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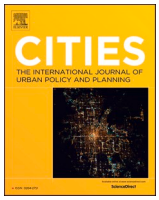

The socio-cultural values of ecosystem services in managed, semi-managed and low-managed urban blue spaces and their surroundings. A case study of Warsaw, Poland

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ABSTRACT

Urban blue spaces provide important ecosystem services (ES), that support health and well-being of city residents. This study examined residents' perceptions of ES provided by managed, semi-managed and low-managed blue spaces and their surroundings in Warsaw, a city dominated by the River Vistula which flows through its centre and is partially unregulated. We conducted a geo-questionnaire, asking respondents to mark their favourite blue spaces and evaluate them for different ES benefits. The data were analysed using cluster, correlation and spatial analysis to identify patterns and synergies among perceived ES. The results revealed five distinct ES clusters, showing synergies among aesthetic, recreational and nature appreciation related values. Managed blue spaces, such as urban parks or promenades, were primarily associated with social bonding, while historical and neighbourhood parks are valued for providing an everyday connection to nature and biodiversity. Low- and semi-managed areas, including vast informal riversides, play an important role in recreation, relaxation, connection to nature, and social bonding. These areas provide similar benefits with minimal interventions, highlighting their potential as Informal Blue Spaces, integral part of urban blue-green infrastructure. The results add to the increasing evidence of the social value of blue spaces and demonstrate how diverse management and investment approaches can support complementary socio-cultural benefits in cities.

1. Introduction

The increased growth of urban areas and decades of rapid sprawl, combined with biodiversity loss and a lack of well-functioning green and blue spaces, call for new ways of sustainable urban planning and design. To design places that serve both human and non-human actors, it is not only essential to have a proper understanding of a local ecosystem, but also to perceive it through the lens of users and consider human-nature interactions in diverse urban spaces. In this context, concepts such as ecosystem services (ES), the benefits provided by the environment to humans, are crucial for health and well-being (Costanza et al., 2017), and offer a useful lens for identifying potential.

Along with economic and ecological assessments, socio-cultural evaluations of the benefits derived from ecosystems are necessary, as

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it has been recognised by the Intergovernmental Platform on Biodiversity and Ecosystem Services (Pascual et al., 2017). The socio-cultural evaluation approach reveals preferences, importance, patterns, conflicts and trade-offs, which are essential for informed planning and management decisions, through awareness raising, priority setting and instrument design (Martín-López et al., 2012; Martín-López, Gómez-Baggethun, García-Llorente, & Montes, 2014; Pascual et al., 2017; Walz et al., 2019). This approach also facilitates targeted educational activities and enhances understanding of governance needs (Miller & Montalto, 2019), allowing for the capture of the complex interactions between social and natural capital (Costanza et al., 2017), as well as the shared or plural nature of values (Kenter, 2016).

To support sustainable urban planning and design it is crucial to explore the socio-cultural values of ES in managed, semi-managed and low-managed blue spaces in Warsaw. This topic is important, since freshwater areas are unique and precious ecosystems, that, compared to green areas, are usually geographically predefined. Therefore, recognition of users' values and preferences is crucial to ensure just access and sustainable development (Wilczyńska et al., 2023; Vári et al., 2022). Freshwater ecosystems are also referred to as blue spaces (BS), encompassing seas, lakes, rivers, as well as artificial reservoirs and canals (Grellier et al., 2017). However, in urbanised contexts, blue and green, as well as grey infrastructures create interconnected and complementary systems, important to the flow of benefits (Andersson et al., 2019). This is why, in this paper we understand blue spaces as areas encompassing not only water bodies, but also their surrounding areas, following an established methodology (Wilczyńska et al., 2021).

From the ecological perspective, urban blue spaces enhance biodiversity, reduce the urban heat island effect, support air purification, food production, extreme weather mitigation, recreation, and restoration, among other functions (Beute et al., 2020; Gunawardena, Wells, & Kershaw, 2017; Haase, 2015; Puppim De Oliveira, Bellezoni, Shih, & Bayulken, 2022; White, Elliott, Gascon, Roberts, & Fleming, 2020). However, there is a limited literature that focuses specifically on the socio-cultural aspects of ES in the urban water context. In previous studies specifically related to green spaces, cultural ecosystem services (CES) and regulating services have been considered important, whereas habitat-related and provisioning services are often overlooked (Chen, Wang, Ni, Zhang, & Xia, 2020; Korpilo et al., 2023). Similar results are shown in studies of urban blue spaces (Hossu et al., 2019; Vierikko & Niemelä, 2016). Some research highlights the importance of examining synergies and trade-offs in socio-cultural evaluations of ES benefits. For example, a survey of urban lakes in Romania revealed that CES appeared in each identified ES trade-off, suggesting potential tensions between how humans value ecosystems and their ecological functions (Hossu et al., 2019). A city-wide study of CES perceptions and use in Berlin by Rall et al. (2017) identified three distinct clusters of CES: immaterial and nature-oriented services (biodiversity and aesthetics), recreational and social-oriented services (recreation and cultural heritage), and everyday uses (such as dog walking).

While aiming at informing landscape management and planning decisions, socio-cultural evaluation must be considered through the lenses of geographical context, landscape character, and related user preferences. The study by Rall et al. (2017) noted that CES related to recreation and social opportunities tend to be concentrated in the city centre, while nature experiences and education, biodiversity, spirituality, and aesthetics, as well as pleasant sounds are more commonly found at the urban edges (Rall et al., 2017). In the urban context, where diverse types of blue and green spaces coexist, including both managed and designed areas, as well as natural and informal ones, they are crucial (Kowarik & Langer, 2005). Studies show that urban parks and informal green spaces can provide comparable ES (Sikorski et al., 2021). Moreover, natural and 'designed' urban green spaces can be perceived similarly in terms of nurturing a sense of connectedness to nature. A perceived sense of wilderness enhances this connection (Samus, Freeman, Van Heezik, Krumme, & Dickinson, 2022). However, the meaning of 'naturalness' can be relative (Muratet, Pellegrini, Dufour, Arrif, & Chiron, 2015). For example, historic parks can be viewed as more biodiverse due to the abundance of greenery and the presence of old trees (Gonçalves et al., 2021). Recently, several studies have highlighted the value of informal and natural urban green spaces, which are used for recreation, allowing informal use, while requiring small investments to assure equal access or feeling of safety (Gawryszewska, Łepkowski, Pietrych, Wilczyńska, & Archiciński, 2024; Grzyb, 2024; Pueffel, Haase, & Priess, 2018; Unt & Bell, 2014).

From a socio-demographic perspective, research suggests that female gardeners exhibit a greater appreciation for ES than their male counterparts (Langemeyer, Camps-Calvet, Calvet-Mir, Barthel, & Gómez-Baggethun, 2018). Age-related differences have also been observed; for instance, teenagers visit forests less for contemplation and more for socialising, unlike adults (Hegetschweiler, Wartmann, Dubernet, Fischer, & Hunziker, 2022). Moreover, visits to urban green areas fluctuated during the COVID-19 pandemic (Grima et al., 2020; Lopez, Kennedy, Field, & McPhearson, 2021).

1.1. Aims and objectives

Various authors emphasize the importance of incorporating users' perspectives in the evaluation of ES benefits in blue spaces, particularly when considering specific socio-ecological contexts (Andersson et al., 2019; Vári et al., 2022). This paper aims to explore socio-cultural values associated with ES in managed, semi-managed, and low-managed blue spaces in Warsaw. Here, based on the results, possible actions are suggested to sustain or enhance perceptions of the studied blue spaces, aiming to make them diverse enough to accommodate different local potentials and needs. Our research is guided by the following research questions:

1. How are ES perceived in the blue spaces of Warsaw?
2. What are the differences in socio-cultural values of ES for managed, semi-managed and low-managed blue spaces perceived by residents?
3. How is the socio-economic background of respondents influencing their perception of ES values in those areas?

2. Materials and methods

2.1. The context of Warsaw

Warsaw is a unique European capital city due to its location on the River Vistula, whose bed within the city has not been regulated as much as most European rivers (Maciejewska, 2021). In addition to the River Vistula, there are other types of water bodies, including a large network of channels within the city, as well as ponds and lakes. These are sometimes managed and integrated into the urban fabric, but many are abandoned and informal (Wilczyńska et al., 2021). A recent geo-survey found that respondents primarily associate Warsaw's urban rivers with recreational benefits, followed by nature-related and climate regulation functions, and education and economic benefits being less recognised. Respondents identified urban rivers as habitats for wildlife, recreational areas and as important for landscape and water provision (Bąkowska-Waldmann, 2022). Another study by Grzyb (2024) highlighted the high value placed on natural heritage, aesthetic appreciation, and nature-based recreation, with lesser importance given to spiritual enrichment. Benefits were concentrated around the central River Vistula, as well as its peripheries, but were mainly found along paths. The study also found that nature appreciation was linked to physical activities on land, while water sports were associated with social interactions and emotional connections. Female respondents tended to appreciate the natural river more than male respondents. Previous studies on socio-cultural evaluation of ES in the urban context of Warsaw and other European cities have primarily focused on green spaces, or exclusively on CES in blue spaces, without addressing how varying levels of management influence

public perceptions of ES.

2.2. Identification of Ecosystem Services associated with blue spaces in Warsaw

2.2.1. Data collection

We identified a total 17 ES associated with urban blue spaces based on the literature and The Economics of Ecosystems and Biodiversity classification for urban areas (TEEB, 2011; Table S1 Supplementary Materials). Some identified ES, strictly speaking, are not ES but represent rather specific human values related to nature, such as the intrinsic value of biodiversity or the relational value of place attachment. While ES usually conceptualise instrumental values of nature (Himes et al., 2023), we included these broader perspectives in line with the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) framework (Anderson et al., 2022). Because final benefits with a direct effect on human well-being are more intuitively evaluated by respondents (Fisher, Bateman, & Turner, 2010), each ES was linked to a specific end-value benefit (Table S1, Supplementary Materials). For simplicity, we refer to respondents' scores as 'ES rates', as most of the considered values are instrumental. To collect spatial data on people's perceptions, we used a Public Participatory Geographic Information System (PPGIS) (Brown & Fagerholm, 2015). The geo-questionnaire was provided in both Polish and English, and an online link was distributed through social media from July 28, 2020, to November 6, 2020. Recruitment took place Warsaw's district-specific Facebook groups, at larger institutions such as the Botanical Garden of Warsaw, and through personal sharing by various individuals. The full questionnaire is provided in the Supplementary Materials. For this study we considered data only from questions in which respondents were asked to:

1. Mark up to five favourite blue spaces on the map, located in or close to the city.
2. Assess ES benefits according to their agreement with a series of statements (Table S1, Supplementary materials) for all chosen places using a scale from 5 to 1, where 5 indicates 'I agree with the statement' of an ES and 1 indicates 'I don't agree'.
3. Provide additional socio-economic background information (Table S2, Supplementary materials)

Questions were written in non-technical language (Miller & Montalto, 2019). More respondents (n = 143, 56.5%) were individuals whose profession or personal interest provided a connection to landscape and nature, with substantially more women (n = 158, 62.5%) than men participating in the survey. The majority of respondents were between the ages of 25 and 54 (n = 210, 83%) and were employed (n = 213, 84.2%). Respondents had spent much of their free time as children in the countryside (n = 83, 32.8%) and nearby forest (n = 58, 22.9%), but also at the seaside (n = 42, 16.6%). Over a half (n = 121, 51.0%) have access to at least a balcony/patio, and 31,6% (n = 80) have access to a private garden. There were only a few who never visited (n = 5, 2%) or visited every day (n = 20, 7.9%) blue spaces. Majority of respondents feel a strong (n = 121, 47.8%) or medium (n = 98, 38.7%) connection to the nature. The largest number of respondents was recorded for the Ochota district (n = 48), followed by Rembertów (n = 22). The smallest number were recorded for Wilanów, Włochy (n = 2 each), and Żoliborz (n = 1). The number of respondents per each district is presented in Table S8 of the Supplementary Materials. However, previous study showed that in Warsaw and other European cities favourite blue spaces were chosen not only in close but also in far proximity to the place of living (Wilczyńska et al., 2023).

When the survey period began, the first wave of COVID-19 restrictions, including limits on the use of urban green spaces, had ended. Although the second wave began in October 2020, access to green spaces remained possible, except for group gatherings of more than 10 people. We asked participants about their favourite blue spaces in general, with only one question specifically addressing visit frequency during the pandemic.

2.2.2. PPGIS data validation

The data collected through the geo-survey was imported into GIS software. The points given by participants were validated by excluding points:

- located more than 15 km away from Warsaw (a one-day trip distance),
- appeared in the middle of the map (limited georeferencing capacity in mobile devices),
- without any answers, outside of any blue space or referring to green spaces without water.

Points that directly referred to a certain blue space (e.g., mentioned by the name), but located outside of that area, were included in further analysis as part of that area. As a result of this manual validation, we refined the initial dataset of 854 responses to the final dataset, in which 268 respondents marked 359 locations, forming the analytical sample (Fig. 1). The sample was volunteer and therefore cannot be assumed to represent the entire population of Warsaw. This is a common limitation of PPGIS studies, particularly those focusing on certain landscape elements, such as blue spaces. Nevertheless, numerous authors emphasize that such approaches remain valuable for revealing spatial patterns and relationships that are important for further studies and future development (Brown, Kyttä, & Reed, 2022; Chelli, Raymond, Korpilo, & Geneletti, 2025; Kahila-Tani, Kytta, & Geertman, 2019).

To proceed with analysis, we transformed the parameters of social background status from numerical to categorical – e.g., numeric values '0' and '1' were recoded as 'FALSE' and 'TRUE', respectively. Additionally, ratings (on the scale of 1 to 5) responding to the question "There is a risk of flood in this place" (Table S1, Supplementary materials) were inverted to match the logic of the services, so minimum value of 1 means there is no protection from flood, and maximum value of 5 means there is no risk of flood.

2.2.3. Blue space character assessment

Next, a database of blue spaces from a previous study in Warsaw was imported for analysis (Wilczyńska et al., 2021). In this study blue spaces were understood as polygons drawn around each water element, based on existing surrounding land use or land cover boundaries, resulting in 77 polygons. (Fig. 1). Each blue space was then evaluated for its landscape character, focusing on two attributes: the relative level of management and the dominant land use or land cover of the area, as determined through inventory, aerial imagery, and personal knowledge of the area, as of 2022.

2.3. Data analysis

The workflow for our analysis is presented in Fig. 2. QGIS software Version 3.26 (Open Source Geospatial Foundation) and ArcGIS Pro were used for all spatial analysis; statistical analyses were done in R 4.3.1, with the factoextra R package v. 1.07 (Kassambara & Mundt, 2016) and Exploratory v.7.2 (Exploratory, Inc., USA, https://exploratory.io). The PPGIS software was provided by Hexagon (hexagon.org). The base map for the geo-questionnaire was obtained from Bing Maps (www.bing.com).

2.3.1. Perceived ES patterns and clusters

We took the average score of ES evaluation per participant to analyse ES rates at the individual level. We used:

a) **Spearman correlation and dissimilarity matrix** to explore similarities and differences among the ES rates. The correlation and dissimilarity matrices suggested a good clustering ability; therefore,

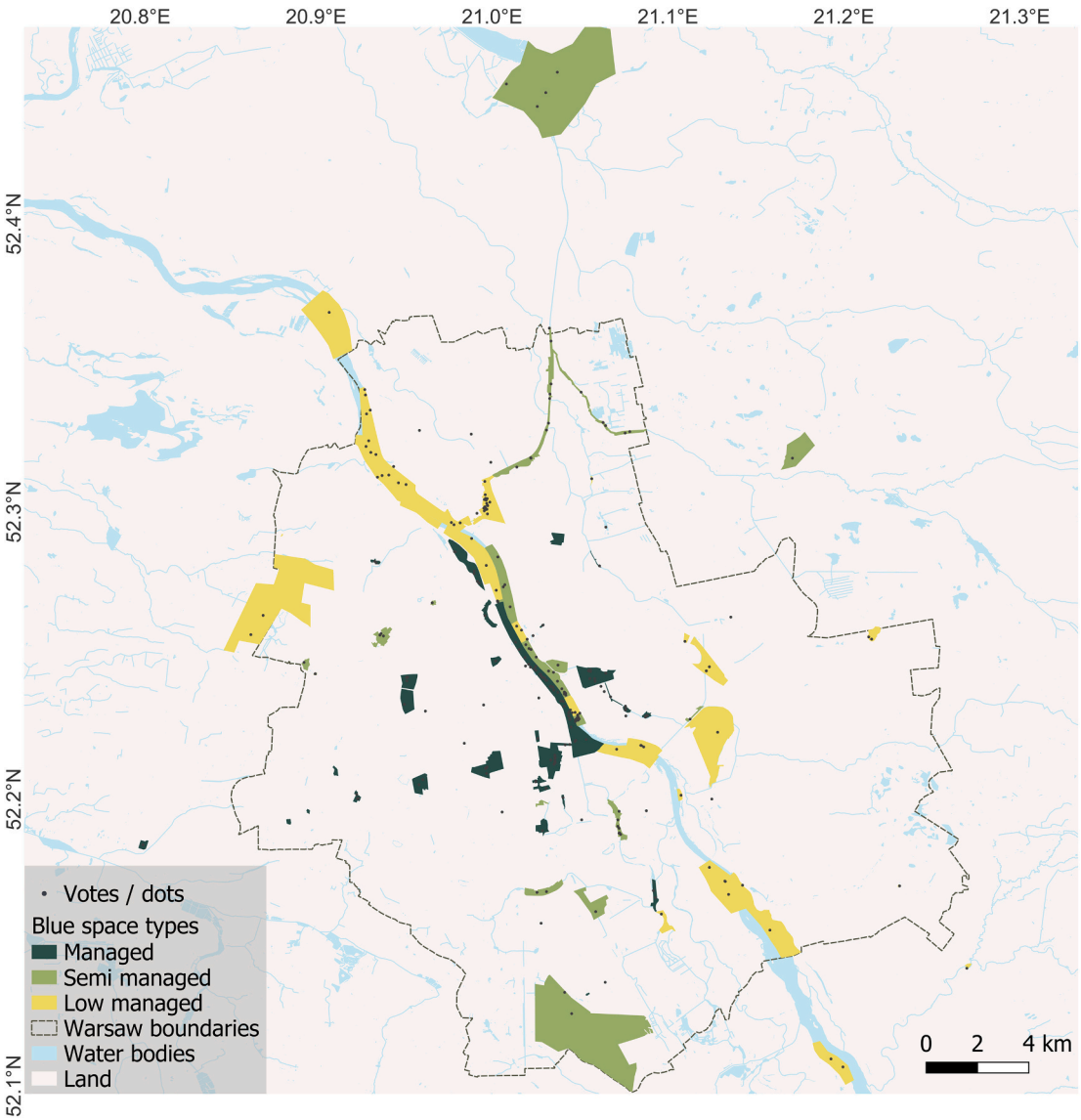

Fig. 1. Distribution of points and study area polygons.

we applied PCA (Principal Component Analysis) to the Spearman's correlation matrix to reduce noise and dimensionality.

b) **PCA components for k-means clustering**, and applied elbow and silhouette methods, which suggested five as the optimal number of clusters in the data. These align with Ward's hierarchical clustering, applied to the PCA components. PCA was used prior to k-means clustering to enhance the accuracy of k-means (Mukherjee, Doerkar, & Zhang, 2024). We also observed more distinguishable clusters based on PCA compared to the raw ES rates. K-means clustering of ES rates reveals their inherent similarity, which we interpret as quantitative bundles of perceived ES benefits.

c) **Getis-Ord Gi* index (**Getis & Ord, 1992**)**, to identify spatial clusters of consistently low (cold spots) and high (hot spots) ES rates per ES bundle and map their spatial pattern to inform landscape-scale blue space possibilities for development and management in Warsaw.

2.3.2. Perception of ES and relation to BS character types and socio-economic background of respondents

a) Firstly, all the BS characters with a frequency of 9 or less were grouped as 'OTHER'.

b) Secondly, we plotted mean ES rates per blue space character using the heatmaply R package (Galili, O'Callaghan, Sidi, & Sievert, 2018). As averages ES rates per blue space type were not normally distributed, we compared the ES rates per blue space type using a non-parametric Kruskal-Wallis test (Kruskal & Wallis, 1952).

c) We deleted/reclassified the categories of socio-economic background variables with very few occurrences. We recoded age values of 55–64 and 65–74 to 55+; and retired, housework, and unemployed working status to the common category 'OTHER'. We deleted 'garden' and 'mountains' from the place where a person spent most of their time as a child and 'NEVER' from visiting frequency of BS.

d) We plotted average ES score per socio-economic characteristic and tested the differences between the perceived ES rates using the non-parametric Kruskal-Wallis test (Kruskal & Wallis, 1952).

e) We modelled the average ES score per ES cluster with both respondent socio-economic characteristics and blue space types, to analyse relationships quantitatively, using linear regression analysis. To address multicollinearity, we applied a pairwise comparison of predictors based on their variance inflation factor (VIF), eliminating predictors with the highest VIF until all VIF values were lower than a commonly used threshold of 10 (O'Brien, 2007). We also used latitude and longitude as predictors in the VIF analysis to ensure that

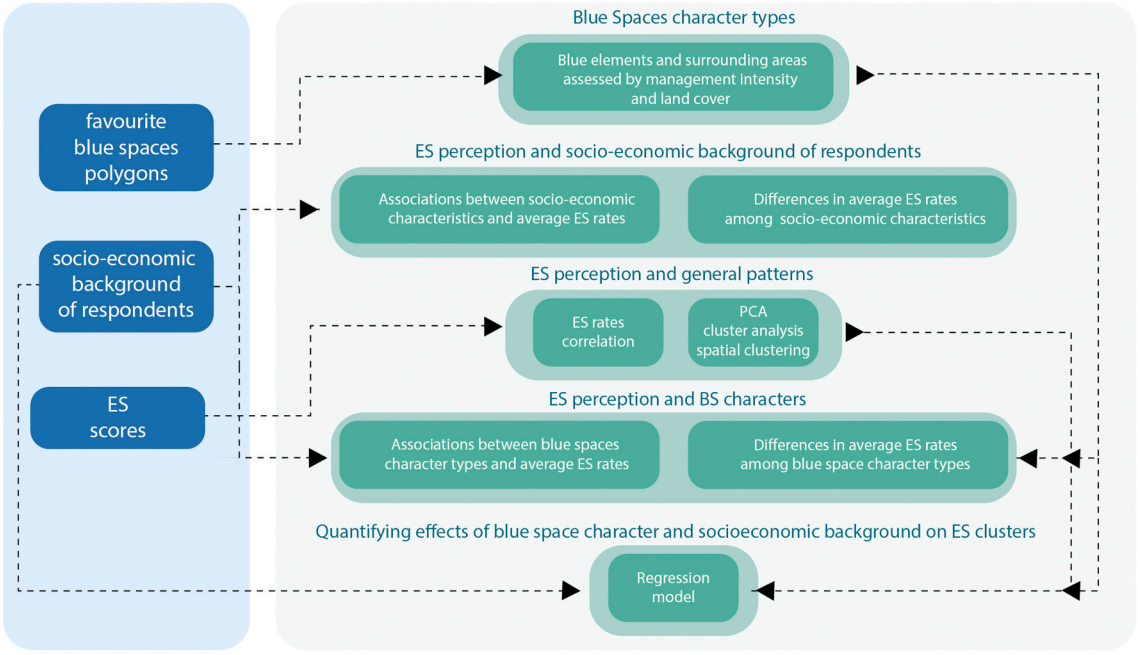

Fig. 2. Workflow of the study

other predictors do not exhibit a spatial gradient. Using the decrease in models' performance when one of the predictors is permuted, we ranked predictors by their relative importance for explaining each ES cluster.

f) Finally, we applied global Moran's I analysis (Moran, 1950) of spatial autocorrelation in the models' residuals to test if our linear regression models contain spatial bias and conceptualised spatial relationships through 8 nearest neighbours. When, in the case of the flood regulation model, Moran's I analysis suggested a strong spatial bias in its residuals, we added one additional categorical predictor – whether the vote/dot is located within a 500 m buffer around the River Vistula ('TRUE'), or not ('FALSE').

3. Results

3.1. *ES perception and general patterns*

ES rates are non-uniformly distributed across the categories (Fig. 3).

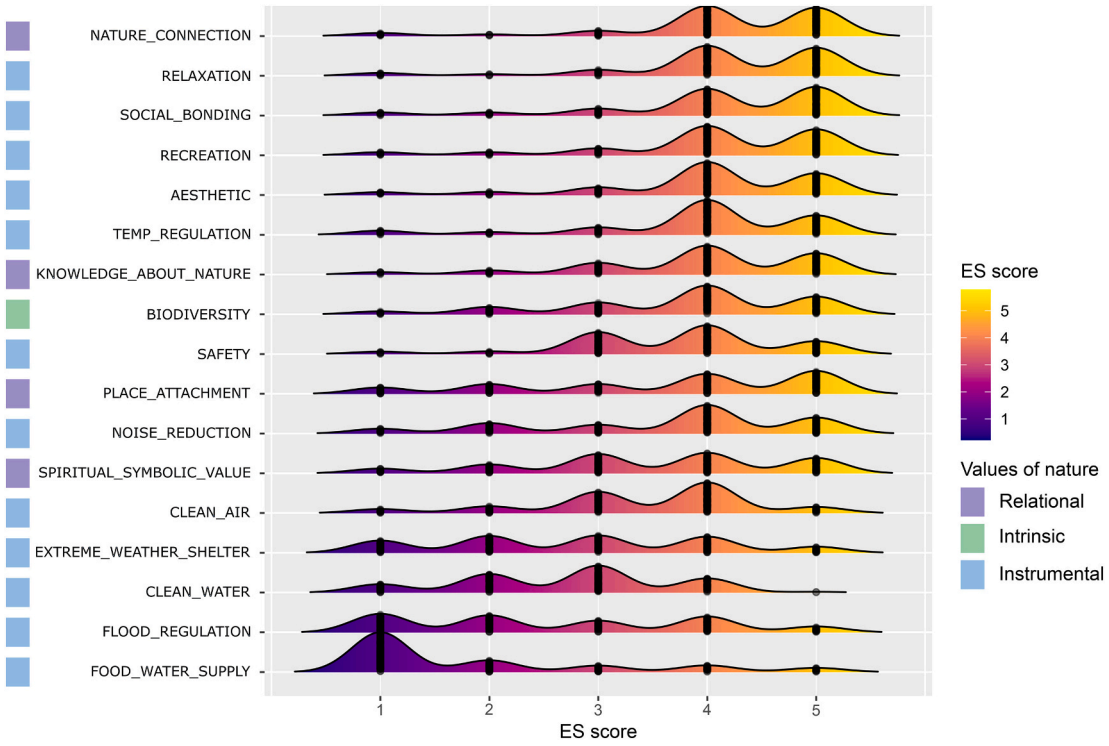

Fig. 3. Score distribution of perceived ES benefits in Warsaw's blue spaces, Abbreviations are explained in the Table S1, Supplementary Materials. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Among relational values, nature connectedness is the most highly appreciated, followed by knowledge. Place attachment and spiritual, symbolic, identity values received relatively low rates. Perceived biodiversity is also highly evaluated, with most rates of 4. The highest overall ratings are observed for ES associated with instrumental values of nature and cultural ecosystem services, such as relaxation, social bonding, outdoor recreation and aesthetics. In contrast, ES associated with instrumental values of a more material character, such as provisioning or regulating ES, including food provision, flood regulation, clean water and air, and extreme weather protection, received lower rates.

The correlation between ES rates given by respondents shows synergies (Fig. 4). The strongest correlation ($r = 0.6$) was found between perceived biodiversity and aesthetic values, as well as the possibility to obtain knowledge about nature. Knowledge about nature and relaxation are correlated with nature connectedness (r = 0.6). Noise reduction demonstrates a positive association with biodiversity, knowledge about nature, relaxation, nature connection, aesthetic and clean air. Additionally, recreation shows strong links to knowledge about nature, connection to nature and social bonding. Many positive relationships suggest redundancy in the data.

Overall, in the PCA analysis (Table S3, Fig. S1, S2, Supplementary materials), Dimension 1 indicates the transition from provisioning and regulating ES to CES. Similarly, Dimension 2 discriminates more greenery-related ES from CES. K-means cluster analysis (Fig. 5) on PCA-reduced data indicates five clusters. The first (clockwise) cluster **(WATER ESSENCE)** is connected to regulating and provisioning ES. The second cluster **(NATURE APPRECIATION)** corresponds to perceived aesthetics, as well as biodiversity and knowledge about nature. On the other hand, it encompasses clean air and noise reduction, as well as protection from extreme weather. The third cluster **(OUTDOOR RECREATION)** encompasses experiential outdoor recreational activities, including social interactions, opportunities for physical recreation, temperature regulation, nature connectedness, feelings of safety and relaxation. It is closely related to Nature Appreciation, but it is more focused on recreational use than aesthetic experience. The 4th cluster **(PLACE BONDING)** encompasses place attachment and blue space, which hold symbolic value for respondents, representing intangible values associated with blue spaces. Flood-regulating ES stand out as the fifth 'cluster' on its own – **FLOOD PROTECTION**.

Spatial concentrations of cold and hot spots at the landscape scale (Fig. 6) show that the '**WATER ESSENCE'** cluster does not reveal a strong concentration; however, hotspots are observed in areas such as Zalew Zegrzyński, a reservoir located north of Warsaw (Fig. 6, panel A). '**NATURE APPRECIATION'** hotspots are found in the more natural riverscape areas of northern and southern Warsaw, along the River Vistula. These hotspots also extend to the larger Kanał Żerański, several smaller channels, the Czerniakowskie oxbow lake, and the lake within the historic Pałac Wilanowski park in the south. Conversely, cold spots are concentrated along the central section of the River Vistula (Fig. 6, panel B). Cold spots of the '**OUTDOOR RECREATION'** cluster are predominantly concentrated along the northern banks of the River Vistula (Fig. 6, panel C). In contrast, hotspots are found in the southern part of Warsaw, particularly in areas such as beaches, parks with ponds, and the Czerniakowskie oxbow lake. The '**PLACE BOND'** cluster represents a pattern almost opposite to the '**NATURE APPRECIATION'**. Hotspots are located in the central part of Warsaw, including the west-side promenade of the River Vistula and the east-side nature path, as well as parks such as Łazienki Królewskie and Pole Mokotowskie, and recreational areas along channels like the Wystawowy and Gocławski. Cold spots, on the other hand, are concentrated along Kanał Żerański and other smaller channels in the north and northeast. The '**FLOOD PROTECTION'** cluster reveals numerous hotspots along the River Vistula in the central part of the city. Cold spots are primarily found in parks (Fig. 6, panel E).

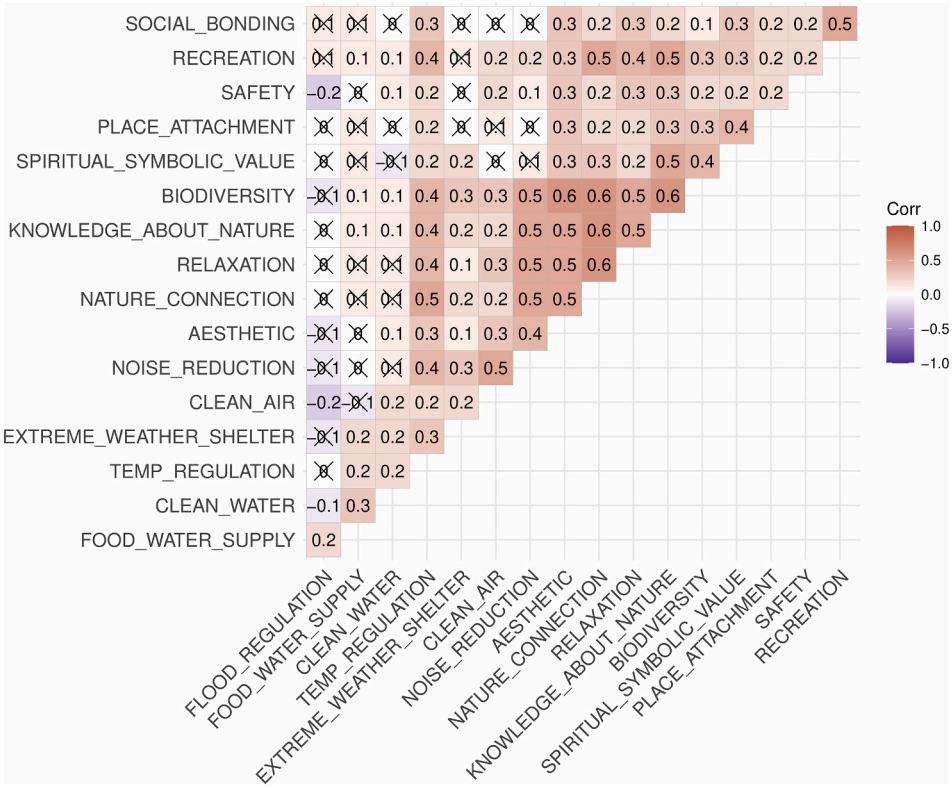

Fig. 4. Synergies between rates of ES are indicated by Spearman correlation (p-values <0.05 are crossed out). Abbreviations are explained in Table S1 (Supplementary materials).

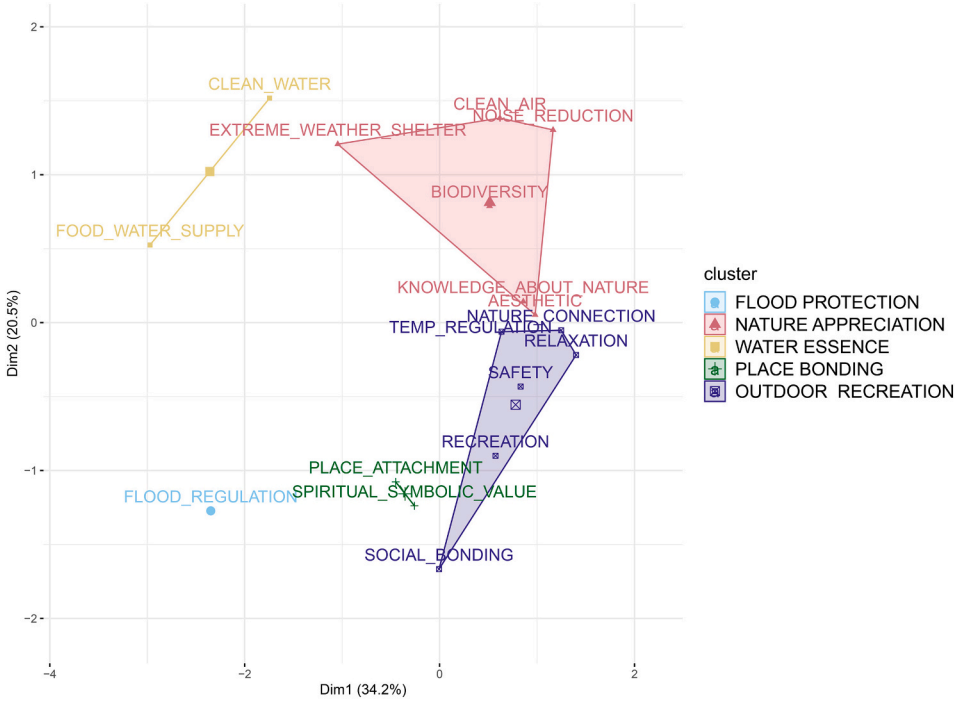

Fig. 5. Clusters of ES revealed through concordance of average ES rates among blue spaces in Warsaw, abbreviations are included in Table S1 (Supplementary materials). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

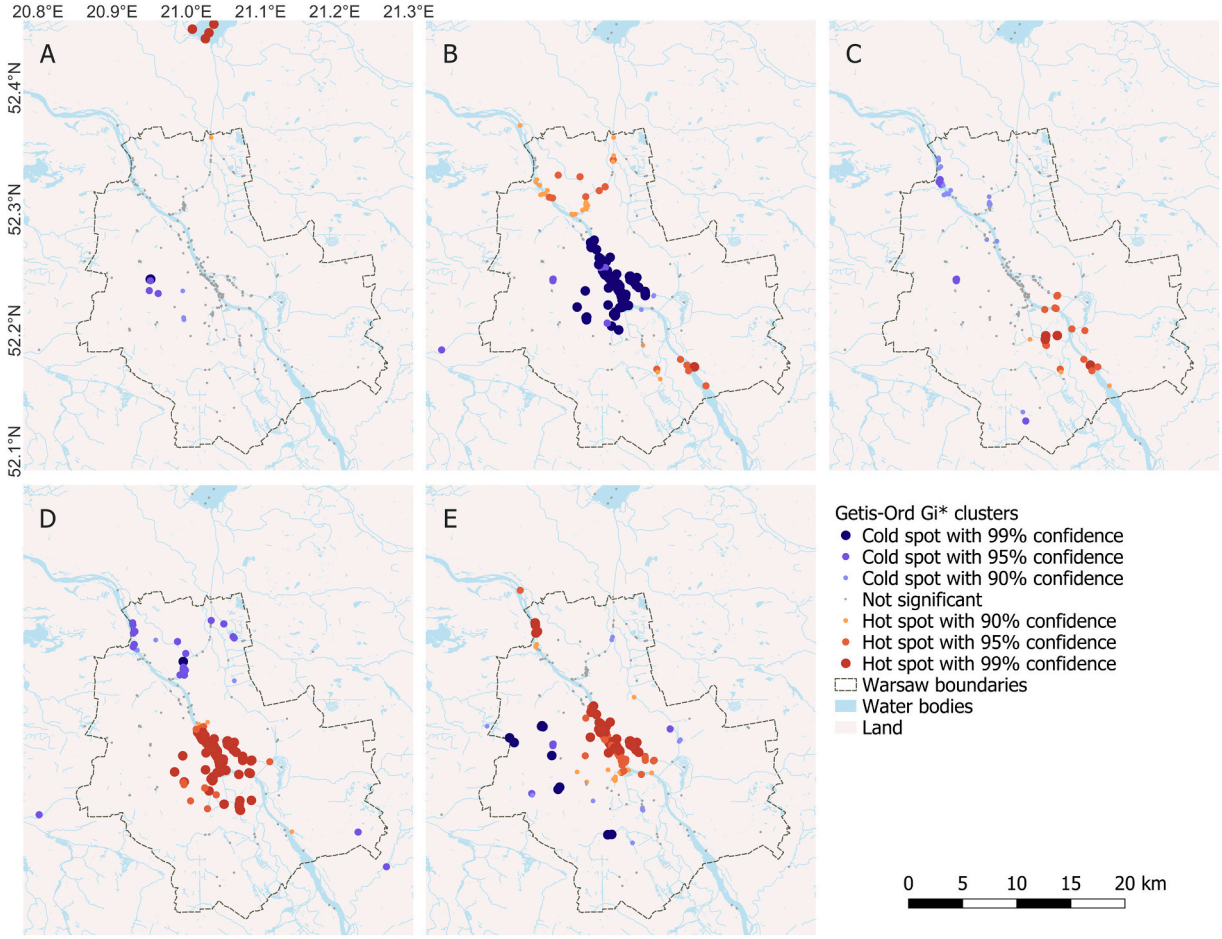

Fig. 6. Spatial clusters of higher (hot spots) and lower (cold spots) mean ES rates per ES clusters: A –'WATER ESSENCE', B – 'NATURE APPRECIATION', C – for 'OUTDOOR RECREATION', D – 'PLACE BOND', D – 'FLOOD REGULATION'.

3.2. Ecosystem services perception and blue spaces characters

We categorised BS into three types of management intensity, based on dominant vegetation and the presence of formal or informal equipment and usage patterns:

- *low-managed* areas: without or with very low management where spontaneous vegetation and uses are dominating. These spaces typically lack infrastructure or equipment, or only feature informal elements created by users.
- *semi-managed* areas: consist largely of spontaneous vegetation and are often located on abandoned sites near the urban fabric. These spaces show signs of human activity, primarily informal, however, in some areas, single top-down investments are also visible, albeit not dominant.
- *managed* areas fully developed, with mostly ornamental greenery, formal landscaping and typical park-style infrastructure.

Each BS was also classified by its dominant land use or land cover type, which together with the type of management, resulted in various BS characters. Table S4 (Supplementary materials) shows examples of pictures representing each BS character in our study.

Managed historical and urban parks, managed promenades and low-managed ports emerged as the most popular choices among respondents (Fig. S3, Supplementary materials). In terms of perceived ES, Figs. 7 and 8 illustrate that BS overgrown with shrubs (low-managed or semi-managed) are preferred for relaxation and the possibility to connect with nature. A similar pattern is visible for the semi-managed meadow areas, which are also recognised for their recreational and social bonding potential. Semi-managed beach areas, along with managed riverside promenades and urban parks, are commonly associated with social bonding, significantly more than low-managed forests. Historic parks stand out for their high perceived aesthetic value – considerably higher than some of the other BS. It is also strongly related to the possibility of connecting with nature and higher perceived biodiversity. This type of BS is much more appreciated for its spiritual identity and symbolic values than other types (especially semi- or low-managed shrubs and forests). Both neighbourhood and historic parks are valued for their potential to connect with nature, gather knowledge about it, for biodiversity, noise reduction and clean air, significantly more so than the managed promenade. The cleanliness of water, possible extreme weather protection and flood regulation are given low ratings.

3.3. ES perception and socio-economic background of respondents

People with access to community gardens report a relatively strong nature connection, and rate the possibility of relaxation, social bonding and recreation highly, especially in comparison with those without access to community or private garden spaces. Younger respondents (aged 16–24) and those in education value higher relaxation and social bonding. Notably, individuals who visited BS less frequently during the COVID-19 pandemic reported a lower degree of nature connectedness and rated the possibility to relax and spiritual identity lower than those who visited them more often (Fig. 9). Fig. 10 shows that there is a significant negative difference between groups who feel a low or medium relationship with nature and those with a strong relationship, in terms of perception of social bonding, feelings of safety, possibilities to learn about nature, aesthetic aspects and biodiversity. Men appreciate biodiversity significantly less than women, but also the aesthetic aspects of the place, in contrast to regulating services. Additionally, those who visited BS several times a week perceived it as a source of food and water significantly more than those who visited less frequently.

3.4. Quantifying effects of blue space character and socioeconomic background on ES clusters

As presented in Tables S5 and S6 (Supplementary Materials), the regression model is relatively strong for the two clusters, “Nature appreciation” and “Flood regulation”. ES in the cluster *Nature Appreciation* tend to be rated relatively low for spaces such as the managed promenade but are rated highly by respondents who have access to community gardens, feel connected to nature and are young (16–24). In contrast, lower rates are observed among respondents aged 35–54, men, and those who spent a significant amount of time in the forest or countryside during their childhood. The *Outdoor Recreation* cluster tends to be assessed as high for managed urban parks, as well as for semi-managed areas with shrubby vegetation. It is rated low by people aged 45–54 or those who spent a lot of time in the countryside as children. Geographic longitude has a minor, though still statistically significant, impact on outdoor recreation, reflecting the orientation of the River Vistula as it runs through Warsaw. The cluster Place Bond tends to be scored highly in managed parks (also historical) and among respondents who visited BS more frequently during the COVID-19 pandemic. Flood regulation aspects of blue spaces are perceived as higher for semi-managed large, shrub or meadow areas, but lower for respondents with a lower connection to nature or men. Finally, the

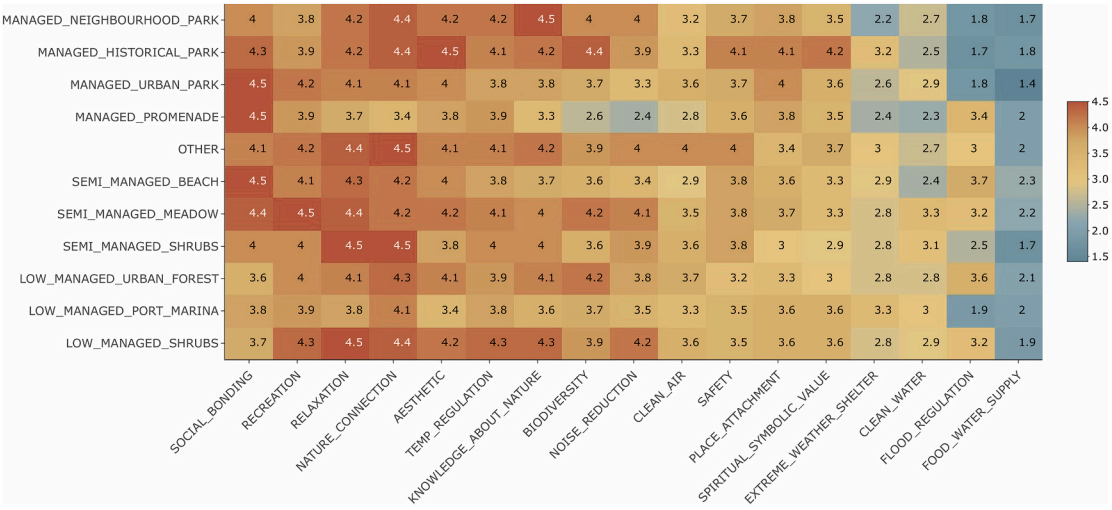

Fig. 7. Associations between blue space character types and average ES rates. Abbreviations for ES are explained in Table S1 (Supplementary materials) and for blue space character types in Table S4 (Supplementary materials). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

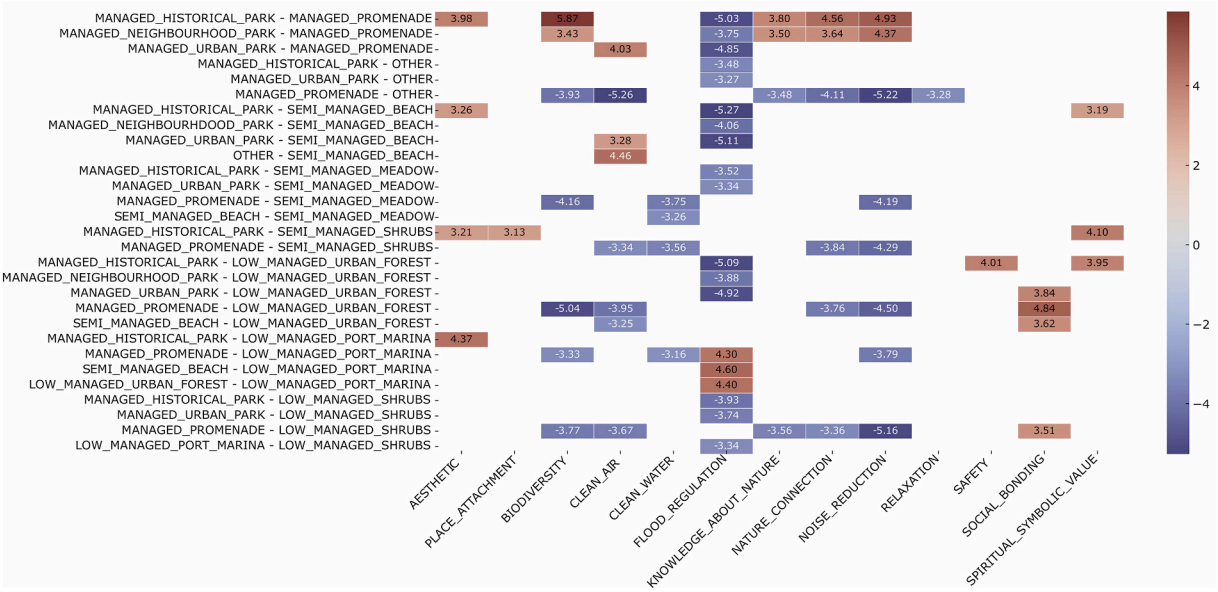

Fig. 8. Pairwise, statistically significant (p-value ≤ 0.05) differences in average ES rates among blue space character types. Reds indicate that ES ratings for the 1st blue space character type exceeds the respective value for the 2nd blue space character of the pair, and vice versa; the blues indicate that the 1st one is lower than the 2nd one in each pair. Abbreviations for ES are explained in Table S1 (Supplementary materials). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

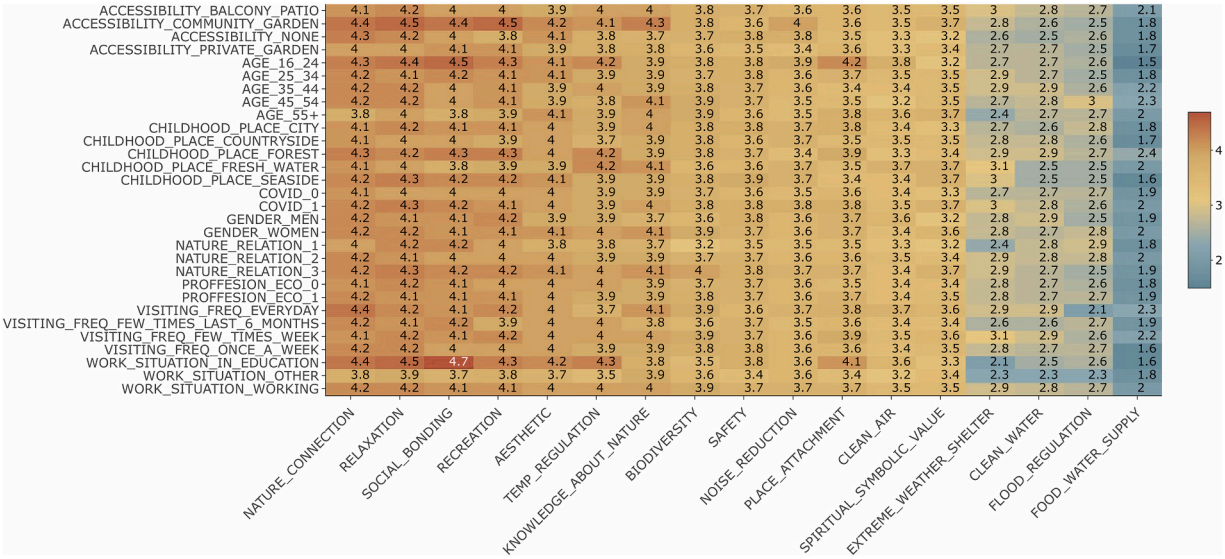

Fig. 9. Associations between personal socioeconomic characteristics and average ES rates (marked). Abbreviations for ES are explained in Table S1 (Supplementary materials) and for socioeconomic characteristics in Table S2 Supplementary materials.

cluster Water Essence tends to be scored higher by respondents who visit BS more often, but lower for respondents who spent a lot of time as children in the countryside, forest, nearby water elements as well as in the city.

4. Discussion

Our study demonstrates that PPGIS based socio-cultural evaluation of ES approach, rarely applied in the blue spaces context, proved to be an important tool for understanding how citizens perceive and spatially value different types of urban blue spaces. For the survey respondents, nature connectedness, recreation, aesthetic appreciation and social bonding were among the higher-scored ES benefits. These findings align with studies of rivers in Warsaw (Bąkowska-Waldmann, 2022; Grzyb, 2024) and other blue spaces (Korpilo et al., 2023; Vierikko & Niemelä, 2016) or peri-urban blue-green areas around Tallinn (Nevzati et al., 2024). Relaxation is the second-highest assessed benefit, supporting previous evidence on the stress-reducing effects of BS (Beute et al., 2020).

We found that socio-cultural values of ES and their synergies offer essential knowledge for balancing ecological functions with respondents' needs. Our data revealed five distinct clusters of perceived ES benefits. The largest is **OUTDOOR RECREATION,** which among others brings together social bonding and recreation, aligning with the study by Rall et al. (2017) and Grzyb (2024). Our findings also suggest that places offering a sense of connection to nature and pleasant temperature conditions may encourage active recreation, relaxation and social interactions. The next cluster, **NATURE APPRECIATION,** is closely

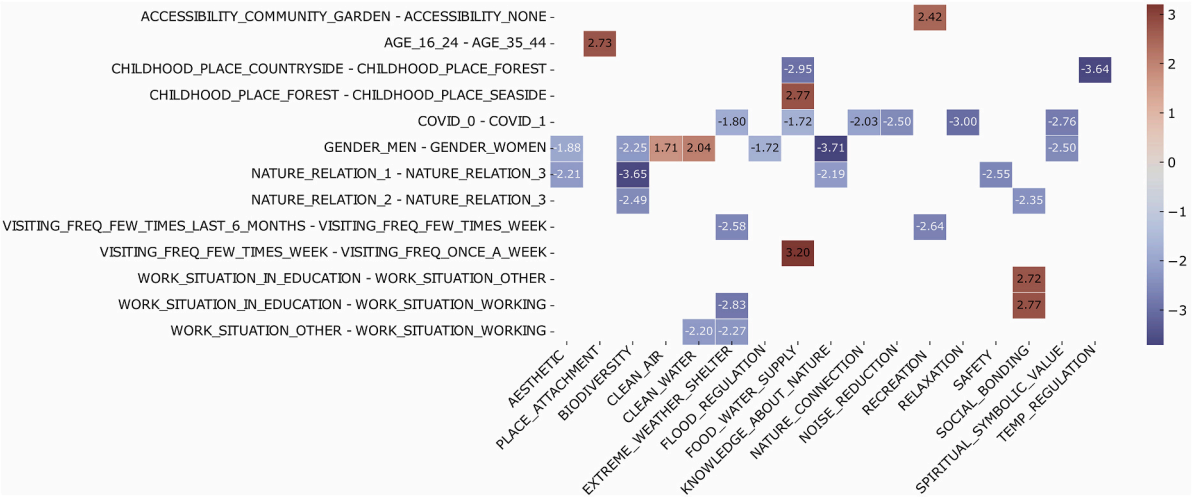

Fig. 10. Pairwise, statistically significant (p-value ≤0.05) differences in average ES rates among socio-economic characteristics. Reds indicate that the score for the 1st characteristic exceeds the respective value of the 2nd one and vice versa, the blues indicate that the 1st one is lower than the 2nd one in each pair. Abbreviations for ES are explained in Table S1 (Supplementary materials) and for socioeconomic characteristics in Table S2 (Supplementary materials).

related to Outdoor Recreation; however, along with regulating services, it also includes aesthetic values and biodiversity, echoing research on the perception of informal green areas (Gawryszewska et al., 2024). Additionally, correlation analysis indicated a positive and strong relation between biodiversity and relaxation (included in the previous cluster). Indeed, spaces with higher perceived biodiversity and plant richness offer greater restorative potential (Muratet et al., 2015; White et al., 2017). The third cluster, **PLACE BOND**, encompasses relational values such as symbolic meaning and place attachment, which were among the lowest-rated CES in our study, unlike the River Vistula study by Grzyb (2024). Better recognition and understanding of these symbolic values can support more effective communication around conservation issues (Vári et al., 2022). The last two clusters, **WATER ESSENCE** and **FLOOD PROTECTION,** are associated with instrumental values connected to provisioning or regulating ES, that received lower rates.

By choosing Warsaw as the study area, we were able to provide a context-specific evaluation of diverse types of blue spaces with different management intensity. The results demonstrated that blue spaces, depending on their type and level of management, serve different yet complementary benefits important to respondents, especially when green, blue and grey infrastructure areas are considered as interconnected layers of the landscape (Andersson et al., 2019). We observed that relaxation and nature connection are strongly associated with semi-managed and low-managed spaces with shrubs or meadows. Other authors suggest that informal areas can enhance the calming effect, however, some, even limited interventions, such as paths and signs of care, should be present to ensure accessibility and safety, without compromising their natural character (Gawryszewska et al., 2019; Grzyb, 2024; Herman et al., 2021; Hofmann et al., 2012; Kowarik, 2023). On the other hand, managed historical parks were appreciated for biodiversity, nature connectedness and aesthetics, which are less likely to be observed in places such as the managed Vistula promenade, which primarily serves as a social hub. Historic parks are often rich in various types of old trees, lush shrubs and meadows, which together with a connection to the place has been shown to support mental restoration (Gonçalves et al., 2021). Managed neighbourhood parks emerged as places for learning about and daily contact with nature, highlighting their role as accessible, everyday green spaces (Gatersleben et al., 2024).

Semi-managed blue spaces can play a crucial role in education and youth engagement initiatives, supporting long-term stewardship and contributing to broader goals of transformative change and inclusive, sustainable, and equitable environmental governance (IPBES, 2024). In our study, we observed a strong association between younger respondents and their perception of ES, particularly in terms of relaxation and social bonding. Moreover, respondents with a stronger connection to nature also showed a higher appreciation not only of ecology-connected ES, but also social aspects, highlighting the importance of exposure to the natural environment during childhood (Milligan & Bingley, 2007) in nurturing future awareness (Gunnarsson et al., 2017). Notably, we found significant differences in perceived biodiversity and other ES among individuals who feel a low or medium connection to nature compared with those who feel a strong connection. This highlights the need to ensure the equal access to blue spaces, as socio-economic barriers may reinforce existing inequalities.

Having access to community gardens emerged as a predictor for perception of the nature appreciation cluster. There are many examples demonstrating the environmental and social importance of community gardens, which can work as places to bring people closer to nature (Certomà et al., 2019; Langemeyer et al., 2018). Respondents who reported visiting BS more frequently during the COVID-19 pandemic rated ES such as nature connectedness and relaxation more highly, reflecting broader evidence of the essential role public nature spaces play during times of crises (Gatersleben et al., 2024; Grima et al., 2020). Interestingly, the Nature Appreciation cluster was rated lower by male respondents, which may support some studies suggesting that women have a greater appreciation for ES (Langemeyer et al., 2018).

4.1. *International context and urban policy recommendation*

Our results align with international research on Informal Green Spaces and urban wastelands, which highlight their social, ecological, and recreational importance in cities across various regions, including Germany (Kowarik, 2023; Pueffel et al., 2018; Samus et al., 2022), Poland (Sikorski et al., 2021), Estonia (Unt & Bell, 2014) and elsewhere (Rupprecht et al., 2015). In this sense the term 'Informal Blue Spaces' can be introduced to describe such multifunctional areas in diverse geographical contexts. However, informal blue spaces may also suffer from pollution and neglect of the waterbody which may pose more problems for using them than for informal green spaces.

The recognition of socio-cultural values of ES benefits and their relation to blue spaces type and management intensity provides planners with tools to set priorities and develop blue-green infrastructure strategies. Considering the less flexible nature of urban water planning and design (it is not as straightforward to provide new waterbodies as it is to establish a small park), this becomes a crucial step in ensuring resilience.

This perspective is particularly relevant for implementing national and EU-level frameworks, such as the Nature Restoration Law (European Commission, 2022), which aims to prevent loses in green spaces, restoring degraded ecosystems and strengthening human-nature relationships. Our findings resonate with Ferraro and Whitehead (2025), who argue that nature restoration efforts, should centre on rebuilding the human-nature relationship, values and perceptions of nature. Both informal and managed blue spaces illustrate how these relationships can be fostered within a dense urban environment. In this context PPGIS based methods for socio-cultural evaluation of ES benefits are valuable tools, that make it possible to identify preferences, values, as well as potential for development.

4.2. Limitations of the study

Our study has several limitations. First, the geo-questionnaire sample did not cover a representative number of respondents in Warsaw; it may exclude certain groups, which is a common issue in PPGIS studies, especially when based on a volunteer sampling method (Brown et al., 2022; Chelli et al., 2025). Like other internet-based methods, prior studies also highlight challenges with this method, such as the willingness to complete surveys, which can be mitigated through improved outreach and targeted communication strategies (Ramirez et al., 2023). Additionally, further research that incorporates qualitative, on-site methods and involves more diverse stakeholder groups is needed to strengthen contextualised findings (Walz et al., 2019) In some cases, there were also technical limitations related to the precision of the PPGIS application, especially on the phone, which resulted in some cases with imprecise marking on the map. Additionally, while the typology of BS was based on dominant land use and management intensity, this necessarily simplifies the more nuanced reality of urban water landscapes. A more granular, qualitative investigation into how specific features within each blue space are perceived would help capture this complexity. With greater resources, the study could be replicated with a larger and more diverse sample and supplemented by on-site or interview-based methods for deeper insight.

5. Conclusions

Blue, green, and grey areas in cities are interconnected, therefore, it is essential to assess and design blue elements, along with their surrounding landscape, as blue spaces. This study examined how people in Warsaw perceive different types of blue spaces and their value, depending on the management approach. We found that, in general, blue spaces are most valued for recreation, social bonding, but also relaxation, nature connection and aesthetic appreciation, linked to their perceived biodiversity. While CES benefits were rated highest, some regulating services, like temperature regulation were also recognised. This was reflected in five distinct, yet interconnected clusters, illustrating the complexity and complementarity of how blue spaces are experienced.

In the eyes of respondents low-managed and semi-managed blue spaces play an important role in delivering a range of ecosystem services, such as recreation, relaxation, connection to nature and social bonding. Our findings highlight the multifunctional character of semi-managed blue spaces, which maintain a natural and informal character important for urban biodiversity, while also providing opportunities for safe, accessible recreation and social use. These areas offer a low-cost alternative to more formal blue and green spaces in cities. Managed blue spaces, such as urban parks or promenades are mainly associated with social bonding. However, historical and neighbourhood parks foster everyday nature experiences and are appreciated for their biodiversity and aesthetic value.

Moreover, our findings suggest that while socio-economic background alone does not strongly influence how people perceive ecosystem services, a closer relationship with nature, frequent visits to blue spaces, and involvement in initiatives like community gardens are associated with higher appreciation of many benefits. This underscores the importance of establishing a connection to nature from a young age, but also emphasises the need to ensure equitable access to blue spaces to develop a foundation for long-term environmental awareness.

CRediT authorship contribution statement

Anna Wilczyńska: Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Oleksandr Karasov:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Formal analysis, Conceptualization. **Izabela Myszka:** Project administration, Investigation, Formal analysis. **Fiona Nevzati:** Writing – review & editing, Writing – original draft. **Simon Bell:** Writing – review & editing, Supervision, Conceptualization. **Sebastian Candiago:** Writing – review & editing. **Olle Järv:** Supervision, Methodology, Conceptualization. **Beata Gawryszewska:** Writing – review & editing, Writing – original draft, Investigation.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used Grammarly in order to proofread the text. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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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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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cities.2026.106902.

Data availability

As we wish to undertake additional analyses, we are currently withholding the database; however, it is available upon request.

The code is available in the following repository: https://github.com/oleksandrkarasov/WarsawES.

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