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Assessing Mismatches in the Provision of Urban Ecosystem Services to Support Spatial Planning: A Case Study on Recreation and Food Supply in Havana, Cuba

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Abstract: Integrating information about how ecosystem services (ES) are provided and benefited from in spatial planning is essential to enhance quality of life in urban areas. This study aims to assess mismatches in the provision of urban ES. Specifically, it compares the amount of services that urban dwellers currently benefit from with the capacity of green spaces to provide service and the ES demand, in order to assess two mismatches: "unsustainable flow" and "unsatisfied demand", respectively. We focus on two ES, recreation and food supply, and conduct an empirical study in two adjacent municipalities of the city of Havana, Cuba. The methodological approach includes: the identification of services providing and demanding areas; and the quantification of mismatches by carrying out a spatial comparison between critical capacity and flow, and demand and flow. Results show that urban green spaces may be potentially exposed to overcrowding. Concerning food supply, a mismatch between demand and flow emerged in both of the municipalities. The assessment can support planners in addressing the sustainable use of green spaces and the equitable distribution of ES benefits. However, its applicability requires a deep understanding of local specificities, including demand levels, accessibility to ES, and sustainability thresholds.

Keywords: urban ecosystem services; spatial planning; mismatches; sustainable use; equitable distribution

1. Introduction

Ecosystems sustain and fulfill human life through the provision of ecosystem services (ES) [1]. ES are desired outcomes of ecosystem structures and functions, which are then translated into multidimensional benefits if they are actively or passively used by humans [2–4]. As humans are the final beneficiaries of the ES provision, urban areas are hotspots of ES demand and flow [5]. This paper focuses on urban ES—i.e., they are produced by green and blue spaces, such as street trees, urban park, urban forest, green sport facility, allotment, river and lake, within urban and peri-urban areas [6–8]. Particularly, we limit the study to ES provided by green spaces. Among others, these services include water and food supply, air purification, urban temperature regulation, noise reduction, runoff mitigation, global climate regulation, social cohesion, aesthetic enjoyment, and recreation [5].

The New Urban Agenda that was adopted in Quito in 2016 [9] identified the sustainable development of urban areas as the main goal of spatial planning. This goal requires, among other things, to adopt ecosystem-based approaches to preserve and enhance the benefits from ecosystems, contributing to citizens' well-being and quality of life [9,10]. Spatial planning may affect the provision and delivery process of urban ES. For example, it affects the provision by determining the location and biophysical features of green spaces [11,12]. The demand, and the delivery process, can be affected by allocating population density [3,13] and by determining natural or artificial solutions that connect the site of ES production with beneficiaries, e.g., natural waterways and transport infrastructure [14]. Therefore, integrating ES knowledge—i.e., information about how ES are provided and benefited from—in spatial planning is instrumental to enhance city design [15,16].

In a recent study [17], authors suggest the need for an active support from research to strengthen the use of ES knowledge in the information base of urban plans. Particularly, such information should provide insights on the spatial distribution and the quantity and quality of ES provision in the urban environment [18]. This should also include information on ES accessibility properties—i.e., the mechanism by which citizens can benefit from ES [19]—as well as on the actual demand by different groups of beneficiaries. The latter issues, which are particularly relevant to address urban environmental justice and ES equity [20,21], have been overlooked in current planning practice [17].

The aim of the research is to assess mismatches in the provision of urban ES in a case study area in the city of Havana, Cuba. Mismatches are defined as the imbalance between capacity—i.e., the potential of green spaces to provide ES [13,22], flow—i.e., services that urban dwellers currently benefit from and—demand—i.e., the required amount of ES to achieve a desired state of well-being for urban dwellers [22]. Mismatches can be assessed spatially and temporally, by mapping and comparing capacity, flow and demand [13,23]. Specifically, the research focuses on two typologies of mismatches, "unsustainable flow" and "unsatisfied demand". The unsustainable flow is often unaddressed in the ES literature, [23], while, in the assessment of unsatisfied demand, access to green spaces is often not properly considered, e.g., they do not consider transportation infrastructures [13].

Unsustainable flow mismatch can be used to measure the sustainability of ES flow [24]. As stated by Costanza [25], ecosystems need a minimal biophysical configuration to ensure healthy and optimal functioning, hence the provision of ES in the long term. Nevertheless, certain levels of ES flow could themselves be a pressure for ecosystems, e.g., over-fishing, moose over-hunting or crowding in recreation areas [2,22]. The flow of some ES is defined "unsustainable" when it interferes with the mechanism that gives rise to the service in a way that degrade the capacity of green spaces to provide the same service because it exceeds certain thresholds. Hence, thresholds of sustainability need to be defined in order to assess mismatches (see Chapter 3, "critical capacity" concept) [24].

The unsatisfied demand mismatch is used to assess whether the ES flow is sufficient to meet the demand [26]. The distinction between ES and benefits highlighted in the cascade model suggests that the provision of ES by ecosystems does not necessarily imply that people benefit from them [2]. While some ES just spill over into adjacent areas by following diverse directional patterns [27,28], e.g., air purification and urban temperature regulation, others can only be enjoyed at the source, e.g., buying fresh products in urban farms or frequenting green areas for recreational purposes. Urban morphological patterns and management practices of green spaces must ensure that ES are provided to all urban areas, irrespective of race, income, class or any other socio-economic condition [14,20].

By quantifying and mapping these two mismatches, this research aims at answering the following questions: (a) How much and where is the flow of ES unsustainable? (b) Which urban areas have unsatisfied demand, hence deficit of ES benefits? and (c) How much is this deficit considering ES demand? The proposed methodology aims support urban planners throughout the design and decision-making process about proper planning actions fostering a sustainable use of natural resources and equitable distribution of ES benefits.

2. Case Study Area and Selected Ecosystem Services

The case study includes part of the city of Havana, the capital of Cuba. Since its foundation in the 16th century, the city has always been the major socio-economic hub of the island. Its urban development has been shaped by the political and economic vicissitudes that Cuba lived during the Spanish colonial period until 1898, the pseudo-republican period with a political domination from the USA, and the Socialist Revolution in 1959 [29]. The province of Havana is one of the largest metropolitan areas in the Caribbean region. It currently hosts 2.09 million inhabitants in a total area of 728 km^2 on the northwestern coast of Cuba. The political-administrative division of the province consists in 15 municipalities that represent the highest local State entity. Municipal institutions are the "*Asamblea Municipal del Poder Popular*", which is a representative institution, and the municipal council, called "*Consejo de Administración Municipal*", which has an executive and subordinated role. Municipalities and related entities must support the socio-economic development of the province based on policies, programs, and plans that are approved by the National Government. Because of its geographical position and its socio-economic and political system, Havana has faced in the last decades, and still does, enormous challenges of diverse nature, from environmental to economic, which threaten the well-being and quality of life of its inhabitants.

Acknowledging the importance of fine-scale assessment of highly heterogeneous and fragmented urban environments [30], we limit our assessment to two municipalities of the city, "*Plaza de la Revolución*" and "*Centro Havana*" in the northwest coastal area (Figure 1). These municipalities have clear differences concerning the urban morphology and population density (Table 1). *Centro Havana*, with the densest population in the country, was built in the 18th century after a densification process outside the walls of the historical city, resulting in a compact urban structure with the scarce presence of green spaces [31]. When the economic situation was buoyant after the First World War, immigrants with limited resources settled in *Centro Havana*, where the classical mansions were subdivided into single-rooms with shared bathroom and sanitary facilities in a common courtyard [32]. Currently, *Centro Havana* is one of the city's municipalities with a major concentration of vulnerable population that are living in substandard housing or slum units, despite their having access to the same education, health care, job opportunities and social security as those who live in privileged neighborhoods [33]. On the contrary, *Plaza de la Revolución*, adjacent to *Centro Havana*, starts its urbanization in the 19th century to accommodate the sugar-plantation aristocracy and the middle-class from *Centro Havana* that were seeking a healthier environment [31,32]. Its urban morphology is characterized by a regular grid defined by tree-lined avenues, green verges, parterres and house gardens, while public green spaces replace entire blocks within the grid. Moreover, the metropolitan park of the city is located along the south-west limits of the municipality and the riverbank of the Almendares' river.

Usually, the high concentration of population entails high demand for ES [20], which combined with low availability of green spaces may contribute to high mismatches. Hence, we expect contrasting results between the two municipalities.

Table 1. Relevant characteristics of the case study for the mismatch assessment.

Municipality	Area	Density [1]	Green Space Per Capita
Plaza de la Revolución	12.3 km^2	11,936.4 inhab./km^2	8 m^2/inhab.
Centro Havana	3.42 km^2	40,710.2 inhab./km^2	0.64 m^2/inhab.

[1] Source: [34].

Figure 1. Location, delineation and land cover map of the case study area, *Plaza de la Revolución* and *Centro Havana.*

In this research, we focus on two ES, recreation and food supply. Recreation is one of the ES that is most frequently considered in the planning process [17]. However, cultural services, which include recreation, are the less addressed in the ES literature [35]. Several social benefits are associated with the recreational use of green spaces such as urban and metropolitan parks, urban forests, etc. They support day-life recreational activities of diverse physical intensities—e.g., wildlife viewing and experiencing nature, meeting other people, brisk walking, running and hiking, children games and organized sports. These activities improve physical and mental health and reduce stress levels and non-communicable diseases [36,37].

Food supply refers to the production of food in urban green spaces [5]. Urban agriculture plays a significant role in the provision of this service and represent a source of income for population of cities in low-income countries [38]. The production of food in urban areas can favorably mitigate economic constraints, e.g., food prices, household income, and physical constraints in purchasing food, e.g., distance and cost from and to markets [39]. A representative example is the Cuban National Food Program, which was launched in the 1990s, still ongoing, aimed at empowering citizens and meeting food sovereignty by promoting and supporting organic urban agriculture [40]. The urban agriculture policy of the island allows only organic methods for food production in urban areas to avoid the use of oil- derived inputs and land pollution. Thus, in the remaining of the article, we will use the term "urban agriculture" to refers to organic agriculture. The strategies that were developed within the program have helped to increase food security and resilience in the face of a trade breakdown and economic crisis after the decline of Soviet aid [41]. Specifically, in 1999, the contribution of urban agriculture to the total national production of vegetable and fruits was 58% and 39%, respectively [42]. Nowadays, urban agriculture represents a primary source of fresh produce for the province of Havana. Based on data from the "*Delegación Provincial de Agricultura de la Habana*", we found that in 2016 urban and peri-urban agricultural production of Havana satisfied 63% of recommended intake of vegetables and fruits [41] for the entire population.

3. Materials and Methods

Capacity is defined as the potential of green spaces to provide ES [13,22]. We define a "critical capacity" as the threshold above which ES flow may degrade the future capacity of ES provision. Thus, critical capacity is generally lower than the maximum capacity (Figure 2). To quantify ES flow, we consider the actual production of ES by urban green spaces and the ability of people to reach these areas. Some urban ES are not used passively and they need additional infrastructure and social capital to enjoy their benefits [25,27]. To assess access, we perform a GIS network analysis that combines data of road networks, pedestrian paths, crosswalks, and physical barriers such as railways and waterways, while considering a maximum travel distance (Table 2). For recreation, it varies according to the size of the urban green space [43]. Based on this analysis, we then identify urban areas where dwellers can reach urban green spaces and benefit from ES ("benefitting areas") [14,26,44].

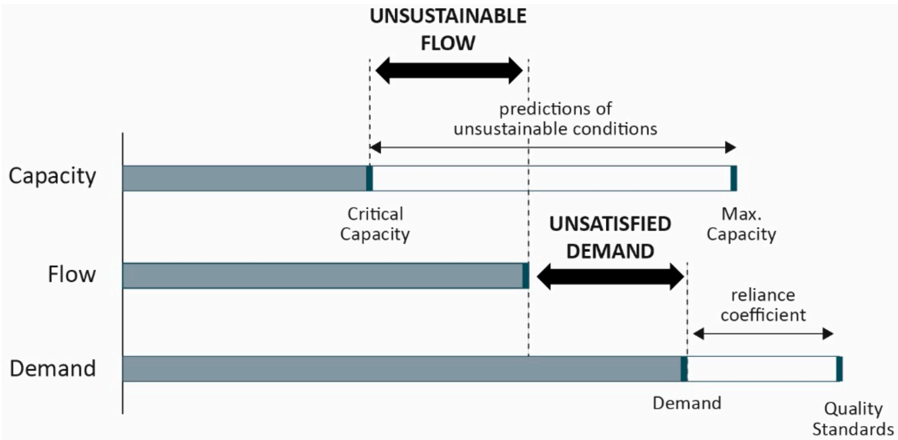

Figure 2. Conceptual diagram of mismatches. Capacity, flow and demand are measured in the same units of measurement. Quality standards are representative of ES demand. They are then reduced by a reliance coefficient. Critical capacity may rely on prediction of conditions of unsustainability and it is always lower than maximum capacity of green spaces. Unsatisfied demand occurs when ES demand is higher than ES flow. Unsustainable flow occurs when ES flow exceed critical capacity.

Table 2. Maximum travel distances.

Ecosystem Services	Urban Green Space Size	Maximum Travel Distance	References
Recreation	0.5 ha–1 ha	400 m	[43]
	1–5 ha	800 m	
	5–10 ha	1600 m	
	10–60 ha	3200 m	
Food Supply	-	500 m	[45]

We have previously defined demand as "the required amount of ES to achieve a desired state of well-being". In this study, the desired state is based on quality standards [26,46] related to desirable conditions (e.g., minimum availability of recreational green spaces within maximum distances from home [43]) and to subsistence needs (e.g., basic intake of vegetables and fruits [47]). However, these standards may not be exclusively achieved by urban green spaces and related ES. Based on the approach that was proposed by Li et al. [48], cities are considered as an integrated holistic ecosystem in which artificial and natural systems must function in combination to provide multiple benefits. ES are only the contribution of the natural capital to all human benefits [25]. Hence, the ES demand is lowered through a reliance coefficient (Figure 2). This expresses how many cities are expected to rely on green infrastructures, which embeds urban green spaces, while considering the contribution of existing alternative options to meet the demand. Examples are represented by standard solutions used for water pollution control, e.g., such as first-flush and a buffer tank [49], and for coastal flood protection e.g., seawalls and breakwaters [50].

3.1. Mapping Service Providing and Service Demanding Areas

Service providing and demanding areas represent the two sides in the provision of ES and the related benefits. On the one hand, service providing areas are considered as sources of ES and include all typologies of urban green spaces [3,14]. In this section, we explain in detail the selection of these areas for recreation and food supply. On the other hand, service demanding areas include urban residential zones, since people are the final beneficiaries in the ES provision.

Land cover and population density maps were developed in GIS software and used as input data in this stage (Figure 1). The land cover map, at a 1:1000 scale, was obtained through manual digitalization of high-resolution images recorded in 2016 from the computer program Google Earth. This included a classification into six broad categories of land cover based on the interpretation of orthophoto followed by ground trothing. Population density map was created by intersecting total population of municipalities (2015) with residential use patterns that were extracted from land use map from OpenStreetMap [51], then, while considering an homogeneous distribution of population within residential areas.

To select recreational green spaces, we first mapped all public urban green spaces that are larger than 0.5 ha located in the two municipalities. Due to their restricted size, small green spaces (with an area lower than 0.5 ha) were excluded from service-providing areas. Urban green spaces located outside the municipality limits within certain distances were included to account for boundary effects. These distances were set based on the dimension of recreational areas, as shown in Table 2. Thereafter, we determined their recreation potential based on the presence of diverse environmental features and facilities that support nature-based recreational activities, e.g., those in Section 2. Features in Table 3 were extracted from the literature [43,52,53]. They were examined and documented during field surveys in all the selected recreational sites. We included in the mismatch assessment only those green spaces having at least two environmental features or facilities.

Table 3. Environmental features and facilities to identify service providing areas of recreation [43,52,53].

Environmental Features and Facilities	Description
Play set	The combination of two or more distinct pieces of playground equipment
Trail	A route used for walking, biking, running, etc.
Open space	It's not obstructed by man-made objects and natural elements. It must be able to be functional for recreation, generally larger than 15 × 15 m.
Water bodies	Include ponds, lakes, streams, swimming pools, beach areas and fountains.
Sport facilities	Include baseball fields, basketball courts, football fields, miniature golf, tennis courts, volleyball courts, etc.
Coverage -shade	Whether trees or other natural elements provide shade to users to get out of the sun. (>30% of tree cover)
Shelters, Pavilions	-
Resting features	Include benches, tables and seat walls.
Wildlife area	Where animals are put there by park personnel versus being there on their own volition. Must be able to see the respective animals.

Urban agriculture in Havana takes many forms, according on crop techniques and types of ownerships. Organoponic and intensive gardens, which are characterized by mixed state and private ownership, are preferred methods of cultivation because of the limited availability of green spaces within the city. The main difference between these two methods concerns with the structure of the garden: in organoponics, cultivation occurs in raised bed filled with organic matter and imported soil from near areas; while in intensive gardens, cultivation occurs in the pre-existing topsoil. To assess mismatches, only public or in-usufruct urban green spaces using either organoponic or intensive garden methods were selected, disregarding household gardens due to the lack of annual agricultural yield records. As for recreation, we included (if present) organoponics and intensive gardens that are located outside the municipality limits up to 500 m [45].

3.2. Quantifying and Mapping "Unsustainable Flow" and "Unsatisfied Demand" Mismatches

For recreation, critical capacity includes threshold values of crowding that may lead to degradation of capacity of green spaces to provide the service. We did not find specificities about this value either in local policies or scientific literature. Thus, we used the inverse of the minimum value of green space per capita (9 m^2/inhab.) of Cuban urban rules as a tentative maximum value of crowding. ES flow of recreation was quantified as the number of inhabitants living within distances ranging from 400 m to 3200 m. ES demand was quantified based on the quality standard for which "everyone should be able to reach at least one recreational area within maximum travel distances" [43]. Moreover, the reliance coefficient was considered to be 100% because of the lack of an urban inventory that reveals non-nature-based recreational sites.

Regarding food supply, critical capacity was not defined after considering results from a field survey in Havana. Interviews, supported by the INIFAT (National Institute of Fundamental Research in Tropical Agriculture of Cuba) in 2017, to five local farmers and managers in five organoponics suggest the absence of a causal relation between the consumption of fresh food products and the annual crop yield. This precludes the occurrence of the unsustainable flow mismatch. The flow component was measured based on the mean crop yield of vegetables and fruits in 2016 for urban agriculture, 18 kg/m^2. Other two values of mean annual crop yield were used, specifically, 22 kg/m^2—i.e., the highest value for urban agriculture in Havana [42]—and 7.6 kg/m^2—i.e., the mean crop yield set by the production plan of four organoponics for the 2017. From the interviews, it also emerged that almost the entire food production was sold to urban residents within organoponics. Food supply demand, which is 66 kg per capita per year, was obtained by combining the minimum intake of fruits and vegetables that was recommended by [47] with the reliance coefficient of 45%. This coefficient derives from multiplying 3 m^2/inhab. devoted to urban agriculture in urban areas, which is the initial goal of Cuba's National Food Program, with the highest value of crop yield, 22 kg/m^2. Then, we compare the excepted annual provision of urban agriculture with the recommended intake.

A fundamental requirement is that critical capacity and ES demand must be assessed in the same units of measurement as the ES flow. The unsustainable flow mismatch was quantified by converting the number of people living in benefitting residential areas, called "potential beneficiaries", into square meter per inhabitants (i.e., crowding values). We then compared this value, which is calculated for each urban green space, with critical capacity by using the formula:

$$\text{Unsustainable Flow } (\%) = \frac{\text{ES flow } \left(\frac{\text{m}^2}{\text{inhab.}}\right)}{\text{Critical Capacity } \left(\frac{\text{m}^2}{\text{inhab.}}\right)} = \frac{\frac{A_{GS} \times c}{N_b}}{9} \times 100 \quad (1)$$

where: A_{GS} is the area of the urban green space in m^2; N_b is the number of beneficiaries; c the availability of recreational green space that each urban block has within maximum travel distances; and 9 m^2/inhab, suggested in Cuban urban regulation. After quantifying the mismatch, we mapped urban green spaces in the condition of unsustainable flow, which is when a person has less than 9 square meters available within the recreational site—i.e., scenario of crowding. Then, we represented how much distant green spaces are from the sustainability threshold.

Moreover, we quantified unsustainable flow mismatch for the "most crowded scenario" for each green space. This was carried out by omitting the availability coefficient in the formula (1), hence by not considering the flow of people to other recreational sites. This operation hypothesizes that all urban residents living within the defined maximum travel distances from a specific green space would use/prefer only that area as recreational site.

The unsatisfied demand mismatch expresses the percentage of people that must travel over maximum travel distances to reach recreational sites, and for whom the production of local organoponics have not met at least 45% of the food requirement. It was quantified after comparing ES flow with demand by using the following formula for recreation and food supply ES, respectively.

$$\text{Unsatisfied Demand } (\%) = \frac{\text{ES flow (inhab.)}}{\text{ES Demand (inhab.)}} = 1 - \frac{N_b}{\text{Tot. pop.}} \times 100;\ 1 - \frac{CY \times A_{GS}}{146 \times c_r \times \text{Tot. pop.}} \times 100 \quad (2)$$

where: N_b is the number of beneficiaries of recreation ES; Tot.pop. is the total population of municipalities; CY is the annual crop yield of vegetables and fruits of organoponics; A_{GS} is the area of organoponics in m^2; 146 is the minimum recommended intake of vegetables and fruits; and c_r is the reliance coefficient, in this case is 45%.

The mapping process for this mismatch differs among recreation and food supply ES. For the first service, we represented the availability of recreational areas within maximum travel distance at an urban block resolution. Based on this map, we spatially identified unsatisfied demand, hence cold-spots of recreational benefits, by mapping urban residential areas with no availability of close-to-home recreational green spaces. For the second service, we mapped benefitting residential areas and then we reported their percentage of people for whom the food demand was not satisfied.

4. Results

4.1. Service Providing and Service Demanding Areas

We have identified 27 recreational sites (Figure 3) that encompass urban parks, metropolitan parks, vacant lots, sports fields, and zoo, with urban parks being the most common for both municipalities as shown in Figure 4. Overall, 262 ha distributed in 24 urban green spaces, located inside and outside administrative limits, provide recreation service to Plaza' inhabitants. However, this value decreases until 82 ha for *Centro Havana* municipality, which has just 4.8 ha of green space (two urban parks and one sports field) within its administrative limits. In this municipality, a consistent share of public green spaces was precluded from the assessment since they each have an area that is smaller than 0.5 ha.

Regarding food supply, *Plaza de la Revolución* currently has five active organoponics (2.73 ha), all in the southern area of the municipality. *Centro Habana* counts only for 0.24 ha devoted to urban agriculture, subdivided in two organoponics near the western limit of the municipality.

Service demanding areas (residential areas) reach 51% and 70.5% of *Plaza* and *Centro Havana* area, respectively.

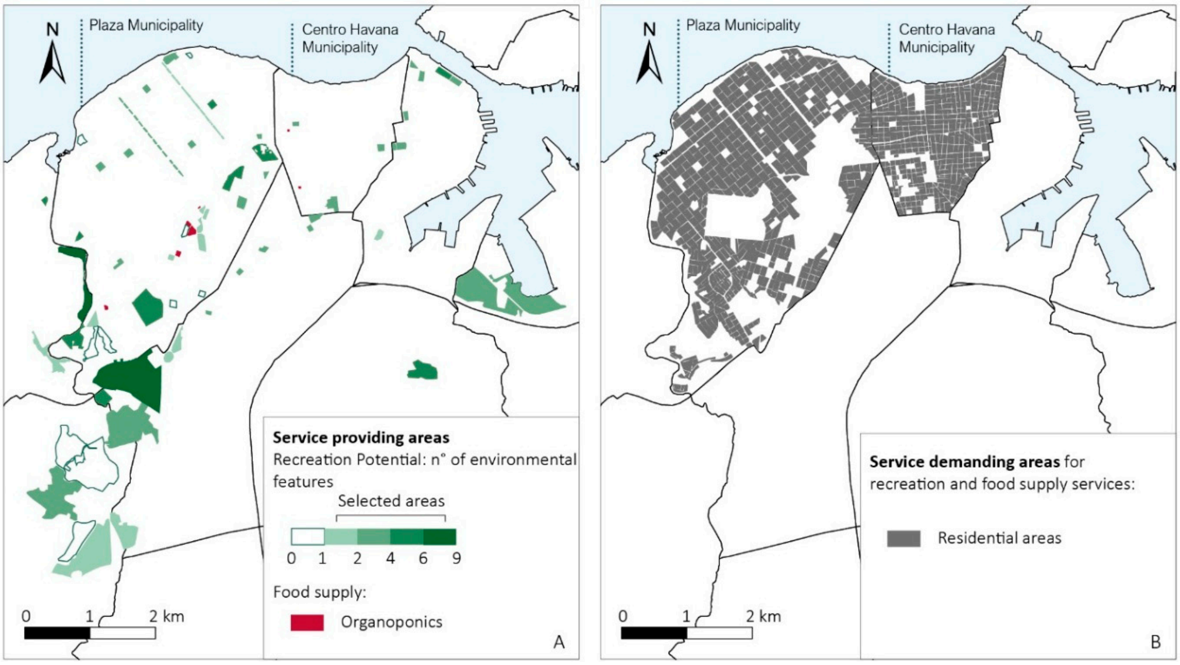

Figure 3. Map of service providing (**A**) and demanding areas (**B**) for recreation and food supply.

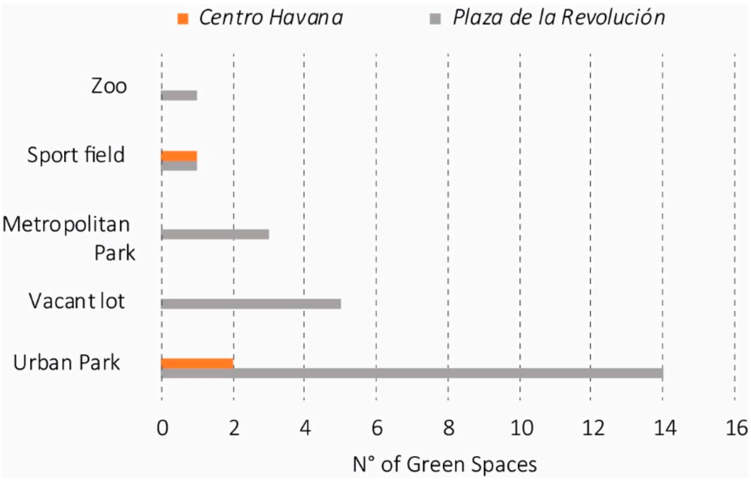

Figure 4. Typologies of green spaces with recreation potential in the case study.

4.2. Quantifying and Mapping Mismatches

4.2.1. Recreation

The unsustainable flow mismatch is shown in Figure 5. In the map, green spaces are classified in five categories of unsustainability and one category of sustainable flow. Results show that 67%

of recreational sites of *Plaza* are under an unsustainable regime and half of them belongs to the (worst) categories, 60–99% under the sustainability threshold. All of the recreational sites mapped for *Centro Havana* have unsustainable flow, and two-third of them are 95% under sustainability threshold. These spaces are predominantly classified as an urban park for both municipalities. Particularly, for *Plaza* they are in the northwestern region near the waterfront of the city.

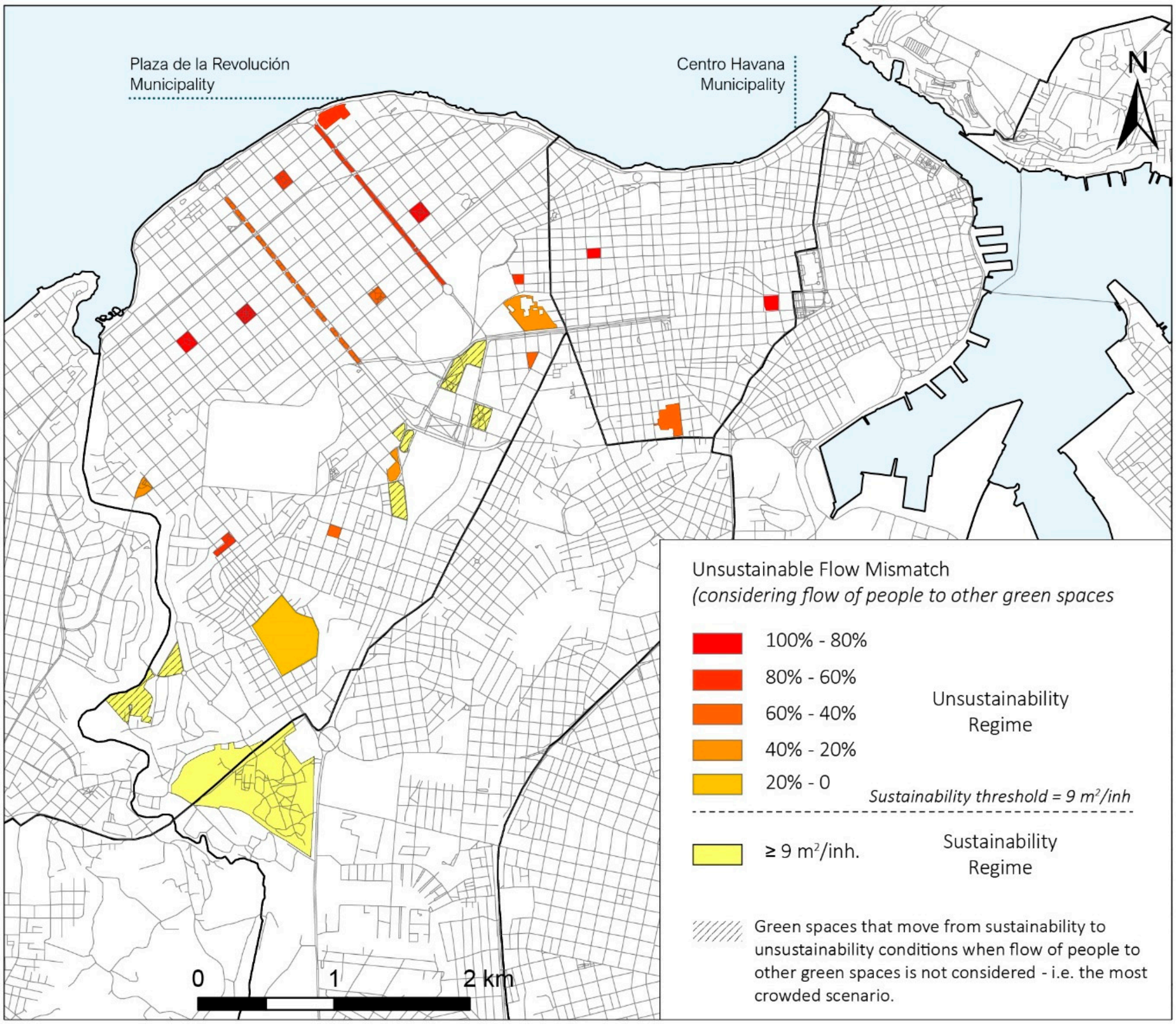

Figure 5. Unsustainable flow mismatch of recreation service.

Figure 6 illustrates the results of unsustainable flow mismatch without considering the flow of people to other existing green spaces—i.e., the most crowded scenario. Our findings show that categories of "sustainable flow" and with "80–100% under sustainability threshold" are those that experience major changes for Plaza. Green spaces with sustainable flow decrease from 33% to 4% in the most crowded scenario (Figure 5). While green spaces with 80–100% under sustainability threshold increase by about 46% (11 green spaces in more). In the case of *Centro Havana*, changes occur within the unsustainability regime, e.g., increment by 33% of urban green spaces in the "80–100%" category.

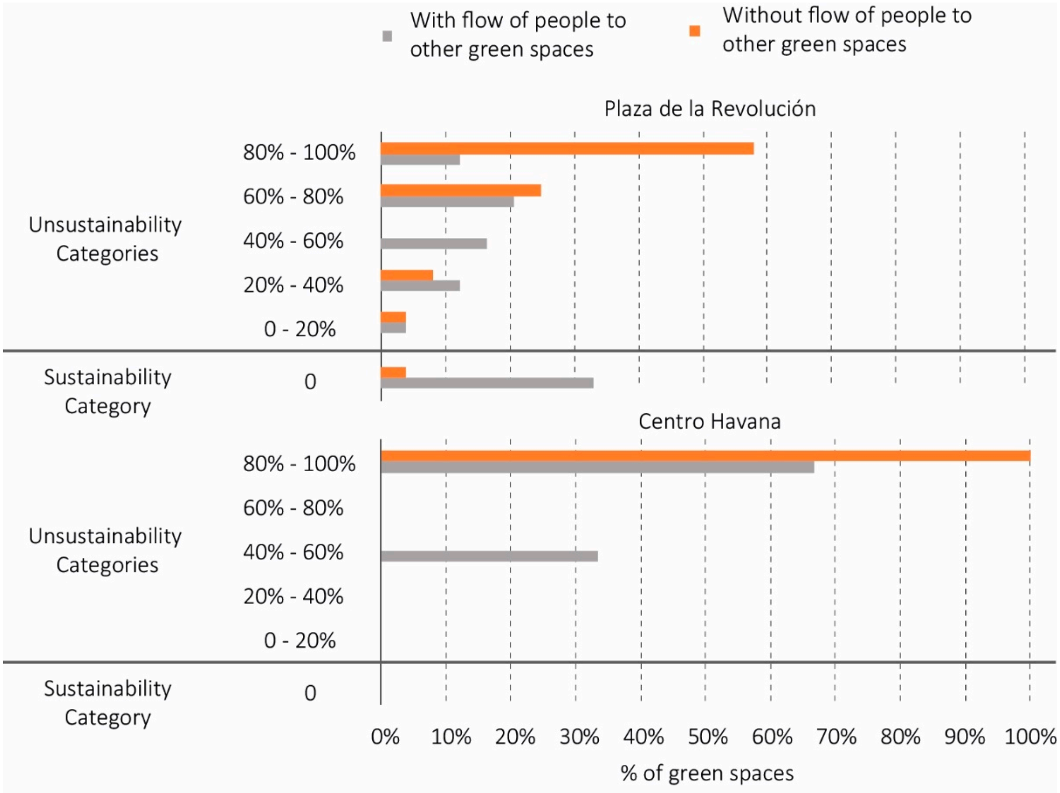

Figure 6. Unsustainable flow mismatch with and without flow of people to other green spaces.

Figure 7 shows the availability gradient of recreational areas within maximum travel distances from each urban block. As expected, the results show that *Plaza* has a better performance in the provision of recreation service, having only 1.3% of unsatisfied demand. On the contrary, for *Centro Havana*, this value is about 15% of its total population. Overall, this population is concentrated in the northern region of the municipalities, close to the sea.

In an attempt to disaggregate these results, we found that big green spaces with an area from 5 to 60 ha have minor effect on the presence of new cold-spots of recreational benefits. For example, the lack of big green spaces will increment by 0.3% the unsatisfied demand in *Plaza*. Instead, they contribute considerably to hotspots that are located in the central and south region of this municipality. Medium green spaces with an area between 0.5–5 ha provide recreation services for urban areas with low availability (1 and 2 green spaces available). Moreover, the absence of green spaces located outside administrative limits would result in an increment of 11% of unsatisfied demand for *Centro Havana* and 0.1% for *Plaza*.

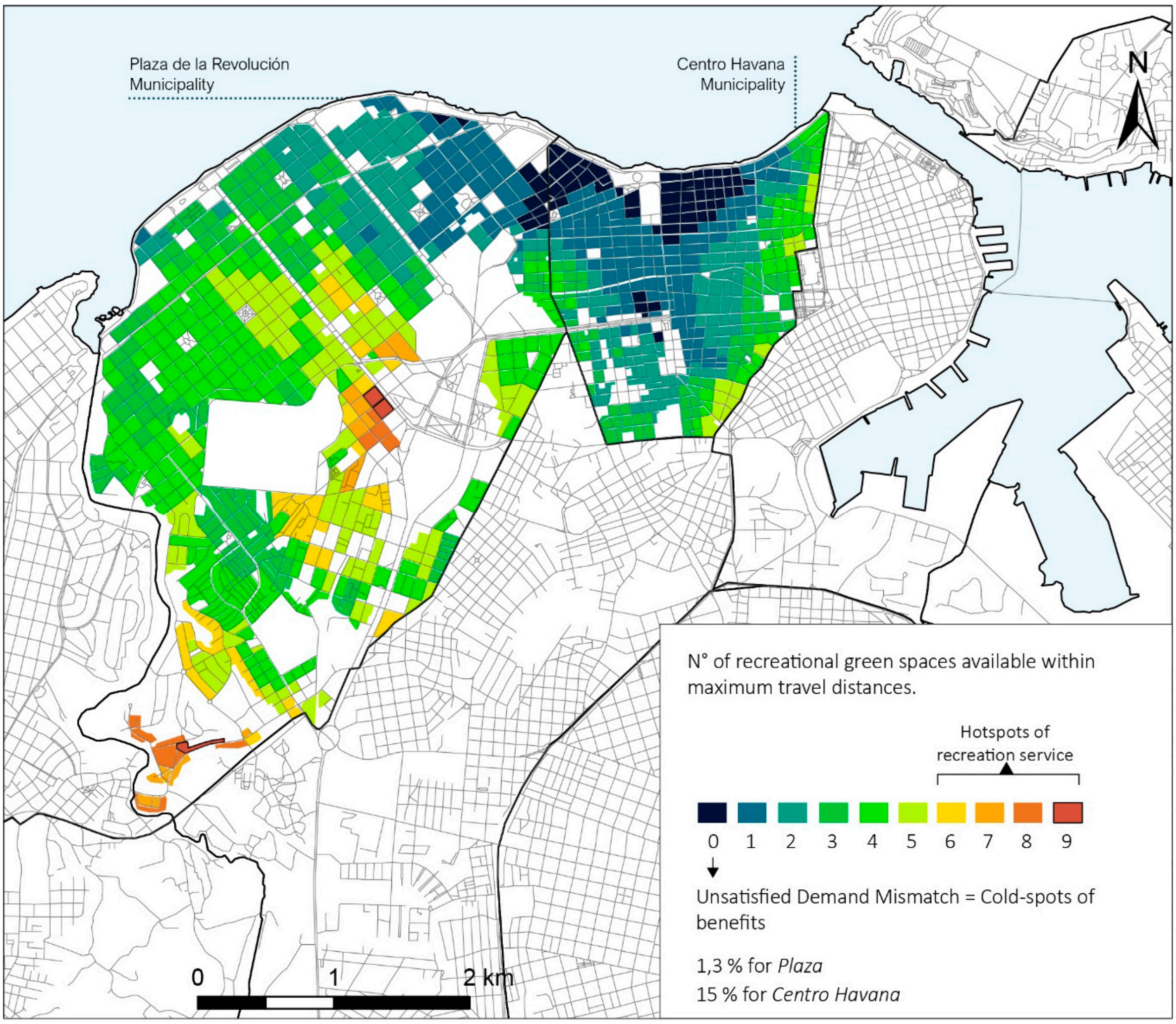

Figure 7. Unsatisfied demand mismatch and cold-spots of benefits from recreation.

4.2.2. Food Supply

Based on the accessibility map, we identified two areas in *Plaza* with access to organoponics within 500 m (A and B, see Figure 8) hosting 9.6% and 1.6% of the municipality population. In 2016, the total production of Plaza' organoponics was not enough to satisfy the demand. In fact, unsatisfied demand for A and B ranges from 53% to 62% of potential beneficiaries, respectively, while at the municipal scale, it reached 95% of the population. In the case of *Centro Havana*, the results are even worse, reaching 99.5% of unsatisfied demand at the municipal level. The two organoponics that are available in this municipality create just one benefiting residential area. Although a relevant share of population lives in this area (22% of total population), local organoponics have satisfied demand for only 2.2% of these residents in the 2016.

Table 4 shows unsatisfied demand mismatch for diverse annual crop yield. Despite the overall deficient performance at the municipal level, the number of people that benefit from food supply in A and B in Figure 8 could increase on average by 8% if the annual crop production would improve by 4 kg/m^2.

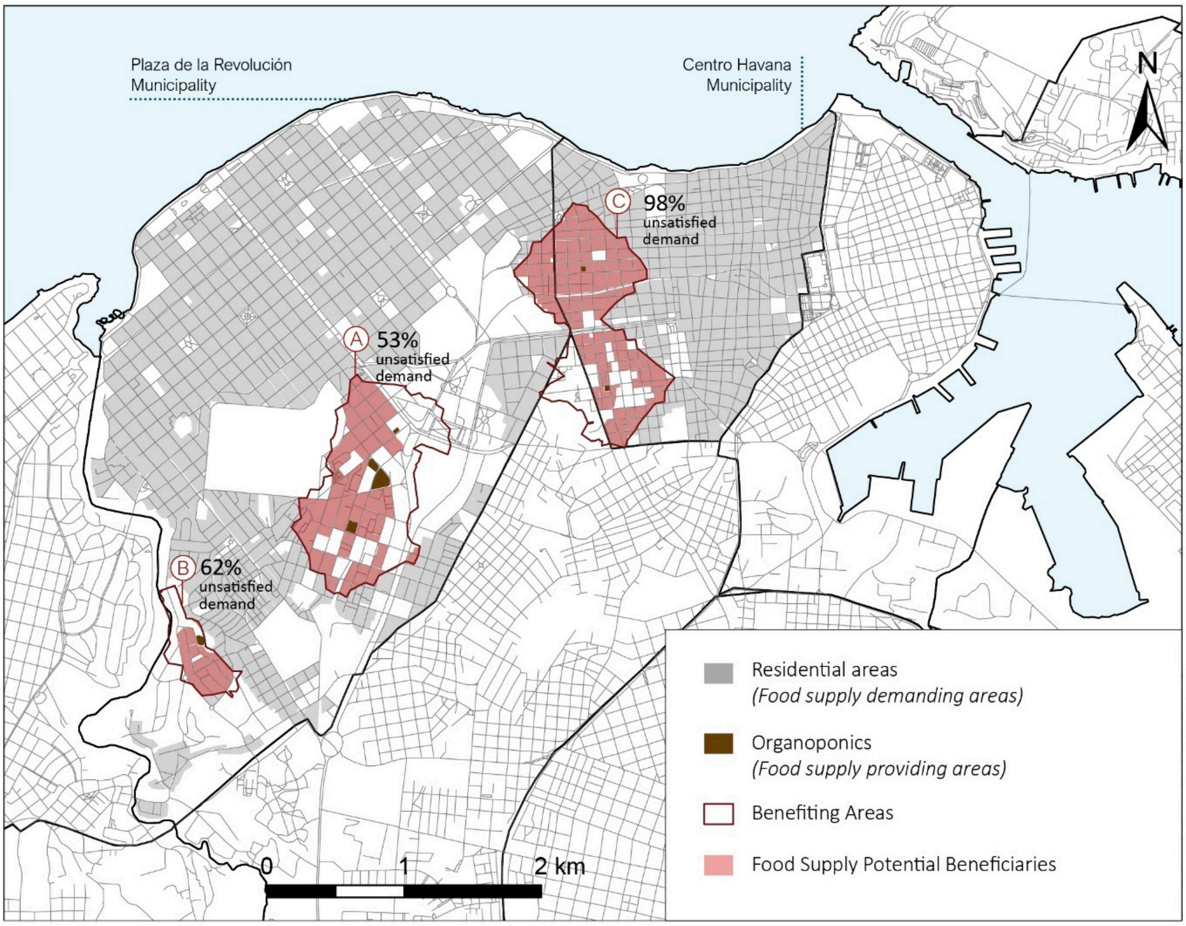

Figure 8. Unsatisfied demand of food supply.

Table 4. Unsatisfied demand of food supply considering diverse values of annual crop yield.

Annual Crop Yield	Local Level—Benefiting Residential Areas	Municipality Level
22 kg/m^2	(A) 43% (B) 53.3% (C) 97%	*Plaza* 94% *Centro Havana* 99.4%
18 kg/m^2	(A) 53% (B) 61.8% (C) 98%	*Plaza* 95% *Centro Havana* 99.5%
7.6 kg/m^2	(A) 80% (B) 84% (C) 99.1%	*Plaza* 98% *Centro Havana* 99.8%

5. Discussion

5.1. Unsustainable Flow and Unsatisfied Demand Mismatches in the Case Study

The local provision of ES within highly-populated urban areas is often jeopardized by the scarce availability of public green space [13,20]. This may potentially lead to the overuse of existing green spaces, hence to the unsustainable flow of ES. This is the case of recreation in *Centro Havana*, highly compact and with an overall lack of green spaces. Particularly, high population density within the benefiting areas results in a number of beneficiaries that may create overcrowding in all green spaces.

Despite the green spaces per capita of *Plaza*, 8 m^2/inhab which is slightly under the National requirements, this municipality shows a predominantly unsustainable flow of recreation service, especially in the northwestern region. However, we found sustainable flow in green spaces near the southeastern limits due to the medium-high availability of green spaces with recreation potential located both inside and outside of the administrative limits. In addition, information about residents' flow from surrounding municipalities to the selected green spaces was not available.

The unsatisfied demand mismatch for recreation varies among municipalities because of their urban morphologies, e.g., in *Plaza* it promotes the integration of green areas, in *Centro Havana* there is a disproportionate ratio between service demanding and providing areas. Particularly, in the latter municipality, the recreation potential of green spaces that are located outside play a crucial role in satisfying the demand. We also found that, in both municipalities, dwellers of residential areas already benefiting from recreation do not have to travel long distances to reach the green space. Several studies suggest that distance from green spaces is inversely associated with use and physically active behaviors [54].

Increasing urban green spaces that are suitable for recreation mainly in the northwestern region of *Plaza* and in the north and central region of *Centro Havana* will contribute to overcome both unsustainable flow and unsatisfied demand mismatches. However, the compactness of existing urban areas limits the development of new green spaces [55]. In this context, enhancing quality, also for green spaces outside the municipality, is particularly important when no further green space can be provided. Innovative greening ideas (e.g., green walls, green roofs, use of various shrub species at door step), combined with smart distribution of small public green spaces could enhance the visibility and the overall visual quality of green spaces [56]. This could promote walking, which is largely a recreational activity [57], as well as socializing and rest and rehabilitation-based activities [58]. Previous research [52,59] suggest that green area attractiveness is an important determinant of willingness to walk to a destination. Particularly, urban greening efforts for the case study should also include devoting urban lots with abandoned buildings to public green. Actions that are aimed at preserving green spaces beyond administrative limits and their recreation potential will help to maintain the sustainable flow in *Plaza* and the percentage of satisfied demand in *Centro Havana*.

Food supply is the ES with the worst performance regarding unsatisfied demand mismatch. Despite the actual high annual crop yield, urban agriculture in both municipalities contributes poorly to food requirements. In addition, an increment of the annual crop yield up to its maximum value would significantly reduce the mismatch within benefiting residential areas of Plaza, but still it would not be enough to satisfy the demand for food from urban agriculture at the municipal level. Our results contrasted data about fresh food production at the city level, which are considerably higher and satisfied a great percentage of fresh food requirements—see Section 2. Several markets that are located within municipalities support the distribution of fresh food coming from urban and peri-urban agriculture of the city of Havana. Hence, our results are not evidences of a crisis in the provision and consumption of vegetable and fruits in *Plaza* and *Centro Havana*. However, the available data do not clarify how many residents from both municipalities had actually benefitted from the overall food production of the province. Generally, the food self-sufficiency increases with increasing distance from the city center [45]. Thus, *Plaza* and *Centro Havana* could experience challenges in purchasing fresh food when compared with other municipalities.

The proximity of production areas to consumers provides advantages in terms of lower final prices and easier quality control [60]. Although the peri-urban agriculture is characterized by a short marketing supply chain, issues that are related to availability and rising prices of oil will make local food supplies (within municipalities) even more valuable [60]. Based on this, planning actions should encourage the proliferation of organoponics, intensive gardens and others forms of urban agriculture in which there is a short distance between food producers and consumers. This would improve food accessibility and promote the co-benefits of this form of food supply, such as social cohesion, sense of community [61], and employment opportunities. New forms of urban agriculture suitable to dense urban areas should be promoted, such as rooftop gardens [62], especially in *Centro Havana*, given the lack of available land.

5.2. Challenges of Assesing Mismatches and Insights for Future Research

We have identified several challenges that are related to the methodology used to assess mismatches. The identification of unsustainable flow is based on predictions about which ES flow may degrade ecosystem functioning. Given that sustainability thresholds are predictions, they may be subjected to uncertainties [25]. In the case of recreation, studies aimed to locally assess correlations between diverse scenarios of crowding and degradation of recreation potential of green spaces are needed. Also, exploring representative indicators of recreation potential that are related to the case study will provide more accurate results [63].

It is important to distinguish between demand and flow of ES in a way that enables one to detect mismatches [23,64]. However, we found in the ES literature several approaches where concepts are used interchangeably, making the identification of unsatisfied demand particularly challenging. For example, "actual ES use" is used in [3] to operationalize demand of ES, while in [22,24] authors used it to obtain ES flow.

Using quality standards to operationalize ES demand allows for quick assessments of demand and cross-city comparison, but it fails to include local context needs [26]. For example, purchasing fresh products from local gardens and community markets represents a day-life behavior of residents in our case study. Hence, food supply standards may be different when compared to other places with a weaker tradition of urban agriculture. Indicators that are used for food supply and recreation assume that urban dwellers have the same preferences and needs. Moreover, regarding recreation, the method assumes that if one person has available two recreational sites within maximum travel distances, that person will be willing to visit both sites to satisfy its recreational demand. These assumptions do not reflect real behaviors and demand of citizens. Individual factors (e.g., attitude toward physical activities), as well as environmental (e.g., nature, maintenance conditions, quietness) and social factors (e.g., culture, history, club membership), may influence preferences and recreational demand of diverse user groups, hence their recreational use of green spaces [43,52,54,65,66]. We consider that future research should focus on targeting more quality standards, e.g., diversity of fresh produce, to diverse social groups and urban areas, e.g., based on their cultural preferences, individual requirements or vulnerability to extreme events expressed by population surveys.

A more disaggregated demand requires data often unavailable, e.g., population and social groups distribution inside and outside geographical boundaries. Their consideration in the assessment will contribute to unveil the currently hidden mismatches. This is a shortcoming of our methodology that should be addressed in a further step, e.g., through ground truthing.

The recreational use of green spaces by floating population (e.g., commuters) or tourists was not considered. Indicators that assess the flow of these population groups, e.g., by directly monitoring number of visitors in green spaces, will help in quantifying ES flow more accurately. Another variable that influences ES flow and needs to be addressed is the perception of specific user groups of obstacles to access to urban green spaces. For example, the perception of safety may influence the recreational uses of green spaces by young children [43].

We use the reliance coefficient to adjust quality standards to local context. For the Havana case study, we found quantitative references to quantify this coefficient for food supply. However, it remains particularly challenging for other services and cases studies, since often city development plans do not define quantitative objectives and targets that are related to ES provision [17].

5.3. How Can Mismatch Assessment Support Spatial Planning?

In the ES literature, several authors maintained that assessing mismatches in the provision of urban ES can help to better design built-up and green spaces [3,23,24,67]. The ability of urban ecosystems to provide ES is jeopardized by anthropogenic pressures such as land consumption, land-use changes, and, in some cases, the ES flow [10]. Particularly, the latter becomes problematic when it implies the degradation of capacity of green spaces to provide ES [22]. In this regard, unsustainable flow mismatch helps to identify urban green spaces that need actions that regulate the ES flow, so as to ultimately ensure proper ecosystem functioning and the long-term provision of ES. Thus, indicators of unsustainable flow can be used by planning and policy instruments for the sustainable management and use of urban green spaces. However, these indicators do not apply to all ES, but only to those that satisfy the condition of rivalry [24]. This condition assumes that one's use of the ES prevents others from using it—i.e., the ES is a finite good, or it can be used once [27]. Most provisioning services (e.g., plants, food, water, raw materials) and some cultural services (e.g., recreation) are considered rival or congestible—i.e., services that become rival for certain levels of flow [24,68]. In line with findings in [24], we argue that the assessment of this mismatch is not suitable for regulating services, typically because they do not satisfy the condition of rivalry. Moreover, their flow does not interfere with the mechanism of ES provision. For example, benefitting from a cooler urban environment does not interfere with the evapotranspiration process of trees and does not preclude others from the same benefit.

Green spaces and related ecosystem services are heterogeneously distributed within cities and disproportionally benefit diverse social groups and urban areas [20]. The equitable distribution of benefits from ES to all urban dwellers is another important goal of spatial planning [9,69]. Its assessment involves, alongside the location of green spaces [20], two other aspects: the provision of ES based on local demands [70] and the means of access to these ES [67,71]. For example, benefits from recreation and food supply depend not only on the presence of urban parks or organoponics, but also on their environmental attractivity/crop yield and on the access to these areas. The methodology that is used in this study to analyze mismatches takes a closer look at these three issues. In fact, it maps green spaces providing services and assesses actual uses of ES by combining actual provision with physical accessibility criteria. Then, unsatisfied demand mismatch identifies priority areas for its deficits of ES benefits based on ES demands.

Urban planners are active agents in developing strategies that may affect this deficit. Locating ES demand in smart locations could reduce the ES deficit. For instance, a planning measure to reduce or avoid demand for flood protection is to locate residential and industrial areas outside and distant from flooding and coastal areas. Another strategy is promoting a more homogeneous distribution of people vulnerable to heatwaves within cities. It could avoid their concentration in places with an insufficient cooling capacity and hence, it would prevent having peaks of unsatisfied demand of temperature regulation service. The presence of these peaks could be a challenging issue to deal with in compact cities, where often the lack of open space limit the use of green spaces as a solution to mitigate effects of climate change. Enhancing access to ES benefits will also contribute to reach the equity goal. This strategy applies only to most cultural and some provisioning services that do not need actors that carry goods to final consumers [67]. Planners could improve connections by removing physical barriers, designing short and security paths and encouraging new routes of public transport. Also, they could play a role in mediating with diverse stakeholder to enable and maintain access to land of resource-dependent communities [19].

6. Conclusions

Information on actual ES distribution, quantity and quality of ES provision as well as accessibility and demand of ES by urban dweller will support spatial planning in enhancing the quality of life in urban areas [72]. The aim of this study was to quantify and map unsustainable flow and unsatisfied demand mismatches of two urban ES, recreation and food supply, in two municipalities of the city of Havana. We developed a methodology based on a quantitative, and spatial-explicit comparison between critical capacity, flow of ES, and demand of ES. To assess unsustainable flow, we define the threshold of flow for rival or congestible ES, as occur for recreation. The methodology includes a GIS-based network analysis to properly account for physical barrier and existing paths that connect beneficiaries with green spaces. It combines these data with actual ES provision to assess unsatisfied demand. Particularly, it identifies green spaces with an unsustainable flow of recreation due to overcrowding. Also, it identifies residential areas with unsatisfied demand, and hence, with a deficit of benefits from recreation and food supply. Thus, our methodology provides quantitative measures of unsustainability and ES deficit. Most specifically, for provisioning and cultural services that are rival or congestible, for which overuse may affect capacity of green spaces to provide the same service, our approach allows assessing unsustainable flow.

By applying the methodology to *Plaza* and *Centro Havana* we have shown that restricting the assessment to the administrative boundaries of municipalities limits the identification of both typologies of mismatches within the case study. Green spaces belonging to other jurisdictions also provide services to *Plaza* and *Centro Havana* residents. As well, population that is located in other municipalities can benefit from ES provided by green spaces of the case study. Thus, boundary effects should be properly considered in the mismatch assessment. Regarding the operational level, we suggest that the scale of ES provision and the scale of management of green spaces should match in order to tackle current unsustainable flow and unsatisfied demand.

Results of *Plaza* suggest that green space per capita standard is not enough to avoid mismatches. Planning actions should promote innovative greening ideas to increase green spaces devoted to recreation in specific areas and to urban agriculture in the whole area of both municipalities. However, enhancing quality and visibility of green spaces is as important as increasing quantity, mainly in highly dense urban areas with a lack of open spaces. Alongside these actions, planners could also counteract mismatches with a smarter location of population groups and by enhancing access to green spaces and related services.

Maps and findings resulting from our assessment may improve spatial information base and promote an evidence-based spatial planning process. Moreover, measuring unsustainable flow and unsatisfied demand represents an opportunity to tackle specific urban issues such as the sustainable use of green spaces and the equitable distribution of ES benefits, respectively. Nevertheless, the assessment of these mismatches is still at its early stage and some aspects need to be further researched. Particularly, these concern a disaggregated analysis of ES demand to capture socio-cultural and economic characteristics as well as preferences in terms of quantity and quality of spatial contexts (e.g., directly expressed by people in interviews and questionnaires or embedded in urban plans); suitable indicators representative of case study to assess potential of ES provision; a detail assessment of constraints and mechanisms that may limit access to services; and the provision of scientific evidences that may support the identification of sustainability thresholds of ES flow.

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