



Which bioindicators are suitable for soil quality monitoring and risk assessment? From relevance study to transfer tool development

Guenola Peres, Benjamin Pauget, Annette De Vaufleury, Michael Coeurdassier, Marina Leguedard, Jean-Jacques Bessoule, Samuel S. Dequiedt, Rémi Chaussod, Lionel Ranjard, Daniel Cluzeau, et al.

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Which bioindicators are suitable for soil quality monitoring and risk assessment? From relevance study to transfer tool development.

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A large research network



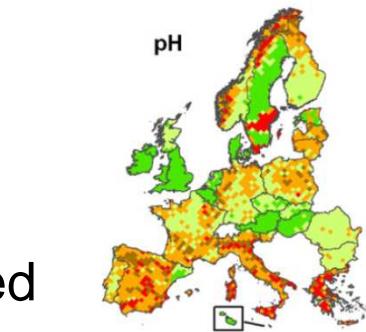
→ large network of national experts: 22 french research teams (i.e. 70 members)



Why do we need bioindicators ?

- ❖ Increasing degradation of soil
- ❖ Tools for soil quality assessment

➔ Tools available :
physical and chemical indicators usually used



BUT : indicators based on biological parameters are still rare



ADEME (French Agency for Environment and Energy Management) initiated a national research programme to develop such indicators :
“Bioindicator Programme” (2006-2013).



Objectifs of Bioindicator programme

<http://ecobiosoil.univ-rennes1.fr/ADEME-Bioindicateur>

- **develop and validate** methods for measuring soil biodiversity and functions
- **test the sensibility** of the bioindicators to different perturbations :
 - modification of soil uses
 - contamination,
- **calibrate bioindicators by initiating some refential values, endpoints**
- **provide and transfer relevant bioindicators and tools** to end-users (policy makers, farmers, research board) depending on the purpose
 - risk assessment
 - characterization
 - monitoring



Strength : test of large number of bioindicators (47)

1) Microorganisms

Parameters of quantity

- Global (Bm, DNA)
- No global (Fungal, Bacterial)



Parameters of activity (examples)

- Enzymatic Activities (12)
- Metabolical Functions (mineralization)

Parameters of diversity, genetical structure

- Bacterial, Fungal

3) Flora

Parameters -> individual effects

- Lipid Biomarkers
- Metal Bioaccumulation
- Free Amino acid content
- ...



2) Fauna

Global Parameter

- Total Macrofauna



Parameters → Community level

- Earthworms,
- Collembola, mites
- Nematodes



Parameters → Individual level

- Molecular earthworm biomarkers (metallothionein coding gene expression, Cd sensitivity)



- Metal Bioaccumulation (snail, micromammal)





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1) Microorganisms

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(metallothionein coding gene expression, Cd sensitivity)



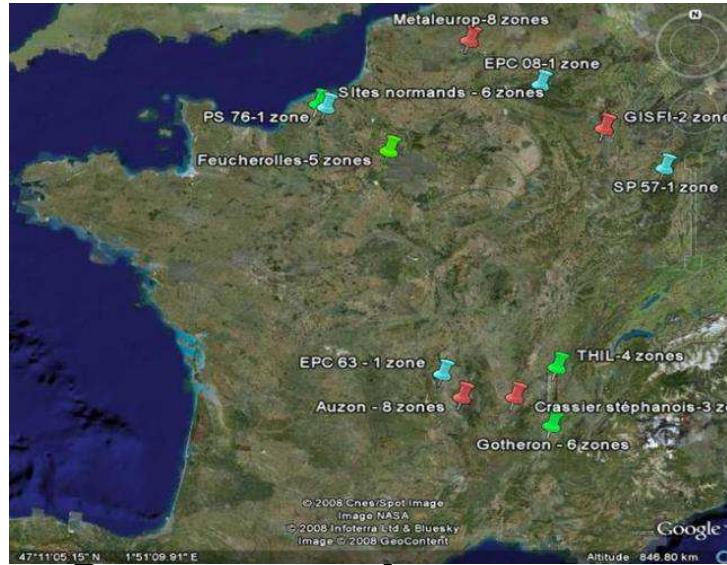
- Metal Bioaccumulation ★
(snail, micromammal)



ISO 23611-1-5 ; ISO 17155 ; ISO 16072, ; ISO 17601, ISO 22939
ISO 10381 ; ISO 14240 ; ISO 29843 :: ISO 11063 ...



13 sites → 47 plots



Forest sites



4 sites (4 plots)

Agricultural sites



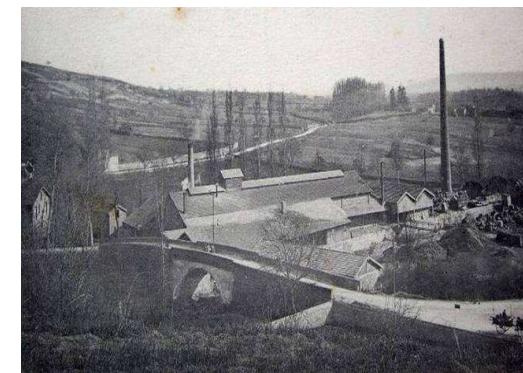
5 sites (25 plots)



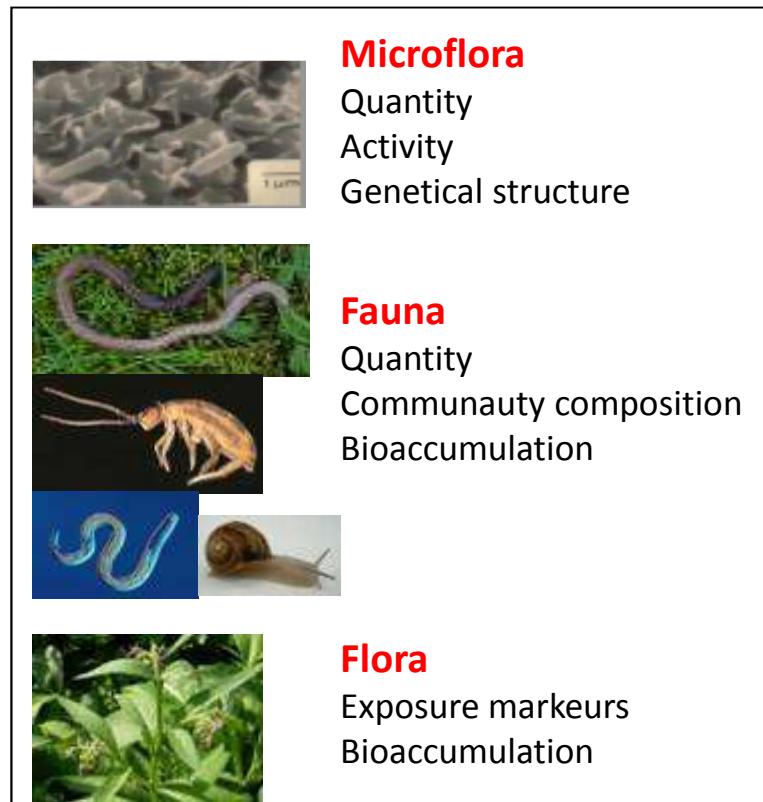
ISO 23 611

→ 188 samples

Contaminated sites

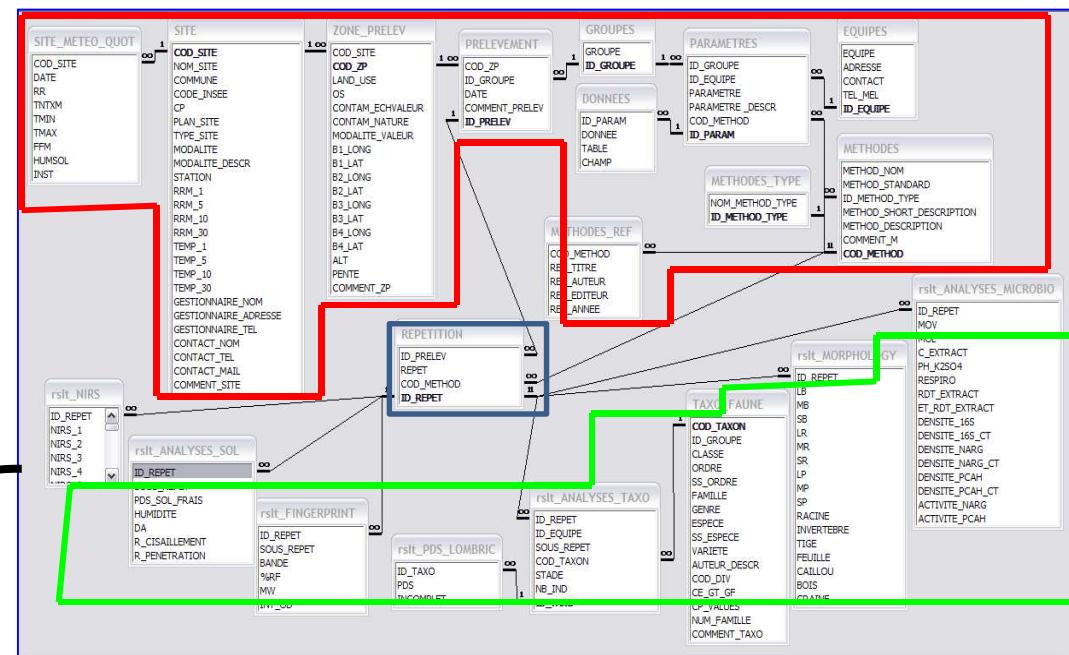


4 sites (19 plots)

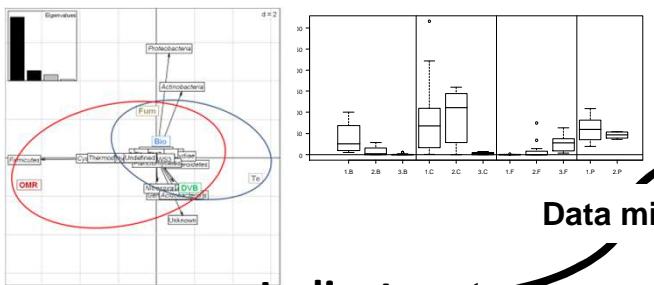


200.000 data

Data base



$$\log(Y+1) = x \log(A+1) + y \log(B+1) + \dots + z$$



Data mining

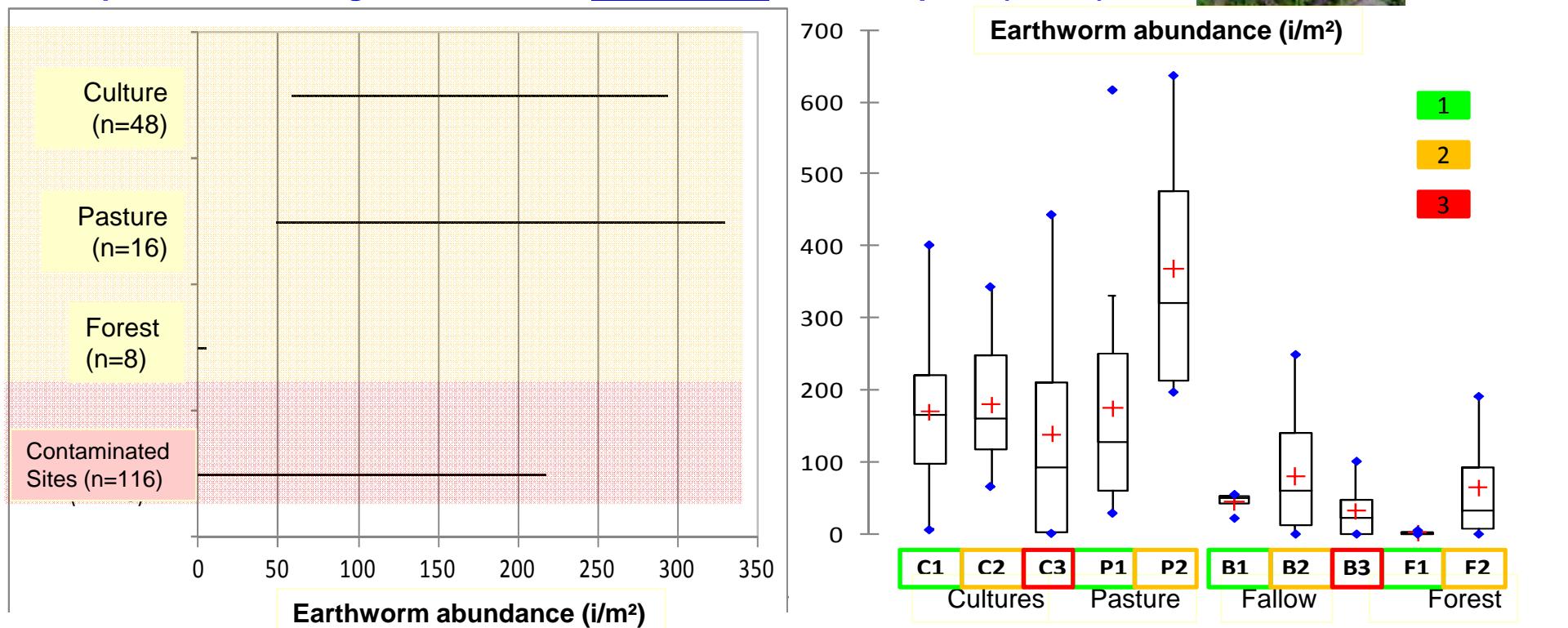
Indicators



1 – Tool : Initiation of a base of reference values



Example: variation range of earthworm abundances on the 47 plots (n=188)



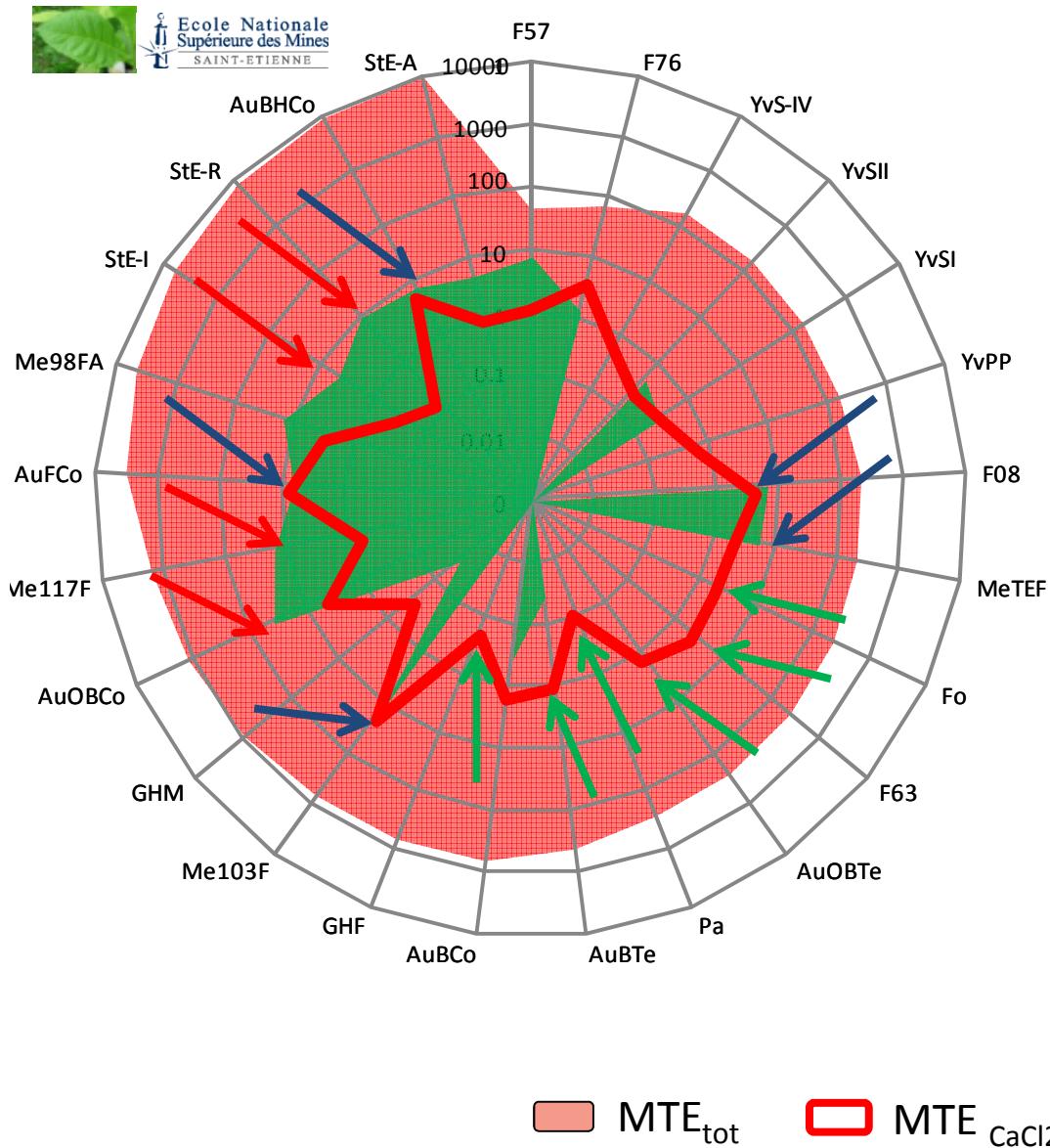
→ calibration of the indicator (range of the biological responses depending on industrial, agronomic, pedological and climate contexts)

→ reference values → help in result interpretation



2 – Tools for Diagnostic (Bioavailability)

Metal Transfer in Plant (CMT)



MTE Total different MTE CaCl₂

MTE CaCl₂ : bioavailability ? (ISO)

Metal Transfer in Plant (CMT)

→ Consistence between CMT and MTE CaCl₂

Inconsistence → new informations

→ Transfer soil- plant

→ No transfer soil- plant

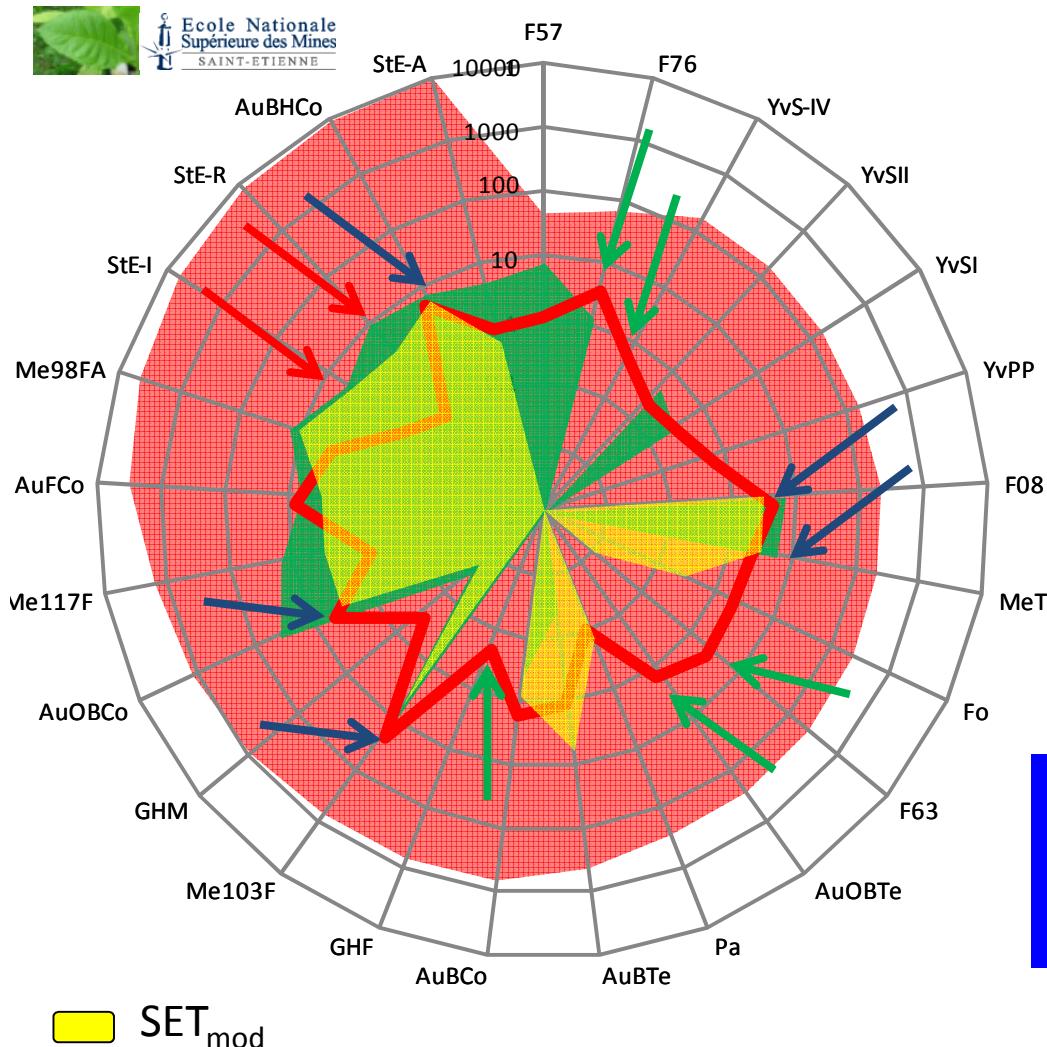


(de Vaufléry et al., 2012)



2 – Tools for Diagnostic (Bioavailability)

Metal Transfer in Plant (CMT)



B. Pauget et al., 2013

MTE Total different MTE CaCl2

MTE CaCl2 : bioavailability ? (ISO)

Metal Transfer in Plant (CMT)

→ Consistence between CMT and MTE CaCl2

Inconsistence → new informations

→ Transfer soil- snail

→ No transfer soil- snail

MTE CaCl2 measurement is not able to estimate and predict biological responses (transfer)



MTE_{tot}

MTE_{CaCl2}

CHRONO
ENVIRONNEMENT

Laboratoire de
BIOGÉNÈSE MEMBRANaire

Ecole Nationale
Supérieure des Mines
SAINT-ETIENNE

(de Vaufléury et al., 2012)



3 - Test of sensibility of bioindicators

Uni-varied Analysis → scoring
(Kruskall- wallis)

Examples microbial parameters



- No significative response (> 0.05%)
- Significative response (< 0.05%)

global

- Total PLFA (BM)
- Free ergosterol (BM f)
- Respiration
- Phosphatase alcaline (P)
- Arylamidase (N)

→ Identification
of indicators

specific

Agricultural soil

- Laccase (C)
- Contaminated soil**
- Pseudomonas (AB bacteria)
- Arylsulfatases (S)
- Galactosidases (C)

Parameters of quantity

		Study sites										
		Pratiques agricoles				Contamination		Occupation				
		Yvetot	Thil	Feucherolles	Gotheron		MetalEurop	Saint Etienne	Auzon	Andra	Forêts	Gisfi
		V	A	S	C	B						
Biomasse moléculaire												
Carbone de la biomasse												
Abondance bactérienne (UFC)												
Ergostérol total												
Ergostérol libre												
ADN 18S												
ADN 16S												
Pseudomonas												
PLFA totaux												
Respiration												
Minéralisation N												
Arylsulfatase												
Galacosidase												
Uréase												
Deshydrogénase												
Laccase												
Phosphatase acide												
Phosphatase alcaline												
Glucosidase												
N-Acetyl-Glucosaminidase												
Cellulase												
Xylanase												
Fluorescein di acetate												
Lipase												
Arylamidase												
Puits positifs												
AWCD												



Synthesis



Which indicators for which purpose under cultivated soils ?

Purposes		Indicators
Organic matter	Microflora	Abundance (total, bacterial, fungal, PLFA, ergosterol) Diversity Respiration Enzymatic activity (C, N)
	Fauna	Earthworms (density) Nematodes (diversity)



Synthesis



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Purposes		Indicators
Organic matter	Microflora	Abundance (total, bacterial, fungal, <i>PLFA</i> , <i>ergosterol</i>) Diversity Respiration Enzymatic activity (C, N)
	Fauna	Earthworms (density) Nematodes (diversity)
Effect of practices (reduced tillage, rotations, agricultural system)	Microflora	Abundance (total, bacterial, fungal) Diversity Respiration Enzymatic activity (C, N, P)
	Fauna	Earthworms (functional groups) Nematodes (functional diversity) Collembola (diversity) → orchards



Which indicators for which purpose under contaminated soils ?

Synthesis



Purposes	Indicator
Bioaccumulation	Flora <ul style="list-style-type: none">• Plant bioaccumulation
	Fauna <ul style="list-style-type: none">• Snail bioaccumulation



Synthesis



Which indicators for which purpose under contaminated soils ?

Purposes	Indicator
Bioaccumulation	Flora <ul style="list-style-type: none">• Plant bioaccumulation
	Fauna <ul style="list-style-type: none">• Snail bioaccumulation
Effects linked to contamination (organic, metallic)	Microflora <ul style="list-style-type: none">• Abundance (bacterial, fungal, PLFA, <i>ergosterol</i>, <i>pseudomonas</i>)• Diversity• Respiration• Enzymatic activities (S, C)
	Fauna <ul style="list-style-type: none">• Earthworm (abundance, diversity)• Nematodes (abundance, diversity)• Macrofauna (abundance, diversity)
	Flora <ul style="list-style-type: none">• Test Oméga 3



What about monitoring ?

Synthesis

Purpose	Famille	Paramètres
Monitoring	Microflora	Biomass (bacterial, fungal) Respiration Diversity <i>Option: activities (C, N, P, S)</i>
	Fauna	Earthworms (functional diversity) Nematodes (functional diversity) <i>Option: Microarthropods (under forest or orchards)</i>



Transfer

Transfer

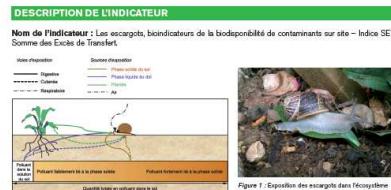




Tools for communication and transfer

<http://ecobiosoil.univ-rennes1.fr/ADEME-Bioindicateur>

1) Technical sheets



Rôle écologique de l'organisme testé : Les escargots sont des macro-invertébrés vivant à l'interface sol-plante. Ces animaux sont des prédateurs phytophages qui consomment des plantes et des déchets végétaux et minéraux. Ils ingèrent des particules de sol au contact duquel ils pondent leurs œufs. Ils réagissent par de multiples sources et voies de contamination (cf. Fig. 1). Les escargots participent aux échanges avec le sol et sont des proies pour de nombreux consommateurs (invertébrés : vers luisant, larves de coléoptères, araignées, petits mammifères, hétéroptères), mais également pour les oiseaux et les amphibiens.

Type d'indicateur : Bioindicateur d'accumulation. (analyse des concentrations internes est réalisée dans les escargots exposés jour sur jour (= méthode statique). 1 seule durée d'exposition). Les analyses sont généralement faites dans cette partie du corps où concentrent les contaminants (mâchoire notamment); voir Gomot de Vaulxey & Phane, ETC, 2002).

DESCRIPTION DE LA MÉTHODE

Normes et/ou protocoles de référence

Bioindication active *in situ* des microscories (cylindres en acier inoxydable de 25 cm de diamètre sur 25 cm de hauteur fermés par une grille de maille 0,5 ou 1 cm, maintenues par 3 à 4 tiges en inox également) sont placés sur les zones d'étude (Fig. 2).

Dans une microscorie on place 15 escargots gris subadultes (5-6 g) tous de l'âge (voir annexe de l'ISO 15695) ou issus d'environnements locaux. Entre la fin de leur élevage et la pose sur le terrain, ils peuvent être stockés au sec dans des boîtes en bois (type « bac à sable »).

Ils sont utilisés pour recenser en activité quelques heures avant d'être placés dans les microscopies dans lesquelles ils seront maintenus jusqu'à ce qu'ils soient dégagés, ayant poussé sur le site et à l'air ambiant afin d'être dans des conditions naturelles d'exposition (classe climatiques).

1. Pour plus de détails, voir ISO 15695 (2009), ou au site <http://microscopie.ufr-rennes.fr/iso15695/>

2. Pour plus d'informations sur la méthode d'application de l'indicateur, voir l'annexe des normes de conduite : <http://www.cetelem.fr/saplay/classif/iso-15695-1/iso15695-1.pdf>

2) Data base for public → range values of the indicators

3) Tool for selection of the indicators



Thank you for your attention

<http://ecobiosoil.univ-rennes1.fr/ADEME-Bioindicateur>

