CHAPTER 60

Tree characterization to improve thermal comfort, in the city of Santiago de Guayaquil

Crossref doi https://doi.org/10.56238/alookdevelopv1-060

Orlando Adolfo Hermida Iturralde
Master in Sustainable Urban Technologies
E-mail: orlandohermida@yahoo.com
ORCID: https://orcid.org/0009-0001-6028-2236

Carlos Alberto Nieto Cañarte
Teacher - Researcher at the State Technical University of Quevedo
E-mail: cnieto@uteq.edu.ec
ORCID: https://orcid.org/0000-0003-1817-9742

Byron Andres Burgos Carpio
Master in Industrial Safety and Environment from the Universidad Andina Simón Bolívar
E-mail: byron.burgos2015@uteq.edu.ec
ORCID: https://orcid.org/0000-0002-2840-9997

Carlos Vinicio Sanabria Yépez
Technician of the Ministry of Agriculture and Livestock
E-mail: csanabria@mag.gob.ec
ORCID: https://orcid.org/0000-0001-5038-3159

ABSTRACT
The reduction of temperature under trees due to evapotranspiration and canopy covering, widely studied according to its species and valued by indexes, has not been studied within Guayaquil, a city that in addition to being characterized by its high temperatures during the year, presents manifestations of the Urban Heat Island (ICU) phenomenon. The present study analyzes the direct influence on the temperature reduction of 19 tree species found within the urban area through the equivalent physiological temperature index (PET) obtained from the Rayman Pro model and details the predominant landscape characteristics in the city exemplified in 2 residential areas, to discern the adjustment of 5 efficient species to mitigate the ICU effect. The results show the introduced species as the most optimal, but of potential conflicts with the urban infrastructure already conceived, it was not possible to determine the location of moderately efficient species without following a specific pattern in both study areas.

Keywords: Urban heat island, Equivalent physiological temperature, Trees, Guayaquil.

1 INTRODUCTION

The city of Santiago de Guayaquil, is the most populated in Ecuador (Ecuadorian Institute of Statistics and Censuses [INEC], 2010) and with a vehicle fleet that has increased to be the largest in the country after the city of Quito (INEC, 2016) developed irregularly in much of its urban component, which is marked by settlements on old branches of estuaries that replaced the extensive mangrove coverage of these by filling gravel and pavement (Estrada, 2000) thus propagating the replacement of vegetation cover by impermeable soils, going from a surface that favored the flow of latent heat that reduced the sensible heat thanks to the physiological action of the mangrove (evapotranspiration) to a surface that gains sensitive heat in the absence of this evapotranspiration, modifying the energy balance and consequently, the local temperature (Jackson et al., 2010).

While the reduction of vegetation cover in favor of palm trees continues, the accumulation of radiative heat in concrete and the addition of greenhouse gases due to an increase in the automotive fleet makes the city increasingly susceptible to the Urban Heat Island (ICU) effect, a phenomenon already reported by the National Institute of Renewable Energies and Energy Efficiency [INER]

(2016), In whose report he mentions the presence in different parts of the city, subject to construction materials and that is accentuated in those areas lacking vegetation, while warning of the increase in energy demand that this phenomenon will cause, feeding back the cycle as mentioned verbatim in the summary published in his scientific journal: "*the warmer the environment, the greater the cooling demand that buildings will need, the greater the consumption of electricity and the greater the heat released in these urban areas, the warmer environment successively contributes"* (INER, 2017).

Although the ICU effect in the city was recently investigated, the lack of trees in the urban area has generated demonstrations by the environmental collective Árboles Sin Fronteras (2018) and El Selectivo (2018) that demand increase tree cover to obtain ecosystem benefits, while others such as La Iguana Foundation (2018) execute reforestation actions with native species within the city arguing an " *immediate solution to counteract the effects of climate change*", although this proposal is laudable, it encompasses all native species as efficient without evaluating their selection according to the place and the objective set, so that their planting actions could not be of benefit in the objective to achieve or ensure their survival in an urban environment.

The Urban Heat Island (ICU) effect defined as *"the increase in the ambient temperature of the city and surfaces compared to that of rural areas"* (Santamouris et al., 2016) was studied by Oke (1982) who revealed the physical principles of this effect: building materials with their capacity to absorb radiation (near infrared) and heat emission (far infrared), The urban morphology capable of modifying the direction of the winds and anthropic activities such as the use of vehicles or thermal systems. Based on the first two principles, INER carried out a study of the building and morphological component of the city of Guayaquil to verify its existence, detecting increases of between 3ºC to 4ºC during the afternoons and nights, with greater incidence in areas devoid of vegetation. (INER, 2016) The energy component was studied by Palme et al. (2017) who concluded that the energy demand for the use of air conditioning in Guayaquil can vary between 17% to 206% when affected by the ICU effect, surpassing coastal cities such as Lima or Antofagasta and adding that "*building functions are connected to the urban environment, Because as the outside temperature increases, the energy demand grows and this, in turn, increases the heat of the city"*

The effect of the ICU phenomenon does not yet have an influence definitively linked to the already confirmed climate change (IPCC, 2014) there are publications based on simulations where it reveals that this is indeed fed back due to energy demand, while others do not assert any relationship (Santamouris et al., 2016) While there is some uncertainty about the effects of global warming on ICUs, years ago the World Bank, (2011) already recommended the inclusion of "*green infrastructure and vegetation to achieve natural cooling"* as one of the responses for adaptation to climate change in cities, this is the same strategy used to placate the ICU phenomenon (Rosenfeld, et al., 1995) (Taha,

1997) since vegetation reduces air temperature by evapotranspiration of the species used (Kornarska et al., 2015) and the shadow generated by the canopy (Andreou, 2014) so that the fulfillment of this recommendation would not only contribute to the coping with climate change in the coming decades, but would also contribute to the attenuation of the Heat Islands.

The potential of the tree as a thermal regulator is subject to its specific characteristics such as size, canopy density, shape, leaf color, and size, orientation, age, and growth; influencing intercepted radiation, temperature, and humidity. (The Nature Conservancy, 2016) which has given the search for correlative results between thermal comfort and the characteristics of the different species, such as the study executed in Tapie, Taiwan by Lin & Lin (2010) that after taking measurements of temperature, humidity, wind speed, and solar radiation under 12 tree species, They found that the surface cooling under the tree is subject to leaf density, thickness, texture, and leaf color in this order, with thicker leaves being more efficient over thin ones, rough leaves more than smooth ones and light green leaves over dark green ones. Abreu-Harbich, Labaki, & Matzarakis (2015) analyzed the bioclimatic behavior under 10 species individually and 6 in a grouped manner in Campiñas, Brazil, and through the Equivalent Physiological Temperature (PET) index linked to the Sky View Factor (SVF), established that the cooling effect is influenced by the permeability of the canopy, decreasing from 0ºC to 2.8ºC individually and between 0.3ºC to 15ºC of PET degrees in canopies conglomerates with variation subject to species type. Kong, et al., (2017) studied the behavior of the Mean Radiant Temperature (Tmrt) and PET in 12 species between trees and palms in Hong Kong, correlating with the SVF under each tree, concluding that the Tmrt has less impact on the pedestrian level when species of small trunks and wide canopy interfere, reducing up to 78% the shortwave radiation that reaches the ground, thus decreasing the reflection as long wave and a decrease between 1.6ºC and 2.5ºC in PET degrees, very significant when compared with 5.2% of shortwave radiation that intercepts a scarce canopy such as that of a palm tree with its PET increase up to 2.2ºC and Konarska, et al. (2015) affirmed the effect of evapotranspiration of urban trees on diurnal cooling by studying 9 most common species from Gothenburg, Sweden.

While cited studies correlate the characteristics of the tree and the thermal comfort experienced under it, a factor alien to the nature of the tree such as location was studied by Sanusi et al. (2016) concluding that the orientation influences at certain times of the day, being more efficient those trees located with East-West direction by following the direction of the solar zenith, unlike the North-South orientation. Research such as that of Georgi & Zafiriadis (2006) and Jiménez (2008) propose the tree hierarchy for thermal comfort, with different methodologies based on the same parameters, have developed an inventory of species suitable for the city of origin or other publications related to urban thermal comfort that incorporate comparisons between two or more species (Fahmy et al., 2010), also

Feyisa et al. (2014) demonstrate the feasibility of analyzing species with their characteristics as a specific strategy to confront the Urban Heat Island phenomenon.

2 THEORETICAL FRAMEWORK

2.1 PRINCIPLES OF TEMPERATURE REDUCTION

2.1.1 Evapotranspiration

Evapotranspiration, linked to the water load capacity of the tree-soil system, is made up of the sum of its parts that are evaporation, which takes place on the surface of the leaf structure, and transpiration, which is manifested through the stomata of the leaf by the action of photosynthesis (Fahmy et al., 2010) and that it is affected by water stress as a result of high temperatures and lack of water, forcing the plant to close its stomata to stay hydrated (Alvarado et al., 2014). Evapotranspiration consumes more than 50% of the solar radiation absorbed by the surface (Trenberth et al., 2009) and has an effect on the principle of radiative balance, which holds that through evapotranspiration, the tree transforms into moisture the water molecule it takes from the soil, and to fulfill this process uses energy, This energy requirement for a change of state is called latent heat flow, as a result, it lowers the temperature of the surrounding ambient air perceived by people or in other words, reduces the sensible heat flow, obtaining a favorable result by balancing radiative energy balance, This has been one of the principles in investigations of climatic aspects attributable to forests (Jackson et al., 2010) and to cities, where experiences applied in the latter maintain that the limited amount of green areas of a city due to the replacement of vegetation by concrete or asphalt, causes a reduction of latent heat flow, inducing the storage of radiative energy in these materials and that will subsequently be released as a sensible heat flow, Increasing the temperature of the air, therefore tree planting becomes one of the principles that supports the balance of the energy balance, direct cause of the ICU effect, however, not all species have the same effect since it varies according to the species and environmental conditions (Dimoudi & Nikolopoulou, 2003) (Fahmy, et al, 2010) (Ballinas & Barradas, 2015).

2.1.2 Canopy shadow

On the other hand, the shade of a wide canopy not only protects from solar radiation (short wave) at pedestrian level, but is capable of providing an air cooling effect that can extend up to one hundred meters away (Shashua-Bar & Hoffman, 2000) the wider the canopy or canopy, the air temperature will be lower and there will be notorious thermal comfort, with greater perception at noon and in the early afternoon, (Spangenberg et al., 2008) this cooling is also subject to leaf structure such as thickness, texture, brightness and density; same characteristics that also influence the decrease of surface temperature under the canopy according to the diversity of its features, in this way the shade of the different trees carry marked particularities that manage to make them efficient in the decrease of the temperature of the air in some species and of the soil in others (Lin & Lin, 2010) this last quality minimizes the thermal inertia in the materials of the city, decreasing the manifestation of heat (long wave) during the nights (The Nature Conservancy, 2016) in addition to a decrease in the temperature of the ambient air carried by convective flows when coming into contact with colder surfaces (Taha, 1997).

2.2 SKY VIEW FACTOR (SVF)

The Sky View Factor or SVF (Sky View Factor) defined by Oke, (1995) *as* "the visible fraction of the sky seen from a given point*" is* dimensionless and its range is between 0 and 1, where 0 is a sky covered by terrain or obstacles while 1 is for an open sky (Matzarakis, 2017) the determination of the SVF is through circular hemispherical photographs called fisheye or "fisheye" of a camera professional digital on a tripod at a certain height and then, manually, discerns those open spaces from the closed ones in specific software such as Rayman Pro (Osmond, 2010) the results are distinguished between white pixels as open spaces and black pixels as closed.

2.2.1 Linking the shadow with the SVF

He et al. (2014) in their studies indicate that an SVF value of less than 0.3, experiences less hot conditions in summer and consider an essential part of the investigation of the urban microclimate and outdoor thermal comfort, since in addition to being an indicator of the geometry of the urban canon, it influences the accumulation of energy on surfaces and air circulation. In a certain way (Osmond, 2010) he agrees when mentioning that the impact of density, shape, and building height on the longwave radiative flux is a significant variable in the quantification of the Urban Heat Island effect.

The link of the SVF with the shade potential of each tree is related to the opening of the canopy or CO (Canopy openness) defined by Gonsamo et al. (2011) as "the *fraction of the area of the sky that is not obstructed by the canopy or other elements when observed from a determinate point"*. The SVF can be known using a camera with a 180º field of view located on a tripod leveled at a certain height and then through software, classify the pixels of the photographs that correspond to free space such as clouds or sky to separate from the space corresponding to obstructing elements such as branches, leaves, etc. (Gonsamo, et al, 2011) Being the same methodology to obtain both SVF and CO, Abreu-Harbich et al. (2015) used it to observe the openings in the canopy that allow the entry of radiation and use it as SVF using the Rayman Pro software as demonstrated in their methodology, while Sanusi, et al., (2016) in thermal comfort studies under the tree canopy showed that the SVF is inversely proportional CO, that is, the higher the SVF, the lower CO.

In recent years there has been the emergence of applications for studies related to obtaining CO with smartphone cameras, although with limited options such as the case of *Gap Light Analysis Mobile Application* or GLAMMA, (Tichý, 2015) CANOPEO, (Patrignania & Oschner, 2015) or HABITAPP. (McDonald & McDonald, 2016). With this background Bianchi, Calahan, Hale, & Gibbons, (2017) compared the results applying the traditional methodology using two pieces of photographic equipment, a Nikon Coolpix 990 camera and a Nikon Coolpix 4500 equipped with an FC-E8 183° converter lens against photographs taken from a Samsung Grand Prime smartphone attached to an Aukey fisheye lens with a 150º field of view without using a tripod or a level to take two samples, one in North-South direction and another East-West and averaging the two values, the results obtained with both methodologies were similar, concluding that the option of using a smartphone is a fast, cheap and reliable alternative.

2.3 MEAN RADIANT TEMPERATURE (TMRT)

Matzarakis et al. 2010 indicate that the influence of shortwave and longwave radiation on the human bioclimatic component can be synthesized as the *Mean Radiant Temperature* (MRT or Tmrt), defined by Fanger (1970) as "*The average temperature of shortwave radiation from the sun and longwave reflected in all directions from surfaces, objects, and entities that surround the human body"*, One of its characteristics is the susceptibility to its modification by clouds, topographic and structural morphologies

and above all, it is the most important parameter in thermophysiological indices based on the Human Energy Balance for bioclimatic studies with summer conditions as in the case of the PET index. (Matzarakis et al., 2007) (Matzarakis et al., 2010) keeping affinity to CO, as it is equivalent to the shade (Abreu-Harbich et al., 2015) and the deciduity of the species (Fahmy et al., 2010) which appeases shortwave radiation by reflection and transmission through its leaves, thus reducing the Tmrt at pedestrian level (Kong et al., 2017).

2.4 EQUIVALENT PHYSIOLOGICAL TEMPERATURE INDEX (PET)

The use of bioclimatic indices is because in the urban space, the atmospheric variables that influence the Human Energy Balance Model are modified, such as air temperature, wind speed and steam pressure, affecting thermal comfort, health and energy consumption of cities, (Andrade & Alcoforado, 2008) One of the bioclimatic indices is the Physiological Equivalent Temperature (PET), this is the most used in urban planning studies (Puliafito et al., 2013) (Abreu-Harbich et al., 2015) (Kong, et al., 2017) since in addition to using parameters based on the simplification of the aforementioned Human Energy Balance Model (Höppe, 1993) such as ambient temperature, relative humidity, wind speed and Tmrt, its results are generated in degrees Celsius, making it more understandable in urban studies, friendly to bioclimatic mapping and recommended for different climates (Matzarakis et al., 1999).

The aforementioned Human Energy Balance Model, whose full name is Munich Human Energy Balance or MEMI (Munich Energy Balance Model for Individuals) (Höppe, 1993) is the basis for the calculation of the PET index. Its equation is:

$$M + W + R + C + ESk + ERe + ESw + S = 0$$

Where M is the metabolic rate (internal energy production); W is physical labor; R is net radiation; C is sensible heat flow and E is the latent heat flow when: ESk is through the skin, ERe by respiration, ESw by evaporation of perspiration and S by stored heat. These values are expressed in Watts in positive or negative form depending on the gain or loss respectively except for M which is always positive while W, ESk, ESw will always be negative and S will be zero when a firm position is assumed. (Matzarakis & Amelung, 2008) (Matzarakis & Rutz, 2017) The individual heat fluxes of the given equation are expressed in the form of energy, but are controlled by meteorological components such as Air temperature: C, ERe; Air humidity: ESk, ERe, ESw; Wind speed: C, ESw; Mean Radiant Temperature or Tmrt: R When the German Association of Engineers or VDI, (1998) defines PET as the "*equivalent to the air temperature required to reproduce the body and internal temperature of a standard person in a standard scenario observed under evaluated conditions*" it refers to a standard person characterized by possessing a basic metabolism or "M", that executes a light activity and a work or "W" of 80W, additionally has a clothing resistance of 0.9 units (Matzarakis & Amelung, 2008).

2.4.1 Rating scale

The range of assessment of temperatures in PET degrees is classified into nine classes of thermal perception according to *Matzarakis & Mayer, (1996)* where exceeding 29 **º PET or decreasing 13 º PET is an indication to reach a degree of thermal stress, on the other hand, staying between 18 º PET to 23 º PET is** comfortable and therefore, Conversely, acquire a degree of thermal stress (Table 1)

Table 1. Equivalent Physiological Temperature Thermal Classification

PET º	Thermal perception	Degree of physical stress
> 41	Very hot	Extreme heat stress
35 - 41	hot	Strong heat stress
29 - 35	warm	Moderate heat stress
23 - 29	Gently warm	Prone to thermal stress
18 - 23	Comfortable	No heat stress
13 - 18	Gently cool	Prone to thermal stress
8 - 13	Fresh	Moderate heat stress
4 - 8	Cold	Strong heat stress
≤ 4	Very cold	Extreme heat stress

Valorization of perceptible thermal classes when taking into account the physiological parameters of a standard person according to Matzarakis & Mayer, (1996)

2.4.2 Method of obtaining

Usually, the achievement of PET is through the use of mobile weather stations that have a sensor in the form of a dark globe to capture radiation from all directions during the time of interest of the research (Mayer et al., 2008) (Thorsson et al., 2006) (Sanusi et al., 2016) the main complexity of this index is obtaining the Tmrt, prevailing parameter in PET validation. When the balloon sensor is not available in common weather stations, the hexa-directional method (six-directional) is also applied, which consists of the combination of a pyranometer for the measurement of incident shortwave radiation and a pyrometer for the measurement of ascending and descending long wave oriented in six directions: sky, ground and the four cardinal points fully measuring radiative fluxes. (Andrade & Alcoforado, 2008) (Matzarakis el al., 2007)

2.5 OBTAINING PET BY SIMULATION

2.5.1 Simulation with Rayman Pro software

Being a long, expensive, and often inaccessible methodology, in climatic and thermal comfort studies the aforementioned parameters are not commonly included, so the results of those indices that use only temperature and relative humidity, for example, come to have significant variations when compared with a bioclimatic index. (Matzarakis & Amelung, 2008) However, now there is an opportunity to determine the PET index through simulation with the RayMan Pro model, (Matzarakis, 2017) this calculates the shortwave and longwave radiation taking into account the complex urban structures thus reaching the Tmrt, the same model calculates PET also using the additional parameters to be relieved with portable instrumentation such as air temperature, relative humidity, wind speed and SVF (Matzarakis et al, 2007) (Matzarakis & Amelung, 2008) (Matzarakis & Rutz, 2017).

2.5.2 Principle of operation

The principle of operation according to Matzarakis et al. (2010) is the simulation of shortwave and longwave radiative fluxes, dividing the environment into a lower and upper separative plane from 1.1 meters, a height that represents the center of gravity of the human body according to Fanger (1972) calculating the global and direct radiation according to the formula of Jendritzky (1990), diffuse radiation according to Valko (1966), the estimation of longwave radiation from surfaces is subject to the Stefan-Boltzman principle and longwave radiation from the atmosphere according to Amgstron's formula, needing only air temperature, vapor pressure and cloudiness in octaves; with these parameters, the model finally computes the Tmrt according to the formula of Fanger (1972) Normally the lower plane has an SVF covered by elements that modify the results of the Tmrt and therefore the PET index (He et al., 2014).

2.5.3 Validation

Studies that include the validation of their results using the Pearson Correlation method with Tmrt values obtained from sensors demonstrate the reliability of the Rayman Pro software. Andrade & Alcoforado, (2008) realization measurements using the hexa-directional method to obtain the Tmrt during the night with SVF values ranging between 0.25 and 0.84, the correlation coefficient was R2 = 0.93, Using the same method Matzarakis, Rutz, & Mayer, (2010) correlated the values obtained in two different environments, under a group of trees and in a semi-open space surrounded by buildings and trees during the day on three summer days. The correlation results were R2=0.96 and R2=0.95 under the tree canopy and the semi-open space, respectively. Lin et al. (2010) using a balloon thermometer, measured the Tmrt in five narrow environments with SVF variations between 0.04 and 0.81 caused by the building and tree component for four days, one in each season of the year and a measurement on the terrace of a four-story building. The total correlation obtained was R2=0.85 in Tmrt values. Chen et al. (2014) experienced its validity in addition to other models compared with the Hexa-directional methodology. The correlation values between Rayman and the hexadirectional method were R2=0.91 and R2=0.92 for a clear and cloudy sky respectively. Additionally, there are publications of studies aimed at the search for arboreo thermal comfort using the Rayman software (Puliafito, et al, 2013) (Abreu-Harbich, et al, 2015) (Sanusi, et al, 2016) (Kong, et al., 2017), the use of Rayman Pro for the calculation of SVF (Osmond, 2010) and the relationship of SVF with air temperature (He, et al., 2014).

2.6 REFORESTATION ASSESSMENT

For species to survive, it is necessary to know the right tree for the right site (Farley, 2013), hence the need for the evaluation of reforestation, which determines what and where to plant (USDA, 2006), in addition to the appropriate methods to prepare the site and reduce possible conflicts, thus ensuring that the chosen tree can survive the conditions inherent to its location (Gilman & Sadowski, 2007). Since urban vegetation has been largely ignored by planners (Vailshery et al., 2013) site characteristics such as available space, adjacent structures, service networks and regulations must be considered before starting a tree planting process; attributes of the species to be selected such as its water requirement, coupling to the available soil, height at maturity and the objective to be raised that can be multiple or unitary (Alvarado et al., 2014).

2.6.1 Characteristics of the species

The size defines the spacing at the time of planting, with distances of 4 to 6 meters for small trees or with height less than 6 meters, between 6 to 8 meters of distance for medium trees or of 6 to 15 meters of height and between 8 to 12 meters of spacing for trees large or larger than 15 meters in height (Alvarado et al., 2014). An appropriate root volume is related to adequate tree functions, a limited volume of soil confines the roots, limits growth reduces anchoring and provides inadequate nutrients and moisture (USDA, 2006) this is why it is necessary to know the Diameter at Chest Height or DAP, not only useful for an approximation of the space that can occupy the thickening of the trunk of each species in a path within a bed or planter, (Alvarado, Guajardo, & Devia, 2014), but also to determine the volume of soil required for normal growth, which can be known according to the correlation of Urban, (1999) (Figure 1) multiplying the planting area to a standard depth of 1 meter (Suchocka, 2013). Plants planted in confined spaces will die of dryness much faster than those that have sufficient soil volume for root anchoring (USDA, 2006).

Diversity is also presented as a significant element to prevent the mortality of species in case some pests or insects harm the same species (Farley, 2013). Gilman & Sadowski (2007) indicates that several 5 specimens are generally recommended to reduce the impact in case of an outbreak, additionally, this creates greater diversity of habitats (USDA, 2006). The water demand depends on each species and the conditions of the place, if this is not higher than rainfall, irrigation is necessary only during the early stages (Ledesma, 2008) thus, it is necessary to recognize the trees adapted to both the water requirement and the local climate, soil type, drainage, sun exposure and compaction, the same that can be achieved with the survey of existing vegetation (USDA, 2006). The survey of the vegetation present in the area of interest helps to know if the area is suitable for a certain species and although native trees are usually recommended for adapting better to local conditions and requiring less maintenance, the urban environment can dictate the selection of a naturalized foreign species for being more resistant to adverse conditions (USDA, 2006). The stage of this evaluation is limited to touring and pointing out the species of the site to be studied, (Gilman & Sadowski, 2007) also details the urban structures around the tree, pointing out the drawbacks and interferences detected (Ledesma, 2008).

2.6.2 Characteristics of the medium

The spatial variables of a city for urban afforestation, present additional challenges to common afforestation, since in addition to needing to know the edaphic and water components of the environment, the scarce availability of space in the absence of an urban planning with which the site was conceived, hinders the task and reduces the life expectancy of the tree (Alvarado, Guajardo, & Devia, 2014) .es for this reason that the evaluation of the place is the first step to choose the species of interest, focusing on the superficial and underground physical attributes through the analysis of the characteristics of the scenario and its components before issuing a selection criterion (Gilman & Sadowski, 2007). The species selection criteria also goes according to the location of the service networks to prevent them from obstructing drains and aqueducts when looking for water naturally, breaking pipes especially in old and deteriorated drains; (USDA, 2006) dispensing with the planting of trees in those locations where visibility is required, whether signs, signs or luminaires, (Alvarado, Guajardo, & Devia, 2014) and the choice of species according to size, favoring the smallest under the aerial cables and the high ones near luminaires in such a way that the canopy grows above the light (USDA, 2006). Sun exposure and runoff are influenced by urban configuration. The sun's rays can be direct or directed by buildings, generating water stress due to the accumulation of heat that not all species can tolerate while steep slopes can shorten the use of rainwater runoff, so drought-tolerant species are suitable for these two types of environments (USDA, 2006).

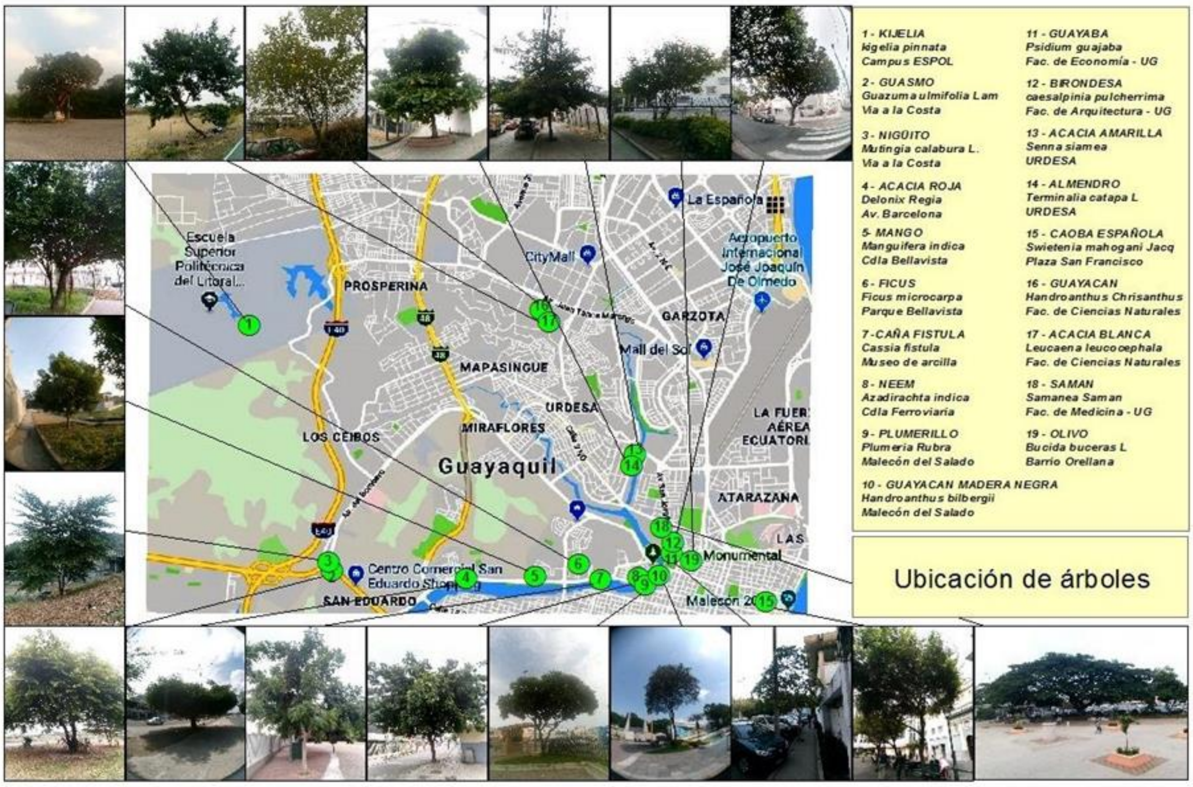
Planting spacing along a street is often restricted by the expansion of tree canopy and the growth of roots that tend to damage and lift the pavement, (Smiley, 2008) with a greater potential for damage to asphalt pavements than to concrete pavements (Wong, Good, & Denne, 1988) in addition to the difficulty of development in compacted soils. Simple solutions to this problem are proposed at the surface level with the use of pavers, expansion joints, setbacks, ramps etc (USDA, 2006) and the most complex at the root level that involves design for its direction, structural soils, or permeable pavements, however, these solutions involve additional costs that can discourage local governments (Smiley, 2008). Another solution proposed by USDA, (2006) to avoid conflicts with service networks is directional pruning, with which Ledesma (2008) agrees, mentioning that pruning is not necessary for open areas such as parks or squares, while in areas with spatial restrictions, it is necessary to drive the tree and avoid interference with overhead wiring lines, vehicular and pedestrian traffic, housing and other obstacles.

3 METHODOLOGY

3.1 PLACE OF STUDY

The city of Guayaquil is located between the coordinates 2°11′00"S / 79°53′00"W at an altitude between 0 to 4 m.a.s.l. and total area of 265 km2 (INEC, 2010), tropical dry according to the Koppen climate classification, between December and May the rainy season occurs with average temperatures of 27.2ºC (maximum of 30.7ºC) accompanied by copious rainfall, while from June to November the dry season occurs with absence of rain and average temperatures of 25.2ºC (maximum 29.2ºC) (INAMHI, 2018). It is intended to represent most of the city by taking two experimental zones (a northern neighborhood and a southern neighborhood) that exemplify the structural and spatial predominance of the city (Figure 1):

Figure 1. Location of study areas



3.2 DESCRIPTION OF THE GENERAL PROCEDURE USED

The parameter for the achievement of arboreal thermal comfort was the PET index, through the use of free software Rayman Pro, whose results allow to establish a hierarchy of species of greater thermal cooling according to the comparison of PET obtained under the canopy of the selected varieties with that obtained under the shade of a roof or a parasol, sorting them in descending order. The necessary parameters surveyed to obtain the PET index were: temperature in degrees Celsius and relative humidity; circular hemispherical photos with a "fisheye" device attached to a mobile phone camera; Average wind speed and cloudiness in octaves.

3.3 BIBLIOGRAPHIC COMPILATION AND RECOGNITION

3.3.1 Species recognition

The text "Trees of Guayaquil" (Molina et al., 2015) as the main guide for the recognition of the predominant species in the city and the visit to the botanical garden of Guayaquil for in situ observation, allowed the pointing of main characteristics for their subsequent search within the urban environment. Specimens away from buildings or other trees that may cause additional shade were sought, their endemic or introduced nature was not considered, nor the size of roots or trunk, but the broad canopy based on the principle of "the greater the leaf abundance, the lower the temperature" (Lin & Lin, 2010) deciduous trees were not taken into account except for those planted by the municipality in the process of urban regeneration, Neither do the palm trees. The variables such as height, water requirement, sun exposure and root shape, and persistence were obtained from the available bibliographic resources, the DAP of the trees used for the measurement was also recorded. The location of the specimens is in Annex A.

3.3.2 Recognition of the area of study

The measurement of sidewalks, width of streets and ramps, (Figure 2) Due to the dimensional inequalities that occurred regularly, values were established using averages. The width of the sidewalks calculated with multiple measurements in random locations and that of the streets with measurements before the intersection with their corresponding cross street, while the different sizes of the width of the entrance ramps to the garages in the two study areas fluctuated between 2.50 m to 3 m so the highest value was established. In the absence of underground plans, the service network boxes were surveyed in a tour using a Google Maps map and the height of the electrical and telephone wiring was assumed contemplating the legislation that regulates the installation of poles and power lines of medium and low voltage.

Figure 2. Sidewalks, streets and parking spaces

It also includes the identification of trees in the area to obtain a preliminary assessment of the environment concerning a possible planting and the search for alternatives.

3.4 TAKING PARAMETERS

3.4.1 Temperature and humidity

Temperature and relative humidity were recorded using a PeakMeter thermo hygrometer model MS6508 at a height of 1.1 meters from the floor, (Matzarakis, 2017) (Sanusi et al, 2016) on sunny days. Sampling consisted of averaging periodic one-minute readings for ten minutes under the shade of the selected tree from 11:00 to 17:00, the same procedure was repeated immediately afterward under the shade of a nearby roof. At the end of the day, 140 temperature readings and 140 relative humidity readings are obtained, both under the canopy and the roof or parasol, (Figure 3) that when averaged are simplified into 14 temperature data and 14 relative humidity data. These are the necessary data to enter into the Rayman Pro software.

Figure 3. Temperature and relative humidity of the species *Ficus Benjamin*

3.4.2 Sky View Factor

The Sky View Factor was obtained with circular hemispherical photographs using a fisheye device for cell phones brand Aukey OL-A1 180 degrees, attached to a Nokia 3 mobile phone with 8-megapixel camera. Unlike temperature measurements, cloudy days were expected to take pictures under the tree canopy 1.30 meters above the ground in a North-South and East-West direction, holding firmly in the hand. The procedure is faithful to the methodology of Bianchi, et al, (2017). SVF photographs can be found in Annex B.

3.4.3 Diameter at chest height (DAP)

The Diameter at Chest Height or DAP is a methodology used to know the diameter of the tree.

It is obtained by surrounding a tape measure of the trunk of the tree at chest height to obtain its diameter, the result is divided by the number π according to the methodology described by UNLP (2002).

3.4.4 Wind speed and cloudiness

Even on sunny and clear days, there are fractions of the sky covered by clouds, that is why by observing the sky and separating it imaginarily into eight parts, cloudiness is estimated in octaves when taking the temperature and humidity, although it is a subjective method, it is valid for meteorological observations, while the wind speed is the average of the last ten years of the INAMHI website (2018).

Figure 4. DAP of brondesa (*Caesalpinia Pulcherrimia)*1 and Spanish mahogany (Swietenia Mahagoni*)*2

3.5 PARAMETERS TO ENTER IN THE RAYMAN PRO SOFTWARE

The main screen of the Rayman Pro software (Figure 5) requests basic parameters to be completed, such as the photographs and thermal units that have been obtained in the survey, while other data are not necessary since the same model calculates it.

3.5.1 Date, day of the year and time

The day of the year allows us to obtain an estimate of the approach of the sun towards the earth, therefore, its influence on temperature. The dates and times of the temperature and relative humidity survey were set.

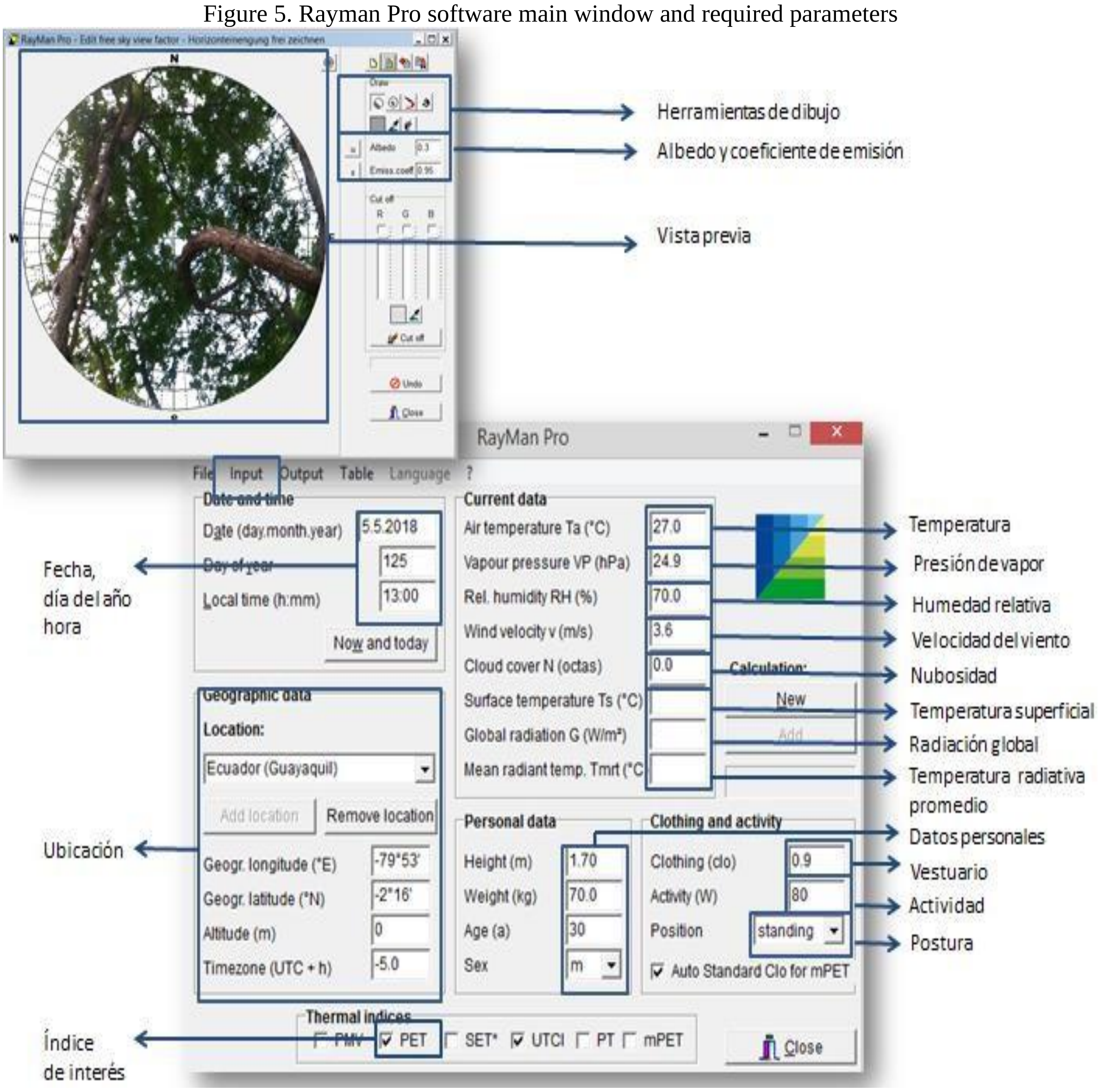
3.5.2 Geographical Location

It is known that the regional temperature and the solar radiation received in a geographical area are affected by latitude and altitude. The Rayman Pro model includes Guayaquil in its catalog and autocompletes the corresponding values.

3.5.3 Thermal Index

Rayman Pro allows you to obtain thermal indices such as Predicted Mean Vote (PMV), Standard Effective Temperature (SET), Universal Thermal Climate Index (UTCI), Perceived Temperature (PT) and Modified Physiologically Equivalent Temperature (mPET). The index of interest was the Physiologically Equivalent Temperature (PET). In the upper left part the window shows the section that calculates the SVF from the "Input" tab (Figure 5):

Figure 5. Rayman Pro software main window and required parameters



3.5.4 Relative humidity and vapor pressure

The vapor pressure is automatically extracted if the relative humidity and temperature are specified (Matzarakis, 2017) while the temperature and relative humidity are obtained in the survey.

3.5.5 Wind speed and cloudiness

The value 3.6 m/s is noted in all trials as a reference value. This value is the average of the last ten years according to INAMHI while cloudiness in octaves varies according to the time of the days studied.

3.5.6 Surface temperature, global radiation, mean radiant temperature

Rayman Pro computes these parameters based on mathematical expressions of Oke (1987) for Surface Temperature; Valko (1966) Kasten & Young (1989) and VDI (1998) for Global Radiation and according to Fanger (1972) Jendritzky & Nübler (1981) (Jendritzky et al, 1990) for Mean Radiant Temperature.

3.5.7 Personal data

Rayman Pro includes this section based on the fact *that "thermal perception is based on the sensation of integrated thermal parameters that is perceived by the skin, the bloodstream and regulated by the hypothalamus*" (Tromp, 1980) and therefore cannot be measured from a single meteorological parameter (Matzarakis, 2017) The parameters noted were: male sex (Sex m), 30 years old (Age) 30, height (Height) 1.70m, weight (Weight) 70kg.

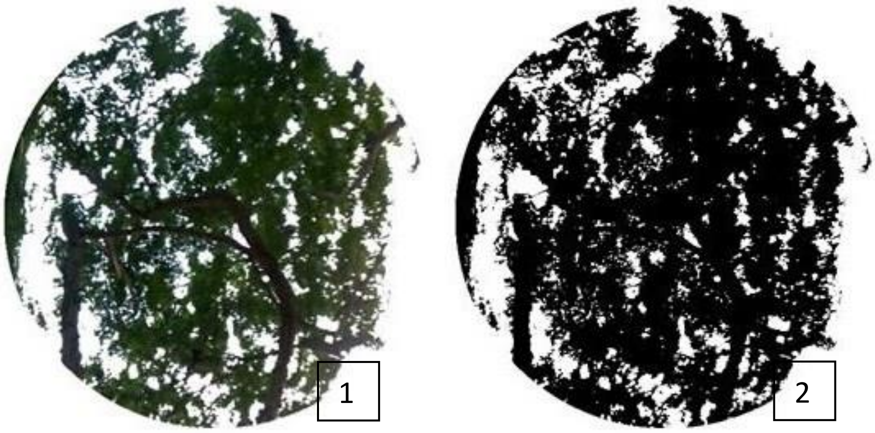
3.5.8 Activity and costumes

In the units of clothing (Clothing) and activity (Activity) Matzarakis & Amelung, (2008) recommend using the values of 0.9 in clothing, corresponding to light work clothes and 80W as light activity.

3.5.9 Input: circular hemispherical photos, albedo and emissivity

The photograph of the species of interest in the North-South direction is entered in the session of the day and the corresponding time to be classified manually with the drawing tools, obtaining a graph separated from the external elements such as the sky or clouds (Figure 6) and repeating with the East-West photograph**.** The albedo value was 2.5 corresponding to green grass according to (Makvart & Castalzer, 2003) and the emissivity coefficient of 0.9 (Oke, 1987). The complete procedure is repeated with the values of temperature and relative humidity relieved under the shade of the roof, for this a graph was included that represented an SVF of 0 (completely covered) with values of 3 and 0.9 for albedo and emissivity respectively:

Figure 6. hemispherical circular of the species *Caesalpinia Pulcherrimia*, North1 and South2



3.5.10 Obtaining PET values of species and hierarchy

The 7 PET values (11:00 to 17:00) of each species, product of the sessions executed with the North-South direction photographs were averaged to obtain a single value, the procedure is repeated with the PET values obtained with the East-West photographs, these two values are averaged to reach the value "PET species", while the value "PET shadow", Achieved in the same way with the values obtained indoors, it is used to achieve the final reduction value:

PET species - PET shade = reduction of PET degrees

4 COLLECTION AND PROCESSING OF INFORMATION

4.1 COOLING BY SPECIES

The temperature result in PET degrees of the 19 species studied is presented in each table individually. The "PET SVF" values correspond to the PET results achieved with the SVF values of the two circular hemispherical photographs taken in each species, while "PET species" is the average of these two values. The last two categories, "outdoor PET" and "shade PET" is obtained in an unshaded area and under a non-tree shade respectively. The range of temperature variation fluctuates from mildly warm or prone to thermal stress for temperatures between 23º to 29º, warm or moderate thermal stress for temperatures between 29º to 35º and hot or strong thermal stress for temperatures between 35º to 41º, according to the classification of Matzarakis & Mayer (1996). The results were grouped as endemic and introduced species, in turn which were subclassified as efficient, when the reduction is >0.9º; inefficient, when the reduction is >0.2 º and inefficient, which presented an increase in temperature concerning the shade.

4.2 EFFICIENT ENDEMIC SPECIES

Guasmo (*Guazuma Ulmifolia*) is shown as the most efficient endemic species among the six identified, reducing -1.6º PET followed by *Samanea Saman or Samán* -1.3º PET and *Mutingia Calabura* or Nigüito with -0.9º PET. While the first and third species show values of SVF <0.1 units, the average SVF the second is 0.25 units (Tables 2, 3 and 4)

Table 2. Saman (*Samanea Saman*)

Hour	PET SVF 0.30	PET SVF 0.21	PET species	PET open-air	PET shadow
11:00	28.8	29	28.9	36	30.8
12:00	29.8	30	29.9	34.4	30.8
13:00	29.7	29.9	29.8	38.1	33.4
14:00	31.4	31.6	31.5	40.1	33.3
15:00	31.8	30.1	31.0	39.9	30.9
16:00	30.9	28.8	29.9	41.9	30.9
17:00	27.6	28	27.8	40	27.7
Average			29.8	38.63	31.1

Table 3. Guasmo (*Guazuma ulmifolia*)

Hour	PET SVF 0.06	PET SVF 0.09	PET species	PET open-air	PET shadow
11:00	28.1	28.2	28.2	37.3	31.5
12:00	28.9	28.9	28.9	36.2	32.3
13:00	30.3	30.3	30.3	35.7	31.1
14:00	29.1	29.2	29.2	37.7	30.9
15:00	29	29	29.0	39.3	30.3
16:00	28	28	28.0	38.9	28.3
17:00	26.5	26.5	26.5	38.5	26.6
Average			28.6	37.7	30.1

Table 4. Nigüito (*Mutingia Calabura*)

Hour	PET SVF 0.05	PET SVF 0.02	PET species	PET open-air	PET shadow
11:00	28.9	28.9	28.9	37.3	31.5
12:00	30.2	30.2	30.2	36.2	32.3
13:00	30.6	30.7	30.7	35.7	31.1
14:00	30.1	30.2	30.2	37.7	30.9
15:00	30	30.1	30.1	39.3	30.3
16:00	28.2	28.2	28.2	38.9	28.3
17:00	26.5	26.5	26.5	38.5	26.6
Average			29.2	37.7	30.1

4.3 EFFICIENT INTRODUCED SPECIES

Six of the thirteen naturalized or introduced species were shown to be the most conducive to temperature reduction. The trees of Ficus (*Ficus Benjamin), Red Acacia (*Delonix Regia*), Yellow*

Acacia (Senna Siamea*), Almond (*Terminalia Catapa) *and Mango (Manguifera* Indica) boast the best results with an SVF <0.1 units, equivalent to a sky hidden by the canopy in almost its entirety, improving the temperature corresponding to the section ºPET shade "the same that presents values above 30º PET (Table 5, 6, 7, 8, 9) Olive tree (*Bucida Buceras*) is the exception in SVF values with an average of 0.2 units of SVF and although it is a value far from the previous ones in terms of shade granting, it reveals a decrease of -1.1º PET (table 10).

Unlike native examples, the cooling curve of all species stays away from the shade pattern throughout the day, with greater notoriety in *Ficus Benjamin*, which lowers the temperature - 2.7º PET subtracting a level in the classification from "hot" to "warm" between 13:00 to 15:00 followed by *Delonix Regia* that lowers - 1.9º PET, *Senna Siamea with - 1.7º PET* Manguifera Indica and Terminalia Catapa *- 1.6º PET and the aforementioned Bucida Buceras* with - 1.1º PET, which keeps a slight approach to the PET shadow temperature between 16:00 and 17:00.

Table 5. Ficus (*FIcus Benjamin*)

Hour	PET SVF 0.08	PET SVF 0.07	PET species	PET open-air	PET shadow
11:00	29.8	29.8	29.8	36.9	31.8
12:00	32.8	32.8	32.8	38.8	35.4
13:00	33.1	33.1	33.1	39.7	36.7
14:00	33.1	33.1	33.1	42.9	36.3
15:00	34.7	32.7	33.7	45.8	37.1
16:00	30.7	30.7	30.7	44	33.2
17:00	28.8	28.8	28.8	42.7	30.2
Average			31.7	41.54	34.4

Table 6. Red acacia (*Delonix Regia*)

Hour	PET SVF 0.05	PET SVF 0.04	PET species	PET open-air	PET shadow
11:00	29.6	29.7	29.65	36.3	30.9
12:00	31.6	31.6	31.6	37.4	33.7
13:00	32.1	32.1	32.1	39.1	34.5
14:00	31.4	31.4	31.4	40.7	33.8
15:00	30.5	30.5	30.5	41.5	32.7
16:00	28.5	28.5	28.5	41.1	30.2
17:00	28.4	28.5	28.45	42.0	29.4
Average			30.3	39.7	32.2

Table 7. Yellow acacia (*Senna Siamea*)

Hour	PET SVF 0.08	PET SVF 0.09	PET species	PET open-air	PET shadow
11:00	28.1	28.1	28.1	35.1	29.5
12:00	28.6	28.6	28.6	34.5	30.8
13:00	30.1	30	30.1	36.1	31.4
14:00	29.8	29.8	29.8	38.6	31.7
15:00	28.6	28.6	28.6	40.1	31.1
16:00	29.2	27.6	28.4	41	30
17:00	26.6	26.6	26.6	39.9	27.7
Average			28.6	37.9	30.3

Table 8. Almond tree (*Terminalia Catapa* L)

Hour	PET SVF 0.03	PET SVF 0.02	PET species	PET open-air	PET shadow
11:00	28.4	28.3	28.4	35.1	29.5
12:00	28.8	28.8	28.8	34.5	30.8
13:00	29.3	29.3	29.3	36.1	31.4
14:00	30.1	30.1	30.1	38.6	31.7
15:00	29.1	29.3	29.2	40.1	31.1
16:00	27.9	28	28.0	41	30
17:00	27	27	27.0	39.9	27.7
Average			28.7	37.9	30.3

Table 9. Manguifera Indica - Mango

Hour	PET SVF 0.02	PET SVF 0.04	PET species	PET open-air	PET shadow
11:00	31.9	31.5	31.7	39.1	33.8
12:00	31.8	31.8	31.8	37.7	34
13:00	33.4	33.4	33.4	39.0	34.9
14:00	32.2	32.1	32.15	41.3	34.6
15:00	31.8	31.7	31.75	42.2	33.2
16:00	29.6	29.7	29.65	41.6	30.6
17:00	28.9	28.9	28.9	42.1	29.4
Average			31.3	40.4	32.9

Table 10. Olive tree (*Bucida buceras* L)

Hour	PET SVF 0.18	PET SVF 0.27	PET species	PET open-air	PET shadow
11:00	29.1	29	29.05	37.3	31.7
12:00	30.9	30.7	30.8	35.3	31.6
13:00	30.4	29.7	30.05	36.6	31.9
14:00	29.6	28..8	29.2	37.1	30.1
15:00	28.9	30.2	29.55	39.8	30.7
16:00	27.2	27.1	27.15	38.4	27.7
17:00	26.3	27.4	26.85	38.6	26.8
Average			28.95	37.59	30.07

5 CONCLUSIONS

It was possible to obtain the classification of species according to the reduction of ºPET, however, the most efficient species cannot be adjusted to the study areas due to the small space that these residential neighborhoods have and the risks of damage to urban structures due to the morphological nature of these. The species that are suitable for the study areas, although they are not the most efficient, achieve a reduction between 1.6º to 0.7º PET and unfailingly require formation pruning to avoid excessive growth of length and width or trunk and canopy respectively. It is necessary to occupy spaces on the road with planters. and the possibility of using efficient species in new urban projects or open spaces where it does not interrupt the aerial wiring.

It is up to governmental considerations to take into account urban trees as a necessary task to face daily problems of cities that threaten the environmental quality and especially in civil society, as main actors in demanding and enforcing actions that link elements of nature for a better quality of life.

5.1 CLASSIFY A GROUP OF EFFICIENT TREE SPECIES FOR THE MITIGATION OF THE ICU EFFECT

In the evaluation of species as a temperature attenuator, different thermal responses were obtained, finding an important cooling characteristically in some and a notable inefficiency for this purpose in others.

The introduced species *Ficus Benjamina*, *Delonix Regia* or red acacia and Senna Siamea *or yellow acacia were the most efficient in reducing temperature, highlighting* Ficus Benjamina *by appeasing 2.7 ºPET, while two specimens of the most common in the courtyards of the houses of the city,* Terminalia Catappa *or almond tree and Mangifera Indica* or handle, achieved a significant thermal loss in 1.6 ºPET. On the other hand, four had an opposite effect to cooling, with an increase in temperature under its canopy such as *Psidium Guajava* or Guava, curiously the other three are in the streets and avenues regenerated by the attractiveness of their flowers, is the case of *Caesalpinia Pulcherrima, Handroanthus Bilbergii and Handroanthus Chrysanthus*, the latter two of endemic nature.

Coinciding with the literature, the SVF values were linked to the reduction of temperature, so mentioned increases have probably been caused by the corresponding SVF values, since the holes or scarce canopy allow the entry of solar rays as shown by the Tmrt values and although during the measurements it was tried to avoid the contact of solar radiation, The reflection in the form of a long wave influences the ambient temperature and therefore the registers of the thermohygrometer, however, these openings concern the natural shape of its corresponding cup.

The most efficient species are distinguished by having an SVF value <0.1, however, this is not a conditioner, since evapotranspiration also intervenes in the decrease in temperature, this can be noticed especially in species of larger diameter and size such as *Samanea Saman*. Those endemic species that had optimal results were *Guazuma Ulmifolia* or Guasmo, *Samanea Saman* or Samán and somewhat distant *Mutingia Calabura* or Nigüito.

Table 25. Reduction of temperatures by species in ºPET and SVF

Scientific name	Common name	Reduction ºPET	SVF middle
Ficus Benjamina	Ficus	-2.7	0.07
Delonix Regia	Red acacia	-1.9	0.04
Senna Siamea	Yellow acacia	-1.7	0.08
Terminalia Catappa	Almond - almond	-1.6	0.02
Mangifera Indica	Mango	-1.6	0.03
Guazuma Ulmifolia	Guasmo	-1.6	0.07
Samanea Saman	Saman	-1.3	0.25
Bucida Buceras	Olive tree	-1.1	0.22
Mutingia Calabura	Nigüito	-0.9	0.03
Leucaena Leucocephala	White acacia- leucaena	-0.8	0.18
Azadirachta Indica	Take	-0.7	0.09
Cassia Fistula	Cane fistula – rain of gold	-0.6	0.35
Swietenia Mahogany	Spanish mahogany	-0.6	0.32
Kigelia Pinnata	African Kijelia	-0.5	0.32
Plumeria Rubra	Search - Plumerillo	-0.2	0.14
Psidium Guajava	Guava	+0.4	0.52
Handroanthus Chrysanthus	Guayacán of the coast	+0.4	0.28
Handroanthus Bilbergii	Guayacán black wood	+0.7	0.61
Caesalpinia Pulcherrima	Birondesa - Clavelina	+0.7	0.23

REFERENCES

Abreu-harbich, l. V., labaki, l. C., & matzarakis, a. (2015). Papereffect of tree planting design and tree species on human thermal comfort in the tropics. *Landscape and urban planing*, 1 - 11; 2.

Alvarado, a., guajardo, f., & devia, s. (2014). Manual de plantación de árboles en áreas urbanas.

Andrade, h., & alcoforado, m. (2008). Microclimatic variation of thermal comfort in a district of lisbon (telheiras) at night. *Theor. Appl. Climatol*(92), 225 -237.

Andreou, e. (2014). The effect of urban layout, street geometry and orientation on shading conditions in urban canyons in the mediterranean. *Renewable energy, 83*, 587 .596.

Árboles sin fronteras. (2018). Recuperado el 23 de agosto de 2018, de http://www.arbolessinfronteras.org.ar/donde_estamos.php

Ballinas, m., & barradas, v. L. (2015). The urban tree as a tool to mitigate the urban heat island in mexico city: a simple phenomenological model. *Journal of enviromental quality*.

Banco mundial. (2011). *Guía para la adaptación al cambio climático en ciudades - resumen ejecutivo.* Washington d.c.

Bianchi, s., calahan, c., hale, s., & gibbons, j. (2017). Rapid assessment of forest canopy and light regime using smartphonehemispherical photography. *Ecoloogy and evolution - pryfisgol bangor university*.

Chen, y.-c., lin, t.-p., & matzarakis, a. (2014). Comparison of mean radiant temperature from field experiment and modelling: a case study in freiburg, germany. *Theor appl climatol*(118), 535–551.

Dimoudi, a., & nikolopoulou, m. (2003). Vegetation in the urban enviroment: microclimatic analysis and benefits. *Energy and buildings, 35*, 69 - 76.

El selectivo: colectivo de arquitectura. (2018). Recuperado el 23 de agosto de 2018

Estrada ycaza, j. (2000). *Guía histórica de guayaquil* (vol. 3). Guayaquil: banco del progreso.

Fahmy, m., sharples, s., & yahiya, m. (2010). Lai based trees selection for mid latitude urban developments: a microclimatic study in cairo, egypt. *Building and eviroment., 45*, 345 - 357.

Fanger, p. (1970). Thermal comfort: analysis and applications in environmental engineering. *Danish technical press*.

Farley, j. (2013). Street tree diversification and location consideration. Universidad estata de utah.

Feyisa, g., dons, k., & meilby, h. (2014). Efficiency of parks in mitigating urban heat island effect: an example from addis ababa. *Landscape and urban planning*(123), 89-95.

Fundación la iguana. (2018). *Www.fundacionlaiguana.org*. Recuperado el 10 de 10 de 2018, de www.fundacionlaiguana-org: http://fundacionlaiguana.org/sobre-la-fundacion/

Georgi, j., & zafiriadis, k. (2006). The impact of park trees on microclimate in urban areas. *Urban* *ecosyst*(9), 195-209.

Gilman, e. F., & sadowski, l. (2007). The urban forest hurricane recovery program. Universidad de florida.

Gonsamo, a., walter, j., & pellikka, p. (2011). A package of programs for determining canopy geometry and solar radiation regimes through hemispherical photographs. *Computers and electronics in agriculture*(79), 207–215.

Höppe, p. (1993). Heat balance modelling. *Experientia*, 49, 741-746.

Inec. (2010). *Censo de población y vivienda.* Quito: instituto nacional de estadística y censos.

Inec. (2016). *Anuario de transporte 2016.*

Iner. (2016). *Estimación del efecto isla de calor urbano en la ciudad de guayaquil*. Instituto nacional de energía renovable y eficiencia energética., quito.

Iner. (2017). El fenómeno isla de calor urbano en urbes costeras. *Revista científica del desarrollo energético, 5*, 25.

Ipcc. (2014). *Summary for policymakers. In: climate change 2014: impacts, adaptation and vulnerability.* Cambrigde university press, intergovernmental panel on climate change., cambridge - uk.

Jackson, r. B., randerson, j. T., canadell, j. G., anderson, r. G., avissar, r., baldocchi, d. D., y otros. (2010). Protecting climate with forests. *Enviromental research letter*.

Jendritzky g, m. H.-k. (1990). *Methodology for the spatial evaluation of the thermal component in the bioclimate of humans.*

Jendritzky, g., & nübler, w. (1981). A model analysing the urban thermal environment in physiologically significant terms. *Arch meteorol graphys bioclimatol, 29,* 313 - 326.

Jiménez, o. (2008). Índice de confort de la vegetación. *Nodo, 3*(5), 49 - 70.

Kasten, f., & young, a. (1989). Revised optical air mass tables and approximation formula. *Appl optics, 28*, 4735-4738.

Kong, l., lau, k. K.-l., yuan, c., chen, y., yong, x., chao, r., y otros. (2017). Regulation of outdoor thermal comfort by trees in hong kongling. *Sustainable cities and society*(31), 17- 25.

Kornarska, j., uddling, j., holmer, b., lutz, m., lindberg, f., pleijel, h., y otros. (2015). Transpiration of urban trees and its impact on daytime and nocturnal cooling in gothenburg, sweeden. *9th international conference on urban climate jointly with 12th symposium on the urban enviroment.*, (págs. 1 - 6). Toulouse.

Ledesma, m. (2008). *Arbolado público. Conceptos. Manejo.* Córdoba: instituto nacional de tecnología agropecuaria.

Lin, b.-s., & lin, y.-j. (2010). Cooling effect of shade trees with different characteristics in a subtropical urban park. *Hortscience*(45), 86.

Lin, t.-p., matzarakis, a., & hwang, r.-l. (2010). Shading effect on long-term outdoor thermal confort. *Build enviroment*(45), 213-221.

Makvart, t., & castalzer, l. (2003). *Practical hadnbooks of photovoltaics: fundamentals and applications*. Elsevier.

Matzarakis. (2017). *Rayman pro: a tool for applied climatology*. Freiburg: research centre human biometeorology.

Matzarakis, a., & amelung, b. (2008). Physiological equivalent temperature as indicator for impacts of climate change on thermal confort on humans. *Springer science*, 161 - 172.

Matzarakis, a., & mayer, h. (1996). Another kind of environmental stress. *Who newsletter*(18), 7 - 10.

Matzarakis, a., & rutz, f. (2017). *Modelling of mean radiant temperature and thermal indices*. Freiburg: german meteorological service.

Matzarakis, a., mayer, h., & izionon., m. (1999). Applications of a universal thermal index: physiological equivalent temperature. *International journal of biometeorology, 43*, 76- 84.

Matzarakis, a., rutz, f., & mayer, h. (2007). Modelling radiation fluxes in simple and complex enviroments - applications of the rayman model. *International j. Meteorol, 51*, 323- 334.

Matzarakis, a., rutz, f., & mayer, h. (2010). Modelling radiation fluxes in simple and complex enviroments: basics of the rayman model. *International journal of biometeorology*(54), 131-139.

Mayer, h., holst, j., dostal, p., imbery, f., & schindler, d. (2008). Human thermal comfort in summer within an urban street canyon in central europe. *Meteorologische zeitschrift*, 241 - 250.

Mcdonald & mcdonald. (2016). *Habitapp*. Recuperado el 03 de noviembre de 2018, de http://www.scrufster.com/habitapp

Molina, m., lavayen, j., & fabara, m. (2015). *Árboles de guayaquil*. Guayaquil: universidad de especialidades espiritu santo.

Oke, t. (1982). The energetic basis of the urban heat island. *Quarterly journal of the royal meteorological society*, 1 - 24.

Oke, t. (1987). Boundary layer climates.

Oke, t. (1995). Boundary layer climates. *Routledge*, 353.

Osmond, p. (2010). Hemispherical photography as a tool for urban sustainability evaluation and design. *Oida international journal of sustainable development*, 63 - 74.

Palme, m., inostroza, l., villacreces, g., lobato, a., & carrasco., c. (2017). *From urban climate to energy consumption. Enhancing building performance simulation by including the urban heat island effect*. Universidad de valparaiso - universidad católica del norte - universidad autónoma de chile - instituto nacional de eficiencia energética y energía renovable.

Patrignania, a., & oschner, t. (2015). *Canopeo: a powerful new tool for measuring fractional green canopy cover.*

Puliafito, s., bochaca, f., & allende, d. (2013). Mitigación de la isla de calor urbana en ciudades de zonas áridas. *Proyecciones - publicación de investigación y posgrado de la facultad regional buenos aires, 11*.

Rosenfeld, a. H., akbari, h., bretz, s., fishman, b. L., kurn, d. M., sailor, d., y otros. (1995). Mitigation of urban heat islands: materials, utility programs, updates. *Energy and buildings*(3), 255 - 265.

Santamouris, m., chrysoulakis, n., grimmond, c., jusuf, s., hien, w., synnefa, a., y otros. (2016). *Urban climate mitigation techniques* (vol. 1). Devon, uk: routledge.

Sanusi, r., johnstone, d., may, p., & livesley, s. J. (2016). Street orientation and side of the street greatly influence the microclimatic benefits street trees can provide in summer. *Journal of enviromental quality*, 167 - 174.

Shashua-bar, l., & hoffman, m. (2000). Vegetation as a climatic component in the design of an urban street: an empirical model for predicting the cooling effect of urban green areas with trees. *Energy and buildings*(31), 221 - 235.

Smiley, t. (2008). Comparison of methods to reduce sidewalk damage from tree roots. *Scientific journal if the international society of arbiculture*.

Spangenberg, j., shinzato, p., johansson, e., & duarte, d. (2008). Simulation of the influence of vegetation on microclimate and thermal comfort in the city of sao paulo. *Sbau, 3*(2), 1-19.

Suchocka, m. (2013). Structural soils and other ways of facilitating tree gorwth in the difficult habitat conditions of cities. *Sustainable development applications*(4), 39-49.

Taha, h. (1997). Urban climates and heat islands: albedo, evapotranspiration, and anthropogenic heat. *Energy and buildings*(25), 102.

The nature conservancy. (2016). *Planting healthy air.* Virginia: the nature conservancy.

Thorsson, s., lindberg, f., eliasson, i., & holmer, b. (2006). Measurements of mean radiant temperature in different urban structures. *Sixth international conference on urban climate.* Göteburg.

Tichý, l. (2015). Field test of canopy cover estimation by hemispherical photographs taken with a smartphone. *Journal of vegetation science*.

Trenberth, k. E., fasullo, j., & kiel., j. (2009). Earth´s global energy budget. *American meteorological society, 90*, 311 - 232.

Tromp, s. (1980). The impact of the weather and climate on humans and their enviroment (animals and plants). *Biometeorology*, 58.

Unlp. (2002). Medición de diámetros, alturas y edad del árbol. *Curso de biometría forestal - guía de clases*.

Urban, j. (1999). Room to grow. *Treelink*(11), 1-4.

Usda. (2006). Urban watershed forestry manual. Part 3: urban tree planting.

Vailshery, l. S., jaganmohan, m., & nagendra., h. (2013). Effect of street trees on microclimate and air pollution in a tropical city. *Urban forestry and urban greening*(12), 408 - 415.

Valko, p. (1966). The sky radiation in its relationship to different parameters. *Archiv für meteorologie*(14), 336–359.

Vdi. (1998). Methods for the human biometeorological evaluation of climate and air quality for the urban and regional planning at regional level. *Enviromental meteorology*.

Wong, t. W., good, j., & denne, m. (1988). Tree root damage to pavements and kerbs in the city of manchester. *Arboricultural journal*(12), 7 - 14.