

Article

# Proposal of a System for Assessment of the Sustainability of Municipalities (Sasmu) Included in the Spanish Network of National Parks and Their Surroundings

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**Abstract:** It is usually considered that Protected Areas (PAs) are an efficient tool for policies to conserve biodiversity. However, there is evidence that some pressures and threats arise from processes taking place both inside them and in their surroundings territories—habitat loss, changes in land use, fragmentation of natural ecosystems. In this paper, we aim to test the hypothesis that municipalities located in the Socioeconomic Influence Zones (SIZs) of the fifteen National Parks (NPs) in Spain are more sustainable than those in their surroundings or, conversely, that the municipalities of their surroundings are more unsustainable. To measure their sustainability, we propose a system for assessment using fifteen indicators selected by experts. The methodology is based on the normalization of the data of each indicator, comparing them with a desirable target value defined in terms of sector policies and strategies. We then aggregate the indicators for each group in three indices that cover the classic dimensions of sustainability—environmental, economic and social. On a network scale, the results show that municipalities inside the SIZs are 1.594 points more sustainable environmentally, 0.108 economically and 0.068 socially than those of their surroundings. A system for assessment of the sustainability of municipalities (SASMU) may be a useful tool for NP managers, and for local and regional administrations, when setting priorities for policies, projects and compensation for regulatory restrictions related to NPs.

**Keywords:** indicators; indices; environmental sustainability; socio-economic sustainability; protected area; Spain

## 1. Introduction

Decades have passed since the concept of sustainability spread throughout the international scientific community, also reaching political discourse and social awareness. However, the adoption and assessment of sustainability are still a challenge [1]. National parks (NPs) are recognised categories for protected areas (PAs), having existed for more than a century, starting with the declaration of the

first NP in Yellowstone in 1872 and, in Spain, the Montaña de Covadonga NP in 1918. Like other protected areas (PAs), they are subject to specific management plans that organise and limit human uses of the land covered by such declarations and, sometimes, of surrounding areas [2].

However, an overall assessment of sustainability in municipalities inside and outside NPs has received little attention from research. The interdependence of the processes that determine sustainability in municipalities within NPs, and in those outside the territorial context of the NP, makes it necessary to study them as a system that shares ecological flows, disturbances and socioeconomic relations. Many threats and pressures for PAs stem from external phenomena arising in the surrounding territorial context, such as the basin hydrology and contamination. The territory surrounding the PA should therefore be considered not only from the point of view of its biophysical variables, but also from that of its social and economic variables [3], given the differences in territorial processes in the external context [4].

It is especially complex to study and establish benchmarks on sustainability on a municipal scale, in comparison with national [5], regional or other larger scales. Yet, the municipal area is ideal for learning about sustainable development and partnership [6]. NPs amount to an excellent network for observing changes, both local and global, in PAs throughout the world. For these reasons, the interface between the NP and external context is of great interest, as is all the surrounding area. A simple hypothesis is that there is a centrifugal gradient for sustainability from inside the NP towards its territorial matrix. However, this would involve many nuances and uncertainties, bearing in mind the environmental, social and economic heterogeneity inside and outside the NP. Moreover, it would be necessary to distinguish whether this theoretical gradient is limited to the environmental dimension, or if it also includes other dimensions of sustainability, both social and economic.

Sustainability is a long-established concept. Bell and Morse [7] distinguish between weak and strong sustainability. The former allows for compensation between the various dimensions of sustainability, but the latter does not. A review of different methodologies for assessing sustainability [8] points to a lack of holistic approaches considering all of its dimensions or analysing its inter-connections.

Before a system of indicators can be developed, it is necessary to establish a mental model providing conceptual support for it. There are not many systematic models guiding the generation and assessment of sustainability indicator systems [9]. Some have been developed at country level [10] or local level [11], or have focused on multifunctional land uses [12]. The principles of sustainability should be converted into specific indicators, allowing decision-makers to identify problems, record trends, establish priorities, understand policy trade-offs and synergies, investments and assess policies [13]. Participation by local agents in the configuration of the indicator model generally helps to make indicators locally relevant [14], but also makes it difficult to build a model that is scientifically robust [15].

Mori et al. [16] have reviewed the main types of indicator and index with the aim of developing a City Sustainability Index (CSI). They conclude that indicators should follow the triple bottom line proposed by Elkington [17], which includes the topics of environmental quality, social justice and economic prosperity, apart from equity and continued existence in the long term. In the case of local governments, the triple bottom line principle is an aspiration that is shared but is difficult to put into operation and to assess in practice [18,19]. Various studies have identified different stakeholder response patterns in municipalities in Portugal [20], as well as the need to develop common local indicators [21] for use in political decision-making [22]. Most environmental indicators models are causal or reactive, such as the Pressure-State-Response framework [23] and the extended DPSIR Driving Force-Pressure-State-Impact-Response of the European Environmental Agency [24]. The DPSIR proposed by Niemeijer and de Groot [25] is an adaptation which is different in that it applies a causal network analysis that is structured before the indicators are selected. Schomaker [26] suggests that indicators should be specific, measurable, achievable, relevant and time-bound (SMART).

Of the different types of model, we stress monitoring models that generate regular information on the progress of policies and programmes and that have mixed users, such as policymakers,

administrators and stakeholders. Control models that use performance indicators referring to targets, standards or benchmarks are also of interest [27].

One approach to the analysis of environmental sustainability in vulnerable territories such as NPs is load capacity, which traditionally refers to the maximum number of visitors the space can receive without damage to the environment or to the tourism-recreational experience itself [28]. Another refers to changes in land use-land cover (LULC) inside and around PAs [29].

Municipal sustainability has mainly been studied in urban areas and, to a lesser degree, in rural areas [30,31]. The City Development Index (CDI), developed by the United Nations Centre for Human Settlements (HABITAT), adopts an approach focused on the provision of infrastructure and access to basic services, such as waste-water treatment, waste management and electricity and telephony supply. Other authors and institutions [32–40] have designed various methods for assessing local sustainability in urban environments.

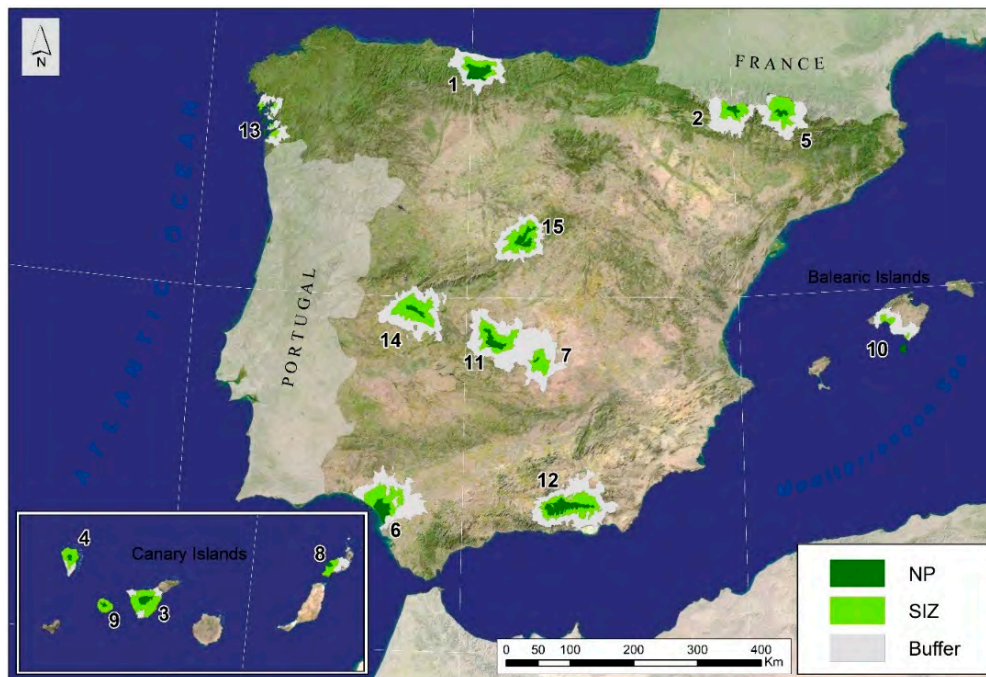
Indicators of municipal sustainability for rural environments have been less widely adopted [30,31]. For this reason, most municipalities located within NPs and other PAs in general have no systems for assessing sustainability. Sustainability indicators have been estimated in municipalities in various countries in the Alps [41], applying principal components analysis (PCA) in the Italian Alps [42], and in other municipalities in Italy [43,44] and in the Netherlands [45]. This has also been done in Spain [46], either generically or using indices that include environmental, economic and social dimensions, with results represented using geostatistical kriging and cokriging methods [47].

The main goal of our study is to develop a method to assess sustainability in municipalities within the Socioeconomic Influence Zones (SIZs) of all the Spanish NPs, as well as those located in their 5km buffer areas. The Socioeconomic Influence Zone of a national park is the territory constituted by the municipalities that contribute land to it. We use a semi-experimental ACI research design with data obtained from post-designation years (After), Control (buffer municipalities), and Impact (declaration of each NP), with expert-selected indicators for the three dimensions of sustainability. We also aim to meet the following specific goals: (1) explore the difference between cases and their controls (inside and outside NPs); (2) find any sustainability differences between municipalities located in NPs in different biogeographical regions; (3) assess differences between environmental, economic and social sustainability in the network as a whole and in each NP; and (4) identify the strengths and limitations of the model, as well as opportunities for planning and managing NPs.

## 2. Materials and Methods

### 2.1. Study Sites

The study area covers the Spanish network, which celebrated its hundredth anniversary in 2018. Until July 2020, the network comprised fifteen NPs (Figure 1) located in four biogeographical regions: Macaronesia, Mediterranean, Atlantic and Alpine [48]. They are governed by Law 30/2014, dated 3 December, on National Parks [49]. This law aims to establish the basic legal regime to ensure the conservation of the national parks and the network they form, as well as the different instruments for coordination and collaboration. All study sites are national parks, category II of the International Union for Conservation of Nature (IUCN). Furthermore, they all belong to the European Nature 2000 network. Additionally, ten are classified as Biosphere Reserve, four are World Heritage Sites, four are Ramsar wetlands, one is a Specially Protected Zone of Importance for the Mediterranean (ZEPIM) and another is covered by the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR).



**Figure 1.** Geographical distribution of NPs. The numbers refer to the NPs in order of the date on which they were declared: (1) Picos de Europa (1918); (2) Ordesa y Monte Perdido (1918); (3) Teide (1954); (4) Caldera de Taburiente (1954); (5) Aigüestortes i estani de Sant Maurici (1955); (6) Doñana (1969); (7) Tablas de Daimiel (1973); (8) Timanfaya (1974); (9) Garajonay (1981); (10) Archipiélago de Cabrera (1991); (11) Cabañeros (1995); (12) Sierra Nevada (1999); (13) Islas Atlánticas de Galicia (2002); (14) Monfragüe (2007); (15) Sierra de Guadarrama (2013). NP: National Park; SIZ: Socioeconomic Influence Zone. Buffer: Municipalities falling within a 5 km. buffer area. The numbers in parentheses show the declaration date of each national park.

Each NP has an SIZ made up of all the municipalities (cases) that have territory within the park (Table 1). The municipality is the most basic territorial administrative unit in Spain, and is the study unit used in this paper. Since many pressures and threats to the conservation of natural resources in national parks come from their most immediate environments, we have used 5 km buffers around each SIZ, studying all municipalities that fall within them either totally or partially (controls). Note that the control municipalities were chosen in line with the Spanish NP legislation. This does not mean that their surface area is completely unprotected, because it may be declared a PA under other legal categories (e.g., Site of Community Importance). These categories have less demanding protection measures. The purpose is to compare the sustainability of municipalities in the SIZs with that of the municipalities in buffers zones that are not subject to NP legislation.

**Table 1.** Main characteristics of the study sites.

NPs		SIZs		Buffers		Provinces
Sites <sup>1</sup>	Area (ha)	Area <sup>3</sup> (ha)	Number of Municipalities	Area <sup>4</sup> (ha)	Number of Municipalities	Number <sup>5</sup>
1	67,127.59	133,683.56	11	225,462.95	20	3
2	15,696.20	89,290.44	6	211,333.50	16	1
3	18,990.00	133,652.30	14	40,606.30	11	1
4	4690.00	54,533.33	9	19,773.51	5	1
5	14,119.00	145,057.75	10	216,767.65	26	2
6	54,252.00	200,601.86	4	359,841.41	36	3
7	3030.00	82,113.86	3	396,192.26	19	2
8	5107.50	35,696.13	2	37,640.43	3	1
9	3984.00	38,592.31	6	0.00	0	1
10	1318.00 <sup>2</sup>	24,918.31	2	141,600.62	16	1
11	40,856.00	182,292.52	6	459,073.29	27	3
12	85,883.00	266,690.91	44	444,822.08	68	2
13	1194.80 <sup>2</sup>	25,328.48	4	134,026.18	28	2
14	18,396.00	195,500.53	14	361,481.17	41	1
15	33,960.00	175,593.40	35	236,311.33	72	3
Total	368,604.09	1,758,627.38	170	3,180,774.11 <sup>6</sup>	387 <sup>6</sup>	22 <sup>6</sup>

<sup>1</sup> The numbers in the first column correspond to: (1) Picos de Europa; (2) Ordesa y Monte Perdido; (3) Teide; (4) Caldera de Taburiente; (5) Aigüestortes i estani de Sant Maurici; (6) Doñana; (7) Tablas de Daimiel; (8) Timanfaya; (9) Garajonay; (10) Archipiélago de Cabrera; (11) Cabañeros; (12) Sierra Nevada; (13) Islas Atlánticas de Galicia; (14) Monfragüe; (15) Sierra de Guadarrama. <sup>2</sup> Only the terrestrial areas of these two maritime-terrestrial NPs are indicated. <sup>3</sup> Includes the surfaces of NPs. <sup>4</sup> Excludes the SIZ surfaces. <sup>5</sup> Includes municipalities within buffer zones. <sup>6</sup> The surface area of municipalities within buffers and in provinces may not tally with the number of such municipalities due to overlaps. Legend: NPs = National Parks; SIZs = Socioeconomic Influence Zones. Sources: Spanish Agency for National Parks and GIS of the DISESGLOB project.

## 2.2. Materials and Methodological Flux

We have taken into account that the data sources are reliable, available, and consistent at the national level. In view of the scope of the methodological approach, in this study we use several sources of geographical information—cartographic, statistical, biophysical and socio-economic. The most relevant is the CORINE Land Cover (CLC) project which provides the maps for occupation and land use in its version 20 for 2006 and 2018 [50]. Another relevant cartographic source is the Nature Data Bank [51], which provides updated and geo-referenced cartographic information on a municipal scale on the distribution of PAs in Spain and on land loss caused by erosion of various types. It also provides cartographic and statistical information at municipal level on forest fires between 2001 and 2014. The VANE [52] project assesses natural assets in Spain and ecosystem services using physical models to assign economic value based on contingent and travel cost valuation methods, among others. To calculate population density, we combine traditional statistical information with that from a European cartographic source [53]. This European Commission GIS represents population distribution, in a spatially explicit way in 1 km<sup>2</sup> grids.

In addition, the Spanish National Statistical Institute provides annual information on population censuses and other socio-economic municipal indicators [54]. Data on the debt of municipalities and on health and educational facilities are taken from the corresponding ministerial data bases [55–57]. Further details and formulae for calculation can be found in the details for each indicator used (see Supplementary Material SM1).

Figure 2 shows the methodological flow followed in this study.

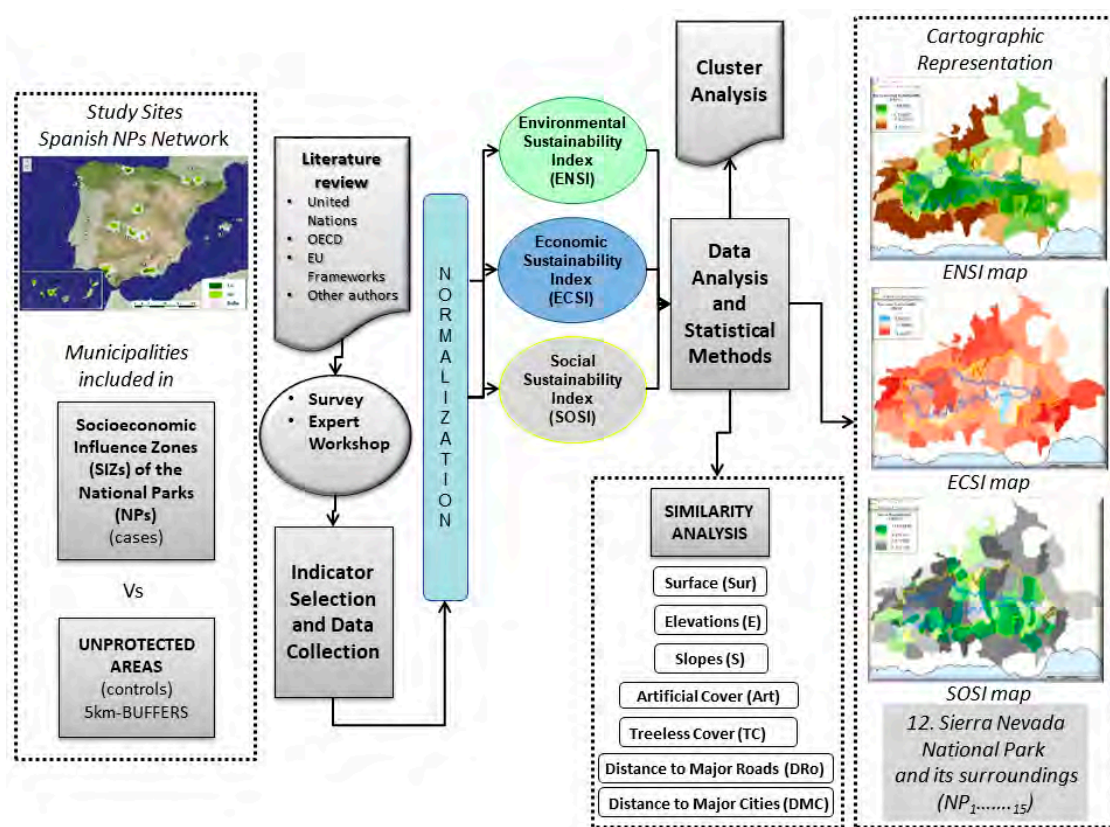


Figure 2. Methodological flux diagram of the study.

### 2.3. Indicator Selection and Data Acquisition

After a review of the literature and of the indicator systems designed for assessment of sustainability [58–68], we performed an initial selection of 42 environmental, economic, social and municipal planning indicators (see Supplementary Material SM1). We then carried out an initial survey among experts ( $n = 32$ ) from different areas of knowledge (natural resources and social sciences) and specialisations (geographers, biologists, environmentalists, forestry experts and topographers), with different profiles (37.5% managers and 62.5% scientists) and belonging to different institutions (regional and national administrations), research bodies and universities, a consultancy and a citizens' observatory. The objective was to know their opinion on which are the main indicators to measure the three dimensions of sustainability on a local level in PAs or its surroundings. After realization of the initial survey, we debugged some of the indicators of our proposal or the procedure to measure them.

We then organised a workshop to present the list of pre-selected indicators to a group of experts ( $n = 32$ ) with different profiles (25% scientists, 72% managers and 3% representatives of environmental NGOs) and from different institutions (local, regional and national administrations), especially those relating to NP management and cartography. They considered the relevance of all the indicators proposed on a Likert scale, from 1 (least relevant) to 5 (most relevant). They also proposed new or alternative indicators (e.g., EC07, see Table 2) in view of the difficulty for finding income data for municipalities with less than 5000 inhabitants. Suggestions were made about measurement methods, and comments were taken into account.

**Table 2.** Extreme values and target values by selected municipal sustainability indicators.

Sustainability Dimension	Code	Indicator	Lowest Value (LV)	Highest Value (HV)	Target Value (TV)	
					Value	Target Value (TV)
Environmental	EN02	Change in artificial area	98.72	100.00	100.00	No loss in natural or semi-natural habitats
	EN09	Index of burnt forest area	37.03	100.00	99.80	According to the Spanish Forestry Plan (2002–2032), it is expected that by 2030 a maximum of 0.2% of the forest area will be burned annually
	EN10	Terrestrial PAs	0.00	100.00	17.00	In the Convention on Biological Diversity, Aichi Target 11 proposes that by 2020 at least 17% of terrestrial and inland water areas must be protected
	EN14	Habitat fragmentation index	1.25	2.00	2.00	No fragmentation of natural and semi-natural ecosystems
	EN23	Soil erosion	3.46	100.00	100.00	No soil loss due to erosion
Economic	EC01	Atmospheric carbon fixation services	0.00	68,209.08	9616.00	85th percentile of all Spanish municipalities
	EC02	Productive services provided by livestock	0.00	7902.00	283.00	85th percentile of all Spanish municipalities
	EC04	Value of recreational services	0.00	333,579.05	326.00/299,200.00	Dynamic; 85th percentile of the sets of inland and coastal municipalities
	EC06	Unemployment rate	34.43	100.00	96.00	Up to 4% unemployment is usually considered full employment
	EC07	Public municipal debt	−302.95	100.00	100.00	85th percentile of all Spanish municipalities
Social	SO01	Population density	0.02	0.58	0.38	85th percentile of data set
	SO03	Second homes	0.00	87.90	26.70	Median of all Spanish municipalities
	SO04	Senile dependency index	−154.00	89.00	71.00	85th percentile of all Spanish municipalities
	SO05	Medical facilities index	0.00	9.09	0.24	Median of all Spanish municipalities
	SO06	Index of educational facilities	0.00	7.09	0.55	Median of all Spanish municipalities

Finally, we selected 15 indicators: five environmental, five economic and five social. The selection process was based on five premises: coherence with established international frameworks for sustainable development [14,23,40,66], their relevance in the Spanish context [46,67–69], balance between the different dimensions of sustainability, availability of data at municipal level and poor statistical correlation among them. The goal was to build indicators in a more systematic, less arbitrary way.

In brief, the approach adopted for the empirical assessment of municipal sustainability enables the transformation from general, abstract frameworks to a specific proposal for a consistent set of indicators that can be quantified, monitored and evaluated. Our aim is that the indicators selected should cover strategic sustainability goals, and that their principles should be translated into measurable parameters. The number of indicators should not be too large to avoid inconsistency. We consider that small sets of indicators are more effective and focus on truly important factors. The approach adopted also accepts the goal of reaching at least a certain status (goal) that is considered sustainable for the municipalities located in NPs and their surroundings.

#### 2.4. Data Analysis and Statistical Methods

For the statistical analyses, we used SPSS v22. For the spatial analyses, we used ARC-GIS v10.3 (ESRI Inc.), especially for vector processing of the geographical data downloaded, and above all for the analysis of LULC changes. Finally, we used GUIDOS-MSPA [70] to analyse the fragmentation caused by artificial areas on natural and semi-natural habitats.

In line with Martínez-Vega et al. [47], the original raw data were transformed (TfV: transformed values) to calculate each indicator and express them in the appropriate unit of measurement (see calculation formulae in the Supplementary Material). In some cases, we related the original data to surface area units or expressed them as a rate in relation to habitants (to make them comparable and establish a ranking of municipalities). In others, we inverted the indicator considered a threat for environmental (EN02, EN09, EN23), economic (EC06, EC07) and social (SO4) sustainability, subtracting them from 100 (best sustainability) and adding them to the other indicators that are positively correlated to the sustainability of each municipality. This operation was not necessary for the other indicators, because desirable trends move in an upwards direction in terms of added value for positive sustainability. Finally, we adjusted the values of another indicator (SO01) to a Weibull distribution [71], considering that the relation with sustainability is not linear.

In line with recommendations by Morse and Fraser [63], in order to standardise the data and obtain normalized values (NV), we divided the TfV by a target value (TV) for each indicator, to gain the desirable threshold in the context of sustainability [64], so:

$$NV_i = \frac{TfV_i}{TV}$$

$$i = 1 \dots 557 \text{ municipalities} \quad (1)$$

Table 2 provides detailed information on the extreme values (minimum, maximum), and on the target values used and how they were established for each indicator. In some cases, we took into account the forecasts and targets laid down in international agreements or in sector plans (such as the Convention on Biological Diversity—the EN10 indicator—or the Spanish Forestry Plan 2002–2030—EN09). In other cases, we established the target value at the level that expresses an optimal or ideal situation (EN02, EN14, EN23, EC06). However, for most of the indicators where there are no clear and widely-accepted references in the scientific literature, or in regulatory frameworks or sector plans, we considered the distribution of value frequency for all the municipalities studied and, where possible, for all Spanish municipalities (N = 8108). In these cases, we set the target value at percentile 85 (EC01, EC02, EC04, EC07, SO01, SO04) or at the median (SO03, SO05, SO06).

Bearing in mind that some of the indicators selected are considered by international systems as having priority, while others are considered complementary [14,40], we had to decide whether or not to apply different weights to the indicators. Some authors [65,72] argue that the allocation of weights tends to be arbitrary. Given this controversy, we have not assigned weights to the indicators.

In the next stage, we integrated the normalized indicators for each dimension in three indices in order to obtain, for each municipality, indices for environmental sustainability (ENSI), economic sustainability (ECSI) and social sustainability (SOSI). We calculated the average value for each dimension (environmental, economic and social) using the following equations:

$$ENSI_i = (\text{Mean}(EN1_i, \dots, EN5_i) - 1) \times 100 \quad (2)$$

$$ECSI_i = (\text{Mean}(EC1_i, \dots, EC5_i) - 1) \times 100 \quad (3)$$

$$SOSI_i = (\text{Mean}(SO1_i, \dots, SO5_i) - 1) \times 100 \quad (4)$$

$$i = 1 \dots 557 \text{ municipalities}$$



We then transformed the values of the environmental, economic and social indices for each municipality into Z units, in order to harmonise measurements and achieve a uniform unit of measurement that would be useful for establishing a reference base line [61,62]. We applied the following formula:

$$Z_i = \frac{X_i - \bar{X}}{\hat{\sigma}_X} \quad (5)$$

where  $X_i$  are the values resulting from operations (2)–(4),  $\bar{X}$  is the mean for the series (557 municipalities) and  $\hat{\sigma}_X$  is the standard deviation for the series.  $Z_i$  indicates at how many units of the general mean the municipality is located. Z scores are designed in such a way that users know if a municipality falls above or below the mean and to what extent. With this design, obviously, the average is zero and standard deviation is 1.

Subsequently, we performed a k-means cluster analysis at network scale on the standardised values of the three indices, in order to classify the municipalities in the SIZs of Spanish NPs among five relatively even groups. We repeated the process with the municipalities in their buffer zones. We tested the grouping of cases into 6 and 4 clusters. In the first test, we obtained one more group with very few cases and very similar to an existing one. In the second test, the cases were not grouped completely homogeneously. Therefore, the solution with 5 clusters reached the highest balance between the identification of characteristics and representativeness.

We then calculated on a local scale the medians of all the municipalities belonging to each of the fifteen NPs for each of the dimensions of sustainability. Taking these summarised values, we performed another k-means cluster analysis and identified five groups.

Finally, to calculate the biophysical and socioeconomic similarity between cases and controls, we used a similarity index based on the normalized Manhattan similarity coefficient [73], according to the following formula:

$$S(X, X') = 1 - \frac{\sum_{i=1}^k |X_i - X'_i| / \text{Range}(X_i)}{K} \quad (6)$$

where  $X_i$  is the median or average value of group  $X$  for variable  $i$ ; Range is the amplitude of measurement  $X_i$  in the study area; and  $K$  is the number of variables used to assess groups  $X$  and  $X'$ . The Manhattan similarity coefficient ranges between 0 (complete difference between compared group values) and 1 (complete similarity). For this analysis, we used six variables: area of each municipality (Sur), elevations (E), slopes (S), proportion of artificial cover (Art) and treeless cover (TC) and distances to the main roads and motorways (DRo) and to major cities (DMC).

### 3. Results

The results of the indicators and indices are given in detail in the Supplementary Material (see Data Sheet in Supplementary Material SM2). The first page shows the results of all 557 municipalities studied. On the following pages, they are broken down by NP.

#### 3.1. Results on a Network Scale

##### 3.1.1. Similarities between Cases and Controls

On a network scale, we can conclude that controls (municipalities in the surroundings of NPs) are very similar both biophysically and socioeconomically to the cases (municipalities within SIZs).  $S$  equals 0.88. The proportion of treeless cover and the biophysical variables have slightly lower similarity values (0.75 for the former, and 0.83 for elevations and slopes). In general, the municipalities inside SIZs have fewer treeless zones and greater altitudes and slopes than those in their surroundings. Conversely, the proportion of artificial surface area and the distance to infrastructure are practically the same (indices of 0.99; see Appendix A).

### 3.1.2. Comparison of Sustainability Indices between Cases and Controls

When we consider the two sets of municipalities, we can conclude that there are significant differences between the municipalities located inside SIZs (170 cases) and those in their buffers (387 controls) (Table 3). The differences are very clear in environmental sustainability and more moderate in the economic and social dimensions.

**Table 3.** Values of the local sustainability indices (environmental, economic, and social) in and around NPs.

Sites	Zone	Z_ENSI <sup>1</sup>	Z_ECSI <sup>1</sup>	Z_SOSI <sup>1</sup>
NPs network	SIZ	<b>0.856</b>	−0.151	−0.207
	Buffer	−0.738	−0.259	−0.275
	d	+1.594	+0.108	+0.068

<sup>1</sup> In bold, above mean values. Legend: NPs=National Parks; SIZ=Socioeconomic Influence Zone; Z-ENSI = Z-values of environmental sustainability index; Z-ECSI = Z-values of economic sustainability index; Z-SOSI = Z-values of social sustainability index; d = difference between SIZ and buffer.

### 3.1.3. Cluster Analysis on a Network Scale

Clusters “ECSI” and “Super-ECSI” in the SIZs (Table 4) include the municipalities in the Teide and Timanfaya NPs in the Canaries, because of the high economic values provided by their recreational services. Clusters “SOSI” and “Super-SOSI” (SIZ) include mountain municipalities linked, among others, to the national parks of Ordesa y Monte Perdido, Sierra Nevada and Sierra de Guadarrama. They have a certain balance between the various dimensions, with the best figures for social sustainability and good environmental sustainability. They have good relative facilities, despite depopulation.

**Table 4.** Value of the final centroids of the clusters at network scale.

SIZs					
Dimension	SOSI P. Eresma	ECSI Yaiza	Super-ECSI La Orotava	Balanced Naut Aran	Super-SOSI Navafría
Z_ENSI	0.588081	0.449153	1.262297	0.784735	0.519577
Z_ECSI	−0.021985	7.926727	12.592188	0.139411	−0.071080
Z_SOSI	1.505438	−0.578523	−0.257768	−0.247683	7.061017
Number of cases	21	4	1	140	3
Buffer					
Dimension	ECSI Arona	Unsustainable Porto do Son	SOSI Potes	Balanced-ENSI Ventas con Peña Aguilera	Balanced-high Bonansa
Z_ENSI	−0.877093	−0.887162	−0.374766	0.715428	1.330672
Z_ECSI	2.662504	−0.203968	−0.152639	−0.133158	−0.095742
Z_SOSI	−0.408193	−0.265704	2.197007	−0.429295	0.846759
Number of cases	2	241	30	88	25

Legend: SIZ=Socioeconomic Influence Zone; Z-ENSI = Z-values of environmental sustainability index; Z-ECSI = Z-values of economic sustainability index; Z-SOSI = Z-values of social sustainability index. In the headings of each column, we have assigned a label that shows the dominant dimension of each cluster. Furthermore, we have added the name of a municipality that is the most representative of each group. We have also coloured each cell with a range of red or green colours to illustrate the negative or positive values, respectively. Light colours (red or green) have values close to 0 while dark colours are the most distant from 0.

Cluster “Unsustainable” (buffer) includes, among others, the urban municipalities in the surroundings of the NPs of Islas Atlánticas, Doñana, Sierra Nevada and Sierra de Guadarrama which give rise to great environmental pressure (fragmentation of natural habitats, forest fires) and socio-economic pressure (unemployment, public debt). Cluster “Balanced-high” (buffer) includes, among others, municipalities in the surroundings of mountainous national parks that could be

considered “central places” in rural or peri-urban areas. They usually have good environmental and social sustainability because of, despite depopulation in some of them, concentrating strategic facilities.

### 3.2. Results on a Local Scale

#### 3.2.1. Comparison of Sustainability Indices between Cases and Controls on a Local Scale

In general terms, the pattern is the same as that at the network scale. Municipalities located inside the SIZs usually have greater environmental and economic sustainability (see Figure 3; Appendix B; Figures A1 and A2 in Appendix C). A representative case is the Doñana wetland. The municipalities inside this NP show good environmental sustainability, while those in its surroundings are subject to soil artificialisation, habitat fragmentation and forest fires.

#### 3.2.2. Cluster Analysis on a Park Scale

Appendix D and Figure 4 show the cluster analysis results broken down by NP. The figure is designed in such a way that the closer a point is to the observer (front top right corner), the higher its sustainability.

There are no points in the optimal area. However, economic sustainability in the municipalities in the Timanfaya NP (point P8) is high, in comparison with the group of municipalities in the two maritime-terrestrial NPs and the Tablas de Daimiel NP (points P10, P13 and P7), which have the lowest figures.

### 3.3. Differences between Biogeographical Regions and Sustainability Dimensions

We grouped municipalities according to their NPs and the location of these to determine if there are significant differences in their sustainability by biogeographical area (Table 5).

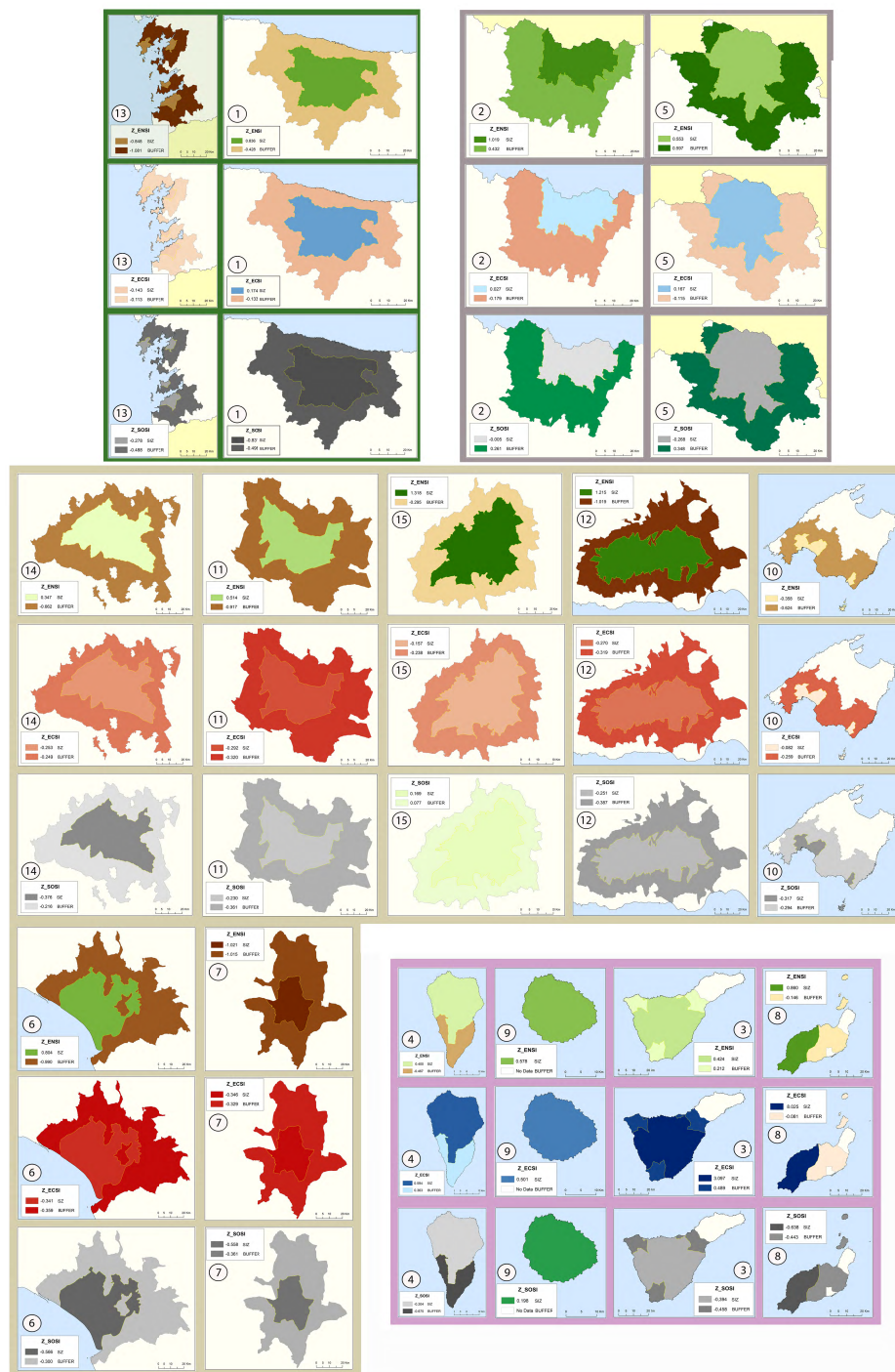
**Table 5.** Municipal sustainability according to biogeographical regions.

Biogeographic Region	Z_ENSI <sup>1</sup>	Z_ECSI <sup>1</sup>	Z_SOSI <sup>1</sup>
Atlantic	−0.006	<b>0.016</b>	−0.555
Alpine	<b>0.786</b>	<b>0.097</b>	−0.137
Mediterranean	<b>0.514</b>	−0.270	−0.317
Macaronesian	<b>0.501</b>	<b>1.846</b>	−0.299

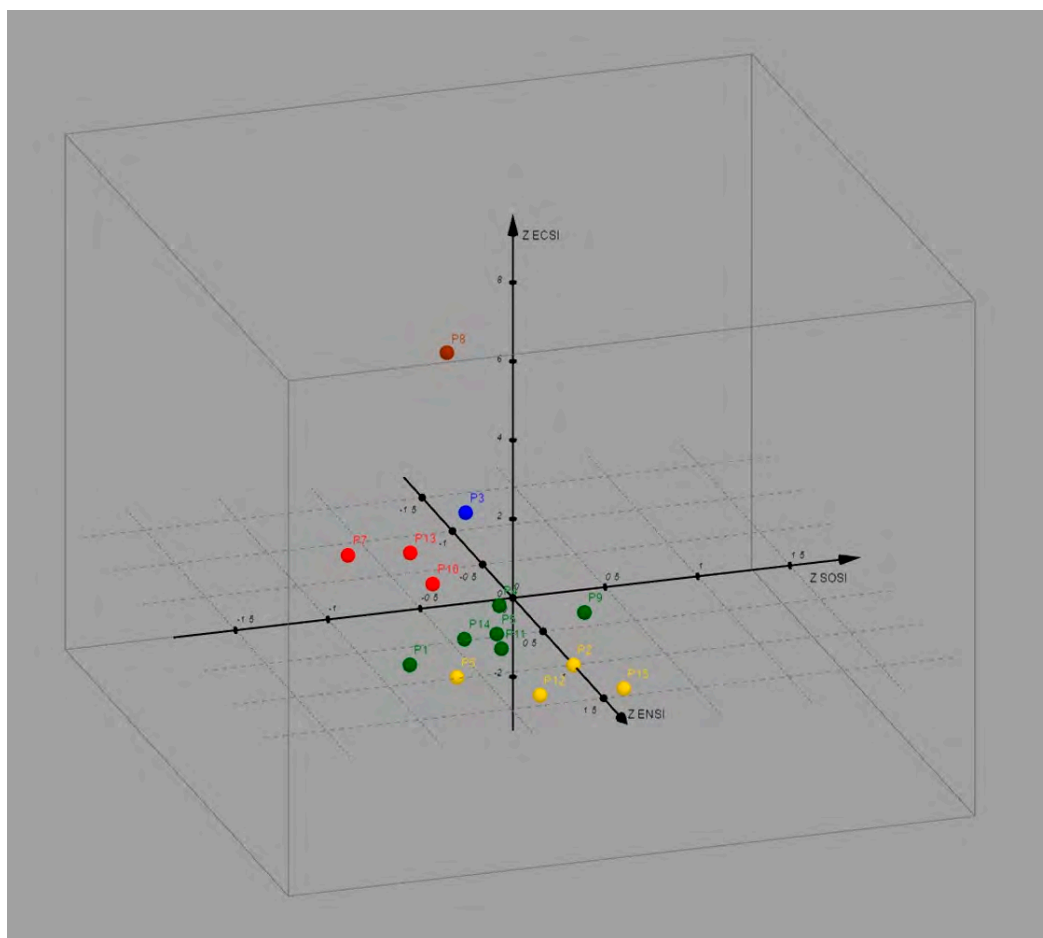
<sup>1</sup> In bold, above mean values. Legend: Z-ENSI = Z-values of environmental sustainability index; Z-ECSI = Z-values of economic sustainability index; Z-SOSI = Z-values of social sustainability index.

The Alpine region is seen to concentrate the highest sustainability in two of the three dimensions.

If the three dimensions of sustainability are compared, we can say in general terms that environmental sustainability is the component that contributes most to global sustainability in the municipalities located in the SIZs. This is usually greater than economic sustainability and both are greater than social sustainability (see Table 3 and Appendix B).



**Figure 3.** Maps of municipal sustainability of Spanish NPs and their surroundings, grouped by biogeographic regions: Atlantic (**top left**), Alpine (**top right**), Mediterranean (**centre and bottom left**) and Macaronesian (**bottom right**). For each park simplified values are shown for environmental (Z\_ENSI), economic (Z\_ECSI) and social sustainability (Z\_SOSI), from top to bottom, bearing in mind the median for all municipalities that fall within their SIZs (cases) and their buffers (controls). The numbers in each map correspond to: (1) Picos de Europa; (2) Ordesa y Monte Perdido; (3) Teide; (4) Caldera de Taburiente; (5) Aigüestortes i estani de Sant Maurici; (6) Doñana; (7) Tablas de Daimiel; (8) Timanfaya; (9) Garajonay; (10) Archipiélago de Cabrera; (11) Cabañeros; (12) Sierra Nevada; (13) Islas Atlánticas de Galicia; (14) Monfragüe; (15) Sierra de Guadarrama. Note that Garajonay NP has no controls, because the municipalities in its SIZ occupy the whole of the island of La Gomera.



**Figure 4.** Grouped representation of environmental, economic, and social sustainability indices for municipalities by NP. The numbers at each point correspond to the municipalities located in: (1) Picos de Europa; (2) Ordesa y Monte Perdido; (3) Teide; (4) Caldera de Taburiente; (5) Aigüestortes i estany de Sant Maurici; (6) Doñana; (7) Tablas de Daimiel; (8) Timanfaya; (9) Garajonay; (10) Archipiélago de Cabrera; (11) Cabañeros; (12) Sierra Nevada; (13) Islas Atlánticas de Galicia; (14) Monfragüe; (15) Sierra de Guadarrama. Legend: Z-ENSI = Z-values of environmental sustainability index; Z-ECSI = Z-values of economic sustainability index; Z-SOSI = Z-values of social sustainability index. Dark red=cluster Super-ECSI (Timanfaya); Yellow=cluster ENSI (Sierra Nevada); Blue=cluster ECSI (Teide); Green=cluster Balanced (Aigüestortes i estany de Sant Maurici); Light red=cluster Unsustainable (Islas Atlánticas de Galicia).

## 4. Discussion

### 4.1. Local Sustainability in and around the Spanish Network of NPs

On a network scale, the results show that municipalities inside NPs are more sustainable in every dimension than those in their surroundings.

On a local scale, the municipalities of Doñana, Ordesa y Monte Perdido, Sierra Nevada and Sierra de Guadarrama (points P6, P2, P12 and P15 in Figure 4) also show good figures for environmental sustainability, as a result of low fragmentation and the artificialisation of habitats and successful fire prevention and fighting.

There are, however, some exceptions. For example, the municipalities in the Tablas de Daimiel NP were affected in 2009 by fires in marsh vegetation. These were caused by spontaneous combustion of peat when it entered into contact with the atmosphere as a result of chronic over-exploitation

of the underground aquifer that sustains this wetland [74]. In this case, there are no significant differences between cases and their controls. Frequent and extensive forest fires also explain the poor environmental sustainability of the two maritime-terrestrial NPs.

Although, in general, the environmental component is the one that contributes most to local sustainability, in the municipalities in the Timanfaya and Teide NPs, it is the economic dimension that is the most relevant. This is because of the high income related to the ecosystem services provided by recreational uses [75].

Regarding the contribution of social sustainability, we have already seen that the social fabric and the provision of facilities is poor in municipalities inside NPs, especially in those that are in mountainous areas, for reasons of rurality and poor access. However, there are exceptions. The municipalities inside the Sierra de Guadarrama NP show greater social than economic sustainability. This is probably due to their proximity to Madrid and Segovia and to their high provision of facilities, which perhaps aim to provide services to the population living in second homes.

#### 4.2. Driving Factors and Consequences

The main findings of this work are in line with the literature on LULC changes [76] and on how they relate to environmental sustainability in PAs [77,78]. Among others, we point out the effect of depopulation and accessibility on the abandonment of farming lands [79], and on the increased risk and occurrence of forest fires [80,81]. Urban, agricultural and grassland interfaces with forests are the main driving factors for forest fires [82], which, in turn, are responsible for the loss of biodiversity.

In addition, the fragmentation of natural habitats [83] and increasing artificialisation of land in peri-urban environments and in the coastal strip [84–86] are responsible for loss environmental sustainability in Spanish PAs and their surroundings, including NPs [78]. This process of change requires careful management [87] to preserve valuable and fragile coastal ecosystems, such as dunes or wetlands.

Other processes of change such as urban sprawl, coastalisation, the expansion of irrigated crop systems, afforestation and depopulation [88] have an impact on the environmental sustainability of PAs and their surroundings [29,77]. In the Doñana NP, for example, the intensification of farming has caused the loss of ecosystem services [89].

Regarding the economic dimension, it is clear that recreational services contribute to total economic value and local sustainability. This has been shown in prior studies in various Spanish NPs [90–94]. The biodiversity, singularity and attractive landscapes of NPs attract large numbers of visitors every year, which is reflected positively in the local economies of their municipalities, especially in the Canary and Balearic Islands and in those located in the Sierra de Guadarrama, Sierra Nevada, Ordesa y Monte Perdido and Picos de Europa [95]. On the other hand, tourism and recreational services generate a cost for environmental sustainability. Some studies [96] show a high correlation between tourism density and the energy ecological footprint in the Canary Islands.

From a social point of view, traditional activities (agriculture or forestry) have been unable to retain the population in remote NPs [97]. In Picos de Europa, depopulation has had negative consequences for socioeconomic development and environmental conservation [98]. Naturbanisation (counter-urbanisation) might help strengthen the social fabric and revert population ageing [99]. As was to be expected, in our study, inland or mountain SIZs are not penalised by the population density indicator (SO01) when the Weibull function is applied.

Finally, the size of population nuclei does not seem to have much of an influence on the scores for the various dimensions of sustainability. Correlation coefficients are very low (<0.15). However, our results are in line with the findings of Zoeteman et al. [45]. Gradually, as the size of municipalities grows, so does their economic sustainability. However, this relation is inverted for environmental and social sustainability.

#### 4.3. Methodological Considerations. Valuation of the Method by Experts

The proliferation of sustainability indicators has led to simplifying initiatives, which aim to systematise them and reduce them to a manageable number [100]. The problem stems from the lack of consensus on what sustainability is, the lack of data [101] and the lack of political will [102].

The effectiveness of indicators to have to real influence on decisions has been studied by several authors [103–105], who find it difficult to show connections between indicators, decisions, and the results of policies.

There is an open debate among scientists on the use of synthetic indicators of sustainability [45] and on methods for aggregating and selecting indicators [63,106–108]. Moreover, the aggregation and selection method may have a significant influence on the end results, so the strengths and weaknesses of indicators should be pointed out with transparency and self-criticism.

In the expert workshop mentioned above, we presented a pilot version of SASMU and the preliminary results of its application to the NPs of Sierra de Guadarrama and Ordesa y Monte Perdido. In a survey, we asked them to assess the method and its implementation, then discussed their feedback.

In their opinion, the development of the methodology has been widely discussed with the bodies interested in applying it. They stated that it would have been useful to also consult with other departments of public administrations (environmental education), and with the managers of river basins. They considered that SASMU is based on careful selection of indicators and sources of information and on rigorous scientific and technical criteria. They also considered that the methodology is extremely useful for the organisations in which they work as experts, that it is a useful tool for local and environmental management and that it expands knowledge of the processes taking place in SIZs.

Regarding adoption of the methodology, the experts considered that this is highly desirable for all the NPs in the Spanish network, for planning and prioritising local and regional investments, for monitoring sustainability on a local scale and for generally making the debate on PAs more objective. They also considered that it would be essential to implement it regularly for efficient monitoring, and that the main limitations were possibly: limited political will, limited funding, insufficient trained staff and insufficient data availability.

#### 4.4. Indicator System Development: Weaknesses and Strengths of the Method

Several indicators that are conceptually relevant for sustainability in PAs (e.g., EN06 defoliation of forest masses, EN12 species richness, EN17 wastewater treatment, EN24-EN25 atmospheric quality, or SO07 service quality) were not included because of insufficient data on a local scale. To provide such data would require large spatial data infrastructure or intensive and periodic surveys, which fall outside the scope of this paper.

Nor did we include certain indicators of biophysical interest such as EN07 (Change in Gross Primary Productivity), even though they would provide very valuable information that is directly related to the photosynthetic function [109] and the global carbon cycle [110]. Such indicators would require the downloading and processing of a large number of satellite images and, although they sparked interest during the workshop among managers and specialists in the conservation of PAs, unanimous agreement was not reached on them. Nor were mayors or other representatives particularly interested in them, perhaps because of insufficient information, or because such indicators are difficult to interpret.

It should also be pointed out that some municipalities in buffers are not pure controls because of multiple PAs in Spain (Natural Parks, Special Areas of Conservation, Sites of Community Importance and Special Protection Areas) that overlap each other or even surround NPs. Even if they do not fall inside NPs, they may belong either fully or partially to another of the PA networks mentioned above. The indicators measured in them may be affected by regulation of such PAs, even though these usually have a less demanding level of protection.

Despite its limitations, we consider that the SASMU methodology is easy to replicate in other Spanish PA networks. The same methodological approach could be used anywhere and for other

PA categories (e.g., Natura 2000 sites). The validity of the research design that we used would be maximized if the control-municipalities did not have any type of legal protection over biodiversity (that is, pure controls). SASMU could also be replicated in other countries, after adaptation to their specific characteristics and to data availability.

It is important to stress that the social dimension is included as an essential component, especially in the context of PAs. The role played by local communities is acknowledged for their contribution to the conservation of biodiversity. However, such indicators are under-used in sustainability policies [111], despite the wide range of methodological proposals on various scales [112].

An advantage of our method is that it can help local and regional authorities to identify and prioritise any necessary political actions [45] in line with the strengths and weaknesses identified in each municipality. It may also help promote interaction between the various administrative bodies (vertically) and across departments that are responsible for different aspects (horizontally).

#### 4.5. Future Developments

Our intention is to replicate the SASMU methodology every 5 or 10 years to track trends in the indicators and indices, and to find to what extent they are close to, or far from, desirable values. As was to be expected, the managers of NPs and the regional heads of nature conservation services pointed out in the survey that, in addition to spatial analysis, monitoring over time is essential for the successful and lasting adoption of an assessment methodology like the SASMU.

In future, it would be advisable to refine the selection of the control municipalities, excluding all those that belong to other PA networks. This decision might lead to a marked reduction in the number of controls.

In future developments, we intend to perform a sensitivity analysis, testing the inclusion of new indicators in each of the dimensions. For example, in a pilot NP, we will calculate the EN07 (Gross Primary Productivity) indicator using data from Sentinel 2 [113], which have better spatial resolution. Wolanin et al. [109] have already tested them successfully in a mangrove ecosystem located inside a PA. In the context of sensitivity analysis, we could also undertake new tests in the future (e.g., other buffer distances [114,115], variation in the number of indicators, or the assignment of different weights to the indicators).

We also intend to analyse the processes that will probably arise in the future considering different land use change [116,117] and climate change scenarios [118], which might affect the sustainability of national parks and their surroundings. The objective would be to provide information to policymakers and managers that would be of use in their decisions, and would help to prevent possible environmental impacts.

## 5. Conclusions

We consider SASMU to be a simple and useful tool for notifying those in charge of NPs and local managers, among others, of the limitations and opportunities for each municipality for promoting sustainable development. In addition, its results may guide the policy of financial aid granted by the Spanish Agency for National Parks to municipalities that belong to the SIZ in each NP, in line with objectives achieved [119].

On a network scale, this study shows that municipalities included within NPs are more environmentally, economically and socially sustainable than those in their surroundings, which are subject to different impacts such as urbanisation, the fragmentation of natural habitats, the intensification of irrigated agriculture, forest fires, etc. NPs undoubtedly provide ecosystem services that must be valued and that contribute to economic sustainability. On a local scale, the results differ depending on environmental and socio-economic characteristics and on the biogeographical region to which the municipalities studied belong. Finally, we show that the environmental component is the dimension that contributes most to local sustainability.



**Supplementary Materials:** The following are available online at <http://www.mdpi.com/2076-3263/10/8/298/s1>, Word file: Supplementary Materials\_SM1.doc; Excel file: Supplementary Materials\_SM2.xlsx.

**Author Contributions:** All the authors contributed equally to the conceptualisation and design of the methodology and to its pilot application in two Spanish NPs. J.M.-V., D.R.-R., P.I. and M.E. organised the expert workshop. J.M.-V. and F.M.F.-L. wrote the first draft of the manuscript. The use of ArcGis and Guidos and the the spatial-temporal analysis of the data and cartographic results were the responsibility of P.E. All authors have read and agreed to the published version of the manuscript.

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## Appendix A

**Table A1.** Biophysical and socioeconomic similarity results.

Covariable	Statistic	SIZs	Buffer	Similarity Index
Number of cases (n)	Sum	170	387	
Area (ha)	Median	6840.63	5163.78	0.86
Elevation (m)	Mean	1134.02	731.19	0.83
Slope (°)	Mean	13.94	9.08	0.83
Artificial cover (%)	Median	0.45	1.18	0.99
Treeless cover (%)	Median	18.85	43.50	0.75
Distance to mayor cities (Km)	Median	20.01	14.30	0.93
Distance to infrastructures (Km)	Median	2.45	1.67	0.99
Global Similarity Index	Median			0.88

Legend: SIZs = Socioeconomic Influence Zones.

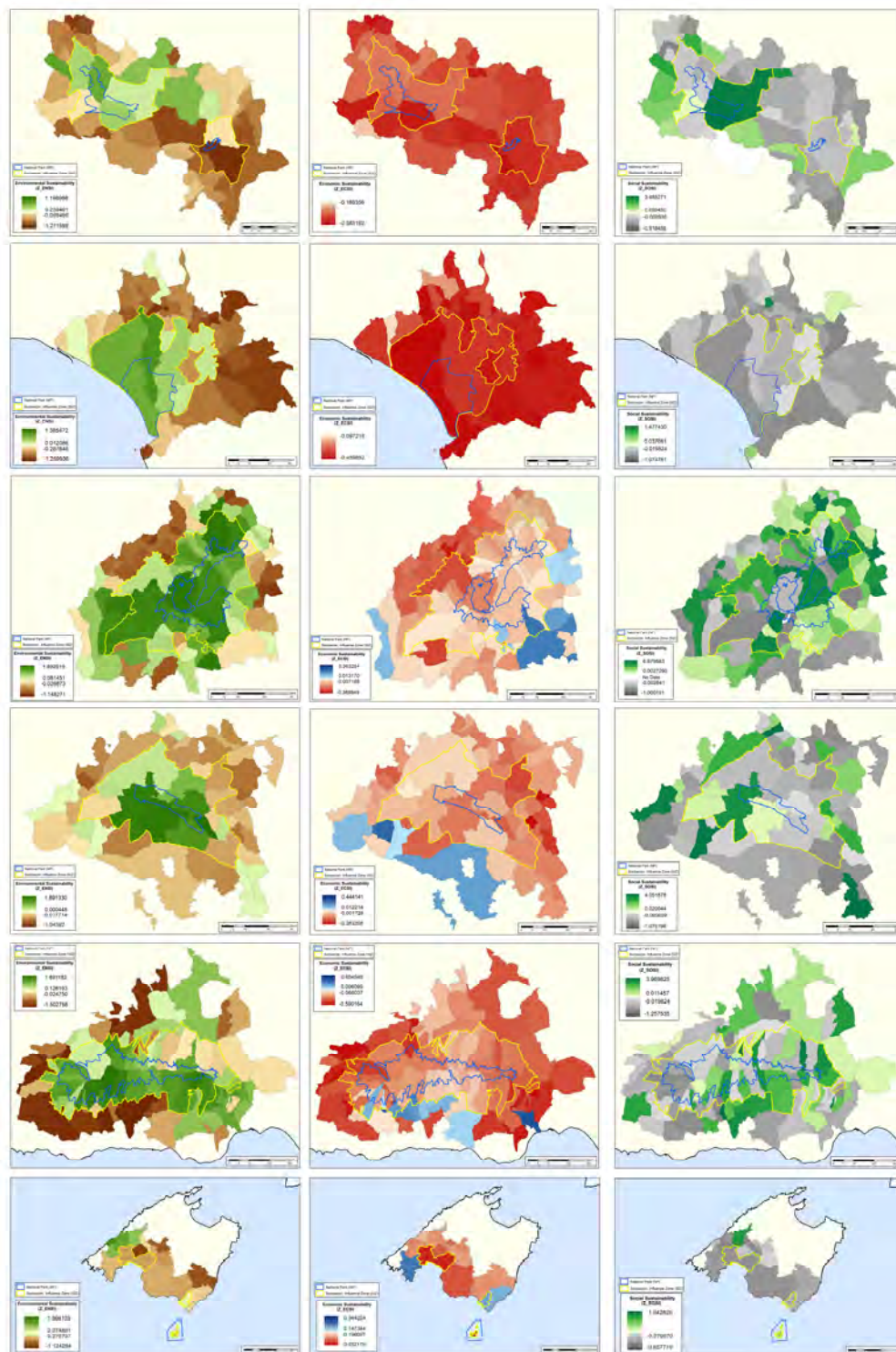
## Appendix B

**Table A2.** Values of the environmental, economic, and social sustainability indices in the Spanish NP network.

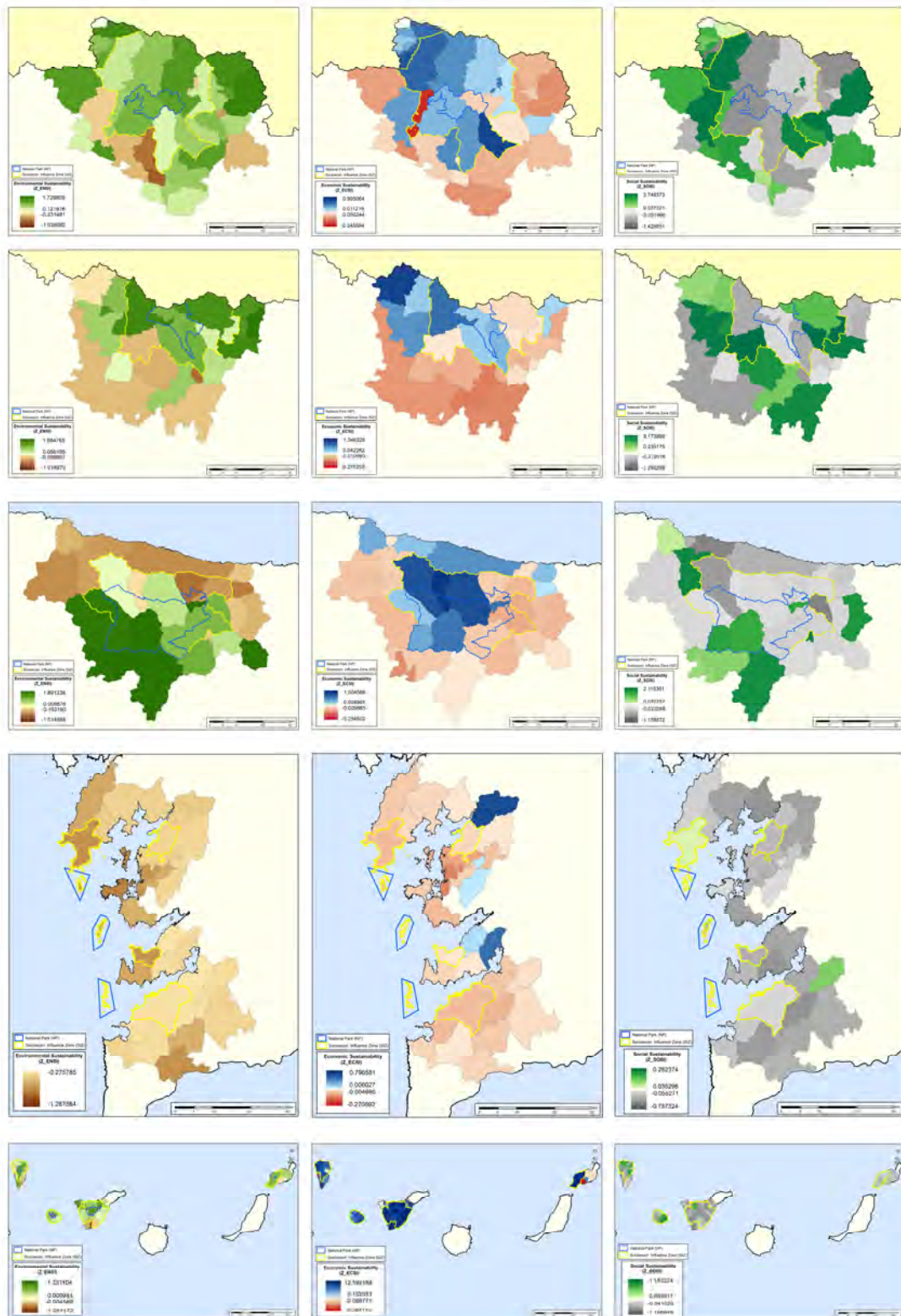
Sites <sup>1</sup>	Zone	Z_ENSI <sup>2</sup>	Z_ECSI <sup>2</sup>	Z_SOSI <sup>2</sup>
1	SIZ	<b>0.836</b>	<b>0.174</b>	−0.831
	Buffer	−0.428	−0.133	−0.498
	d	+1.264	+0.307	−0.333
2	SIZ	<b>1.019</b>	<b>0.027</b>	−0.005
	Buffer	<b>0.432</b>	−0.179	<b>0.261</b>
	d	+0.587	+0.206	−0.266
3	SIZ	<b>0.424</b>	<b>3.097</b>	−0.394
	Buffer	<b>0.212</b>	<b>0.489</b>	−0.458
	d	+0.212	+2.608	+0.064
4	SIZ	<b>0.400</b>	<b>0.594</b>	−0.204
	Buffer	−0.467	<b>0.363</b>	−0.675
	d	+0.867	+0.231	+0.471
5	SIZ	<b>0.553</b>	<b>0.167</b>	−0.268
	Buffer	<b>0.597</b>	−0.115	<b>0.348</b>
	d	−0.044	+0.282	−0.616
6	SIZ	<b>0.804</b>	−0.341	−0.566
	Buffer	−0.990	−0.359	−0.300
	d	+1.794	+0.018	−0.266
7	SIZ	−1.021	−0.346	−0.558
	Buffer	−1.015	−0.329	−0.361
	d	−0.006	−0.017	−0.197
8	SIZ	<b>0.860</b>	<b>8.025</b>	−0.638
	Buffer	−0.146	−0.081	−0.443
	d	+1.006	+8.106	−0.195
9	SIZ	<b>0.578</b>	<b>0.501</b>	<b>0.198</b>
	Buffer	---	---	---
	d	---	---	---
10	SIZ	−0.358	−0.082	−0.317
	Buffer	−0.624	−0.259	−0.294
	d	+0.266	+0.341	−0.023
11	SIZ	<b>0.514</b>	−0.292	−0.230
	Buffer	−0.917	−0.320	−0.361
	d	+1.431	+0.028	+0.131
12	SIZ	<b>1.215</b>	−0.270	−0.251
	Buffer	−1.019	−0.319	−0.387
	d	+2.234	+0.049	+0.136
13	SIZ	−0.848	−0.143	−0.278
	Buffer	−1.081	−0.113	−0.488
	d	+0.233	−0.030	+0.210
14	SIZ	<b>0.347</b>	−0.253	−0.376
	Buffer	−0.662	−0.249	−0.216
	d	+1.009	−0.004	−0.160
15	SIZ	<b>1.318</b>	−0.157	<b>0.169</b>
	Buffer	−0.295	−0.238	0.077
	d	+1.613	+0.081	+0.092

<sup>1</sup> The numbers in the first column correspond to: (1) Picos de Europa; (2) Ordesa y Monte Perdido; (3) Teide; (4) Caldera de Taburiente; (5) Aigüestortes i estani de Sant Maurici; (6) Doñana; (7) Tablas de Daimiel; (8) Timanfaya; (9) Garajonay; (10) Archipiélago de Cabrera; (11) Cabañeros; (12) Sierra Nevada; (13) Islas Atlánticas de Galicia; (14) Monfragüe; (15) Sierra de Guadarrama. <sup>2</sup> In bold, above mean values. Legend: NPs=National Parks; SIZ=Socioeconomic Influence Zones; Z-ENSI = Z-values of environmental sustainability index; Z-ECSI = Z-values of economic sustainability index; Z-SOSI = Z-values of social sustainability index; d = difference between SIZ and buffer.

**Appendix C. Cartographic Representation of the Dimensions of Municipal Sustainability in the SIZs within NPs and in Their Buffer Zones**



**Figure A1.** Maps of municipal sustainability in the SIZs within NPs in the Mediterranean region and their buffer zones. From top to bottom: (Cabañeros to the west and Tablas de Daimiel to the east; Doñana; Sierra de Guadarrama; Monfragüe; Sierra Nevada and Archipiélago de Cabrera) and from left to right (environmental, economic and social sustainability).



**Figure A2.** Maps of municipal sustainability in the SIzs in NPs in the Alpine, Atlantic and Macaronesian regions and in their buffer areas. From top to bottom: (Agüestores y Estany de San Maurici; Ordesa y Monte Perdido; Picos de Europa; Islas Atlánticas de Galicia e Islas Canarias: from west to east Caldera de Taburiente, Garajonay, Teide and Timanfaya) and from left to right (environmental, economic and social sustainability).

## Appendix D

**Table A3.** Value of the final centroids of the clusters on a NP scale.

Dimension	SIZs				
	Cluster 1s	Cluster 2s	Cluster 3s	Cluster 4s	Cluster 5s
Z_ENSI	0.8600	1.0890	0.4240	0.5380	−0.7423
Z_ECSI	8.0250	−0.1853	3.0970	0.1485	−0.1903
Z_SOSI	−0.6380	−0.1633	−0.3940	−0.2852	−0.3843
Number of cases	1	4	1	6	3

Legend: SIZ=Socioeconomic Influence Zone. Z-ENSI = Z-values of environmental sustainability index; Z-ECSI = Z-values of economic sustainability index; Z-SOSI = Z-values of social sustainability index.

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