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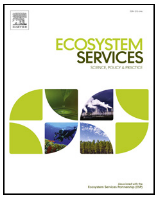

Short Communication

Ecosystem services and ecosystem degradation: Environmentalist's expectation?

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ABSTRACT

In this article, we explore the connections between ecosystem degradation and ecosystem services. We discuss an operational definition of ecosystem degradation and applied it to the terrestrial ecosystem of Chiloé Island (southern Chile). Results show that provisioning services correlated positively with degradation (the environmentalist's paradox) while regulating and maintenance services showed the opposite trend (the environmentalist's expectation). We propose, given these contextual results, that there is more than one type of relationship between degradation and services and that this field of study could learn more from local, context-oriented studies, than large-scale analyses.

1. Introduction

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2020) defines *ecosystem degradation* as: "*A long-term reduction in an ecosystem's structure, functionality, or capacity to provide benefits to people*". If we use this concept in the study of ecosystem services (EESS); that is, *the benefits people get from ecosystems* (IPBES, 2020); then degradation becomes a tautology since it already implies a reduction of services. Some articles invoke this decline in EESS due to degradation (e.g. Kindu et al., 2016; Owethu Pantshwa and Buscke, 2019), and it is captured in "The environmentalist's expectation" by Raudsepp-Hearne et al., (2010). Yet, other authors propose alternative views (Hobbs et al. 2006) or even paradoxes (Raudsepp-Hearne et al., 2010). If we use the contingency ecosystem perspective proposed by Schmitz (2010), then the relationship between ecosystem degradation and EESS may be contextual without a general rule. But its analysis requires conducting research based on the null hypothesis that both are independent variables. In this article, we propose an operational definition of ecosystem degradation that may be used to analyze its relationships with EESS. We then show an empirical study for Chiloé Island terrestrial ecosystem, in the southern Chilean coast (South America).

2. An operational definition of ecosystem degradation

A literature search for definitions of ecosystem degradation, using the Web of Science[1], showed only one article (Veldman, 2016) where the author proposes the use of contextual degradation frameworks based on human-induced changes. Many other articles use the term in diverse contexts (ecosystem, chronic, environmental) but without a definition. An ecosystem may be considered degraded, with a high degree of anthropization in the sense of Lai et al. (2017), if its structure and functioning changed due to human activities (e.g. agriculture, forestry, coastal ocean farming). The degraded ecosystem may still provide services (e.g Hobbs et al., 2006; Lennox and Gowdy, 2014), or the severity of the degradations may change it to "unused and degraded land" (Kollert, 2017). The basic idea is that only human modifications produce ecosystem degradation. Natural phenomena (e.g. earthquakes transforming land ecosystems into wetlands; Delgado et al., 2009) may change the ecosystem's structures and functions but should not be considered degradation.

A non-degraded ecosystem, based on the ideas discussed by Buckley et al. (2016: page 1) about pristine protected areas, "*is one without any human modification* ", which today are almost non-existent. So, most earth ecosystems are in a range of pristineness conditions from low anthropization to unused and degraded land. If degradation is one of the research targets, it requires measuring pristineness (Buckley et al., 2016). Sanderson et al. (2002) proposed a proxy that can be used to study degradation under the name of "Human Influence Index" (HII); a composite 8-variable index reflecting the effects of humans on nature. Higher HII values would correspond to higher degradation and vice versa. Since the index does not include EESS, it can be used as

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[1] http://apps.webofknowledge.com/ search date: May 12th, 2020.

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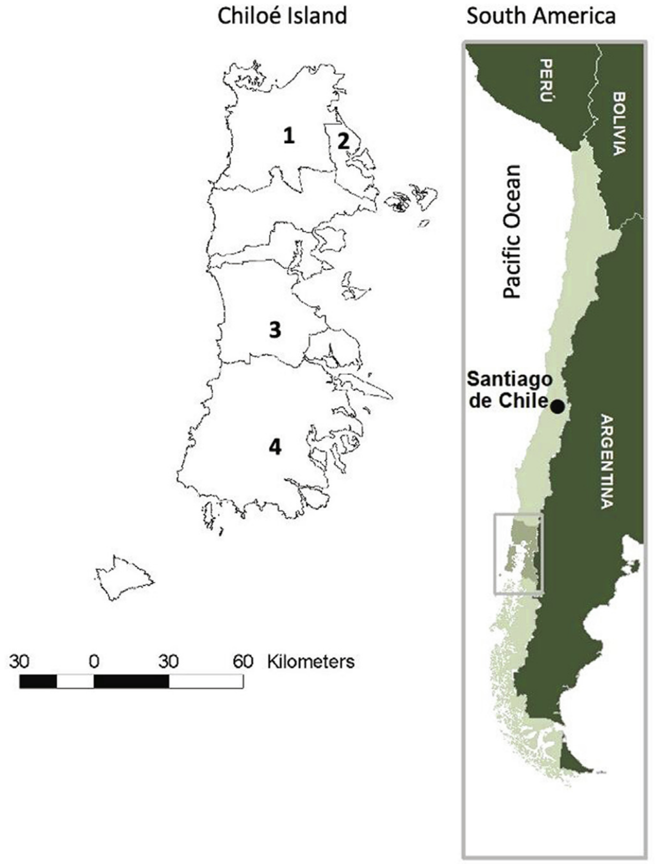

Fig. 1. Geographic location of the study area in the Pacific coast of South America. 1 = Ancud, 2 = Quemchi, 3 = Chonchi, 4 = Quellón.

independent variable.

3. Materials and methods

We studied the relationship between degradation and EESS for the terrestrial ecosystem of Chiloé Island; an 8.39×10^3 km^2 insular space located in southern Chile (South America), with rural areas comprising 99% of its surface (Fig. 1). The island is divided into 7 communes with a North-South increasing gradient of native forest coverage (from 48% to 84%; CONAF/UACH, 2014). We obtained published data to calculate a modified version of the HII (see below) of four communes; two in the north (Ancud and Quemchi), one in the center of the island (Chonchi), and one in the south (Quellón).

We modified the HII proposed by the Wildlife Conservation Society and Center for International Earth Science Information Network Columbia University (2005), from here on WCS-CIES-2005. The original index has 8 components, but five of them did not apply to our study site (railroads, major roads, navigable rivers, coastlines, and nighttime stable lights). We calculated the modified HII (HII_{mod}), for each commune, based on the following equation:

$$HII_{mod} = \text{Pop.density} + \text{Urban}(\%) * Sc_2 + \text{agr} - \text{for}(\%) * Sc_3$$

Where,

Pop. density = influence scores of the human population per unit area (1/km^2) extracted from WCS-CIES-2005, using population data for each commune from the 2017 Chilean population census (INE, 2017).

Urban (%) = percentage of the commune corresponding to urban areas, extracted from CONAF/UACH (2014) dataset.

Sc_2 = influence score for urban areas extracted from WCS-CIES-2005.

agr-for (%) = percentage of the commune covered by agricultural or forestry areas, extracted from CONAF/UACH (2014).

Sc_3 = average influence score for agricultural-forestry areas, the used value (6) was modified from WCS-CIES-2005.

We did not consider the percentage of each commune covered by native forests since its score, as proposed by WCS-CIES-2005, is zero. But we show the information, extracted from CONAF/UACH (2014), for comparative purposes.

We obtained information on provisioning and regulation & maintenance EESS through a household survey during January 2019. The survey had a similar structure to those used for other Chilean rural ecosystems (Delgado and Marín, 2016), allowing inter-ecosystem's comparisons. The questions were oriented to gather the necessary data to calculate Delgado and Marín (2016) Provisioning Services Index (*PSI*) and the Regulation & Maintenance Index (*RSI*), based on key services used by people living in rural areas of southern Chile (Delgado et al., 2013):

$PSI = Wood + Water$

where, *Wood* = fraction of households obtaining native wood from their property, and *Water* = fraction of households obtaining water from sources other than the private (paid) service.

$RSI = Cattle + (Agriculture * Fertility) + Sewage$

where, *Cattle* = fraction of households raising cattle in their property, *Agriculture* = fraction of households developing subsistence agriculture, *Fertility* = fraction of households not adding fertilizers, and *Sewage* = fraction of housing not using the public (paid) sewage system.

The survey universe was the number of rural households in each commune (average = 3141; St. Dev = 769). The sample size (average = 58; St. dev = 5) provided results with 95% confidence and ± 13% error; all participants signed informed consents. We used the Statistical Package for Social Sciences (SPSS version 26) to code and analyze survey responses.

4. Results

The modified Human Influence Index (HII_{mod}) showed a North-South decreasing trend (Table 1), with its largest value at Ancud (25.78) and its smallest value at Quellón (10.24). Values were negatively correlated with the percentage of native forest coverage in each commune (Pearson r = -0.89, $p < 0.05$). The distribution of EESS indices showed two different trends (Table 2; Fig. 2). *RSI* values increase southward, showing a quasi-significant correlation (Pearson $r = -0.76$, $p < 0.1$) with HII_{mod}, while *PSI* values decrease southward, positively correlated with HII_{mod} (Pearson r = 0.85, $p < 0.05$).

So, human influence decreases from North to South, with an associated increase in regulation & maintenance services. But provisioning services are higher in the more degraded communes. If we use the average values for *RSI* ($\langle RSI \rangle = 1.27$) and *PSI* ($\langle PSI \rangle$ = 1,27) from Chiloé (population density = 11.7 people km^{-2}), they lay between those published by Delgado and Marín (2016) for an ecosystem with low anthropization (Aysén; ($\langle RSI \rangle = 2.16$; $\langle PSI \rangle$ = 1,58; population density = 0.8 people km^{-2}) and a degraded ecosystem (Cruces; $\langle RSI \rangle = 1.07$; $\langle PSI \rangle = 0.96$; population density = 20.9 people km^{-2}). This calculation shows that the relationship between degradation and EESS

Table 1
Results of the calculation of the modified Human Influence Index (HII_{mod}) and the percentage of native forest coverage for four communes of Chiloé Island. The first three columns are the computed scores of the HII_{mod} components as described in eq. 1.

Commune	Pop. density	Urban	Agr-for	HII_{mod}	Native forest (%)
Ancud	10	3.90	11.88	25.78	53.42
Quemchi	10	3.10	10.56	23.66	43.22
Chonchi	10	3.10	0.90	14.00	63.95
Quellón	7	3.00	0.24	10.24	84.07

Table 2
Ecosystem services indices (*RSI* and *PSI*) for four communes of Chiloé. See text for indices calculations.

Commune	*RSI*	*PSI*
Ancud	1.09	1.36
Quemchi	1.23	1.27
Chonchi	1.24	1.22
Quellón	1.26	1.23

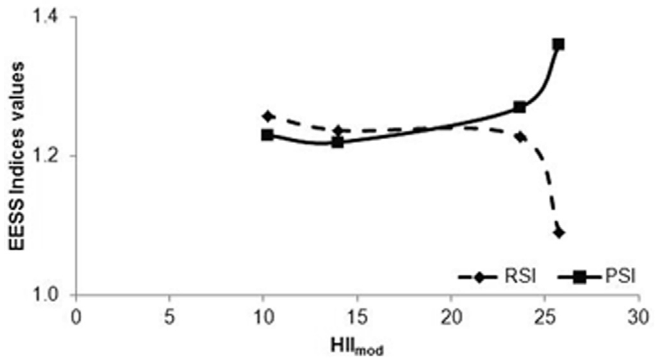

Fig. 2. Relationships between the modified Human Influence Index (HII_{mod}) and EESS indices.

may change if evaluated within an ecosystem (intra-ecosystem analysis) or between ecosystems (inter-ecosystem analysis). In this latter case, both types of EESS agreed with "the environmentalist's expectation".

5. Discussion

We have shown, using an operational definition for ecosystem degradation, estimated through a modified version of Sanderson et al. (2002) "Human Influence Index" (HII_{mod}) as a proxy, that it is possible to study the relationships between degradation (as an independent variable) and EESS (Fig. 2). In our case study, results show that both provisioning and regulation services, when analyzed between rural ecosystems, and regulation services when analyzed within the Chiloé Island terrestrial ecosystem, follow "the environmentalist's expectation". But provisioning services within the Chiloé ecosystem followed "the environmentalist's paradox" (Raudsepp-Hearne et al., 2010). What explanation can be offered for such a paradox? We can only offer a working hypothesis, given the small number of analyzed services and the limited geographic extension of the area, based on hypothesis 4 (time lag) of Raudsepp-Hearne et al. (2010) and the "limitless resource perception" discussed by Delgado et al. (2013). Chiloé is well known for its traditions, which are the basis of the big tourism industry on the island. This is especially important in northern areas (e.g. Ancud) which are close to the continent (Barton and Román, 2016). One of these traditions is the use of native firewood. For example, 95.5% of the interviewees stated they use firewood and 25% commented that "firewood is never missing". Thus, provisioning services (wood and water) are used as limitless resources, even in degraded areas such as Ancud. Hypothesis 4 from Raudsell-Hearne et al. (2010) proposes that we have yet to see the consequences of declines in ecosystem services. We suggest that provisioning EESS are heavily used in degraded rural areas because people living in them have a limitless resource perception, but eventually, the ecosystem could reach its production limit and provisioning services will start decreasing.

So, the relationships between ecosystem degradation and EESS seem to be contextual, and they will, at least, depend upon the analyzed service, the type of analysis (intra-systemic versus inter-systemic), and the analyzed environment, which in our case study corresponded to a rural area in southern Chile where human well-being depends on ecosystem services (Delgado and Marín, 2016). Also, the elements used here to calculate HII_{mod} not necessarily will apply to other study areas. For example, as explained in materials and methods (section 3.), we eliminated five elements from the original HII because they do not apply to Chiloé Island, but it may not necessarily be the case for other areas. Future studies of degradation and EESS, given this contextual relationship, will have to adjust both the services indices (*RSI* and *PSI*) to key services for each study area and the elements of the HII. This condition may generate problems when conducting large-scale studies. We could learn more about ecosystem degradation and its effects on ecosystem services conducting local, context-oriented studies of ecosystems worldwide. In summary, our main conclusion is that the proposed operational definition and the use of the HII_{mod} as a proxy variable, allow evaluating the many possible relationships between degradation and EESS, instead of assuming by definition the environmentalist's expectation as it would be the case if we use the degradation concept from the IPBES (2020).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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