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

Guénola Pérès, Benjamin Pauget, Annette De Vaufleury, Michael Coeurdassier, Marina Le Guédard, Jean-Jacques Bessoule, Samuel 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.

G. Pérès^{1,2}, Pauget, B.³, De Vaufleury, A.³, Coeurdassier, M.³, Leguedard, M.⁴, Bessoule, J.J.⁴, Dequiedt, S.⁵, Chaussod, R.⁵, Ranjard, L.⁵, Cluzeau, D.², Guernion, M.², Rougé, L.², Hedde, M.⁶, Cheviron, N.⁶, Dur, J.C.⁶, Nelieu, S.⁶, Mougín, C.⁶, Gattin, I.⁷, Gangneux, C.⁷, Laurent, N.⁷, Legras, M.⁷, Laval, K.⁷, Lepelletier, P.⁷, Taibi, S.⁷, Villenave, C.⁸, Faure, O.⁹, Hellal, J.¹⁰, Cortet, J.^{11,12}, Beguiristain T.¹³, Leyval, C.¹³, Bodilis, J.¹⁴, Criquet, S.¹⁵, Hitmi, A.¹⁶, Ruiz, N.¹⁷, Vandenbulcke, F.¹⁸, Grand, C.¹⁹, Galsomies, L.¹⁹, Bispo, A.¹⁹

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A large research network

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



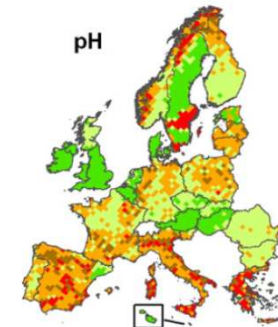
Why do we need bioindicators ?

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

→ Tools available :
physical and chemical indicators usually used



Y. Lebissonais



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 referential 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



Strenght : test of large number of bioindicators (47)

1) Microorganisms

Parameters of quantity

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



Parameters of activity (examples)

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

Parameters of diversity, genetical structure

- Bacterial, Fungial

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 sensivity)



- Metal Bioaccumulation
(snail, micromammal)





Strenght : test of large number of bioindicators (47)

1) Microorganisms

Parameters of quantity

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- No global (Fungial, Bacterial) ★



Parameters of activity (examples)

- Enzymatic Activities (12) ★
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- Metal Bioaccumulation ★
- Free Amino acid content ★



2) Fauna

Global Parameter

- Total Macrofauna ★



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- Molecular earthworm biomarkers ★
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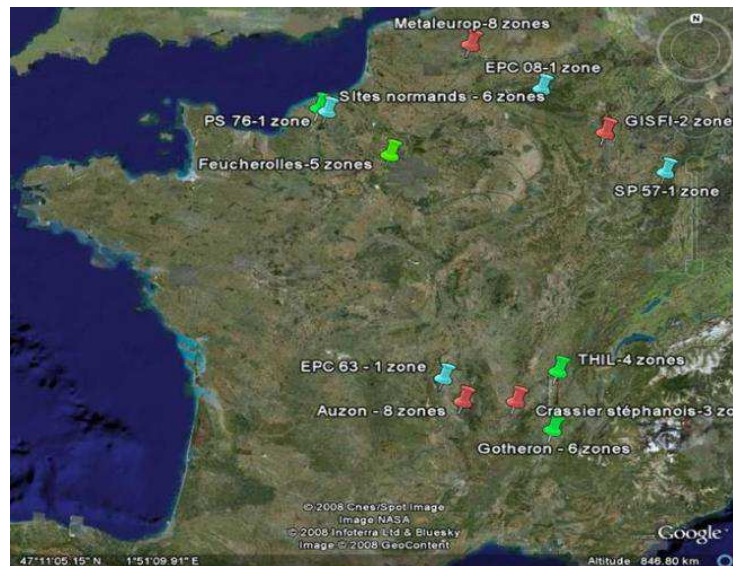


- Metal Bioaccumulation ★
(snail, micromammal)





13 sites → 47 plots



ISO 23 611

→ 188 samples

Forest sites



4 sites (4 plots)

Agricultural sites




5 sites (25 plots)

Contaminated sites




4 sites (19 plots)






Microflora
Quantity
Activity
Genetical structure



Fauna
Quantity
Community composition
Bioaccumulation

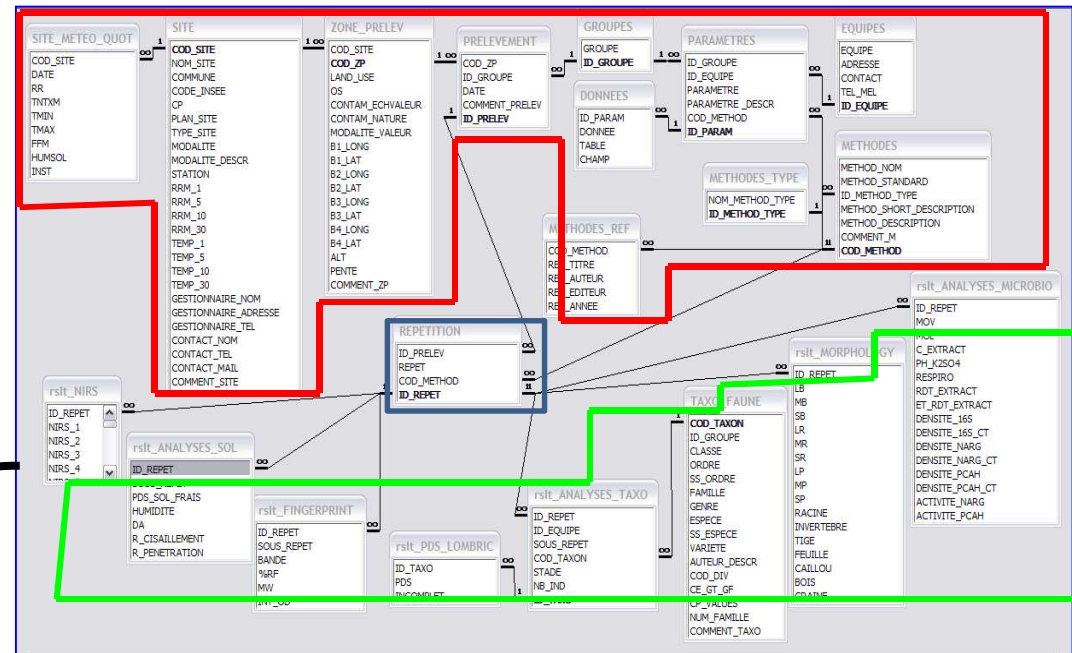


Flora
Exposure marqueurs
Bioaccumulation

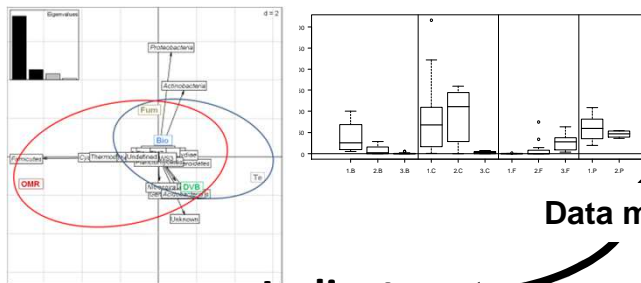


200.000 data

Data base



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



Data mining

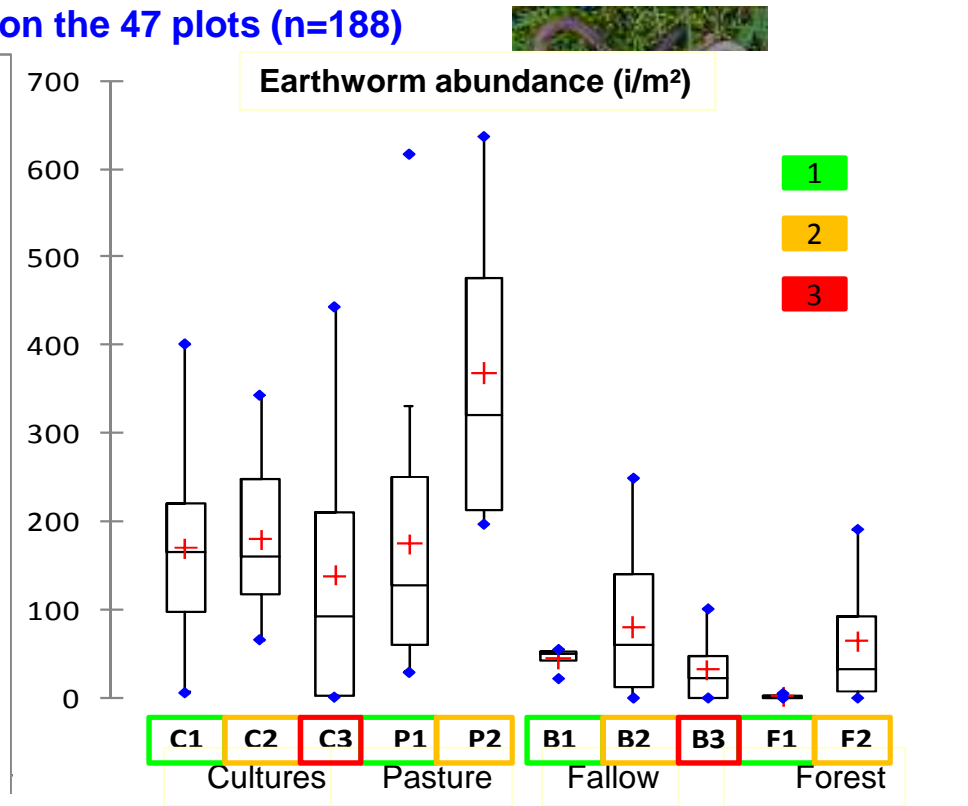
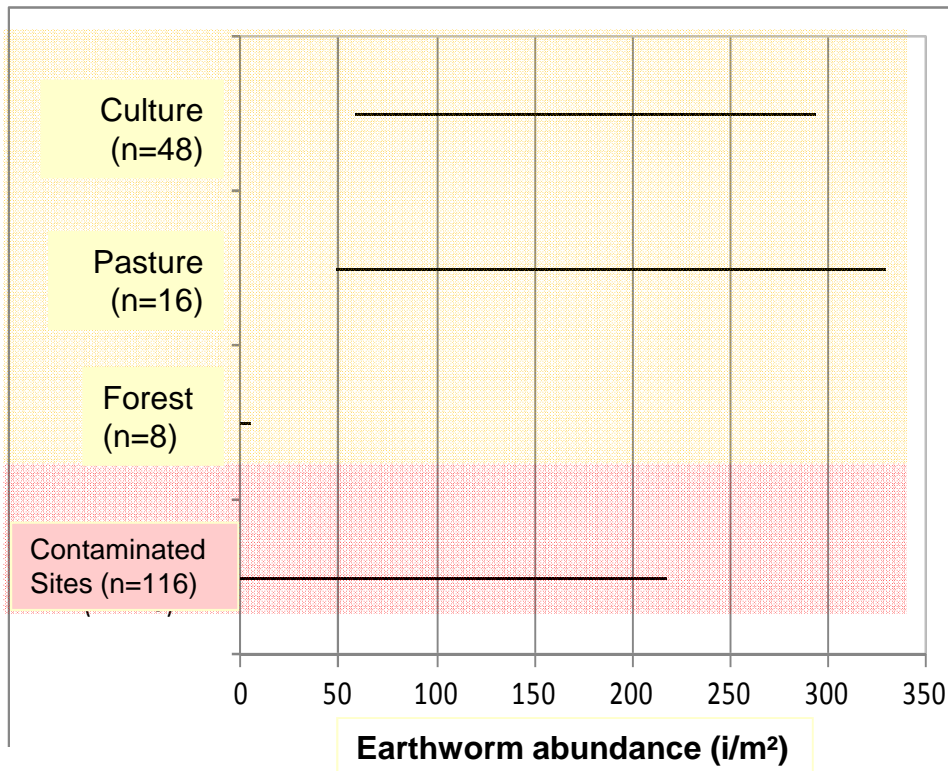
Indicators



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

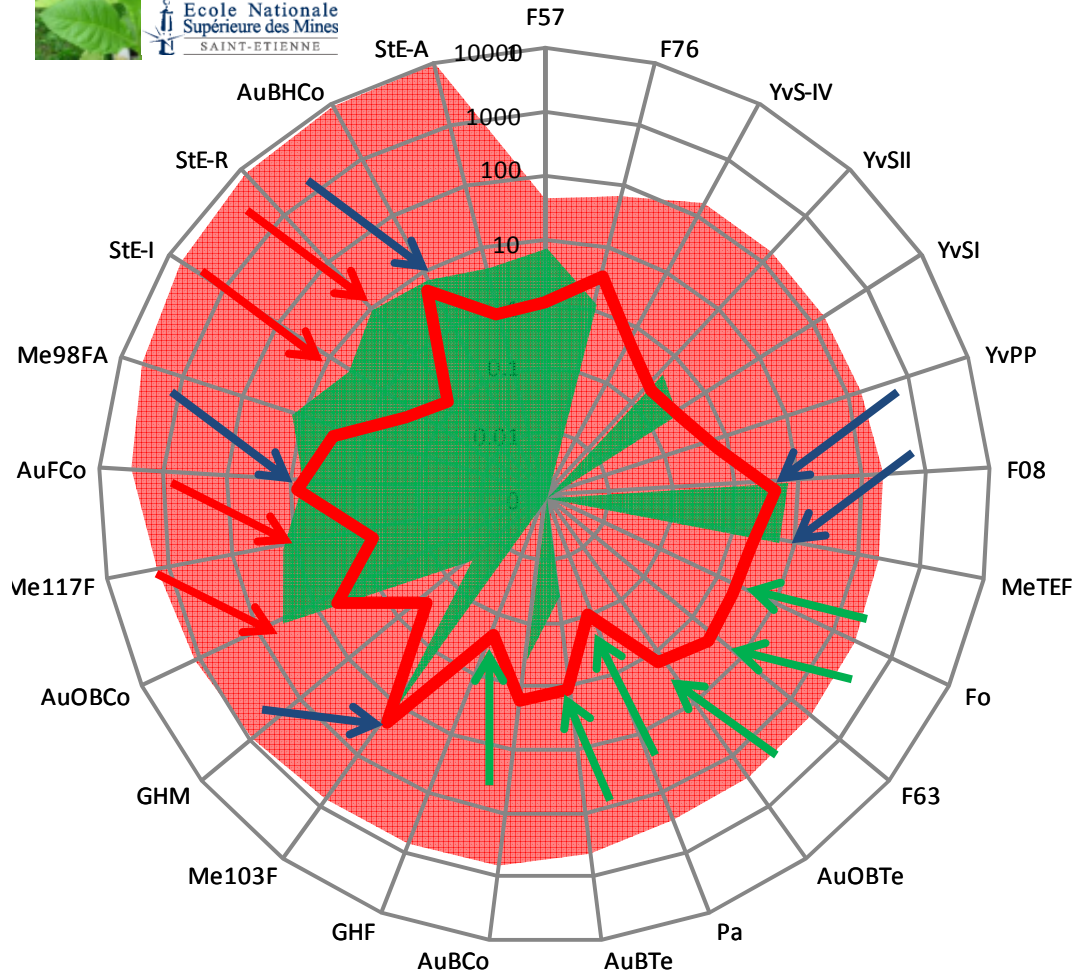


2 – Tools for Diagnostic (Bioavailability)

Metal Transfer in Plant (CMT)



Ecole Nationale Supérieure des Mines SAINT-ETIENNE



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

MTE_{tot}

MTE_{CaCl₂}

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(de Vaufleury et al., 2012)

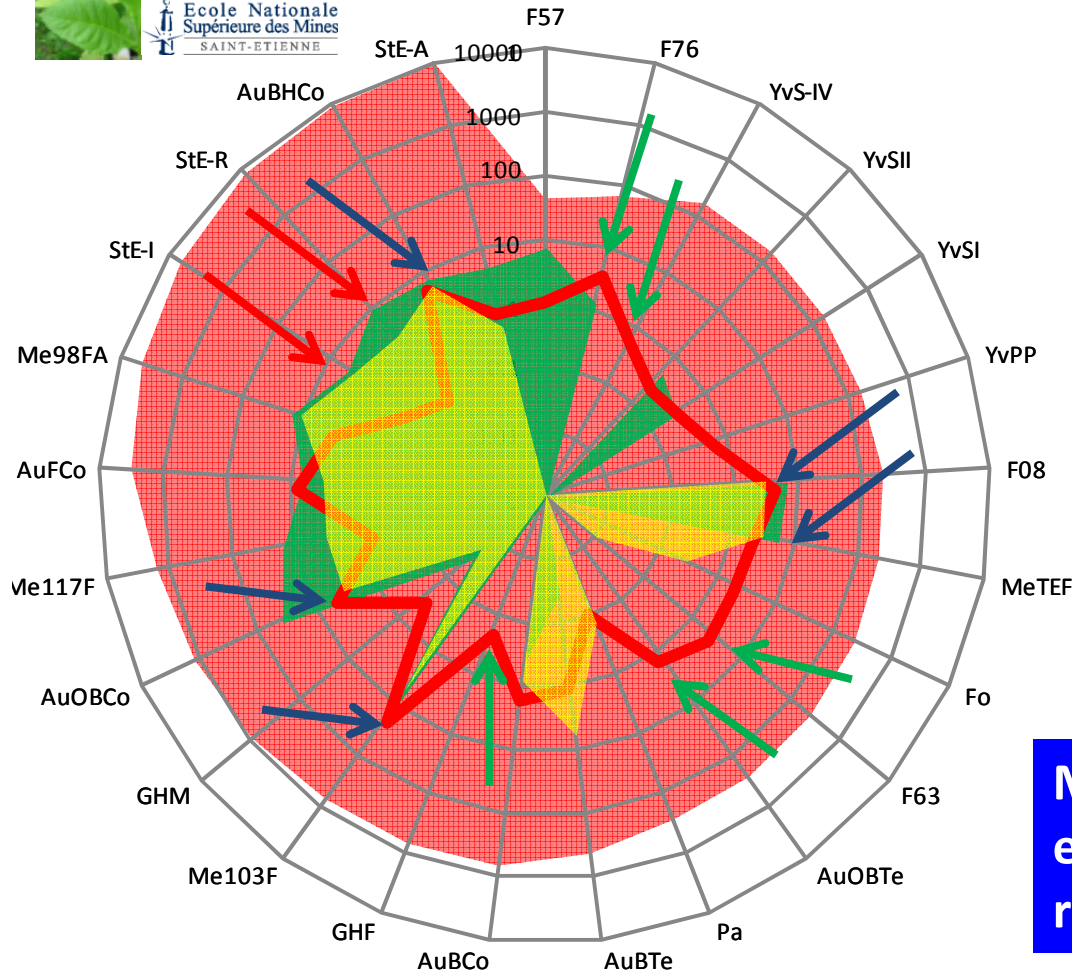


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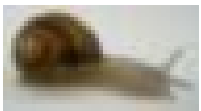
Inconsistence → new informations

→ Transfer soil- snail

→ No transfer soil- snail

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

SET_{mod}



B. Pauget et al., 2013

MTE_{tot}

MTE_{CaCl₂}

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(de Vaufleury et al., 2012)

3 - Test of sensibility of bioindicators



Uni-variated 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												Total	
	Pratiques agricoles						Contamination			Occupation				
	Yvetot	Thil	Feucherolles	Gotheron			MetalEurop		Saint Etienne	Auzon	Andra	Forêts		Gisfi
			V	A	S	C	B							
Biomasse moléculaire														10
Carbone de la biomasse														10
Abondance bactérienne (UFC)														8
Ergostérol total														9
Ergostérol libre														12
ADN 18S														8
ADN 16S														5
Pseudomonas														8
PLFA totaux														12
Parameters of activity														
Respiration														12
Minéralisation N														10
Arylsulfatase														10
Galactosidase														8
Uréase														10
Deshydrogénase														7
Laccase														11
Phosphatase acide														9
Phosphatase alcaline														12
Glucosidase														9
N-Aceyl-Glucosaminidase														5
Cellulase														6
Xylanase														6
Fluorescein di acetate														6
Lipase														9
Arylamidase														12
Puits positifs														5
AWCD														8



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



Which indicators for which purpose under cultivated soils ?

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



Synthesis



Which indicators for which purpose under contaminated soils ?

Purposes		Indicator
Bioaccumulation	Flora	• Plant bioaccumulation
	Fauna	• 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>pseudmonas</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





Thank you for your attention

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



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BIOGÈNESE MEMBRANAIRE



Université d'Auvergne
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