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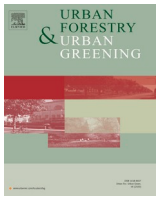

Assessing distributional justice around Cultural Ecosystem Services (CES) provided by urban green areas: The case of Bologna

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ABSTRACT

Cultural Ecosystem Services (CES) and related flows of benefits – heavily influencing societal and individual health and wellbeing - are usually ascribed non-consumptive values. However, despite the increasing recognition of their contribution to citizens' quality of life, the intangible nature of CES makes it difficult to quantify them and hard to be integrated in decision making and planning processes. Nevertheless, the assessment of the societal relevance of CES would largely help to improve people wellbeing and quality of life. CES depend not only on the characteristics and features of urban green areas, but also on preferences and needs of the users that interact with them and that contribute to co-produce ES related benefits and values. These diverse needs, coupled with the uneven distribution of urban green area and diverse ways of managing them in the city, could affect the way ES are produced and further exacerbate existing inequalities and disparities. This contribution investigates the case study of the city of Bologna, introducing a spatial approach based on a new and pluralistic notion of urban green area that consider sport facilities and Green Stewards activities, to assess the related CES co-production paths and distributional dimension of justice in the city. Results show a good accessibility to urban green area throughout the city of Bologna (around .70 %). Nevertheless, CES co-production paths are limited in those areas of the city with higher population vulnerability index, due to lower urban green area facilities and green stewards activities, thus highlighting areas with higher distributional and procedural injustice path.

1. Introduction

Cultural Ecosystem Services and related flows of benefits – mostly related with health and personal wellbeing - are usually included under non-consumptive values (millennium Ecosystem Assessment, 2005) and, despite the increasing recognition of their value into citizens' quality of life, they still suffer from poor quantification and integration in decision making and planning processes (Tandarić et al., 2020).

Whereas mapping the location and quantifying the benefits of regulating services can be straightforward, the quantification of 'intangible' cultural ecosystem services could be more challenging. Since CES are not understood as "a priori products of nature that people utilise for a particular benefit to wellbeing, but rather as relational processes and entities that people actively create and express through interactions with ecosystems" (Fish, Church, & Winter, 2016), humans are critical to both CES production and valuation - as both occur at least partly in the mind of the observer (Dickinson & Hobbs, 2017). Therefore, cultural services strongly depend not only on the characteristics and features of Green and Blue Infrastructure (GBI), but also on perceptions and expectations of the users who interact with the existing GBI (demand factors) (Hegetschweiler et al., 2017).

For this reason, considerable conceptual and technical work is needed to adequately represent and model the complex socio-ecological relationships that define and constrain a given cultural eco-system service (Daniel et al., 2012). CES are also strongly place-based as different sites, even presenting similar characteristics and features, would generate unique experiences, and related benefits, for users (Satterfield, Gregory, Klain, Roberts, & Chan, 2013).

Moreover, CES co-production and benefits uptake could be affected by different socio-cultural characteristics of the population (income, ethno-racial characteristics, age, gender, (dis)ability, and other axes of difference) defining some groups of users as vulnerable because having uneven accessibility to urban greenspace (J. R. Wolch, Byrne, & Newell, 2014). Since the benefits generated by CES such as landscape aesthetics, outdoor recreation, and educational services are strictly dependent on the access to and the activities that beneficiaries perform in a specific

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place and time, the uneven distribution of ecosystem services (in general) and cultural services (in particular) in urban areas can exacerbate exiting disparities (Jennings, Larson, & Yun, 2016), touching issues related with the distributional aspects of justice (Fang et al., 2023; Nazmul Haque & Sharifi, 2024). Despite the recommendation coming from the World Health Organization (WHO, 2016) and from the Sustainable Development Goals 11.7 to develop an indicator reflecting proximity of population to urban green areas, so far most of European cities have assessed the presence of green areas through a recognized planning standard, normally consisting of a quantitative indicator, defined by m^2 of green space per capita(De Luca et al., 2021). Such an indicator does not consider urban green areas spatial distribution and may result in bias towards certain locations and hence, social groups (Texier et al., 2018). Proximity and accessibility to urban green areas for citizens is at present one of the most debated indicators for making cities more equitable, resilient and sustainable (Van Herzele and Wiedemann, 2003; Baycan-Levent and Nijkamp, 2009; Quatrini et al., 2016; Martins and Nazaré Pereira, 2018).

Cities are complex adaptive socio-ecological systems with urban GBI being key in enabling humans' perceptions and experiences of nature therein. Understood as co-produced services distributed by the existing GBI to the population, CES valuation is increasingly gaining attention through participatory and bottom-up processes (Andersson, Tengö, McPhearson, & Kremer, 2015; Colding & Barthel, 2013) to improve current GBI management and to reinforce future GBI planning. According to Rockström, 2015, stewardship of ecosystem services (ES) is one of the greatest challenges for landscape and urban planning in the 21st century, but underlying factors enabling ES stewardship are still poorly understood. Social, procedural and institutional processes can significantly influence the perception of ES values in the urban GBI since community management and enhanced property rights stipulate place identity and social cohesion (Andersson et al., 2017). Researchers have used a variety of monetary and non-economic approaches to assess the 'intangible' and valuate CES. The methods to evaluate CES demands include expenditures or willingness to pay for pre-defined services (van Berkel & Verburg, 2014), travel costs and experience valuation (Ruiz--Ballesteros & Cáceres-Feria, 2016), surveying perceptions through offline and online questionnaires (Subiza-Pérez, Hauru, Korpela, Haapala, & Lehvävirta, 2019), stakeholder workshops (Schubert et al., 2018) or experts' interviews and visitor observations. Very different methodologies have been developed and used so far to assess potential CES supply. Several studies mapped habitat, structural or even species diversity, while most of them evaluated accessibility and proximity of urban GBI (Martins and Nazaré Pereira, 2018; Quatrini et al. 2016), availability (De Luca et al. 2021) and data about the size or shape of the green space (Hegetschweiler et al., 2017). The supply and distribution of green spaces in the city, district, or neighborhood was addressed by many authors, using data on facilities for sport, play or relaxation, though only their presence or quantity have usually been taken into account (Camps-Calvet et al., 2016; Hamstead et al., 2018; Ye, Hu and Li, 2018).

Nevertheless, the distributive dimension of justice and CES, considering people's needs in terms of their recognized vulnerability, has often been overlooked.

Based on this and building on (Ernstson, 2013; Jennings, Larson and Yun, 2016; Baró et al., 2019), this study looks at distributional justice/injustice related to the provision of CES in the city of Bologna. The specific aims of this paper are to i) investigate the role of sport facilities and green stewards in assessing the potential supply of CES and its implication for planners and decision makers in dense and compact cities and ii), exploring CES supply and demand correlation with the lens of distributional justice, looking at CES supply and accessibility in relation with population vulnerability distribution. In this context, this works aims at addressing the research gaps identified in the agenda for urban green spaces in Europe highlighted by (Rutt & Gulsrud, 2016), specifically regarding the development of spatial analyses based on a new and pluralistic notion of quality (including sport features and co-production path in the assessment of CES supply) and relating this with CES distributional dimension of justice in the city.

2. Material and methods

2.1. Case study and Data

Bologna is a dense and compact city, at the heart of the Emilia-Romagna region, with around 390,000 inhabitants. The southern hilly area is predominantly forested and features semi-natural landscapes, hosting a relatively small population. In contrast, the city center and its immediate surroundings are densely populated, characterized by limited urban green spaces and no available land for expansion. The average population density is around 2700 inhabitants/km^2, reaching around 10,000 inhabitants/km^2 in the historical city center. According to the latest georeferenced data from 2020, Bologna is home to 391,984 residents, with around 53 % of women and 47 % of men. Of this population, around 30 % are adults (45−64), followed by the 21 % of younger adults' (30−44). Older adults over 65 years old make up the 24 % of the population while youth (15−29) account for just 14 %, and children (0−14) represent 12 % of the total demographic (Città Metropolitana, n.d.).

Looking at the aims of this study, Bologna is an illustrative case since current land use and population projections make it hard to develop new green areas in the densest part of the city, and availability of existing green area is quite limited, making them crowded and overused ((De Luca et al., 2021). Furthermore, while other studies have focused on regulating ecosystem services (Vignoli et al., 2021), and despite the significant role that cultural ecosystem services (CES) have played in the recently published Master Plan for the city, a comprehensive assessment of CES has yet to be conducted. Most of the spatial data utilized—pertaining to urban green spaces, road networks, building locations, and land use—originates from the open-access platform of the Municipality of Bologna. The georeferenced information of the population living per street number was retrieved from direct communication with city functionaries since this information is not publicly available. Most of the other data (e.g., urban green area access point, sport features presence and type) have been obtained through field visits, social media, and analysis through Google Earth and Google Street View.

2.2. Methods for CES supply and demand assessment

CES supply is intended here as the potential of urban green area for urban outdoor recreation and education activities and will be calculated through proximity analysis and through the development of the Urban Recreation Potential Indicator (URPI). In particular, we will refer to "proximity" as the distance calculated through a network analysis from urban green areas access point through the available road network (Comber et al., 2008; Martins & Nazaré Pereira, 2018). Proximity can thus be considered as one feature of accessibility, defined as the geographical distribution of urban green areas. Specifically, in this study we will refer to the methods and results described in (De Luca et al., 2021).

Based on (Cortinovis et al., 2018; Paracchini et al., 2014), this work developed the URPI as an urban-tailored composite indicator for assessing CES potential supply in an urban environment considering:

i) Urban green areas size: larger areas with more natural vegetation might offer more or deeper restoration than small areas with little vegetation (Ekkel & de Vries, 2017; Ibes, 2015), thus influencing experiential and cultural related services; thus, urban green areas' size will be considered as a proxy for people's preference for more diverse and bigger areas. Urban green areas' size has been measured using land use satellite data coming from Copernicus and computed through GIS software.

ii) Sport feature presence and quality: while most of current studies considered just the mere presence of sport features into a defined urban

green area (Hegetschweiler et al., 2017), this study takes into consideration the potential users' needs. For stimulating physical activity, that enable most of CES related health benefits uptake, the presence of sport features may influence the activity (Hegetschweiler et al., 2017) and the target groups addressed (Gong, Zheng and Ng, 2016; Ekkel and de Vries, 2017; Kabisch and van den Bosch, 2017). Within this work we considered the following kind of sport features (e.g. running path; sports fields; hiking trails; children playground; advanced equipment and equipment's for seniors) Aware that other socio-demographic characteristics may have been considered (e.g. gender, race, etc.), in this work we focused on 3 diverse target groups based on age of potential users: children (children playground), young and adults (running path, sport fields, hiking trails, advanced sports equipment, e.g. Calisthenics) and older adults (exercise equipment for seniors) (Marcos-Pardo et al., 2023). We then assume that the more numerous the target groups that could be addressed by those features in one urban green area are, the higher the quality of sport features present in an area is, as shown in Table 1. Within this work, urban green areas' sport features have been analyzed through the street view navigation of Google maps and further detailed through the online reviews posted by the users of the parks, consulted manually between the end of 2021 and the beginning of 2022.

iii) Urban green stewards: facilitating social cohesion and educational services could require not just properly designed urban green areas, but also actors able to facilitate the flow and the co-production of such services. Environmental organizations, associations or community initiatives that implement a wide range of activities in urban green areas (e.g. educational and cultural activities, green maintenance, urban farming, social activities, etc.) can be considered as green stewards (Andersson et al., 2017; Ferreira et al., 2020) and largely support the flow of benefits to part of the population that otherwise may be excluded. Actors enabling nature-based practices and recreation opportunities in green areas are here considered as urban green stewards capable to reinforce and enable CES flows within urban green areas. To assess the presence of these green stewards in the city we propose to map community-based initiatives, organizations, or single citizens actions active in urban green areas, to understand the type of activities they perform (Maintenance, Social, Cultural, Educational, Environmental, Sports) and their frequency (weekly, monthly, annually, just once). Within this work, we mapped green stewards operating in the urban green areas through institutional sources (Iperbole, n.d., Fondazione Innovazione Urbana, n.d.) and through open access maps representing the districts' participatory processes "Laboratori di quartiere" (Fondazione Innovazione Urbana, n.d.). Social media pages of citizens groups or association were also investigated for a better understanding of the presence and the typology of activity proposed and of their frequency. All the identified green stewards have been georeferenced and located within the urban green area where they are operating. Websites have been consulted between the end of 2021 and the beginning of 2022.

The three components of the URPI (size, sport features and green stewards) present different units of measurement. Therefore, we propose a normalization procedure to perform a comparison among different urban green areas. Among the several existing normalization techniques, here we use a Min-Max, 0-Max normalization, identifying, where relevant, outliers to the value function that would need to be removed at first. As for green stewards, we considered the total numbers of community-based initiatives, organizations, or single citizens actions mapped in each urban green area as the value to be normalized, this assigning 0 to the urban green area with less green stewards active, 1 to the areas with the maximum value and then interpolating the other values in between 0 and 1. Concerning sport features quality, the assigned values already falls within the 0–1 range (see Table 1). Then, within this work we considered the 3 components of the URPI as equally important, but they could be weighted according to stakeholders' and or experts' judgment.

Table 1
Values assigned to the urban green areas in relation with sport features identified.

Target groups address	Value assigned to the urban green area
No target groups addressed – no sport features	0
One target group addressed	0,4
Two target groups addressed	0,8
Three target groups addressed	1

CES demand refers to the socio-demographic and socio-economic characteristics, and relative preferences, needs and values of the population (Plieninger et al., 2013). The literature defines children, older adults and low-income people as having the greatest needs for urban green area (Talen, 2003; Wolch, Wilson and Fehrenbach, 2005). This work will not explore expressed preferences of the population, but it will consider available georeferenced data on socio-economic characteristics of the population such as age, socioeconomic status (income and level of educational attainment) and risk of social exclusion (immigration rate). This data are found in a composite index developed by the City of Bologna (Comune di Bologna, 2020) and available per census track. The values of the vulnerability index have been reclassified defining three classes of vulnerability (low, medium, and high) associated with the city census tracks.

2.3. CES supply and demand correlation method

To assess the access to urban green areas in the city, a proximity analysis of urban green areas was performed and then correlated with population georeferenced data. To better evaluate accessibility at a spatial level and to support planners and decision makers in the identification of hotspots of mismatches, three accessibility classes have been defined considering the distance of 300 m, as suggested by (WHO, 2016):

- low accessibility (<50 % of population has access to urban green areas within 300 m),
- medium accessibility (50–70 % of population has access to urban green areas within 300 m)
- high accessibility (>70 % of population has access to urban green areas within 300 m)

Then, urban green areas Accessibility and urban green area URPI values aggregated per census track have been related with population's vulnerability to assess distributional and procedural justice/injustice in the city.

Indeed, while accessibility analysis may show mismatches in terms of CES quantitative supply (proximity) and demand (population), without considering qualitative characteristics of the supply (URPI) or the demand (population vulnerability), this second analysis complements the previous results by looking at the relation among these different components. To investigate the relation and the dependencies among population vulnerability, urban green area quality (URPI) and urban green area quantity (accessibility) a *linear regression* on R was used to determine whether there was a statistically significant difference between the distribution patterns of the response and the explanatory variables under investigation. Continuous measures of classes of the 3 variables have been considered. We then performed the Durbin-Watson test for autocorrelation and inspected residuals for model validation.

3. Results

3.1. CES Supply and demand results

As explained in previous section, we performed a network analysis approach to calculate proximity to urban green areas in the city of Bologna and the results are shown in Fig. 1 below (see also De Luca et al.,

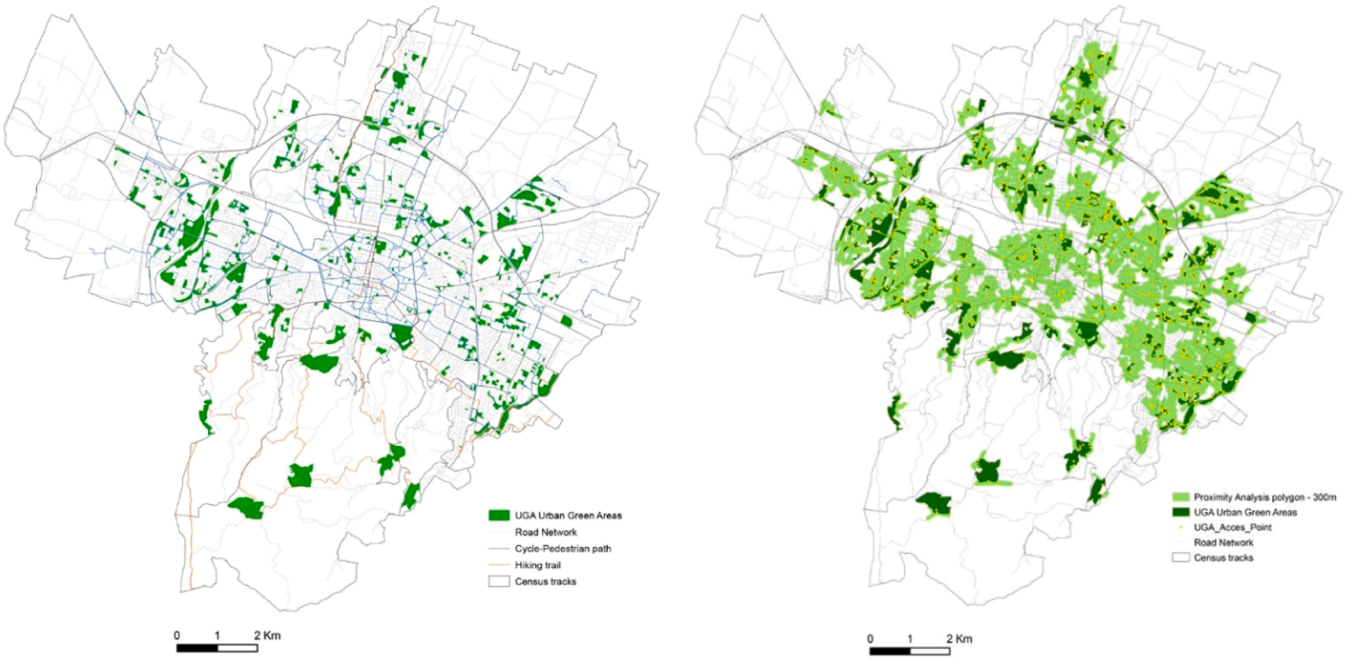

Fig. 1. Urban green area's distribution in the city of Bologna and proximity analysis results.

2021).

There are 321 accessible urban green areas in the city of Bologna and their distribution looks inhomogeneous, with small urban green areas located within and around the city center and within the first ring of periphery, while the biggest urban green areas are far from the city center. The network analysis for proximity assessment produced polygons as green buffer areas around urban green areas. These buffer areas correspond to the area of the city that could potentially be covered by the Cultural Ecosystem Services provided by urban green areas.

As described in Section 2.1, the URPI has been built considering 3 different indicators: i) urban green area's size, ii) urban green area's sport features quality and iii) urban green area's Green Stewards. This section presents first the results of the three diverse indicators, and then shows the final composite URPI for each urban green area.

i) Urban green area size: The scatter chart in Fig. 2 shows the size (ha) of all the urban green areas mapped in the city of Bologna. 80 % of urban green areas in Bologna are smaller than 2.5 ha and just 5 % of the urban green area covered an area bigger than 10 ha. The mean value is 2.3 ha, while the median corresponds to 0.89 ha. In the normalization process, the maximum value (1) has been assigned to outliers' values (above 14 ha). A significant share of urban green area is located at the riverside on the eastern part of the city and at the southwestern border line. Generally, as

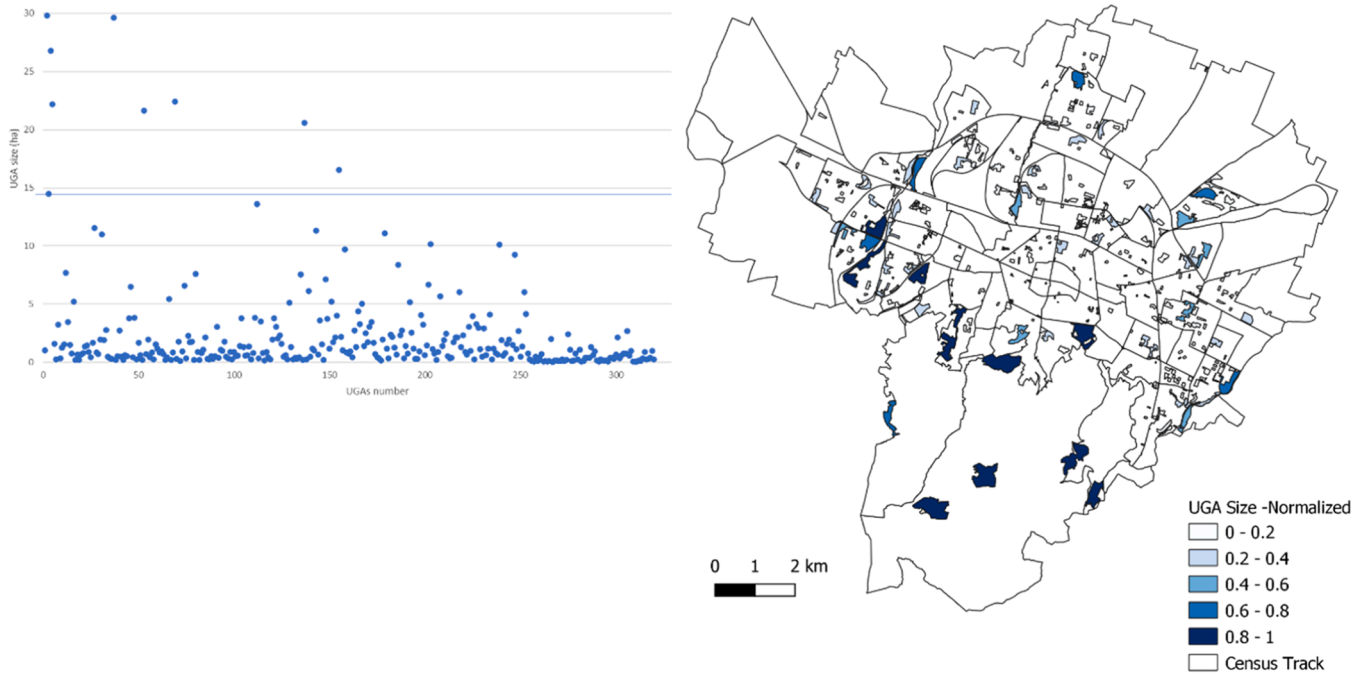

Fig. 2. Scatter chart of Bologna urban green areas size, highlighting outlier values, (left) and normalized values per urban green areas size (right).

also acknowledged in similar studies (Aquino & Gainza, 2014; Tian et al., 2014), there is a significant gradient from smaller areas in the city centre to wider areas moving out to the peripheric areas.

ii) Sport features quality: While the 8 % of the urban green areas presents advanced sport equipment, allowing users to perform free body exercises and thus enabling more vigorous physical activities, just 2 urban green areas (0.8 %) include older adults' sensitive equipment. As shown in Fig. 3, 54 % of the urban green areas do not present any sport features, while 40 % of urban green areas address one or two target groups. Just 18 urban green areas (6 % of the total) of the city include sport features addressing all the three considered target groups and these areas are mostly distributed in the northern districts of the city. While pocket parks (< 0,5 ha) mostly present low-quality or no sport features, the dimension of the urban green areas does not always correspond with higher quality in terms of sport feature. All the bigger urban green areas (10 ha) in the southern part of the city present low-quality values addressing just one target group. Notably, several neighborhood parks (2.5 ha < urban green area < 10 ha) in the northern part of the city present high-quality values addressing 2 or 3 target groups. Last, there are two community parks (0.5 ha < urban green area < 2.5 ha) within the city center, one of which rather small (1 ha), that address two target groups (children and young adults), while all other urban green areas include low-quality features or no features at all.

iii) According to our findings, 221 Green Stewards are active in 72 urban green areas of the city (Fig. 4). We found a very diverse range of activities going from theatre in urban green areas, to sport associations performing physical activities (e.g. yoga, hiking, runners, calisthenics, etc.), to food related activities and events (baking breads in a community oven, urban farming, food festivals) and educational activities (e.g. children in the nature, wild species recognition). The type of mapped activities well covers the 6 defined categories, with a predominance of social related activities (43 %), followed by cultural activities (17 %). Educational (14 %), sport related (12 %), and maintenance activities (12 %) present similar shares. The results of our mapping exercise do not show a positive direct correlation between the number of green stewards and the size of the area. Specifically, as shown in Fig. 4, bigger areas do not always host more green stewards than smaller ones, i.e Parco della Montagnola in the city centre, or other pocket and community parks in the eastern or northern part of the city, result very active in terms of activities implemented by green stewards. Notably, even though we cannot find a clear gradient distribution of green stewards within the city, most of urban green areas located in the city centre or close to the city centre present high values of green stewards (0.6). As for the rest of the city, the riverside areas at the east side of the city lack green stewards, while one main urban green area, namely Parco dei Giardini, stands out in the northern peripheral part of the city, hosting a wide range of activities.

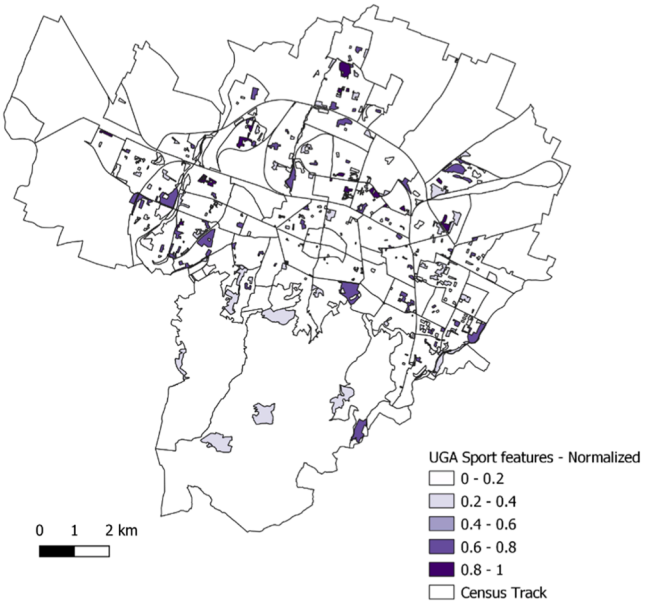

Fig. 3. Sport feature quality in urban green area, normalized values from 0 to 1.

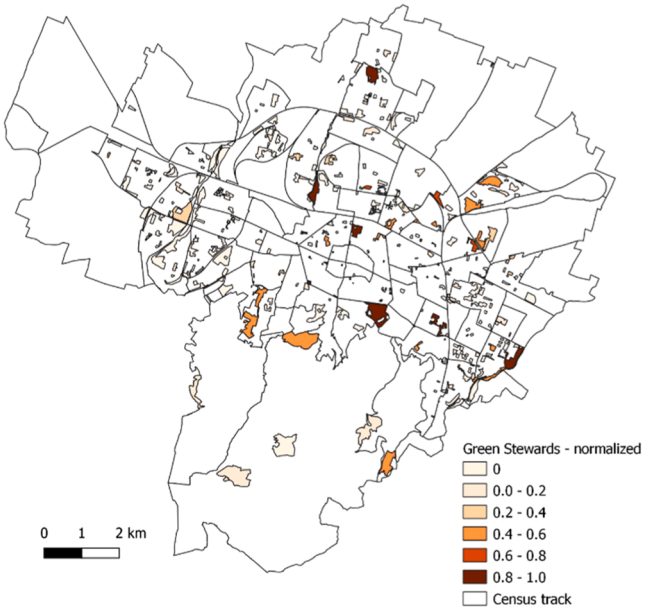

Fig. 4. Green Stewards distribution in Bologna's urban green areas. Normalized values from 0 to 1.

Aware that the three considered components (size, sport features quality and Green Stewards) could assume different weights in the composition of the URPI, within this work we used a simple not-weighted average calculation to define the overall Urban Recreation Potential Index of each urban green area. Specifically, around 67 % of all urban green areas present URPI values below 0.25 and have been considered within the low-quality class. Medium quality is defined by values of RPI ranging from 0.25 and 0.5 and embraces 26 % of urban green areas, while just 6 % of urban green areas in Bologna presents an overall high quality, described by URPI values over 0.5.

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The spatial distribution of the URPI in the city of Bologna is show in Fig. 5. Even though quite few urban green areas present high quality (6 %) they are quite evenly distributed around the city, except for the city centre that include just one high quality urban green area, Parco della Montagnola, and one medium-quality area, Parco 11 Settembre. The areas at the south of the city generally presented medium high-quality area, while districts in the northern part mostly include low quality areas, except from two example of high quality urban green areas.

On the other side looking at CES demand, the vulnerability index (Comune di Bologna, 2020) was considered suitable for our analysis. Fig. 6 shows an irregular distribution of vulnerability classes within the city, with a higher concentration of high vulnerability census tracks in the first periphery line heading north from the city centre. Overall, the city centre presents a medium value of vulnerability mostly given by a high social vulnerability (high share of over 70 years living alone, high

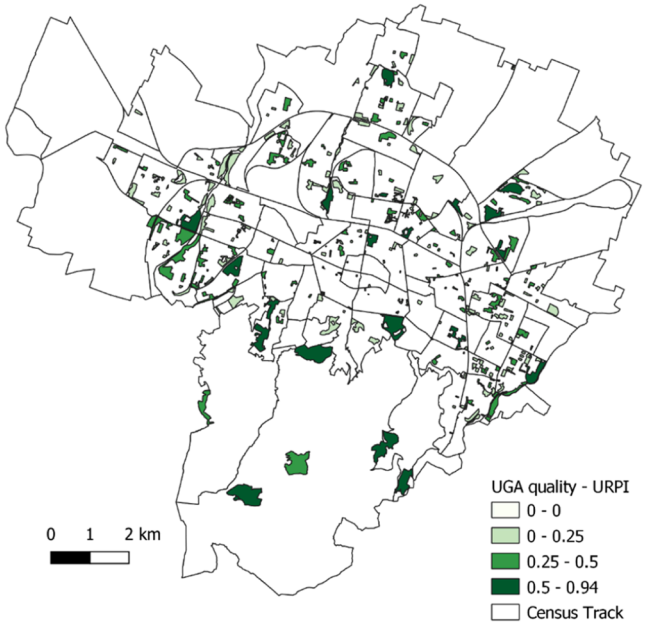

Fig. 5. URPI values of urban green areas, normalized from 0 to 1.

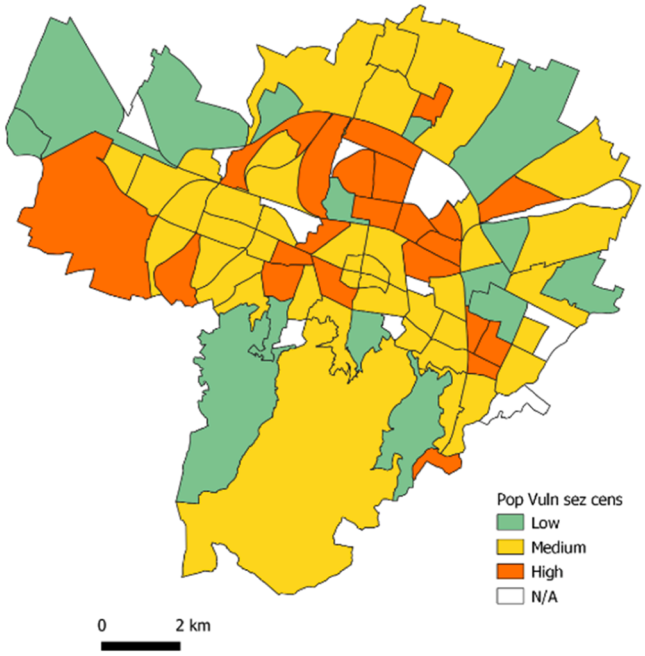

Fig. 6. Population Vulnerability values divided in classes per census track.

share of empty or rented houses). Even though economic indicators are in balance or above the average values, areas at the eastern part of the city present medium to high vulnerability given by demographic characteristics (high share of people over 70 years among residents and negative variation of resident population over the last 5 years).

3.2. CES Supply and Demand correlation results

Accessibility to urban green areas has been calculated considering the results of the proximity analysis and overlapping to it the georeferenced population layer (see Section 2.3). Fig. 7 shows the served (green dots) and non-served (red dots) population by urban green area (300 m) in the city of Bologna. Overall, the ratio of inhabitants who find at least one urban green area within 300 m is approximately 71 %. This means that around the 30 % of city dwellers, approximately 115.000 people, do not have access to any kind of urban green area within 300 m network distance from their place.

Fig. 7 shows the distribution of the different accessibility classes highlighting that Bologna city center generally presents low to medium accessibility to urban green areas, except from one area in the northwest, where a high level of accessibility is assessed. Around 60 % of the inhabitants of the city center, one of the mostly densely populated area of the city does not have access to any urban green area within 300 m from their house. On the other side, the other highly populated areas of the city on the west side and the southeast areas, present medium to high accessibility values. The southern area of the city, despite the high share of wooded and green areas, present low accessibility. Because of a low-density population, few people fall into the 300 m network distances from the urban parks present in this area, that resulted to be inaccessible for most of the population.

As detailed in the methods section, we performed a linear regression to assess the relation among accessibility, vulnerability and green areas URPI, to explore potential distributional justice issues in Bologna. To do so, we aggregated the URPI index per census track and we defined 3 classes (low, medium and high), as already done for population vulnerability and accessibility to urban green area, as shown in Fig. 8.

The linear regression was performed using accessibility and quality as explanatory and vulnerability as response values. We first calculated the regression of each explanatory variable separately, not obtaining significant results (p-value = 0.0689 and p-value = 0.15 for accessibility and quality respectively). Then, we combined the two and obtained a global p-value of 0.02641 making the positive and negative correlations found with accessibility and quality respectively statistically significant. The Adjusted R-squared of this model equals 0.06728, meaning the two explanatory variables considered explain ~ 7 % of the variability found in the response variable. The figure below (Fig. 9), helps visualizing the positive and negative correlations vulnerability has with accessibility and quality respectively.

In addition, the Durbin-Watson Test for autocorrelation resulted in DW = 2.1698 (p-value = 0.7724), confirming the null hypotesis of no autocorrelation. Fig. 10 shows the model validation through residual inspection. The upper left panel shows non-linearity of residuals, the upper right confirms the normality of their distribution, the lower left panel confirm their homogeneity of variance (homoscedasticity) and the lower right shows the influential observations.

4. Discussions and limitations

4.1. CES Supply and demand discussion

Within this work, we assume that differentiated sport features and the presence of community-based initiatives, no-profit organizations or single citizens actions that are actively working on urban green areas should be considered as proxies of potential supply of CES within urban areas (Joassart-Marcelli et al., 2011). We believe that the cultural and social factors involved in such practices underpin the generation and enable the flow of many CES, emphasizing the significance that people attach to places. The analysis of green steward provides interesting results on the type and the frequency of the activities taking place in urban green areas, enhancing the level of attractiveness that these places represent for the local communities. In absolute terms, we found that almost 500 activities are taking place in Bologna urban green areas, with various frequency, with some seasonal event but well-distributed all over the year. Interestingly, the type and the frequency of the activities led by green stewards in the city of Bologna does not relate with the size of urban green areas. We can then argue the flow of CES facilitated by green stewards in urban areas may not be size-dependent, allowing small green areas to assume multifunctional values in the urban environment. While many studies acknowledged size as the main proxy of

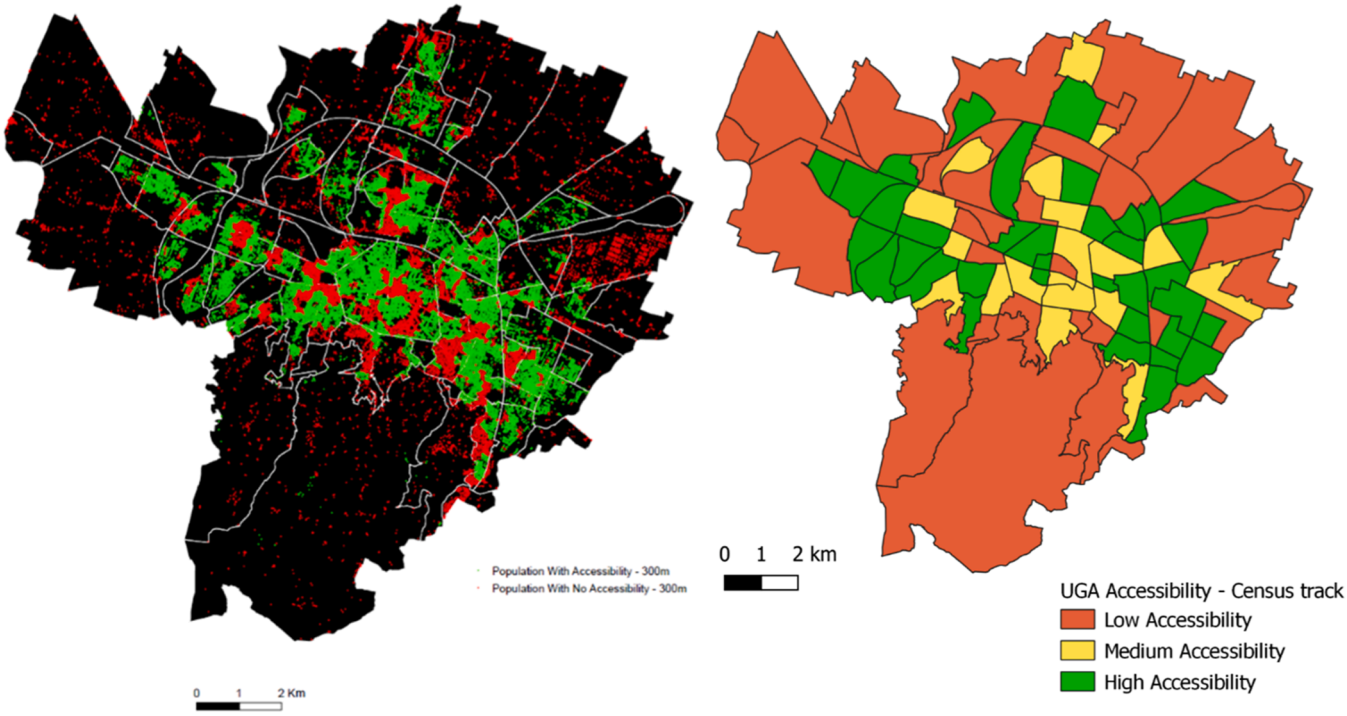

Fig. 7. Accessibility results in the city of Bologna. The map on the left shows the population per street number that has an accessible urban green area within 300 m (green dots) and that do not have an accessible urban green area within 300 m (red dots). The map on the right presents average data of accessibility aggregated per census track.

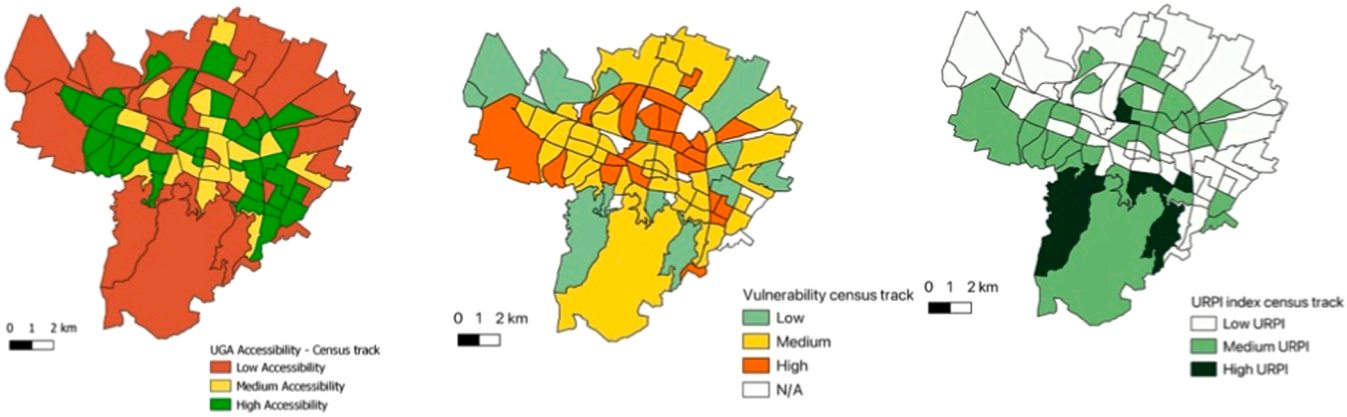

Fig. 8. Accessibility to urban green area, population vulnerability and URPI aggregated at census track level.

urban green areas quality in cities, we suggest that even pocket and community parks (<2.5 ha), if properly equipped, designed and animated by local green stewards, can provide a wide range of services to the population. This could be particularly interesting for compact dense cities with low possibility of de-sealing and creating new green areas. This assumption should encourage urban planners to develop dedicate funding and governance models for green stewards, enhancing regeneration models that could facilitate CES flows in small green areas in densely compact city model. In the case of Bologna two specific planning instruments are supporting this process: i) the collaboration pact, a form of Public Private or Public Public partnership defined within the Regulation on Public Collaboration for the Urban Commons and ii) the participatory process of "laboratori di quartiere" developed through the participatory budget of the city. Both these activities allowed many community-based associations to propose and further kick-off nature--based recreational activities in urban green areas. The type of activities mapped well-cover the 6 defined categories, with a predominance of social related activities (39.6 %), thus enhancing social relation and cohesion, followed by cultural activities (15.8 %) boosting cultural and recreational services. Notably, in most of the cases maintenance is considered as a side activity, as a necessary condition to make use of the urban green areas. Recreational, educational and raising awareness activities, involving a wide range of target groups from children (gardening activities, outdoors schools) to families and adults (learning hiking's, biodiversity walk, natural heritage discovery) and older adults (urban farming, slow walk, soft maintenance work) strongly contribute to enhance the co-production flow of CES raising also people sense of place.

4.2. CES supply and demand correlation discussion

The GIS application demonstrated to be a useful monitoring tool to visualize the accessibility to urban green areas and to support planners and decision makers identifying mismatches between supply and

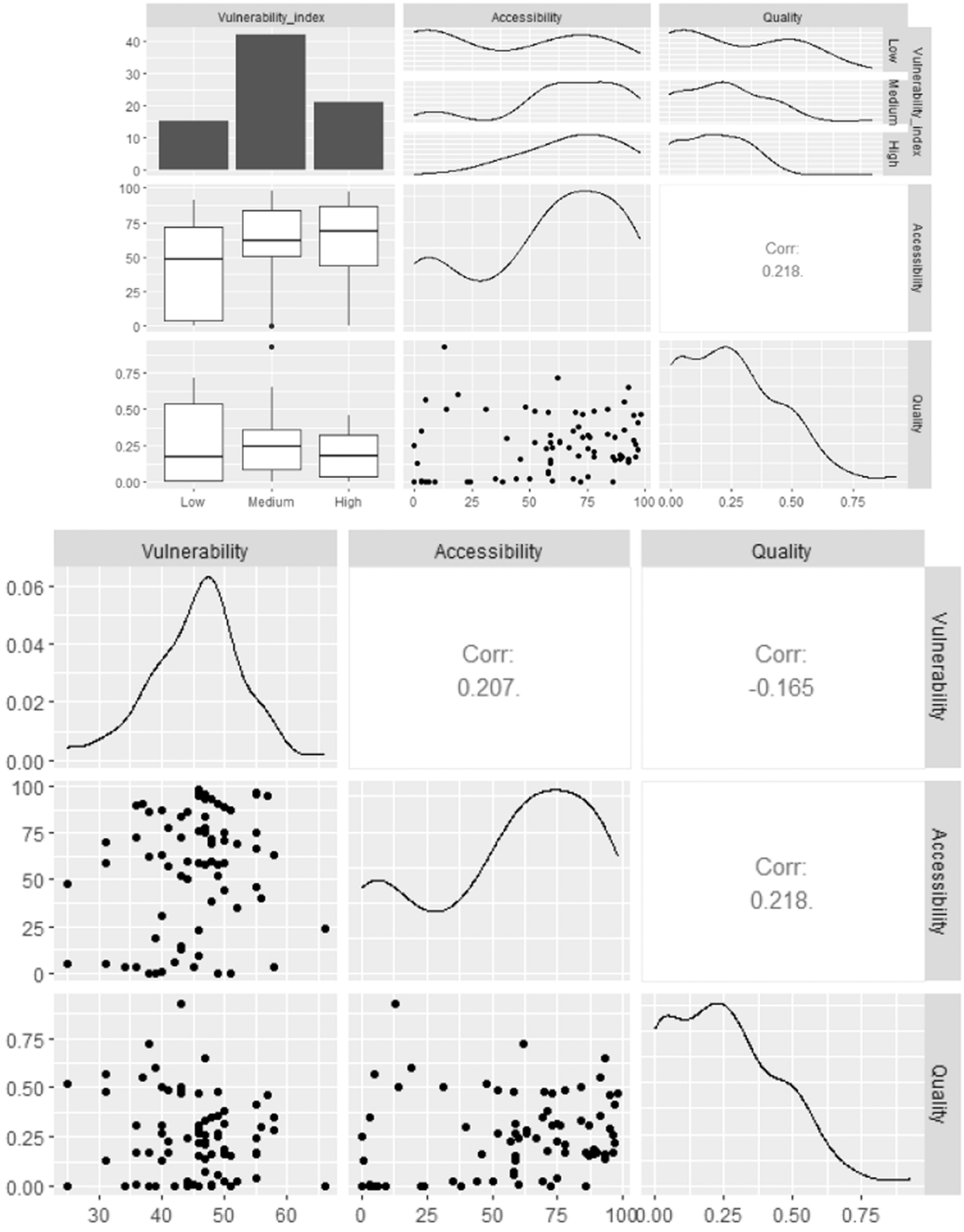

Fig. 9. Graphical correlations between the Vulnerability index and the explanatory variables Accessibility and Quality.

demand for related CES. In the analyzed case study, about 30 % of residents do not have access to any urban green area within the 300 m network distance considered in the analysis. Comparing it to other case studies (Quatrini et al., 2019; Šiljeg et al., 2018; Van Herzele & Wiedemann, 2003), the accessibility values are quite high (70 % of the population having access to urban green areas within 300 m from their home), thus acknowledging an overall good level of accessibility to urban green areas in the city. As presented in the results, just the 6 % of the green areas of the city include sport features addressing all the three considered target groups. Also, while children's playgrounds and sport features enabling physical recreation for youths and adults are sufficiently supplied in the city, urban green areas are not adequately including older adults' needs. Older adults are more likely to visit urban green areas for 'rest and restitution' than the younger age groups

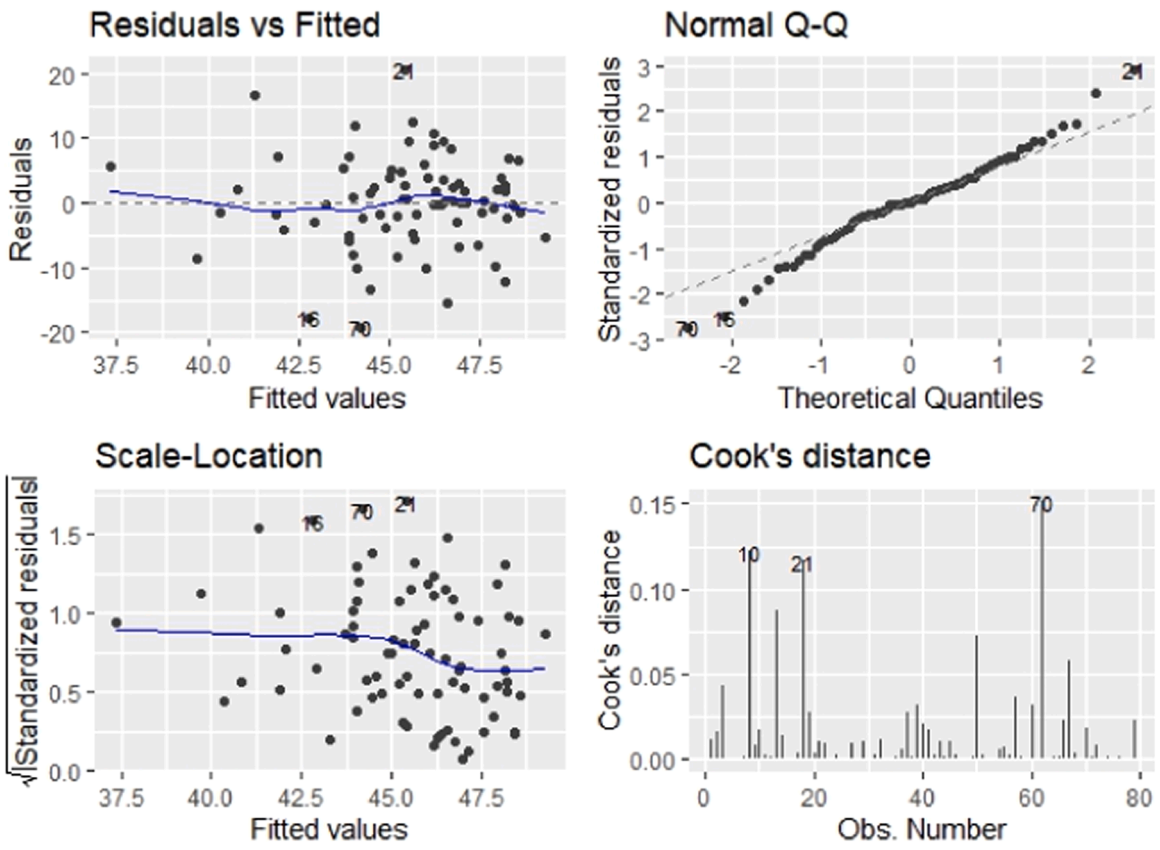

Fig. 10. Model validation through residual inspection.

(Peschardt et al., 2012) and the World Health Organization noted that urban green areas could be key in improving age-friendly city. Thus, in an increasingly ageing society, it is necessary to design urban green areas for the promotion of healthy ageing, that could support personal healthcare and alleviating medical burdens (Tan et al., 2019).

While several authors described the relation among quantity and distribution with vulnerable social groups (Dempsey et al., 2012; Kabisch & Haase, 2014; Wüstemann et al., 2017) finding contrasting results, to our knowledge there is no previous research that explicitly links urban green areas quality (URPI) and population vulnerability. Results in the city of Bologna show a positive, although weak correlation among population vulnerability and urban green area accessibility, while the correlation between population vulnerability and URPI is stronger and negative, meaning that at higher vulnerability corresponds lower urban green area quality and vice versa. Based on the assumption that urban green areas with high URPI values may provide multiple functions and multiple benefits through the co-production paths enhanced by Green Stewards and high-quality sport feature, we could then assume that in the city of Bologna such benefits are not fairly distributed among the population. Green Stewards develop, among other, activities aiming at cultural integration and social cohesion (i.e laboratory and theatre with migrants in urban green areas, activities targeting children or urban farming addressing older adults) and could largely support the distribution of benefits to more vulnerable social groups.

4.3. Limitations

This study has several limitations: first, we did not collect nor assessed preferences or attitudes of the population, but we rather relied over exiting studies and literature to assess the potential increase in supply of CES in relation with specific sport features (Hegetschweiler et al., 2017; Marcos-Pardo et al., 2023). Also, actual flow of people visiting urban green area has not been assessed, limiting the scope of this study to the potential supply of CES, but without assessing the current flow of such services. We acknowledge that outdoor recreation potential normally refers to degree of naturalness, natural protected areas, presence of water and biodiversity (Paracchini et al., 2014), but in this study we limit the definition of the URPI considering green stewards' activities and sport features, using them as proxies of quality recreation potential and highlighting their role in urban context. As well, while this study does not directly assess perceived safety or municipal maintenance of urban green areas, green stewards may be used as a proxy of these characteristics as discussed by Locke et al., 2014; Santos et al., 2023. Last, while Bologna can be considered a good case study for the scope of this research, further case study applications would be needed to further discuss our findings.

5. Conclusion

Fair, high quality and distributed access to urban green areas can improve health and wellbeing by encouraging residents to be more physically active, socialize with neighbors, and enhance community satisfaction. Also, outdoor exercise can provide unique contributions to mental health when compared to exercising indoors (Jennings et al., 2016). The developed URPI that has been tested in this study is intended to support the operationalization of the concept of CES co-production in urban areas, acknowledging that green stewards and multifunctional sport features can positively enhance human-nature interactions enabling CES flow and related health and wellbeing benefits. Nevertheless, the mere access to public urban green areas do not express the quality of the recreation opportunities that urban green areas offer to urban dwellers (Maes, Zulian and Thijssen, no date). Through the development and the application of the Urban Recreation Potential Indicator (URPI) we aim at supporting planners and decision makers not only in assessing mismatches, hotspots, and areas of possible

regeneration intervention, but also in evaluating urban green area quality and multifunctionality. Acknowledging that other valuable approaches such as the ESTIMAP model (Zulian et al., 2013 and Cortinovis et al. 2018) and several other indicators such as naturalness (Arnold et al., 2018; Paracchini et al., 2014), connectivity among urban green areas (Rusche et al., 2019), or structural green space elements (Daniels et al., 2018) and diverse target groups for the sport features could be considered, we believe that the proposed URPI can enhance the understanding of urban dynamics related with the management and the governance of urban green areas. Indeed, improving existing urban green areas to deliver multiple benefits or creating new multifunctional pocket or community park in densely inhabited districts could greatly enhance local quality of life supporting social cohesion and wellbeing. The URPI, with the possibility of adapting it to other context, can support to showcase a systematic assessment of different functions helping identifying areas where action is needed to increase multifunctionality and/or promote priority functions thus providing planners with crucial information about needed improvement or transformation sites (Hansen et al., 2019).The replicability of the proposed methodology in other urban contexts would largely support the tailoring and testing of the proposed index for defining urban green area quality, opening up to possibilities for its integration into planning practices and tools. These findings may contribute to the development of a new and pluralistic notion of quality of urban green aeras. Moreover, when looking at the demand side, we have used the population vulnerability index to assess whether vulnerable social groups have sufficient and equitable access to urban green areas (Wüstemann et al., 2017) and we focused over the distributional aspect of the URPI and population vulnerability. Through this assessment, we acknowledge potential injustice in the access and flows of CES, that could be addressed without creating new urban green areas, but rather improving quality of existing urban green areas. In our view, planners should look at urban regeneration actions and procedure aiming at improving the quality of urban green areas within areas of the city showing high vulnerability to support a just and fair distribution of CES related benefits in the city. We recognize that one of the challenges to balancing these inequalities is the risk that increasing or improving urban green areas in highly vulnerable areas can lead to higher housing prices and thus a shift to residents with higher income (Wolch, Byrne and Newell, 2014), resulting in green gentrification processes (Anguelovski et al., 2017). Nevertheless, we acknowledge that while meeting the expectations of all social groups in the city is hardly possible, the main priority should be given to satisfying the needs of the most vulnerable inhabitants (Raymond et al., 2016), thus careful planning to enhance urban green areas quality in highly vulnerable areas should be sought, regulating speculation mechanism that could support gentrification process in such areas. In this light, delegate power to other actors (formal and informal groups of people, NGOs) which are directly interested in shaping green and recreational spaces (Biernacka and Kronenberg 2018), their quality and their greater accessibility (Colding and Barthel 2013), would largely support CES co-production and relevant flow of benefit for all.

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CRediT authorship contribution statement

Claudia De Luca: Writing – original draft, Methodology, Data curation, Conceptualization. **Simona Tondelli:** Supervision. **Fulvia Calcagni:** Writing – review & editing, Formal analysis, Data curation.

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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