



Agro-Eco Sol, a soil function diagnostic tool based on bioindicators to provide advice on agronomic practices



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Agroecological transition and soil functions

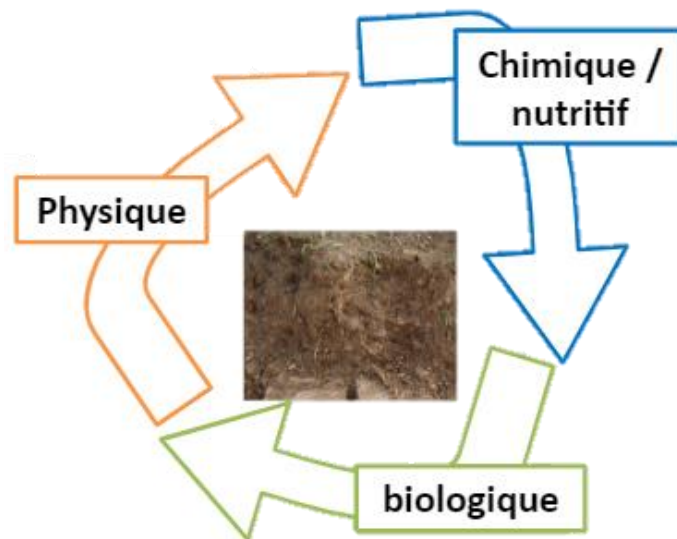
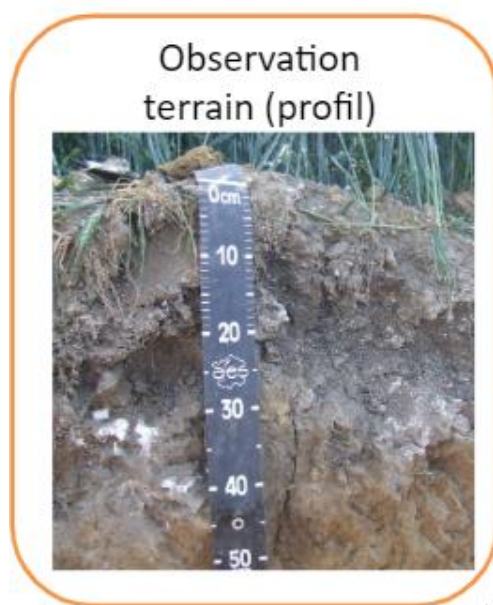
- As part of the agro-ecological transition, **soil plays an important role** in the implementation of sustainable agricultural practices.
- The **services provided by soils are numerous**:
 - Plant production (supply of mineral elements, regulation of pests and diseases, structural stability, etc.) ;
 - Carbon storage;
 - Biodiversity maintenance;
 - Regulation of air and water quality;
 - etc.
- **Need to optimize the ecological functions of soils** for the sustainable provision of agrosystem services.



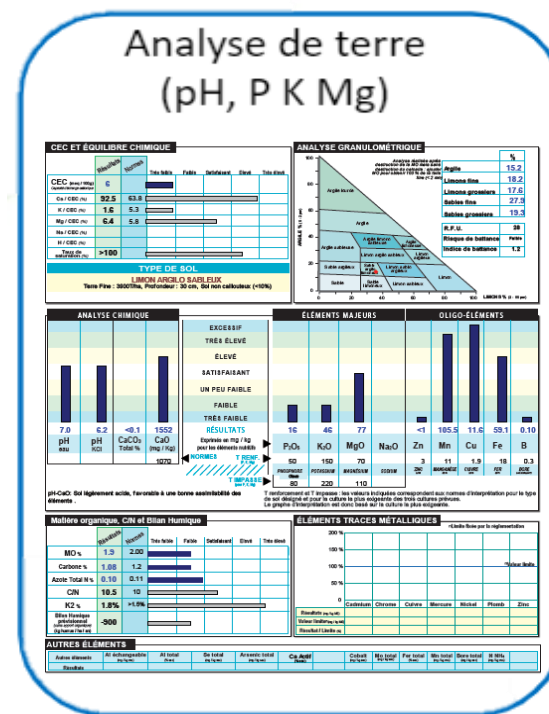


Need for diagnostic tools

- To maximize soil services, **diagnostic tools** are needed to assess current levels and potential for improvement.



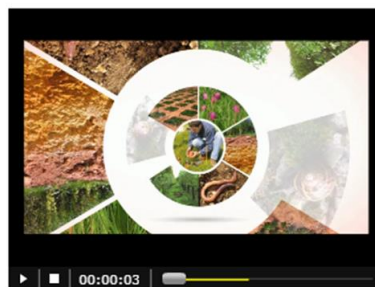
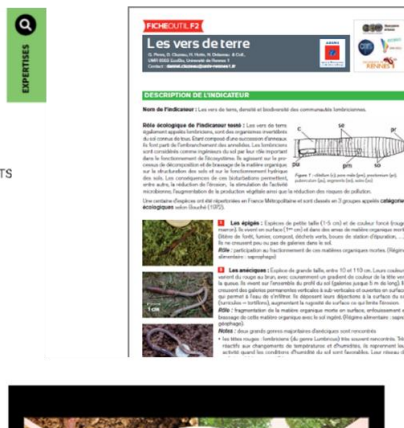
MO, C/N,
indicateurs
biologiques



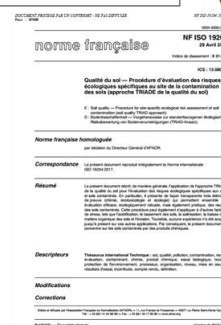


Bioindicators - Significant advances

1998



2023



Microbioterre

Des indicateurs microbiologiques dans l'analyse de terre de routine

« Présentation du projet Casdar Microbioterre »

Barbot Christophe¹, Benneadi-Laurent Nadia², Bouthier Alain³, Cusset Elodie⁴, Deschamps Thibaud⁵, Gendré Sophie⁶, Houot Sabine⁷, Leclerc Blaise⁸, Perrin Anne-Sophie⁹, Recous Sylvie¹⁰, Riah-Anglet Wassila¹¹, Roussel Pierre-Yves¹², Trinsoutrot-Gattin Isabelle¹³, Vale Matthieu¹⁴

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Séminaire de restitution 13/01/2022 MICROBIOTERRE : Intégrer des indicateurs microbiologiques dans l'analyse de terre de routine des parcelles agricoles Microbioterre 2



Montant total du projet : 5,4 M€ dont 2 M€ d'aide PIA

Projet accompagné par l'ADEME dans le cadre du programme Industrie et Agriculture éco-efficaces du programme des investissements d'avenir





What is an indicator?

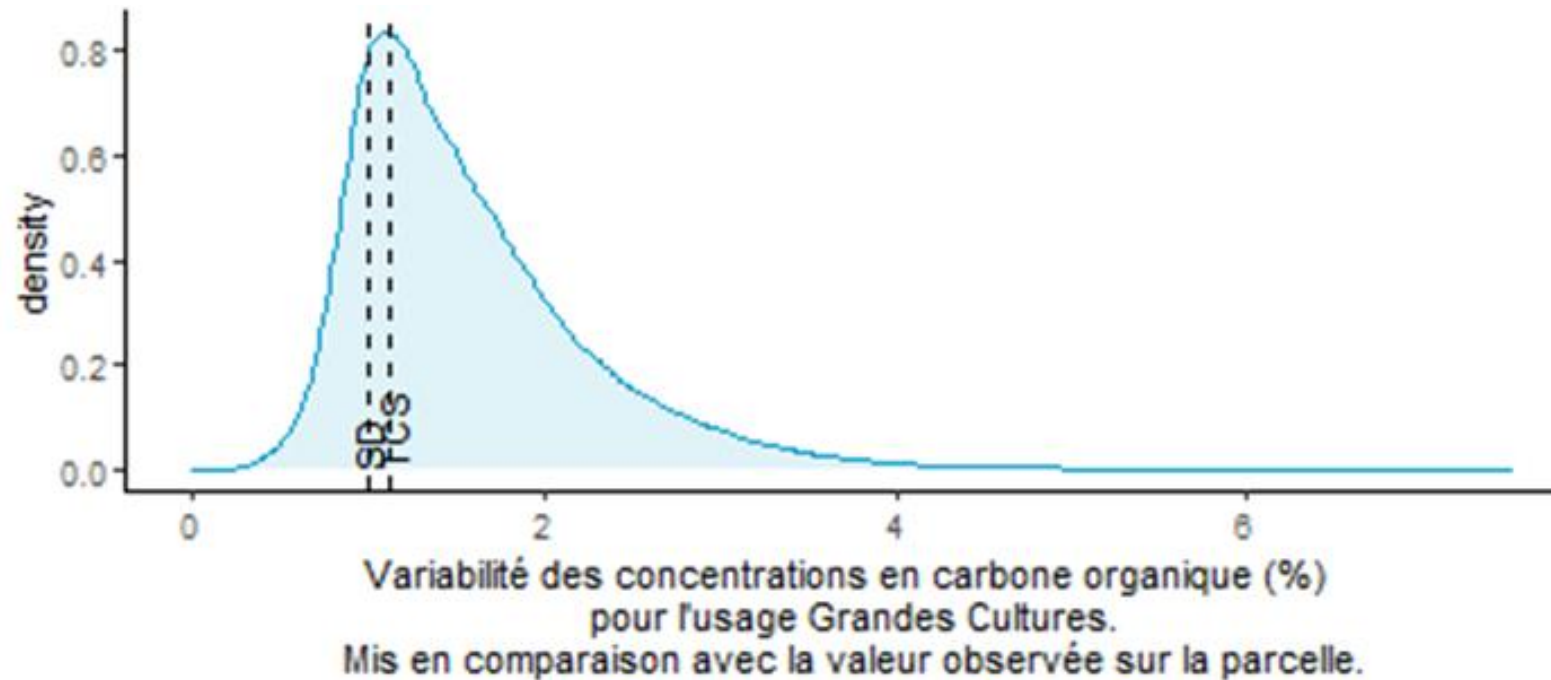
1. **Sensitive, reproducible (standardized) measurement methods**, with control of the steps upstream of analysis (sampling, packaging/sending, preparation/storage, etc.)
2. **Indicators = methods** with **interpretation references** and **links to soil functions** for **diagnosis**
3. **Advisory tools = aggregation of indicators** with **operational implementation** to maintain, improve and guide soil functions



What is an indicator?

2. Indicators = methods with **interpretation references** and **links to soil functions** for **diagnosis**

From the simple range of variations for a descriptive purpose...



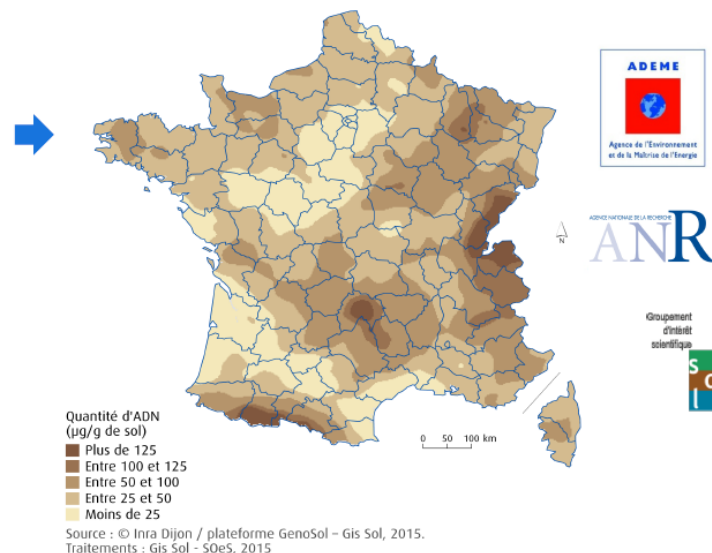


What is an indicator?

2. Indicators = methods with interpretation references and links to soil functions for diagnosis

... Improved by knowledge of the impact of pedoclimate and agronomic practices, which helps to explain the value ...

Carte de France de la biomasse moléculaire microbienne



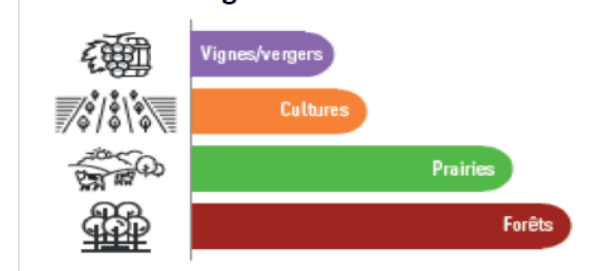
Source : © Inra Dijon / plateforme GenoSol – Gis Sol, 2015.
Traitements : Gis Sol – Soes, 2015

<http://indicateurs-biodiversite.naturefrance.fr/indicateurs/evolution-de-la-biomasse-microbienne-des-sols-en-metropole>

Type de sol

Carbonates de Calcium ⊖⊖	ratio C/N ⊖
Potassium ⊖	pH ++
Teneur en argile ++	Carbone organique +++

Mode d'usage

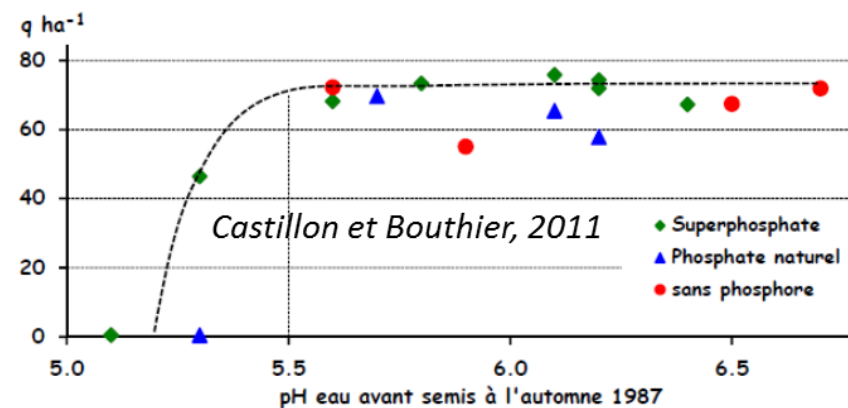
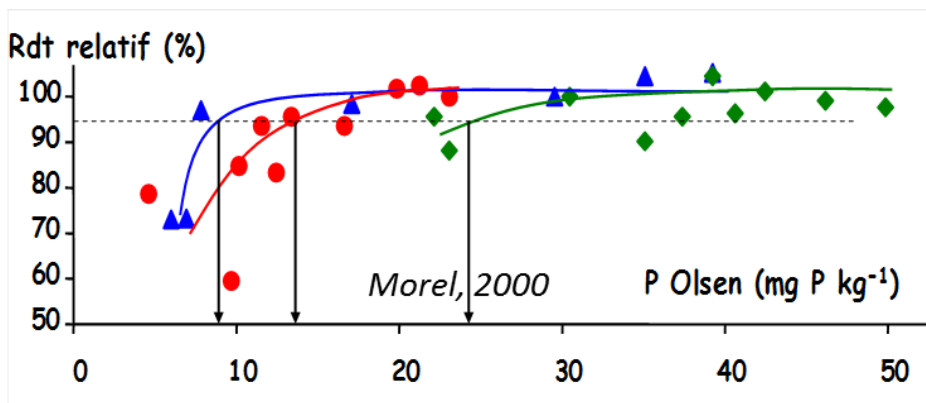




What is an indicator?

2. Indicators = methods with interpretation references and links to soil functions for diagnosis

... up to the link with soil functions, which can be used to define a targeted level and propose operational advice ...





Agro-Eco Sol project (2017-2023)



PORTEUR
DU PROJET



PARTENAIRES



CONTRIBUTEURS

Sociétés
expertise conseil



Coopératives



Laboratoires
privés



Laboratoires de
recherche



Ecole
d'ingénieurs



Montant total du projet : 5,4 M€ dont 2 M€ d'aide PIA



Projet accompagné par l'ADEME dans le cadre du
programme Industrie et Agriculture éco-efficientes du
programme des Investissements d'Avenir



Objectives :

- **Industrialize innovative soil analysis processes** (bioindicators of soil quality), designed to give farmers easier access to comprehensive advice on the management of agricultural soils (field crops).
- **Build operational advice based on these bioindicators** (interpretation references according to the effect of pedoclimate and cultivation practices, definition of targeted levels of functions indicated by these bioindicators, as well as possible agronomic practices to reach these levels).



L'EXPERTISE AGRO-ECO SOL : composition de l'offre





Agro-Eco Sol offer



CONNAÎTRE

- Plot environment
- Soil structure

(BIO)INDICATOR

FIELD OBSERVATIONS
STRUCTURAL CONDITIONS

ANALYSIS

- Plot context
- Surface condition
- Soil profile
- Spade test (ISARA method)

INTERPRETATION REFERENCES

- references from research and technical institutes (ISARA, Arvalis) and internal references (>500 plots)





Agro-Eco Sol offer



CONNAÎTRE

- Plot environment
- Soil structure

- The reservoir of chemical elements
- Physical and chemical characteristics of soil

(BIO)INDICATOR

FIELD OBSERVATIONS
STRUCTURAL CONDITIONS

PHYSICAL-CHEMICAL SOIL ANALYSIS

ANALYSIS

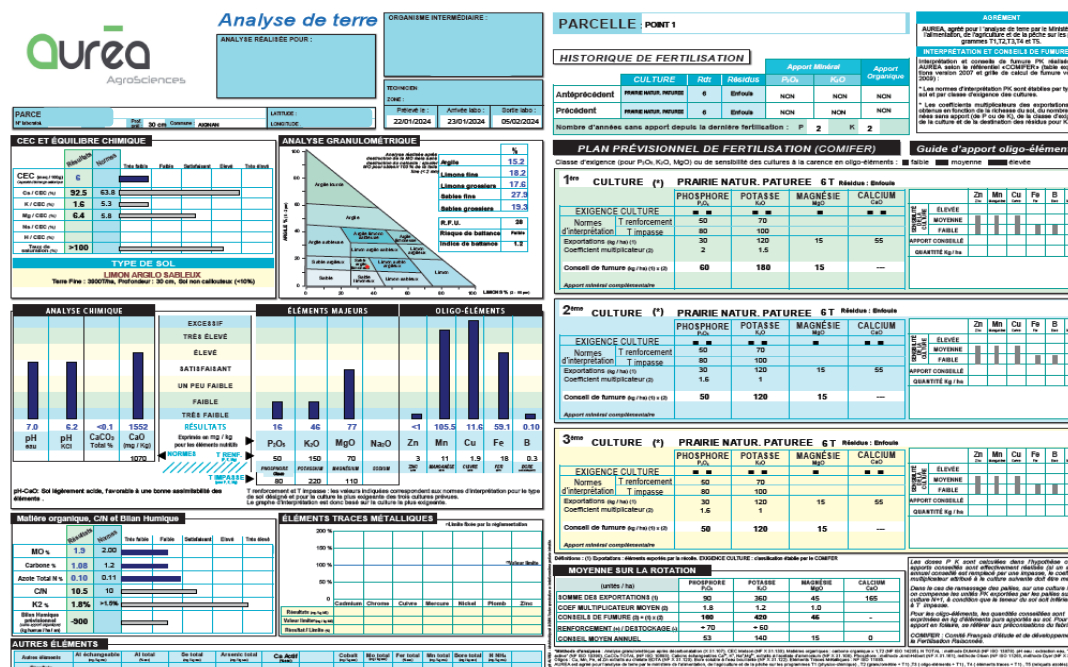
- Plot context
- Surface condition
- Soil profile
- Spade test (ISARA method)

- Total limestone
- pH
- Nutrients (P2O5, Cu...)

- Texture
- Organic carbon
- Total nitrogen

INTERPRETATION REFERENCES

- references from research and technical institutes (ISARA, Arvalis) and internal references (>500 plots)
- COMIFER and internal references (160,000 analysis/year)





Agro-Eco Sol offer



CONNAÎTRE

- Plot environment
- Soil structure

- The reservoir of chemical elements
- Physical and chemical characteristics of soil

- The soil's larder for organisms and crops in the short, medium and long term
- The C cycle (storage, recycling, transformation)

(BIO)INDICATOR

FIELD OBSERVATIONS
STRUCTURAL CONDITIONS

PHYSICAL-CHEMICAL SOIL ANALYSIS

C AND N INDICATORS

- Labile/stable carbon and nitrogen
- Microbial resources
- Living carbon
- Biologically mineralizable nitrogen

ANALYSIS

- Plot context
- Surface condition
- Soil profile
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- Total limestone
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- Nutrients (P2O5, Cu...)
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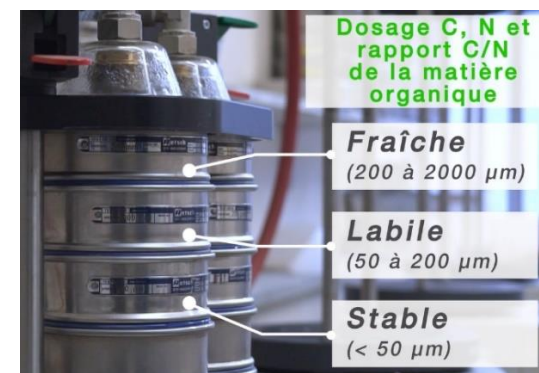
- C and N particle size fractionation
- Oxidizable carbon with KMnO4
- Microbial carbon (fumigation / extraction)
- Nitrogen mineralized by anaerobic incubation

INTERPRETATION REFERENCES

- references from research and technical institutes (ISARA, Arvalis) and internal references (>500 plots)

- COMIFER and internal references (160,000 analysis/year)

- AUREA internal references since 2008 (>7000 samples, by type of use - field crops, meadows, perennial crops, gardens)





Agro-Eco Sol offer



CONNAÎTRE

- Plot environment
- Soil structure

- The reservoir of chemical elements
- Physical and chemical characteristics of soil

- The soil's larder for organisms and crops in the short, medium and long term
- The C cycle (storage, recycling, transformation)

- Biodiversity
- The transformation of elements in the soil (nutrient cycle)
- Decomposition of organic matter
- Structural stability
- Water infiltration
- System sustainability

(BIO)INDICATOR

FIELD OBSERVATIONS STRUCTURAL CONDITIONS

PHYSICAL-CHEMICAL SOIL ANALYSIS

C AND N INDICATORS

- Labile/stable carbon and nitrogen
- Microbial resources
- Living carbon
- Biologically mineralizable nitrogen

MICROBIOLOGICAL BIOINDICATORS AND SOIL FAUNA

- Microbial abundance
- Fungi/bacteria ratio
- Bacterial and fungal diversity
- Enzymatic activity
- Abundance and diversity of earthworms, ground beetles, collembola and nematodes

ANALYSIS

- Plot context
- Surface condition
- Soil profile
- Spade test (ISARA method)

- Total limestone
- pH
- Nutrients (P2O5, Cu...)
- Texture
- Organic carbon
- Total nitrogen

- C and N particle size fractionation
- Oxidizable carbon with KMnO4
- Microbial carbon (fumigation / extraction)
- Nitrogen mineralized by anaerobic incubation

- Molecular microbial biomass
- Relative abundance fungi/bacteria by 16S and 18S rDNA qPCR
- Bacterial and fungal diversity by 16S and 18S rDNA high-throughput sequencing
- Carbon cycle (beta-Glucosidase, beta galactosidase), Nitrogen cycle (Arylamidase), Phosphorus cycle (Global Phosphatase), Sulfur cycle (Arylsulfatase)
- Soil fauna: morphological identification (density, biomass, specific diversity, functional diversity)

INTERPRETATION REFERENCES

- references from research and technical institutes (ISARA, Arvalis) and internal references (>500 plots)

- COMIFER and internal references (160,000 analysis/year)

- AUREA internal references since 2008 (>7000 samples, by type of use - field crops, meadows, perennial crops, gardens)

- Bacteria, fungi and enzymatic activities : RMQS data + INRAE experimentations >2000 samples
Auréo is co-owner of the F/B ratio interpretation references
- Nematodes: ELISOL references (>7000 samples)
- Earthworms, carabid beetles, collembola: around 1,000 samples from research works

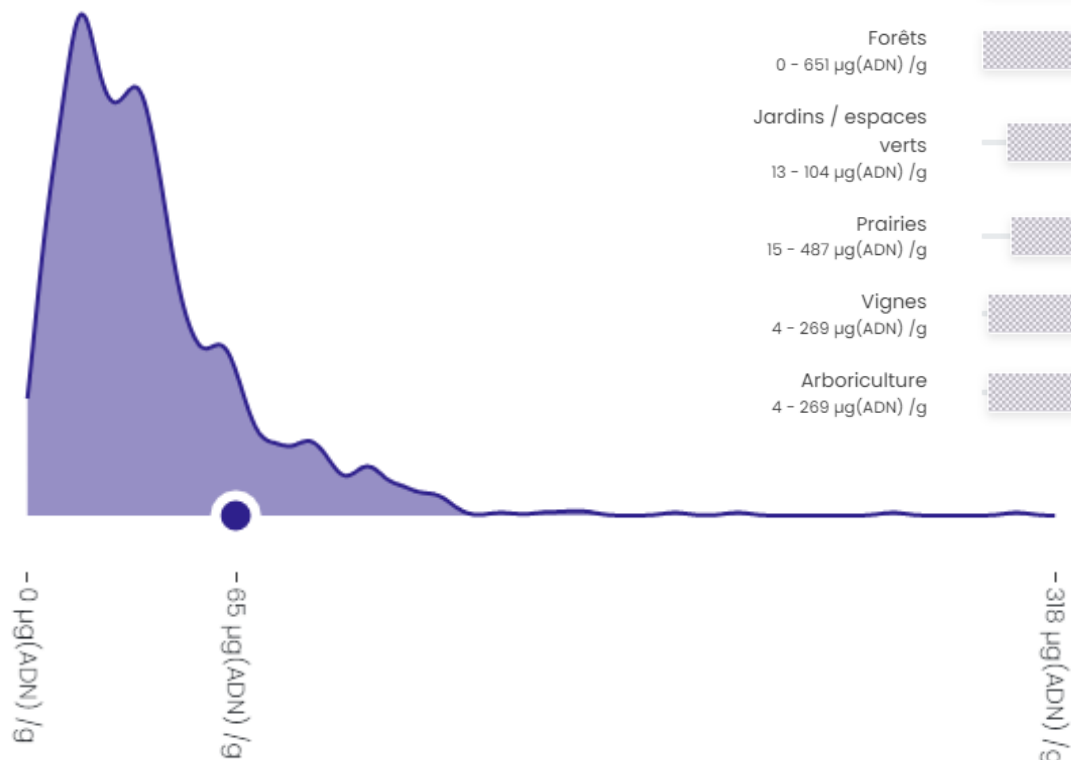


Interpretation - Relative positioning

Biomasse microbienne moléculaire

■ Référentiel Grandes cultures ● LA GRANGE GRAND-MÈRE 2023

Distribution des parcelles



Grandes cultures
0 - 318 $\mu\text{g(ADN) / g}$

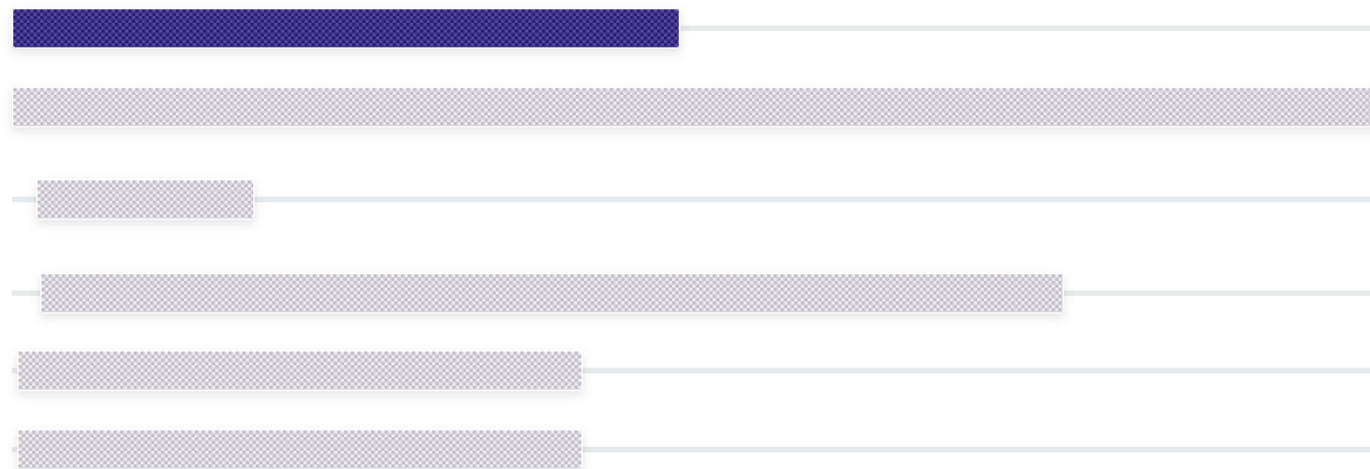
Forêts
0 - 651 $\mu\text{g(ADN) / g}$

Jardins / espaces
verts
13 - 104 $\mu\text{g(ADN) / g}$

Prairies
15 - 487 $\mu\text{g(ADN) / g}$

Vignes
4 - 269 $\mu\text{g(ADN) / g}$

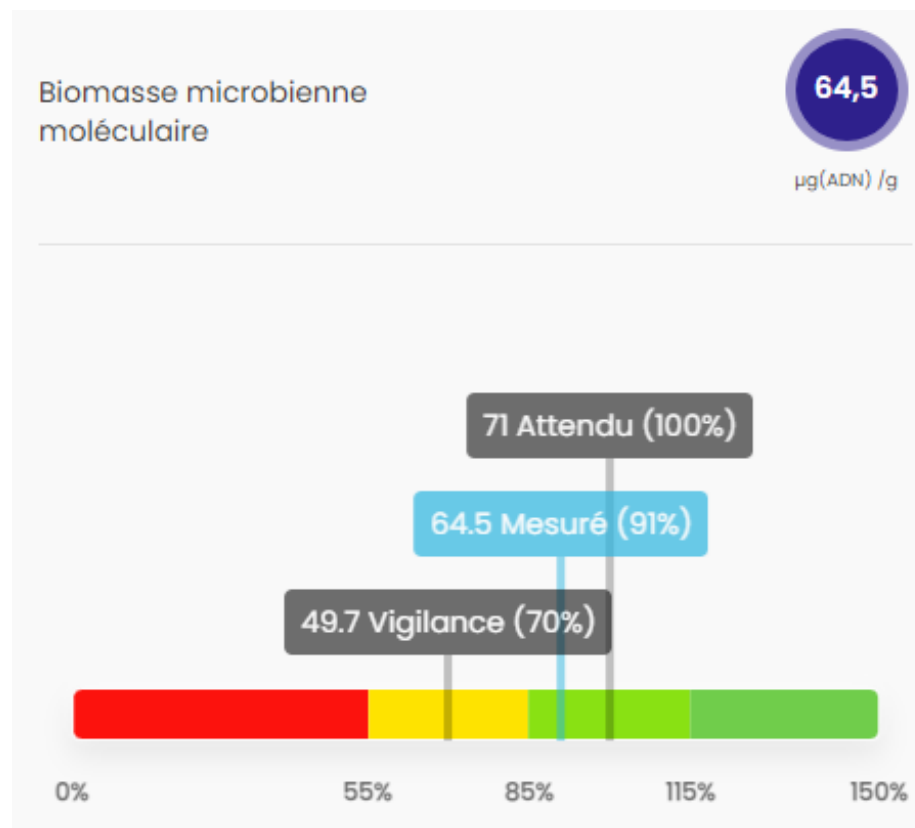
Arboriculture
4 - 269 $\mu\text{g(ADN) / g}$





Interpretation - Predictive models

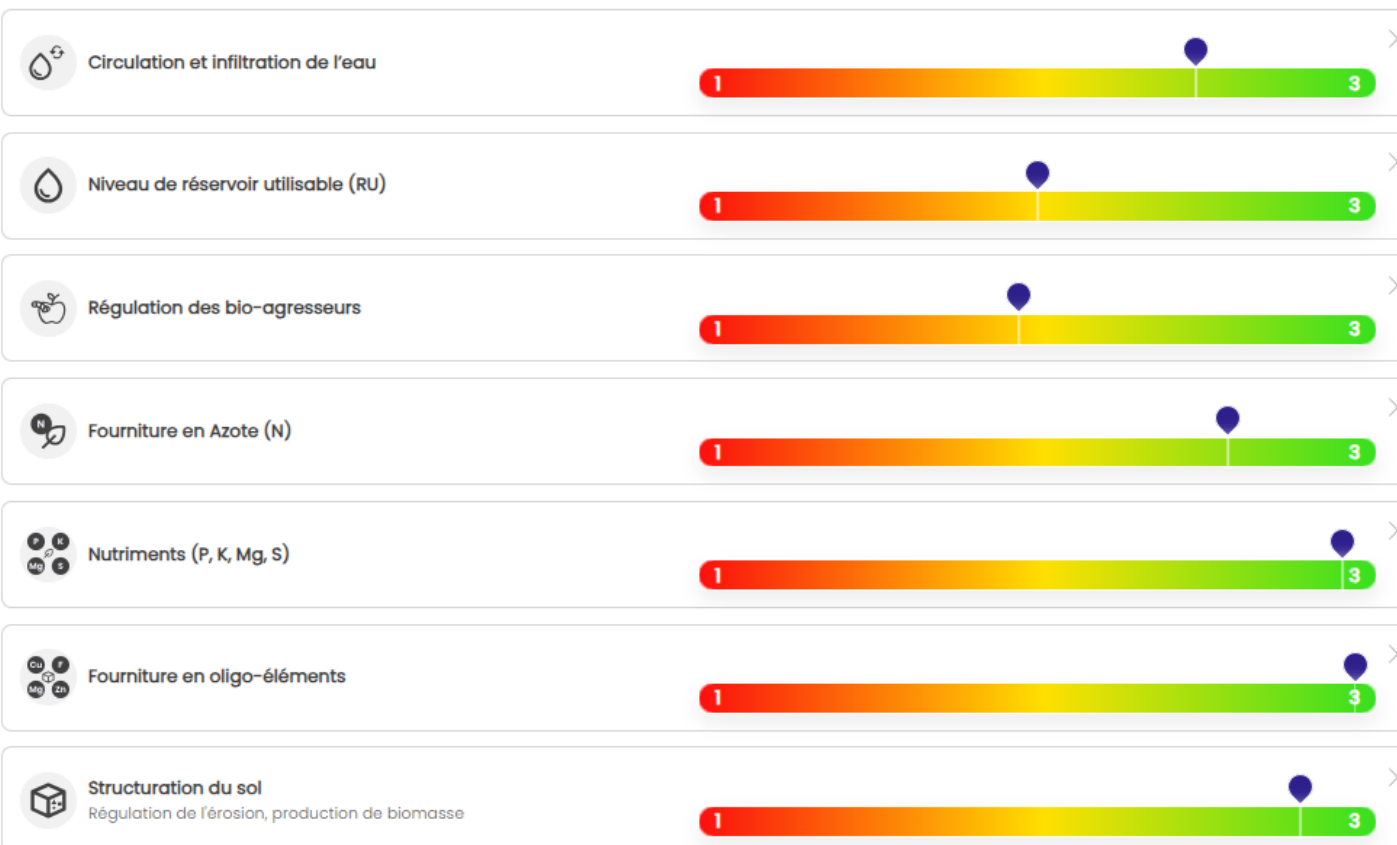
- **Estimation of an expected value** (and a vigilance value) as a function of physico-chemistry and plot location
- Predictive models for **molecular microbial biomass, F/B ratio and bacterial and fungal diversity**
- Assessment of the **impact of agronomic practices** by comparing the measured value with the expected value





Interpretation - Functional diagnosis

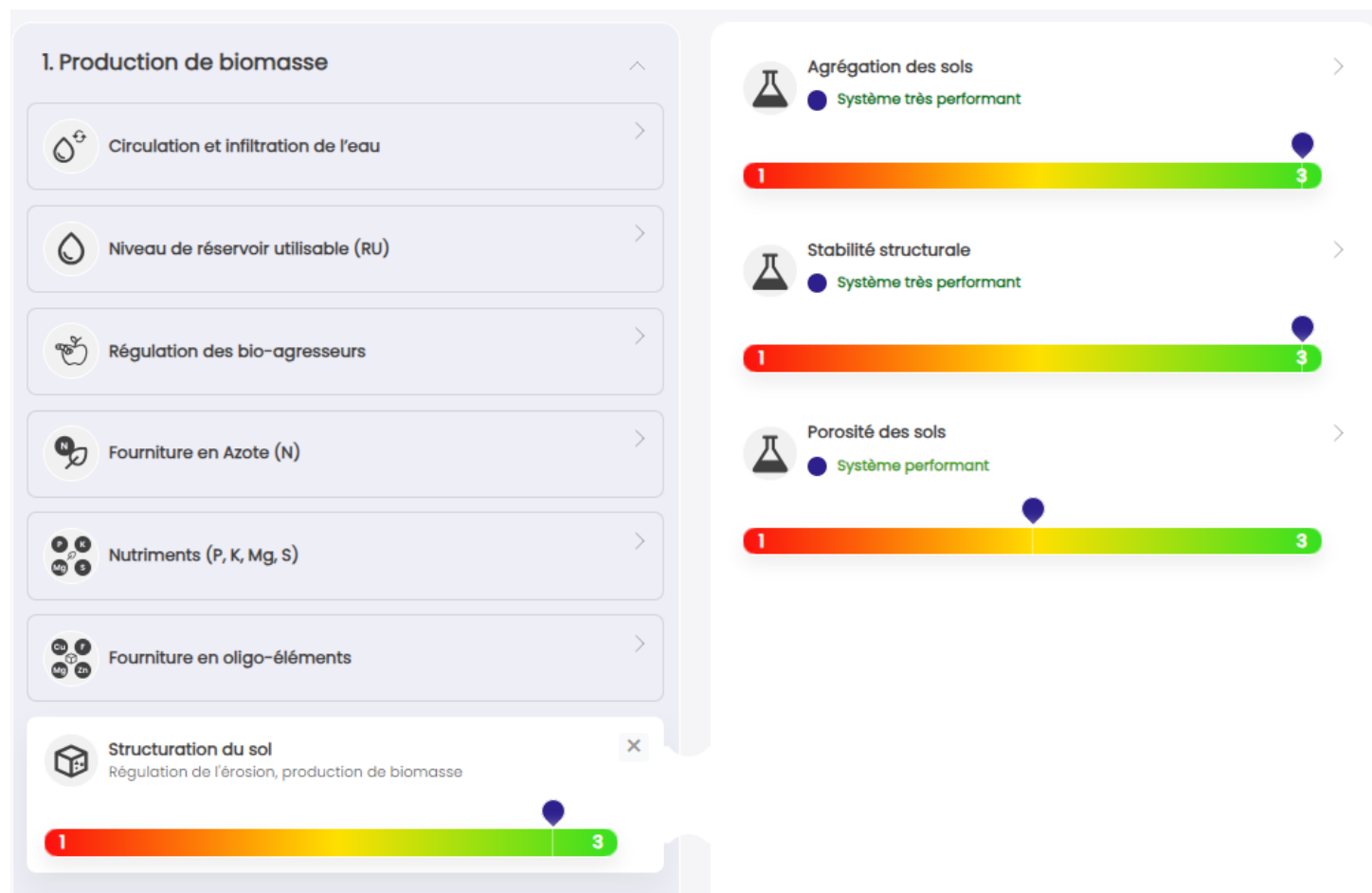
1. Production de biomasse





Agro-Eco Sol offer

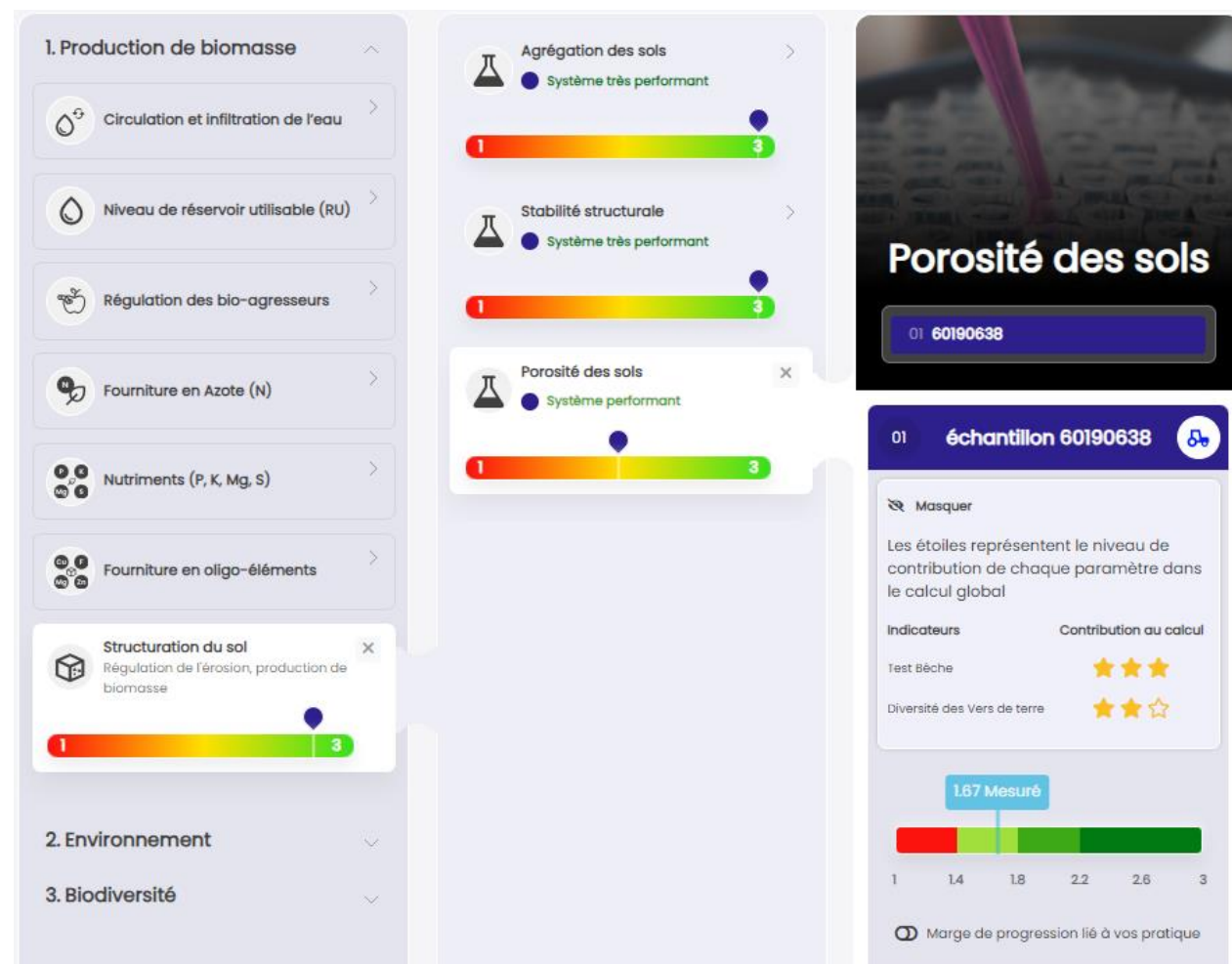
Interpretation - Functional diagnosis





Interpretation - Functional diagnosis









Process score resulting from a comparison between a measured level (aggregation of indicators) and an expected level (based on pedoclimate and agronomic practices).





Advice – Suggested agronomic practices

Proposal for prioritizing
agronomic practices
based on functional
diagnosis

A mettre en place	A considérer	Continuez ainsi !
<div>À METTRE EN PLACE Travail du sol Réduire la fréquence de travail du sol</div>	<div>À CONSIDÉRER Gestion des résidus de culture Augmenter la fréquence de restitution des résidus de culture</div>	<div>CONTINUER AINSI Paysage Développer des habitats faunistiques</div>
<div>À METTRE EN PLACE Gestion des couverts Augmenter la fréquence de couverts intermédiaires dans la succession</div>	<div>À CONSIDÉRER Succession de culture Diversifier la rotation culturale</div>	RAS !
<div>À METTRE EN PLACE Apports organiques Augmenter la quantité de Produits Organiques apportée</div>		<div>PAS D'ACTION PRIORITAIRE Aménagements hydriques Les Aménagements hydriques de votre parcelle ne permettent pas de dégager des pistes d'amélioration</div>
		<div>PAS D'ACTION PRIORITAIRE Apports minéraux Limiter au maximum les excès d'apport d'azote</div>



Agro-Eco Sol offer

Advice – Suggested agronomic practices





Perspectives - Extension to other land uses and pedoclimatic contexts

Indicators

Measurement methods: a priori compatible with all uses, but check representativeness in media with a high coarse element load (analyses carried out on fraction < 2 mm).

Interpretation references : to be validated/constructed for ranges of variation and consolidated for links between indicators and soil functions.

Functional diagnostic and advice

Soil functions: what are the priorities and targeted levels for different uses?

Advice: what are the requirements for different uses?



LE GRAND PLAN
D'INVESTISSEMENT