Vegetation Modules for evaluation of urban green areas

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Abstract: This work is a study of the green areas of the city of Huelva, Spain. It focuses on the evaluation of green areas through landscape indicators called modules. When they are calculated they facilitate the work of city planners in the distribution of urban green spaces. This method provides a new approach to appraisal urban landscape. This rating system is valid to do it between different areas of a city and also to compare the green spaces among cities. The vegetation module evaluation system is a useful tool for urban green areas planning.

Keywords: green planning, landscape appraisal, urban model, landscape management, urban planning

1 Introduction
Cities are extremely complex elements, especially when ecologically diverse factors coexist in the same space. This variety of factors provides for a vast array of outdoor settings [1]. Nowadays, urban green areas are not always formed by appropriate or indigenous species, but tend to feature exotic varieties, and in the worst of cases, species with no affinity to the area's local vegetation, therefore creating greater demands in upkeep [2].

The enhancement of green areas has the potential to mitigate the adverse effects of urbanisation in a sustainable way, making cities more attractive to live in, reversing urban sprawl, and reducing transport demand. Nowadays, there is an increasing societal support for more green space in and around cities [3]. Sang-Woo Lee [4] researched the relationship between neighborhood structure and landscape, as well as the satisfaction within urbanized areas.

It is important that landscapers consider surrounding nature and cultural aspects, especially in cases when these aspects have not been defined using rating techniques for normalized green areas. Green areas contribute to cultural identity and sustainability [5]. Sustainable approaches are needed for planning and managing landscapes worldwide. New tools are needed to effectively apply sustainable principles to planning and management. The spatial dimension of sustainability engages processes and relations between different land uses [6].

Landscape metrics can quantify landscape patterns and facilitate the comparison between different planning scenarios. Gradient analysis can systematically reveal the effects of urbanization on landscape patterns and provides some insights into land-use planning at a regional scale. Combined together, the method of analyzing landscape patterns paralleling an urban-to rural gradient has the potential to assist land-use planning with the aim to better integrate the human world with the environment [7]. The term landscape focuses upon the visual properties of the environment, which include natural and man-made elements and physical and biological resources that could be identified visually but also include non-visual biological functions, cultural/historical values, wildlife and endangered species, wilderness value, opportunities for recreation activities and a large array of tastes, smells and feelings [8]. Knowledge on how green space is used, why it is used, and which factors influence its use, is becoming interesting for researchers, city planners and managers of green space [9]. Adequate management of parks and green areas increases the biological complexity of species, which favors the improved well-being of the humans, as well as conserving biodiversity [10].

From a city planning perspective, the results indicate how urban green spaces can be viewed as elements of importance to public mental health. However, before the dimensions can be used by practitioners as tools to promote health through city planning, more research is needed [11].
Research was conducted to determine the role of parks and green areas in the comfort of Valencia (Spain), which is a prototypical Mediterranean city. A climate analysis of the city was conducted, as well as a study of "comfort indices" across different sections of the town, with a definition of each urban area in context to the rest. Certain of these comfort indices were calculated in green areas, with a calculation of their size within their urban section. The above methodology was considered valid for use by city planners when designing green areas [12].

Landscaping fulfills diverse functions. However, there is little information regarding the spatial variation of landscaping functions. Quantifiable aspects of landscaping include the ability to provide goods and services [13].

Very little research has been conducted on the proportion and distribution of urban green areas in relationship to city dwellers. Based on the aforementioned, it would be beneficial to be able to analyze and evaluate the “Urban Vegetation” (UV) of any city; in this study, this is achieved using a model of Vegetation Modules (VM). More specifically the objective of the present work was:

- To develop modules which analyze and assess “UV” in an insightful and objective manner.
- To determine the balance between vegetative and non-vegetative elements within downtown areas.
- To apply the model for the assessment of the urban green areas of Huelva and determine where future improvements are needed.
- To calibrate the modules in order to make them applicable to any city.

2. Materials and methods

Materials used include cartographical, statistical, bibliographical, and other direct research data. Also, spreadsheet software such as Excel and geographic information systems, such as ArcView and Arc Gis were used. Currently, there are no objective temporal or spatial methods in existence to evaluate urban vegetation in relation to buildings, streets and sidewalks; therefore, this study can be credited as an important innovation in this field.

- The methodology includes a series of phases:
  - Divide the different urban areas into zones
  - Take inventory of the city's green areas
  - Apply the Vegetation Modules (VM) model.

The downtown city area was divided into eight districts according to census data. The green areas were inventoried by zone, and grouped by type and district. The downtown area of the sample city (Huelva - Spain) has been divided into eight zones (Z1...Z8), whose types of landscape has been analyzed and inventoried. Six types of green areas were identified: Park (P), Garden (G), Square (Sq), Alignment (Al), Dispersed plants (Dp), and Ungrounded plants (Up).

2.1. Inventory criteria for the different types of landscape were as follows:

Park (P): these are considered superior green areas, serving as gathering points as well as places where the city’s inhabitants can relax (urban parks). Normally they occupy a larger amount of space due to the tree stratum.

Garden (G): green areas with variable sized surfaces and design, intended to provide beauty and serenity, as well as to offer areas for walking, relaxing, as well as its visitors’ visual enjoyment. Normally, bush and herbaceous strata predominate over trees.

Square (Sq): an urban space with very well-defined characteristics, generally crossroads. The majority of these are paved, and principle uses are recreational and aesthetic, with a varied amount and type of vegetation.

Plant alignment (Pa): this consists of a continual sequence of woody vegetation (trees, bushes, or mixed) with homogenous separations between plants (generally).

Scattered plants and/or grass (Sp): this is an area with incidental sporadic or wild species, and those only featuring grass.

Potted plants (Pp): Vegetation which is planted or sown in transportable recipients of different sizes (pots, window boxes, containers), generally lined up or organized into small groups.

2.2. Vegetation Module (VM)

A basic element of the method explained and utilized in this study is the variable upon which the suggested methodology has been developed. The variable in question is the Vegetation Module (VM). The VM evaluates a facet of the quality of urban vegetation based on other objective parameters, depending on the urban environment as well as the feature being studied. The evaluation of the urban landscape is done through the calculation of the VM using the parameters streets, buildings and vegetative elements.
There are six basic analytic VM: three of them refer to constructive or structural elements: non-vegetative elements (Modules I, II, and III - “Evaluation Constructive Elements” - ECE), and another three, which are vegetative elements (Modules IV, V, and VI - “Evaluation Vegetative Element” - EVE).

2.3. Module I: Types of urban buildings (TUB)
Cities are characterized by the concentration of buildings and by population size and density. This module includes different types of buildings, including their height and green areas, rating each of them from 0 to 10 (A, B, C, D, E, and F with their specific assessments, 10, 8, 6, 4, 2, and 1).

For Module I, building ranking was carried out based on the availability of green areas, as well as the amount of space their vegetation provides to ecological conditions such as light, oxygen, water conservation, etc. The abandoned areas were also taken into account, as well as plots of land and walled-up areas, all of which provide no aesthetic benefit to the scenery, although they do not directly limit ecological functions.
The following rating was applied according to types of residences:
A = House or single-family home with a garden surrounding the building. Rating: 10.
B = Single-family home with front garden, or townhouse with garden. Rating: 8.
D = Outstanding buildings (public, with front or side yards, or without surrounding garden but with at least five plants). Rating: 4.
E = Apartment (blocks with collective entrances over two stories high; those with just 2 stories are categorized as C), and exceptional buildings with over five stories and without their own garden. Rating: 2.
F = Plot of land, closed or walled off (including buildings under construction and those creating visual impact). Rating: 1.
Using the example of the calculation of the different types of buildings (TUB), the following are considered: urban area, street being classified, complete street name, and parameter ratings for left and right side of the street with a final subtotal from 1-10. For the study area given example, there are a total of three buildings on the right side of the street. The calculation for the final result for Module I is:
Fr1 = (2.666+2.666)/2 = 2.667.

2.4. Module II: Types of urban streets (TUS)
This module ranks the width of the urban streets. This is ranked from 1 to 10 (its alpha-numerical value is: A, B, C, D, E, F with the corresponding numbers: 10, 8, 6, 4, 2 and 1). This module contemplates measurements based on width and length; in the case of differences in width, the partial values will be added. Using respective values the final rating (Fr) of module II (TUS) FR2= 5.059 +0.627 = 5.686.

2.5. Module III: Type of urban sidewalk (TUSW)
This module ranks the width of the sidewalks. The maximum rank here is 10. The established rank is from 1 to 10 (alpha-numerical values are: A, B, C, D, E, F with the corresponding numbers 10, 8, 6, 4, 2, and 1). This results of Module III (TUSW) analyzes the width of the sidewalks. These average the results from measuring their width; in the case of segments with differing widths, the partial rankings are added together to obtain the final result. Therefore, the final value (Fr) of the module III (TUSW) is:
Fr3= (4.00+6.00)/2 =5.00.

2.6. Module IV: Type of urban garden (TUGA)
This module is for green areas valuation (direct on the site) on the street that is being evaluated. Each landscaping type is assigned a rating, considering projections of length of these areas which border the side of the street, to obtain the final rating (Fr). The landscape type with direct access and the characteristics of the lengths that are directly accessible from the street, distance = 0. If the sum of the projected length is greater or lesser that the length of the street, it is considered, obtaining a parameter of k≠1, which is proportional to the degree of their overlapping. Therefore, the K corrector is used when the total length (TL) is not equal to the length of the projected green areas (GL), with K = GL/TL.
The result of Module IV (TUGA) calculates the green areas which are directly accessible from the street. Each landscape type is assigned a rank, and based on this, and considering the longitudinal projections of the green areas bordering the sidewalk, resulting in the final ranking (Fr). The final rating is obtained from the half the sum of both sides of the street, therefore, the Final rating (Fr) of modules IV is:
Fr4= (1.524+6.362)/2 = 3.943.
2.7. Module V. Accessibility to green areas from the street (AGAS)
This module evaluates the influence of different green areas according to their distance from the street being studied, taking into account a maximum distance of 100 meters. The evaluation is divided into six intervals (interval scores).
The results of Module V (AGAS) analyzes the accessibility of the different green areas depending on their distance from the street, taking into account that the maximum distance in 100 meters. 0 meters corresponds to the green areas with direct access from the street being studied (analyzed in Module IV). The final ranking is obtained from half the sum of the results on each side of the street.
Therefore, the Final rating (Fr) of Module V (AGAS) is as follows:
Fr5=(0.867+0.80+0.48+0.48+0.347+0.027)=3.00.

2.8. Module VI: Green areas-degree of influence on the street (DIS)
The degree of influence of green areas in the streets should be calculated in two phases: area of indirect and direct influence (DIS-I and DIS-D, respectively). The calculation of Module VI (DIS-D). It is estimated the size of green directly areas (DIS-D).
Final ranking = Green area rating + Average frequency formula;
Fr6 (of DIS-I) = (Gar + Aff)
The Total score of direct influence of Module VI is calculated as follows:
Fr6 (of DIS-D)=ΣRto = 8.053,
(Rdt) = Accessibility score/10.
were Rdt is the Rating Distance coefficient
[Surface value (a) x Type green area (b)] + [(Type green area (b) x Score green area (c))]/2 = d.
Final rating of the degree of indirect influence Fr6 = (Rdt) x Intermediate ratings (d).
The Total score of indirect influence of Module VI DIS-I is:  \( \sum Fr = 40.7 \)
Considering the previous calculations the following formula is applied: DIS = [(DIS-D) + (DIS-I)/2]/2 to obtain the complete Module VI.
The total ranking of the green areas according to their degree of direct and indirect influence is:
FR6DIS = [(DIS-D) + (DIS-I)/2]/2
Fr6= [(8.053 + 40.7/2)/2 = 14.201
Therefore, the total for green areas according to degree of direct/indirect influence is 14.201.

2.9. Final calculation methodology
The final evaluation of each street was achieved through a prior assessment of the “Evaluation Constructive Elements” (ECE) and the “Evaluation Vegetative Element” (EVE). Both variables are introduced into the proposed matrix (“Equilibrium Matrix”). ECE module is represented in the axis (x) and module EVE abcissa is represented on the axis (y) and provide an interpretable point in EM. The graph of the equilibrium matrix (EM) is empirical and classifies the different streets according to the ECE modules and EVE (Fig. 1).

Fig. 1 - Equilibrium matrix and streets studied within the downtown area. Streets are represented by dots.

3 Results
The example used in this work in the city of Huelva (Spain) confirms a net imbalance between the quantity of different vegetation types within each urban area. Table 1 shows the diversity and quantity of green areas in various urban zones. In tables 2 to 9 it can be seen the results after calculation of the six modules for the city of Huelva.

Table 1 - Average modular ratings of the urban area into which the city center was divided.

<table>
<thead>
<tr>
<th>AREAS</th>
<th>Area 1</th>
<th>Area 2</th>
<th>Area 3</th>
<th>Area 4</th>
<th>Area 5</th>
<th>Area 6</th>
<th>Area 7</th>
<th>Area 8</th>
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</thead>
</table>

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114
Table 2 – Final Results of Module I

<table>
<thead>
<tr>
<th>Key zone 4</th>
<th>Key street 4.22</th>
<th>Final rating 2.867</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street: Doctor Cantero Cuadrado</td>
<td>Length (m) 370</td>
<td></td>
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</tbody>
</table>

Table 3 – Final Results of Module II (TUS)

<table>
<thead>
<tr>
<th>Key zone 4</th>
<th>Key street 4.22</th>
<th>Final rating 5.686</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street: Doctor Cantero Cuadrado</td>
<td>Length (m) 370</td>
<td></td>
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</tbody>
</table>

Table 4 – Final Results of Module III (TUSW)

<table>
<thead>
<tr>
<th>Key zone 4</th>
<th>Key street 4.22</th>
<th>Final rating 5.686</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street: Doctor Cantero Cuadrado</td>
<td>Length (m) 370</td>
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</tbody>
</table>

Table 5 – Calculated values of Module IV (TUGA)

<table>
<thead>
<tr>
<th>Key area 4</th>
<th>Key street 4.22</th>
<th>Final rating right side 1.854</th>
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<tr>
<td>Street: Doctor Cantero Cuadrado</td>
<td>Total Length (m) 370</td>
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</tbody>
</table>

Table 6 – Data and final results of Module IV (TUGA)

<table>
<thead>
<tr>
<th>Key zone 4</th>
<th>Key street 4.22</th>
<th>Final rating 3.043</th>
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<tr>
<td>Street: Doctor Cantero Cuadrado</td>
<td>Length (m) 370</td>
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Table 7 – Final results of Module V (AGAS)

<table>
<thead>
<tr>
<th>Key zone 4</th>
<th>Key street 4.22</th>
<th>Final rating 9.200</th>
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<tbody>
<tr>
<td>Street: Doctor Cantero Cuadrado</td>
<td>Length (m) 370</td>
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</table>
The results in Fig. 2 indicate the ranking of constructive module (ECE), vegetative module (EVE), and final ranking (Fr). Zones 1 and 5 possess lowest ECE and EVE scores, while Zones 3 and 4 have the highest. The latter not only has balanced green areas, but also are better-equipped to maintain and to enrich.

In Fig. 3. This is a breakdown of the equilibrium matrix, which indicates the relationship between the average ECE-EVE scores for each urban zone. Zones 1 and 5 are in the very low critical zone. Zone 6 has an uneven distribution of green areas which (in other words, it hasn't realized potential) 3, 4, 7, 8, and 2 are balanced (balanced rating). This means that the relationship between the constructed and the green areas are in proportion.

4 Discussion
This study examines the relationship between and within urban green areas, with roads and the type of green area to play an important role: parks (p), gardens (g), etc. Several of the basic elements are its size and location of green areas in the city, which is why the landscape modules have been developed (I, II, III, IV, V and VI) and synthesis modules (ECE, EVE, Fr.). Communication methods can be used to

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Table 8C Final results of Module VI (DISC-D)

<table>
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<tr>
<th>Key Area</th>
<th>Key Street</th>
<th>6-2</th>
<th>Final rating (direct area)</th>
<th>8.093</th>
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<td>Type</td>
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<td>6</td>
<td>60</td>
<td>8</td>
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Table 9C Final results of Module VI (DISC-I)

<table>
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<tr>
<th>Key Area</th>
<th>Key Street</th>
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<th>Final rating (direct area)</th>
<th>8.093</th>
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Fig. 2 – Modular ratings: ECE (evaluation constructive elements), EVE (evaluation vegetative elements) and Fr (final rating=TM total module). FRA= average final rating. Minimum critical ratings ECE and EVE.

Fig. 3 – Breakdown of the equilibrium matrix. Average ECE and EVE ranking of the different areas. Critical, low ratings, very low, and minimum critical ratings. EVE ratings which are favorably uncompensated and EVE ratings which are unfavorably uncompensated.

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4 Discussion
This study examines the relationship between and within urban green areas, with roads and the type of green area to play an important role: parks (p), gardens (g), etc. Several of the basic elements are its size and location of green areas in the city, which is why the landscape modules have been developed (I, II, III, IV, V and VI) and synthesis modules (ECE, EVE, Fr.). Communication methods can be used to

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assist in planning parks and green areas for different land use. Using the GIS (geographic information system), social data regarding urban forests and other green areas of interest may be obtained [14].

With the advances of virtual technology, the visual analysis of the constructed city environment can be made using a virtual model. Initially, a basic (virtual) model is made, to which modifications and changes are made regarding the height of buildings and street vegetation, and how this affects the visual quality of the street is analyzed. Once the digital model has been made, it can be used by future urban designers [15]. Today's society in urban centers "set value" green spaces. Therefore, each type of plant cover provides various services for citizens in particular and society in general [16].

5. Conclusions
This study relates green areas with built-up land, analyzing whether the relationship is balanced or not and indicate the reasons of unfavorable balance. The implications of this study include the analysis of city areas, covering the number, type, size, and accessibility of green areas which interact with the immediate environment. The results of both the synthetic modules as well as analytic modules might be useful for the managers of urban planning. Urban vegetation must provide contact with nature in order to fulfill the needs of city dwellers. Hence, pleasing environments for strolling, relaxing, and playing must be designed. There should be an adequate proportion between the green areas and number of inhabitants which satisfies the need to relation with nature.

References: