Resilience indicators as instruments of management of protected spaces

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Abstract:

Environmental sensitivity is increasingly a socio environmental sensitivity. So sustainability has begun to be reformulated from the Nature Sciences through the concept of socio-ecological resilience, claiming a transdisciplinary that is capable of operationally articulate the natural and cultural dimensions of the environment.
Along these lines, we suggest a set of Resilience Indicators (RI) with the aim of fully evaluating pressure conditions within protected spaces. In order to work out the RI, it will be necessary to describe, primarily, the systemic characterization of the space set out to be analysed. This task is to facilitate later identification of the core variables of analysis, which will compose the bottom line for the formulation of the indicators intended to assess and monitor the resilience of protected spaces over time. The main goal in ecosystem conservation and management could be summarized as the preservation of ecosystem integrity in relation to human needs. Conservation is mainly based upon ecological stability and its relation to disruptions of human origin. This stability comprises two core components: resistance and resilience.

Key-Words: Environment, Protected Spaces, Resilience Indicators, Sustainability,

1 Introduction

1.1. 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". 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).

1.2. Background

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).

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. Resilience indicators as instruments of management of protected spaces (Spain)

Resilience indicators are mechanisms that make it possible to articulate sustainability objectives. Their relevance lies in the fact that, both sectorally and integrally, they are formulated in a unique, socially unrepeatable context, both in terms of administration and territory. According to the approach, information selected and the relation established among variants to be assessed, we will obtain certain key points that should indicate ideal interpretation of local management-driven sustainability. Indicators can be defined as variants full of specific scientific meanings, which synthetically mirror a social concern as to the environment which may be coherently incorporated into the decision-making process (Rueda, 1999). The concept of indicator derives from Latin *indicare*, which means, "to reveal", "to signal". Moreover, as regards sustainability, it is the parameter that provides information about the relationship: society-nature. Identification of central variants, interactions, cause-effect relations, vulnerability conditions, and management provisions are all relevant aspects for the construction of resilience indicators, as shown in Table 1.

5. Discussion

The environmental crisis in many developed countries has strongly highlighted the role played by protected spaces. Concurrently, awareness and knowledge of the countless beneficial effects of protected 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 protected spaces directly provide (García & 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.

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

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

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.

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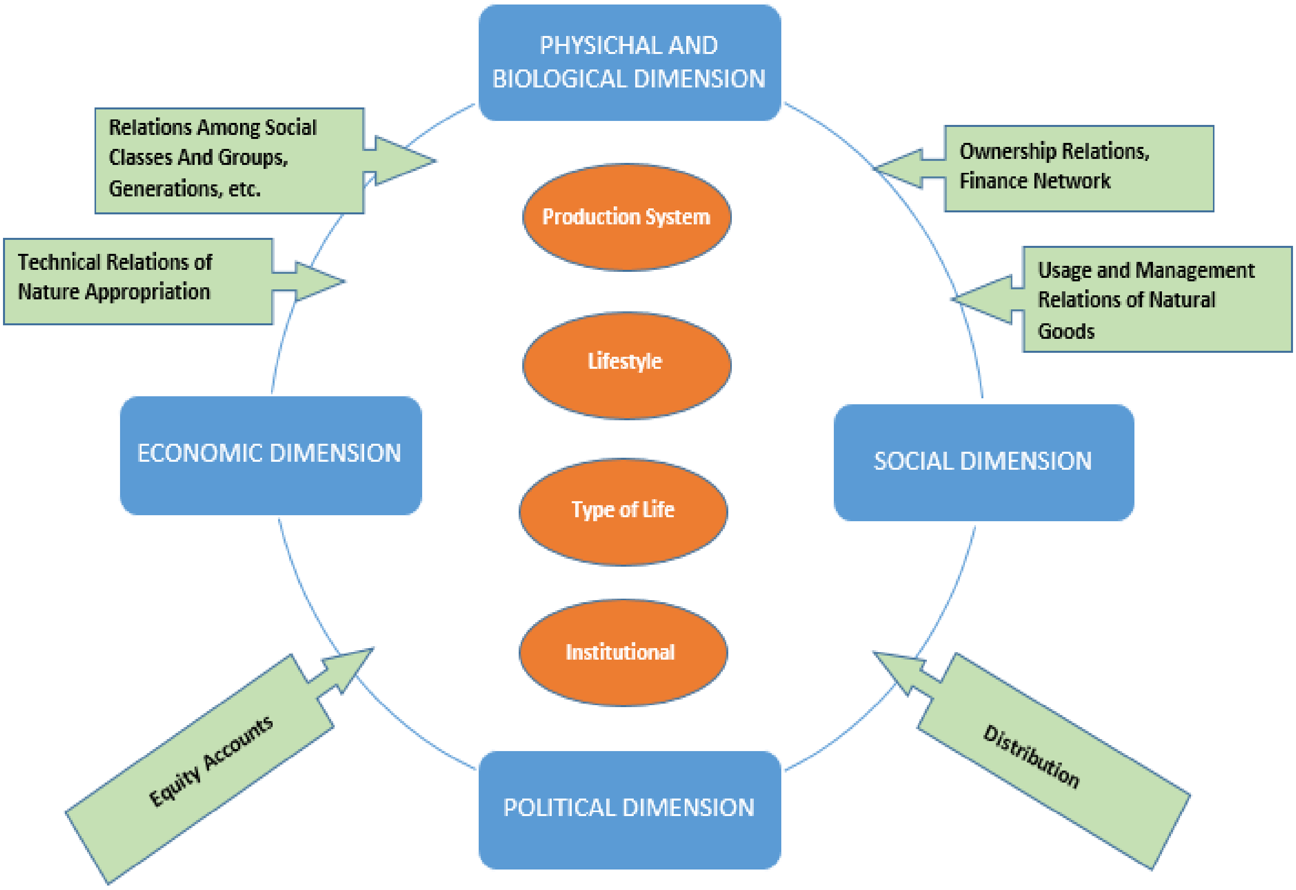
Figure caption:

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



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

Table caption:

Table1: Showing 15 indicators grouped into six categories or criteria. Author-compiled indicators from criteria set out by Allen (2006)

Criteria	Indicators
A) Reference indicators	1) Foliage-covered ground 2) Sustainable human load
B) Holistic indicators	3) Ecologic functions 4) Equity index
C) Cause-effect indicators	5) Environmental impacts 6) Social impacts 7) Economic impacts 8) Residents' satisfaction 9) Visitors' satisfaction
D) Projective indicators	10) Touristic market trend 11) Projection of administrations' investment in natural spaces.
E) Hazard and uncertainty indicators	12) Natural vulnerability 13) Patrimonial vulnerability 14) Social vulnerability
F) Management control indicators	15) Full management of natural spaces

Source: Author-compiled indicators from criteria set out by Allen (2006)