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Soil Macroinvertebrate Communities as Indicators of Ecosystem Services in American Tropical Environments

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Abstract

Soil macroinvertebrate communities comprise 16 commonly found orders with a vast range of functions and adaptive strategies. They are highly sensitive to chemical, physical and biological conditions found in the different strata of the soil system, from surface litter and humus system to organic horizons down to ca. 30cm depth. This review synthesizes studies realized at 4 different American tropical sites with identical methodologies. They evaluated the value of the components of this community as indicators of range (high, medium, low) values of a set of soil biodiversity, chemical, physical quality and macro aggregation synthetic indicators, proxies of soil-based ecosystem services. In all 4 situations studied, we found taxa that were significant indicators of all 4 soil quality sub indicators considered, with only one exception. Soil biodiversity (19 indicator taxa in total) and chemical quality (10) had a larger number of indicator taxa than macro aggregation (9), soil macro aggregation (9) and physical quality (3). Large taxonomic units (orders) had a better average indicator value (0.50±0.10 on a range of 0 to 1) than species level (0.22±0.03). Ants, Coleoptera, Arachnida and termites were the groups with the largest indicator values. Macroinvertebrate communities may therefore serve as simple tools for field evaluations of ranges of ecosystem services. Comparison of the sets of indicator taxa extracted with the scientific method should be compared with farmers and other field practicians knowledge, to elaborate certified systems for ES evaluation, in support of public policies that aim at enhancing their provision.

Introduction

With the recognition by economists of the concept of ecosystem services, these goods and services of nature useful to humans, a new economy of Nature is created [1]. While one can rightly discuss the violently anthropocentric nature of this concept, it establishes a vision of the world where the work, accumulated over geological ages, of millions of species in a logic of self-organization, is appropriated by the latest comer, the Homo, self-declared sapiens, barely born from yesterday at a geological scale. This slow process has allowed the development of life on planet Earth through the ages. The significant decrease in the atmospheric CO_2 content in the carboniferous is an emblematic example of it. This result was achieved with the participation of newly appeared trees whose dead trunks fell in the vast swamps which covered a good part of the earth at that time. They were slowly buried and transformed into coal and oil, this climatic garbage that the Homo sapiens went to extract and burn to recover its energy, with the annihilation of 60 million years of processes that we know.

Ecosystem services: which value has this concept as regards the conservation of ecosystems and biodiversity?

This seemingly unnatural concept, however, could be the lifeline of a planet in distress. Economists have in fact hastened to do what they know how to do, quantify these natural treasures with their currencies, this myth invented by them to facilitate the circulation of all goods, those of nature and those invented by them [2]. The results of such an approach left economists in disbelief. According to [1], a year of "services" would have cost between 16 and

54 trillion US $, the equivalent of the world PBI estimated this year at 31.5 trillion. In 2014, the same estimate rises to 145 trillion for a global GDP of 87.8 trillion, and the authors estimate the benefits obtained from land transformation between 4.3 and 20.2 trillion [1,3,4].

Despite the astronomical price of these services, the concept has served as a basis for intense debates [5-9]. Very diverse public policies have been created which are gradually showing their interest, and even their effectiveness, within the limits of the exercise. It is interesting to see that in some cases, like the study by [10], even a relatively symbolic payment for ecosystem services can have measurable short-term effects on soil biodiversity (measured by populations of macroinvertebrates) and seem to last even after the end of the payment which will have lasted only two years. This example, confirmed by various socio-economic surveys carried out in various regions of Colombia, shows the value of this payment process to meet the demands of farmers. The main problem then is how to measure it.

Measuring ecosystem services

The international literature shows a great offer for measurement methodologies, but most often, based on mapping methods coupled with cumbersome and costly analyzes of ecological parameters indicative of ecosystem services [11,12]. In most cases indeed, the proxy used to assess ES is the type of vegetation cover. This approximation, only partly verified, allows the establishment of maps whose precision sometimes defies the reality on the ground [11,13]. Public policies and in particular payment systems will be based on these documents. In less numerous cases, scientists roam the field and make precise measurements of water, climatic or production support services or soil biodiversity with all the arsenal of pedological and biological analyzes available. These have a high cost and require the intervention of specialists.

The result of this situation is that the knowledge generated by such studies cannot reach the one who needs it most, the farmer who by his work and that of his family or his company produces the ecosystem services.

It is therefore necessary to provide farmers with simple indicators that they can evaluate with the knowledge that is theirs and that can be linked to scientific knowledge, the only one recognized in the design of public policies. This work was carried out at three study sites in Nicaragua, Colombia and Peru, using soil macroinvertebrate communities as indicators of ecosystem services.

Soil macroinvertebrates as universal indicators of soil-based ES?

The sites studied are family farming systems in semi-arid regions of Nicaragua [14], the humid savannas of the Llanos Orientales of Colombia [15] and the deforested areas of the Colombian (Caqueta) [16] and Peruvian Amazon (Loreto) [17].

Identification of indicator taxa

In all these sites a similar methodology was applied. All the variables describing the various soil functions that support ecosystem services have been measured by scientists and transformed into a small number of synthetic indicators following the method proposed by [18,19] (Table 1). All chemical variables that support plant production were synthesized into a Chemical quality indicator ranging from 0.1 to 1.0. Synthetic indicators of soil physical properties, macro aggregation pattern and biodiversity were calculated the same way from their respective sets of variables. The soil macrofauna was then sampled with the standard ISO/TSBF method [20] and identified up to large groups (orders or families) and, for ants (Llanos Orientales, Amazonia) and termites (Amazonia) down to the genus and species level.

Table 1: List of variables used to measure synthetic proxy indices of soil-based ecosystem services.

Ecosystem Services	Type of Data	List of Variables	Methods
Biodiversity	Quantitative assessment of soil macroinvertebrate communities	Density per m 2 of 16 orders of soil macroinvertebrates	ISO 23611-5 sampling method
Plant production	Chemical fertility	Macronutrients, pH, C an	Standard methods
Water related services	Physical quality	Bulk density, resistance, to penetration, shear strength resistance, water content	Standard methods
Resistance to erosion	Macro aggregation	Relative proportions of biogenic, physical and root macroaggregates and non-aggregated soil	[19]

The values of the soil service indicators (chemical fertility, resistance to erosion, water functions, climate control and protection of biodiversity) were then divided into three classes of low, medium or high values. The Individual method [21] makes it possible to calculate the indicator value of each taxonomic unit for each service indicator according to the fidelity of the taxon to a determined class of values (maximum when the taxon is present in all sites that present this class of values) and of its specificity (maximum when the taxon is only found in the sites that present the given class of values). In each site studied, a number of taxonomic groups were thus recognized as indicators of value classes with a p value < 0.05 (Table 2).

Table 2: Number of taxa ($p<0.05$) indicators of the 4 indicators of soil based ecosystem services in the four study sites.

	Sites	High	Medium	Low
Biodiversity	La Danta	6	1	0
	Llanos	5		0
	Caqueta		1	
	Loreto	6	0	0
	Total	17	2	0
Chemical Fertility	La Danta	1		1
	Llanos	2		1
	Caqueta	1		
	Loreto			4
	Total	4		6
Physical Quality	La Danta	0		0
	Llanos			
	Caqueta			1
	Loreto	2		
	Total	2		1
Soil Macro aggregation	La Danta	2		
	Llanos	5		
	Caqueta		1	
	Loreto	1		
	Total	8		1

Results

Indicator taxa were found in all sites and for all ES with one exception, the physical quality of the soil in the Nicaraguan site. The biodiversity of the macroinvertebrate community is the attribute indicated by the greatest number of taxa, 19 in total in our study, against 10 for chemical fertility, 9 for soil macro aggregation and only 3 for physical quality. Most often, indicator taxa report high values of the soil quality indicator (31 occurrences) against 8 for the lowest values and 3 for the intermediate values. All large groups can be indicators: ants, termites, Coleoptera, Chilopoda, Isopoda y Blattaria. It is also noted with interest, that the indicative value of taxa at the order level is better (0.50±0.10) than that of the taxa identified at the species level, ants and termites here (0.22±0.03).

Conclusion

These first results show a great potential of soil macroinvertebrates for the indication of soil characteristics that support the production of ecosystem services. They are easy to observe indicators, assessed at a low cost. They also are generally well known to field operators, farmers in particular. They seem to indicate in particular the state of biodiversity insofar as soil degradation is accompanied by the disappearance of the superficial litter system associated with trees. Soil macro aggregation is the second best indicated factor, which is consistent with the fact that among these invertebrates, ecosystem engineers are actively constructing these macroaggregated structures [14]. Another remarkable fact is the lack of indicative value of earthworms noted on this still small sample of sites. The great diversity of adaptive strategies of earthworms, between the epigeics which compost the litter and the endogeics which feed on soil organic matter, on the one hand, and between the invasive parthenogenetic species and the amphymictic natives on the other hand, can explain this fact. It is anyway important to accumulate more data to extract clear and generalizable patterns. The comparison of the results of scientists with the knowledge of farmers, only addressed so far in the work of [12] is an essential step towards the use of these indicators in support of public policies intended to support the efforts of farmers. and other soil managers to keep soils in the best possible condition with a measurable effect on the production of ecosystem services.

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