Urban Park in Maia – Porto: A Case Study of Application of 'Space Syntax' to Landscape Architecture

António Ascensão[1], Catarina Ruivo[2], Franklim Morais[3], Laura Costa[1,4]

[1]Laura Roldão, Landscape Architecture Ltd/Portugal · lauracosta.ap@sapo.pt
[2]Faculdade de Arquitectura da Universidade de Lisboa/Portugal · catarinaruivopereira@gmail.com
[3]Escola Superior Artística do Porto/Portugal · franklim@concinnitas.eu
[4]Universidade de Trás os Montes e Alto Douro/Portugal · lauracosta@utad.pt

Abstract: The paper explores the potential of the application of Space Syntax methodology to Landscape Architecture. Dealing with the landscape architectural design process of an Urban Park as a case study, intensive use of DepthSpace3D, a software for 3D Space Syntax analysis, led to:

a) a better understanding of the relations between the urban space shapes (spatial configuration, visibility and accessibility) and functions (physical, social and psychic);

b) the implementation of an iterative process of project improvement, optimizing the fulfilment of the desired (by the landscape architect) character of the Urban Park, through mastered changes in ground shaping and selection of the species and spatial distribution of trees and shrubs;

c) the improvement and suiting of DepthSpace3D to the special requirements of Landscape Architecture to Space Syntax digital tools.

A deep research was endeavoured regarding the digital modelling of the vegetation: form and dimension, growth speed and visual permeability (transparency/opacity) of the crown in winter and summer.

Keywords: Space syntax, landscape visibility, landscape accessibility, landscape spatial configuration

1 Introduction

Public space plays a major role on the quality of life of the citizens by making direct or indirect human interaction possible. Thus, it has become important to understand how spatial design affects the relations and actions between people and the spaces they use.

Many digital tools for landscape architecture focus on presentation and rendering. Although all are invaluable instruments for the professional practice of landscape architects, and some tools are filling the gap, such as GIS, parametric and Space Syntax, many do not provide methods specifically targeting the creative part of the design process.

Space Syntax (HILLIER & HANSON 1984) is a set of methods with an underlying set of theoretical assumptions. It has profound roots in classical architectural theory, but it has been developed in recent and formal languages since the 1970s. Although in dynamic progress, Space Syntax is already a proven and very well disseminated instrument in architectural and urban studies.

Current studies applying Space Syntax methods to Landscape Architecture demonstrate its current advantages in evaluating green spaces. These studies evaluate the effect of planting

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design in urban parks (MAHMOUD 2011, MAHMOUD & OMAR 2015), senior walking behaviour in urban parks (ZHAI & BARAN 2016), accessibility indicators and trail use prediction in natural parks (SETOLA et al. 2018, BARAN & WU 2018) and could influence the design process of green spaces. Although these are interesting analyses, it is considered that some parameters that could be applied to current software, to further study and analyse Landscape Architecture projects, are missing. In green spaces, topography and ground shaping, vegetation (ROBINSON 2004) and time (TEBYANIAN 2016) are the resources that the designer can use to promote their desired natural, human and social functions. The relationship between these components influences the visibility, connectivity and accessibility of spaces, resulting in different perceptions and uses over time. The application of Space Syntax methods in Landscape Architecture seems very promising but, nevertheless, its use has been very sporadic.

Space Syntax formal algebra is highly consuming in 'numerical calculus'. It can scarcely be of any use without the availability of information technologies tools. With gradual dissemination of Space Syntax, user-friendly apps have been developed, again demonstrating the historical inter-influence relation between the tool and the product in human work.

The research reported in this paper uses DepthSpace3D, a software for 3D Space Syntax analysis (previously developed by some of the authors, and freely downloadable for academic use). 3D analysis seems to have some advantages over current 2D syntactic analysis in situations which are particularly fitting to the study of landscape architecture, such as:

- rough altimetry of the terrain, either natural or sought by the designer;
- very dynamic volumetric geometries, in size, configuration, elevation and interpenetration, such as those created by vegetation;
- 3D analysis could very well be a powerful tool in formalizing the classical theoretical and aesthetical space concepts such as proportions and scales, hierarchy or rhythm.

2 Objectives

With the previous arguments in mind, the paper describes a research endeavour that tries to fulfil three different goals:

- The first is the optimization of the design process in Landscape Architecture of the considered space ('Urban Park' in Maia − PORTO) considering both its linguistic characteristics (syntax / connotational semantics) and in its functional relations (denotational semantics / pragmatics) to physical, social and psychic environment;
- The second is the disclosure of Space Syntax analysis (and specially 3D analysis) as an invaluable method to reach such desiderata;
- The third is the adaptation and improvement of the developed DepthSpace3D software to suite the special requirements of Landscape Architecture.

3 Methods

To produce an operative model of the real problem, several problems had to be tackled:

3.1 Spatial Delimitation of the Case Study

The first was the delimitation of the area to be studied. As Space Syntax does not behave as a distributive algebraic group it is not possible to study the whole problem in pieces and then join them in a single solution; the entirety of the space must be studied together. Therefore, the intention of the research team to study the relation between the inside of the Park and its surroundings lead to the consideration of a broader area than the park itself.

3.2 Geometric Model of the Case Study

The geometry was then modelled through the three conceptual types of spaces which are present in DepthSpace3D models – the viewed, the viewing and the obstacle spaces.

The **obstacle (to visibility) space** is modelled by the surfaces of:

- the ground, considering the curved topography;
- the facades and other solid surfaces of the buildings, inside and surrounding the Park;
- some sculptures and art specimens;
- all the trees and large shrubs in the Park.
  Several species have been modelled, considering their life cycle, including both their growth and seasonal changes to their opacity, depending on their being deciduous or evergreen trees. Point 3.3 details this important research topic.

The **viewed space** has 2 components:

- the ground, buildings and vegetation surfaces; although conceptually different, they are physically identical to the obstacle spaces;
- the global volume, the surrounding 'air' that is modelled by a grid, vertically with slices of ten meters in the two flat directions, enveloping all the case study space; and horizontally (in height) with slices located three meters apart.

The **viewing space** is the space where the viewing subjects can move, as opposed to the entirety of the studied volume. Several different instances have been studied, taking advantage of DepthSpace3D's possibility of modelling many visibility paths:

- the exterior paths following the longitudinal profile of the streets, at 1m height; and the pedestrian paths at a 1.5 m height along the sidewalks, not entering the Park;
- the paths for pedestrians walking across the Park to reach different destinations;
- the peripatetic paths of those pedestrians enjoying the Park;
- the stadiums formal and informal benches;
- several remarkable locations, designed by the landscape architect to provide outstanding views over the Park.

3.3 The Special Case of the Vegetation Models

Landscape Architecture brings new challenges to current Space Syntax tools. DepthSpace3D underwent several levels of improvements.

To be able to study the previously mentioned instances in Landscape Architecture, it was necessary to select a set of attributes and parameters that could be applied to ground modelling and vegetation. The latter, due to the intricacies that involve the natural development of plants, had to be studied to reach a summarized set of concepts to be utilized in the analysis. Plants are live and dynamic structures in continuous development, showing great variability, affecting visibility and the use of space through time. Therefore it is essential to consider the evolution of site visibility considering these factors.

To reach the set of attributes and parameters for Landscape Architecture it was necessary, at an initial stage, to understand what attributes and parameters could be applied to 3D Space Syntax analysis. Four parameters were chosen to be applied for trees and large shrubs:

- Dimension. Involving three parameters: height, width and trunk height defined by MOREIRA (2008) (Table 1).

Table 1: Vegetation: attributes, classes and parameters considering Mediterranean and temperate climates – Europe

Trees and large shrubs	*Dimension* [1] *Considered maturity age*			Form [1]	Growth speed [2, 3] Considered after 20 years			Permeability [4]		
	Height (m)	*Width (m)*	*Trunk height)*	*Classification*	*Classification*	*Height (m)*	*Width (m)*	*Classification*	*Summer*	*Winter*
Alnus glutinosa	25	8	4	conical	fast	17	5	deciduous	83	49
Acer pseudoplatanus	30	25	4	rounded	slow	10	8	deciduous	88	60
Arbutus unedo	8	8	2	wide	slow	3	3	evergreen	92	92
Betula pendula	25	10	4	conical	fast	17	7	deciduous	76	44
Betula verrucosa	25	10	4	conical	fast	17	7	deciduous	76	44
Casuarina equisetifolia	20	8	4	conical	fast	13	5	evergreen	73	73
Cedrus libani	25	18	4	pyramidal	slow	8	6	evergreen	75	75
Cercis siliquastrum	10	10	3	wide	medium	5	5	deciduous	86	41
Chamaecyparis lawsoniana	40	5	-	pyramidal	fast	27	3	evergreen	99	99
Cupressus sempervirens 'sempervirens'	30	3	-	columnar	fast	20	2	evergreen	99	99
Frangula alnus	5	5	-	wide	fast	3	3	deciduous	83	62
Laurus nobilis	12	5	3	conical	slow	4	2	evergreen	83	83
Ligustrum japonicum	4	2,5	-	columnar	fast	3	2	evergreen	97	97
Liquidambar styraciflua	30	14	4	conical	fast	20	9	deciduous	81	23
Magnolia grandiflora	22	20	4	conical	slow	7	7	evergreen	87	87
Magnolia x soulangeana	10	8	4	rounded	slow	3	3	deciduous	86	34
Nerium oleander	6	3	-	wide	fast	4	2	evergreen	90	90
Melia azedarach	13	8	4	rounded	fast	9	5	deciduous	77	50
Olea europaea	15	10	3	rounded	slow	5	3	evergreen	87	87
Picea abies	40	6	-	columnar	fast	27	4	evergreen	87	87
Pinus pinaster	24	9	6	conical	fast	16	6	evergreen	77	77
Pinus pinea	25	14	6	wide	medium	13	7	evergreen	92	92
Prunus cerasifera "Pissardi"	8	8	3	rounded	fast	5	5	deciduous	84	46
Quercus coccinea	20	15	4	rounded	fast	13	10	deciduous	84	32
Quercus robur	35	22	4	wide	medium	18	22	deciduous	83	33
Quercus suber	15	20	4	rounded	slow	5	7	evergreen	76	76
Salix atrocinerea	6	5	-	rounded	fast	4	3	deciduous	85	46
Salix alba 'Vitellina'	25	10	2	rounded	fast	13	7	deciduous	77	57
Ulmus procera	40	15	4	rounded	fast	27	10	deciduous	86	58

- Form. Another attribute established by MOREIRA (2008). In order to avoid overloading computation resources (time and memory), the volumes were simplified to 6 and 12 triangles shapes, and with or without distinct trunk. (Table 1).
- Growth speed was considered as slow, medium and fast. This classification was based on VIÑAS et al. (1998) and COSTA (2015) considering the dimensions after 20 years of growth (Table 1).
- Visual permeability of the crown in winter and summer, considered transparency/opacity applied to deciduous and evergreen plants. For evergreen plants visual permeability in winter and summer was considered the same. The method used for evaluating the permeability of the crown comprises three phases: 1) selecting images for each species; 2) calculating crown transparency, adapting the methods of CLARK et al. (2003) and BORIANNE et al. (2017) which consist of a simple delimitation of the crown and obtaining the total number of pixels (Tp) (100% of the crown area) and obtaining the visible light area through the crown (Sp) (number of pixels corresponding to the visible light/sky area, through the crown); 3) Calculating permeability (P) through:

$$P = 100 - \left(\frac{\mathrm{Sp} \cdot 100}{\mathrm{Tp}} \right).$$

4 Results

Fig. 1: Plan of the urban park

Space syntax methodology provides tools to analyse the linguistic characteristics of space − configuration (BENEDIKT 1979), visibility (TURNER 2001) and accessibility − and their functional relations to physical, social and psychical environment. Space Syntax language contain a large semantic network of quantified concepts, formally defined, such as isovist, connectivity, depth, integration, entropy, controllability among others. This case study explores how the integration of spatial analysis in the design process of the park was able to produce useful results for the implementation of an iterative process of project improvement.

Firstly, by allowing for an immediate understanding of visibility, it proved effective in answering a series of questions about the initial design of the park − What do people see? What do people see more often? What do people see throughout the year? What do they see throughout time? While other tools, such as renderings and drawings, exist for understanding visibilities, they cannot provide an understanding of the totality of the designed space, and therefore of the relative qualities of each one of its parts. Figure 2 shows how 3D renderings were used for both the study and presentation of the visual qualities of the design, and were complemented with a visual connectivity analysis, which allowed for an understanding of the global visibility of the park.

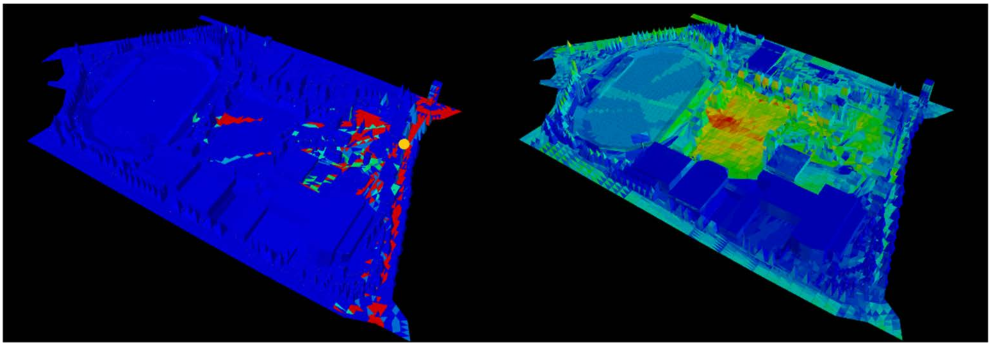

Fig. 2: Complementary approach to the design process: a) visibility from the main entrance, b) isovist from the main entrance; c) visual connectivity map

Additionally, as it is shown in Figure 3, it was possible to analyze the effects of time in the park visibility, by taking into account vegetation growth and deciduous trees and shrubs. However, while the differences in visibility are clear as vegetation grows, the density of the park causes visibility values to be similar for winter and summer months. Our model of adding opacities does not seem to fit perfectly with reality: although the sum of the opacities of every individual tree decreases 30.6 % at the peak of abscission, the global opacity of the park only decreases 10 %. Our model for the operation of opacity addition does not seem to fit perfectly with reality. Future work will bring better results.

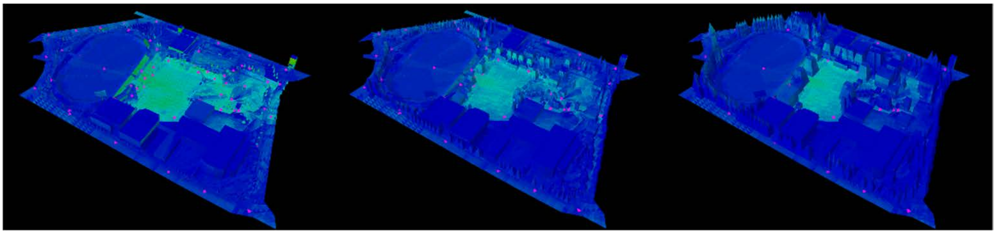

Fig. 3: Visual connectivity maps of the effects of time: a) initial growth; b) expected growth in 10 years; c) full growth

The analysis also contributed for an understanding of the spatial behaviour of the design, allowing for the confrontation of design objectives with the actual results. This was most useful in the construction of a desired relationship between the interior and exterior of the park, where the interior should be felt removed from its urban surroundings. Subtle manipulation of vegetation and topography could be experimented with, until the design expectations were validated through visibility analysis, resulting in the final design on figure 4, showing low levels of visibility both from the exterior pathways to the interior of the park, and vice-versa. It was also possible to verify that the area where the park entrance was placed behaved as a logical entry, allowing for the highest levels of visual permeability between the park and its immediate surroundings.

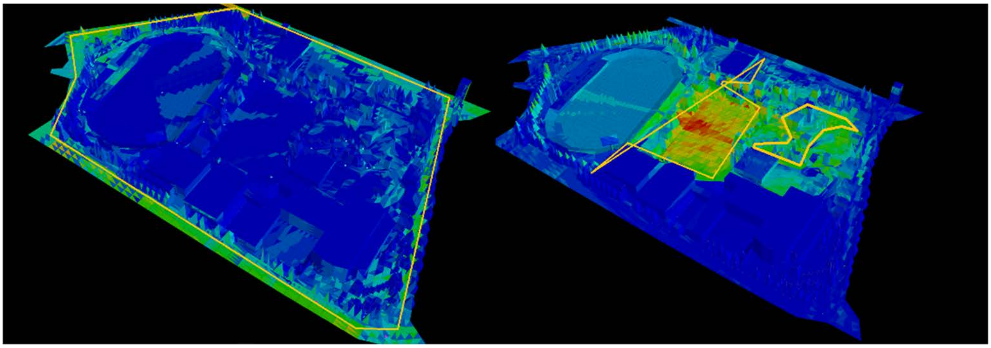

Fig. 4: Relationship between the park and the urban space: a) visibility from the exterior road; b). visibility from the interior of the park

Visibility analysis was also applied at a smaller scale, to better understand the characteristics of particular spaces. Within the park itself, it was important to validate the design of spaces with particular functions and of those designed as referential points. An example of this can be seen in figure 5f, which represents the visibility of a set of terraces designed to behave as informal benches facing the secondary sports field. It is possible to identify, in the visibility map, spaces with lower visibility levels, where it was necessary to improve the articulation between topography and vegetation.

Similarly, three particular parts of the park, designed as referential points, were analysed in order to verify whether they translated into separated spaces, and whether these resulting spaces were distinct. Figures 5a, 5b and 5c show the isovists of these points − with dark blue representing complete lack of visibility, red complete visibility, and light blue the decrease of visibility caused by the percentage of opacity of the treetops − and were meant to verify the range of visibility from each of these points. This allowed for the identification of a problem in the design of the gazebo, which isovist shows high levels of visibility to the exterior of the park, not intended by the architects. On the other hand, it was also helpful for the validation of the walkway design, which large isovist encompassing the lake corresponded to the project's intentions.

Additionally, aggregated visibility maps for the three areas were created (Figure 5d and 5e), in order to understand the variations in the designed spaces. The design intention of creating visual variation with movement, so that the entirety of the park could not be grasped from a single point but only through exploratory meandering, was considered successful. The three spaces appear clearly defined, with variations between high and low levels of visual connectivity appealing to movement throughout the park.

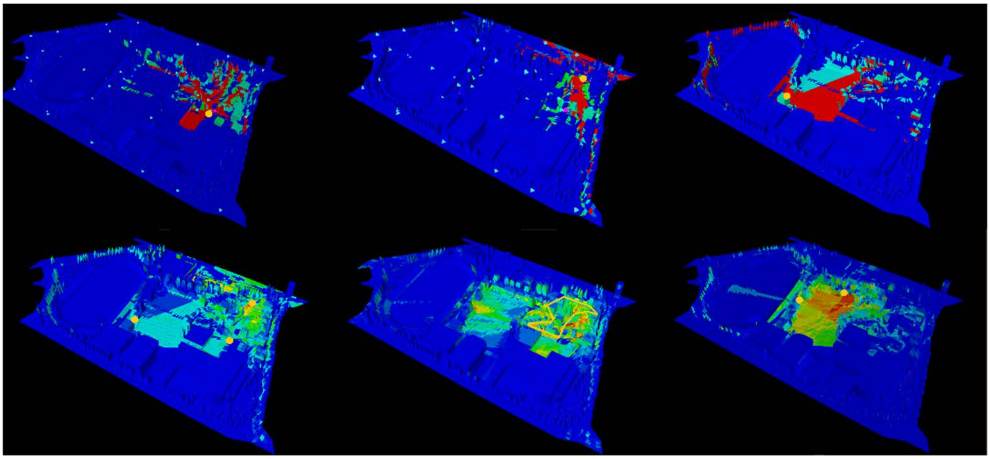

Fig. 5: Visibility analysis of particular spaces and definition of differentiated spaces: a) isovist from the walkway; b) isovist from the gazebo; c) isovist from the bar; d) visibility from the 3 referential points: walkway, gazebo and bar; e) visibility from a meandering path in the park; f) visibility from the informal stands

This paper focused on the results of the conducted analysis which had more impact in the design process. However, many other types of analysis, such as those presented on figures 6 and 7, contributed to the understanding of the designed spaces.

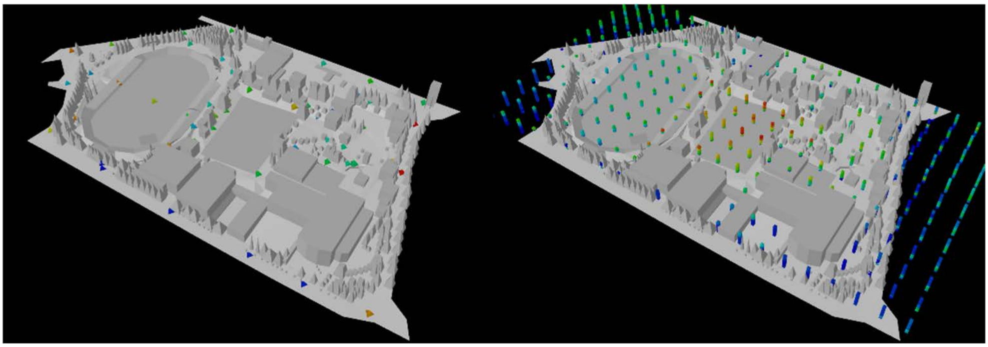

Fig. 6: Other analysis: a) visibility levels of viewpoints; b) visibility of points in space

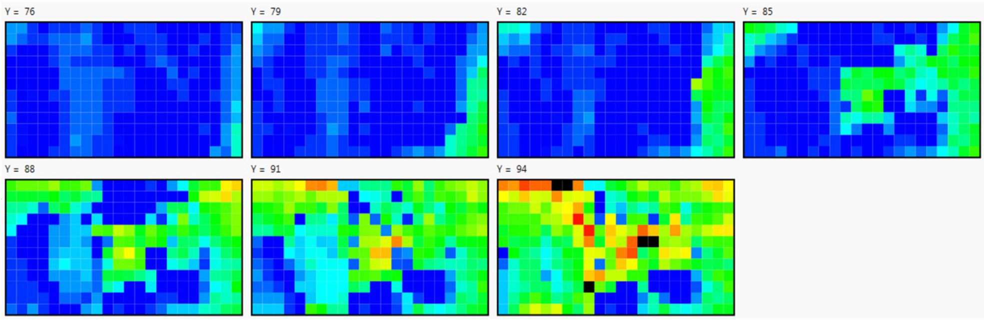

Fig. 7: Other analysis: visual connectivity maps in horizontal slices

5 Conclusion

The experimental application of the attributes and parameters in the DepthSpace3D software allowed to understand the interest of this software during the development of the project. While it is a process that is still being developed, the results obtained in experimental applications lead to the conclusion that the application of attributes and parameters relating to modelling and vegetation are of great interest for a wide community of professionals of diverse areas in urban design.

The analysis was a continuous process, taking place in various stages of design development. Consequently, as the project experimented with and adapted to the obtained results, the developed software evolved to accommodate design necessities that had not been foreseen. The connection between analysis and design proved a useful step both towards the development of a successful design, and the furthering of a useful tool for landscape architecture. It is expected that future work will expand this further. In addition to connectivity, Space Syntax theory provides designers with other quantified concepts relative to spatial configuration for understanding likely movement and interaction in space which can contribute to further understanding of designed spaces.

References

ALMEIDA, A. L. (2006), O Valor das Árvores: Árvores e Floresta Urbana de Lisboa. Ph.D thesis, Universidade Técnica de Lisboa, Lisboa.

BENEDIKT, M. L. (1979), To Take Hold of Space: Isovists and Isovist Fields. Environment and Planning B: Planning and Design, 6 (1).

BORIANNE, P., SUBSOL, G. & CARAGLIO, Y. (2017), Automated efficient computation of crown transparency from tree silhouette images. Computers and Electronics in Agriculture, 108-118.

CLARK, N. A., LEE, S.-M. & ARAMAN, P. A. (2003), Finding a good segmentation strategy for tree crown transparency estimation. Proceedings of the 19th Biennial.

COSTA, L. C. (2015), A vegetação na Implementação de Projetos de Execução em Arquitetura Paisagista. Caracterização e Definição de Critérios de Avaliação. Ph. D thesis, Faculdade de Ciências da Universidade do Porto, Porto.

HILLIER, B. & HANSON, J. (1984), The Social Logic of Space. Cambridge University Press, New York.

MAHMOUD, A. H. & OMAR, R. H. (2015), Planting Design for Urban Parks: Space Syntax as a Landscape Design Assessment Tool. Frontiers of Architectural Research, 4, 35-36.

MAHMOUD, A. H. (2011), Integrating Space Syntax Theory in Sustainable Planting Design of Parks. Built and Natural Environment Research Papers, 4 (1).

MOREIRA, J. M. (2008), Árvores e Arbustos em Portugal. Argumentum, Lisboa.

ROBINSON, N. H. (2004), Planting Design Handbook. Ashgate, United Kingdom.

SETOLA, N., MARZI, L. & TORRICELLI, M. C. (2018), Accessibility Indicator for a trails Network in a Nature Park as Part of the Environmental Assessment Framework. Environmental Impact Assessment Review, 69, 1-15.

VIÑAS, F. N., SOLANICH, J. P., VILARDAGA, X. A. & MONTLLÓ, L. (1998), El Árbol en Jardinería y Paisajismo. Barcelona: Ediciones Omega, S. A.

TEBYANIAN, N. (2016), Reflecting Time in Computer-aided Landscape Design and Analysis: Developing an Application for Modelling Seasonality and Resiliency in Small Scale Landscapes. Journal of Digital Landscape Architecture, 214-221.

TURNER, A. (2001), From isovists to visibility graphs: A methodology for the analysis or architectural space. Environment and Planning B: Planning and Design, 28 (1).

Workshop on Color Photography, Videography and Airborne Imaging for Resource Assessment. Logan, Utah.