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A concept of a degraded ecosystem in theory and practice – a review

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A concept of a degraded ecosystem in theory and practice – a review

1. The purpose and the scope of the review

The decisions adopted by the 10th meeting of the Conference of the Parties to the Convention on Biological Diversity, held in Nagoya, Japan, on 18–29 October 2010, include, *inter alia*, a key policy document of high importance not only for the CBD – the Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets (UNEP 2010). Among the latters, the Target No. 15 says that "By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification."

In line with the global decision, the EU Biodiversity strategy 2020 includes a target 2 defined as "By 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15 % of degraded ecosystems" (EC 2011).

Therefore, the review aims at presenting various current approaches trying to define "a degraded ecosystem". It covers not only scientific literature, but science-policy interface and policy documents were also reviewed.

2. Degraded ecosystems

In environmental science as well as in environmental protection and management, environmental degradation is one of the key wordings highlighting particularly disturbance caused by humans on natural, semi-natural or artificial ecosystems. The impact is perceived generally on the environment. Thus, ecosystem degradation is used less often in this field, often substituted by land degradation. From main ecosystem types, there have been attempts to define forest and wetland degradation.

2.1. Environmental degradation

The terms degradation, damage, destruction and transformation all represent deviations from the normal or desired state of an intact ecosystem. The meanings of these terms overlap, and their application is not always clear. **Degradation** pertains to subtle or gradual changes that reduce ecological integrity and health. **Damage** refers to acute and obvious changes in an ecosystem. An ecosystem is **destroyed** when degradation or damage removes all macroscopic life, and commonly ruins the physical environment as well. **Transformation** is the conversion of an ecosystem to a different kind of ecosystem or land use type (CLEWELL *et al.* 2004). When applying the above definitions, the Aichi Target No. 15 deals with both degraded and damaged ecosystems.

Different ecosystems, as well as different values placed on environmental resources by different societies make the definition of **environmental degradation** difficult and complex.

Generally, environmental degradation is a process when humans have exceeded a resource´s natural replacement rate and the available supply has begun to shrink (MILLER & SPOOLMAN 2011). When an ecosystem is under attack as a result of natural or man-made disturbance it is extremely difficult to calculate the ripple effects throughout nature. When two or more ecosystems are being degraded the probabilities of synergistic destructiveness multiply. In other words, environmental degradation is the deterioration of the environment through depletion of resources such as air, water and soil, the destruction of ecosystems and the extinction of wildlife. It is defined as any change or disturbance to the environment perceived to be deleterious or undesirable (CHOUDHURY & JANSEN 1999).

According to another definition, environmental degradation is depletion or destruction of a potentially renewable resource such as air, water, or wildlife, by using it at a rate faster than it can be naturally renewed (PARK 2007).

2.2. Land degradation

Environmental degradation is sometimes expressed through **land degradation** which is the reduction in the value, health, and productivity of land. Generally, degraded land is a land which due to natural processes or human activity is no longer able to sustain properly an economic function and/or the original natural ecological function (CHOUDHURY & JANSEN *l.c.*).

The best known definition of land degradation is that used by the United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, particularly in Africa (UNCCD). Land degradation means reduction or loss of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as:

i. soil erosion caused by wind and/or water;
ii. deterioration of the physical, chemical and biological or economic properties of soil;
iii. long-term loss of natural vegetation (UNITED NATIONS 1994).

From a point of view of soil biology and pedology, land degradation is general lowering of land surfaces by erosion (PARK *l.c.*).

2.3. Ecosystem degradation

Generally, **ecosystem degradation** is any process or activity that removes or lessens the viability of ecosystem processes and hence biodiversity (DUNSTER & DUNSTER 1996).

Traditional approach to ecosystem degradation combines land degradation and some changes in the particular non-physical patterns within an ecosystem. Ecosystem degradation is all human interventions in nature which diminish the 'development space' for nature through land use, the development potential of nature is seen as one of its most vital characteristics, giving nature its 'wildness' and richness, applying land-use changes (DE GROOT 1992).

Therefore, proposed set of indicators for quantification of ecosystem degradation may include:

i. Gross Primary Production (GPP).
ii. Net Primary Production (NPP).
iii. Net Community Production (NCP).
iv. Biomass state.
v. Biological diversity.
vi. Top soil erosion.
vii. Top soil state.
viii. Energy/substance balance.
ix. Authenticity relaxation time.
x. Rareness.
xi. Landscape perception (BLONK *et al.* 1997).

Some approaches relate ecosystem degradation closely to another recently popular concept - ecosystem services. Regarding this, ecosystem degradation is a persistent reduction in its capacity to provide ecosystems services. The degradation of an ecosystem service is:

a) For provisioning services, a decreased production of the service through changes in area over which the service is provided or decreased production per unit area.
b) For regulating and supporting services, a reduction in the benefits obtained from the service, either through a change in the service or through human pressures on the service exceeding its limits.
c) For cultural services, a change in the ecosystem features that decreases the cultural benefits provided by the ecosystem (MA 2004).

Degradation of the particular ecosystem should be evaluated by ecosystem characteristics to be restored:

2. Composition: species present and their relative abundances.
3. Structure: vertical arrangement of vegetation and soil components (living or dead).
4. Pattern: horizontal arrangement of system components.
5. Heterogeneity: a complex variable made up of components 1-3.
6. Function: performance of basic ecological processes (*i.e.*, energy, water, nutrient transfers).
7. Species interactions: pollination, seed dispersal, *etc.*
8. Dynamics and resilience: succession and state-transition processes, recovery from disturbance (HOBBS 2009).

2.3.1. Forest degradation

Since 2002, there have been efforts to define **forest degradation** as a part of broader process seeking for harmonization of internationally applicable definitions related to forests to facilitate monitoring and reporting on progress towards the achievement of the global objectives on forests and sustainable forest management. Harmonization in this context does not mean standardization, i.e. the purpose is not necessarily to achieve common definitions but to improve consistency, compatibility and comparability among the existing ones (FAO 2002).

Degradation is a change process within the forest which negatively affects the characteristics of the forest. The combination of various forest characteristics (*forest quality*) can be expressed as the structure or function, which determines the capacity to supply forest products and/or services (FAO 2001). Taking place within the forest, degradation is different from deforestation which denotes change process from *forest* to *non-forest*. According the classification used by the FAO Global Forest Resources Assessment, *non-forest* can be *other wooded land* or *other land* (SIMULA 2009). The Convention on Biological Diversity's Inter-Sessional (Second) Meeting of the Ad Hoc Technical Expert Group on the Review of Implementation of the Programme of Work on Forest Biological Diversity in 2005 stated that (forest) degradation is a loss process covering a combination of several environmental components (soil fertility and compaction, forest cover, natural function, salinization) and qualifying it to impeding or retarding natural recovery (*unassisted forest recovery through secondary succession* – UNEP 2005).

2.3.2. Wetland degradation

Attempts to define wetland degradation have been carried particularly by the Wetlands International for the Convention on Wetlands of International Importance, especially as Waterfowl Habitat (Ramsar Convention). They distinguish between *wetland loss* and *wetland degradation.* Wetland degradation is the impairment of wetland functions as a result of human activity. In practice, wetland loss is rarely independent of wetland degradation, since loss of part of a wetland is likely to impair the functions of the remaining wetland area. Conversely, wetland degradation frequently occurs without the loss of wetland area, through upstream impacts on hydrology and water quality, *etc.* Thus, both wetland loss and degradation relate to the change in quantity and/or quality of the wetland resource around a baseline (MOSER *et al.* 1996).

3. Threatened ecosystem

The potential for conservation of individual species has been greatly advanced by the International Union for Conservation of Nature's (IUCN) development of objective, repeatable, and transparent criteria for assessing extinction risk that explicitly separate risk assessment from priority setting. At the IV World Conservation Congress in 2008, the process began to develop and implement comparable global standards for ecosystems. A working group established by the IUCN has begun formulating a system of quantitative categories and criteria, analogous to those used for species, for assigning levels of threat to ecosystems at local, regional, and global levels.

A final system will require definitions of ecosystems; quantification of ecosystem status; identification of the stages of degradation and loss of ecosystems; proxy measures of risk (criteria); classification thresholds for these criteria; and standardized methods for performing assessments. The system will need to reflect the degree and rate of change in an ecosystem's extent, composition, structure, and function, and have its conceptual roots in ecological theory and empirical research.

On the basis of these requirements and the hypothesis that ecosystem risk is a function of the risk of its component species, the IUCN proposes a set of four criteria:

(i) Recent declines in distribution or ecological function.
(ii) Historical total loss in distribution or ecological function

(iii) Small distribution combined with decline
(iv) Very small distribution.

Most work has focused on terrestrial ecosystems, but comparable thresholds and criteria for freshwater and marine ecosystems are also needed. These are the first steps in an international consultation process that will lead to a unified proposal to be presented at the next World Conservation Congress to be held in Jeju, South Korea, on 6-15 September 2012 (RODRÍGUES *et al.* 2011).

4. Ecosystem/ecological integrity

The other approach how to define a degraded ecosystem is to determine whether the particular ecosystem is in the good condition or in the favourable status. For that purpose, both the ecosystem integrity and ecosystem health concepts have been proposed particularly by U.S. scientists.

Ecosystem integrity refers to a ecosystem's wholeness, including presence of all appropriate elements and occurrence of all processes at appropriate rates (PIMENTEL *et al.* 2000). Whereas diversity is a collective property of system elements, integrity is a synthetic property of the system. Unlike diversity, which can be expressed simply as the number of kinds of items, integrity refers to conditions under little or no influence from human actions; a biota with high integrity reflects natural evolutionary and biogeographic processes (ANGERMEIER & KARR 1994).

Similarly to the above recent concept of ecosystem degradation, ecosystem/ecological integrity is assumed as the ability of an ecosystem to function healthily, continue to provide ecosystem services, and maintain biological diversity (PARK *l.c*).

The U.S. National Park Service suggests that ecological integrity is a concept that expresses the degree to which the physical, chemical, and biological components (including composition, structure, and process) of an ecosystem and their relationships are present, functioning, and capable of self-renewal. Ecological integrity implies the presence of appropriate species, populations and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa and processes (NPS 2011).

The main difficulty closely related to the ecosystem integrity concept is an issue of baseline indicating natural ecosystem incl. its viable biota. American scientists developed the multimetric Index of Biological Integrity (IBI, KARR 1981, KARR & DUDLEY 1981). They define ecological integrity as the sum of physical, chemical, and biological integrity. Biological integrity, in turn, is the capacity to support and maintain a balanced, integrated, adaptive biological system having full range of elements (genes, species, and communities/assemblages) and processes (mutation, demography, biotic interactions, nutrient and energy dynamics, and meta-population processes) expected in the natural habitat of a region (KARR & CHU 1999). Scientists can measure the extent to which a biota deviates from integrity by employing an IBI that is calibrated from a baseline condition found "at site with a biota that is the product of evolutionary and biogeographic processes in the relative absence of the effects of modern human activity, in other words, wild nature. Degradation or loss of

integrity is thus any human-induced positive or negative divergence from this baseline for a variety of biological attributes (KARR 1996).

5. Ecosystem health

Furthermore, the ecosystem integrity approach has been more elaborated into the concept of **ecosystem health**.

Ecosystem health is a trans-disciplinary concept developed particularly in the U.S., that bridges the natural, social, and health sciences. It can incorporate the human values and perceptions that are inseparable parts of management.

Ecosystem health, especially in the 1970s and 1980s, was often defined in nebulous terms — definitely not as clearly articulated constructs (LACKEY 2003). Nowadays, a healthy ecosystem is defined as a social-ecological unit that is stable and sustainable, maintaining its characteristic composition, organization, and function over time while remaining economically viable and sustaining human communities (RAPPORT *et al.* 1998, RAFFAELI & FRID 2009). In other words, healthy ecosystem is one that is sustainable – that is, it has the ability to maintain its structure (organization, *i.e.* particularly biological diversity) and function (vigour, *i.e.* productivity) over time in the face of external stress (resilience in the U.S. approach, resistance and resilience used more by European ecological schools, *i.e.* ability to resist or recover from stress), in terms of both biophysical functions and socioeconomic aspects. Vigour or productivity refers to the capacity of the ecosystem to sustain the growth and reproduction of both plants and animals. Organization refers to the capacity of the ecosystem to support a diversity of life forms and their interactions. Resilience is the capacity of the ecosystem to buffer perturbations: *i.e.*, the capacity to rebound after disturbances such as fire, flood, windstorms, *etc.* (COSTANZA & MAGEAU 1999, RAPPORT *et al.* 2001).

Therefore, a healthy ecosystem is defined as being stable and sustainable, maintaining its organization and autonomy over time and its resilience to stress (HASKELL *et al.* 1992). Similarly to ecosystem degradation, the most recent definition employs ecosystem services: A healthy ecosystem sustainably delivers a range of benefits to people now and in the future (LEVIN 2011).

COSTANZA (1992) summarizes the concept of ecosystem health as:

1. Homeostasis.
2. Absence of disease.
3. Diversity or complexity.
4. Stability or resilience.
5. Vigor or scope for growth.
6. Balance between system components.

Various methods to quantify the three ecosystem attributes (structure, function and resilience) have been proposed. In addition to indicators of regime shifts in ecosystems (CONTAMIN & ELLISON 2009), a comprehensive set of ecosystem health indicators has been recently proposed:

Level 1. Presence or absence of specific species.

1. Bellan's Pollution Index.
2. Pollution Index Based on Amphipods.
3. AZTI Marine Biotic Index.
4. Bentix.
5. Macrofauna monitoring index.
6. Benthic response index.
7. Conservation Index.

Level 2. Ecological strategies

1. Index of r/K strategists.
2. Nematodes/Copepodes Index.
3. Polychaetas/Amphipods Index.
4. Infaunal Index.
5. Feldman index.

Level 3. Ratio between classes of organisms.

1. Nygard's algal index.
2. Diatoms/nondiatoms ratio.

Level 4. Concentrations of chemical compounds (*e.g.*, total phosphorus concentration).

Level 5. Concentrations of entire trophic levels (*e.g.*, concentration of phytoplankton as indicator for the eutrophication of lakes).

Level 6. Process rates (primary production determinations as indicators for eutrophication; a high annual growth of trees in a forest as an indicator for a healthy forest ecosystem; high mortality in a population as an indicator of unhealthy environment).

Level 7. Composite indicators (biomass, respiration/biomass, respiration/production, production/biomass, primary producers/consumers).

Level 8. Holistic indicators.

1. Vigour, organization, and resilience (V-O-R model).
2. Buffer capacity.
3. Diversity indexes (Shannon–Wiener index, Pielou Evenness Index, Margalef Index, Berger-Parker Index, *etc.*).
4. Size and connectivity of the ecological network.
5. Turnover rate of carbon/nitrogen.

Level 9. Thermodynamic variables (exergy, energy, exergy destruction, entropy production, power, mass and energy system retention time (JORGENSEN *et al. l.c.*).

The breadth of these definitions indicates that ecosystem health is an integrative notion that acknowledges societal values in defining future desired conditions while relying on scientific criteria (STEEDMAN 1994). Because the concept of ecosystem health can involve inherent value judgments about what actions are socially desirable, its definition and use require public involvement (LACKEY 2001).

As an integrative notion, ecosystem health is not meant to rely solely on its scientific basis, in the hypothetico-deductive sense, nor does it pretend to give predictive descriptions of causal mechanisms of the complex behaviour of social-ecological systems; instead, it provides for case-bycase evaluations in real-world settings with stakeholder input. Viewed in this light, ecosystem health furnishes a theoretical framework and practical methods for monitoring and assessing the condition and quality of ecosystems. Because most people have an intuitive idea of what constitutes health, the term facilitates understanding among citizens, managers, and scientists when formulating management decisions (RAPPORT 1998, JORGENSEN *et al.* 2010, KHAMNUEVA & PANKAJ 2011).

6. Conclusions

Although environmental/ecosystem degradation has been one of the most often used subjects in environmental protection and nature conservation and management, a precise definition has been lacking both in science and policy. Degraded ecosystem has been understood and consequently recognized more intuitively than based on the well-developed criteria applied during ecosystem assessment. Land degradation is commonly based on physical changes within the land: some indicators to quantify this type of degradation have been also developed. There are some attempts to define degradation in some ecosystem types, *e.g.* arid and semi-arid (UNCCD), forest (FAO, CBD) and wetland (Ramsar Convention) ecosystems. The International Union for Conservation of Nature (IUCN) has been developing the criteria and categories to be used for the Red List of Threatened Ecosystems to be applied at various spatial and time scales.

The other approach is to define a healthy ecosystem: a degraded ecosystem should be unhealthy one. Particularly American scientists have been dealing with the concept of health ecosystem, ecosystem/ecological integrity respectively. For assessing whether the particular ecosystem is healthy or not, *i.e.* whether it is degraded, a comprehensive set of indicators was proposed: at this moment. Moreover, some of the indicators are too complicated and technical for everyday practice. Nevertheless, similarly to the attempts to define a degraded ecosystem, the efforts to shift both the concepts which are based on metaphor to the way when they can be applied in conservation practice have been facing serious problems.

Therefore, the degraded ecosystem, healthy ecosystems respectively concepts should be further elaborated.

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