Indicators for sustainable management in the Yasuni national park

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Abstract: The National Park are unique spaces for the study and monitoring of a resilient development. This interest is especially because the natural harbour protected areas, social components and ecological processes, subject to social and economic changes, which follow from these protected areas, have an intrinsic and comparative interest. To guide the scope and content of the resilient development requires the identification of a number of relevant environmental, social and economic indicators to develop a system of evaluation and monitoring, it is intended to determine the degree of deviation of the values of the indicators of reference values initially determined. The objective of this research proposal is to design and functioning of an Indicator System Resilience in the National Parks in general and in the Yasuní National Park in particular, that responds to the need to have a sufficient set of data capable of monitoring the short, medium and long term the persistence of protected area against changes or environmental impacts.

Key-Words: - Resilience Indicators, Environmental Management, Socio-Ecological, Yasuní National Park, Environmental Impacts, Sustainable Management

1 Introduction

Undoubtedly, the great environmental problem of our planet is the demographic explosion that is experiencing. In the last century, we have witnessed a rate of rapid population growth, having surpassed in 2015, and the 7.4 billion people. Obviously, the behavior is not homogeneous across the globe; there are areas in Southeast Asia, Africa and some Latin American countries where natural growth is at a rate of more than 20% per year, which implies that its strength doubles every 25 or 30 years; on the contrary, in other areas of North America and Europe, natural growth is negative and only grows by immigration processes.

However, due to the more globalized economic development, a decrease of the rates of population growth is evidencing, predicting that the maximum is reached in the year 2050 with about 8.5 billion humans on the face of the earth. Its explanation is in a contrasted law that shows that as a country increases its levels of economic development decreases its demographic growth and that is happening now in most emerging nations.

Consequently, it is undeniable that the demographic growth next to the model of industrial development generates impacts on the planet. On the one hand, the permanent emission of CO2 in the most advanced countries, as well as in the emerging ones, and, on the other hand, the decrease of the forest area in the most backward countries that, by the increase of their population, transform their tropical and equatorial forests to obtain new agricultural and pasture soils for livestock, as well as wood for the construction and export.

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 (Crome, 1996; Gascon *et al.*, 2000). We can find an illustrative example in forest fragmentation, which leads to a decrease of reproduction and gene flow, thus promoting species extinction (Nason & Hamrick, 1997). These fragments of forest become more vulnerable to fire, invasion of foreign species, and other habitat degradation processes (Cochrane *et al.*, 1999, Nepstad *et al.*, 1999; Jackson *et al.*, 2000). 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 (Andersson *et al.*, 2000). 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 (Dorren *et al.*, 2004). 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 (De-Leo & Levin, 1997). 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 (Crome *et al.*, 1996; Sheil *et al.*, 2004). 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 (De Leo & Levin, 1997; Sheil *et al.*, 2004), 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 (Bellwood *et al.*, 2004). 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 ecosystems, thus creating the bases to predict both present and future ecological changes while helping to identify the most disruption-susceptible ecosystems (Dornbush, 2004).

1.1.Resilience

The term "resilience" comes from Latin *resiliens, entis*, which means "jumping upwards", and it is commonly accepted as an equivalent to "elasticity". There is another definition, coming this time from the field of Physics, which refers to "*a material´s capacity to come back to its original shape after being exposed to high pressures*".

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 (Mora Aliseda, 2013).

So far, three dimensions of this interrelation were unfailingly incorporated within the concept of "sustainability":economy/development,society/equity, 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 (Doak *et al.*, 1998). 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 (Ludwig *et al.*, 1997). 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 (Holling & Meffe, 1996). 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 (Death, 1996; Fritz, 2004), because unstable environments are more likely to be dominated by certain *taxa* with short lifecycles and latency processes (Townsend & Hildrew, 1994).

2. Sustainability of the environmental system

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 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.

3. Resilience as an indicator of the state of preservation of natural spaces

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 (Weaver *et al.* 1996).

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 (Leak & Smith, 1996). 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 (De Luis *et al.*, 2004). Plant adaptations to fire include the ability to form seed banks in the ground or in the canopy, and a high capacity for dispersion (Agee, 1996; Wells *et al.*, 1997). 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 (Laterra *et al.*, 2003; Ghermandi *et al.*, 2004). 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 (Guo, 2003). 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 (Minshall *et al.*, 1997).

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 (Daskalakou & Thanos, 1996), which entails very important implications for management approaches regarding the effects of fire and control of rare and endangered species (Wells *et al.*, 1997). 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 (Abensperg-Traun *et al.*, 1996).
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 (Rapport *et al.*, 1998). 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 (Danielsen, 1997).

4. A proposal of resilience indicators for the Yasuní National Park

4.1. Study área
The Yasuní National Park (YPN) is located in the middle east of the Amazon region of the Republic of Ecuador. With an extension of 102,736 hectares, the YPN is considered the largest protected area of the Latin American country (Ambiente, 2011). This Park is famous for its extraordinary biodiversity, has the largest number of tree species per hectare in the world. Only one hectare of the Yasuní is the same number of species of native trees as all of North America (Green Gold, 2015). Located in the provinces of Pastaza and Orellana between the river Napo and river Curaray, about 250 kilometers southeast of the capital of Ecuador (Quito) the YPN is considered one of the most biodiverse places in the world for its important natural and cultural contribution (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.

4.2. Resilience indicators
The global goal of this study is to design and put into operation a system of resilience indicators in

the Yasuní 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 (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 territory and the right balance between environment, economy and society. For Yasuní National Park following the previous parameters a total of 100 indicators of resilience, 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 (Table 1).

For the analysis of the proposed indicators by thematic area for this study we used the conceptual scheme "Pressure-State-Response” (PER) (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 (OECD, 1993) 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 (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 (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) (Table 2).

Occasionally, some response indicators can also be considered state, for example the percentage of repopulated surface reflects the situation or state of the physical environment and in turn, it can be considered a response to changes suffered through a series of corrective policies.

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.

5. 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, thus 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 (OECD) (1998), the two main functions of environmental indicators are:

a) 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.

b) 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:

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

6. Conclusions

The main conclusions of this work are:

- As a final result we propose Resilient System Indicators for Yasuní National Park, which can provide a basis for more productive and efficient reorganization of Yasuní National Park.

- 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.

- Also, it is intended to observe to what degree Yasuní is able to self-organize, as well as develop and increase the ability to learn, innovate and adapt.

- Likewise, it is intended to establish compatible development between conservation of natural resources and economic development, defined as "environmental resilience"

7. 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 (García y Guerrero, 2006). 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.

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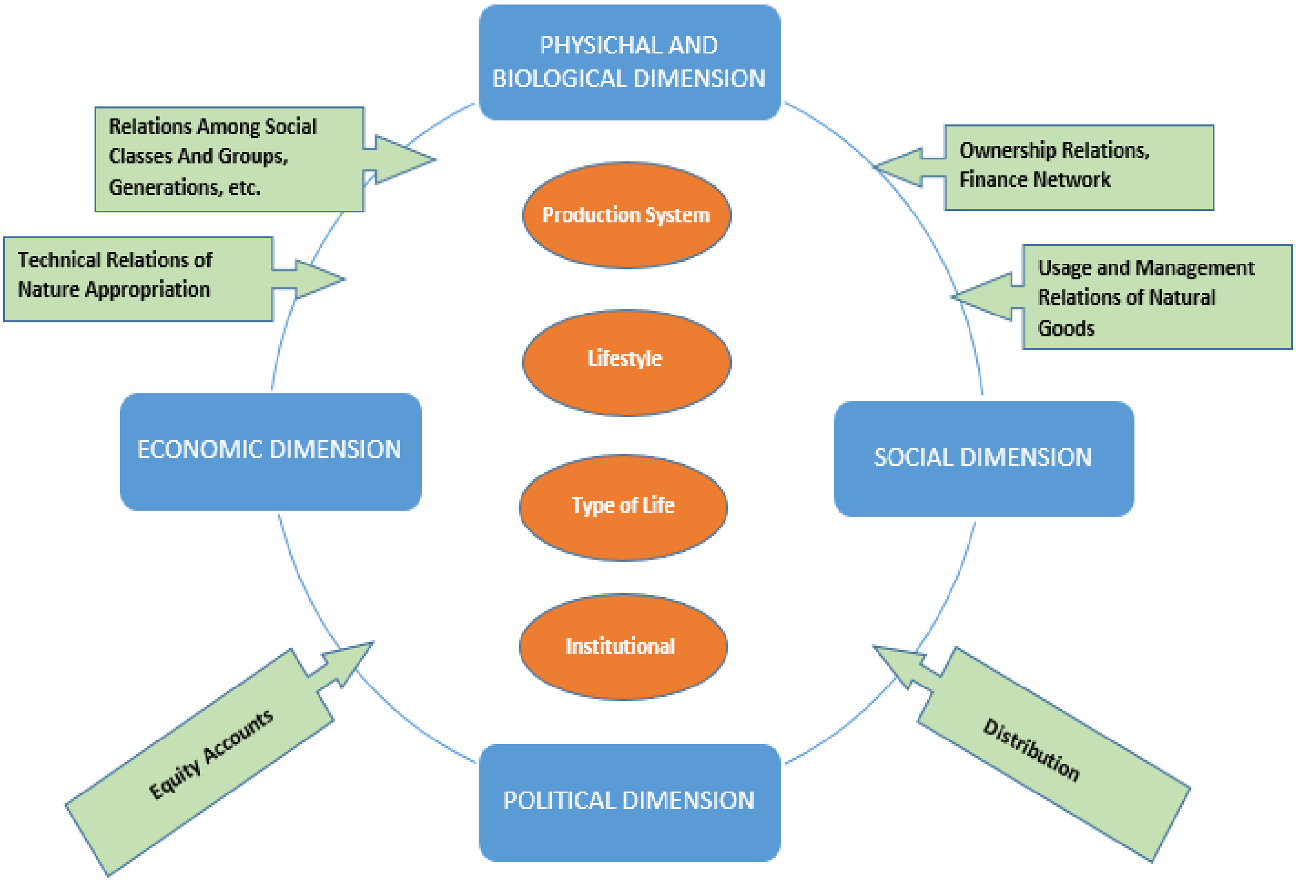
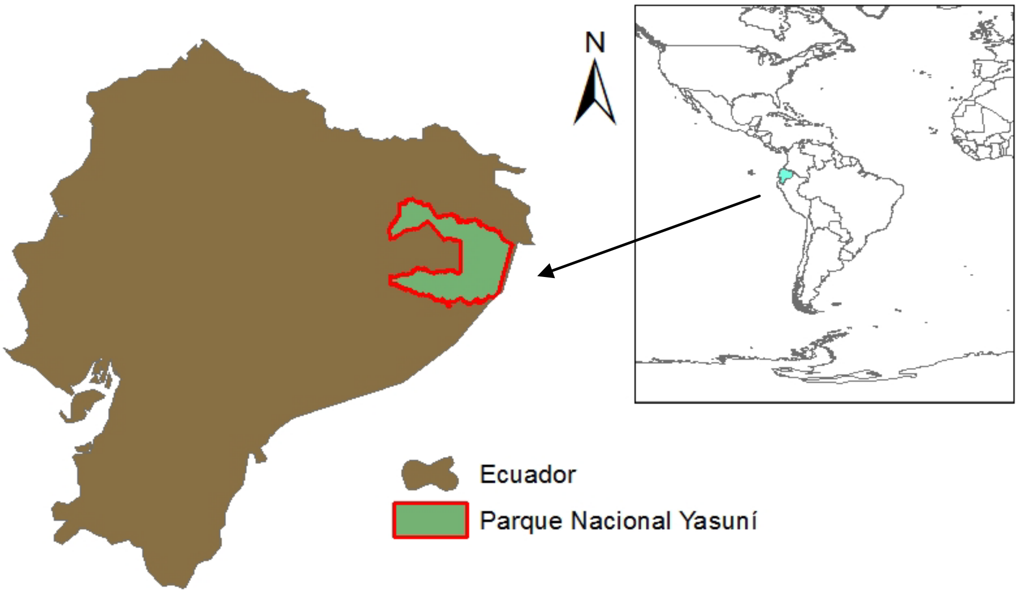
Figure caption:

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



Source: Compiled by author from criteria set out by Achkar, 1999.

Fig. 2. Yasuní National Park location map.



Source: Compiled by author

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

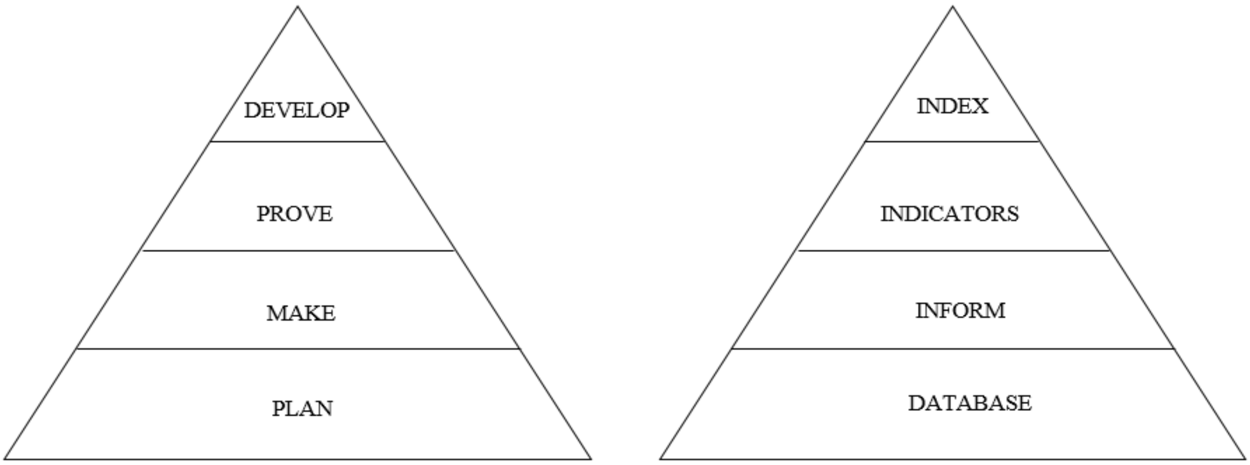


Table Caption:

Table 1. Thematic areas and number of indicators analyzed.

	Nº 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. Governance. Resources. Materials. Administrative. economic Implementation of quality strategies **ZONES OF PUBLIC USE** Equipment 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 Protected Natural Space Cultural resources. Sanitation and education equipment	
3. 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 Business activity **POLITICS AND PROJECTS** Policy convergence / development. Projects, inversion	

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

APPENDIX

Environmental System

- 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
- Groundwater pressure
- Contaminated water
- Sensitive areas
- State of surface and groundwater
- Contaminated aquifers
- Annual CO_2 emissions by Industry
- Total methane emissions by sector
- N_2 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.
- Governance. Composition participation bodies
- Implementation of quality strategies
- Equipment
- Signposting
- Communication and Participation
- Visitors. Loading capacity

Social System

- 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. Livestock trails
- Telecommunications. Internet connection.
- Participation. Policy. Social
- Human Resources. Workers in Protected Natural Spaces
- Cultural resources.
- Sanitation and education equipment

Economic System

- 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
- Business society
- Convergence policy / development.
- Project investment.
- Convergence and development policies