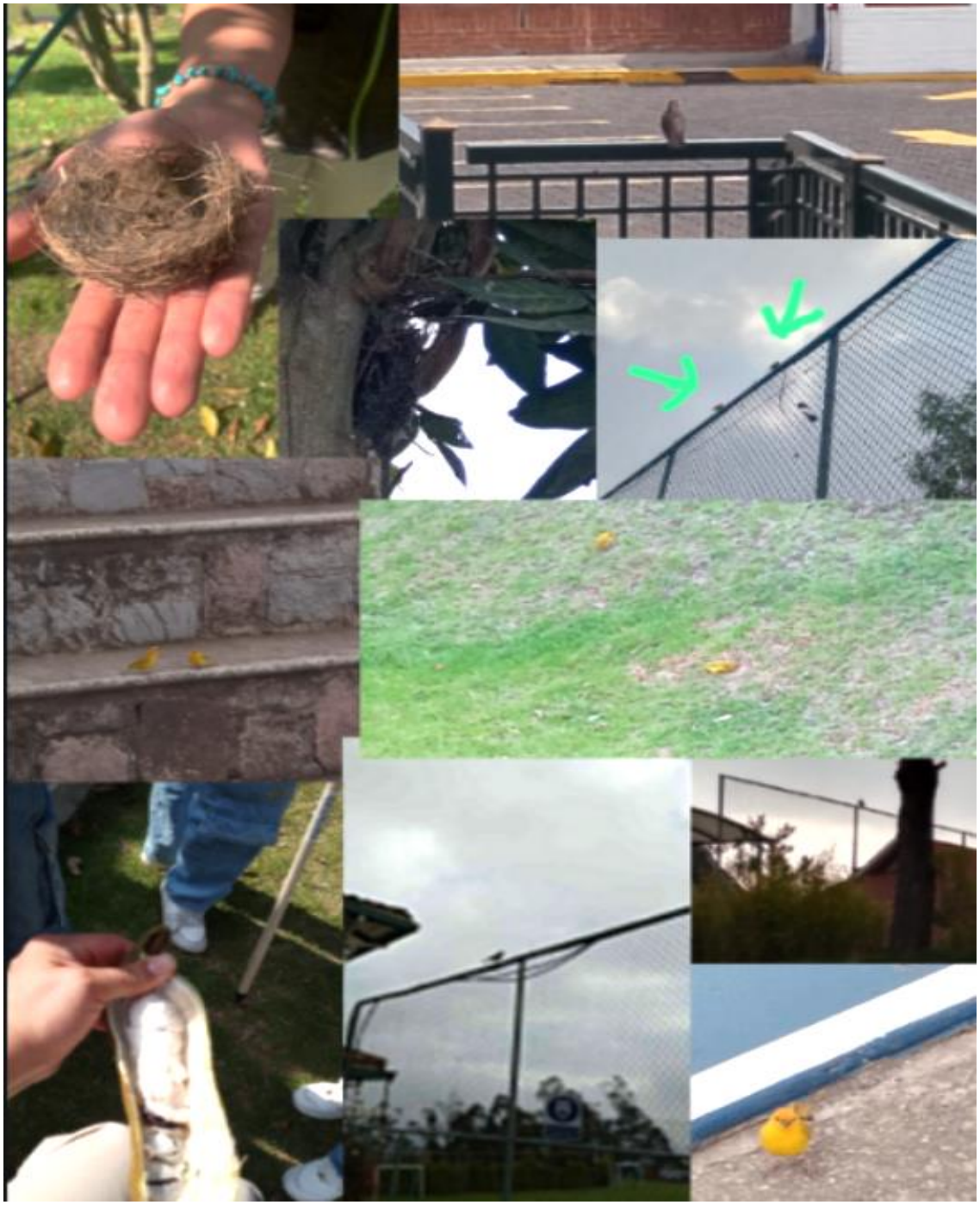


Illustration 6. Collage of photos with birds, nests, insects spotted.

Illustration 7. Mapping of bird observations.

In the map, red spots represent the places where different species of birds have been spotted frequently, it seems evident that they are always either close to the places where trees are located, or at their border. There seems to be a relationship between the sites where they can find food from leftovers and the places birds have been seen, picking up crumbles and fallen food.

RELATIONSHIP OF TREE - AIR AND SURFACE TEMPERATURE

We measured air temperature in relation with several random trees, all temperatures were taken the same day in a lapse of 30 minutes time, each data set was taken at 3 different points in relation to tree location:

0m from the tree (right under) - YELLOW
3m from the tree - RED
6m from the tree - BLUE

Results show that trees have a direct impact on air and surface temperature, the closer the measurement is taken to the tree the lower the temperature is. In the only one that this pattern did not follow the rule was with the Pittosporum undulatum, and we suspect it is due to the slope where it is located.

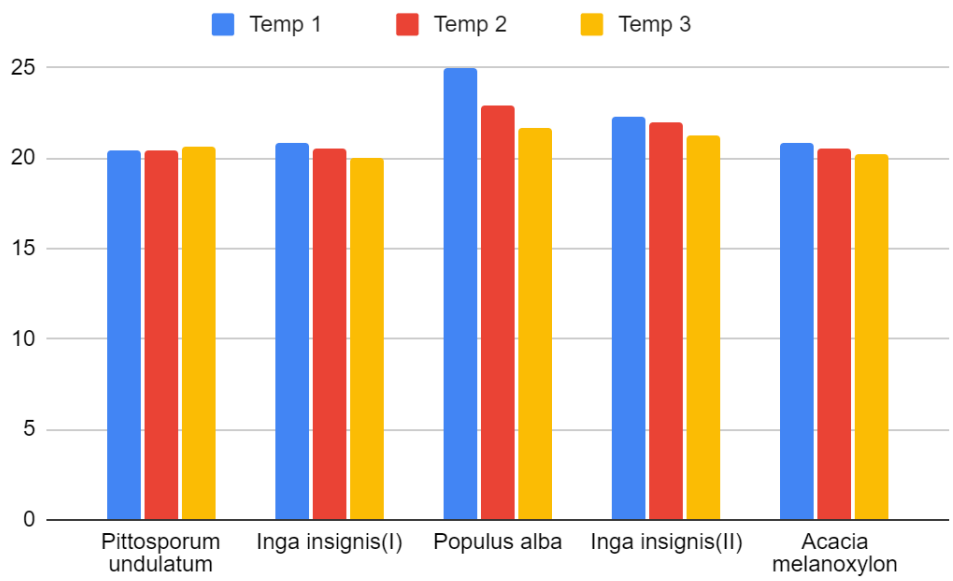


Figure 3. Air temperature related to distance from tree. Made by the team.

The same pattern is observed for soil temperature, which has a direct equivalence towards the width the tree branches reach to that they project their shadow, and therefore they keep lower temperatures on the soil the closer they get to the tree trunk.

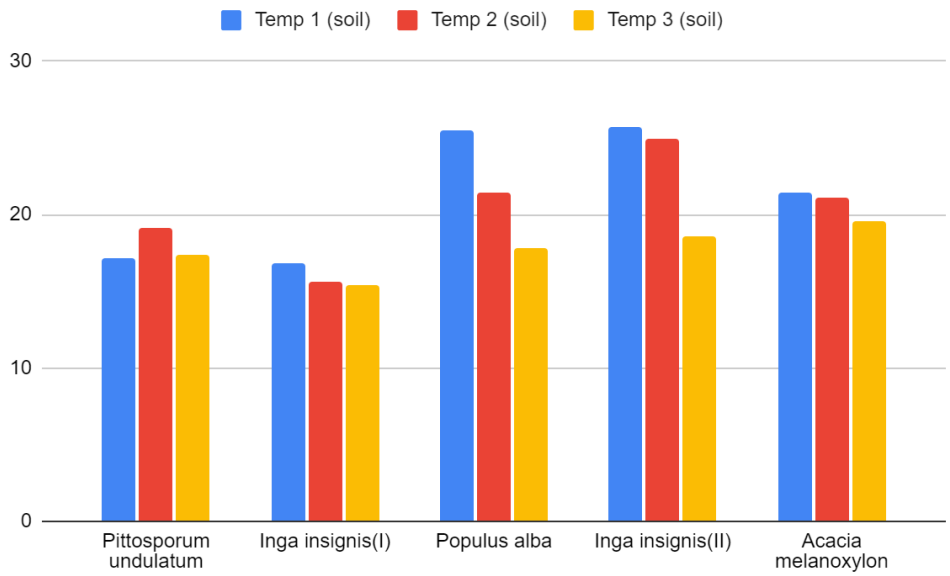


Figure 4. Soil temperature related to distance from tree. Made by the team.

Analysis and Results

BIODIVERSITY AT SCHOOL

The data collected by students in the school campus regarding tree diversity, temperature around the trees, their size measurements and classification according to native, emblematic, exotic and toxic species are detailed below:

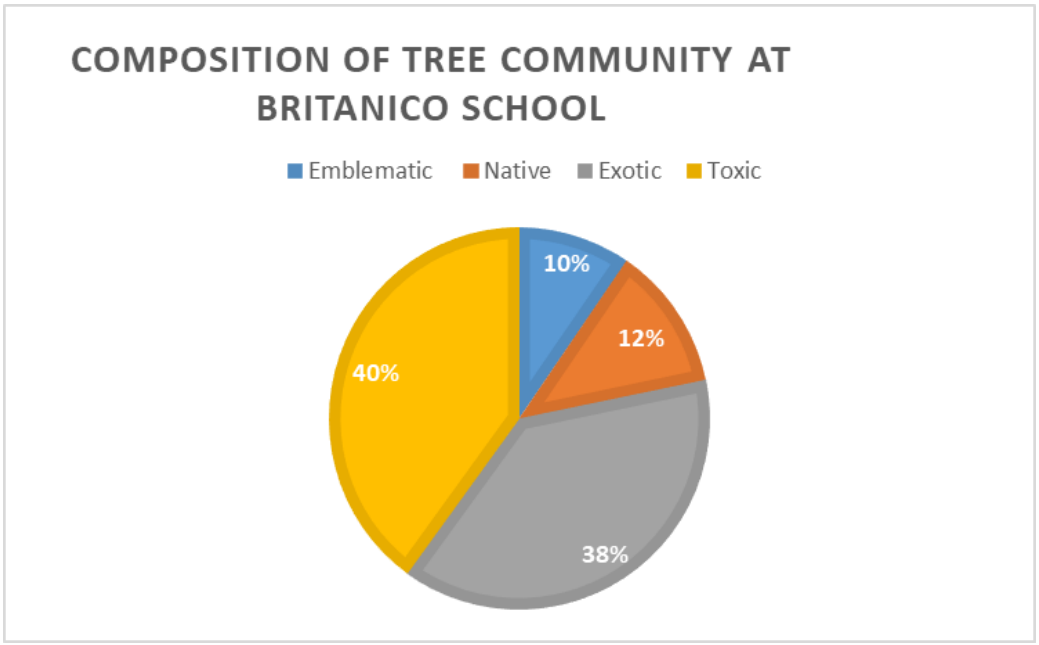


Figure 5. Composition of school campus trees classified in emblematic, native, exotic and toxic categories

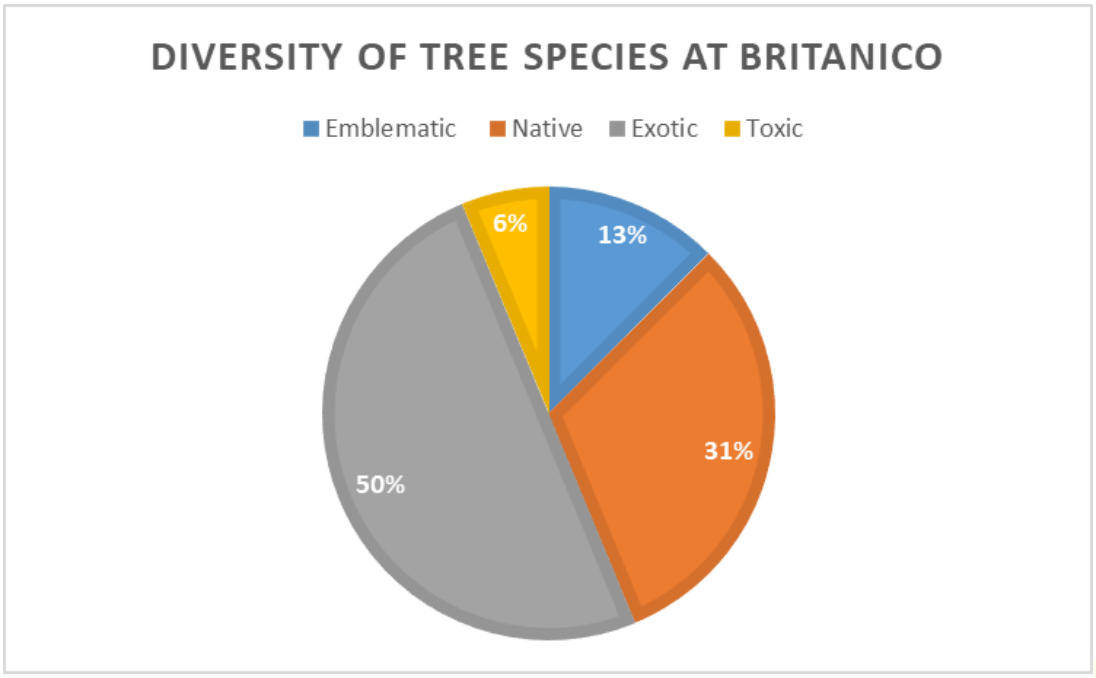


Figure 6. Diversity of tree species classified according to emblematic, native, exotic and toxic categories.

The total number of trees observed and identified were **N= 115** from **n=16** species.

To analyze these results, the Simpson's index was used as a way of quantifying the biodiversity of the tree communities. The value of Simpson's index reflects how many different types of species are in a community and how evenly distributed the population of each species is.

The formula used to calculate the Simpson´s index was:

$$D = \frac{\sum n_i(n_i - 1)}{N(N-1)}$$

where:

- n_i — Number of individuals in the i-th species; and
- N — Total number of individuals in the community.

The calculated Simpson's Index (D) for this set is **0.24.** The way to interpret this Simpson's Diversity Index is that any number close to 0 means little to none biodiversity and as numbers approach 1, the species richness can be considered high. **An index of 0.24 suggests that the diversity of species in the area being measured is relatively low.** This means that there is a high dominance of one or a few species compared to others. It could imply a higher level of dominance by certain species within the ecosystem.

Simpson's diversity index can also be expressed as Gini-Simpson index (1-D), which measures the probability of two randomly selected individuals from the community belonging to the same species. The formula used for this index is presented below:

$$\text{Gini-Simpson index} = (1 - D)$$
$$= 1 - \left(\frac{\sum n_i(n_i - 1)}{N(N - 1)} \right)$$

The Gini-Simpson's Diversity Index (1-D) for this set is 0.76, which means that there is a 76% probability that if 2 trees were randomly selected from the community of the school campus trees, they belonged to the same species.

TREE GROWTH

This research investigated the growth rate of trees on campus using the Average Growth Rate (AGR) formula and data collected from the GLOBE DATA VISUALIZATION SYSTEM.

Key Findings:

- Growth Rate Range: The analyzed trees exhibited a growth rate range of 16 cm to 82 cm during the measured period.
- Fastest Growing Tree: Ulmus americana demonstrated the fastest growth at 82 cm, raising questions about its suitability in its current location.
- Slowest Growing Tree: Persea americana (avocado) displayed the slowest growth rate at 16 cm. The authors speculate if this could be related to the fruit production season.
- Growth Rate Percentages: The findings were also presented as percentages, with Ulmus americana achieving a 71% growth rate and Persea americana reaching a 19% growth rate.

Overall, the study identified significant variations in growth rates among the examined trees, prompting further investigation into the factors influencing their individual performance.

TEMPERATURE AND TREES

	Temperature in Celcius degrees (C°)				
Distance from tree (m)	*Pittosporum undulatum*	*Inga insignis(I)*	*Populus alba*	*Inga insignis(II)*	*Acacia melanoxylon*
0	20.6	20	21.7	21.3	20.2
3	20.4	20.5	22.9	22	20.5
6	20.4	20.8	25	22.3	20.8
Variation of temp (C°) from the tree to 6 m. distance	**-0.2**	**0.8**	**3.3**	**1**	**0.6**

Table 6. Temperature variation from 5 trees in the school campus, collected at 0, 3 and 6m distance from the trees .

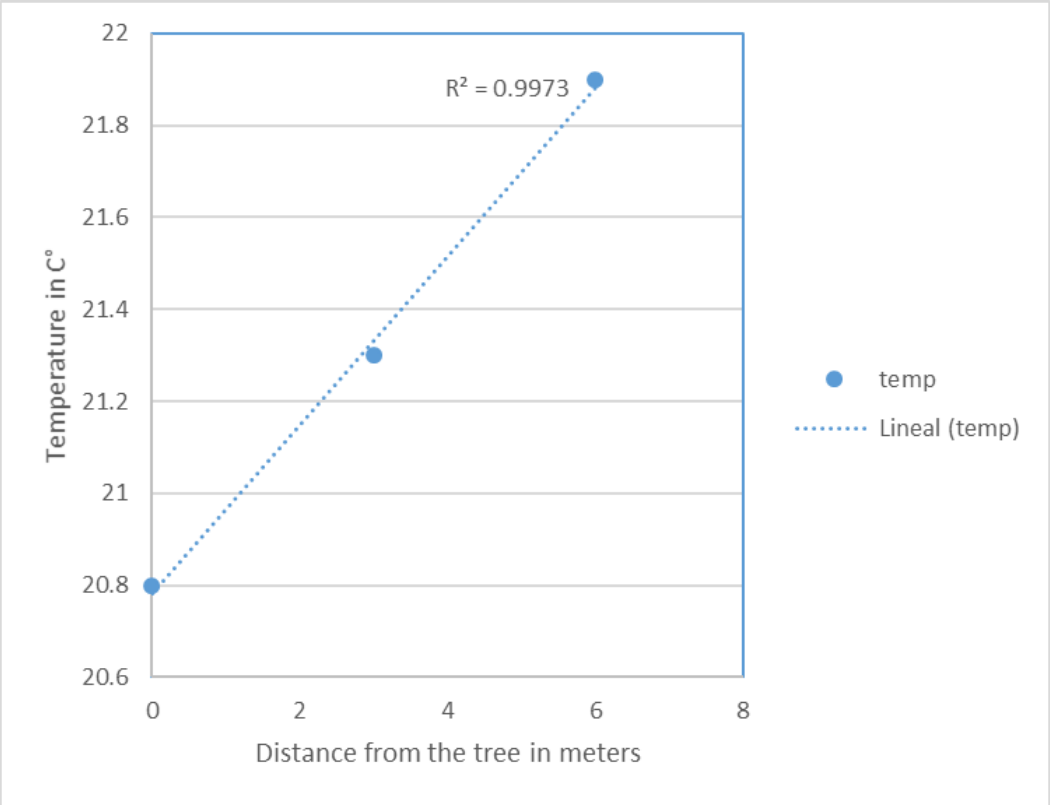


Figure 7. Average air temperature under 5 trees (0m), 3m and 6m distance from it.

These variations show that in general, the air temperature under tree shadow is at least 1 degree lower from the one further away from it. *Populus alba* had the biggest variation of temperature from 21.7°C to 25 percent, and *Pittosporum undulatum* presented the least variation in temperature with an actual increase of it at 0m from the tree.

	Soil temperature in Celcius degrees (C°)				
Distance from tree (m)	*Pittosporum undulatum*	*Inga insignis(I)*	*Populus alba*	*Inga insignis(II)*	*Acacia melanoxylon*
0	17.4	15.4	17.8	18.6	19.6
3	19.1	15.6	21.4	25	21.1
6	17.2	16.8	25.5	25.7	21.4
Variation of temp (C°) from the ground under the tree to 6 m. distance	**-0.2**	**1.4**	**7.7**	**7.1**	**1.8**

Table 7. Soil temperature variation from 5 trees in the school campus, data collected at 0, 3 and 6m distance from the trees.

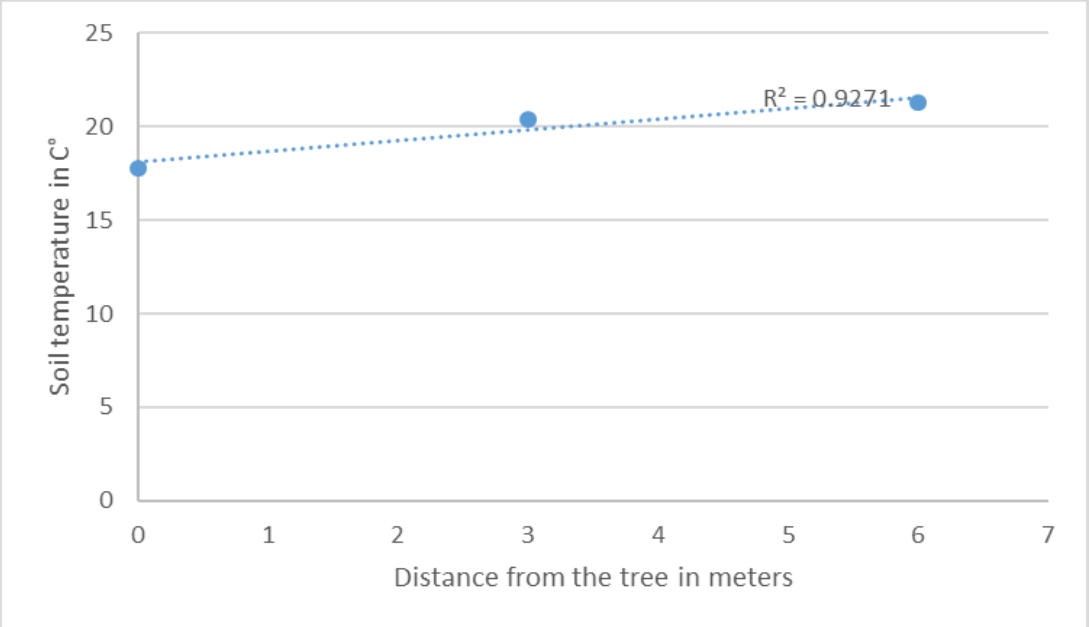


Figure 8. Average soil temperature under 5 trees (0m), 3m and 6m distance from it.

These variations show that in general, the soil temperature has a positive correlation with air temperature under tree shadow is at least 0.8 degree lower from the one further away from it. *Populus alba* had the biggest variation of temperature from 21.7°C to 25 percent, and Pittosporum undulatum presented the least variation in temperature with an actual increase of it at 0m from the tree.

Conclusions

With data evidence we concluded that the school has just a 22% of native and emblematic species which could lead to a new long term trees project to increase these numbers by introducing other species referred in the Tree Manual from the City hall. Nevertheless, there is a 40% existence of a toxic specie, and 38% of introduced species. There has been a recent introduction of new native species, but they are still too small to be measured through the application.

Evidence shows the dominant animal group is birds from at least 11 different species, which confirms the impact trees have on adequate habitat existence
.
From the data analyzed, as the distance increased from the trees, the temperature increased as well, demonstrating a positive correlation between both temperature and distance from trees. Moving 6 meters away from the trees, on average, increased the surface temperature by more than 1 °C. The temperature change went from 20.8°C to 21.9°C in the data collected.

The variation of temperature in the soil under the tree (0M), close to the tree (3m) and further away from it (6m) was more significant, increasing by 3.5°C.
This confirms the relationship between trees (its shade) and the capability of trees to regulate and maintain low temperatures.

Discussion

Suggested improvements:

- Register all other species, even if they are smaller than 2 meters
- Finish the Canva album to be shared with the community.
- Register insect species for further studies.
- Improve the monitoring of biodiversity around the school trees by recording all bird species that feed and nest in the trees. Taking photographs of them and identifying them using bird guides, iNaturalist app or Merlin bird identifier app.
- Increase the collection of surface and soil temperature data around trees in the school campus.
- Repeat the temperature collecting protocol at least 2 times per month in order to increase the data entries and therefore be able to do statistical analysis.

Our team of students chose the name project Lorax because they recognized the need to bring back native trees to our school. By collecting data these past 6 months they have seen, and the numbers confirm it, that the trees in campus are mostly introduced species and the students realize the importance of planting native species in the near future to increase the habitat for birds and insects.
Students have also acknowledged the significant role of trees to cool down the temperature. This is relevant because now they value and appreciate more the trees on campus and everywhere else. This motivates us to have a tree nursery of native species in school as a future project.

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References

Brockerhoff, E. G., Barbaro, L., Castagneyrol, B., Forrester, D., Gardiner, B., & González, J. R. (2017, 4 Nov 2017). Forest biodiversity, ecosystem functioning and the provision of ecosystem services. *Biodiversity and Conservation*, *26*(1), 3005. springer. https://doi.org/10.1007/s10531-017-1453-2

Cheng, Y., Wang, J., Wang, S., Cai, Z., & Wang, L. (n.d.). Effects of temperature change and tree species composition on N2O and NO emissions in acidic forest soils of subtropical China. *Journal of Environmental Sciences*, *26*(3), 617-625. https://doi.org/10.1016/s1001-0742(13)60450-7

Chung, H., Muraoka, H., Nakamura, M., Han, S., Muller, O., & Son, Y. (2013, may 21). Experimental warming studies on tree species and forest ecosystems: a literature review. *Current Topics in Plant Research*, *126*(1). https://doi.org/10.1007/s10265-013-0565-3

CONVENTION ON BIOLOGICAL DIVERSITY & United Nations Environment Programme. (n.d.). *Ecuador - Country Profile Biodiversity Facts Status and trends of biodiversity, including benefits from biodiversity and ecosystem services.* Convention on Biological Diversity. Retrieved February 21, 2024, from https://www.cbd.int/countries/profile?country=ec

Way, D. A., & Oren, R. (2010, June). Differential responses to changes in growth temperature between trees from different functional groups and biomes: a review and synthesis of data. *Tree Physiology*, *30*(6), 669 - 688. https://doi.org/10.1093/treephys/tpq015

ANNEXES

ANNEX 1

SPECIES IN CAMPUS DATA TABLE

SPECIES FOUND		ID IMAGE	No. #
COMMON NAME	***SCIENTIFIC NAME***		
Olmo Americano	*Ulmus americana*		1
Guaba	*Inga insignis*		10
Guantugcillo o Ajicillo	*Iochroma fuchsioides*		3

Molle	*Schinus Molle*		2
Guayaba	*Psidium spp.*		2
Eugenia	*Eugenia myrtifolia*		5
Aguacate	*Persea americana*		2

Pino	*Pinus ponderosa*		1
Palmera de abanico Chino	*Livistona chinensis*		2
Palma Fénix	*Phoenix Canariensis*		2
Yuco	*Yucca aloifolia*		30

Álamo Plateado	Populus alba		4
Fitosfero, Laurel Huesito	*Pittosporum undulatum*		1
Cepillo rojo llorón	*Callistemon viminalis*		2
Capulí	*Prunus serotina*		2
Acacia Negra	*Acacia Melanoxylon*		46

ANNEX 2

GROWTH RATE RAW DATA

tH (tree height)

tD (tree diameter)

TREE SPECIE	DATE 1	tH1 cm	tD1 cm	DATE 2	tH2 cm	tD2 cm
Eugenia	08 nov 2023	248	30	04 mar 2024	276	30.75
Palma Abanico	30 ago 2023	659	150	31 ene 2024	722	195
Aguacate	8 nov 2023	378	50.8	31 ene 2024	394	52.5
Acacia preescolar	30 ago 2023	666	128	6 mar 2024	7.27	133
Acacia audi1	30 ago 2023	5.90	77	4 mar 2024	664	78
Olmo Americano	8 nov 2023	4.25	55	3 mar 2024	5.07	55

ANNEX 3

Tree	Temp 1 6 m	Temp 2 3 m	Temp 3 0 m	Temp 1 6m (soil)	Temp 2 3m (soil)	Temp 3 0m (soil)
Pittosporum undulatum	20.4	20.4	20.6	17.2	19.1	17.4
Inga insignis(I)	20.8	20.5	20.0	16.8	15.6	15.4
Populus alba	25.0	22.9	21.7	25.5	21.4	17.8
Inga insignis(II)	22.3	22.0	21.3	25.7	25.0	18.6
Acacia melanoxylon	20.8	20.5	20.2	21.4	21.1	19.6
Average	21,9	21,3	20,8	21,3	20,4	17,8

TEMPERATURE DATA