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Urban Green Infrastructure as a Strategy to Address Urban Energy Efficiency and Sustainability. A Case Study of Milagrosa (Pamplona) †

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Abstract: Green Infrastructure (GI) has gained importance in recent years as it has been revealed as an essential piece to face the environmental problem generated by the incessant growth of urbanization, loss of biodiversity, and climate change. In this vein, the results of a research aimed at investigating the challenges posed by the implementation of the GI in the usual compact urban spaces in the cities of the Mediterranean area are presented, based on the analysis of indicators on green spaces in the Spanish city of Pamplona. A comparative analysis of the indicators (green spaces and trees) in the city's neighbourhoods using GIS tools reveals the high intra-urban inequalities as well as the existence of, particularly, underfunded areas. The morphological analysis of one of the underfunded spaces (La Milagrosa neighbourhood) also shows that the narrowness of the road and the shortage of green spaces constitute obstacles that must be addressed from the planning tools of the GI. The results allow us to reflect on the importance of the scale of analysis in the planning processes of the UGI (Urban Green Infrastructure) and on neighbourhood the suitability of Nature-based Solutions (NbS) as an alternative for the design and implementation of the UGI.

Keywords: urban green infrastructure; sustainability; GIS; compact cities

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1. Introduction

The need to introduce nature in cities is not something new, but it has become an imperative need hand in hand with increasingly widespread awareness of the environmental crisis we are experiencing (and that could reach dramatic consequences and compromise our existence on the planet) and the importance of urban spaces in the transition to a more sustainable model of relationship with the planet.

In recent decades a high volume of research has demonstrated the numerous and important benefits that urban green spaces produce both to their inhabitants and to the ecosystem [1]. On the other hand, the need and the appropriateness of green elements and infrastructures to avoid and alleviate the effects of climate change in cities is also becoming increasingly evident. The reasons add up so that the renaturalization of cities (in the most complex context of a global transition to sustainability) has been incorporated into the agenda of environmental and social priorities.

The UN Rio+20 conference (United Nations Conference on Sustainable Development, also known as the Earth Summit), held in Rio de Janeiro in 2012, was an important milestone in terms of the relationship between the environment and habitat, as it definitively instituted awareness of the inescapable relationship between ecological problems on a global scale and the extension of the urbanization process [2].

At that conference, the development of urban green spaces was also considered an important indicator of urban sustainability [3]. The Third United Nations Conference on Housing and Sustainable Urban Development (Habitat III), held in Quito in 2016, incorporated into the Urban Agenda important references on green spaces as a key aspect for achieving more sustainable and resilient cities.

Within the thematic line dedicated to public space, the value and role of green spaces in climate change mitigation and adaptation strategies and as wildlife habitats were highlighted. The Spanish Urban Agenda, elaborated to fulfil the commitments acquired by Spain in the fulfilment of the international agreements, has as its first strategic objective "to order the territory and make a rational use of the land, conserve it and protect it." This strategic objective integrates three specific objectives, the third of which is to "improve green and blue infrastructures and link them with the natural context." Finally, the EU Biodiversity Strategy by 2030 includes a call from the European Commission on cities with more than 20,000 inhabitants or more "to develop, by the end of 2021, ambitious urban greening plans that include measures to create accessible and biodiversity-rich urban forests, parks, and gardens; urban farms; green walls and roofs; tree-lined streets; urban meadows and urban hedgerows" [4] (p. 15).

The growing interest in urban green spaces as an area of action and research to alleviate the environmental and sustainability problems of urban areas has led, in recent years, to a sustained increase in scientific production. In this way, a vast field of research has been generated in which numerous scientific disciplines participate. From Ecology, Urbanism, Forest Sciences, Biology, among many others, very diverse and also very dispersed lines and approaches of research are developed [5]. In 'Advancing Urban Ecology toward a Science of Cities,' McPhearson [6] identified up to 20 different fields of knowledge in urban ecology research. This type of work demonstrates the complexity of a task that requires a multidisciplinary, interdisciplinary, or transdisciplinary approach (or even a synthetic discipline) and that demands, above all, clear answers and orientations that can guide the transformation of current models and urban spaces. The need for an integrative approach to knowledge, disciplines, and even methods is a topic in this field of research, which usually also highlights the difficulties arising from the persistence of the silos of researchers and professionals [7].

In this context dominated by thematic and disciplinary dispersion, there are three concepts that represent systemic approaches in which specific interventions are used to solve sustainability problems: green infrastructure (GI), nature-based solutions (NbS), and ecosystem-based adaptation (EbA) [8].

Regardless of the differences in approach involved in each of the three concepts and the debates regarding the precise meaning of them, all three have common features and constitute theoretical-practical tools to address the renaturalization of cities in a holistic way or, if preferred, their ecological restoration.

In 2013, the European Commission defined the GI as a strategically planned network of high-quality natural and semi-natural areas with other environmental elements, designed and managed to provide a wide range of ecosystem services and protect the biodiversity of both rural and urban settlements. It includes green spaces (or blue for aquatic ecosystems) and other physical elements in terrestrial (natural, rural, and urban) and marine areas [9]. As a spatial structure that generates benefits from nature to people, green infrastructure aims to improve nature's ability to provide multiple and valuable ecosystem goods and services, such as clean water or air.

In the case of the GI, beyond a concept, we can speak of an approach, that is, of a way of understanding the relationship, nowadays very deteriorated, between the human being and nature, to improve that relationship and to address the problems related to it. Bearing in mind that harmonizing economic development with ecological integrity and social justice are the greatest challenges that threaten social well-being across the globe, the fourth approach seeks to provide solutions through a framework of thought and action aimed at reconciling divergences between conservationist positions, economic development, and social equity.

In the field of urban planning, the concept of GI is replacing that of green areas, whose function is fundamentally related to aesthetics and recreation. Interconnected green spaces, forming a network, provide a much wider range of services (ecosystem services) from health to supply (urban gardens) to adaptation and resilience to the effects of climate change (heat islands, floods). On the other hand, the connection between green elements generates communication corridors for flora and fauna, thus contributing to slowing the loss of biodiversity. In short, regardless of the specific objectives and the particular characteristics of the different local environments, the UGI is defined by its multifunctionality and connectivity [3], being able to define itself as "an interconnected and complementary network of urban green spaces that includes all those elements highlighted by their environmental, landscape or heritage importance, as well as their corresponding ecological processes and flows" [10]. The network is therefore composed of the elements and the processes and flows that occur within and between them.

The construction of green infrastructure, whatever the scale at which it is proposed, is a bet and a challenge of great magnitude for those responsible for its creation that, in the case of the Spanish state, are the autonomous communities and the municipalities.

Taking into account that in urban-territorial intervention policies, the effective separation between urban and environmental strategies still dominates (theoretically surpassed in academic and institutional discourses) [2], the challenge is, to a large extent, to incorporate the ecological approach to regional planning and urban planning, placing ecology, ecosystem services and environmental risks as central concerns of planning practice [11].

However, the challenges are not over yet. The construction of a UGI, that is, a network of spatially and functionally connected green spaces, in many cases, must be designed and created from scratch, generating new green spaces or carrying out ecological restorations where conditions allow it. The objective is not to increase, without further ado, the parks and green surfaces of the cities but to integrate in-network spaces that act as habitats and refuges of species or as connectors of these and that contribute to the improvement of the quality of the water or the air, to the control of the runoff, to regulate the microclimate or to connect the city with its surroundings.

In short, the creation of a UGI requires a thorough planning work in which numerous decisions must be made, and priorities must be hierarchized with regard to urban areas that need the highest level of intervention or, more urgent, the type of ecosystem services that should be prioritized or the solutions that can be used in order to obtain the greatest possible number of functions for the same space. In any case, the criterion of optimizing multifunctionality should be a key objective of UGI planning [12].

The design and implementation of the UGI are especially complex in compact and consolidated urban environments in which there are also usually particularly large and variegated sectors or neighbourhoods, characterized by the juxtaposition of buildings and roads with limited interstitial spaces to insert green elements. This type of urban plots, which abound in cities that experienced rapid and poorly planned growth, of "developmentist" Spain require special attention from planners.

This work exposes the results of a study carried out to map and quantify the spaces that can be part of the UGI of the city of Iruña, in order to detect the differences between the different urban sectors as a basis for identifying areas of preferential action in the design of the UGI. It is intended to provide results that can be incorporated in the form of criteria and proposals to the urban planning processes of the city, from the disciplinary perspective of architecture and incorporating the ecological approach and key aspects of the GI such as connectivity and multifunctionality.

As we will see in the methodological explanation of this article, we are going to use the most common quantitative indicators in the scientific literature related to UGI: the number of trees, the surface of green areas and the accessibility to them. Trees are visual and symbolic elements that play an important role in the overall improvement of the quality of spaces from an environmental and social point of view.

2. Area of Study

Pamplona is a medium-sized city located in the north of the Spanish peninsular territory, within a corridor that runs from east to west the mountain range of the Pyrenees, known as the Pre-Pyrenean Middle Depression (Figure 1). It is the capital of the autonomous community of Navarre and the nucleus of reference of a region in which 661,023 people live (1 January 2021, INE. Instituto Nacional de Estadística, Spain).

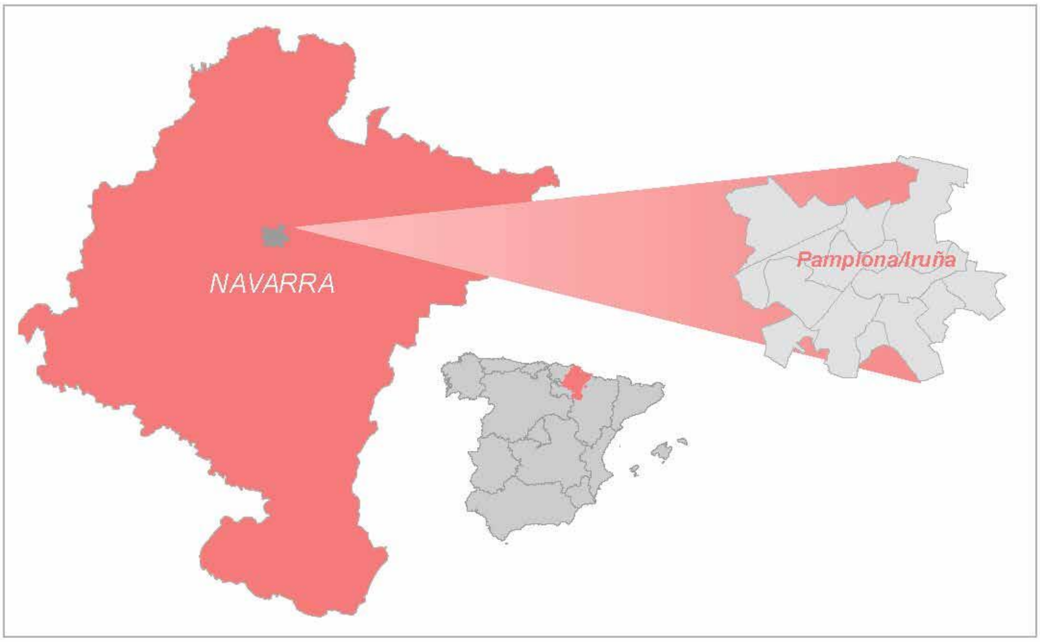


Figure 1. Location map.

Similar to many of the Spanish cities that had a process of industrialization and accelerated urbanization since the 1960s of the 20th century, the urban structure of the city is organized in a central area surrounded by peripheral neighbourhoods emerged in a process of growth more guided by the obtaining of benefits than by the quality of the built space.

Although the central area (old town and expansion district—Ensanche—) and the stripe of peripheral neighbourhoods form a fairly compact built continuum, the city of Pamplona has a good number of parks and gardens that alleviate the density and compactness of the urban fabric. In fact, in 2018, the Spanish Association of Public Parks and Gardens rated Pamplona as one of the Spanish cities with the highest proportion of trees and green surfaces per inhabitant. The recovery of the banks of the Arga, Elorz, and Sadar rivers and the creation of a river park or pioneering actions such as the campus of the Public University of Navarra, Pamplona, Spain provided high-quality green spaces to the city, reflecting the interest of public managers in improving the urban space.

However, although the indicators on green and wooded areas are very positive for the city as a whole, there are important internal differences and, above all, frankly disadvantaged areas. This is the case in the neighbourhood of La Milagrosa.

La Milagrosa is a neighbourhood in the south of the city, in spatial continuity with the orthogonal Ensanche, whose construction began in the early 1960s of the last century to respond to the residential demand of the immigrant population that came to meet the demand for labour from the industry. Built on the pre-existing rural plot and on a complex and sloping topography, the need of some and the ambition of others came into play to create an urban space devoid of squares, public spaces, and endowments, of narrow and disjointed streets. Although some subsequent actions have created public spaces in the edge areas of the neighbourhood, on the whole, the original urban fabric is maintained, whose ecological regeneration should include actions to free up the urban fabric and incorporate green spaces that could be integrated into the future network of the green infrastructure of the city.

3. Methodology

For the study, all urban areas with some type of vegetation (herbaceous, shrubby, or arboreal) in direct contact with the natural soil, regardless of the size of the property, are considered green spaces. Although the ecosystem services provided by the different green spaces can be very variable, depending on the composition or the conservation state (among others), the fact that they are permeable surfaces, added to the possibility they offer as connectivity elements of the UGI has led to not excluding any of them from this initial inventory.

As a source of information has been used the digital cartography of gardens of the City of Pamplona, which has been completed with the cartography made by Nasuvinsa, Pamplona, Spain for the study Green Infrastructure Area Pamplona and surroundings ceded by that entity. The information has finally been completed with the digitization using ArcMap software from the municipal orthophoto of 2020, at 1/5000 scale (Figure 2).

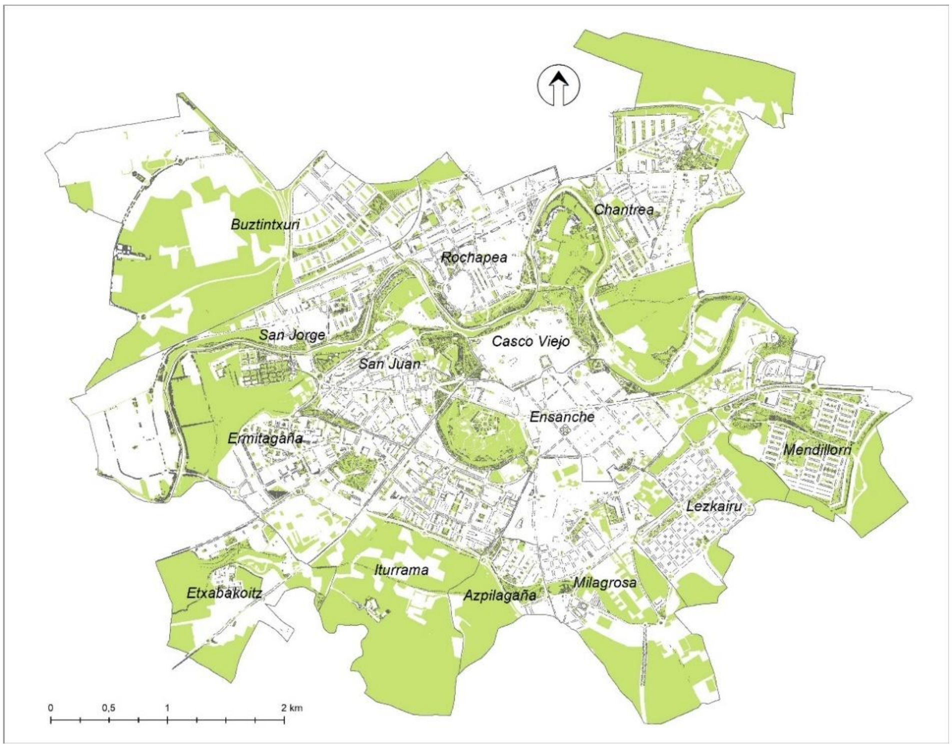


Figure 2. Map of green surfaces. Authors' elaboration on a cartographic base of the City council of Pamplona. In green, the green surfaces. In dark grey dots, the woodland.

In order to analyze the internal differences in the availability and spatial distribution of the elements likely to be incorporated into the future green infrastructure of the city of Pamplona, the three most common quantitative indicators in the scientific literature have been used: the number of trees, the surface of the green areas and the accessibility of the population to them [3,13].

Trees are primordial and structural elements of the urban space. They are also visual and symbolic elements and, above all, play an important role in the mitigation of the heat island, the cooling of the air through evaporation, in the infiltration of water into the soil [14], in public health, environmental justice, water quality and environmental pollution [15].

The calculation of the woodland has been carried out in reference to the unit of area (trees per hectare) and the number of inhabitants of the unit of analysis (number of trees per inhabitant).

The surface of green areas calculates the percentage of green spaces in relation to the total area of the selected spatial unit (neighbourhood, city, etc.). In addition to the information on the availability of green areas of the study area, this indicator is used to evaluate the permeable surface and, therefore, the properties of the area as a water regulator. Through the two indicators, information is obtained regarding the quality of life and, therefore, the differences between urban sectors (objective of this study) and the areas that, due to their scarcity of permeable soils or the presence of complex plots, will require greater effort and priority in the planning of the UGI.

The weighting of the data in relation to the inhabitants has been carried out using the information provided by the Statistical Institute of Navarra (NASTAT), Pamplona, Spain, updated to 1 July 2020. The feature provided the georeferenced population data, grouped at portal scale. This has allowed us to calculate, in an adjusted way, the ratios of the woodland and the green surfaces in relation to the inhabitants without depending on other statistical units than those elaborated for the present study.

For the calculation of the accessibility of the population to green spaces, the proposal of Hernández [16] in relation to the optimal surfaces of green spaces has been taken as a reference. The proximity green spaces, that is, those that offer a function of daily contact with the green, are the garden areas, squares, and areas that occupy a surface greater than 1000 m^2 and that are located at a distance of fewer than 200 m with respect to the place of residence.

The spatial unit of analysis chosen has been the neighbourhood because it is a morphological and structural unit that presents a homogeneity compared to other neighbouring areas in terms of social composition, types, or constructive densities [17]. However, based on the objectives of the study, it has been decided to take into account not the entire surface of the different neighbourhoods but only the surface of the areas that form a continuously built environment (Figure 3).

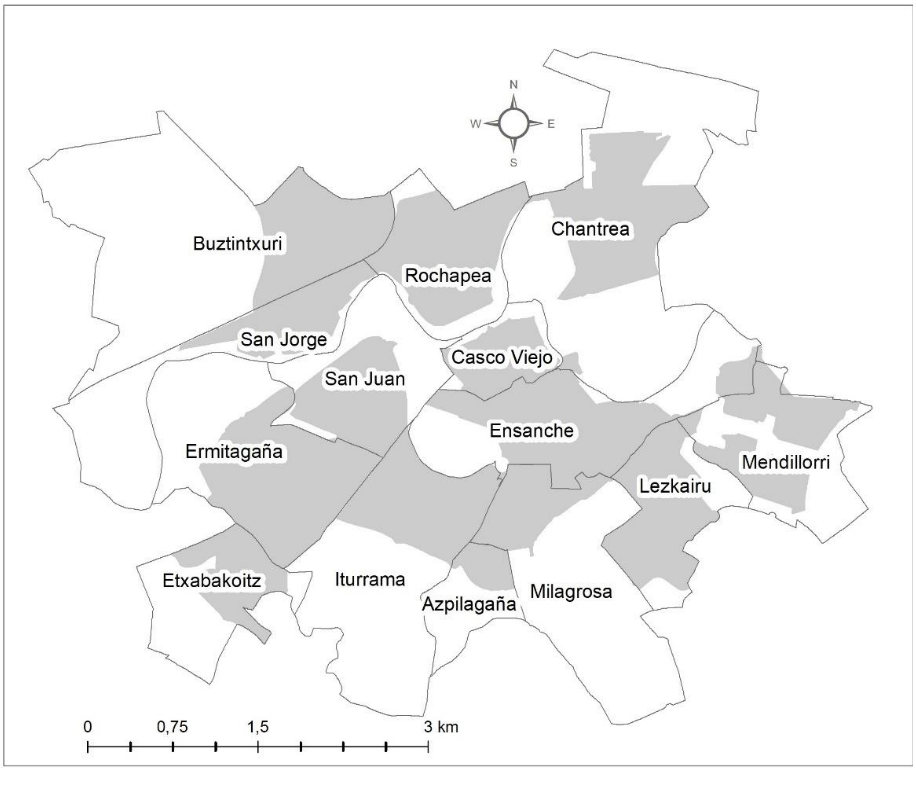


Figure 3. Delimitation of Pamplona's neighbourhoods. The grey spots on the inside correspond to the built continuums. The contours correspond to the administrative boundaries of the neighbourhoods. Performed by the authors, based on the cartography of the Pamplona City Council.

This leaves out of the calculation green spaces such as urban parks greater than 1 ha, developable areas, or preservation soils so that it is possible to obtain a real comparison between the urban plots (continuous built) of the neighbourhoods. The inclusion of large green spaces in the calculations significantly raises the figures of some neighbourhoods, masking, in some cases, the existence of environmentally problematic areas and providing an image of them quite far from reality.

4. Results

The analysis of the spatial distribution of the green areas in the different neighbourhoods of the city (Figure 4) reveals high differences and, therefore, a strong internal imbalance. The green surface indicator (percentage of the surface of the considered area) shows a very important range of variation. The Milagrosa and the Old Town, with 6 and 7% of green surfaces, respectively, are well below the average and, of course, at an abysmal distance from sectors such as Mendilorri or Etxabakoitz, which reach values up to 25 and 34%, respectively. The differences are just as striking in the green surface per inhabitant indicator. Again, we find La Milagrosa and the Old Town at the head of the worst endowed spaces, with 2 and 3 m^2 of green surface per inhabitant, that is, with values more than four times lower than the averages. On the other hand, the average values are very high due to the influence exerted by the high values of Buztintxuri, Etxabakoitz, and Mendilorri.

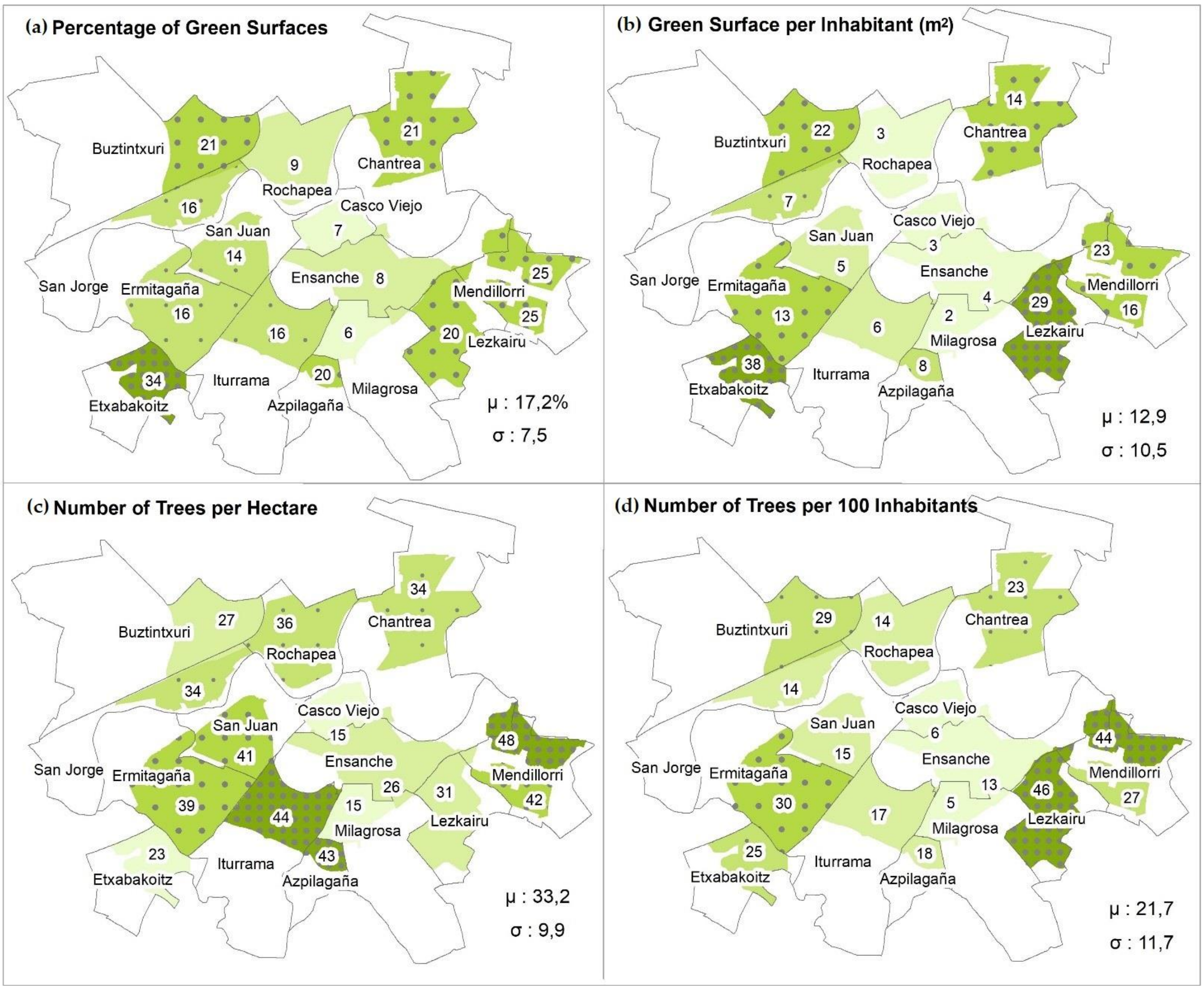


Figure 4. Green and wooded surfaces. Performed by the authors, based on the cartography of the Pamplona City Council.

The results obtained for the Lezkairu area must be interpreted in a strictly provisional way since it is a neighbourhood currently under construction. The results for the indicator of trees per inhabitant (100) and per area unit also show high variability, but their spatial distribution differs with respect to the distribution of green surfaces. These results complete the image of the urban green spaces of Pamplona. Note, for example, that in contrast with the low values obtained for the Ensanche on green surfaces, the tree indicators present figures much closer to the average of urban continuums and also, for example, to the average of 14.4 trees per inhabitant of Spanish cities [18] or a tree for every three inhabitants recommended by the World Health Organization [19]. In the most unfavourable position is, as in the previous case, the area of La Milagrosa: 15 trees per hectare (against an average of 33.2) and 5 trees per hundred inhabitants (compared to an average of 21.7), followed closely by the Old Town. The situation differs in the area of Etxabakoitz, which has the highest values in green surfaces and is far from the best-endowed areas. The best results have been obtained for the northern sector of Mendilorri, with the highest values in the two indicators, being this sector the one that presents the best overall situation (Green surfaces plus trees).

Beyond noting the imbalance aforementioned, assessing the results implies using reference values in order to compare the figures obtained. This is a delicate task because there is no consensus on the ideal number or amount of green space in the city. On the other hand, the use of metric assessments itself is a controversial issue [5] and, in many cases, contested [3,20,21]. Jim, talking on Green-space preservation and allocation for sustainable greening of compact cities [22] is adamantly clear about this when he urges planners to deal more with the geometry of the green net and the quality of vegetation than with the surface of green spaces and tree counts. Zhan, Van den Berg, Van Dijk, and Weitkamp [23] fully address the issue in an article whose title is very significant: "Quality over quantity: Contribution of urban green space to neighbourhood satisfaction."

However, and this is what is advocated in this paper, these types of metrics are appropriate (rather necessary) in the context of urban planning and green infrastructure when working at the city level, and the objective is to define the guiding layout of the GI of the entire urban space and detect problematic or disadvantaged areas that will require special or priority attention in the design and implementation of the green network. In the case of Pamplona, the results obtained from 'green surface per inhabitant' of the neighbourhoods of La Milagrosa, the Ensanche and Old Town—between 2 and 4 m^2—are very far, for example, from the 9 m^2 recommended by the World Health Organization [19] or the 27.14 m^2 per capita of the cities of Austria [3]. The combined metrics of green and woodland surfaces show that, although the Ensanche is deficient in green surfaces, it contains a number of trees per inhabitant close to the recommendations of the World Health Organization.

Very different is the situation of La Milagrosa, with markedly deficient values in both green and wooded surfaces. These results are relevant when it comes to evaluating the ecosystem services provided by the elements and green spaces of different urban areas. A difference of 7 trees per 100 inhabitants between the Ensanche and La Milagrosa, has considerable environmental repercussions: taking into account that a tree absorbs an annual amount of CO_2 between 15 and 30 kg, the extra woodland of the Expansion District absorbs annually between 25,250 kg of CO_2 more than the woodland of La Milagrosa.

The results of the analysis of the accessibility to green spaces complete the diagnostic picture of the situation. Figure 5 shows the areas of the city that have a green space within a radius of 200 m. It is observed that most of the urban space is within the area of influence of a green surface located at 200 m or less. However, in the centre of the map, the coral colour delimits a semicircular strip that is outside the area of influence, and that corresponds to the most compact and underfunded sectors, as far as the green areas are concerned, of the neighbourhoods of La Milagrosa, the Expansion District and the Old Town. These results, on top of their usefulness to know which part of the population of Pamplona lack green spaces in the immediate proximity to their homes (quality of life), are also very relevant when it comes to identifying and delimiting the critical spaces for the design of green infrastructure.

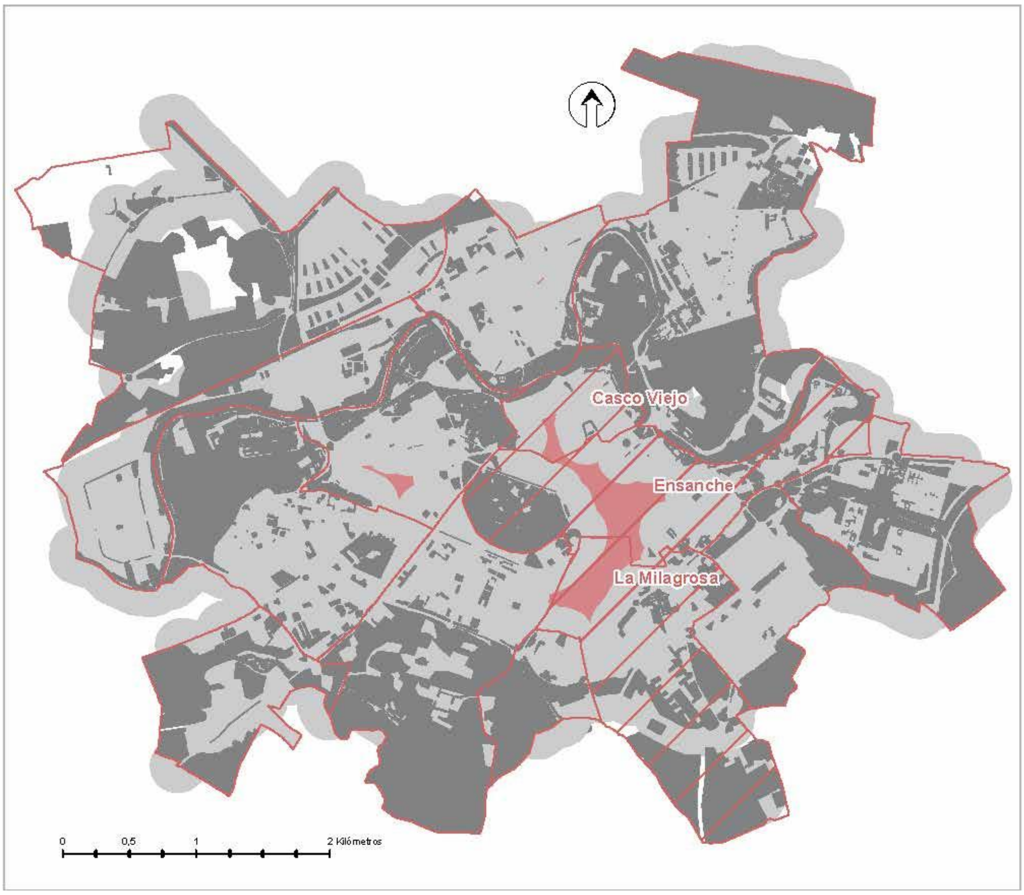


Figure 5. Map of accessibility to green spaces. Performed by the authors, based on the cartography of the Pamplona City Council.

The combined results of the three indicators analyzed show that La Milagrosa is the sector (continuous built) that presents the worst situation of the entire area studied: because of its endowment of green spaces and trees and because part of this area is outside the area of influence of a green surface 200 m away.

The morphological analysis of La Milagrosa shows that it maintains a disordered urban fabric, the result of having been built urgently on the existing agricultural plots. The irregularity of the resulting layout, together with the complex topography on which the neighbourhood sits, gives rise to a morphology of labyrinthine and narrow streets (Figure 6a), generally inaccessible (Figure 6d), and with little public space. It is also the car that has taken over most of this little public space (Figure 6b) (it occupies 75% of the surface, both on roads and in car parks, leaving minimal space for pedestrians (Figure 6c). Thus, we find street profiles with a significant relationship between the height of the building and the width of the street: ground floor buildings plus four floors in streets that do not reach 10 m wide, with two parking lots on each side and a one-way lane, which leaves two sidewalks on the sides of 20 meters for the pedestrian.

Figure 6. Photographs of La Milagrosa show the compactness and complexity of urban space and the difficulties in creating a network of green spaces. (**a**) Narrowness of the streets; (**b**,**c**) Priority of vehicles over pedestrians in the public areas; (**d**) Inaccessible streets; (**e**,**f**) Installation of lifts or street furniture occupying public roads; (**g**,**h**) Low quality of urban space; (**i**–**l**) Recent interventions that have not taken into account the scarcity of green spaces.

This domain of the car entails a high environmental noise due to the road traffic, general throughout the neighbourhood and in particular in the avenue of Zaragoza because it is the exit and south entrance to the city and that divides the neighbourhood into two poorly connected areas.

This situation is aggravated by the installation of lifts in residential buildings occupying public roads (Figure 6e), or due to poorly located urban furniture (Figure 6f), which results in public spaces of poor urban quality in general (Figure 6g,h). It is also observed that both the new spaces created (squares) (Figure 6i) and recent interventions of urban improvement (Figure 6k,l) have not taken into account the green space. Even the recently built parks follow each other but without continuity (Figure 6j), which is an essential feature of the UGI.

See the location of the images within Milagrosas's urban plan in Figure 7.

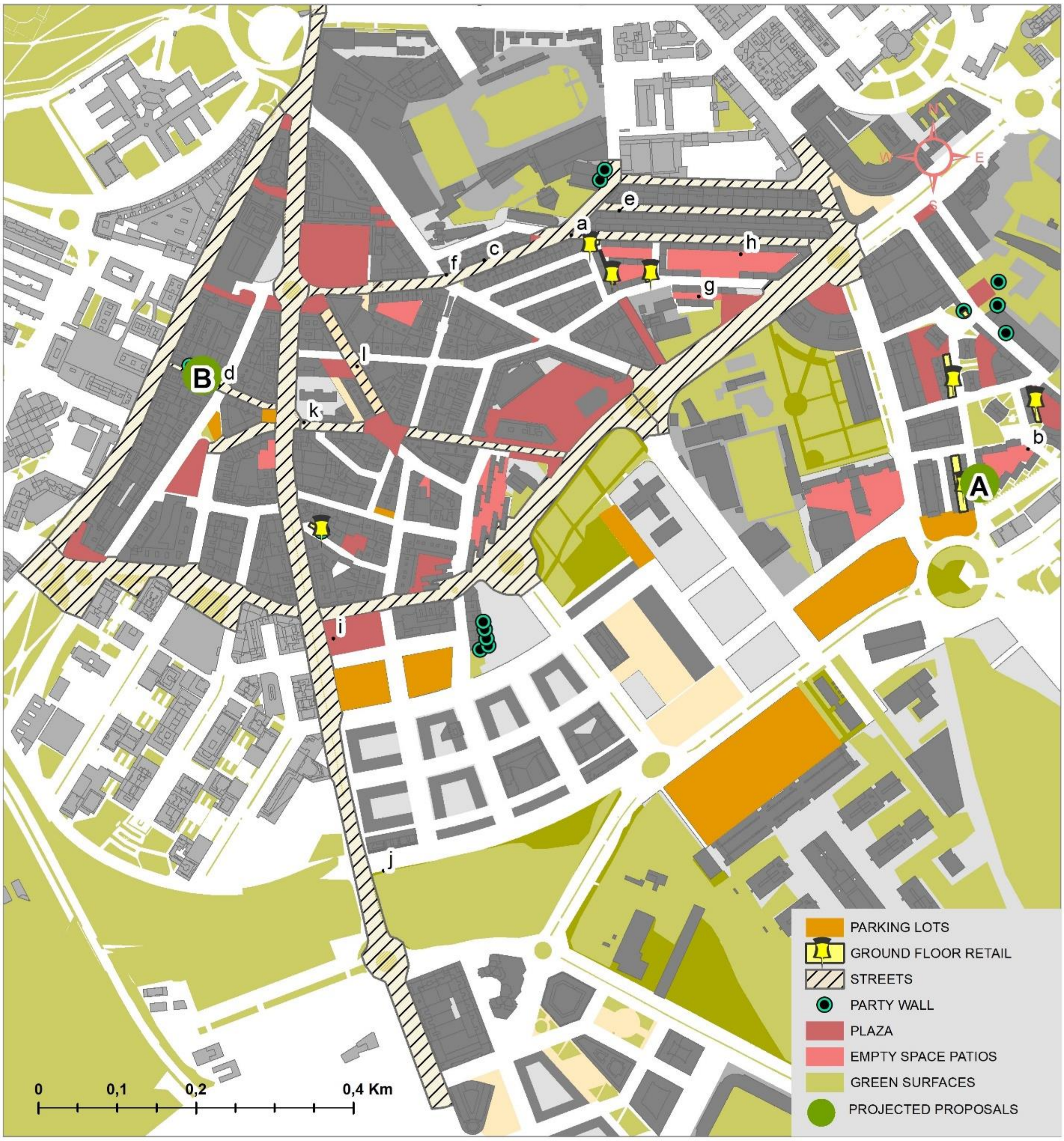
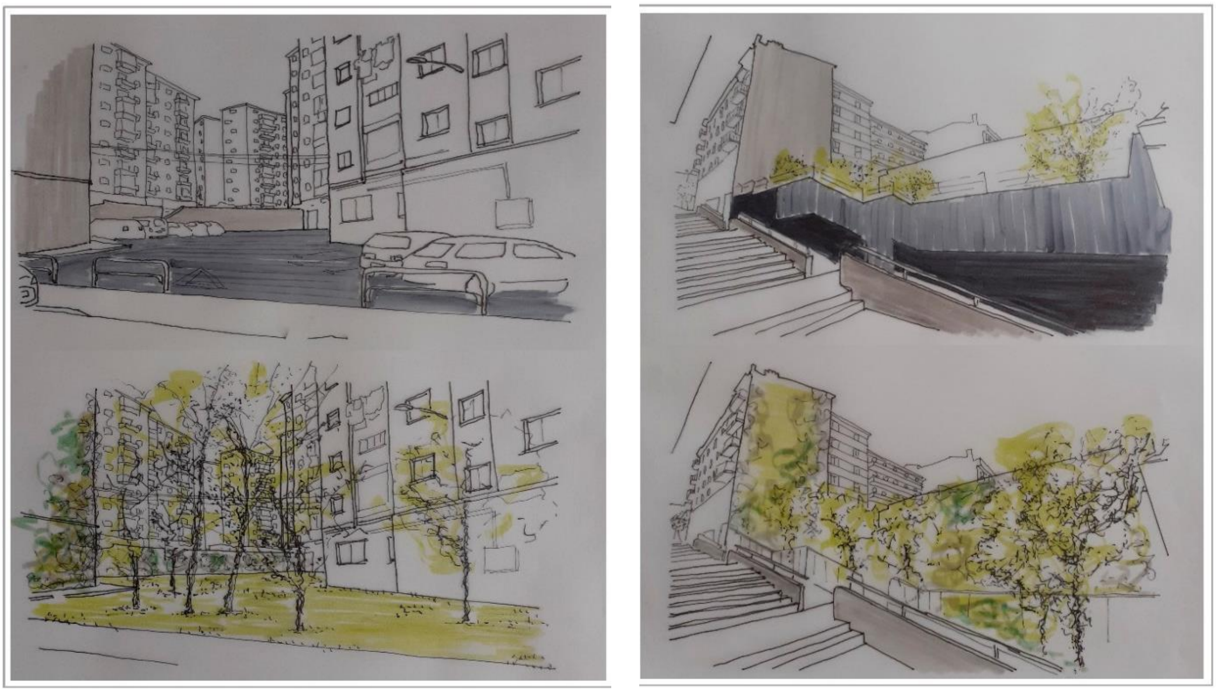


Figure 7. Map of spaces of opportunity of La Milagrosa. Performed by the authors, based on the cartography of the Pamplona City Council. The numbers (from a to l correspond to the location of the photographs in Figure 6.

5. Discussion

The results of the study show that most of the population of the city of Pamplona has a green space at a distance of 200 or 300 m from their place of residence. However, they also show that there is a significant number of people living in very compact urban sectors in which they lack spaces and green elements in the immediate surroundings of their homes. The analysis carried out has allowed us to detect the existing inequalities in the provision of green spaces. These inequalities are, on the other hand, very common in cities that alternate historical urban developments with modern peripheries [24,25] and alert us of the need to pay special attention to urban areas where the compactness of the urban fabric and the scarcity of public spaces hinder the implementation of the UGI. This fact has to be known and recognized by the municipal authorities who, in turn, should acquire the commitment to implement urban green infrastructures that improve equity between areas and citizens and that allow a more rounded and complete green network throughout the whole urban space. The level of knowledge available to the scientific-technical community shows that if the appropriate measures are taken, excessively compact urban spaces can be improved and incorporated into the network of urban green spaces, providing a higher quality of life to its inhabitants, making the city more ecological and resilient. In this sense, Figure 8 shows two proposals that illustrate the possibilities of introducing green spaces and elements in compact urban fabrics, through interventions in small spaces, using Nature-Based Solutions. The two proposals correspond to two real spaces of La Milagrosa, whose location is indicated in Figure 7A,B.



(**A**) (**B**)

Figure 8. Proposals for renaturalization in two sectors of La Milagrosa (Location of proposals in Figure 7). (**A**) Renaturalization of parking already eliminated in the draft of the PEAU (Special Urban Action Plan) of the Milagrosa (2019). (**B**) Opening of inner courtyards inside blocks and implantation of vegetal façade.

The design and implementation of Green Infrastructure in compact urban sectors present its own particularities, requiring the elaboration of ad hoc planning projects, with novel, ingenious measures [26] and participated by the population and the different stakeholders involved [27]. Although there are no universally valid solutions (in fact, we lack integrative vision on how to approach compact and green cities and how to manage trade-offs between urban densification and the provision of green space [27,28] it is possible to point out some of the implications of UGI planning in compact urban areas (Table 1).

Table 1. Implications of UGI planning in compact urban areas.

Objectives	Action Lines	Timescale
Better equity between the distribution, access and quality of urban greenspaces [29]	Identify and map areas with specific deficiencies in terms of elements and green spaces.	Short Term
	Diagnose and evaluate deficiencies in terms of ecosystem services and in relation to the supply and demand of such services in the area. [24,27]	Medium Term
Integrate UGI into Urban Planning processes [30].	Inclusion of the UGI in the Urban Planning in order to harmonize the city model with the objectives of the UGI and give it the necessary legal support.	Long Term
	Promote the development of special protection and conservation plans provided by the Land Law, as tools to perform diagnoses and policy proposals in critical areas.	Lomg Term
	Promote cooperation across authorities and departments in order to identify common objectives and synergies (cross-scale and cross-departmental co-operation). Integrated spatial analyses, in particular, require expertise from different fields. [27,28]	Long Term
Improvement and increase of the elements of UGI network and increase the efficiency of green spaces through combining different functions: (multifunctionality as the main planning principle [28,29].	Prepare a geolocated inventory of spaces and locations that could increase the area (public or private) dedicated to the UGI: parking spaces, public spaces and waterproof leisure spaces, inner courtyards of buildings and educational centres, party walls, vacant lots [31]. Figure 7 shows a map with that kind of opportunity spaces located in La Milagrosa neighbourhood through exhaustive fieldwork. The introduction of green spaces and elements in these locations could significantly improve the ecological, environmental and social conditions of this space.	Short Term
	Develop an inventory of resources and NbS for implementation in small spaces: biodiversity micro spaces, vertical gardens, vegetal facades, green roofs, schoolyards and all kinds of elements and green spaces that can provide ecological, economic and social functions. Figure 8 shows two proposals for the renaturalization of two small spaces of La Milagrosa through the use of Nature-based Solutions.	Medium Term
	Protect and incentive private vegetation development [25]	Medium Term
	Incorporate citizen participation in order to identify improvement possibilities of green spaces [27,28,32] and to design them [33].	Medium Term
	Increase accessibility to public uses with pocket parks or small public urban green spaces [25,29,34–36]	Medium Term
	Plant urban trees in the most compact spaces that show little chance of implementing new green spaces [24].	Medium Term
	Use green roofs as a form of compensating the loss of greenspaces, ecosystem services and biodiversity in urban areas [29]	Medium Term
	Promote the renovation and rehabilitation of buildings through facades and green roofs. Green roofs can improve shading, insulation, evapotranspiration and thermal mass so, they allow buildings to be more sustainable in terms of energy efficiency [29].	Long Term
	Promote the participation of educational centres in the elaboration of proposals for the increase and improvement of green spaces and network.	Short Term
	Incorporate the Academy (technical schools and faculties), through researchers and their research projects and through the practices of undergraduate and postgraduate students in order to get them involved in the search and research of technical and natural solutions for the design and implementation of green infrastructure in complex urban areas.	Medium Term

Table 1. *Cont.*

Objectives	Action Lines	Timescale
Improving energy efficiency	Implement Pocket Green Spaces (green space with a size less than 2 ha) in all possible spaces [35].	Long Term
	Changing surface materials and using low heat capacity materials [32].	Long Term
	Design the green network in order to provide more shade, especially on hard surfaces, and using evapotranspiration to cool the environment [32].	Medium Term
Improving ecological connectivity. Physical and functional connectivity between green spaces is particularly important as this will increase the functionality of single green spaces [27].	Prepare an inventory and map of the points and areas where achieving the necessary connectivity can be a complex problem, difficult to solve.	Short Term
	Develop a database of good practices and resources to address ecological connectivity in compact urban areas	Medium Term
	Incorporate connectivity objectives into sustainable mobility plans (harmonize programs and actions in order to optimize resources and results).	Long Term

6. Conclusions

The results obtained have allowed us to highlight and quantify the enormous differences that exist between the different neighbourhoods of the city in terms of the provision of trees and green spaces. The analyses prove that Pamplona is a green city when taking into account the large parks and green surfaces of the urban centre, the river parks, or the non-developable areas that enclose the neighbourhoods. However, they also prove that the average values of green spaces and trees for the city as a whole are strongly influenced by the high values of some areas. The urban continuums of the Old Town, Expansion District, and La Milagrosa, which account for almost a fifth (2.04 km^2) of the total area (10.9 km^2), are clearly in deficit.

The use of the urban continuum instead of the neighbourhood as a unit of analysis proves to be an ideal strategy to establish a hierarchy of urban areas according to their internal availability of spaces and green elements. When the neighbourhood is used as a unit of analysis, the existence of large green surfaces in specific areas provides average figures for the unit that mask the presence of particularly poorly endowed urban pieces. Only by applying the indexes to the urban continuum is it possible to highlight the situation. This is especially useful and necessary when designing urban green infrastructure since it reveals the sectors that will require adapted solutions to reach minimum thresholds of connectivity and permeability (both of the space itself and of the soil) due to their special compactness and impermeability. On the other hand, the fight to reduce and mitigate the effects of climate change requires a reduction in non-renewable energy consumption. Increasing the energy efficiency of cities becomes one of the important objectives of the aforementioned struggle. Notwithstanding technological solutions to achieve efficiency, today, realizing that vegetation is a great ally in this battle and that imitating nature (Nature-Based Solutions or NbS) is one of the best strategies and remedies.

In short, the results illustrate the need for specific intervention strategies for greening some sectors of the urban area and, especially, La Milagrosa. To this end, some proposals are made that illustrate the possibilities of "inserting" in the neighbourhood of La Milagrosa green spaces that (a) constitute neighbourhood nodes of the future UGI (b) initiate a process of improving the energy efficiency of the sector, and (c) improve the quality of urban space. Exhaustive fieldwork has allowed us to detect what we will call spaces of opportunity for renaturalization (Figure 7) or to create what is known as SPUGS (Small Public Urban Green Spaces). Greening actions on these spaces can help meet the needs of ecological restoration and increase the energy efficiency and sustainability of the area. [34]

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