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Clustering public urban green spaces through ecosystem services potential: A typology proposal for place-based interventions

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ABSTRACT

Public Urban Green Spaces (PUGS) are the main drivers for increasing the quality of urban environments, potentiating local resilience, promoting sustainable lifestyles, as well as improving both the health and well-being of their users. Municipal leaders are responsible for the maintenance of PUGS. However, current evidence identifies limited knowledge about urban green infrastructure governance since the lack of data about PUGS is the main obstacle to effective intervention. Set against this background, this study aimed to identify clusters of ecosystem services potential in 25 PUGS in the city of Porto, Portugal, through a validated tool application. Multivariate techniques allowed identifying predictor dimensions of ecosystem services potential: the environmental quality and facilities. Five PUGS clusters were validated: i) Environmentally Empowered and Socially Expectant Spaces, ii) Socioenvironmentally Empowered Spaces, iii) Environmentally Empowered but Socially Un-dynamic Spaces, iv) Socioenvironmentally Disempowered Spaces, and v) Socioenvironmentally Unexplored Spaces. This typology proposal brings to the discussion a possible solution for better qualifying these spaces, as it complements PUGS type with a socioeconomic and environmental characterisation. Furthermore, these results are useful in the design of place-based intervention in PUGS, contributing to the increase of ecosystem services potential and improving urban environment quality and sustainability.

1. Introduction

Public Urban Green Spaces (PUGS), namely those that provide the opportunity to develop recreational activities, are important elements in cities due to the ecosystem services they can deliver. City dwellers mostly use these spaces to restore, relax and exercise, while also being a space for socialisation in the middle of the dense urban fabric (Gao et al., 2019b; Home et al., 2012; Song et al., 2015; Vidal et al., 2020). Furthermore, PUGS can make a difference in underserved communities by promoting urban resilience, developing a sense of belonging and enhancing social cohesion (Jennings and Bamkole, 2019; Liotta et al., 2020). Many scholars have devoted attention to the importance of urban parks in city sustainability, especially through the links between the biophysical and health dimensions that emerge from the connection with nature (Chiesura, 2004; Díaz et al., 2015; Enssle and Kabisch, 2020; Frumkin et al., 2017; Hartig et al., 2014; Kuo, 2015; Ma et al., 2019).

Abbreviations: PUGS, Public Urban Green Spaces.

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Worldwide, studies often focused on PUGS categorisation based on what users do in these spaces (Van de Voorde et al., 2011; Voltersen et al., 2014). Besides the importance of this approach, the motivations to choose and use PUGS are mainly influenced by space's physical characteristics, which determine the possibilities to perform certain activities (de la Barrera et al., 2016; Guneroglu and Bekar, 2022; Madureira et al., 2018; Maraja et al., 2016; Pinto et al., 2021). These motivations and uses should be understood as symptoms and not causes once they are constrained by PUGS physical characteristics and ecosystem services potential. According to Burkhard et al. (2012), ecosystem services potential refers to the opportunity to use structures and processes of ecosystems and landscapes based on the hypothetical maximum yield of the ecosystem services. Since ecosystem services are at the core of policy interest (Haines-Young et al., 2012; Maes et al., 2016, 2012), the ecosystem services' potential assessment can be of particular relevance to policy-makers. Ecosystem services potential means that improving ecosystem services is not a complete task, but rather a process, a path to improve, and a stronger contributor to regional and urban development by supporting decision-making. Also, this assessment can provide greater opportunities that consider the integration of environmental consideration into decision making on land use. The design and implementation of policies regarding nature conservation in urban settlements mainly depend on the availability of reliable and spatial information on ecosystem services and, most importantly, on their potential (Cowling et al., 2008).

City leaders are responsible for the maintenance of many PUGS. However, a recent study by Dias et al. (2020), which aimed to compare the municipal master plan strategies on PUGS of the two Portuguese metropolitan areas (Lisboa and Porto), revealed a neglection on the socioecological value of PUGS and limited knowledge on its governance, reinforced by a lack of municipal strategies for managing these spaces. Alongside the lack of data, public consultation and urban expansion are identified as the main constraints preventing proper intervention in PUGS (Ordóñez et al., 2020).

Data collection on PUGS often occurs through remote-sensing (Edwards et al., 2013; Taylor et al., 2011), and its accuracy could be somewhat compromised (Hoffimann et al., 2018). Data collection on-site could be an expensive resource, as it requires a great effort from the researcher and is time-consuming (Kawulich, 2012). However, the quality of the data will be more robust and complete. For that reason, an ESP evaluation grid for the PUGS framed by the ecosystem services classification has already been proposed and validated to relate the provision of these services in areas of distinct socioeconomic and environmental (Vidal et al., 2021c, 2021a). The ESP evaluation grid development was inspired by the Public Open Space Tool (POST) (Broomhall et al., 2004), which aims to capture the physical activity of urban green spaces. Despite POST many advantages, this instrument does not consider the existence of bar/coffee shops, toilets and environmental education centres, which can be determining factors when a family chooses a PUGS for a picnic, for instance, or the existence of accessibility for people with reduced mobility. This way, the ESP evaluation grid aims to be more objective in assessing PUGS since the answers are dichotomic (i.e. yes or no), thereby reducing the subjectivity level.

Previous works by Farinha-Marques et al. (2014, 2014b) identified and mapped 95 PUGS in the city of Porto, resulting in 79 parks and gardens and 16 garden squares, all being fully accessible to the public and managed by the local authority. Parks and gardens are defined as designed green areas with more than 35% of the pervious surface, whereas garden squares refer to designed green areas with 15–35% of the pervious surface. Due to the combination of ecological and social benefits to citizens' health, well-being and quality of life, the recreational functions, as well as the proximity to residential areas, these spaces are recognised by the municipality as being of utmost importance in the urban context (Farinha-Marques et al., 2018).

This work can be considered a refinement of the prior mapping of PUGS in Porto made by Farinha-Marques et al. (2014a), (2014b) using a previously developed quality assessment tool for ecosystem services potential (ESP evaluation grid) and the Socio-Economic Deprivation Index (SEDI) (Monteiro et al., 2013). The ESP evaluation grid aggregates the four dominant functions of the PUGS according to Selman's (2012) proposal: recreation, conservation, education and amenity. SEDI divides the city of Porto into five areas of deprivation and combines social, economic and environmental variables to measure it. The ESP evaluation grid (Vidal et al., 2021a) was applied in 25 PUGS of the city of Porto to identify clusters based on their ecosystem services potential.

Furthermore, this study also aimed to validate the groups obtained by the cluster technique using discriminant analysis and identify which of the dimensions analysed are group predictors. These procedures combine both qualitative and quantitative approaches and multivariate analysis to identify the clusters. Ultimately, the main objective is to prove that the ESP evaluation grid application provides useful information for municipal leaders when designing place-based interventions in PUGS that better fit the users' needs and expectations regarding its ecosystem services potential and attributes. Thus, the research question of the present study is: How can the ESP evaluation grid be useful in the identification of PUGS clusters for the design of effective interventions to increase ecosystem services potential?

2. Material and methods

2.1. Study area: Porto as a case-study

This study was developed in Porto, a Portuguese coastal city located in the northwest of the country that is the centre of the second-largest metropolitan area and integrates the Iberian Peninsula. The city has a warm-summer Mediterranean climate influenced by the Atlantic ocean. The municipality has an area of 41.42 km^2 and a population density of approximately 5000 inhabitants per km^2, according to the last data available (Pordata, 2020).

This study follows a case approach, which according to Yin (2018, p. 16) is "…an empirical inquiry that investigates a contemporary phenomenon (the 'case') in-depth and within its real-world context". Porto has lost a large part of the green structure due to an accelerated urbanization process that occurred in the second half of the 20th century. Currently, Porto holds a variety of urban green spaces scattered throughout the dense urban fabric, with varying locations and characteristics in terms of age, size, use, spatial quality, surroundings, vegetation cover and structure (Farinha-Marques et al., 2014a). Alongside, the socio-economic profile of their inhabitants is quite diverse and is well documented (Alves, 2016, 2012). All these factors, the geographic location and the socioeconomic and environmental setting make this space a living lab to study how PUGS differ from each other and how the socioeconomic patterns are associated with these differences among them. Also, the profound social and urban transformations that the city has experienced in the last century, which led to changes in landscape urban planning, have affected both positively and negatively PUGS. Thus, an assessment of their current ecosystem service potential is needed to propose place-based interventions.

Table 1
PUGS identified in Farinha-Marques et al. (2014) study and the correspondent sample analysed in the present study.

Urban green spaces	Farinha-Marques et al. (2014) *n* (%)	Sample *n* (%)
Public gardens	75 (78.9)	19 (76.0)
Garden squares	16 (16.8)	2 (8.0)
Public parks	4 (4.2)	4 (16.0)
Total	95 (100)	25 (100)

2.2. Sampling

Farinha-Marques et al. (2014) identified and mapped 95 PUGS in Porto, and a subset of these was sampled. The PUGS selection (Table 1) followed, when possible, the percentage of each type identified in the same previous study.

From each of the five areas of SEDI, five PUGS were selected, totalizing 25. In this case, a perfect match between this study sample and the identification of the Farinha-Marques et al. (2014) study is not possible since some clusters do not have parks or garden squares. Regarding public gardens, as it is the majority type in the city (78.9%), it was decided to maintain this coherence in this study sample (76.0%). Garden squares selection was based on those more likely to be used as a public garden and promote recreational activities to its users. Due to the environmental and recreational importance (Vidal et al., 2021b), the four city parks were integrated into this study sample.

2.3. Measures

The tool used in this study was the ESP evaluation grid developed by Vidal et al. (2021c), (2021a), with good reliability and internal consistency. The tool embodies four domains assessed in PUGS and its 36 attributes, which will be used in the cluster analyses and are summarized in Table 2.

The four dimensions assessed aggregate the dominant function of the PUGS according to Selman's (2012) proposal: recreation, which is part of Activities Performed, Facilities and Security dimensions and refer to the possibility to use the PUGS for social and physical activities with adequate infrastructure that supports those; conservation, visible in the Environmental Quality dimension measure by the historical and cultural value of the PUGS; education, present in the Activities Performed and Facilities dimensions, which relates to the educational purpose of PUGS, such as environmental education activities; and, finally, the amenity, which is part of the Environmental Quality dimension and represents the PUGS capability to contribute to the surrounding environmental quality.

The ESP evaluation grid is filled by a dichotomous answer: No = 0; Yes = 1 (except the question 'Are their signs of vandalism?' in which 'Yes' is equal to '0'). The application followed the principles defined by the POST manual for direct observation (Lange et al., 2004). Each PUGS was audited individually from January to March 2019, and rounds in the PUGS lasted between 20 and 30 min. The PUGS were audited at least 3 times to reduce the possibility of incorrectly filling the ESP evaluation grid. Some of them were audited more than three times due to their size. Following Lange et al. (2004) guidelines, the ESP evaluation grid was carefully filled by walking around and through each PUGS to assess the environment and facilities. When all visits to the PUGS were concluded, the results from the ESP evaluation grid were discussed by the team to ensure that the space was correctly assessed.

2.4. Data analyses

Data were inserted on Excel and exported to the IBM® SPSS® Statistics 26.0. to perform the statistical analyses. To identify groups of PUGS and describe their characteristics, a hierarchical cluster analysis, based on the scores of each dimension assed, was applied to the results obtained from the ESP evaluation grid application. The squared Euclidean distance between each pair of observations was used, as well as Ward's hierarchical clustering method. After these steps, the groups were selected according to the statistical significance among the clusters. To do that, an analysis of variance (ANOVA) was applied to identify where the differences between the identified clusters were considered at a 0.05 level. The clusters data were analysed through R software and presented in radar charts as attributes diagrams, commonly used to display multivariate data. To meet the criteria to compare the collected data, and only if the clusters do not have the same number of PUGS, a normalisation procedure was performed. The score of each attribute

Table 2
Dimensions, attributes, definitions and benefits assessed through ESP evaluation grid.

Dimension	Code	Attribute assessed	Socioecological benefits
Activities Performed	**Spor**	Sport activities	To improve recreational activity provision, to enhance physical activity and socialisation; to develop a sense of belonging and to increase environmental awareness (Gao et al., 2019a; Jennings and Bamkole, 2019; Rudl et al., 2019; Song et al., 2014).
	Game	Table games	
	Thea	Theatres activities	
	Fest	Civic meetings, festivals or concerts	
	Fair	Traditional fairs	
	Reli	Religious gatherings	
	Educ	Environmental education activities	
Environmental Quality	**Sur**	Surrounding area	Contribute to making urban green spaces surrounding area more pleasant; to make urban green spaces more pleasant and to increase the possibility to perform the physical activity; Contribute to slowing the passage of runoff, to offer shelter against winds, dust, heat waves, noise and to offer recreational activities (Gao et al., 2019b; Łaszkiewicz et al., 2018; Lopez and Souza, 2018; Takano et al., 2002; Vieira et al., 2018).
	Vand	Signs of vandalism	
	Arti	Heritage or artistic elements	
	Path	Paths	
	Bike	Bike paths	
	Grov	Grove density	
	Shad	Shaded spaces	
	M-bu	Urban furniture maintenance	
	M-gr	Green infrastructure maintenance	
	Clea	Cleaning	
	Wate	Blue spaces	
Facilities	**Cent**	Centres or environmental education activities	To improve recreational activity provision; to develop a sense of belonging; to increase environmental awareness; to promote universal access and social cohesion (Elands et al., 2018; Hoffimann et al., 2017; Jennings and Bamkole, 2019; Ward Thompson et al., 2019a).
	Chil	Playgrounds	
	Carp	Ccar park or nearby parking	
	Tran	Public transport	
	Leis	Leisure spaces	
	Cont	Containers for animal waste	
	W-an	Water sources for animals	
	W-hu	Water sources for humans	
	Equi	Cultural and/or recreational equipment	
	Cafe	Cafes/bars/ restaurants	
	Toil	Public toilets	
	Mobi	Accessibility for people with disabilities and/or reduced mobility	
Security	**Stre**	Visibility to the streets that surround green space	To increase the feeling of safety and the possibility to develop recreational activities (Artmann et al., 2017; McEachan et al., 2018; Moran et al., 2014; Ngulani and Shackleton, 2019)
	Hous	Visibility to the houses that surround green space	
	Visu	Areas of little visualisation	
	Inf	Adequate infrastructures for physical/sports activity	
	Ligh	Lighting	
	Vigi	Vigilance	

Source: Adapted from Vidal et al. (2021c)

assessed was divided by the number of PUGS in each cluster. In this way, a four-point rating ranging from (0) poor to (1) very good, was applied to the attribute diagrams, in which scores closer to 1 were better than scores closer to 0.

A discriminant analysis was performed to determine the discriminant function and to validate the groups formed by the clusters technique. Before performing this test, it was necessary to assess whether the data met the discriminant analysis assumptions: the covariance matrices were homogeneous and the variables presented normality. When the covariance matrices are homogeneous, the discriminant function to be used is the (Fisher 1938). This analysis has the advantage of indicating which variable mostly contributes to the formation of the groups helping to explain and interpret them.

3. Results

3.1. Clusters determination and predictor dimensions identification

In the first step of identifying PUGS groups, the aim was to assess the cluster analysis results based on the ESP evaluation grid application final scores (sum of all dimensions assessed). After several tentatives, five groups were identified, and the PUGS memberships seemed adequate with what was observed on the field. A descriptive analysis is presented in Table 3 to determine whether the clusters are statistically different.

Regarding these results (Table 3), it is confirmed that only the "security" dimension is not statistically different among clusters ($p = 0.164$), suggesting that the dimension attributes are similar across the PUGS analysed. On the other hand, the remaining dimensions assessed presented a $p < 0.001$, which suggests heterogeneity among PUGS clusters. A discriminant analysis was performed to determine the validity of this clustering. The clustering process presents high classification accuracy (84%) for PUGS in the groups to which they belong.

The next step consisted of discriminant analysis to identify the main function of the clustering previously performed to the PUGS. A discriminant function was identified as the main one since it explains 89.0% of the clusters variation, being statistically significant ($p < 0.001$). Additionally, Wilk's lambda indicates that only Function 1 is significant and only 0.050% of the variability is unexplained. Through the coefficients for each dimension assessed (Table 4), it is possible to identify the main predictors. The environmental quality dimension was the strongest predictor, while the facilities dimension was next in importance as a predictor. These two variables with large coefficients stand out as those that strongly predict the allocation of PUGS in the groups. The scores of the security and activities performed dimensions were less successful as predictors. The unstandardised coefficients (*b*) presented were used to create the discriminant function (Eq. 1).

3.2. Clusters profile

As previously identified, the environmental quality and facilities are the dimensions of the main predictors of PUGS ecosystem services potential. Therefore, the study of the attributes of these two dimensions is the best way to provide a distinctive profile of each cluster.

An overview of the five clusters by the four dimensions assessed is visible in Fig. 1. This preliminary analysis already indicates the characteristics of the clusters, namely, which dimensions have higher ecosystem services potential and which ones present the lowest ecosystem services potential. It is noteworthy that Cluster 2 presents the highest scores in three of the four dimensions assessed, namely, activities performed, environmental quality and facilities. At the bottom, it is notorious that cluster 4 presents the lowest scores in the dimensions assessed.

The cluster analysis profile has followed a zoom-in of each cluster, including the typology and localisation of PUGS, and a rap-up naming the cluster (Fig. 2).

Starting with cluster 1, the most important dimensions are the environmental quality and facilities, complemented by the security dimension. Zooming in on this cluster, the environmental quality dimension attributes oscillate between "good" and "very good". The attribute of bike paths (bike) is the one that presents the worst performance, but it still got a rating of "good" as well as the attribute surrounding area (sur). Some attributes present poor scores in the facilities dimension – specifically, the water sources for animals (w-an) and humans (w-hu). These PUGS are used for fairs (fair), sports activities (spor), and some cultural festivals. However, some attributes have poor and fair performances in the security dimension, which could undermine the efforts to make these spaces more pleasant. Concerning its locations and typology, these PUGS are mainly part of the city's coastal area, being all public gardens located in wealthy and touristic areas, with a strong presence of university students as potential users (Fig. 3). It can be stated that this cluster presents high environmental quality and facilities with great potential to be explored regarding the activities dimension.

Cluster 2 aggregates the PUGS with the highest scores in all domains assessed, except for the security dimension. Zooming in on this cluster based on the predictor dimensions, the environmental quality dimension presents a "very good" score in all attributes assessed, except the bike paths (bike). The same happens in the facilities dimension, where all attributes have "very good" scores. In this dimension, it would be interesting to provide opportunities for outdoor meetings. In this specific cluster, the security dimension scores imply a careful interpretation: the existence of quiet and demure spaces could be assumed as a positive factor when PUGS users prefer quiet and secluded spaces to rest and relax; on the other hand, it can be considered negative since it can result in the exposure to and greater vulnerability to crime. These spaces

Table 4
Function and correspondent coefficients and unstandardized coefficients obtained through discriminant analysis.

	Dimensions	Function	Coefficients	Unstandardized coefficients*
Structure Matrix	**Environmental quality**	0.810	0.727	0.638
	Facilities	0.658	0.519	0.381
	Activities performed	0.558	0.084	0.071
	Security	-0.123	-0.190	-0.231

Note: *constant = −6.731.

$$\text{Discriminant Function} = -0{\cdot}231 \times \text{Safety} + 0{\cdot}381 \times \text{Facilities} + 0{\cdot}638 \times \text{Environmental quality} + 0{\cdot}071 \times \text{Activities performed} - 6{\cdot}731 \quad (1)$$

Table 3
ESP evaluation grid scores mean for each dimension assessed by cluster.

Dimensions Assessed	Average Scores					ANOVA	
	Cluster 1 (*n*=5)	Cluster 2 (*n*=3)	Cluster 3 (*n*=5)	Cluster 4 (*n*=4)	Cluster 5 (*n*=8)	*F*	Sig.
Activities Performed	3.2	6.0	2.4	0.3	0.9	14.1	< 0.001
Environmental Quality	9.6	10.7	9.4	3.5	6.4	27.7	< 0.001
Facilities	8.2	11.7	7.0	3.8	5.1	18.9	< 0.001
Security	4.2	3.0	3.2	4.0	4.0	1.8	0.164

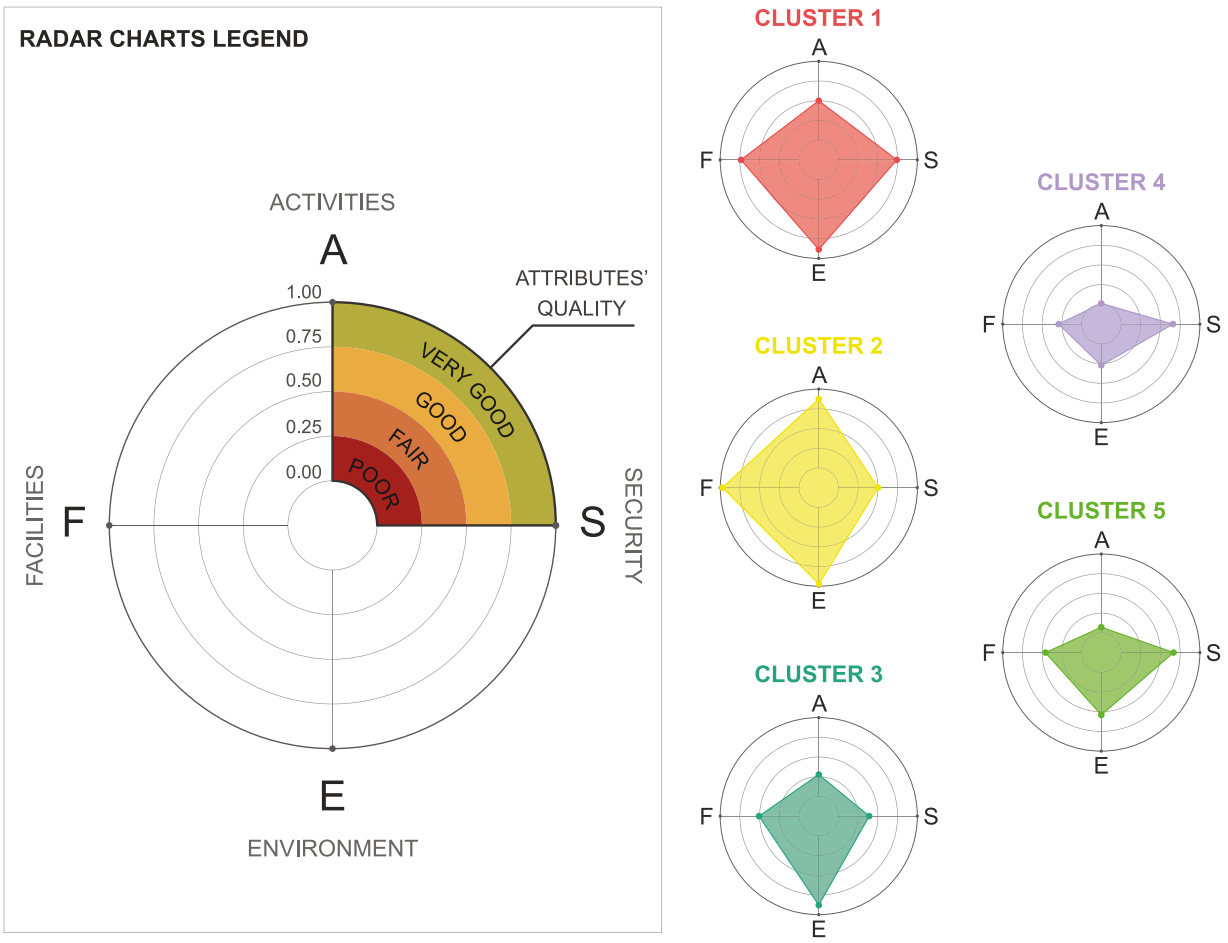

Fig. 1. Global view of the five clusters by the four dimensions assessed through the ESP evaluation grid.

are mainly located close to the river or the sea, two of them in the occidental area of the city and another in the central/historic (Fig. 3). They comprise PUGS with the highest dimension (two parks and one public garden). These PUGS design does not condition its use, offering the users freedom of movement (an invitation to get lost in the PUGS).

Cluster 3 presents PUGS with generally "good" environmental quality scores but with "fair" scores in the facilities and security attributes. The activities dimension is the one that reveals the worst performance in almost all attributes assessed, except for sports activities (spor). Concerning the environmental quality, the existence of bike paths (bike), heritage elements (Arti) and built infrastructure maintenance (M-bu) presented "good" performance. Relating to facilities, these PUGS have a car park nearby (Carp) or public transport (trans), as well as leisure spaces (leis). Water sources for animals (W-an) and humans (W-hu), the public toilets (toil) and the accessibility to people with reduced mobility (mobi) are those with "good" and "very good" performance. The remaining attributes in these dimensions are poor. The possibility of performing activities in these PUGS is reduced since only sports activities (spor) have been identified. This cluster contains two parks located in the eastern area of the city and a garden square located in the western area (Fig. 3).

Cluster 4 presents the worst scores in all dimensions assessed, except for the security dimension (but as stated before, this dimension assessment is relatively similar across all clusters). All attribute scores are "poor" in the environmental quality, except for the existence of paths (path). Regarding the facilities, the existence of car parks (carp) and public transport (trans) nearby are the only "very good" scores, and the existence of leisure spaces is good (leis). About activities, all attributes are "poor". It is worth remarking that, in the security dimension, the scores are "good" since these PUGS represent small public gardens integrated into the city's dense urban fabric. One of them is located in the western part of the city, and the other two are in the eastern area (Fig. 3). This cluster represents the PUGS with fewer ecosystem services potential.

The last cluster is the one that aggregates the most PUGS. In the environmental quality dimension, the attributes with the best performance are the paths (path) and the maintenance of the built infrastructure (M-bu). Regarding facilities, the best attributes are the nearby car parks (carp) and public transport (trans) and the existence of leisure spaces (leis). The security assessment emphasises "good" scores in global visualisation (visu) and lighting (ligh). These are mainly pocket PUGS, located in the central/historic and touristic area of the city, which are frequently used due to their proximity to the users' residence and work (Fig. 3).

Based on the ESP evaluation grid results and in the predictor dimensions identified through the discriminant analysis, a summary of each cluster is present in Table 5. This summary can be useful to local policy design, namely in place-based interventions, to effectively intervene the PUGS in a non-fragmented way, but more in a logic of green infrastructure since some PUGS have similar needs.

Fig. 3 presents the distribution of the clusters by PUGS type in the city of Porto.

4. Discussion

The application of the grid showed that PUGS ecosystem services potential is not similar across the city of Porto, namely suggesting a situation of environmental injustice. In other words, in spaces

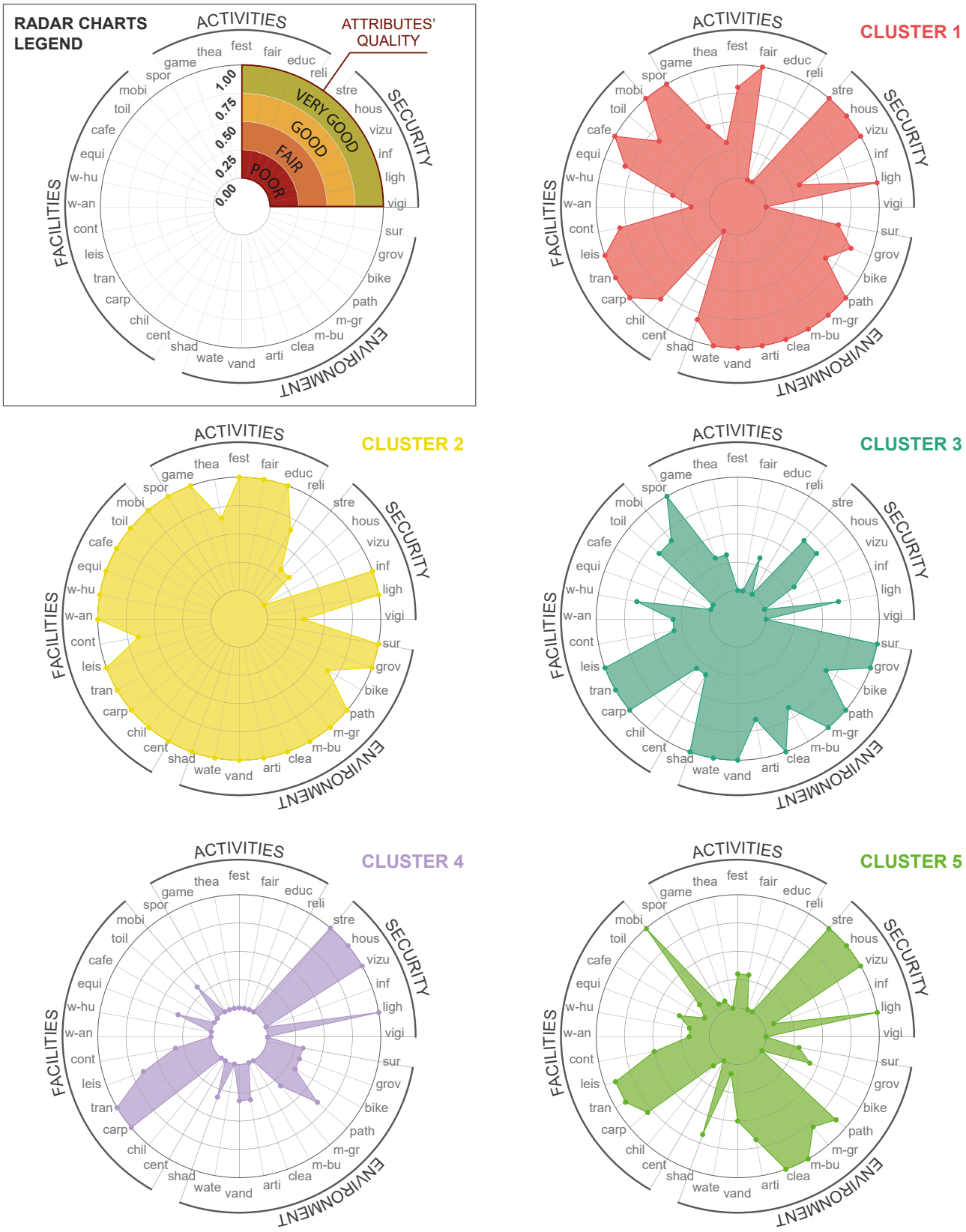

Fig. 2. Zoom-in of each cluster by the attributes assessed through the ESP evaluation grid.

experiencing socioeconomic and environmental deprivation, the PUGS ecosystem services potential is lower than in the others (Vidal et al., 2021c). Set against this background, the current PUGS planning literature highlights the need to develop methodologies that combine both data collection and monitoring in the citizen co-creation framework (Bisschops and Beunen, 2019; Davis and Andrew, 2017; Erjavec, 2017; Gutiérrez et al., 2018; PROGRESS, 2017). The proposed clustering process for identifying PUGS typologies based on ecosystem services

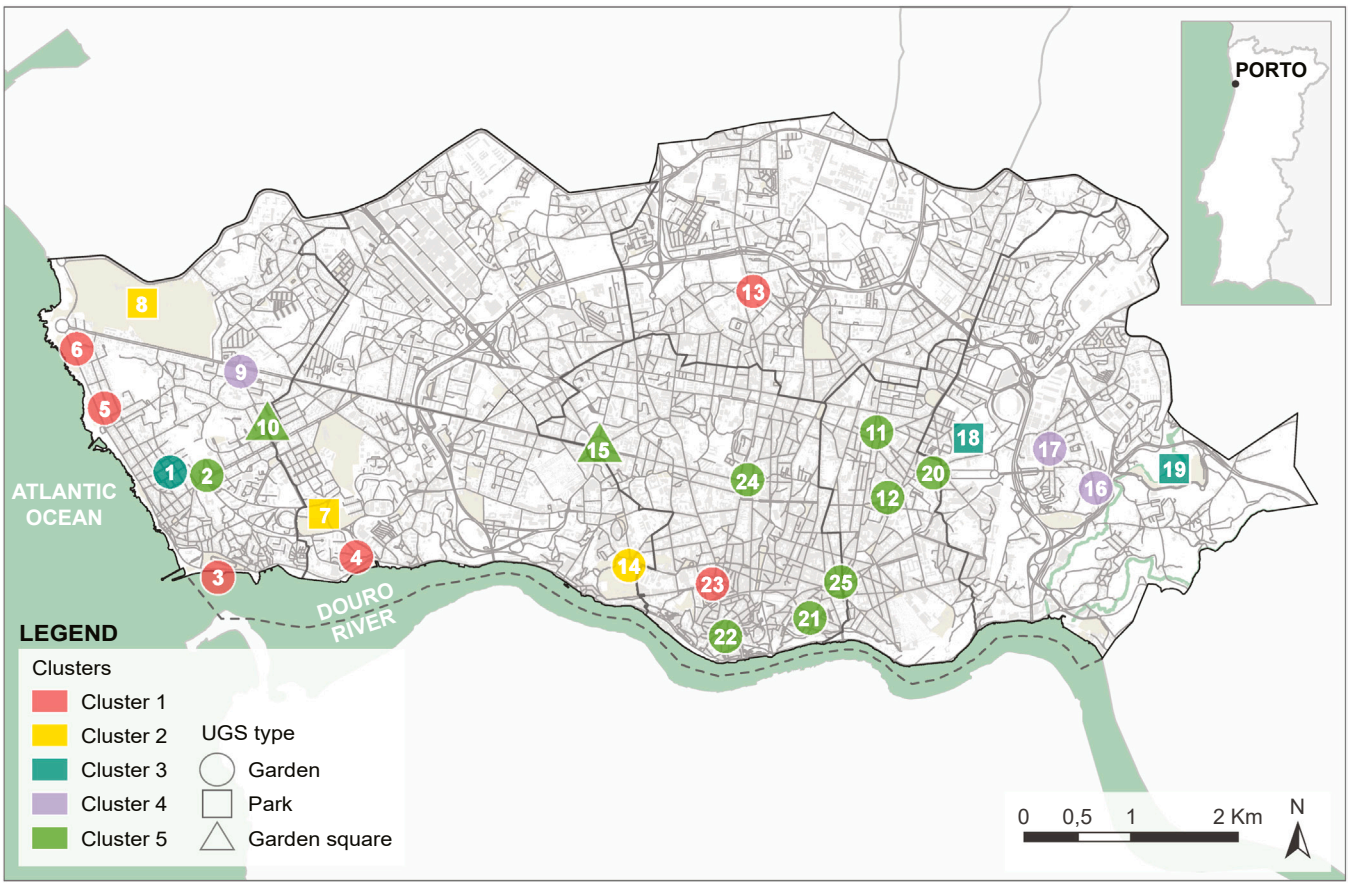

Fig. 3. Clusters distribution by PUGS type.

Table 5
PUGS Clusters summary profile after the discriminant analysis.

	Cluster 1 (n=6)	Cluster 2 (n=3)	Cluster 3 (n=3)	Cluster 4 (n=3)	Cluster 5 (n=10)
Name	Environmentally Empowered and Socially Expectant Spaces	Socioenvironmentally Empowered Spaces	Environmental Empowered but Socially Un-dynamic Spaces	Socioenvironmentally Disempowered Spaces	Socioenvironmentally Unexplored Spaces
Profile	Good performance in the environmental dimension and a high possibility to fully potentiate the social dimensions	Both environmental and social dimensions present, in most attributes, very good performance.	Good environmental performance but they do not have social dynamics	Both environmental and social dimensions present poor performance	Environmental and social dimensions have good performance but nearby residents do not fully explore the opportunities of these spaces
Recommendations	Mainly improve recreational opportunities and activities, namely creating connectedness through bike paths	Maintaining the current strategy. Maybe create more opportunities for outdoor meetings and improve security elements due to the size of these PUGS	Develop a strategy to create more attractiveness regarding social dynamics, such as outdoor meetings, table games, cultural initiatives. The social uses of these PUGS are currently inactive.	It is the priority intervention cluster since all the dimensions assessed need improvement.	A strong strategy is needed to create connectedness among these PUGS since are mainly of small size and integrated into the dense urban fabric of the city. This connectedness, by creating a strong bond between them, may lead to an increase in ecosystem services potential.

potential proved to be adequate to the objectives of the study, with a high rate of accuracy.

Local authorities are still testing the application of Geographic Information Systems (GIS). Thus a transfer of scientific knowledge about which PUGS attributes should be analysed and monitored should exist. The attributes analysed by the ESP evaluation grid applied in this work can support the development of tools for public participation based on GIS (PP-GIS) and place-based planning and design of interventions. It is important to provide reliable information about PUGS that can contribute to these spaces' empowerment and promote its ecosystem services potential.

The multivariate analysis performed in the present study allowed for the identification of five cluster typologies of PUGS: i) Environmentally Empowered and Socially Expectant Spaces, ii) Socioenvironmentally Empowered Spaces, iii) Environmental Empowered but Socially Un-dynamic Spaces, iv) Socioenvironmentally Disempowered Spaces and v) Socioenvironmentally Unexplored Spaces.

These typologies resulted from the profile identified from the configuration of the shared PUGS attributes. Beyond the important contribution of the previous study regarding the identification of urban

green spaces typologies in the city of Porto (Farinha-Marques et al., 2016), the categorisation proposed in this work brings to the discussion a possible solution for better qualifying these spaces, as it complements PUGS type (i.e., whether they are gardens, parks or square gardens) with a socioeconomic and environmental characterisation (SEDI) of the PUGS location (Fig. 4).

As can be seen by the cluster distribution across the city, according to SEDI and PUGS type, some patterns can be identified: clusters 1 and 2 are located by the river or by sea. These are the clusters that simultaneously are part of SEDI with the lowest deprivation. On the other hand, clusters that aggregate PUGS that are socially and environmentally unexplored/disempowered (clusters 4 and 5) are mainly located in areas where SEDI presents a high deprivation. This evidence is not new, as several studies reveal the presence of environmental injustice in the city of Porto (Graça et al., 2018; Hoffimann et al., 2017; Vidal et al., 2021c), which is a trend of the south-European cities (Kabisch et al., 2016; Ribeiro et al., 2017). However, some studies focused on central-European cities, with a similar dimension to Porto, have also identified this uneven distribution of PUGS, namely Brussels (Stessens et al., 2017), Halle (Haase and Wolff, 2022) and Salzburg (Artmann et al., 2019).

Nevertheless, the information that these clusters present can be useful for the local authorities to identify the main dimensions that must be improved to revert this situation. The areas of the city that experience more socioenvironmental and economic deprivation are those that have PUGS that are socially unexplored, which means that nearby residents do not fully explore the opportunities of these spaces. This can be a symptom that results from the lack of facilities and infrastructures, or it can be due to the poor maintenance of the natural and built environment. In these areas, the presence of the elderly and unemployment rate is more prevalent than in other areas of the city (Alves, 2016). In many cases experiencing social isolation, these social groups are more exposed to a social disconnection that can be a root cause of depression and a diminished quality of life. Being closer to urban green spaces with potential and spending time there promotes human connection and a sense of community, belonging, empowerment and social support (Braubach et al., 2017; Elands et al., 2018; Hubbard et al., 2020; Jennings and Bamkole, 2019; Ward Thompson et al., 2019b, 2019a; World Health Organization, 2017). But these benefits can be undermined by many factors, such as the quality of a given green space, the type of social engagement programs offered in that space, and surrounding social conditions (Jennings and Bamkole, 2019).

From the public policies viewpoint, this work identified the predictor dimensions of PUGS ecosystem services potential that should be the target of urban planners and local authorities if effective interventions are needed. Environmental quality and facilities dimensions can lead to a significant increase of ecosystem services potential, namely in the clusters where PUGS are environmentally and socially disempowered, thus contributing to the regeneration of the surrounding areas and benefiting residents. The application in different regions worldwide can also be made by adapting the dimensions and attributes to be analysed and the socioeconomic gradient of the area. In these cases, it would be interesting to understand if predictor dimensions are the same or different.

5. Conclusions

PUGS are vital to environmental regeneration and the well-being promotion of its users by offering opportunities to perform recreational activities, such as outdoor sport and recreation, landscape aesthetics, or nature conservation. In the city of Porto, several PUGS are scattered in the middle of the dense urban fabric. Local authorities are

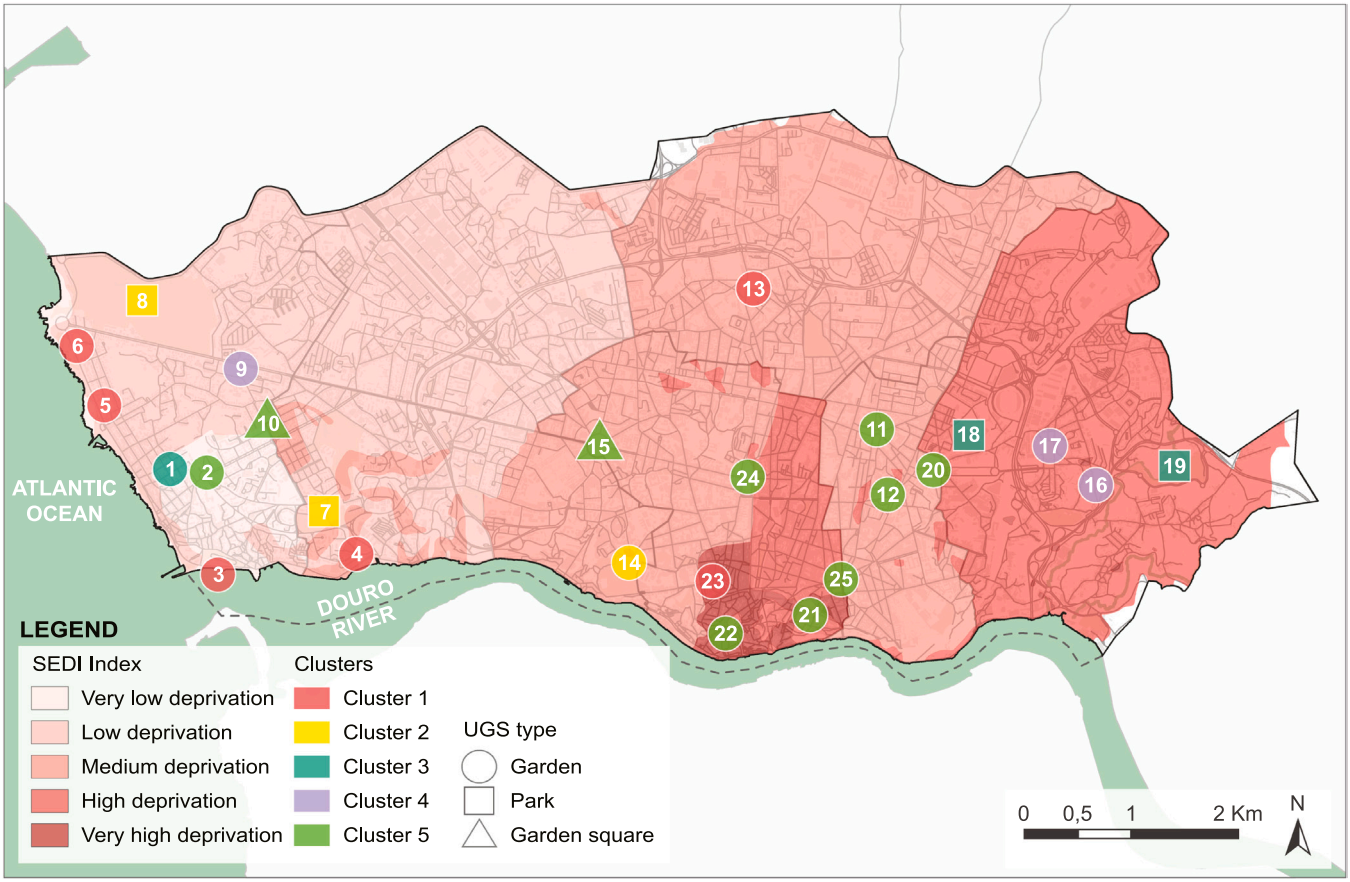

Fig. 4. Cluster distribution by SEDI areas according to PUGS type.

the main ones responsible for the PUGS management. Thus a straightforward tool that allows identification of typologies based on ecosystem service potential may be useful for place-based interventions. This study provides a new methodological approach to identify PUGS typologies based on ecosystem services potential. Through the application of a validated tool (the ESP evaluation grid) in 25 PUGS in the city of Porto, Portugal, it was identified five PUGS clusters were validated: Environmentally Empowered and Socially Expectant Spaces, Socio-environmentally Empowered Spaces, Environmentally Empowered but Socially Un-dynamic Spaces, Socioenvironmentally Disempowered Spaces and Socioenvironmentally Unexplored Spaces. These clusters identification are useful in the design of place-based intervention in PUGS, contributing to the increase of ecosystem services potential and improving urban environment quality and sustainability through the identification of its main predictors: environmental quality and facilities. Furthermore, the ESP evaluation grid also shows that the ecosystem service potential differs within the city and, in some cases, results in situations of environmental injustice: clusters that aggregate PUGS that are socially and environmentally unexplored/disempowered are mainly located in areas where SEDI presents a high deprivation.

In this context, the application of the ESP evaluation grid can be advantageous for developing new place-based interventions that, instead of focusing on political-administrative jurisdictions, enhance ecosystem services potential at a municipal level. Finally, although applied to the city of Porto as a case study, this new methodological approach can be used in other urban areas with similar characteristics, such as coastal cities in southern Europe and elsewhere, to prove insightful and further the ability to discern ecological value, both in terms of function and service provision.

Some limitations need to be addressed regarding this study's development in future research. The first one relates to the lack of data concerning PUGS characteristics, making it impossible to compare with the data collected. The second limitation refers to the amount of time spent in the field since it is necessary to audit the PUGS more than once to guarantee that the data collected is accurate. Regarding these two limitations, future research is recommended to provide more information on PUGS characteristics and make data comparison possible at a national and international scale. However, this new methodological approach, by combining multiple dimensions that relate to environmental and social benefits highlighted predictors drivers of ecosystem services potential, namely the PUGS Environmental Quality and Facilities dimensions, which are useful to improve their potential in the city of Porto.

CRediT authorship contribution statement

Diogo Guedes Vidal: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition. **Ricardo Cunha Dias:** Validation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization. **Catarina Patoilo Teixeira:** Software, Validation, Formal analysis, Writing – review & editing, Visualization. **Cláudia Oliveira Fernandes:** Validation, Writing – review & editing, Visualization. **Walter Leal Filho:** Validation, Writing – review & editing, Visualization. **Nelson Barros:** Validation,Writing – review & editing, Visualization, Supervision. **Rui Leandro Maia:** Validation, Writing – review & editing, Visualization, Supervision.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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