Characterization, generation of orthophotos, and mapping of tree cover within an educational environment

Caracterización, generación de ortofotografías y plano del componente arbóreo dentro de un entorno educativo

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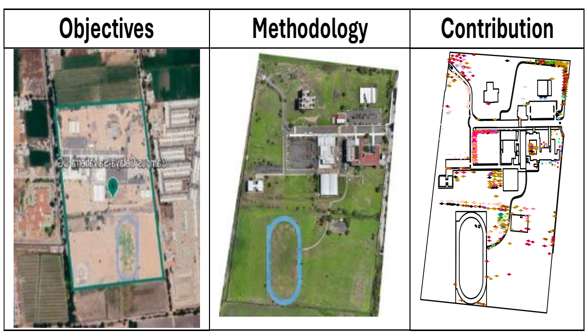
Abstract

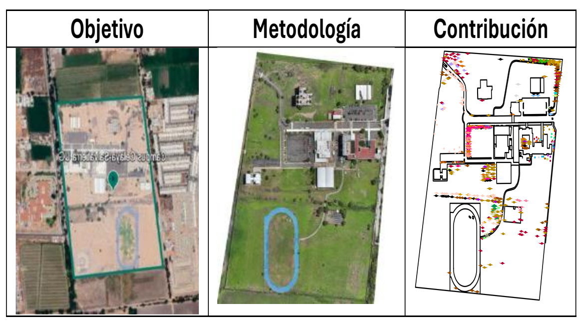
This research aims to quantify and characterize the tree assets of the Juan Pablo II site on the Celaya-Salvatierra Campus of the University of Guanajuato. It identified 559 trees, 75 species, and 34 families, detailing each tree's condition, sun exposure, and trunk diameter. A two-dimensional map was generated, locating the trees by family and drawing contour lines. This information allows for evaluations and decision-making regarding maintenance, reforestation, future growth, and sustainable land-use management for the area. The goal is to prevent the displacement of vegetation due to urbanization.



Urban trees, Sustainability, Orthophotography.

Resumen

La investigación busca cuantificar y caracterizar los activos arbóreos de la Sede Juan Pablo II del Campus Celaya-Salvatierra de la Universidad de Guanajuato, identificando 559 ejemplares efectivos, 75 especies y 34 familias familia, se detalló la condición del árbol, exposición al Sol y diámetro del tronco. Se generó un plano en dos dimensiones ubicando los ejemplares por familias, así como dibujando las curvas de nivel. Esta información permite realizar evaluaciones y toma de decisiones en términos de mantenimiento, reforestación, crecimiento a futuro y la gestión sostenible del uso del suelo para el espacio en cuestión. Con el objetivo de que se evite el desplazamiento del componente vegetal a causa de la urbanización.



Arbolado urbano, sustentabilidad, ortofotografía.

Area: Dissemination and universal access to science

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Introduction

The rapid growth of cities has led to urban trees being replaced by urban development, giving way to changes in land use that are not compatible with the conservation of vegetation. This displacement of vegetation cover brings about unfavourable changes in the environmental conditions of cities and, consequently, in the quality of life of their residents. By the end of 2022, around 56% of the world's population [4.4 billion people] will live in cities. This trend is expected to continue, with the urban population more than doubling by 2050, when almost 7 out of 10 people will live in cities [World Bank, 2022]. But vegetation is essential for the life of all species inhabiting the Earth, especially trees, as they produce oxygen, purify the air, form fertile soils, prevent erosion, keep rivers clean, capture water for aquifers, serve as shelters for wildlife, reduce soil temperature, encourage the establishment of other species, regenerate soil nutrients and improve the landscape [Ministry of Environment and Natural Resources, 2018]. Urban trees are generally located in public spaces and green areas such as parks, gardens or along city streets and medians, as well as in areas reserved for growth, which are becoming increasingly scarce. The University of Guanajuato has a significant environmental heritage, which is why there are constant efforts such as reforestation and preservation of the environment, particularly trees, at all its campuses, in line with the UN's Sustainable Development Goals. The study seeks to continue these actions by generating an inventory of the tree component and calculating the area of the Juan Pablo II Campus of the Celaya-Salvatierra Campus, beginning with mapping and surveying species and botanical families to obtain the distribution of trees on the land, monitoring at different periods during 2024 and 2025 due to the reforestation work carried out; aerial views were obtained with a drone to visualise the impact of the rainy and dry seasons on the tree component of the Campus. Locating and characterising the trees in the study area seeks to increase their visibility, leading to recognition of their real importance in the ecosystem services necessary for survival. It is essential that in cities with high levels of pollution, trees are allowed to survive regardless of changes in land use and the different economic activities to be carried out, as they can improve the quality of environmental conditions, making cities more suitable places to live.

Importance of urban trees

Talking about nature in the city is another challenge for sustainability, as urban ecology is significantly deteriorating due to increased urbanization [Galvez-Nieto, 2020], and trees are a key element in achieving urban sustainability.

The potential benefits of coexisting with trees in a given space are holistic. Environmentally, the strategic location of trees in cities can help cool the air by between 2 and 8 degrees Celsius. A mature evergreen tree, for example, can intercept more than 15,000 litres of water per year [ONU-Habitat, 2019]. socially, it creates more comfortable environments; some studies even suggest that the crime rate in certain cities in the United States of America is inversely proportional to urban tree cover [Pérez et al., 2024].

A mature tree can absorb up to 150 kilograms of polluting gases per year. As a result, trees play an important role in mitigating climate change [ONU-Habitat, 2019]. The presence of tree cover in large cities is key to reducing the concentration of CO_2 in the atmosphere. Urban areas are responsible for generating more than 80% of greenhouse gases [GHG] [Duval et al., 2023].

Therefore, a city with high green cover and a compact distribution of this vegetation has greater potential to store and sequester carbon. Urban trees capture suspended solid particles [PM_{10} or particles smaller than 10 microns] which adhere to the leaves and are washed away during rainy periods, thus carrying these particles into the sewerage system [Molina-Prieto y Vargas-Gómez, 2012].

Trees also have a dramatic influence on incoming solar radiation. In fact, they can reduce solar radiation by 90% or more. The radiation absorbed by the tree canopy leads to evapotranspiration, which lowers the temperature of the leaves, vegetation and air [Nowak et al., 1997].

In economic terms, improving the environmental quality of cities generates a social benefit for their inhabitants by raising their quality of life, and by raising the quality of life, the land is revalued, as these areas of the city acquire added value [Galindo-Bianconi y Victoria-Uribe, 2012].

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Characteristics of the study site

The study area is located on the grounds of the Juan Pablo II Campus of the Celaya-Salvatierra Campus of the University of Guanajuato, located at Ing. Javier Barros Sierra 201, CP. 38140, in the city of Celaya, the micro-location [Figure 1] and macro-location [Figure 2]. The municipality of Celaya is located between parallels 20° 42' and 20° 21' north latitude; meridians 100° 38' and 100° 56' west longitude; altitude between 1700 and 2700 m; the predominant soils are Vertisol [71.79%], Phaeozem [10.33%] and Leptosol [5.17%] [National Institute of Statistics and Geography, 2010]. It occupies 1.81% of the state's surface area. Its highest slopes range from 5 to 10 per cent. Celaya has a semi-dry, semi-warm climate [65%], sub-humid with lower humidity in summer [21%], semi-dry temperate [7.4%], temperate sub-humid with lower humidity in summer [4.5%] and temperate sub-humid with medium humidity in summer [2.1%]. Among its characteristics, it has a climate with an approximate temperature range of 6°C to 31°C [Official Gazette of the Federation, 2022]; the temperature peaks in August with a range between 26 and 34°C.

Box 1

Figure 1
Micro-location Juan Pablo II Headquarters, Celaya-Salvatierra Campus, UG (Google Earth, 2025)

Box 2

Figure 2
Micro-location Juan Pablo II Headquarters, Celaya-Salvatierra Campus, UG (Google Earth, 2025)

The average annual rainfall ranges between 600-800 mm [National Institute of Statistics and Geography, 2010]. The Celaya Valley aquifer is overexploited. This aquifer has an annual recharge of 286.6 Mm^3 [million cubic metres] per year; with an extraction volume of 593 Mm^3, groundwater is the main source of water supply and irrigation for crops in Celaya; The dynamic level in all wells averages 110 metres, but drilling is currently taking place in risk areas at depths of more than 600 metres to capture water in areas where there is no arsenic.

The municipality of Celaya is mainly a plain, with soils suitable for agriculture, urban development and other anthropogenic activities, which is why most of its natural cover has been transformed to make way for agriculture, pastures and urban areas [Municipal Institute of Research, Planning and Statistics of the Municipality of Celaya., 2023].

According to the analysis of information reported by the municipality's monitoring network, practically since the beginning of its operations, the main air quality problems in Celaya have been related to high concentrations of PM_{10} and environmental ozone [O_3]. Based on municipal reports, Celaya is one of the cities in Guanajuato with the most serious problems of PM_{10} pollution [Celaya Municipal Council, 2019].

The most important natural vegetation consists of oak forests, low deciduous forests, scrubland and grasslands, mainly comprising trees of the Bursera genus and other species such as Acacia spp., Opuntia spp., Myrtillocactus, and Mimosa spp., such as ahuehuetes [sabinos], huizaches, mesquites, pirules, sapotes, ash trees, willows, cazahuates [palos bobos], nopales, granjenos, tepeguajes, sicuas, tepames, nopal, and maguey [Celaya Municipal Council, 2019].

Most of the green areas in the municipality are complementary or linked to the road network [central and side medians; tree, shrub, and herbaceous vegetation in roundabouts]. There are also fragmented urban green areas [public planters and private gardens; parks, vacant lots, boulevards, and public and private academic institutions] [Municipal Institute of Research, Planning and Statistics of the Municipality of Celaya, 2014], such as the study area.

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Methodology

The entire Juan Pablo II campus of the Celaya-Salvatierra campus of the University of Guanajuato was georeferenced, delimiting the built-up, open and permeable areas, with particular attention to the location of the trees contained within the space. Altitude [elevation] data was collected from different points on the terrain and the location of those points [X, Y coordinates] for the contour lines. The survey was carried out with a drone, obtaining photogrammetric images.

The drone flew between 9:00 a.m. and 12:00 p.m. and/or between 3:00 p.m. and 5:00 p.m.; the time range was essential to avoid any shadows or interruptions in the visual line between the camera and the object to be reconstructed, as this constitutes an obstacle for the algorithm; Orthophotographs or orthoimages were taken at different times to determine the condition of the trees during the dry and rainy seasons.

It is stated that, during the use of the drone and the processing of this data, the privacy of the university community on campus was respected.

Subsequently, each of the tree specimens found at the Juan Pablo II site was located, quantified and characterised by species and botanical family. This process was carried out by a team on foot in the area, using chalk [completely washable] to mark the trees and label them, which would then be represented on the map.

The characterisation by species and family was carried out with the help of the Plant Palette of the Municipality of Celaya and other plant catalogues from similar geographical areas.

The following details were also recorded: tree condition [excellent, good, fair, poor, critical, dead], circumference [cm], sun exposure [full, partial, shade], distance to the nearest building [m] and direction to the nearest building.

Finally, a map of the Juan Pablo II headquarters was drawn up, showing all the families found in the area surveyed in both years, providing a graphical representation of the trees in the study area.

Results

Two orthophotographs were obtained from the drone flights, the first of which was taken during the dry season, when it is possible to see the vegetation in a dry state [Figure 3]. In contrast, during the rainy season, the entire area is green [Figure 4]. This provides an overview of the behaviour of plant species and their resilience.

Box 3

Figure 3
Orthophotograph of the Juan Pablo II Headquarters, taken during the dry season.
Own work.

Box 4

Figure 4
Orthophotograph of the Juan Pablo II Headquarters, taken during the dry season.
Own work.

The approximate area of the headquarters is 184,009.11 m². The maximum height above sea level at the headquarters is 1,751 metres and the lowest point is 1,749 metres, indicating a difference of 2 metres.

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This allows for surface runoff and the creation of a micro-catchment area for rainwater, and therefore an important absorption area, since the surrounding areas are impermeable, covered with rigid and flexible pavement. The contour lines can be seen in Figure 5.

Box 5

Figure 5

Contour lines John Paul II Headquarters

Own elaboration

A total of 75 botanical species were identified, for a total of 590 specimens, of which 31 could not be identified due to their condition, since at the time of data collection in the field, the tree had no foliage, which made correct identification difficult. Therefore, there are 559 effective trees. Table 1 breaks down the species, with Vachellia farnesiana I being the most abundant species.

Box 6

Table 1

Botanical species found at the John Paul II headquarters

	Scientific name	No.
1	Unknown	31
2	Senna corymbosa	8
3	Schinus areira L.	11
4	Schinus molle L.	47
5	Senna corymbosa	8
6	Cascabela thevetiodes [Kunth] Lippold	1
7	Plumeria rubra L.	30
8	Thevetia peruviana [Pers.] K. Schumann	3
9	Phoenix roebelenii	3
10	Jacaranda mimosifolia	17
11	Casuarina cunninghamiana	8
12	Euphorbia cotinifolia	3
13	Acacia saligna [Labill.] H. L. Wendl.	12
14	Delonix regia [Bojer ex Hook] Raf	19
15	Acacia shaffneri [S. Wats] F. J. Herm.	1
16	Acacia pennatula [Schldl. & Cham.] Benth	12
17	Prosopis laevigata [Humb. Et Bonpl. Ex. Wild.]	6
18	Prosopis glandulosa. Torr.	5
19	Albizia occidentalis T. S. Brandegee	1
20	Lysiloma divaricatum [Jacq.] MacBride	1
21	Leucaena esculenta [DC.] Benth	1
22	Umbellularia californica [Hook & Arn] Nutt.	1
23	Gossypium	1
24	Hibiscus rosa-sinensis	20
25	Ficus benjamina	7
26	Eucalyptus camaldulensis	3
27	Psidium guajava	1
28	Bougainvillea	57
29	Fraxinus uhdei. Wenzig.	25
30	Fraxinus americana L.	20
31	Rhaphiolepis bibas [Lour] Galasso & Banfi	1
32	Citrus x aurantium L.	3
33	Solanum aviculare	11
34	Albiza lebbeck L	20
35	Bauhini variegata	2
36	Bursera fagaroides	2
37	Carica papaya L.	1
38	Casimiroa edulis la llave	1
39	Leucaena leucocephala	2
40	Chilopsis linearis	2
41	Cissus verticia L.	1
42	Delonix regia	3
43	Dodonia viscosa jacq	6
44	Ficus microcarpa L. F	1
45	Ficus Retusa L.	4
46	Flaxinus Angustifolia Vahl	1
47	Fraxinus uhdei	1
48	Fraxinus velutina	13
49	Gutierreza sarothrae	1
50	Heptapleurum actinophynum	1
51	Lophostemon confertus	1
52	Manikara zapota	10
53	Melia azedarach L.	3
54	Olea europaea L.	17
55	Orcopanax nymphneitolious	1
56	Parkinsonia aculeada	8
57	Piptadenia goanacatha [Mart] J.F. Macbr	1
58	Prosopis velutina	1
59	Punica Granatun L.	1
60	Rhamnus saxatilis aiaca	1
61	Rhamnus saxatilis jaca	2
62	Rhus virens	2
63	Robina pseudoacacia	3
64	Roseodendron donell smithi [Rose]	1
65	Salvadora Persica	10
66	Sena occidentalis	2
67	Sesbama Punicea Cav. Benth	1
68	Ulmus parusfolia sac	4
69	Vachellia farnesiana l.	73
70	Vachellia nilotica	2
71	Viburnum adoratissimum	3
72	Vitex agnus cactus	1
73	Ficus rubiginosa	1
74	Psidium cattleyanum Sabine	2
75	Morus alba	1
76	Prunus serotina	1
	Total	590

The 559 species were subsequently grouped by family in order to manage more compact data on the map, quantifying a total of 34 families, catalogued by colour [Table 2]. The family with the most abundant species is Fabaceae.

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Box 7

Table 2

Botanical families found at the John Paul II headquarters

	Family	Quantity
1	Unknown	31
2	Anarcadiaceae	60
3	Apocynaceae	39
4	Arecaceae	3
5	Asteraceae	1
6	Bignoniaceae	20
7	Casuarinaceae	8
8	Euphorbiaceae	3
9	Fabaceae	103
10	Lauraceae	1
11	Malvaceae	21
12	Moraceae	10
13	Nyctaginaceae	57
14	Olaceae	77
15	Rosaceae	2
16	Rutaceae	4
17	Sapindaceae	6
18	Solanaceae	11
19	Ulmaceae	4
20	Burseraceae	2
21	Caricaceae	1
22	Vitaceae	1
23	Ficus	4
24	Araliaceae	1
25	Myrtaceae	7
26	Sapotaceae	10
27	Meliaceae	3
28	Leguminosae	8
29	Lythraceae	1
30	Rhamnaceae	1
31	Eukaryota	2
32	Salvadoraceae	10
33	Vachellia	73
34	Adoxaceae	3
35	Lamiaceae	1
35	Nymphaeaceae	1
	Total	590

Using orthoimages, a map was created in AutoCAD showing the location and distribution of trees on the grounds of the Juan Pablo II headquarters by family [Figure 6].

Box 8

Figure 6

Map of the trees at the headquarters by botanical families

Prepared by the author

In terms of tree characteristics, the minimum diameter is 4 cm and the maximum is 270 cm. The condition of the trees was recorded, finding that 22.54% of the trees are in excellent condition, 34.92% are in good condition, 4.75% are fair, 10.34% are poor, 19.32% are critical, and 8.14% are dead [Table 3].

Box 9

Table 3

Tree conditioner

Condition	Quantity
Excellent	133
Good	206
Fair	28
Poor	61
Critical	114
Dead	48
Total	590

In addition, the exposure to sunlight of each of the specimens was observed, finding that 85.76% are completely exposed to sunlight, 14.24% are partially exposed, and none are in the shade, as shown in Table 4.

Box 10

Table 4

Sun exposure

Exposure	Quantity
Full	506
Partial	84
Shade	0
Total	590

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Conclusions

The findings show that vegetation changes dramatically depending on the season, low water period [March-May] and rainy season [June-August], which is consistent with the type of vegetation that exists in the area, namely low deciduous forest and scrubland, as can be seen from the orthoimages. Celaya is a municipality with little natural vegetation, which speaks to its degree of anthropisation, but the remnants of vegetation, such as those at the Juan Pablo II headquarters, are well preserved and consist of continuous massifs with little fragmentation of the landscape. The tree species found in the study area are native to the area, indicating that they are adapted to the soil and have the necessary nutritional requirements, so it can be deduced that they do not suffer from stress, allowing them to perform their carbon sequestration and water capture functions.

Of the 559 trees counted, 75 species were found, with Vachellia farnesiana being the most abundant, followed by Bougainvillea and, in third place, Schinus molle L. As for families, 3.4 were characterised, with Fabaceae occupying first place, followed by Olaceae and then Vachellia. The location of the trees within the headquarters suggests that they can help cool the air by between 2 and 8 degrees Celsius. The mature trees found regulate water flow and play a key role in preventing flooding and reducing the risk of natural disasters. This ecosystem benefit is relevant given that the Celaya region suffers from severe flooding due to its mostly flat topography.

The University of Guanajuato's commitment to reforestation is evident, as it was possible to visualise the planting of young trees, and 57.46% of existing trees are in excellent or good condition. It is worth mentioning that none of the trees counted are in the shade, which allows them to carry out the process of photosynthesis properly, in addition to regulating the ambient temperature and providing ecosystem services.

The growth of a city is inevitable in most cases because it is essential to meet the demands of urban environments, including education, as in the case of the Juan Pablo II Campus; however, these vocations should not conflict with each other.

This inventory may be useful for the campus, as knowing the location, distribution, and characteristics of the trees with the help of spatial analysis allows for assessments and decision-making in terms of maintenance, reforestation, future growth, and sustainable land use management for the space in question.

Declarations

Conflict of interest

The authors declare that they have no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Contribution of the authors

Palacios-Hernández, Otoniel: Contributed to the management of the field brigade to obtain orthoimages, contour lines, and a 2D plan with the spatial location of the trees.

Moreno-Martínez, Viridiana: Contributed to the identification of trees with respect to species, family, condition, diameter, and sun exposure.

Availability of data and materials

The data are available for use for research purposes.

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