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ID 1333 | PLANNING OF URBAN GREEN AREAS BASED ON GIS TOOLS

Fernando Cruz[1], Nuno David[2], Nelson Mileu[3]
[1]LEAU/ULHT, IST, ULisboa/IGOT
fcruz@gmail.com ; nunomigueldavid@gmail.com ; nmileu@municipia.pt

ABSTRACT: Decision processes regarding the use of public resources in green infrastructure requires new approaches capable of providing on-going evaluation and trade-off analysis concerning the level of service that new urban green areas can provide in social-ecological terms. Such information is critical either to improve decision-making, planning practice (e.g. new locations) or even to improve landscape design processes. In order to solve these concerns, the present study aims to provide a model-based tool that allow to estimate service areas in Oeiras municipal ecological structure, but also capable to geographically identify socially meaningful areas for public investment regarding new urban green spaces. The study was developed in two phases. Grounded on kinematic laws and multi-criteria decision principles a conceptual model was initially shaped. Incorporating criteria and sub-criteria such as (i) the friction of slopes and (ii) the friction regarding physical conditions of the pedestrian public space (e.g. materials, dimensions, accessibility conditions, and others) into the model, the results revealed to be consistent with reality. This allowed developing a decision support system based on GRASS GIS and Bottle, in a second phase. The application was developed in Opensource environment using the Phython language, which allows programming the model and having as outputs the simulation of green space service areas and the

identification of geographical locations for new ones, improving decision-making in landscape planning context and optimizing human and financial public resources.

KEYWORDS: Service area; Green spaces; GRASS; Python; GIS processing; Web-Based DSS.

1 INTRODUCTION

The importance of urban green spaces nearby residential areas, as well as solid accessibilities from such areas are increasable related with quality of life indicators (Madureira, 2012; Schipperijn et al., 2010; Figueiredo et al., 2016), and became a priority issue in terms of good governance practices. The present study aims to contribute for better decision making, concerning the optimization of public resources (e.g. financial and human) in local administrations regarding management of urban green infrastructure.

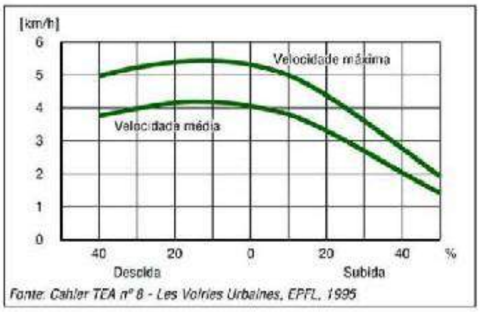
The accessibility of urban green spaces is an important issue regarding the contribution for the quality of urban environment in cities (Herzele & Wiedemann, 2003). Therefore the estimation of 'green space service areas' (GSSA), can provide a good framework for understanding the social influence of a given green space, by combining territorial coverage with a set of external attributes that can influence user's behavior (e.g. physical conditions in road network or slopes). By using Geographical Information Systems (GIS), we have created spatial illustration of distances by measuring accumulated distances through an accurate representation of urban pedestrian network in Oeiras municipality (e.g. promenades, plazas and pedestrian streets).

This accurate representation of pedestrian network and it´s physical characteristics, allows obtaining a more realistic framework for decision-making, when comparing with alternative approaches based in direct Euclidean distances analysis and considering the territory as an isotropic feature. Firstly, we have combined classical mechanics principles and kinematic laws within a classification system for representing physical conditions of public pedestrian network. We used a multi-criteria analysis model in order to obtain a weighted representation of pedestrian conditions of accessibility along urban network, according to municipal experts. Combining results (accumulated distances) with demographic census information, allows visualizeing the influence of existing urban green spaces, and permits a geographical identification for new potential locations in the future.

Secondly, we develop a web decision support system based on GRASS GIS and Bottle in order to operationalize the model. The advantage of this system is the fact that it is simple and straightforward, and does not require expertise in GIS applications, but only being familiar with web and the basic concepts related with green urban areas modelling.

2 METHODOLOGY

Service areas are directly related with pedestrian accessibility conditions and mobility. Beside physical conditions of users, accessibility conditions are influenced by public space attributes (e.g. quality and type of pavements, street dimensions, existence of architectural barriers) and topographic conditions (e.g. slope values along pedestrian network). The relation between pedestrian travel speed, it is also related with topographic conditions or slope degree (Figure 1).



Fonte: Cahier TEA nº 8 - Les Voiries Urbaines, EPFL, 1995

Figure 1 -Pedestrian speed according to different slope values

We consider the maximum speed of 1.5 m/s (5.4 km/h) in a flat surface, as reference value for an adult in regular physical form. We also consider that an elderly person or someone in a wheelchair under the same topographic conditions can travel at an average speed of 1.2 m/s (4.3 km/h) (Silva, s/d). The slope (D) establishes a relation between the altimetric values of the terrain (H) and distance (d), corresponding to the tangent of the angle of the terrain ( ), and can be expressed as a percentage:

$$D_{\%} = \frac{\Delta H}{d} * 100 = tg\,\varphi^{o} \qquad [1]$$

The image bellow represents an extract of a slope map generated from Delaunay triangulation (Figure 2).

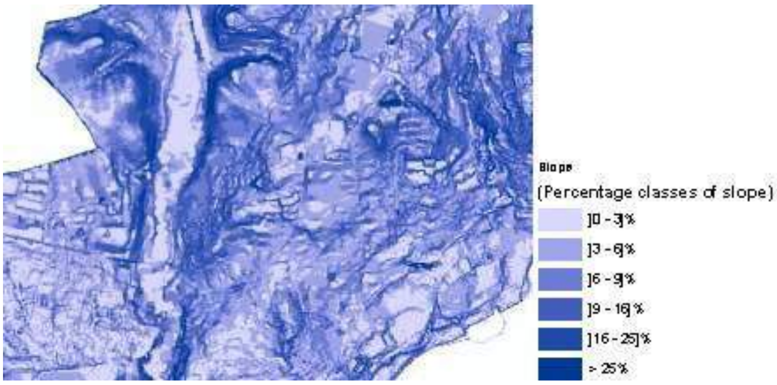


Figure 2 -Pedestrian speed according to different slope values

Modal walking width (m) Typologies of public spaces	**Average walking speed, (V) (m/s)**	**Average walking speed, (V) (Km/h)**
]0,00 – 0,90]	]0,00 – 0,75]	]0,00 – 2,70]
]0,90 – 1,20]	]0,75 – 0,98]	]2,70 – 3,50]
]1,20 – 1,80]	]0,98 – 1,22]	]3,50 – 4,40]
> 1,80	]1,22 – 1,81]	]4,40 – 6,50]
Footpath	]1,81 – 2,40]	]6,50 – 8,60]
Zebra crossing	1,22	4,40
Road / parking / crossings	0,75	2,70
Car traffic separator and roundabout interior	0,00	0,00

Table 1 -Pedestrian average velocities (m/s and Km/h) according to different characteristics of public spaces. Based on Silva, n/d; Seabra et al., 2011; Seco et al., 2008.

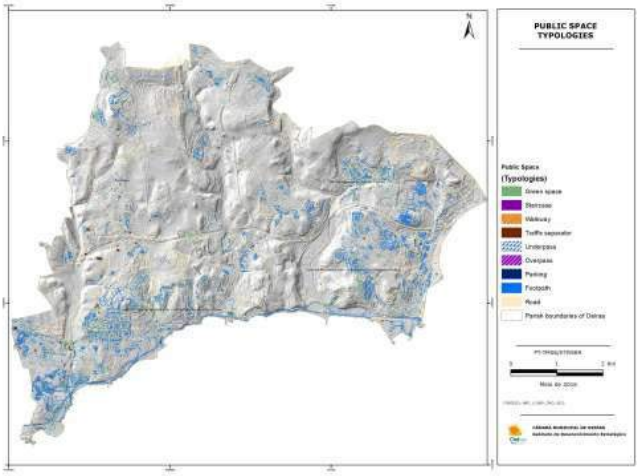


Figure 3 -Different typologies of public space in Oeiras municipality.

Through classical mechanics formalizations (Halliday, 2009), it is possible to represent space (e, in meters) and time (t, in minutes), on a friction surface (2D) using the following algebraic expressions, where R represents a spatial resolution (in meters):

$$[2] \qquad t = \frac{60.e.R}{v.10^3 \left(\frac{\text{km}}{\text{h}}\right)} \ (\text{min})$$

$$[3] \qquad e = \frac{v.10^3 \left(\frac{\text{km}}{\text{h}}\right).t\ (min)}{60.R} \ \ (\text{m})$$

By generating accumulated cost surface in public space, it is possible to represent several pedestrian velocities according to different values of slope friction and distinct architectural characteristics. Weighting 60% for slope friction and 40% to characterize public space friction, a global friction surface was obtained as well as global velocities. After testing 'in situ' in a limited number of places, the results seem to be consistent with the perceived reality. As result, we propose a friction surface that represent the crossing time over each pixel in public space (Figure 4).

Figure 4 - Pedestrian velocities according to different typologies of public space.

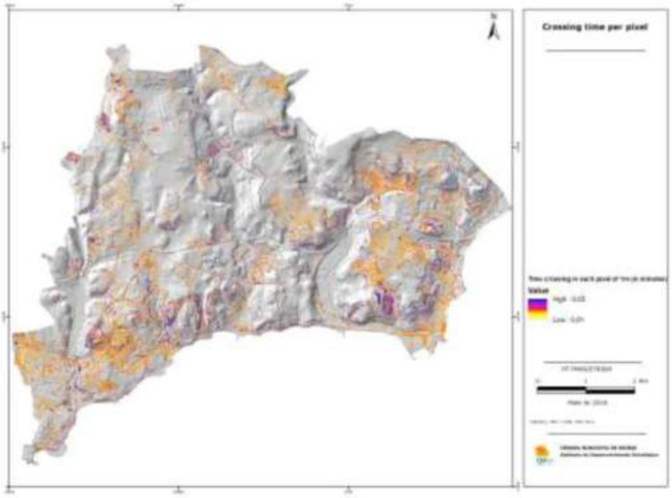


Figure 5 -Time crossing in each pixel (in minutes).

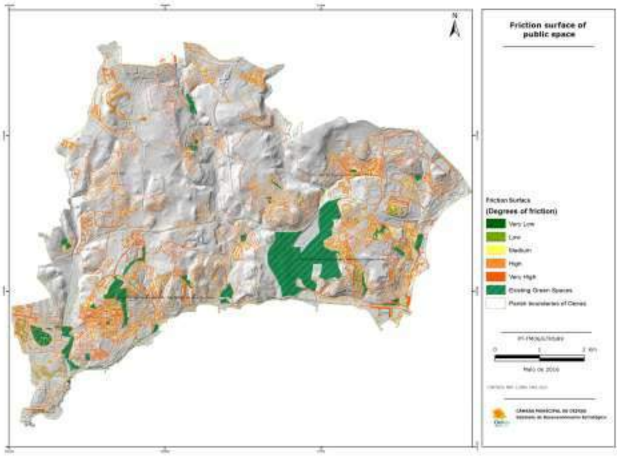


Figure 6 -Friction surface of public space.

2.1 ACCUMULATED COST SURFACE

The accumulated cost surface matrix represents the irradiation of pedestrian mobility, in ‘time-distance’ thought public space network, from each green space. Therefore, the influence of their distances were defined through time intervals in minutes (Figure 7), and time-distance can be represented by time-space in meters (Figure 8). The cumulative values of each pixel allows generating distances (fluxes) of influence from the radiation points or in this case, each green space. The geographical information was generated using Spatial Analyst extension from ArcGIS10.1 software.

Figure 7 - Detail of the friction surface in public space.

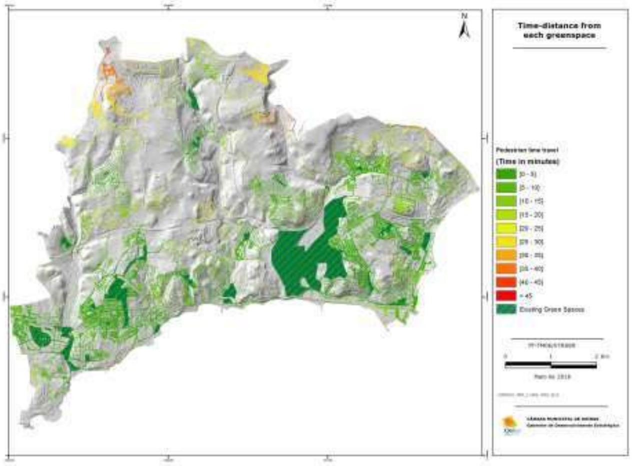


Figure 8 -Pedestrian time travel from each greenspace (accumulated cost surface).

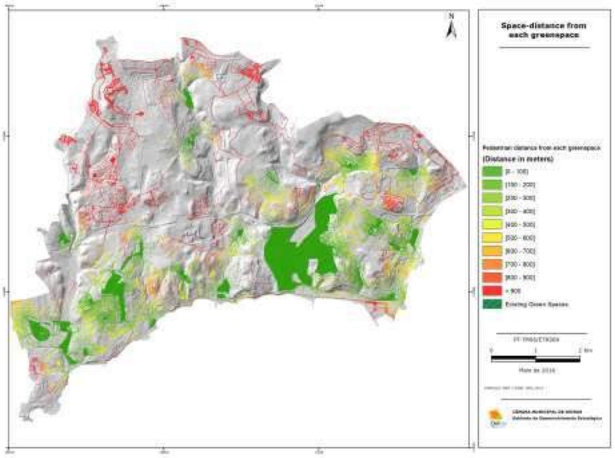


Figure 9 -Pedestrian distance from each greenspace (accumulated cost surface).

2.2 GREEN SPACE SERVICE AREA

After generating accumulated cost surface, we have conducted a reclassification in order to obtain time-breaks (in minutes) and distance-breaks (in meters). This information was intersected with census polygons (BGRI) in order to obtain a green space service area (GSSA), Figure 10.

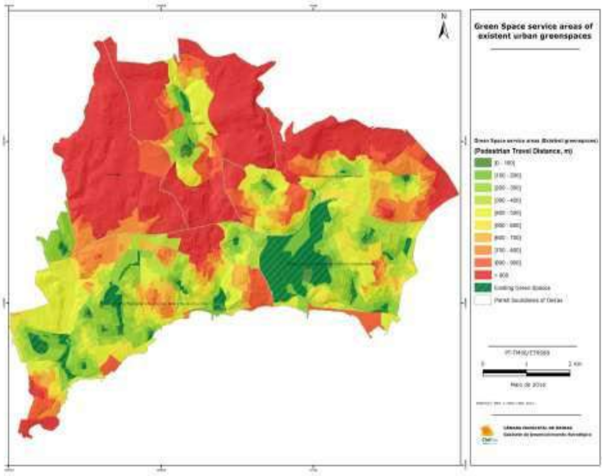


Figure 10 -Green Space service areas of existent urban greenspaces.

This analysis allowed modeling the spatial coverage of green spaces, by identifying which areas are near or distant from urban green spaces. Based on literature, we adopt 500 meters as initial reference distance in which an average individual might be willing to move in to a green space.

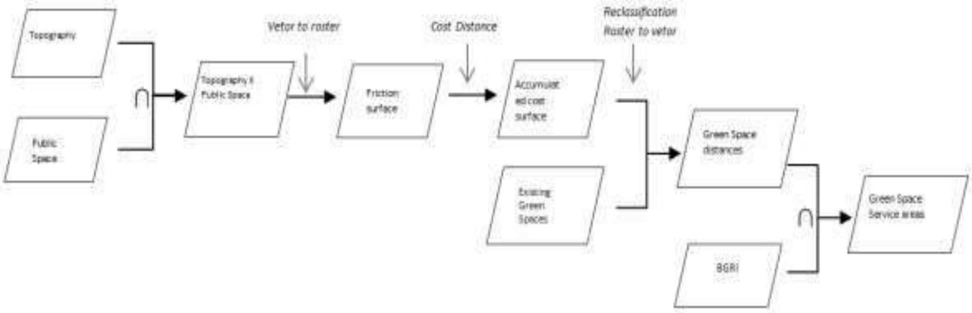


Figure 11 -Workflow for green space service areas.

Intersecting GSSA information and BGRI polygons, allows merging statistical data (e.g. individuals, families, residences, buildings) with urban plots, in order to obtain socio-demographic, socio-economic and socio-urban profiles.

2.3 COVERAGE ANALYSIS AND DETERMINATION OF PRIORITY LOCATIONS FOR NEW GREEN SPACES

In order to prioritize investments regarding new urban green spaces, we choose to use a multi-criteria decision analysis (MCDA) model, and specifically the weighted sum model. Taking 500 meters as reference distance for accessing urban green space, we have estimated low coverage areas (figure 12), as well as criteria and value scales (Table 2). Considering C1, C2 and C3, we rank C3 > C1 > C2, and after applying Swing Weight technique (Goodwin, 2004) the result was WC3=0.37, WC1=0.34 e WC2=0.29.

	Criteria	Value-scales
1	Population density. This allows to identify low, medium and high density area	]0 – 25] inhabitants/hectare – low density;]25 – 50] inhabitants/hectare – medium density; > 50 inhabitants/hectare – high density
2	Cost distance	]500 – 600] m,]600 – 700] m,]700 – 800] m;]800 – 900] m and >900m
3	Transferred areas (green spaces) for public domain or potential areas loca municipal domain	Binary (yes/no)

Table 2 -Criteria and value-scales for MCDA model.

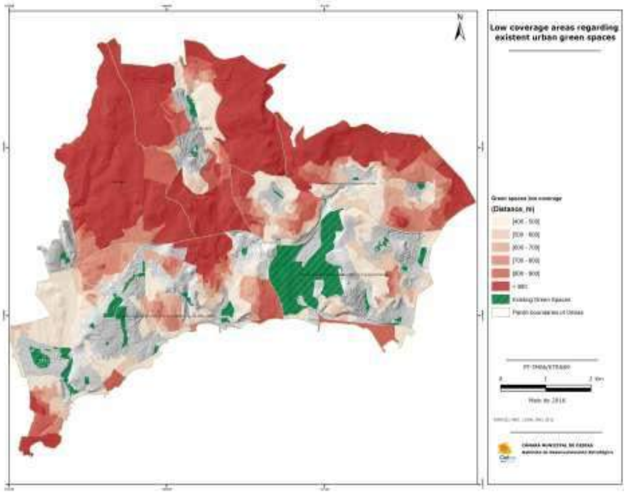


Figure 12 -Low coverage areas regarding existent urban green spaces.

In order to normalize criteria increasing (from 0 to 100 percent) and binary (yes/no) scales were used (Table 3). The priority level (P) of each green service area (alternative) is expressed in percentage and it's given by the weighed sum model [4], in which Wi express the weigh in each criteria and Ci express the value in each criteria. This model is also called 'weighted linear combination model' and has the advantage of enabling weighting criteria and allowing ranking the results (Goodwin, 2004).

C_1-Population density (Hab/ha)	C1 (Value 0 .. 100)	C_2-Cost-distance (m)	C2 (Value 0 .. 100)	C_3-Transferred areas for public domain (Yes; no)	C3 (Value 0 .. 100)
0 (null)	0	]500 – 600]	25	no	0
]0 -25] (low)	25	]600 – 700]	50	yes	100
]25 – 50] (medium)	50	]700 – 800]	75	-	-
> 50 (high)	100	]800 – 900]	85	-	-
-	-	]800 – 900]	95	-	-
-	-	>900	100	-	-

Table 3 -Value-scale normalization.

3 RESULTS

3.1 COVERAGE ANALYSIS AND DETERMINATION OF PRIORITY LOCATIONS FOR NEW GREEN SPACES

Figure 13 expresses, in quartiles, the priority level for each green service area (alternative) inside the low coverage areas. The areas above 75% represents the ones that should be consider 'priority areas' regarding the installation of new urban green spaces. The result allows programming new green spaces that have the potential for being socially relevant, and that should be critical to better rationalize public resources, particularly in periods of great restriction regarding public investment. These reserves for urban green spaces are accessible in a maximum distance of 400 meters for the secondary ecological structure (e.g. neighborhood gardens and small parks) and 800 meters for main ecological structure (e.g. urban and metropolitan parks, urban forests).

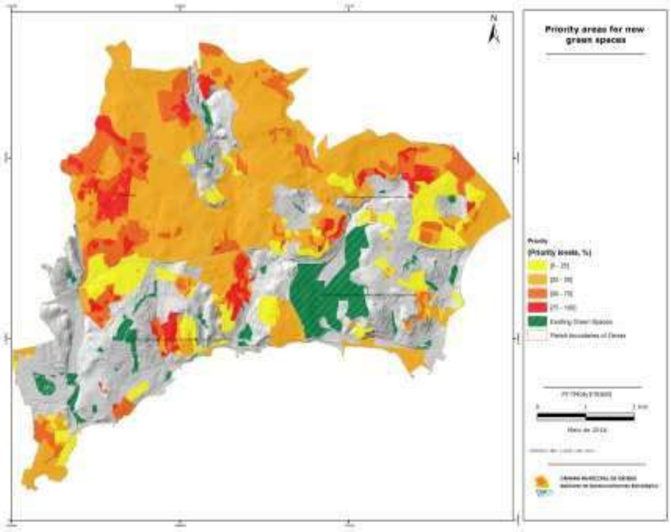


Figure 13 -Priority areas for new green spaces.

3.2 DESIGNING AND DEVELOPMENT GUADSS

The web green urban areas decision support system is based on the client\server model, following the structure shown in figure 14. The client\server approach has a three tiered consisting of: Tier1: web browser; Tier 2: web server, GIS Server, web-framework for Phython and a geoprocessing server; Tier 3: data.

The system was developed using Python Tools for Visual Studio, Java Script, and GRASS Python Scripting Library for the geoprocessing functions implementation.

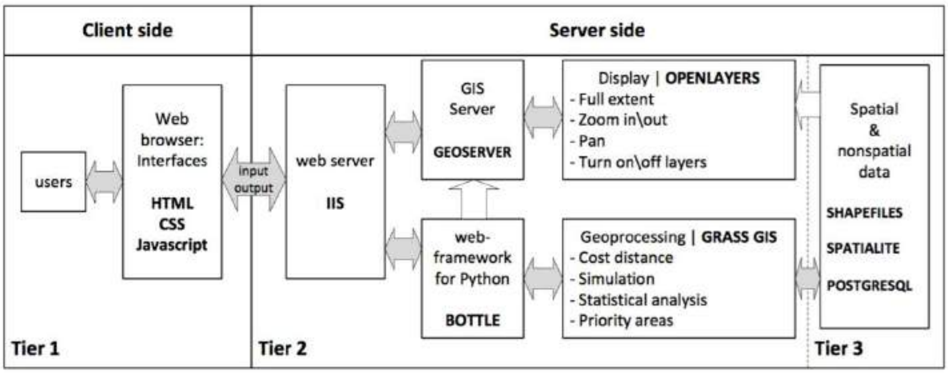


Figure 14 -GUADSS architecture.

The information flow is as follows:

1) Users initiates a request setting the input layers, the cost surface and priority layer weights and drawing (or importing the geometry) the new green urban areas on the web browser; 2) the web server passes the requests to the geoprocessing server to do the processing such as cost distance, influence of the new green urban areas, statistics and priority areas definition; 3) the geoprocessing server creates the intermediate data, the final layer and passes the results to the web server and GIS server; 4) the geographic output is displayed using Geoserver, the statistics graphics are displayed using D3 javascript library; and 5) the web browser displays the results using Ext and jQuery javascript libraries allowing all the outputs to be downloaded.

3.3 THE DECISION SUPPORT SYSTEM -GUADSS APPLICATION

The application was developed and tested using Oeiras municipality data and was deployed only for the municipality intranet users. Figure 15 shows the main interface, where it is possible to access the general GIS functions like full extent, pan, zoom in, zoom out or layer turn on/off. The three buttons near the general GIS functions are the specific tools that allow the users to upload new input layers or delete existing layers, start the processing system and access the results.

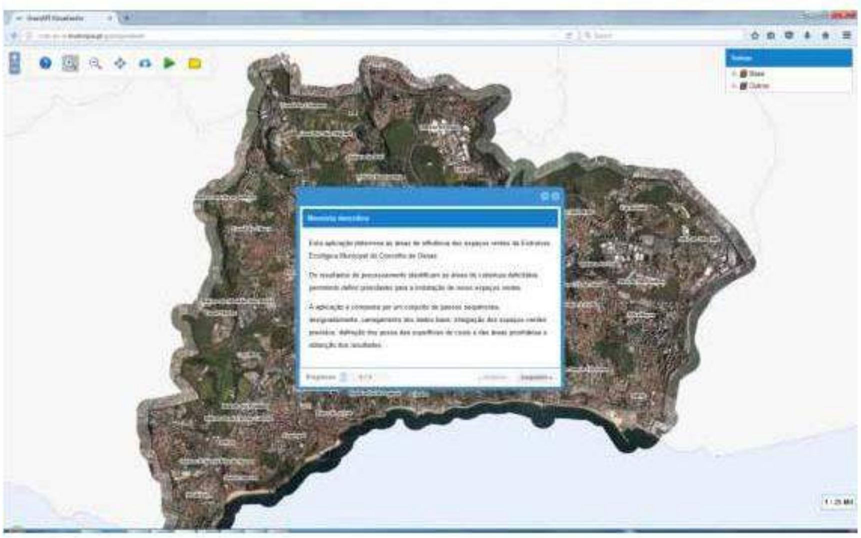


Figure 15 – GUADASS main interface.

The user needs to go through the seven sequential interfaces to start a simulation process (Figure 16). The first interface is an overview of the system. The second interface is used to select the input layers, like existing urban green areas, ceding areas, statistical sub-sections and reclassification rules. In the third interface, the user must draw the new urban green area in the map or upload a shapefile (e.g. polygon) with the urban green area project limit. The following two interfaces are used to define the cost surface and priority areas by defining weights. The weights have default values, but it is also possible to create different scenarios by setting them. In the next interface, users need to set the output workspace and output name. Since the processing takes some time, it is possible to receive an information e-mail when the process is finished. Finally, users just need to click the processing button and wait for the email, or wait until the page displays the end process message.

Figure 16 -GUADSS main interface.

Figure 17 exemplifies an analysis result, for a new green urban area in Porto Salvo parish, based on the default parameter settings. The results interface gives the possibility to download or delete the output layers, add the areas of influence of existing and planned green spaces layer as a WMS to the map window and access a statistical analysis. This statistical analysis is based on the simulation process results and over nine 2011 census variables (population, age structure, school grades, buildings), and allow a more effective support to decision making.

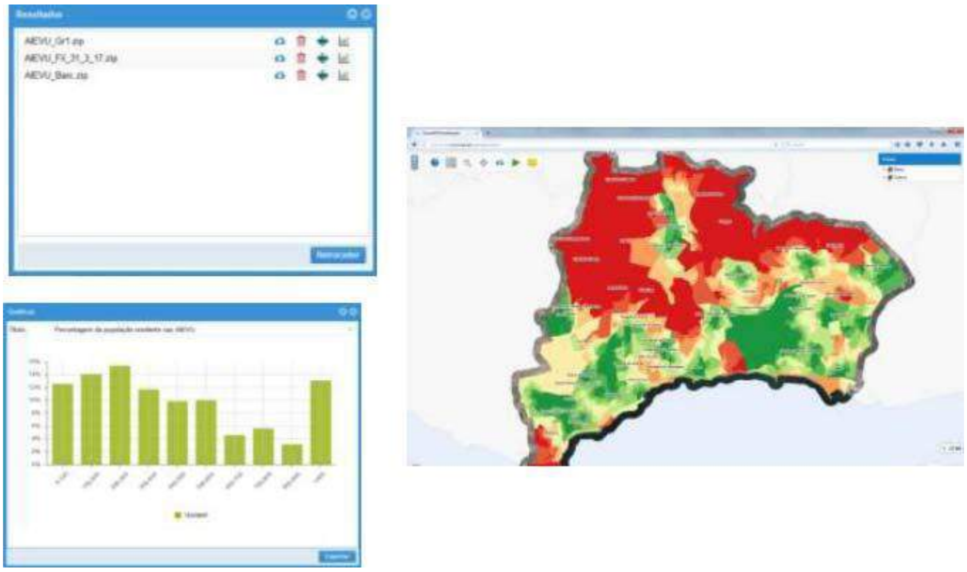


Figure 17 -GUADSS results interface.

4 CONCLUSIONS

The methodology that was used appears to be appropriate and innovative because it considers pedestrian mobility and accessibility over public space from an integrated perspective, by exploring MCDA models, which allowed considering diverse points of views in decision-making. The information regarding public space typologies in the municipality of Oeiras was characterized from considering factors like terrain roughness, architectural features and characteristics of the public space. Based on classical mechanical principles, we explore the potential given by a simple and reliable model that is able to represent pedestrian speed, travel time and space traveled. By using BGRI information, we add useful statistical information (e.g. individuals, families, residences and buildings) which allows drawing GSSA. Those were then typified by using non-euclidian intervals of 100 meters, enabling to identify low, medium and high coverage classes for the entire municipal territory. Using criteria like population density, cost-distance and the availability areas for new green spaces, we used a MCDA model that enables a geographically identification of priority areas for future green spaces. The model also provides better decision-making because it improves transparency and robustness regarding the allocation of public resources (e.g. human and financial). Regarding decision support system GUADSS, the experiments indicates that this web geoprocessing approach have several advantages when compared with the traditional desktop solution. The main advantage is time saving and the simplicity of using it. With friendly user interfaces, GUADSS allows any user to simulate different green urban areas scenarios without having specific GIS knowledge. Timely response is critical to attract the application users. However, geoprocessing with large datasets and with complex tasks takes time. This performance issue is being analyzed and all the hardware and software improvements are being considered. Another direction for futures development includes some algorithm improvements to solve problems related with areas that don’t have public space. For this problem, a possible solution could be based on the iteration over adjacent or not null results to obtain the average.

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