Soil bioindicators: how soil properties influence their responses and to select them in function of the site issues?

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1. Introduction

Despite no European directive exists for soil protection, this key component of ecosystem needs to be protected. To fill the lack of tools to monitor the soil threats and to assess the impact of soil management, biological indicators have been developed in the French program Bioindicators 2 (ADEME) and a website allowing selection of relevant bioindicators depending on the question asked achieved. On the 47 plots of 13 sites (agricultural, industrial and forest), the influence of soil characteristics and soil use on the response of 80 biological parameters (fauna, flora and microorganisms) have been assessed by using linear multivariate regressions.

2. Materials and methods

In order to identify the parameters influencing the responses of bioindicators, multiple linear regressions regressions were developed as (Eq 1) : $\log (Y + 1) x = \log (A + 1) + y \log (B + 1) + ... + z$

where Y is the response of the bioindicator, A, B, ... represent the characteristics of the soil (physicochemical measurements and use, Table 1).

Biological Indicators					Soil characteristics	
Microbiology			Flora	Fauna	PC / Use	Contaminants
Com. Microb.	Phosphat.	Laccase	PhytoMet	SET (snails)	Use	MetTot : Σ Total Metals
Com. Fung.	Phosphat.	Pseudomonas	Omega3	Small mammals	Clay	Cd total
Com. Bact.	Xylase	Arylamidase	IPSP	Microarthropods	Silts	Cu total
Microb. Mol. B.	ADN 18 S	Lipase		Nematofauna	Fine Sands	Pb total
Microb. B.	Total Ergo.	Resp. oxitop		Earthworms	Corg	HAP$_H$: Σ Heavy HAP
Arylsulfatase	Free Ergo.	Cellulase		Metallothionein	C/N	OC : Σ organochlorinated P.
Deshydro.	Biolog RF	FDA		IBQS	pH	Trzin : Σ triazines
Urease	AWCD	ß Glucosidase			CEC	MtxTrzin : Σ methoxytrzin.
Galactosidase	PLFA	NAG			SEC	UrSubst : Σ PU metabolites

FDA : Fluorescéine di acétate ; PLFA : phospholipid fatty acid ; IPSP : photosynthesis index; Phytomet et SET : indexes of bioaccumulation for plant or snails

Table 1: Biological and physico-chemical parameters used for the multiple linear regressions

All combinations of the 18 available soil parameters were tested. Only models having a maximum of five independent variables and a ΔAICc <2 (Akaike criterion) were selected to choose a model from this selection, the indicator officials had a choice of three methods: (i by default) the selected model corresponded to the first model with the lowest number of explanatory variables (parcimony), (ii) the selected model corresponded to the model with the largest number of soil characteristics (explanatory variable) correlated to biological variable (response variable), (iii) if none of the above methods was selected, then the model chosen was based on the expertise of the scientist who have developed the indicator, identifying the most appropriate regression.

3. Results and discussion

3.1. Influence of soil parameters on the biological responses

The multiple linear regressions highlighted the influence of pool of soil parameters on the response of the bioindicators. By focusing on the occurrences of the parameters in equations, a clear influence of the soil texture (% clay, silt) and the rate of C_{org} is observed. Contaminants (metalic or organic) are also present in most equations. These strong influences of soil contaminants coupled to the soil parameters emphasize the need measure their bioavailability instead of total contents.

Type of indicator	Biol. Param.	Use	Texture	Corg	C/N	pH	CEC	SEC	Metal Contam.	Organic Contam.
Bioaccumulation	2	0	0	**100**	0	**50**	0	0	**100**	**100**
Effect: Biomarker	3	0	33	0	33	33	**67**	33	**100**	33
Effect: biomass and abundance	15	27	**87**	47	33	27	20	33	33	**80**
Effect: Functional diversity	17	35	**59**	59	29	29	29	35	**53**	82
Effect: Genetic diversity	4	**75**	25	0	0	**100**	25	0	0	100
Effect: Community	38	24	**76**	32	21	11	34	18	**55**	53

Table 2: Occurrence (%) of the parameter identified as modulating the biological responses

3.2. Implementation of web site devoted to the bioindicators

Following requests from potential users of bioindicators, a web site has been created (Fig 1). In this interface is listed all Bioindicators 2 program information. Another request was to have access to the program results. Thus, a component of the interface has been dedicated to the presentation of indicator results. Thus, users have access to "benchmarks" and can compare these values with the data generated on their own site. To allow users to select the bioindicator which best fits their site problematic, a screening tool has been developed based on scientific and technical (cost, standardization of the indicator, ease of implementation and ease of interpretation) criteria. With these criteria a scoring assigning a score to each tool for each of the four criteria has been achieved. The user can choose his site problematic, the type of indicator that wishes to use (indicator of accumulation, effect ...) and prioritize the four criteria. Then, user can have access to a set of detailed information on the selected bioindicator.

Figure 1: menu of the web site

4. Conclusions

For the first time, the soil properties influence on the response of 80 bioindicators was characterized under similar environmental conditions. As each bioindicator is influenced by a specific pool of soil parameter, chemical measures cannot be used as a surrogate of biological measures. This program has provided usable tools for a biologically-based site management. The operational structures to implement bioindicators coupled with the web site will simplify the use of bioindication by end-users.