A proposal of resilience indicators for Monfragüe National Park

Jacinto Garrido Velarde and Julián Mora Aliseda

Abstract— Natural spaces represent environmental systems with a double function, both social and ecological, where environmental sustainability conditions can be assessed.

One of the most important features of the socio-ecological systems is called resilience, which is related to the magnitude of the forces or pressures that a system can absorb remaining in a stable state and thus being able to self-organize and improve their ability to learn and adapt. The main objective of this study is to design and propose a resilience indicator system for Monfragüe National Park, in response to the need for a set of enough data to monitoring the short, medium and long term persistence of protected area against changes or environmental impacts, social and economic environment of the Park. We expect that, by laying down the objectives, it will be possible for the relevant authorities to adopt strategies of sustainable management.

The resilience indicators systems proposed in this study for Monfragüe National Park, could be recommended for subsequent application of resilience indicators in other National Parks

Keywords— Environmental Sustainability, Natural Spaces, Resilience Indicators

I. Introduction

A. *Theoretical framework*

THROUGHOUT history, interactions between human activities and the environment in systems both terrestrial and marine, have given rise to some diverse processes of habitat disruption, fragmentation and degradation, which have potentially affected our planet´s biodiversity in a variety of ways [8], [20]. We can find an illustrative example in forest fragmentation, which leads to a decrease of reproduction and gene flow, thus promoting species extinction [31]. These fragments of forest become more vulnerable to fire, invasion of foreign species, and other habitat degradation processes [7], [24], [32]. A well-preserved ecosystem needs some functions that are essential to its sustenance and organization (e.g. air and water purification, creation and preservation of fertile soil, pollination of native flora and crops, seed dispersal, nutrient recycling, etc.). These functions are directly affected during a phase of disruption, thus causing environmental damage with serious biological implications. Therefore the primary objective of management strategies has been to protect, sustain and restore the essential ecosystem functions by using processes and elements intrinsic to these ecoregions [4]. All these characteristics have to do with ecosystem integrity and stability as related to its associated human value (e.g. forestry techniques), and contribute to high ecosystem integrity [16]. Hence, the need to reduce human impact on ecosystem processes has led to pressures to cope properly with these issues. However, the urge to generate such a solution is fostering oversimplification of notions such as sustainable development and "healthy" ecosystem detection, which leads to somewhat overlooking the complexity of natural systems [12]. There are merits and limitations in every ecosystem definition. The same applies when assessing ecosystems based upon a brief outline of the links underlying biological diversity and ecosystem functioning and "resilience", and based also upon a description of the issues underlying the task of telling apart disruptions which are natural from those which are anthropogenic [8], [34]. It is also important to emphasize how difficult it is to establish the economic value of different species and habitats. Moreover it is important to deploy management policies for natural ecosystems which have proven to be more biologically complex than managed systems, such as farming.

Consequently, we should identify, for each space-time scale and each hierarchic level [12], [38], the biological indicators of ecosystem state of conservation, which will enable the development of different strategies for ecological management, preservation and restoration. Resilience is an indicator that enables identification and environmental monitoring, as well as development of management and preservation strategies. It can be defined as an ecosystem's ability and capacity to absorb, buffer and withstand biotic and abiotic changes after some natural or anthropogenic disruption [5], [28], [39]. This capacity for recovering or buffering is determined by specific variants associated with regeneration, such as plant composition, yield, biomass, soil nutrient accumulation and ecological diversity. Preservation and management by using resilience as an indicator will allow us to embed the role of human activities in the functioning of

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ecosystems, thus creating the bases to predict both present and future ecological changes while helping to identify the most disruption-susceptible ecosystems [15]. One of the objectives of this paper is, therefore, to give prominence to the concept of “resilience” as a suitable indicator for the ecosystem´s state of conservation and its implications on biodiversity, on preservation policy development and management plans.

B. Concept of resilience

Both natural and anthropogenic changes in ecology take place in very complex ways, and they rarely operate in just one direction or at the same rate over time. This diminishes the forecasting potential as to how an ecosystem may change in the future. The concept of resilience is an excellent tool to aid understanding of how ecosystems work, thus replacing more strictly the “sustainability” concept, which is already being deferred after the last “Rio+20” Summit (2012), where the concept of resilient development strongly emerged. This concept makes it possible to establish more objective indicators that can also be extrapolated from one country to another, as opposed to the previous criterion, that is, a pre-eminence of environmental perspective over the social and economic ones. Resilient development is a more scientific concept and proves more attuned to the necessities and priorities of each territory.

The term “resilience” comes from Latin resiliens, entis, which means “jumping upwards”, and it is commonly accepted as an equivalent to “elasticity”. In material science, resilience represents the ability of a material to reacquire its original shape after a deformation while, in the business sector, resilience refers to the ability of a company to resist to a serious damaging event [6].

At this point, resilience requires, both for its territorial and socio-environmental approach, the establishment of dynamic relations at higher scales between economic and ecological systems, where, consequently, the effects of anthropic activities never exceed environmental boundaries which may destroy or minimize the diversity, complexity, and the characteristic functions of virgin, or even slightly modified ecosystems, where the very resilience of the systemic structure must be held over time, in order to attest its potential for balance and stability, which is the aim. Therefore, human impacts that clearly reduce stability and make it harder to return to the original state must be avoided, as far as is feasible [30].

So far, three dimensions of this interrelation were unfailingly incorporated within the concept of “sustainability”:economy/development, society/equit and environment/natural preservation. But resilience is making headway, both in the environmental and the social field, as an indicator for better understanding possibilities for diagnostic processes and, therefore, for systemic characterization of the dynamics involved at diverse territorial (global and local) scales: interrelations and complex interchanges between social systems and natural ecosystems, their threats and opportunities.

Thus, the value of “resilience” as a concept is important in understanding the different exploitation systems of natural resources [14]. The concept of “resilience”, as well as many others bio-indicators applied in specialized literature, depends on the targets set, the different types of disruption, the control measures available, and the time and the interest scale we are using [27]. The strategies where the concept of resilience has been applied for ecosystem preservation are based upon minimizing the biological impacts of the disruptions and increasing the ecosystems´ potential for self-recovery. Human population growth is associated with a decrease in natural resources.

Consequently, endeavours by various institutions to control and manage natural resources turned out to be insufficient, leading in many cases to a biodiversity loss and collapse of natural resources. This is directly linked to a loss of “resilience” in the ecosystems, and therefore, if natural systems are being reduced, a decrease in “resilience” to disruptions ensues [23]. For instance, we can observe that assemblies of species inhabiting frequently disrupted environments show higher levels of resilience than those occurring in less-disrupted environments [11], [17], because unstable environments are more likely to be dominated by certain taxa with short lifecycles and latency processes [40].

II. Resilience as an Indicator of the State of Preservation of an Ecosystem

Ecosystems comprise a great variety of species and respond differently to stress situations. The main pressures causing ecosystem alteration are physical restructuration and the introduction of non-native species. For instance, urbanization directly transforms landscapes and affects biodiversity, yield, and biogeoeconomic cycles. As a response to these pressures, different groups have evolved a certain degree of resilience. For instance, carnivores have evolved some behaviours and characteristics of life stories that endow them with some amount of “resilience” to disruptions over different time and space scales [40].

Monitoring studies on tree species composition in deciduous and coniferous forests over time show that resilience is a good indicator of the state of the ecosystem, since there is an increase in species composition by natural succession over a few years , which reveals that natural disruptions have little effect over species [26]. On the other hand, fire is known to be a natural element in ecosystems, and species in this kind of ecosystems have evolved via a series of “filters”, resistance and resilience to disruptions such as fire, which can reduce water infiltration, increase erosion and degradation of soil structure, thus desertifying these ecosystems and affecting the structure of communities of flora [13]. Plant adaptations to fire include the ability to form seed banks in the ground or in the canopy, and a high capacity for dispersion [3], [42]. Specifically, different species of pastureland and bushes in semi-arid environments show great resilience as a response to the presence of fire, thus increasing the diversity of species by composing big post-fire seed banks from a large number of species, and regenerating the original community in terms of persistence and self-replacement [21], [25]. Therefore, the resilience of such type of species suggests that greater diversity and biomass ensue in early stages after fire events, subsequently diminishing in later stages [22]. On the contrary, it has been reported that different insect communities show little resilience after disruptions such as fires or floods, due to the low recolonization within insect population [29].

The importance of resilience in coniferous forests may be specifically attested by the case of *Pinus halepensis* (an endemic species around the Mediterranean), which presents a high level of resilience after frequent fires, by means of seed banks in soil and canopy, high seed viability, high germination rates during the rainy season, and a great recruiting of seedlings during the first five years after the fire [10], which entails very important implications for management approaches regarding the effects of fire and control of rare and endangered species [42]. We can find a similar case in South-East Australian termites, which show great resilience after fire under conditions of high floristic diversity. The results are consistent with the hypothesis that a high floristic diversity increases “resilience”. The most important mechanism is a wide range of plant species availability (food) with different regeneration responses to serious fires [1].

It is hard to recognize the levels of natural resilience in certain ecosystems, so it is vital to know the history of the place and conduct a thorough monitoring program in order to assess the ecosystem stress signs and to apply distinct management strategies so these signs can be reduced [36]. Unfortunately, many studies do not provide a compelling basis for this hypothesis, because the applied methodology cannot be contrasted and/or the description of disruption framework is inadequate, which suggests that well-coordinated studies in different areas, with good standardized variables of many habitats, may be of considerable significance [9].

III. Environmental Relations of Sustainability

Sustainability can be understood as the state of condition (linked to usage and style) of an environmental system when it comes to production, renovation, and mobilization of substances and elements in nature, so minimizing the production of system degradation processes, both present and future. Similarly, sustainability presents four dimensions with

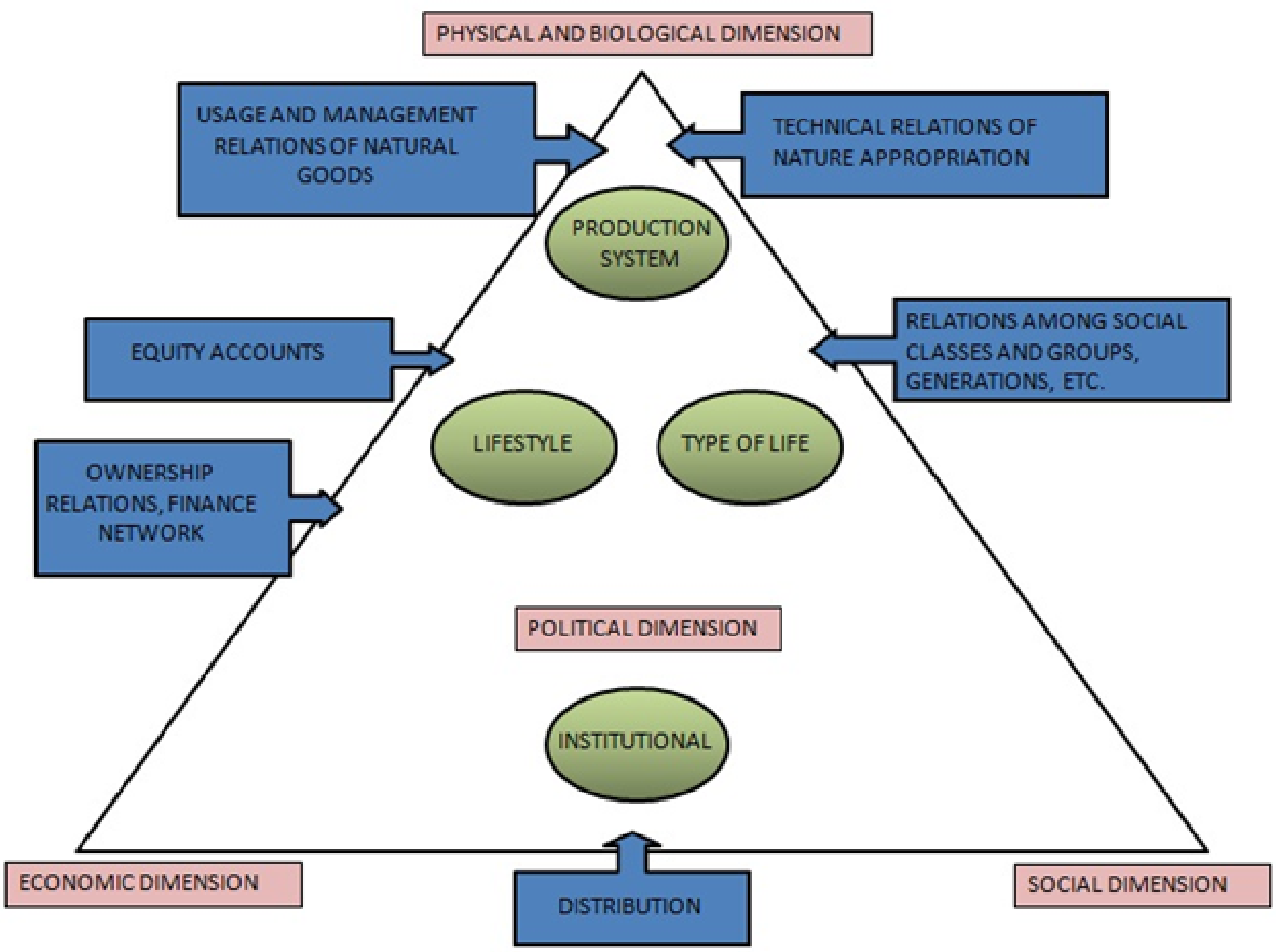

Fig 1: Tethrahedron of environmental relations-sustainability. Achkar, 1999.

mutual interaction. A schematic diagram of the interactions of these dimensions is shown in Fig. 1.

The *physical and biological dimension*: this deals with aspects related to preserving and boosting the diversity and complexity of the ecosystems, their yield, natural cycles and biodiversity.

The *social dimension*: this deals with equitable access to nature goods of a natural origin, both in intergeneracional and intragenerational terms, for different genders and cultures, different groups and social classes, but also on an individual scale.

The *economic dimension*: this comprises the full set of human activities related to production, distribution, and use of goods and services.

The *political dimension*: this enables all agents involved to take part in decisions concerning management of natural spaces, both through institutional (central, regional and local authorities) and private (business and associations) representatives.

It is necessary, therefore, to redefine some concepts of traditional economy, especially those of necessities and satisfiers, material and immaterial, social and individual necessities.

IV. A PROPOSAL OF RESILIENCE INDICATORS FOR MONFRAGÜE NATIONAL PARK

A. Study area

The Monfragüe National Park is located in the north of the Cáceres province, among the cities of Plasencia, Caceres and Trujillo, constituting an approximately rectangular strip that borders the confluence of the rivers Tajo and Tiétar. It covers an area of 18,396 hectares which includes land belonging to seven municipalities: Casas de Miravete, Jaraicejo, Malpartida de Plasencia, Serradilla, Serrejón, Toril y Torrejón el Rubio. (see Fig. 2).

The National Park comprises singular spaces for the study and monitoring of a resilience development. This interest is mainly due to the fact that protected areas contain natural components, social and ecological processes susceptible to change.

B. Resilience indicators

The global goal of this study is to design and put into operation a resilience indicators system for Monfragüe National Park to respond to the need to have enough set of data capable of monitoring the short, medium and long term persistence of this protected area against changes or environmental impacts, social and economic environment of the Park. Therefore, according to the criteria established by García Gastelum et. al., (2005), we propose to use the information pyramid (see Fig. 3), which is composed of four levels. The first level is composed of the environmental, economic and social data, collected in the area of planning, in the second level is performed an analysis from the database with the aim of executing the planned. The third level consists of the indicators derived from the database that make up the model and finally, at the top of the pyramid we have the indices derived from the assessment of resilient indicators.

In our study, for the proper development of territorial diagnosis three blocks of contents were generated: environmental system, social system and economic system. The sum of them will ultimately result of resilience indicators, and they show us the degree of adaptability of the analyzed

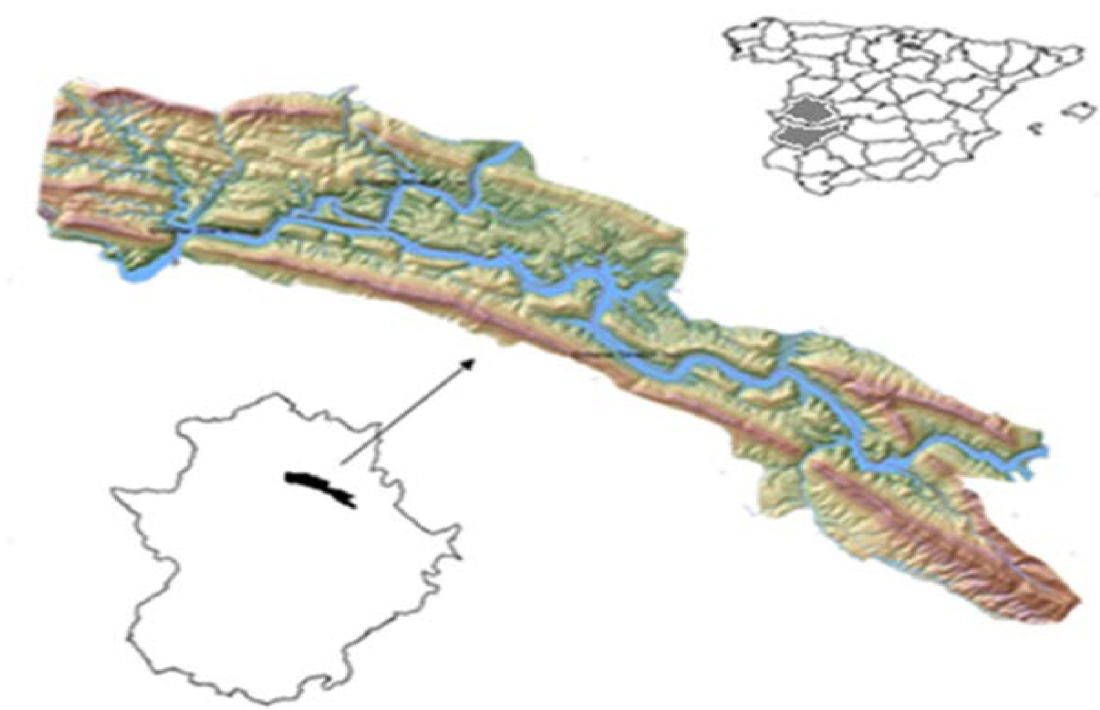

Fig 2. Location map of Monfragüe National Park

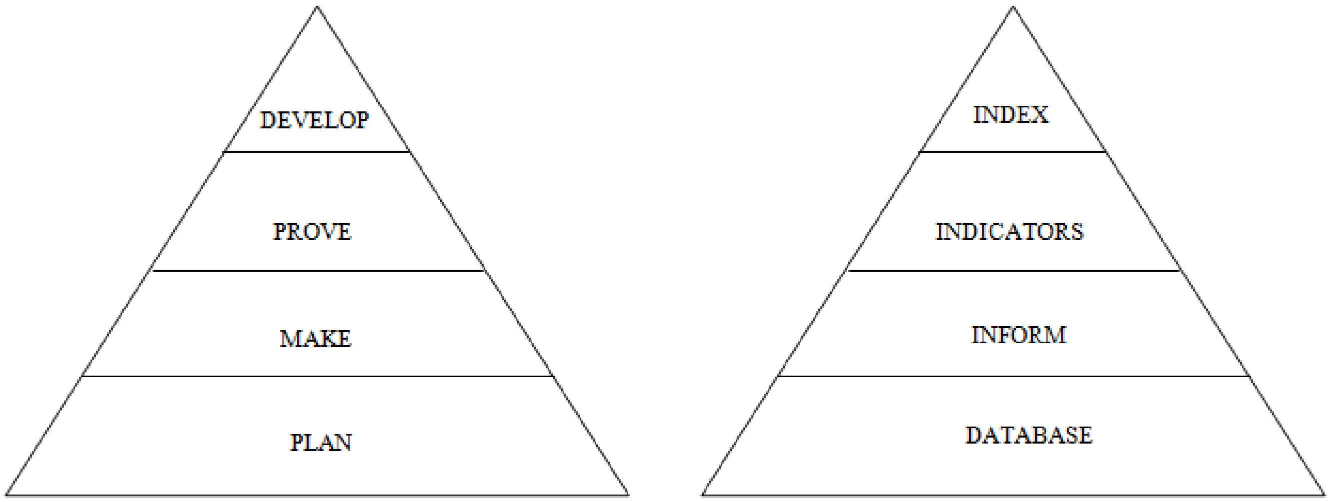

Fig. 3. The information pyramid. García Gastelum *et al.*, 2005

territory and the right balance between environment, economy and society. For Monfragüe National Park following the previous parameters a total of 100 resilience indicators, which are proposed have been classified according to the type of information they provide (to consult the 100 resilience indicators, see appendix). Each of them were assigned to a specific thematic block (see Table 1).

For the analysis of the proposed indicators by thematic area for this study we used the conceptual scheme "Pressure-State-Response" (PER) (see Table 2) that was used and adapted by the United Nations for the development of environmental statistics. At the same time, that scheme was adopted and modified by the Organization for Economic Cooperation and Development [33] released from this date internationally. To Quevedo Reyes (2007), the PER is based on the set of the interrelationships of human activities which exert pressure (P) on the environment, modifying the state (E) of natural resources then, society responds (R) to such transformations with general and sectoral policies, both environmental and socioeconomic, which affect and is feedback of the pressures of human activities. This model stands out as a multisystem (environmental, social and economic system).

In the environmental system the indicators of respond, are predominant due to the high number of protection and conservation policies. Following in number the pressure; directly related to human activity; contaminated water, fire, etc. And finally, 11 are the indicators related to the state, that is, those associated with the quality and quantity of environment and natural resources (see Table 2).

Regarding social system, there are numerous state indicators, constituted among others for population structure, natural movements, migration, etc. The response of this system focuses on social participation, investment in social facilities, etc. Unemployment rates and the rate of aging form pressure indicators (see Table 2).

Finally, in relation to the economic system, those productive activities that generate some conflict are analyzed. The state indicators are the most numerous, these indicators offer local variables to predict economic developments and are useful for planning actions and policies that should be applied (response indicators) (see Table 2).

Once the selection and analysis of each of the indicators is done, it is grouped into a hierarchy of values. To standardize these values, in a reasoned manner we categorize them as optimal or desirable levels and negative or critical levels. And therefore, the level and range management is determined for each indicator:

Critical level. It is detected when it is necessary to apply measures of resource conservation and demand management to promote their maintenance implementation of relevant policies.

Caution level. When the indicator is on it means that the process is about to break and therefore we have to take some action to bring the indicator to acceptable levels. It is not considered critical situation, but if we do not to take action it is very likely that the situation, process or variable observed will derive in stress levels.

Normal level. It implies that the indicators are above average values recorded in the historical series of indicators.

In good condition threshold refers to the value of the indicator that is required to achieve or maintain.

	Indicators
THEMATIC AREAS	
1. Environmental System	37
NATURAL RESOURCES Biodiversity: Flora and fauna Land water Air quality Natural environment indicator Natural nationally and internationally recognized figures **ENVIRONMENTAL MANAGEMENT** Planning instruments. PRUG, PORN, PDS, PUP Governance. Resources. Materials. Administrative. economic Implementation of quality strategies **ZONES OF PUBLIC USE** Equipments Signposting Communication and Participation Visitors	
2. Social System	31
SOCIODEMOGRAPHY Population. Population growth. Demography. Population structure. Youth rate. Aging rate. Natural movements. Birth rate. Natural growth. Migratory movements. Immigration rate. Foreign population Social Participation Index Education levels **ACCESIBILITY** Communications network. IMD roads. Telecommunications. Internet connection. **OTHERS** Participation. Policy. Social Human Resources. Workers in ENP Cultural resources. BIC. Sanitation and education equipment	
2. Economic System	32
ECONOMICS SECTORS Job market. Activity. Occupation. Unemployment Indicators of socioeconomic dependence Wellbeing Index: Economic Level. Employment accessibility Municipal spending. Family income (available) Agriculture / employment. Tenancy regimes Forestry / employment. Land distribution Livestock / employment. Livestock units Industries / employment. Industrial investments Energy / employment. Energy consumption Tourism / employment. Establishment and squares Construction / employment **FINANCIAL ACTIVITY** Financial system (features): Bank offices. Credit institutions Business. Number and legal form of establishments Business society IAE. Business activity **POLITICS AND PROJECTS** Policy convergence / development. Projects, inversion LEADER/PRODER OAPN/Gobex	

Table 1. Thematic areas and number of indicators analyzed.

Table 2. PER model applied to the analysis of the indicators proposed by thematic area.

	Environmental System	Social System	Economic System	Total
Pressure	12	5	5	22
State	11	21	20	52
Response	14	5	7	26
TOTAL	37	31	32	100

V. Discussion

The relevance of indicators lies in the way they can be used. Ideally, they must provide information to public managers and users in order to help them clarify a given issue and reveal the relations between its components, so leading to decisions on firmer foundations. They are also an excellent public information tool, because, when supplemented with a good communication strategy, they exemplify some concepts and scientific information, thus contributing to the understanding of key issues, and so leading society to take on a more active role in the solution of environmental problems.

According to the Organisation for Economic Cooperation and Development [34], the two main functions of environmental indicators are:

1. To reduce the number of measurements and parameters usually required in order to provide a rendition of a situation which is as accurate as possible.
2. To simplify communication processes. These basic functions turn indicators into a tool to provide users involved in decision-making, as well as the general population, with some concise and scientifically sustained information that can be easily understood and used.

Environmental indicators have been used at international, national, regional, state and local scales, in order to achieve different goals. These include: to act as tools to report the state of the environment, to assess environmental policy management and to communicate advances in the search of sustainable development. Nonetheless, indicators must have certain features in order to comply fully with these functions. A list of the most important features follows:

1. To offer a vision of environmental conditions, pressures endured and the responses of society and government.
2. To be simple, easy to interpret and capable of showing trends over time.
3. To respond to changes in environment and related human activities.
4. To provide some foundation for international contrast (when necessary).
5. To be applicable on a regional or a national scale, depending on the situation.
6. Preferably having a value as a reference to be contrasted with.
7. To have firm theoretical and scientific foundations.
8. To be based upon international agreements.
9. To be capable of interrelating economic models and information systems.
10. To be available at a reasonable cost/benefit rate.
11. To be well documented and of recognized quality.
12. To be regularly updated by reliable procedures.

In most cases, the commonly proposed indicators do not comply with all these characteristics. Similarly, it is important to bear in mind that, the fewer of these features an indicator has, the lower its reliability is, and, therefore, an interpretation deriving from them must be taken with all due restraint.

VI. Conclusion

The main conclusions of this work are:

1. As a final result we propose resilient indicators system for Monfragüe National Park, which can provide a basis for more productive and efficient reorganization of Monfragüe National Park.
2. Moreover, we assess the amount of changes or transformations occurred in the Park, analyzing those that can be supported keeping the same functional properties and structures.
3. Also, it is intended to observe to what degree Monfragüe is able to self-organize, as well as develop and increase the ability to learn, innovate and adapt.
4. Likewise, it is intended to establish compatible development between conservation of natural resources and economic development, defined as "environmental resilience"

VII. Final considerations

The environmental crisis in many developed countries has strongly highlighted the role played by natural spaces. Concurrently, awareness and knowledge of the countless beneficial effects of natural spaces have increased over the last few years. In this regard, it is important to guarantee that the effects of human activity are confined within limits, so as not to destroy the diversity, complexity and functioning of the ecological system that underlies life, thus preserving the services or environmental functions that natural spaces directly provide [19]. It is also important to preserve local communities and to protect their traditional activities, since virgin spaces do not really exist, rather they have been slightly modified through history; and human presence, paradoxically, is required to guarantee their preservation. Therefore, it is to be expected that the establishing of resilience indicators in this paper may act as a foundation for a more efficient and productive territorial rearrangement of protected spaces.

APPENDIX

A. *Environmental system indicators*

- Foreign species; forest and Fauna
- Variation forest mass
- Total surface: wooded and unwooded area burned
- Forest or wooded area (%)
- Protected forest area
- Surface restored
- Reforestation
- Km2 per unit area roads
- Increasing artificial surface: soil built
- Alterations surface water masses (reservoirs)
- Pressure surface water masses (Central Nuclear Almaraz)
- Groundwater pressure
- Contaminated water
- Sensitive areas
- State of surface and groundwater
- Contaminated aquifers
- Annual CO2 emissions by Industry
- Total methane emissions by sector
- N2 emissions by sector
- Protected areas
- Vulnerable species and endangered
- Vertebrate species: introduced / reduction
- Land affected by desertification risk
- Protected areas with Management Plan of natural resources.
- Endangered species with recovery plans.
- Investment in conservation
- Loading capacity
- Public expenditure on soil decontamination erosion control
- Public expenditure on water sewage management
- Investment in water management
- Planning instruments. PRUG, PORN, PDS, PUP
- Governance. Composition participation bodies
- Implementation of quality strategies
- Equipments
- Signposting
- Communication and Participation
- Visitors. Loading capacity

B. *Social system indicators*

- Total population
- Total population by sex. Femininity index
- Age population. Age pyramids
- Spanish and foreign population
- Density of population
- Age levels
- Childhood index
- Youth rate
- Index of old age
- Aging index
- Population structure
- Replacement rate
- Natural movement of the population
- Crude birth rate
- Crude mortality rate
- Vegetative growth of the population
- Index structure of the population in potentially active age
- Replacement rate of the population in potentially active age
- Natural movement of the population
- Crude birth rates
- Crude mortality rate
- Vegetative growth of the population
- Migratory movements. Immigration rate. Foreign population
- Social Participation Index
- Training levels
- Communications network. IMD roads. Livestock trails
- Telecommunications. Internet connection.
- Participation. Policy. Social
- Human Resources. Workers in ENP
- Cultural resources. BIC.
- Sanitation and education equipment

C. *Economic system indicators*

- Job market.
- Activity.
- Occupation.
- Unemployment
- Indicators of socioeconomic dependence
- Wellbeing index
- Tourist index
- Index restoration and bars
- Index of total economic activity
- Municipal spending.
- Family income (available)
- Agriculture / employment.
- Tenancy regimes
- Forestry / employment
- Land distribution
- Livestock / employment.
- Livestock units
- Industries / employment.
- Industrial investments

- Energy / employment.
- Energy consumption
- Tourism / employment.
- Establishment and squares
- Construction / employment
- Financial system (features): Bank offices. Credit institutions
- Business activity.
- Number and legal form of establishments
- Corporations
- IAE. Business society
- Convergence policy / development.
- Project investment. LEADER / PRODER
- OAPN / Gobex

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