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## Comfort level of green areas in public spaces in Guayaquil

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**Abstract.** Green spaces in urban areas generally have a positive impact on the physical and mental well-being of residents, as well as providing ecological benefits, such as improving air and water quality. Green areas in public spaces can contribute to the overall comfort level of an urban environment that requires shade, reduce heat island effects, and improve air quality. They can also provide a sense of calm and relaxation and can serve as a gathering place for community members. Studies have also shown that access to green spaces can have a positive effect on mental health and can reduce stress levels. However, the comfort level of a specific green area in a public space depends on quality and comfort indicators. Microclimatic conditions and human thermal comfort and demonstrate how the presence and quality of green spaces can affect the urban heat island effect and mitigate the impacts of high temperatures in urban areas. In the present study, the quality, and comfort indicators such as accessibility, design, maintenance, and biodiversity of the existing green areas will be determined in samples taken in public spaces in the south, center and north of the city of Guayaquil as a comparative study for Improvements in street furniture and new selections of plant species were established. The objective of this study is to reduce the effect of heat islands and generate an increase in the urban green index of Guayaquil. The qualitative methodology is applied by applying the AHP-TOPSIS decision-making method to determine design strategies and guidelines for green areas in public spaces. The study concludes that the application of these indicators to green spaces have a positive impact on thermal and spatial comfort and can reduce the urban heat island effect and improve the habitability of public spaces.

**Keywords.** Green spaces, public spaces, street furniture, quality, comfort, AHP-TOPSIS decision-making

### 1 Introduction

Green spaces in urban areas can have a positive impact on the physical and mental well-being of the inhabitants (Ode Sang et al., 2020), in addition to providing ecological benefits, such

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as improving air and water quality. Green areas in public spaces can contribute to the overall comfort level of an urban environment by providing shade (Canto Lopez, 2014), reducing heat island effects, and improving air quality. They can also provide a sense of calm and relaxation and can serve as a gathering place for community members. Studies have also shown that access to green spaces can have a positive effect on mental health and can reduce stress levels. However, the level of comfort of a specific green area in a public space can depend on many factors, such as accessibility, design, maintenance, and the presence of services such as seating, play areas, and restrooms (Juhola, 2018).

Guayaquil, characterized as a warm tropical zone, generates temperatures ranging from 27 to 30 degrees Celsius, but this effect is maximized in the downtown area of the city, since the high-rise buildings, the design of pedestrian and vehicular paths generate a retention of solar energy which causes the thermal sensation to reach 40 degrees Celsius, thus causing the so-called heat islands.

Urban Heat Islands (UHI) refer to the phenomenon in which temperatures in urban areas are higher than those in surrounding rural areas due to the presence of man-made structures and the absence of vegetation (Arreaga et al., 2020). Central areas of cities are typically the most affected by UHIs, as they have the highest density of buildings and the least amount of green space. This can lead to increased energy consumption, air pollution, and health problems related to exposure to heat from UV rays.

The objective of this study is to obtain strategies through the previous analysis of the quality of green spaces in public spaces to mitigate the effects of heat islands.

## **2 Materials and methods**

### **2.1 Biodiversity in Guayaquil**

Biodiversity is established by the introduced, ornamental and endemic vegetation of the sector, since generally in the ornament of public spaces these species predominate, which in effect have provided the space with green coverage but not protection, which is why endemic species are included (Peek et al., 2018). Guayaquil to increase its use since they provide broader benefits due to their protection, shade, color, and smell.

Some of the more common trees found in Guayaquil include:

**La Palma Real:** A tall and elegant tree that is a symbol of the city, it is the tallest palm tree in the world.

**The Guava Tree:** A fruit tree that is native to the Americas, it is known for its delicious fruit and beautiful flowers.

**The Ceibo Tree:** A large tree that is native to South America and is known for its striking pink and red flowers.

**The Jacaranda Tree –** A tree native to South and Central America is known for its beautiful lavender-blue flowers.

**The Ficus Tree –** A tree native to tropical regions is known for its large, distinctive leaves.

Guayaquil is also known for its historical parks, such as the "Parque de las Iguanas" and the "Parque Seminario" and the "Malecón 2000", which is a large and modern park along the Guayas River. These parks feature many different types of trees and plants and are popular places for locals and visitors alike to relax and enjoy nature.

However, it is important to note that the city has faced problems of urbanization and pollution, which can threaten the health of the trees and green spaces in the city (Roufechaei et al., 2014). Therefore, the city government has been implementing programs to preserve and

protect its green areas, including planting new trees and educating the public on the importance of protecting the environment. The concept has been limited since endemic species that provide ecosystem services and higher comfort are not used.

## **2.2 Quality and comfort indicators**

The quality of green areas in public spaces can be assessed using several different indicators, including accessibility, maintenance, design, and biodiversity.

**Accessibility:** This refers to how easy it is for people to reach and use the green space (Thomas & Littlewood, 2010). Factors that can affect accessibility include location, transportation options, and the presence of sidewalks and other infrastructure.

**Design:** This refers to the overall design and functionality of the green space. Factors that can affect the design include the presence of amenities such as seating and restrooms, the availability of shade and other features that make the space comfortable to use, and the overall aesthetic appeal of the space.

**Maintenance:** Refers to how well the green space is cared for and kept in good condition. Factors that can affect maintenance include the frequency of mowing and pruning, the presence of trash and debris, and the general cleanliness of the space (Xu et al., 2019).

**Biodiversity:** This refers to the variety of plant and animal life in the green space. Factors that can affect biodiversity include the presence of native plants and trees, the presence of threatened or endangered species, and the overall health of the ecosystem.

A high-quality green area in public spaces would have high accessibility, adequate maintenance, well-designed and comfortable features, and good biodiversity. Government, community, and private organizations can work together to keep green areas in good condition and accessible to the public.

## **2.3 AHP-TOPSIS method**

The Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) are two separate multi-criteria decision-making methods that can be combined to form the AHP-TOPSIS method (Awasthi et al., 2018).

AHP is a method used to prioritize and evaluate alternatives based on a hierarchy of criteria and sub-criteria. It involves breaking down a decision problem into smaller, more manageable parts and evaluating each part relative to the whole.

TOPSIS, on the other hand, is a method that uses a combination of relative closeness and separation to evaluate alternatives. It compares each alternative to an ideal solution and a negative ideal solution, which are determined based on the decision criteria.

The AHP-TOPSIS method combines these two methods by using AHP to determine the relative importance of the criteria and TOPSIS to determine the relative closeness of each alternative to the ideal solution (Ceballos et al., 2013). This method allows decision-makers to consider both the relative importance of different criteria and the relative performance of alternatives in a single process.

In the first place, the decomposition consists of structuring the problem at a hierarchical level, where the objective occupies the first level, the attributes occupy intermediate levels, and the last level presents the alternatives to be judged. Fig. 1 illustrates a generic hierarchical structure with four levels, where the objective is related to alternatives through criteria and sub-criteria as linking dynamics that address the decision-making alternatives.

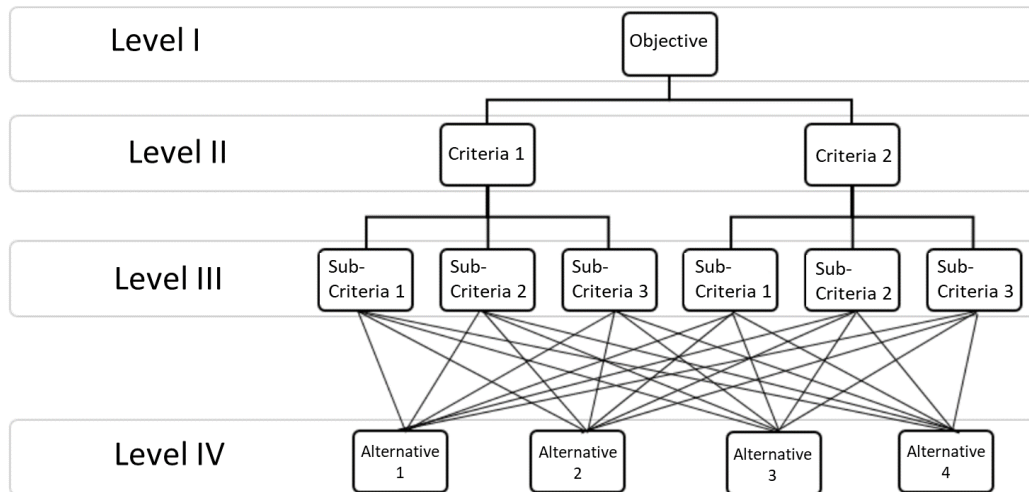


Fig. 1. Analytical hierarchical structure.

Among the analyzes assigned to TOPSIS, 3 of these will be assigned to the study to demonstrate an idyllic choice in decision making:

ELECTRE (i), family of multicriteria decision analysis that means elimination and choice translating reality. It is composed of two main parts in an ELECTRE application: first, the construction of one or several overcoming relationships, which aims to comprehensively compare each pair of actions; secondly, an exploitation procedure that develops the recommendations obtained in the first phase.

Usually, the ELECTRE Method is used to rule out some unacceptable alternatives to the problem. After that, we can use another multi-criteria decision analysis (MCDA) to select the best one. The advantage of using the Electre Method is that we can apply another MCDA with a restricted set of alternatives, saving a lot of time.

The Weighted Sum Model (WSM), also called Weighted Linear Combination (WLC) or Simple Additive Weighting or SAW (ii), is the best known and simplest Multiple Criteria Decision Analysis (MCDA) method for evaluating various alternatives in terms of decision criteria and the Linear Assignment Methodology (iii) determines numerical rankings of results [12], so both variables operate together.

As a verification method, the Realization of Matrix Consistency (i) will be applied, which uses a priority vector that shows the relative weights between the things that we compare and can be used in the AHP method (Chen, 2021).

### 3 Methodology

The methodology applied is of a qualitative/quantitative nature, applying a comparative analysis of the green areas in relation to the level of quality and comfort in the southern zone (Ciudadela las Acacias), center (urban area of Guayaquil and commercial zone) and north (Alborada), this comparison will be studied under indicators and determinations through measurements with a thermographic camera for the location of the clusters in areas of higher heat incidence that determine the heat islands and their direct relationship with the user in the public space.

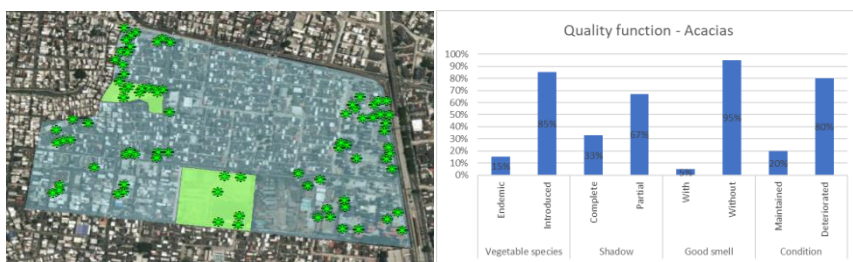
In the second stage of the methodological study, options will be applied around the strategies proposed to reduce the heat island determined by a multi-criteria decision framework with the use of the Decision Radar mathematical platform, which develops a decision-making

scheme for the election. -tion of plant species as a multicriteria analysis to obtain the hierarchical analytical spectrum. In accordance with these methodological analysis tools, the final proposal for the design of comfortable green areas in the public space was elaborated.

## 4 Results

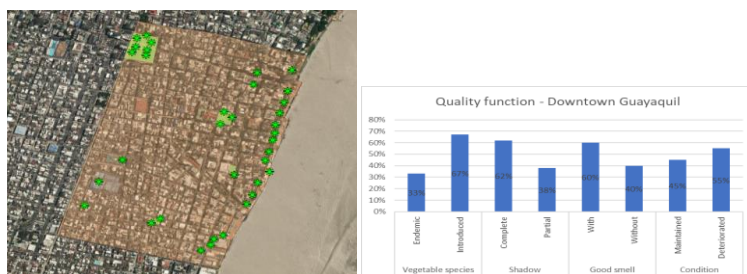
### 4.1 Comparative analysis green areas

In relation to the comparative scheme, the green areas of each study area were analyzed, focusing on the level of comfort and quality of spaces based on initial criteria of type of plant species, shade, smell and state of the species, determining qualitative data in an initial phase of results configured in the data mapping using the ArcGIS tool.



**Fig. 2. Quality function - ArcGIS of green areas in Acacias, Guayaquil.**

In terms of quality of green areas in the Acacias sector, endemic species have little predominance in the study sector and provide a partial amount of shade that does not meet the needs of users and are species that mostly do not they have odor conditions and present a deterioration in their maintenance due to lack of pruning and irrigation. The urban green index of the sector is low since it does not comply with what is established by the World Health Organization (9 m2. per inhabitant) since in the visit to the site it was possible to verify that there are 4.53 m2 per inhabitant.



**Fig. 3. Quality function - ArcGIS of green areas in Downtown Guayaquil.**

The polygon of the center of the city of Guayaquil was determined by the commercial center and the traditional center of Guayaquil, allowing to obtain a regular polygon that begins at Avenida Malecón to the West, Pedro Moncayo to the East, Junín to the North and Carlos Gómez Rendón to the South. The quality of the green areas tends to improve in the downtown area of Guayaquil since its level of comfort with respect to shade is high in the wooded areas, the high level of introduced species is maintained, thanks to the intervention on Avenida Malecon there is many species that generate a pleasant smell, although in summary the level of deterioration in green areas still predominates. The urban green index is 2.44 m2. per inhabitant, being the lowest of the three study areas.



Fig. 4. Quality function - ArcGIS of green areas in Alborada, Guayaquil.

The quality of green areas in the Alborada sector, introduced species predominate, the level of comfort due to shade is partial, almost all plant species do not generate a pleasant odor and the level of deterioration is high. The urban green index is 4.24 m<sup>2</sup>. Per inhabitant.

## 4.2 Decision Radar

With the use of the Decision Radar mathematical application, the AHP-TOPSIS calculations can be affected by designating objective options (first level objectives), evaluation criteria or subcriteria to obtain relevant alternatives of results to obtain a clear decision-making process. decisions around the established problems. For the hierarchical analytical process, 3 types of order analysis and a multicriteria verification system based on TOPSIS preferences were considered.

For the initial analysis of TOPSIS, objective options were considered in terms of introduced, endemic and ornamental species, put to the test in criteria of accessibility, design, maintenance and biodiversity as multi-criteria analysis components, designating weights for their weighting of the decision matrix, obtaining preferences towards endemic species (see Fig. 5). The full spectrum of results demonstrates that the best response vector maintains an acceptable alternative distance.

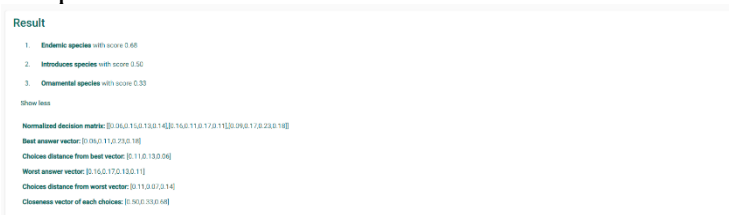


Fig. 5. TOPSIS analysis - Decision Matrix.

In the construction of overcoming relationships, it can be noted that endemic species adapt better than species introduced into the territory. (see Fig. 6). The full spectrum of results demonstrates a mean discrepancy of 0.75, which defies an acceptable agreement matrix.

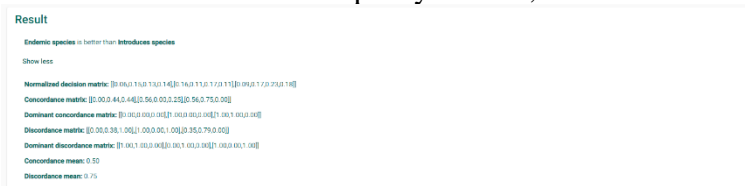


Fig. 6. TOPSIS analysis - ELECTRE.

The simple additive weighting (SAW) gave as a result that the best alternative is the endemic species and later the ornamentals, since they generate a higher yield in biodiversity and design with long-term maintenance, reducing the incidence of death in the species that yield the lowest normalized value of total yield (see Fig. 7).

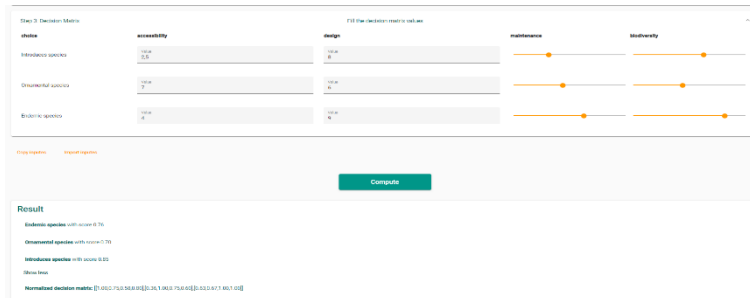


Fig. 7. TOPSIS analysis – SAW.

The priority criteria vector shows that the maintenance and biodiversity factor are important in the design of green areas, while accessibility is correlated to the ornament aspect within the design, so the judgment of the comparison matrix is not consistent. among all the criteria (see Fig. 8).

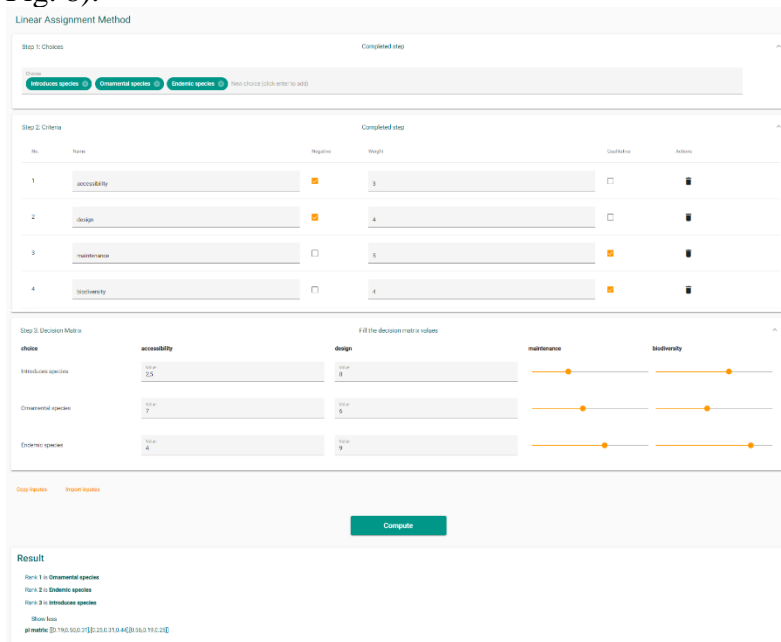


Fig. 8. TOPSIS check method – Matrix Consistency Realisation.

## 5 Discussion and conclusions

The choice of endemic species generates a higher level of comfort due to maintenance conditions that reduce their long-term cost by 45%, determined in the selection matrix. The level of accessibility according to the species is maintained and does not generate a decrease when using ornamental species. The design in terms of green areas has a greater influence on the design that contributes to the level of comfort in terms of shade and smell of the species. Biodiversity influences the integration of endemic and ornamental species, obtaining direct benefits to the design.

Compliance with the design indicators of green areas improves the quality of permanence and interaction, since the evaluation in the study areas determines that there are no shady conditions and adequate maintenance, which is why users do not tend to use them.

As a future line of research, it is proposed to integrate these criteria and indicators for the redesign of green areas and the choice of plant species that contribute to the growth of the deficient urban green index in the city of Guayaquil.

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