BENEFITS OF URBAN GREEN SPACES IN NOISE, AIR QUALITY AND THERMAL COMFORT: THE CASE STUDY OF BRAGANÇA

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INTRODUCTION

Urban population is increasing all over the world. Approximately 75% of the European population live nowadays in urban areas. To face this problem new policies have been developed. These policies are focused in urban sustainability by integrating diverse aspects that can improve quality of life of inhabitants and resource preservation.
Under this context, green spaces are essential elements in urban sustainability, balancing the three essential dimensions: environmental, social and economic (Fig. 1), since they can provide multiple environmental services, contributing to high-quality environments in our cities (Givoni, 1991; Bolund P. and Hunhamar S., 1999; De Ridder et al., 2004; Nowak D. J., 2006).

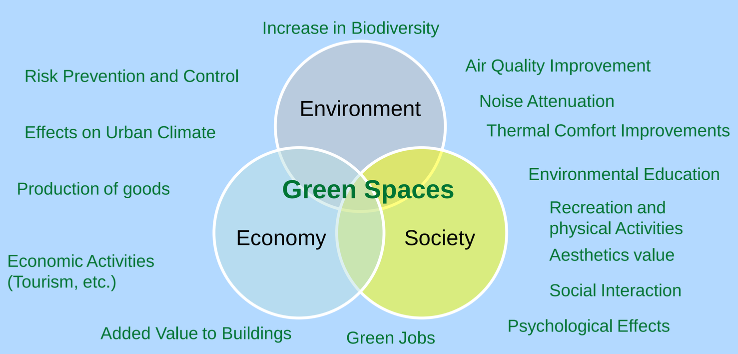

Figure 1: Environmental, social and economical functions of green spaces.

The GREENURBE Project aimed to assess the global impact of green space on urban environmental quality, in order to formulate recommendations regarding green spaces design, as an essential activity in urban planning. This research was developed throughout the last four years in the city of Bragança, a small city located in the Northeast of Portugal, having an approximated area of 25 km^2 and 27000 inhabitants. Furthermore, the city of Bragança has a complex land cover mosaic including, besides paved surfaces, a large portion of both formal (gardens and parks) and informal open spaces (farms, woodlands, etc.) (Figure. 2).

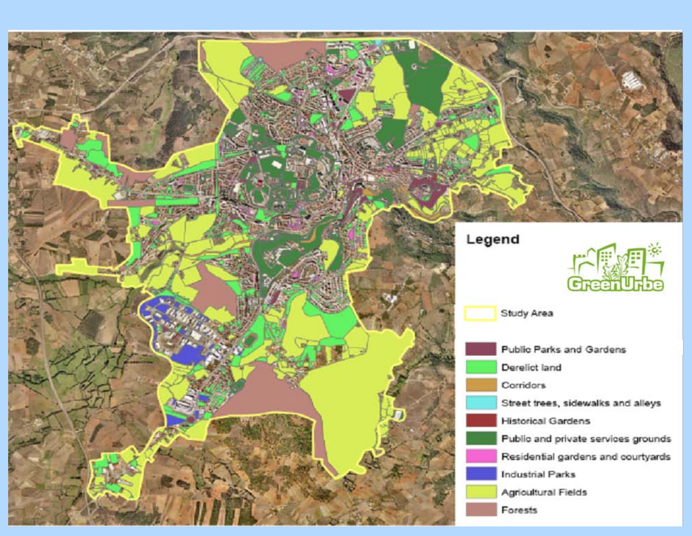

Figure 2: Simplified urban green structure, represented by 10 land use classes.

This project addressed the interactions between green spaces and urban environmental quality, namely their effects on air quality, acoustic environment and thermal comfort, as these spaces can have a positive effect on its surrounding environment , at both micro and urban scales.

A brief overview of the project framework as well as the main results are presented in this poster.

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GLOBAL METHODOLOGY

The objectives of the GreenUrbe Project were approached from physical and social perspectives. The physical approach involved several field studies at both the urban and green spaces scale, covering measurements of air pollutants concentrations (ozone, nitrogen dioxide, volatile organic compounds and PM10), sound pressure levels, meteorological and other parameters related to thermal comfort (Figure 3). The social approach consisted in assessing perceptions of citizens over green spaces and their influence on the environment, alongside with the assessment of their attitudes towards those spaces, by means of domiciliary questionnaires applied to a representative sample of local inhabitants as well as to on-site users of such spaces. Physical analyses were then related with social perception on green spaces characteristics and users attitudes. Users were asked about their preferences and the way they perceive the environmental quality of each green space.

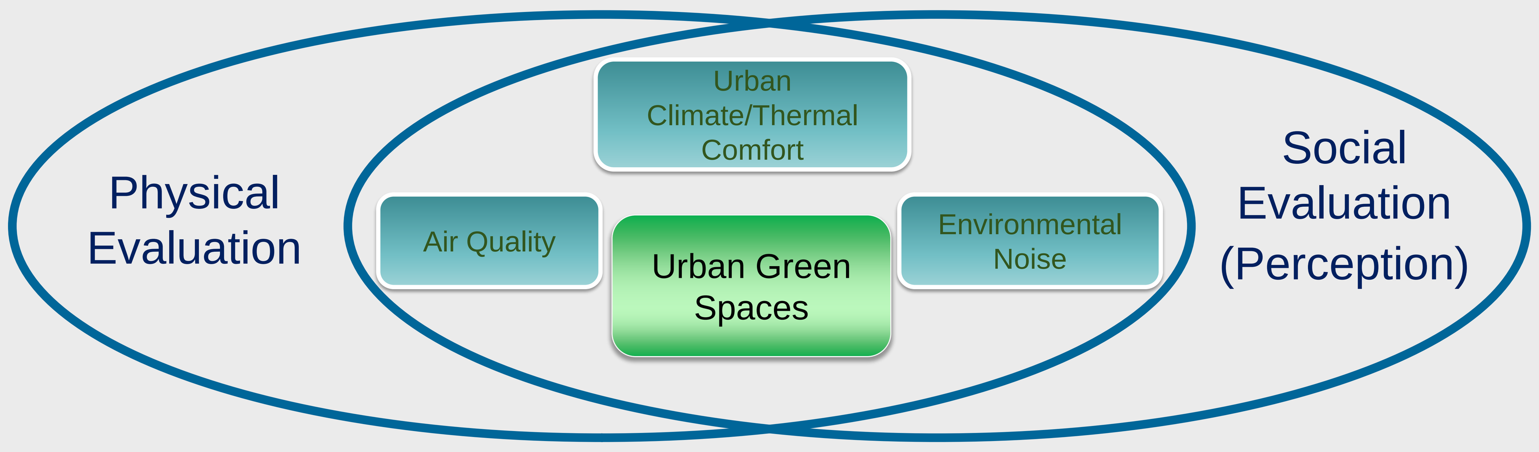


Figure 3: a) Overview of the research framework; ***b)*** Pictures illustrating some experimental details.

MAIN RESULTS

AIR QUALITY

The influence of urban green spaces on local air quality was evaluated by performing measurements of gaseous pollutants such as O_3, NO_2 and VOC, at urban scale, from later spring to early summer, in 2006 and 2007. Air samples were collected by means of passive sampling devices. Real time measurements of PM10 were also conducted at green space scale with purpose of evaluating the capability of vegetation in removing airborne particles. Results showed that urban green spaces are zones where people is exposed to lower concentrations of primary pollutants (e.g. NO_2 and VOC). The same can not be said for secondary pollutants such as ozone, which tends to occur in higher concentrations in areas somewhat away from the sources. Vegetation is also directly related with VOC distribution since it is a source of biogenic VOC. The presence of vegetation in the vicinity of air pollution sources (e.g. greenbelts along traffic roads) plays a key role in lowering air concentrations of both particulate and gaseous pollutants (Figure 4).

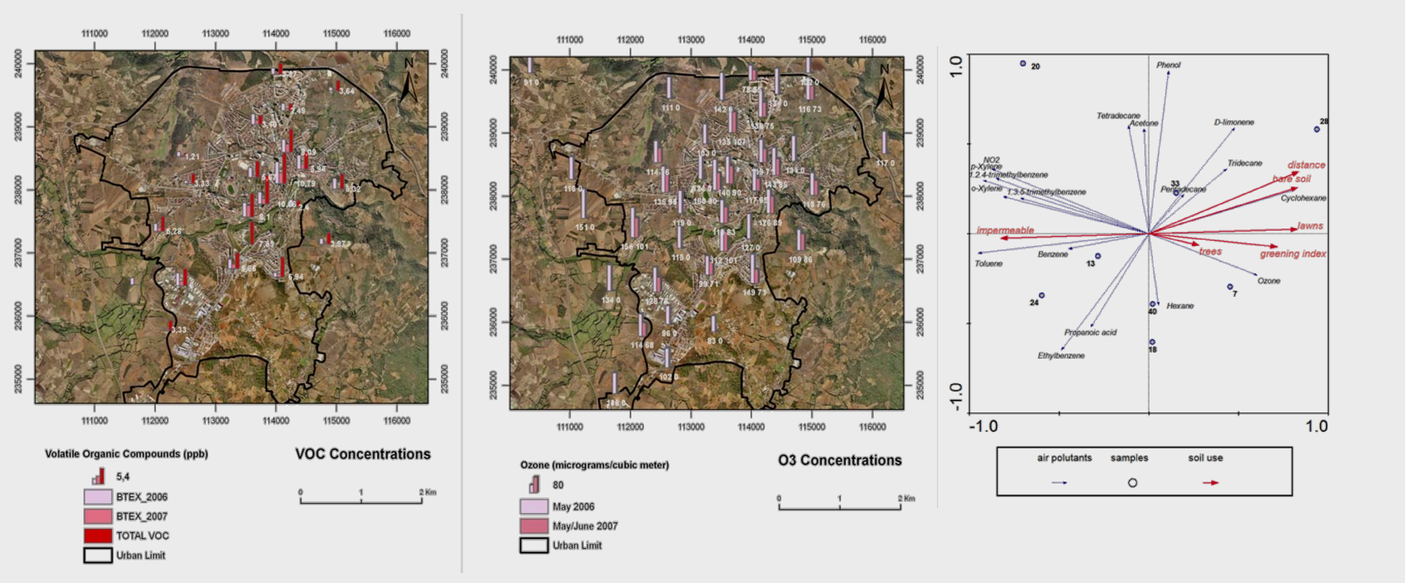


Figure 4: a) Long-term concentrations of air pollutants at urban scale; ***b)*** Triplot of PCA with samples, pollutants and environmental variables for a set of points exposed to traffic emissions.

SOUNDSCAPES QUALITY

Soundscapes were evaluated in four urban green spaces, during the daytime period, by performing sound measurements and field surveys between May and September of 2007. Results showed that traffic noise has a negative influence on soundscapes in urban green areas, although some interviewees expressed favourable opinion about it. It was evident that acoustic comfort evaluation can not be based only on sound magnitude. People react to sound magnitude but other attributes also have a relevant influence on sound perception. The introduction of a pleasant sound can enhance the acoustic comfort considerably, even if the magnitude of sound is high. Green spaces seem to be important elements in creating pleasant soundscapes, as they might be habitats of several natural and human pleasant sounds (Table 1 and Figure 5)

Table 1: Average values of acoustic and psychoacoustic indicators obtained in the four urban green spaces - Fervença greenway – Polis (PO), Quinta da Braguinha park (BR), Cavaleiro Ferreira Square (CF) and António José de Almeida garden (AA).

Acoustic/Psychoacoustic parameter	AA	BR	CF	PO
LAeq (dBA)	57	56	65	60
LA1 (dBA)	65	65	70	68
LA10 (dBA)	60	58	66	63
LA50 (dBA)	56	52	64	57
LA90 (dBA)	52	48	63	55
LA99 (dBA)	50	45	52	54
LApk (dBA)	91	92	97	95
LAr (dBA)	58	57	65	62
G (Hz)	411	350	431	615
N (sones)	10	8	17	10
Nº of measurements	56	39	53	53

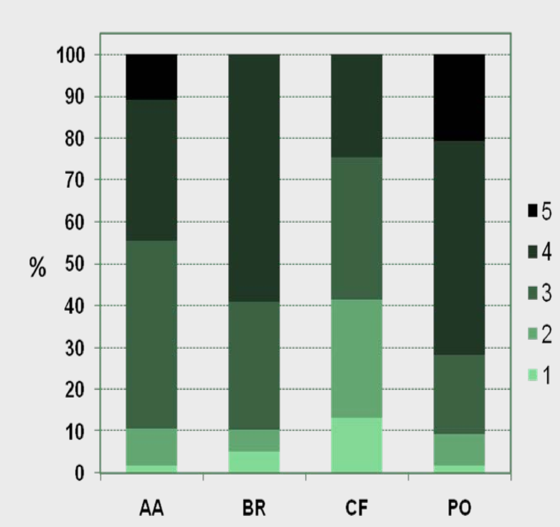


Figure 5: Subjective rating of the acoustic comfort in the different green spaces in accordance with a five level Likert scale.

THERMAL COMFORT IN GREEN SPACES

The approach to thermal comfort in green spaces consisted on different experiments, including structured studies, carried out in four different locations, in late spring to early fall conditions .The methodology is presented in Figure 5. Data was analyzed using multinomial logistic regression (Hosmer and Lemeshow, 2000). Results (Table 2) show that there is an expected impact on thermal sensations driven by the change in meteorological conditions. Under colder conditions, the increase in air temperature (Ta) and global radiation (St) determines an approach to neutrality, while the same change in predominately warm conditions increases the heat stress. In such situation more intense wind could help restoring comfort conditions. The change of individual from female to male significantly reduces the odds of people feeling cold under the prevailing conditions. Choices on green spaces configuration, generated relevant changes in global radiation and wind, therefore influencing thermal comfort (Table 2 and Table 3).

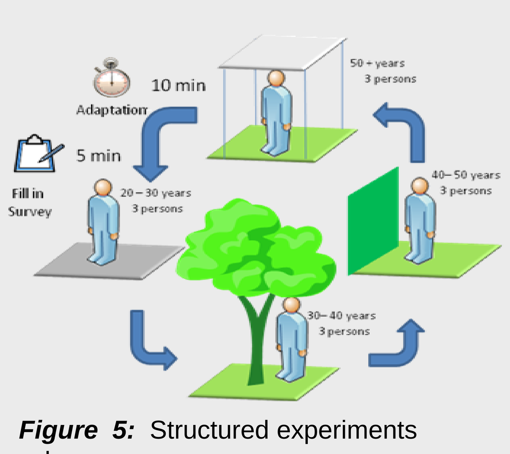


Figure 5: Structured experiments scheme.
From Top anti-clockwise: Shadow under artificial cover, sun over pavement, shadow under tree and sun near wind shelter

Table 2: Number of surveys, mean and standard deviation for some of the monitored variables, at the four location

Location		Ta (º C)	St (Wm^{-2})	Tmrt (º C)	V (ms^{-1})	RH (%)
Shadow Under Artificial Cover	N	108	108	108	108	108
	Mean	26,2	189,9	39,1	,6	37,3
	Std. Deviation	6,0	79,5	5,6	,6	13,6
Shadow Under Tree	N	108,0	108,0	108,0	108,0	108,0
	Mean	24,5	97,2	30,8	,6	41,7
	Std. Deviation	4,2	33,1	4,1	,6	15,0
Sun Near Wind Shelter	N	108,0	108,0	108,0	108,0	108,0
	Mean	26,1	593,1	45,9	,1	35,9
	Std. Deviation	5,0	179,4	4,4	,2	11,6
Sun Over Pavement	N	108,0	108,0	108,0	108,0	108,0
	Mean	25,4	624,0	51,5	,6	36,9
	Std. Deviation	4,9	190,3	6,6	,6	13,9
Total	N	432,0	432,0	432,0	432,0	432,0
	Mean	25,6	376,0	41,8	,5	38,0
	Std. Deviation	5,1	272,4	9,4	,6	13,7

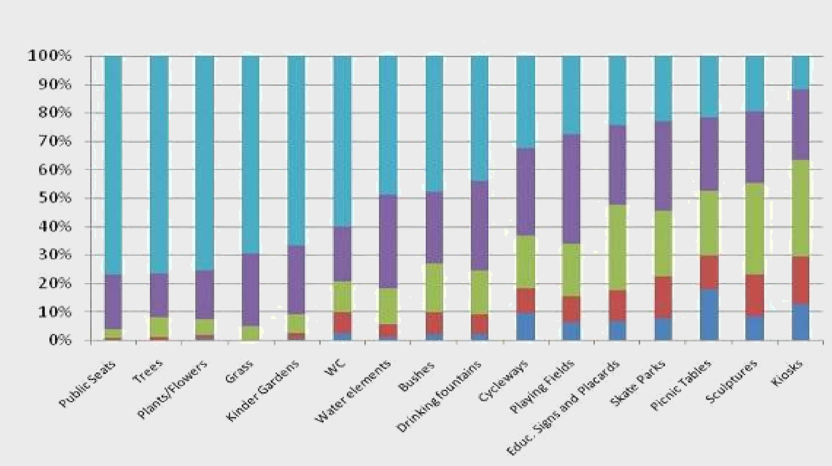
Table 3: Parameters Estimation with Multinomial Logistic Regression (using neutrality as reference)

Thermal Sensation		Coeficient (B)	Stand. Dev	Wald	Sig.	Exp(B)
Cold -2	Intercept		2,362	9,554	0,002	
	Ta	-0,528	0,111	22,527	0,000	0,590
	V	0,832	0,832	1,000	0,317	2,299
	St	-0,009	0,003	10,673	0,001	0,991
	GEN (M)	2,267	0,646	12,302	0,000	9,648
Slightly Cold -1	Intercept	7,719	1,594	23,462	0,000	
	Ta	-0,426	0,070	37,364	0,000	0,653
	V	0,443	0,505	0,768	0,381	1,557
	St	-0,011	0,002	24,439	0,000	0,989
	GEN (M)	1,784	0,426	17,556	0,000	5,952
Slightly Hot 1	Intercept	-3,881	1,076	13,008	0,000	
	Ta	0,088	0,033	7,185	0,007	1,092
	V	-0,496	0,340	2,131	0,144	0,609
	St	0,005	0,001	33,480	0,000	1,005
	GEN (M)	-0,174	0,329	0,278	0,598	0,841
Hot 2	Intercept	-6,506	1,330	23,944	0,000	
	Ta	0,142	0,039	13,391	0,000	1,153
	V	-1,614	0,416	15,024	0,000	0,199
	St	0,010	0,001	80,575	0,000	1,010
	GEN (M)	-0,450	0,381	1,395	0,238	0,637
Very Hot 3	Intercept	-15,981	2,293	48,586	0,000	
	Ta	0,314	0,066	22,470	0,000	1,369
	V	-2,816	0,610	21,308	0,000	0,060
	St	0,016	0,002	79,766	0,000	1,016
	GEN (M)	-0,005	0,543	0,000	0,993	0,995

Green – unit change in variable increases odds of event
Red - unit change in variable increases odds of achieving the reference condition (neutrality)

PERCEPTION OF CITIZENS ON THE URBAN GREENSPACES

Surveys addressing the general population were conducted in order to assess inhabitants attitudes towards green spaces and users perceptions on their benefits. Most of the respondents greatly value the presence of natural elements in green spaces such as plants / flowers, lawns, trees, in combination with some artificial ones (water features, benches and playgrounds) and show their preferences towards larger and more complex spaces. Respondents positively evaluate most of green spaces, and show awareness on some existent problems, thus identifying moderate to low quality environments in some of the spaces, consistently with both air quality and noise assessment (Figure 7).



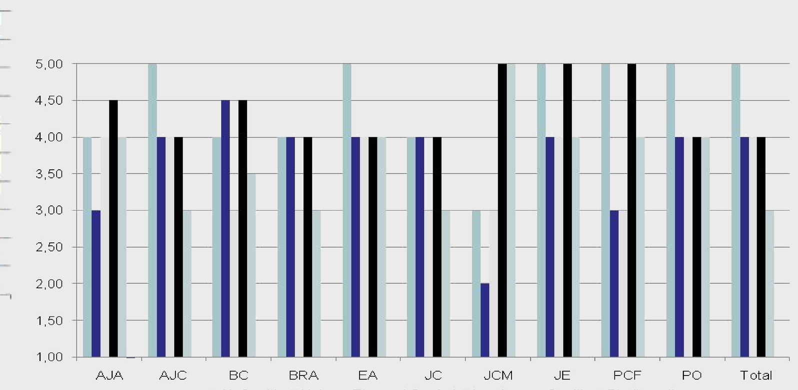


Figure 7: a) Relative distribution of perceptions regarding the importance of different elements in green spaces, in accordance with a five level Likert scale; ***b)*** Environmental quality assessment of the main urban green spaces (median values).
Green Spaces - Almeida Garden (AJA), João da Cruz Avenue(AJC), Coxa Park (BC), Braguinha park (BRA), Castle Gardens (JC) Municipality Garden (JCM), Bus TerminalGardens (JE), Cavaleiro Ferreira Square (PCF) and Fervença greenway – Polis (PO)

CONCLUSIONS

The Greenurbe project highlighted the importance of the green spaces in contributing to improve air quality, generating more pleasant soundscapes and providing adequate thermal comfort conditions. Relations between benefits of green spaces and their sizes, their physical and biological diversity, and their location were found as well. Users attitudes are driven not only by proximity, but also by the perceived quality, thus generating choices stimulated by the complexity of spaces and the environmental and social services provided.

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