

Article

Perception of Ecosystem Services and Adaptation to Climate Change: Mirador Sur Park in Santo Domingo

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Abstract: The rapid urbanization of cities has resulted in the deterioration of urban forests and the loss of important benefits from green infrastructure, such as the removal of Greenhouse Gases (GHG) and carbon sequestration. The Mirador Sur Park is one of the main green spaces in the city of Santo Domingo. The objective of this research was to identify citizen participation in the design and management of urban forests as a strategy for guiding cities towards a more sustainable and resilient model in the face of climate change. In this study, changes in the park's land use were identified, 136 park users were interviewed to find out their perception of the benefits of forest cover, and the ecosystem services of Mirador Sur Park were quantified using the i-Tree Canopy tool. It was found that the ecosystem services related to the removal of atmospheric pollutants are clearly perceived by the users of the park. However, there are other services that could not be identified if there is no relationship with the users of the park, such as those related to the benefits of human well-being. Citizens' perception and appropriation are important elements for the co-management of the park, and it would be appropriate for them to become involved in the design and implementation of environmental public policies, as well as nature-based solutions, that contribute to adequate and inclusive urban planning aimed at adapting to climate change.

Keywords: urban forests; greenhouse gases; urban resilience; ecosystem services; city planning; citizen perception



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1. Introduction

More than half the world's population currently lives in urban areas, and according to projections, urbanization will continue to increase. It is estimated that there is a world population of 7.674 billion people, and it is expected that by the middle of this century, two-thirds of this population will live in cities [1–3].

One of the main consequences of this urban expansion is the pressure it exerts on urban and peri-urban ecosystems [4–6]. In cities, networks or systems made up of trees (stands), groups of trees, and individual trees located in urban and peri-urban areas are categorized as urban forests; they provide a wide range of ecosystem goods and services and contribute greatly to the livelihoods and quality of life of the inhabitants [7–10].

Some of these ecosystem services are microclimate regulation and the mitigation of the effects of the so-called heat islands, biodiversity conservation, urban hydrology, air and water filtration, and noise reduction, among others [11–15].

In addition to the ecosystem benefits, green spaces are important to improve the standard of living, human health and well-being, or cultural identity in cities, as well as

increasing the social cohesion of the community, as proposed by the New Urban Agenda and the Sustainable Development Goals (SDGs) [4,16,17]. However, most of the world's cities are experiencing environmental challenges such as deteriorating air quality, water pollution, street noise, and heat island effects that undermine urban environmental quality, development, and sustainability [15,18–21].

From the above arises the need to create adequate public policies to restore, create, and/or maintain urban forests. One proposal for the creation, design, and management of urban green spaces is to integrate citizens as an essential part of the development of these spaces, thus spatially promoting co-responsibility for urban forests in developing countries, as well as avoiding attracting undesirable elements or activities [8,22–24].

The participation of citizens and a qualitative evaluation of their needs and interests help urban communities to articulate commonly shared values that can serve as reference criteria for local planners to foresee assertive strategies oriented towards a sustainable cities approach. Based on this, it is suggested that sustainability indicators for urban development should include more parameters on public spaces and open green areas, as well as indices that reflect citizens' satisfaction and perception of their living environments [25–28].

The Dominican Republic has a high climatic vulnerability. In addition to this, the green spaces of the National District are affected by pollution and human settlements. Existing and planned rivers, coastlines, and green spaces could experience further stress, damage, and degradation due to rising temperatures, changes in rainfall patterns, a future rise in sea level, and increased storm surges [29,30]. Over the last 20 years, there has been an increase in the temperature in the Distrito Nacional, causing an increase in the heat islands, especially in the city center and particularly in winter. This situation could become worse in the future due to the scarcity of vegetation cover [31,32]. The expansion of the city's development threatens the existence of the green belt around Santo Domingo. In fact, a positive correlation can be perceived between when the temperatures began to increase and the start of the urban expansion [33].

Some policies have been implemented in the search for solutions to these environmental challenges, such as the city's Land Management Plan (POT) [31], which establishes guidelines to transform the land use of the city in order to make the city more resilient, green, compact, integrated, and livable. Some relevant aspects of the POT influence the organization and development of land use policies in order to determine what can be done in each particular area of the city and how such actions should be integrated. At the same time, an orientation is established to generate urban infrastructure that can accompany the growth and development of the city, introducing a focus on adapting to climate change and an evaluation of the city's natural attributes. In this context, the POT 2030 will create a green urban system made up of spaces that may be parks, aquifers, protection zones, squares, or areas of natural value connected by green corridors, such as linear parks, tree-lined streets, or avenues that give continuity and aim to guarantee protection for species as well as urban and environmental sustainability [31]. As for the guidelines to be established by the POT 2030, the Urban Forest Plan for the Distrito Nacional was created. It proposes generating a participative process, including residents, neighborhood groups, schools/colleges, churches, community centers, institutions, and enterprises, in order to plant and maintain trees that are adequate for the city [34].

In the understanding that citizen participation and perception are important elements to establish guidelines for the successful implementation of urban plans, this research proposed a case study of one of the most important green areas in the city, quantitatively estimating the value of ecosystem services and integrating the population's perception of services related to climate change. The rest of the paper sets out the materials and methods used in the analysis, including a general description of the area under study. We then present the main results obtained in the estimations of the ecosystem services. Finally, the results are discussed, and the most relevant conclusions of the research are set out.

2. Materials and Methods

2.1. General Description of the Study Area

The research was carried out in the Mirador Sur Park, located in Circumscription 1 to the southwest of the National District, capital of the Dominican Republic, located in the Greater Antilles of the Caribbean (Figure 1). The geographic coordinates of the National District correspond to 18.476389 latitude, -69.893333 longitude. The city has a surface area of 91.6 km^2 , a population of 965,040 inhabitants, and a population density of 10,538 inhabitants/ km^2 [35,36]. The study area is territorially divided into three wards [35].

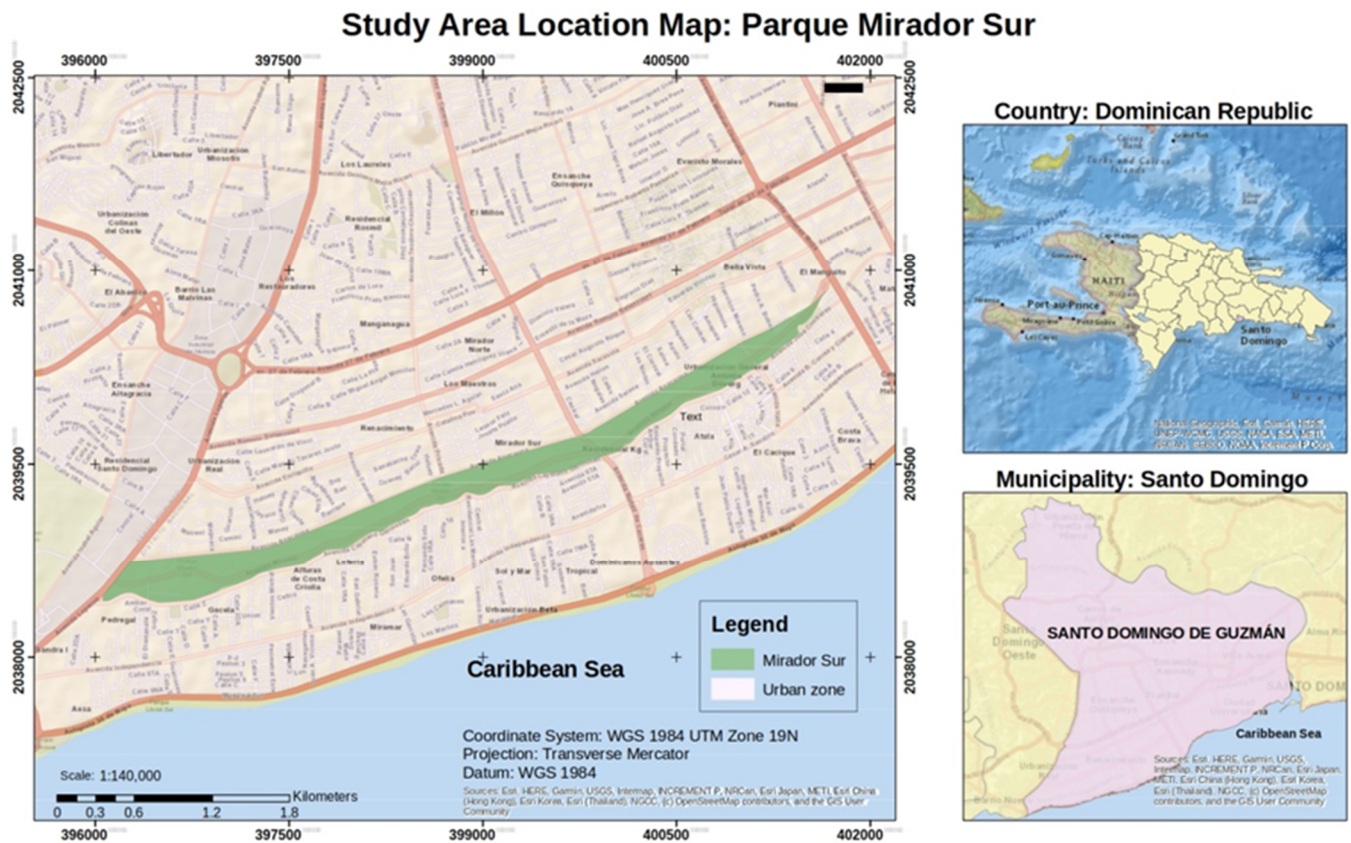


Figure 1. Mirador Sur Park, Santo Domingo, Dominican Republic.

The Mirador Sur Park was inaugurated in 1970. It is the first urban ecological park in the Dominican Republic. It not only functions as a place of leisure for nature lovers and a green lung for the city, but it also helps to conserve the biodiversity of the native and endemic flora. The Park is characterized by such components as caves, rocks, green areas, underground lakes, and exclusive fauna and flora. It has an area of 7 km^2 at 30 m above sea level and represents one of the green lungs of Santo Domingo, as it is one of the important natural areas of the city's landscape. The Park is administered by the Mayor's Office of the National District [37].

2.2. Methods

The methodology used was developed, under the qualitative-quantitative approach, to identify if there is a change in the forest cover of Mirador Sur Park and if this relationship is derived from the participation of park users. Three methodologies were used: 1. Analysis of satellite images to identify the change in the forest cover of the Park; 2. Semi-structured interviews with park users (Appendix A); and 3. Analysis of ecosystem services.

2.2.1. Analysis of Changes in the Land Use of Mirador Sur Park

Satellite images of Google Earth from the years 2000, 2010, and 2021 were used to identify the percentage of change in territorial patterns. To do so, land uses were digitized [38] according to the classification: tree/shrub; grass/herbaceous; impervious road; soil/bare ground; and water.

The results obtained from the change in the forest cover of the park were related to social variables obtained from the semi-structured interviews (years of visiting the park, participation in actions aimed at changes in the park, perception of visitors about the benefits of the park), using a Spearman correlation analysis with the INFOSTAT 2018 software (National University of Córdoba, Córdoba, Argentina).

2.2.2. Perception of the Users of the Mirador Sur Park

In total, 136 semi-structured interviews were applied. The size of the sample was determined with a 95% confidence level, considering the total population as the number of households in district 1, the official delimitation of the area where the park is located. The people surveyed were randomly selected, applying the methodology proposed by Fisher et al. and Sonti et al. [39,40]. Their methodological proposal consists of waiting at the site to interview a random person, letting two people pass without interviewing, and to interview the third person who passes. The objective of the interviews was to know the perception of park users regarding the benefits and ecosystem services provided by trees [41,42]. The interview addressed questions related to the frequency of visits to the park, the activities carried out during their stay, the distance traveled from their home to the park, the benefits perceived from the trees, and whether the person is involved in activities that contribute to improving the park and its benefits, as well as some socioeconomic aspects (age, gender, educational level, profession, etc.). The surveys were applied in the Mirador Sur Park during the period from November 2020 to April 2021 on different days of the week and at different times, selecting park visitors over 18 years of age. The analysis of the data obtained from the interviews was carried out with the SPSS v11 software. Cross tables were made taking age, sex, and occupation as dependent variables. This set of variables was crossed with the remaining 17 variables, and Pearson's correlation statistic was used for nominal values to determine the significant correlations between the variables. Likewise, a frequency analysis was carried out to determine the percentage of responses from visitors.

2.2.3. Economic Valuation of the Ecosystem Services

For the quantitative estimation of the Ecosystem Services, the i-Tree Canopy version 7.1 software was used, with Google satellite images to identify the number of sampling plots (Table 1), of which 20% were supervised in the field. Diameter data were taken at breast height, as well as tree height, crown width, tree species, and health [43,44].

Table 1. Land use categories and i-Tree Canopy sampling points in Mirador Sur Park.

Cover Class	Sample Points
Tree/Shrub	348
Impervious Roads	113
Impervious Buildings	6
Grass/Herbaceous	33
Soil/Bareground	33
Water	3
Total	536

i-Tree Canopy is a web-based software developed by the US Forest Service designed for land cover and land use assessment with photo interpretation of random data and sample points on satellite images obtained by the Google Web service.

3. Results

Regarding the change in land use of the Mirador Sur Park, from 2000 to 2021, a change rate of 6% in the use of grass/herbaceous land was identified, of which 27.8 hectares corresponded to increased forest cover. Figure 2 shows a strong association between the period of visitation and the participation of visitors in actions that contributed to the change in the forest cover of Mirador Sur Park.

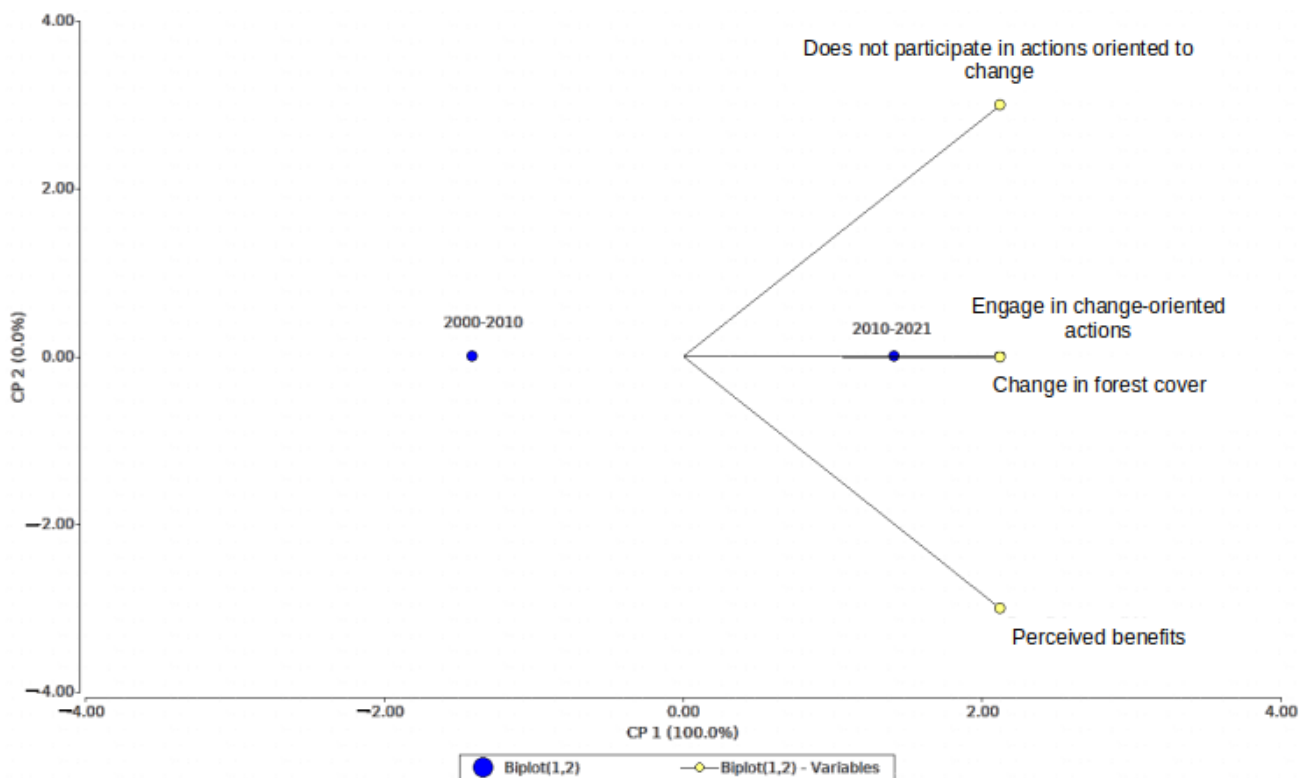


Figure 2. Principal Component Analysis between variables related to the change in forest cover in Mirador Sur Park according to the visitation period (Appendix C).

The correlation analysis identified the statistical value of the associations in Figure 2, where it is shown that there is a negative correlation between the years of visitation of the park and the change in forest cover; that is, the population that had been visiting the park for less than 10 years is more involved in actions aimed at a change in forest cover, while the actions (although not statistically significant) are mainly driven by the perception of greater environmental benefits (Table 2).

Table 2. Change in forest cover of Mirador Sur Park with respect to influencing variables.

Principle Variables	Spearman Correlation	Variables
Change in forest cover	0.14	Participation in actions aimed at changes in the park.
	0.01	Perception of environmental benefits.
	-0.09	Years of visiting the park (less than 1 year to 10 years and more than ten years).

Spearman’s correlation is significant if the value is less than 0.05.

3.1. Perception of Visiting Users of Mirador Sur Park

Of the total visiting users ($n = 136$), 47% were women and 53% men; they prefer to visit the park during the day (55%), while 39% prefer the afternoon and 5% the night.

The results show that the female population has a higher correlation with the selected variables (Table 3). In the frequency analysis, it was found that the visitors of the Mirador Sur Park mainly value the benefits of air purification (29.6%), the shade of the trees (7.4%),

the tranquility (33.3%), and the scenic beauty of the space (15.9%); they use the space mainly to walk (25.9%), carry out family activities (18.5%), and recreation (11.1%); while the main motivation for visiting the park is the proximity of the park to the residence of the visitors (81.5%). With reference to the aspects to improve in the park, the main suggestions were to increase security (18.5%), improve park facilities (7.4%) and maintenance pruning (7.4%).

Table 3. Correlation between the study variables of the perception of the visiting population of the Mirador Sur Park.

Education	Age	Gender	Variable	Correlation	Observation
Secondary	31–45	Female	Number of visits 1–3, 7–12	0.046	Reason for visiting was closeness of park
Degree	18–30	Female	Moment of the day to visit	0.046	Morning and afternoon
Degree	40–60	Male	Park maintenance good/excellent	0.05	Park close to home and beauty of park
Degree	18–30	Female	Does not know which authority runs the park	0.046	The park is close to home or work

Pearson’s correlation is significant if the value is below 0.05.

When asked about their main motivation for visiting the park, 63% of those interviewed said that they do so to enjoy nature. Moreover, 14% do so for recreational activities, and 10% to enjoy a space with quality air. Other motivations are related to tranquility 8%, a perception of security 3%, and the facilities that the park offers visitors 2% (Figure 3).

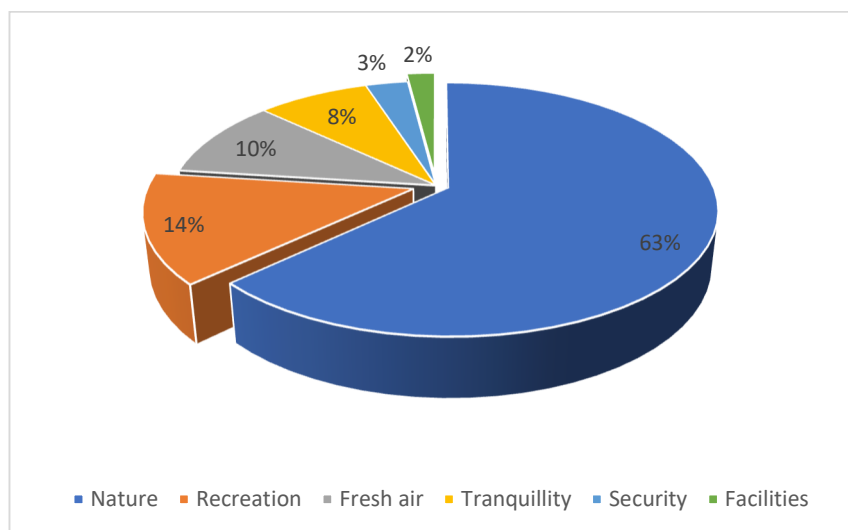


Figure 3. Main motivations of the interviewees to visit the Mirador Sur Park according to the visitation period.

3.2. Valuation of Ecosystem Services

People’s perception of environmental benefits coincides with the environmental services quantified in the i-Tree analyses, where the main contributions of the park’s trees are related to air purification and carbon sequestration (Tables 4 and 5). According to the information collected in the field, the forest cover of the park space corresponds to 65% trees and shrubs, 21% roads and sidewalks, 1% buildings, 6% grass and herbaceous plants, 5% bare ground, and 1% water (Appendices B and D).

Table 4. Tree benefits estimation: carbon sequestration.

Description	Carbon (t)	CO ₂ Equiv. (t)	Value (USD)
Sequestered annually in trees	282.38	1035.40	53,088
Stored in tress (Note this benefit is not an annual rate)	7091.66	26,002.74	1,333,231

Table 5. Removal of contaminants associated with the trees in Mirador Sur Park.

Abbr.	Description	Amount (Kg)	Value (USD)
CO	Carbon Monoxide removed annually	116.86	172.00
NO ₂	Nitrogen Dioxide removed annually	645.55	311.00
O ₃	Ozone removed annually	4986.70	14,280.00
SO ₂	Sulfur Dioxide removed annually	317.34	47.00
PM2.5	Particulate Matter less than 2.5 microns removed annually	245.75	29,895.00
PM10	Particulate Matter greater than 2.5 microns removed annually	1415.33	9485.00
Total		7736.53	54,485.00

The removal of atmospheric pollutants is an indicator of relevance, as it is directly related to aspects of human health and global warming of the planet.

4. Discussion

The co-management of urban spaces is extremely important for a more balanced development between society and the authorities [6,45–48]. This research shows that the Mirador Sur Park provides important ecosystem services related to the adaptation and mitigation of climate change, both in district 1 where it is located, mainly related to the benefits that the visiting population of the park perceives (shade, purification of the air, landscape beauty, emotional benefits), and in the city for the removal of atmospheric pollutants and carbon sequestration. These results are similar to those reported by [47,49–54], who suggest that breathing less polluted air is something that the population of an urbanized city values highly.

According to what was proposed by [22], the criteria that the population has valued can function as indicators for the co-management of wooded spaces in cities. In this investigation, two groups of relevant factors were identified. The first is related to planning aspects: the proximity to the residence of the green areas, the security within the area, the complementary facilities of the park, and its good maintenance; while a second group of factors focuses mainly on perceptible ecosystem services, such as clean air, shade from trees, scenic beauty, the well-being that the space can provide for relaxation, walking, recreation, and family activities, which are the same as those found by [8,40,47,49,51,55–58].

The factors related to ecosystem services are related to the constant increase in temperature registered in the National District, as well as the increasing loss of trees within the city [29,31,43]. Furthermore, temperature regulation and the aesthetic and recreational values of urban parks are elements which are highly valued by the population that frequents these spaces [10,57,59]. Additionally, states that trees increase people's desire to live near these green spaces. This situation was clearly identified by the visitors interviewed in the Mirador Sur Park, which facilitates their involvement in the co-management of the space. However, it was evident that the population of this study does not identify the authority responsible for managing the park, which is why a disconnection between the managers of the space and the users is visualized [58,60]. Paradoxically, emphasized that involving the population in the design and management of green spaces is crucial to generating co-responsibility [61].

Although the authority that manages the park interacts with some visitors to Mirador Sur Park, it is unknown if they are involved in the management or decision-making of the park. There is no evidence that the municipal authorities of the National District have made efforts to know the perception of the population in relation to the trees and green areas of the city, despite the fact that citizen surveys can provide urban planners with knowledge about the attitudes and perceptions of citizens regarding urban trees and green areas [9,19,60–63].

In addition to this, the existing urban tree and green area policies are not guided by elements of urban forestry; other guidelines were taken into account in their formulation. The said guidelines are focused on creating sustainable cities, such as those proposed by UN-Habitat, which are made up of a global framework to improve the policies, plans, and

designs for more compact, socially inclusive, and better integrated and connected cities and territories in order to promote sustainable urban development that is also resilient to climate change [3,7,46].

In the local context, there are ordinances for the organization of land use in specific sectors. In this way, municipal policies are adapted to the needs of each sector, as proposed by [43]. Tree planting policies should focus on the sectors of the city that need to be reforested; while the sectors that already have sufficient coverage should focus efforts on the maintenance and safety aspects of these green spaces.

It has been shown that there are sometimes discrepancies between green spaces created by municipal authorities and the wishes of citizens in terms of the use, appearance, and accessibility to these spaces [63]. Citizen participation is a strategy to improve the results of policies that seek to solve environmental problems [28,46,56,64]; therefore, it is essential to incorporate citizen opinion in order to find out their preferences. It is the responsibility of city dwellers to decide on the best balance that meets their needs [48,50,52,65–67].

The Mirador Sur Park provides valuable ecosystem services to the city of Santo Domingo. It stores 7091.66 metric tons of carbon, which represents more than 26 thousand tons of CO₂ equivalent. Similarly, the park removes more than 7 thousand tons of pollutants and GHG annually. These services represent an annual economic value of more than USD 1.5 million.

This is consistent with other studies [6,10,43,50,60,68] carried out in both the city of Santo Domingo and in the Latin American and Caribbean region. It is important to promote the growth of these areas, so as to improve the benefits in health and lifestyle that people who live near parks and open public spaces have [53,63,69,70].

This study also highlights the importance of incorporating nature-based solutions into urban planning to guarantee the provision of important ecosystem services and the adaptation of cities to the effects of climate change [14,16,19,20,24,56,71].

5. Conclusions

The ecosystem services provided by the Mirador Sur Park are partially recognized by park users, and mostly refer to the benefits in air quality. The population that has been visiting the park for less than 10 years is more involved in activities aimed at improving the forest cover of the park, contrary to the population that has been visiting the park for more than 10 years. The proximity of the park to the homes of visitors and the type of recreational activities carried out within the park are factors that influence user perception. It was identified that the greater the perception of environmental benefits, the greater the participation in park co-management activities.

The ecosystem services related to the improvement in air quality that were perceived by the users coincide with the quantitative estimation of the removal of atmospheric pollutants made with the i-Tree software. However, there are other services that are difficult to estimate, such as those related to the emotional aspect and human well-being.

The quantitative evaluations of ecosystem services are useful indicators for decision makers. However, the quantitative evaluation of the social perception of benefits could generate important benefits related to the costs of park management and investment in public health.

The Mirador Sur Park can be considered an element that contributes as a measure of adaptation to climate change in District 1 of the National District.

The inclusion of the population for the co-management of urban forests could be a viable alternative for the generation of inclusive public policies that contribute to the modeling of cities with ecosystem-based solutions and a co-responsible design and management that better adapts to the challenges of climate change.

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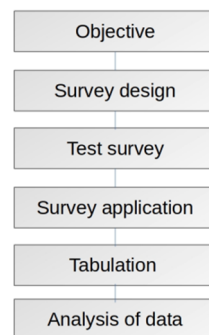
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Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Process Diagram



Appendix B. Change in the Forest Cover of the Mirador Sur Park

Classification	2000		2010		2021	
	M ²	%	M ²	%	M ²	%
Tree/Shrub	718,240.972	53	746,608.438	55	996,743.985	73
Grass/Herbaceous	357,045.955	26	222,787.816	16	91,323.9599	7
Impervious Road	225,327.286	17	330,805.684	24	224,398.01	16
Impervious Buildings	39,384.2589	3	24,973.5777	2	35,422.6754	3
Soil/Bare Ground	15,888.1113	1	31,014.0615	2	11,369.6132	1
Water	5955.36079	0	5636.19489	0	2837.70926	0
Total	1,361,841.94	100	1,361,825.77	100	1,362,095.95	100

Appendix C. Principal Component Analysis

Auto Vectors		
Variables	E1	E2
Change actions	0.5	0
No change actions	0.5	0.71
Perceived benefits	0.5	−0.71
Change in coverage	0.5	0

Appendix D. Study Area Map

Coverage and land use 2000: Parque Mirador Sur



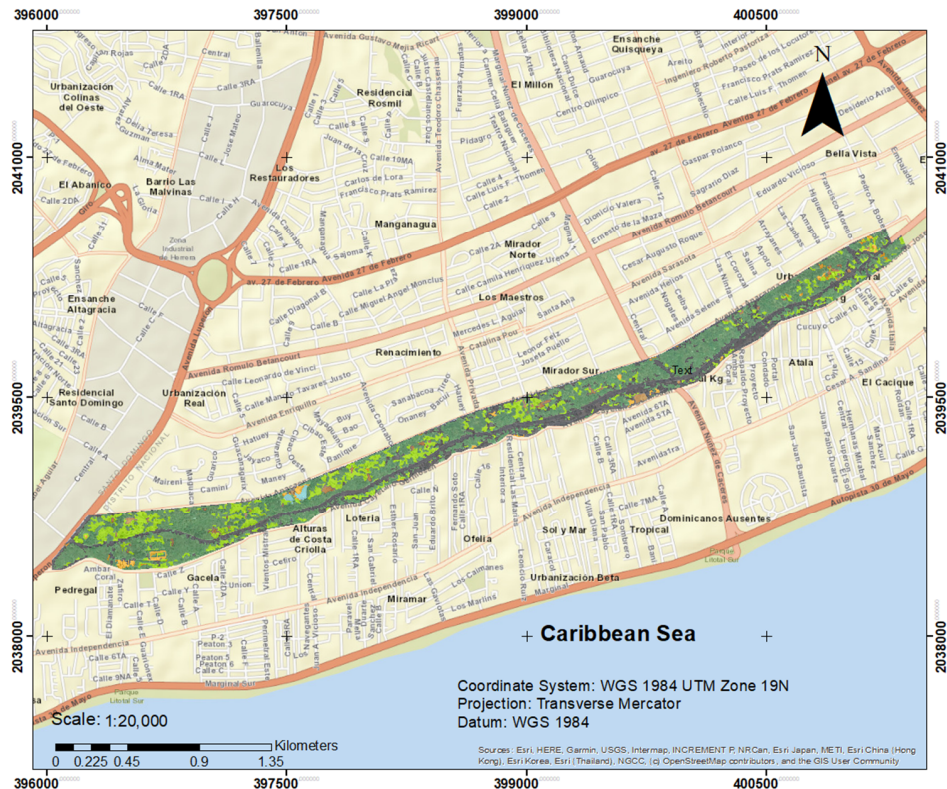
Satelital Image



Legend

- Tree/Shrub
- Grass/Herbaceous
- Impervious Road
- Impervious Buildings
- Soil/Bare Ground
- Water

Coverage and land use 2010: Parque Mirador Sur



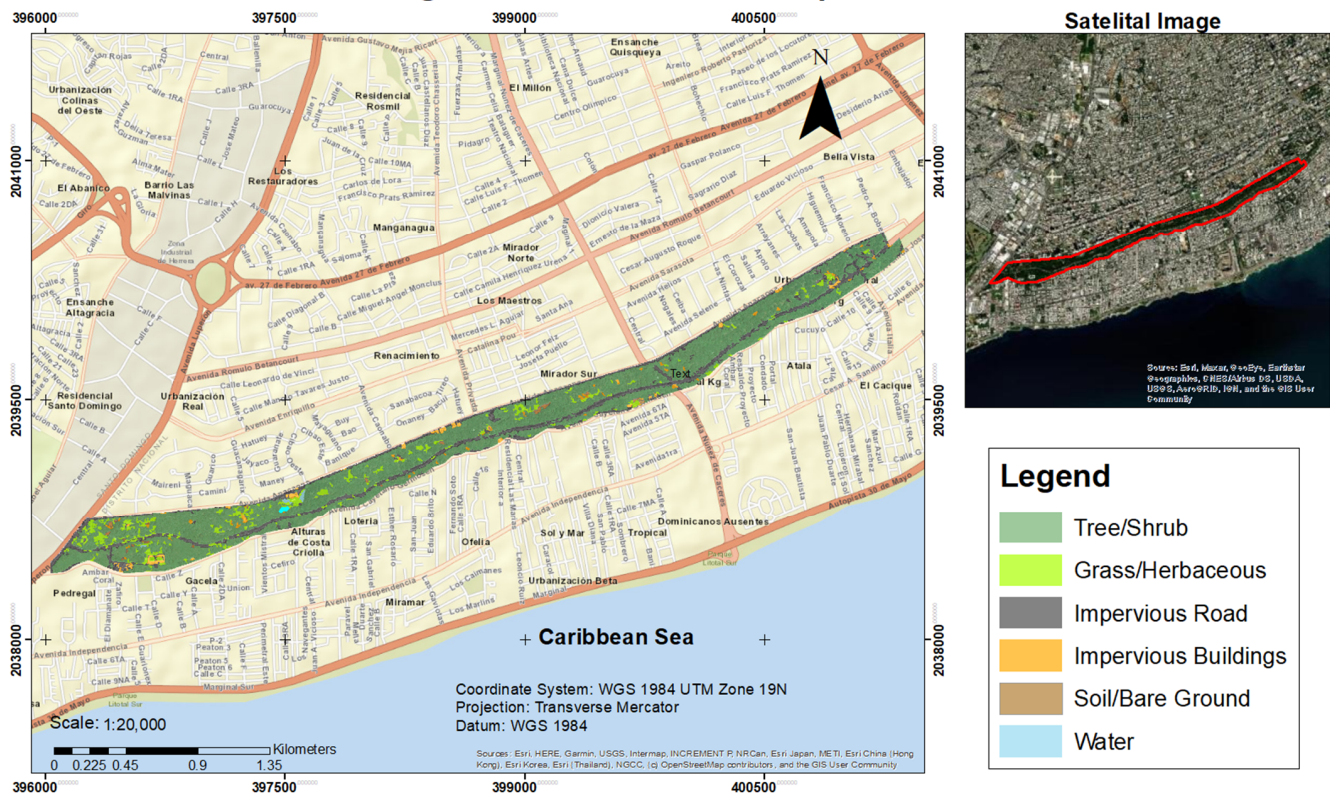
Satelital Image



Legend

- Tree/Shrub
- Grass/Herbaceous
- Impervious Road
- Impervious Buildings
- Soil/Bare Ground
- Water

Coverage and land use 2021: Parque Mirador Sur



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