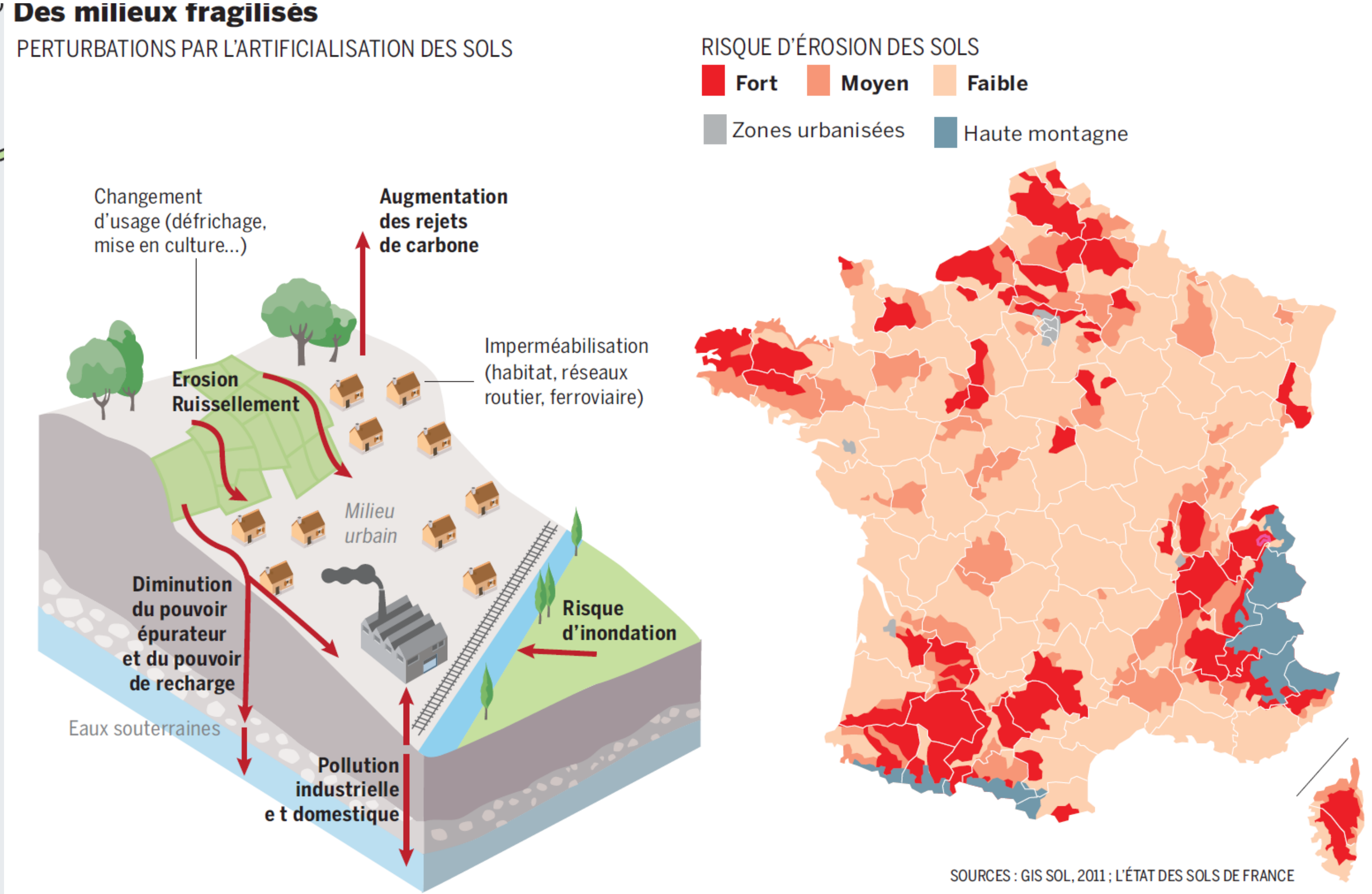
S O S

Béton, érosion, pollution minent les sols français

Fruit de dix ans de travail, le premier bilan de l'état pédologique du territoire invite à une gestion plus durable



Steve

Le mode de gestion des intrants organiques des sols à l'échelle de la parcelle contrôle la distribution, la biodisponibilité et l'impact du Cu à µ-échelle

Jean M.F. Martins, Aline Navel, Lionel Ranjard, Alain Manceau, Pierre Alain Marron, Isabelle Lamy, Pierre Faure, Lorenzo Spadini.

Remédiation :

restauration de la fertilité des sols

par des amendements organiques

Project funded by the French national EC2CO program

L T H E

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CONTEXT

Copper : oligo-element naturally present in soils (~2-50 ppm)

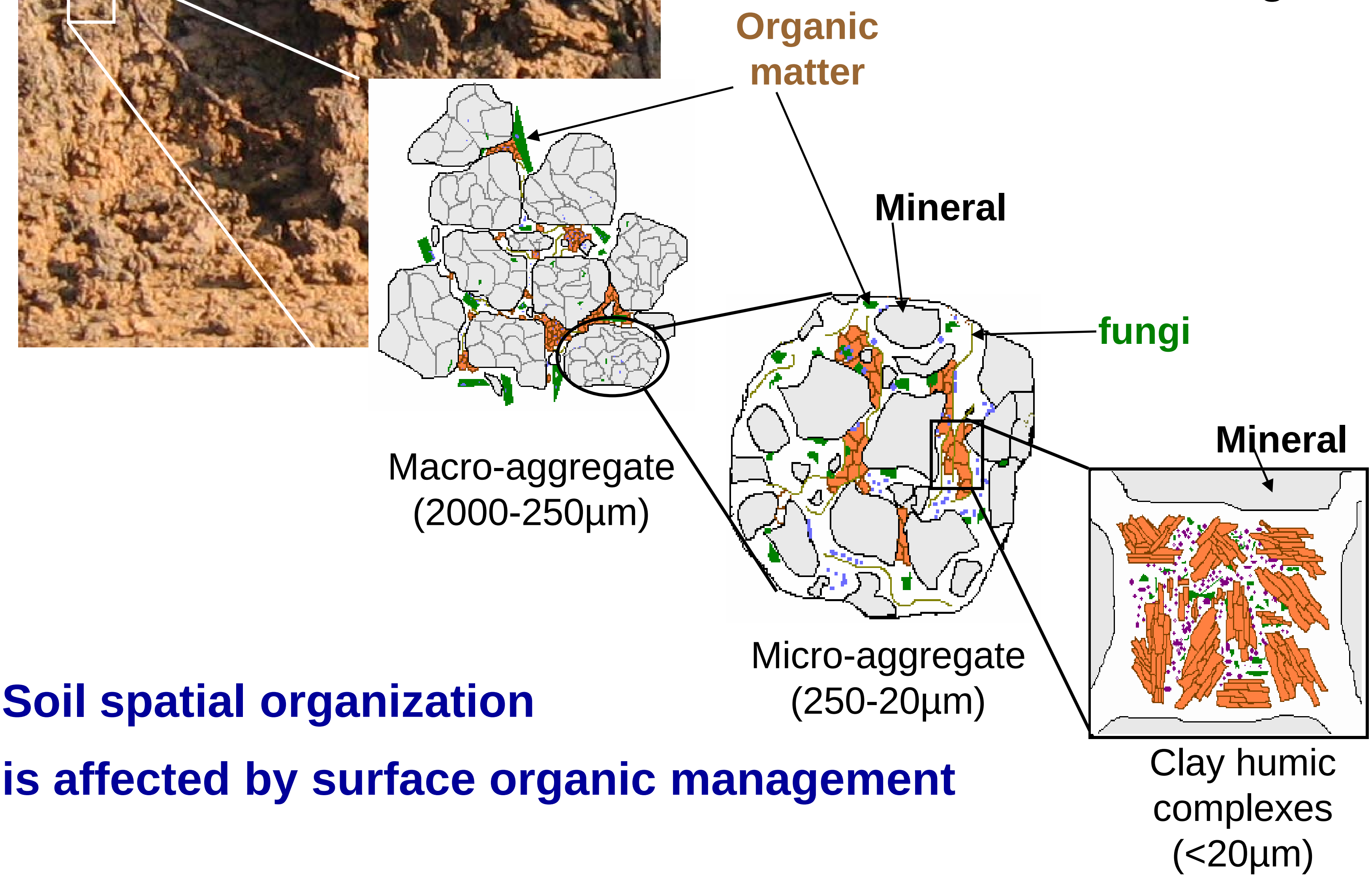
Vineyard soils:

* * Copper is largely used in France as **pesticide** (Bordeaux mixture)
* * Copper strongly a**ccumulates > 1000 ppm**
* * **Toxic** to soil organisms at such high concentration

Biogeochemical factors that control copper impact on soils are poorly understood, especially in vineyard managed soils

Natural soils are spatially structured heterogeneous systems

➔ present an aggregate-based organization

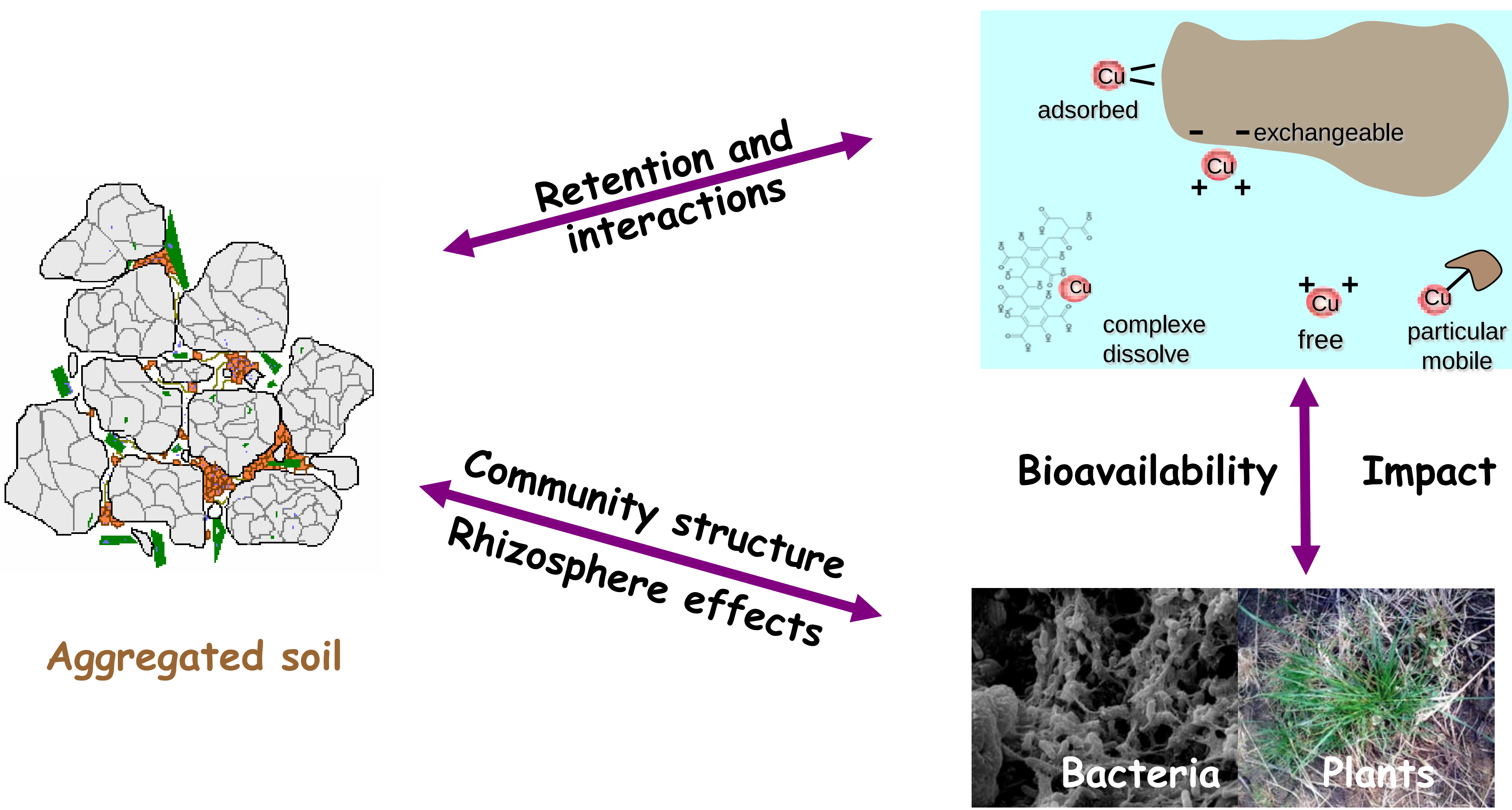


Soil spatial organization

is affected by surface organic management

Objectives :

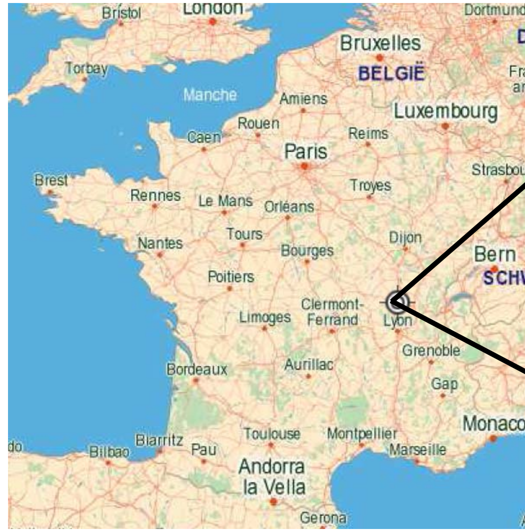
To investigate the relation between the field scale management of organic matter of a vineyard soil and the distribution and speciation of copper at the micro-aggregate scale and its bioavailability to bacteria and plants.



MOBIPO-Cu project funded by the French national program EC2CO, CNRS

The field site

Vineyard soil – Clessé (Burgundy, France)

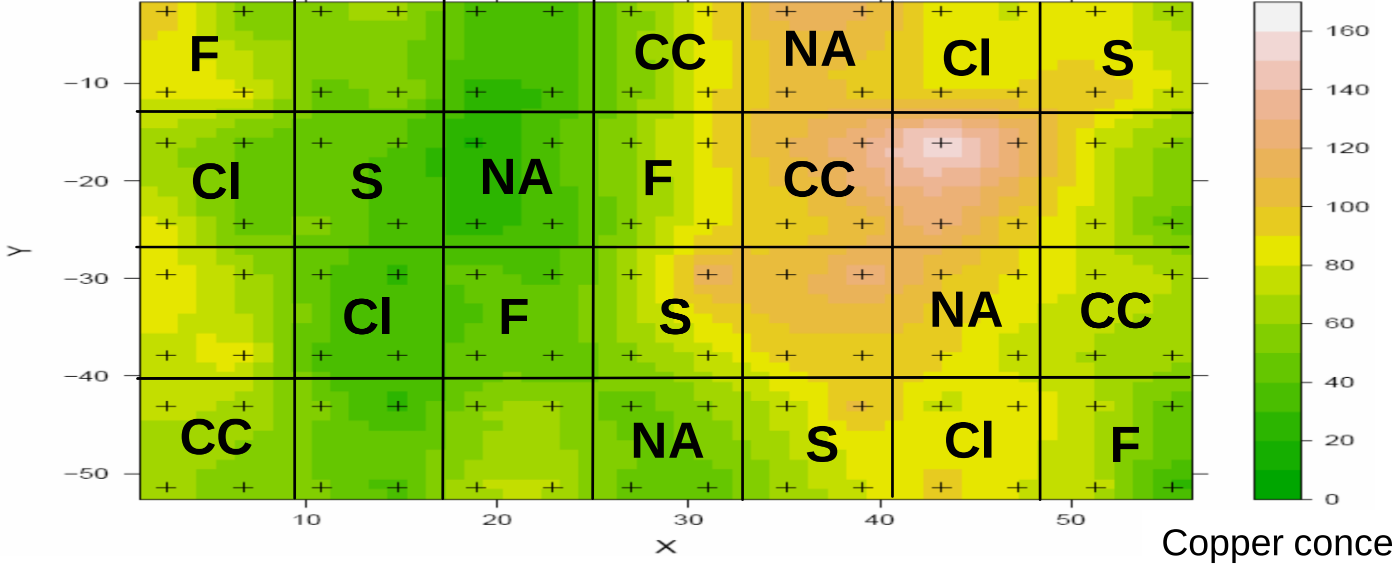


1 soil

➔ **5 organic status :**

Soil amended/vegetated during 20 years:

- **Non Amended Control soil (NA)**
- **Straw amendment (S)**
- **Conifer Compost amendent (CC)**
- **Fescue vegetation (F)**
- **Clover vegetation (Cl)**



Sampling of <u>50 kg of the 5 surface soils</u>

Soil pre-drying and sieving

Soil analysis

All collected soil samples ➔ same analytical characterization

1 → Soil fractionation

2 → Soils and size fractions analysis (OC, N, Cu, Major elements…)

3 → Copper speciation and availability

Cu retained in the solid matrix

$[Cu]_{Tot.}$
ICP-OES after extractions (*aqua regalis*)

Solid speciation :
EXAFS Spectroscopy

Cu released to soil solution

Ca-exchangeable Cu

$[Cu_{ex}]_{tot}$: **ICP-AES**

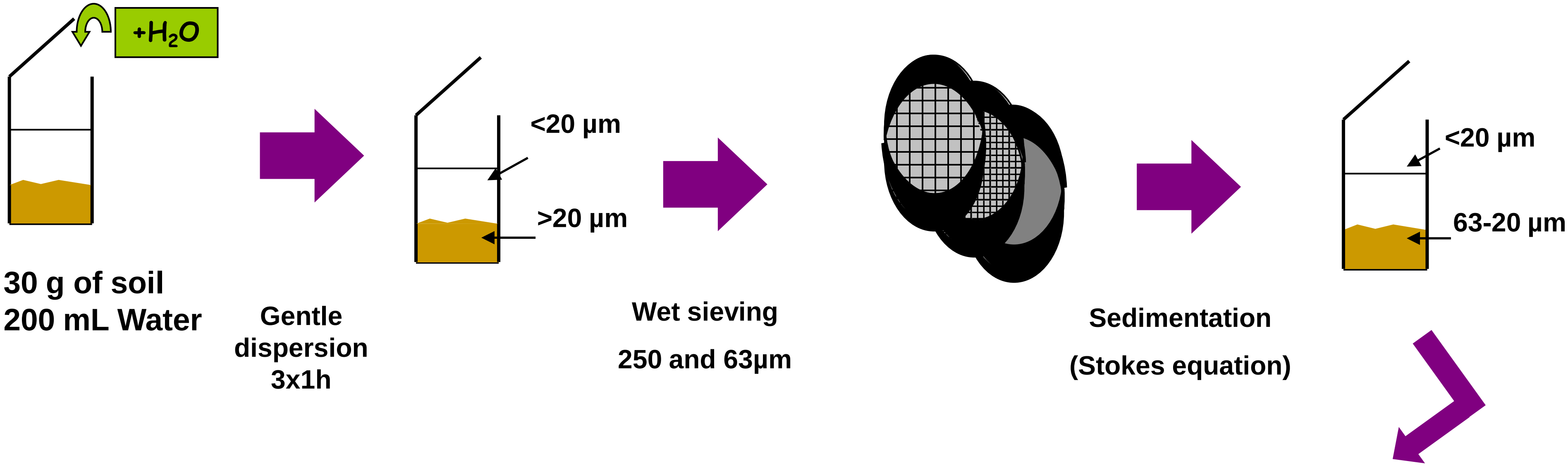
Cu bioavailable to bacteria and plants

Cu-Biosensor: *Pseudomonas fluorescens* DF57 $[Cu]_{Bio}$
(Tom-Peterson et al. 2001)

Cu-accumulation by the ryegrass *Lolium perenne*

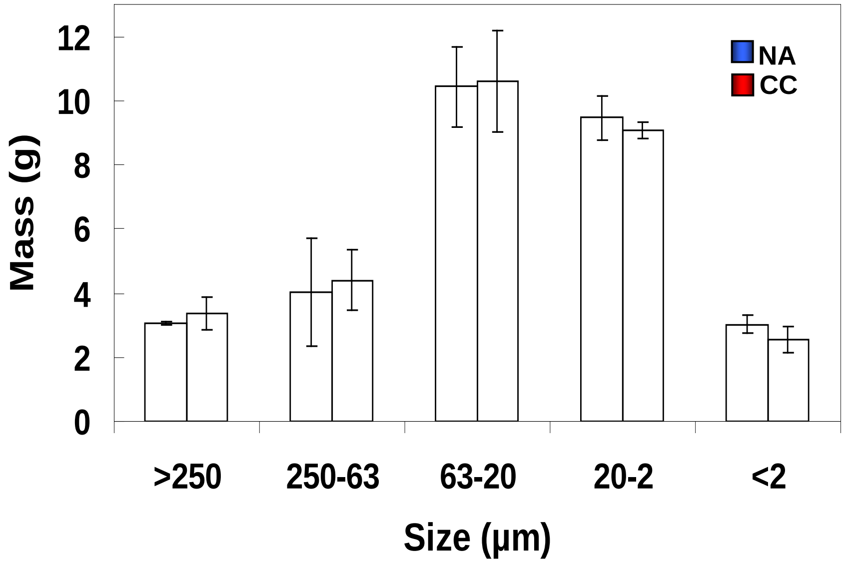
Total copper | **Mobile copper** | **Toxic copper**

Non destructive physical fractionation of soils using Ladd's procedure adapted by Monrozier et al. (1991)



5 size-fractions (NA and CC soils):
Specific functional compartments

➔ **Loamy soil**



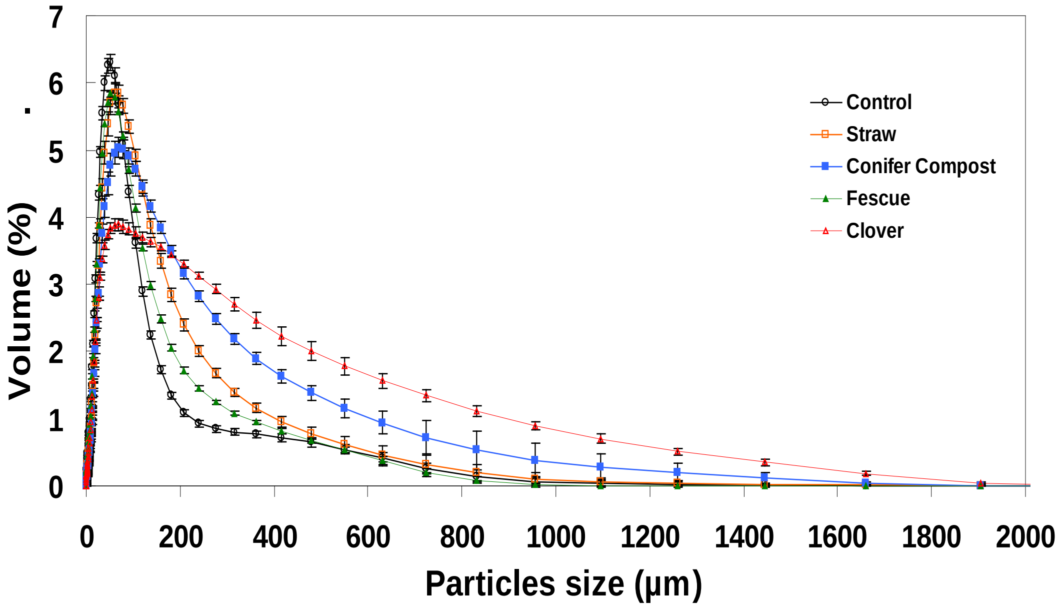
Main bio-physical-chemical properties of the five soils

	Texture (%)			Bulk Density	Tot. Org. C	Tot. Org. N	pH_w	Total Cu	Biomass-C
	Sand	Silt	Clay	$g.cm^{-3}$	$g_C.kg^{-1}{}_{ds}$	$g_C.kg^{-1}{}_{ds}$		$mg_{Cu}.kg^{-1}{}_{ds}$	$mg_C.kg^{-1}{}_{ds}$
Control	16,3 ± 0,7	73,5 ± 1,4	10,2 ± 0,4	1,34 ± 0,03	15,2 ± 5,1	1,1 ± 0,2	6,3 ± 0,03	118 ± 4	238
Straw	23,6 ± 0,3	68,6 ± 0,5	7,8 ± 0,1	1,38 ± 0,13	20,4 ± 6,7	1,5 ± 0,3	5,9 ± 0,03	91 ± 4	465
Conifer Compost	20,2 ± 0,4	70,6 ± 0,7	9,2 ± 0,1	1,33 ± 0,08	30,3 ± 3,9	1,6 ± 0,1	6,3 ± 0,03	102 ± 5	492
Fescue	22,9 ± 0,6	68,7 ± 1,1	8,3 ± 0,1	1,35 ± 0,09	17,3 ± 4,2	1,3 ± 0,2	6,1 ± 0,02	89 ± 9	430
Clover	30,1 ± 0,6	64,3 ± 0,6	5,7 ± 0	1,33 ± 0,07	23,6 ± 3,6	1,9 ± 0,2	5,6 ± 0,1	106 ± 6	432

➔ The soil treatments induced mainly increases of Organic Carbon content and microbial biomass

➔ All other parameters remained almost constant

Particle size distributions (PSD) of the five soils otained by laser granulometry with and without ultrasonication

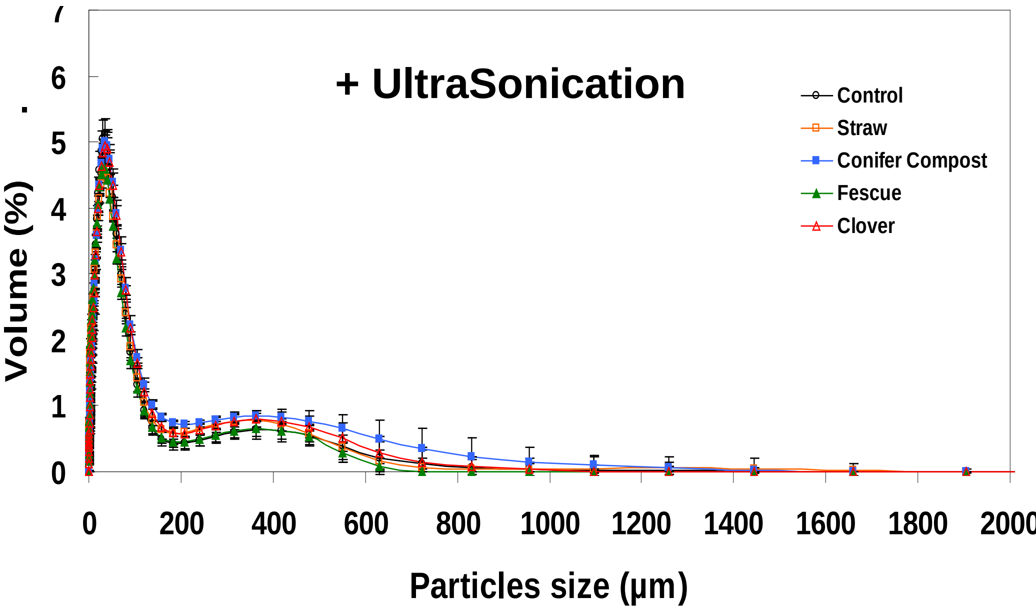


➔ Strong modification of the soil PSD by the 20 years of organic amendment and vegetation

➔ Increased aggregation of the smallest particles (<50µm) into larger aggregates of sizes ranging from 0.1 up to 2 mm with the **Conifer compost** **and** **clover**

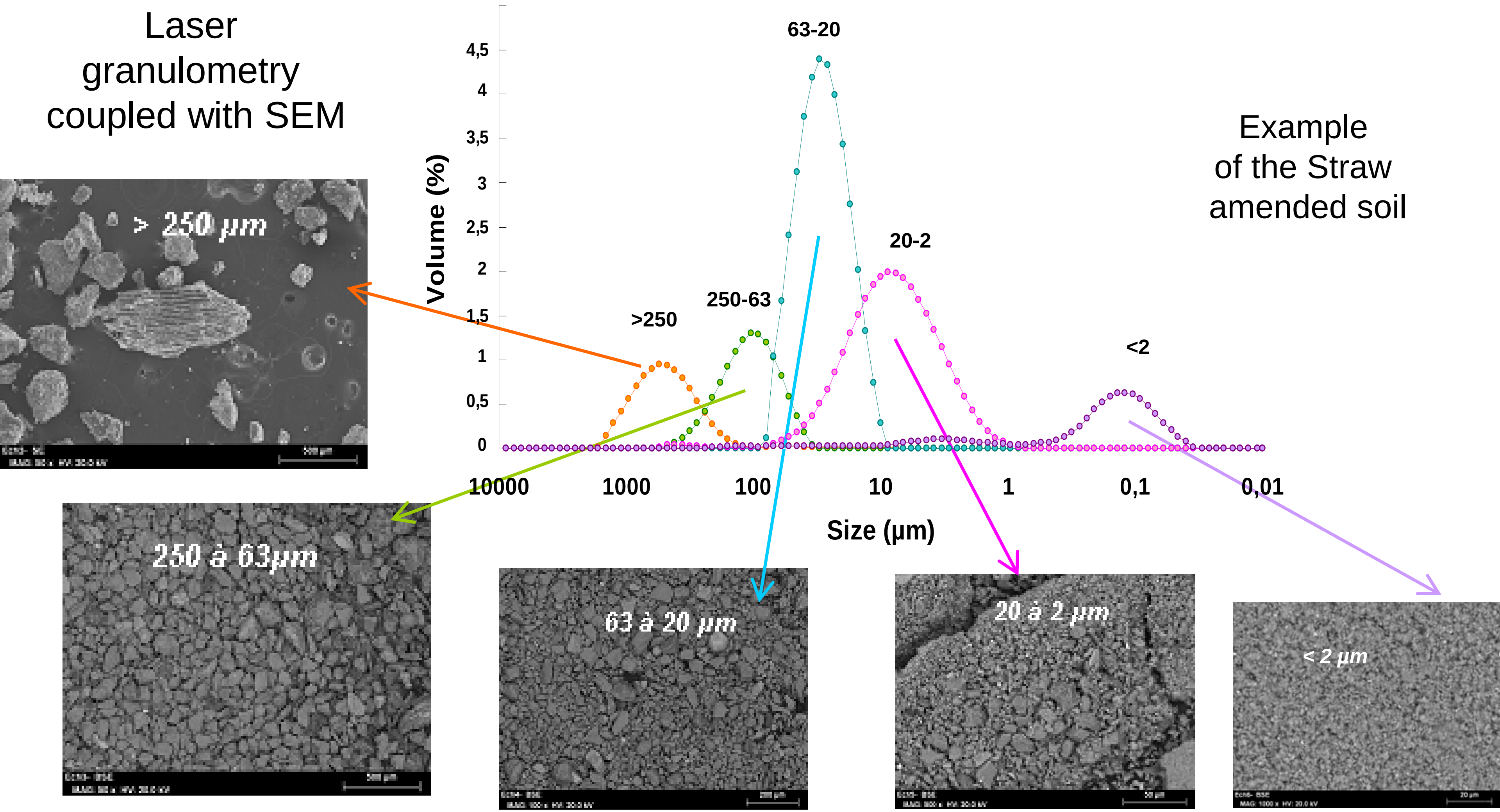
Ultrasonication destroys soils aggregates

➔ Same texture of the 5 soils



Particle size distributions (PSD) of the size-fractions of the 5 soils

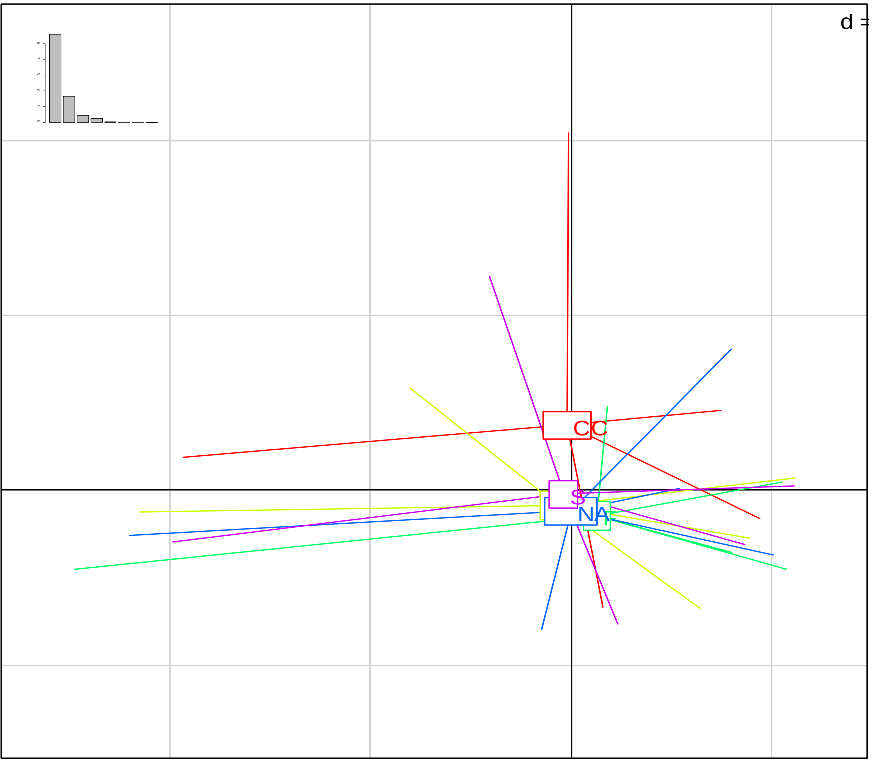
Laser granulometry coupled with SEM

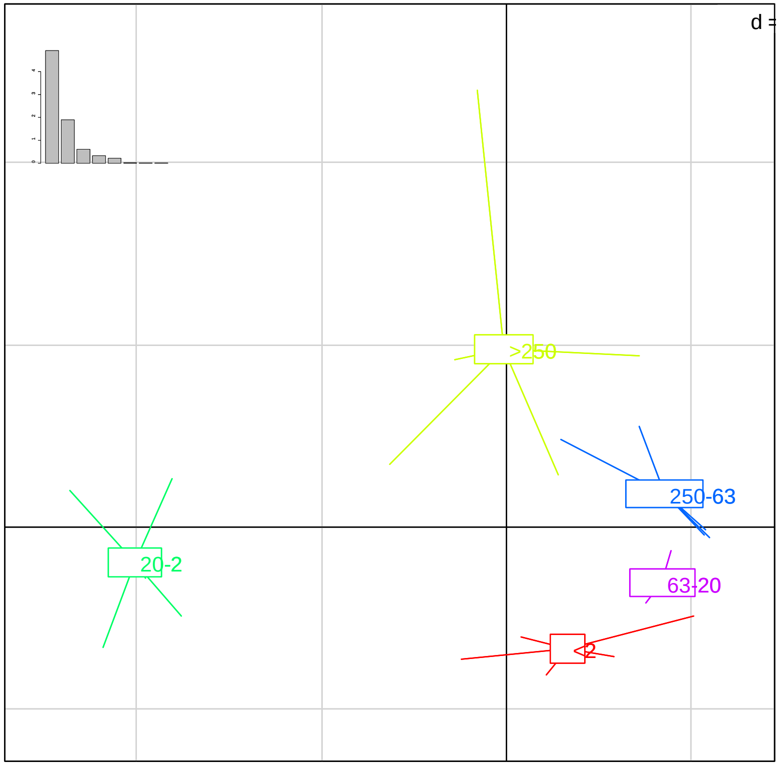


Example of the Straw amended soil

➔ Good separation of the soil compartments and preservation of their aggregated structure by the physical fractionation procedure

PCA of the major elements contents in the five soils and in their size-fractions





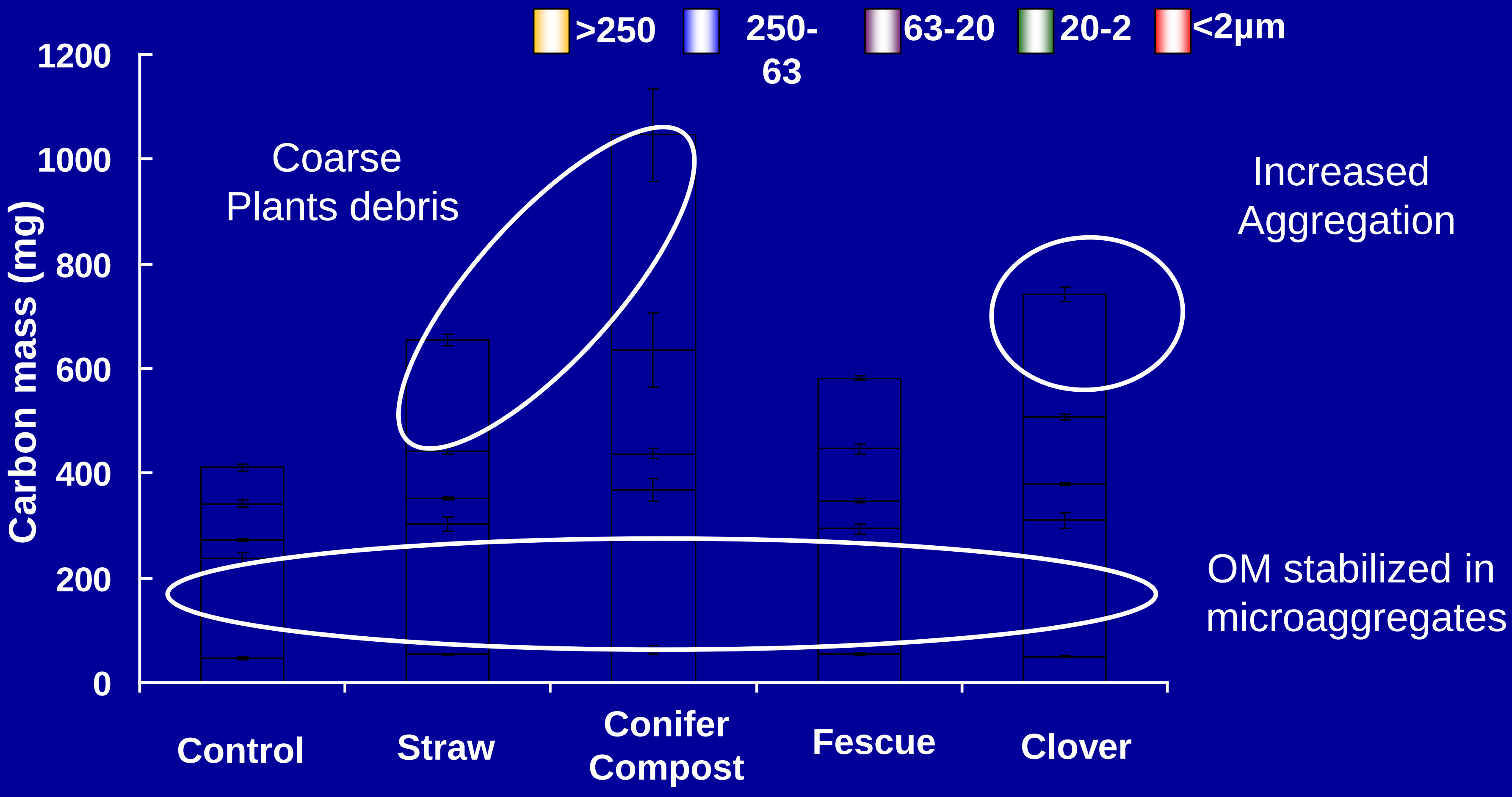
No significant difference between soils

➔ soil treatments did not modify soil's elementary composition.

The 5 subfractions of the soils appeared strongly different in terms of chemical composition confirming that

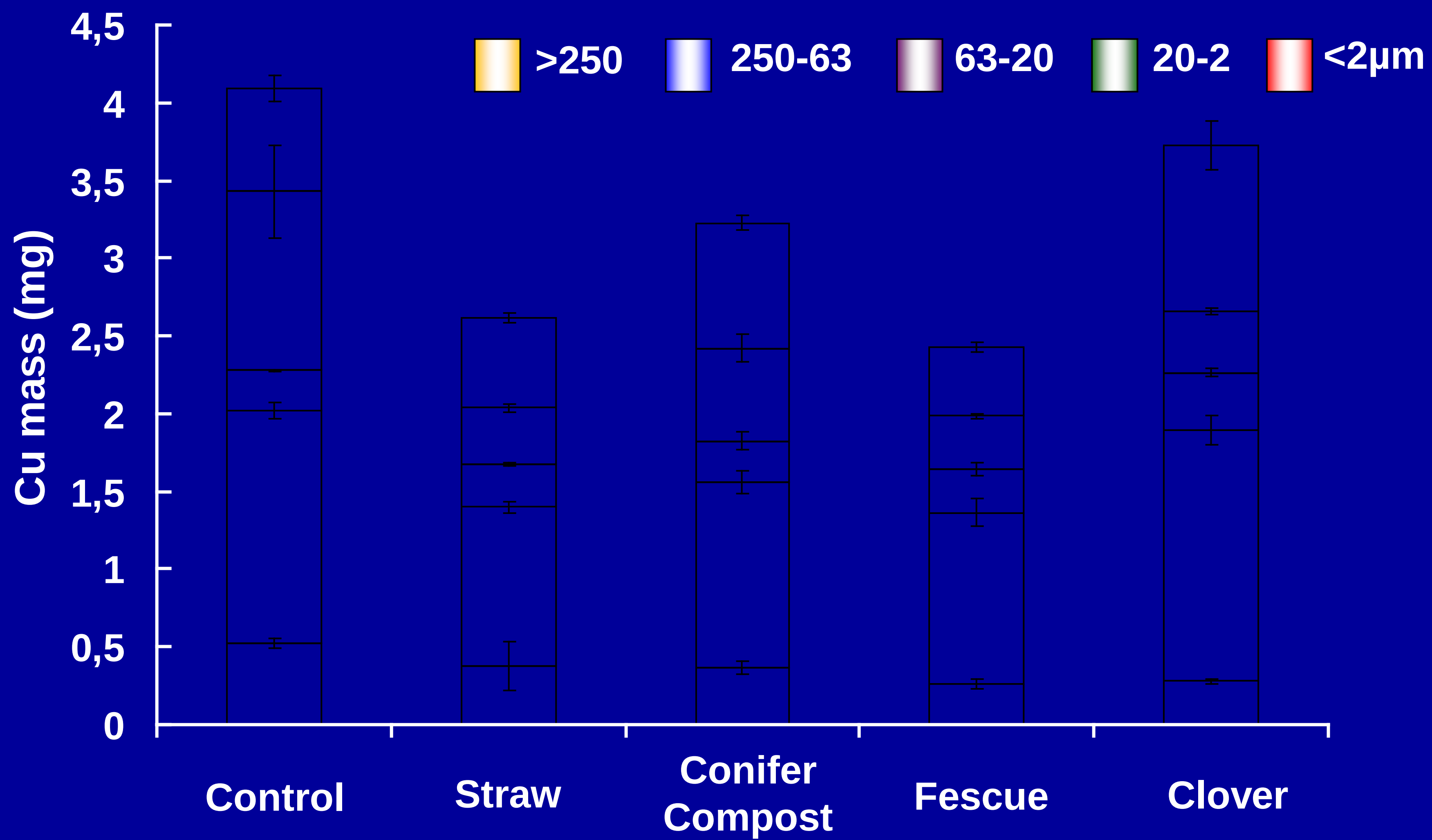
➔ each soil size fraction constitutes an independent biogeochemical fabric.

Distribution of the mass of total organic carbon in the five size-fractions of the Clessé soil



<2µm and 63-20µm fractions are insensitive to soil treatments

Distribution of the mass of copper retained in the five size-fractions of the Clessé soil



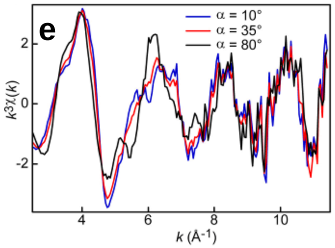
Copper accumulates preferentially in the finest (>20µm) and coarser (>250µm) fractions ➔ up to 80% of Cu

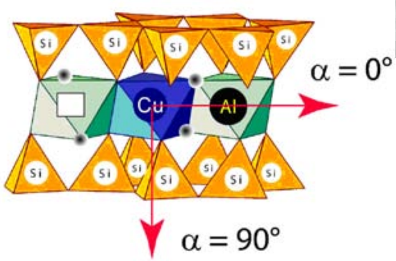
Solid Copper speciation in the bulk soils

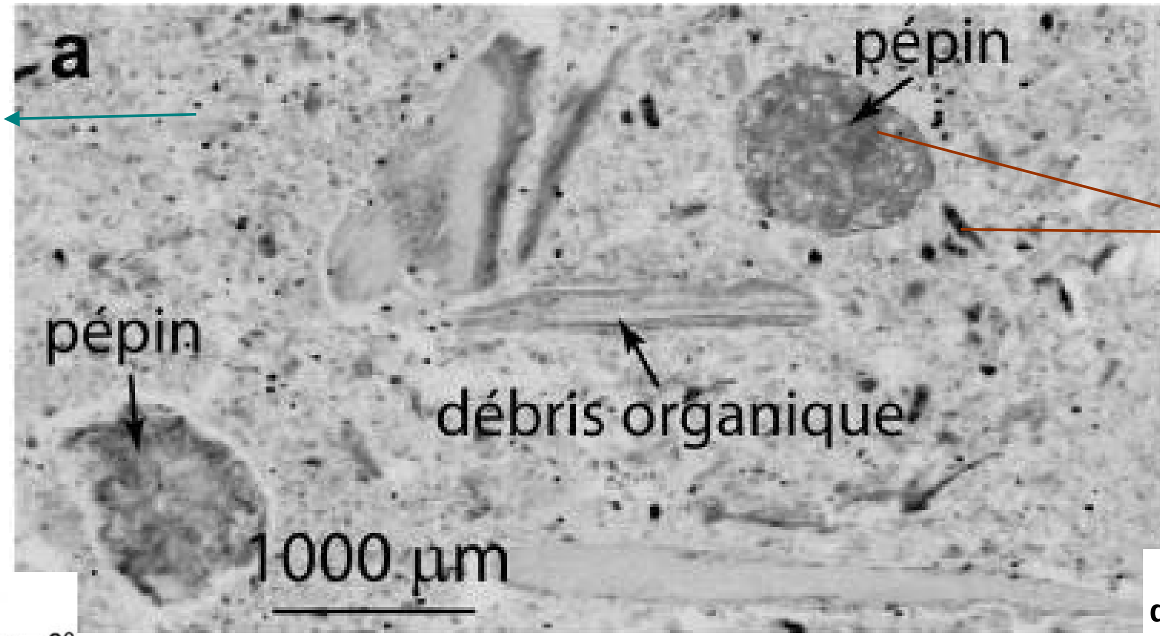
(Data from Alain Manceau)

Map of Cu distribution at the Cu K-Edge

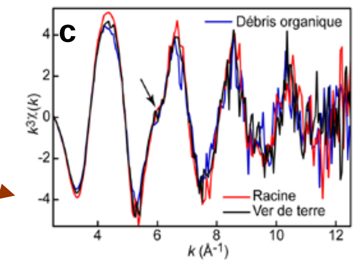
Cu-Clay associations



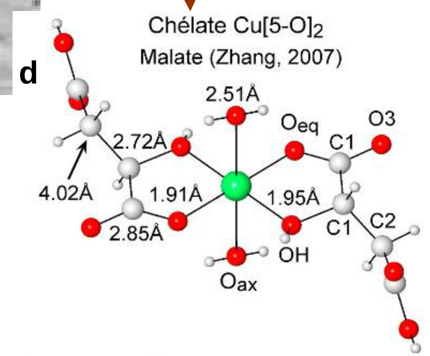




Organic elements



Similar spectra



Courtesy of Alain Manceau

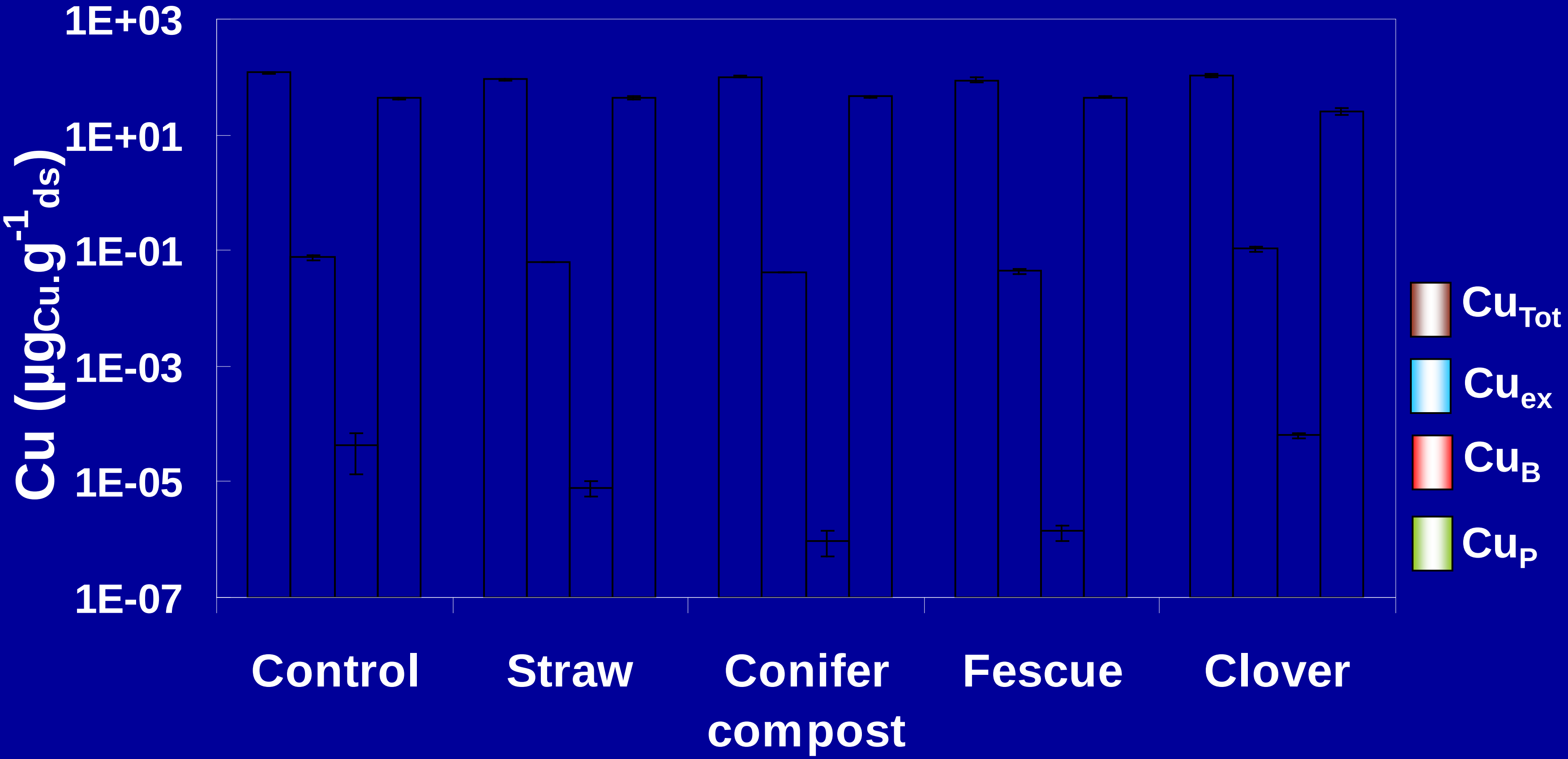
[Cu] = grey scale

Copper penetrated the whole soil matrix : organic and inorganic compartments.

➔ **Diffuse association of Cu with the crystalline network of clays (light grey)**

➔ **Specific Cu accumulation in organic components (dark grey or black).**

Effect of soil treatment on copper retention, speciation and bioavailability



Cu_{Tot} similar in the five soils

Cu exchangeable with Ca is lower in the amended soils (decreased mobility)

Cu bioavailable to bacteria is lower in S, CC and F soils (decreased toxicity)

Cu accumulated in the ryegrass *Lolium perenne* is lower in the clover soil (decreased Cu accessibility)

Soils are constituted of a mosaic of functional compartments (habitats)

Conclusions & Outlook

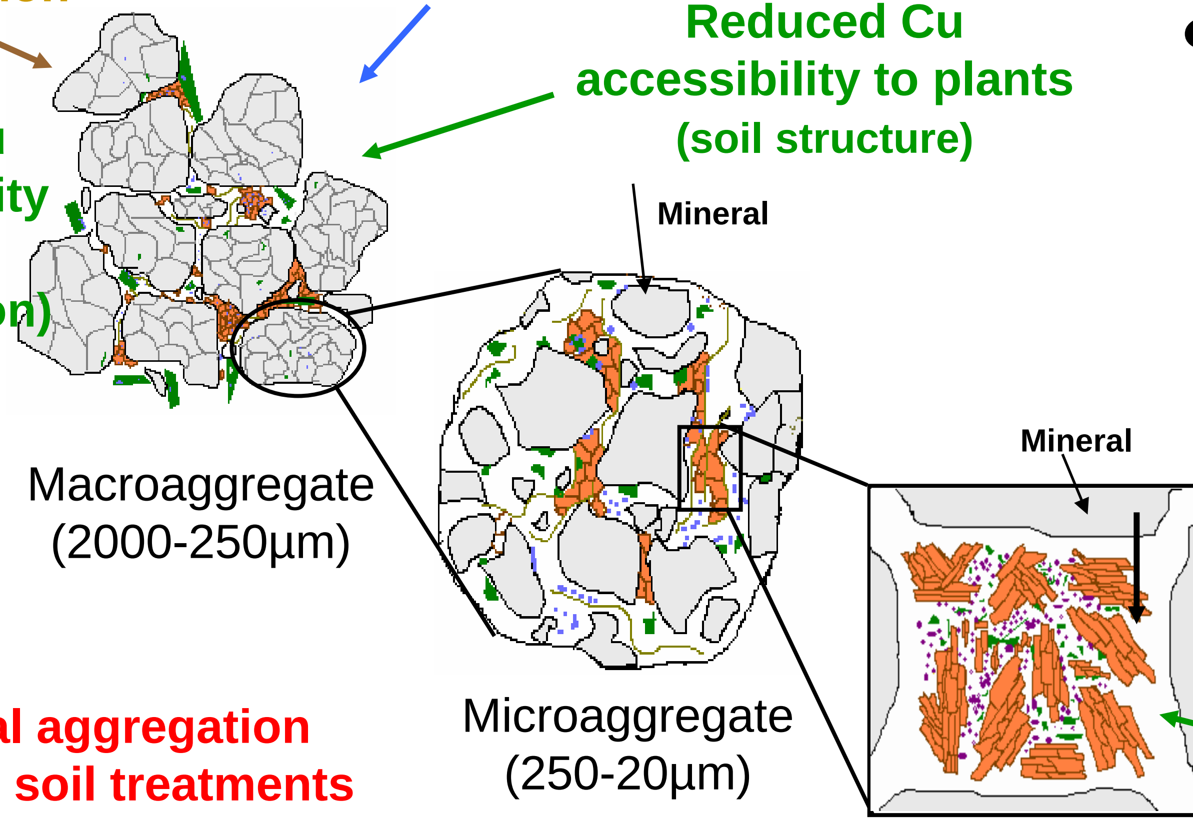
Preferential OM accumulation

Cu retention by coarse OM

Reduced Cu accessibility to plants (soil structure)

Reduced Cu Bioavailability (ligand complexation)

Cu retention by clay & OM



Macroaggregate (2000-250µm)

Microaggregate (250-20µm)

Clay-humic complex (<20µm)

Evolved and reactive OM

Increased Cu bioavailability and toxicity to bacteria

Differential aggregation effect of the soil treatments (clover and compost)

Thank you for your attention

LTHE

MARTINS Jean

SPADINI Lorenzo

LGIT

SPADINI Lorenzo

MANCEAU Alain

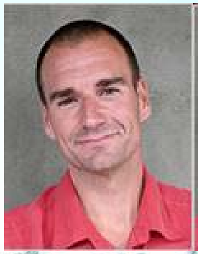
G2R

FAURE Pierre

INRA Pessac

LAMY Isabelle

INRA Dijon



RANJARD Lionel

NAVEL Aline

VINCE Erwann

MARON Pierre-Alain

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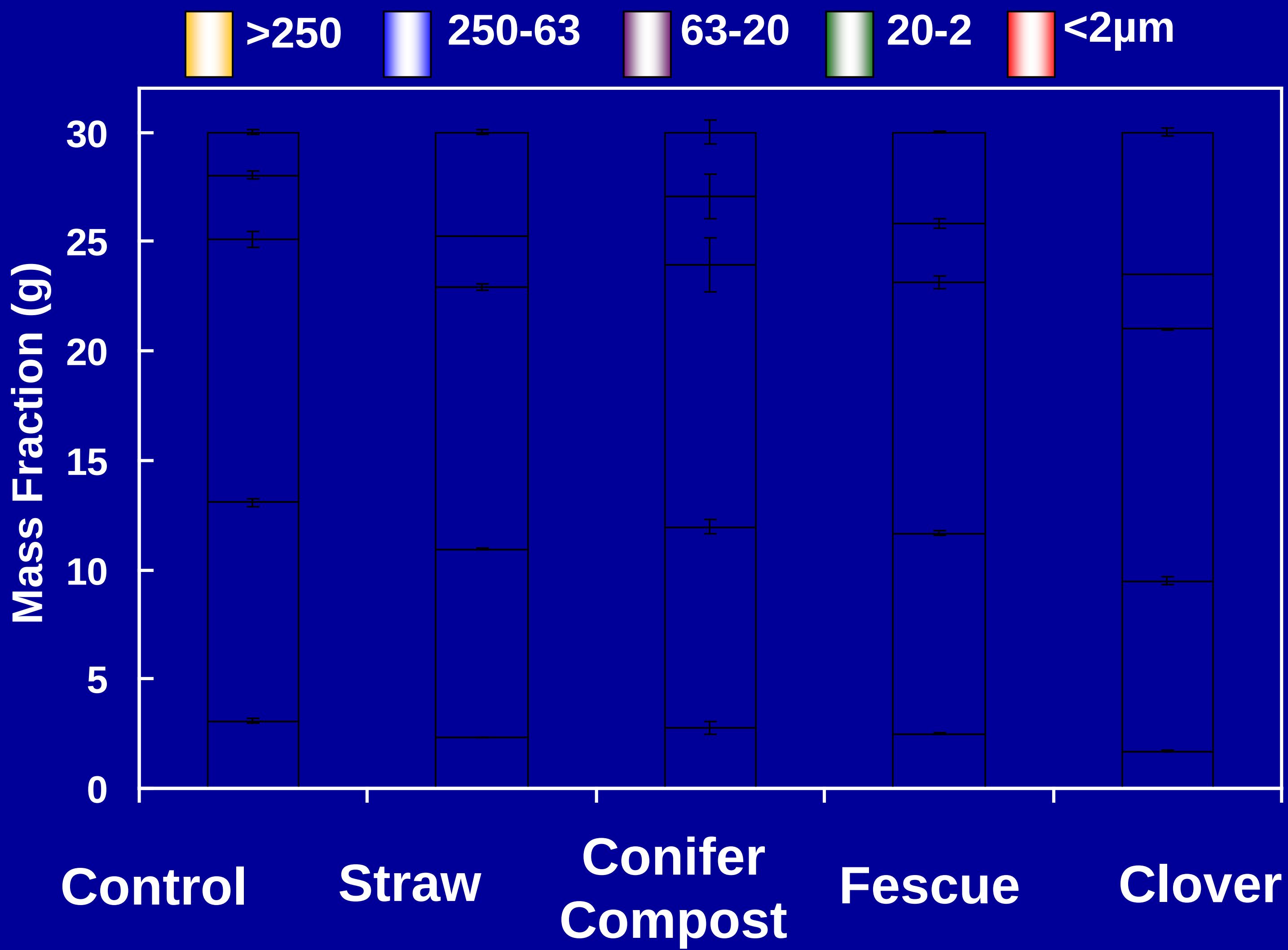
Chambre d'agriculture de Saône et Loire : CROZIER Philippe

EC2CO

CNRS INSU

Bourse ministérielle

Distribution of the solid mass of the five soil size-fractions of the Clessé soil



Conclusions and outlook

Both amendment and vegetation treatments induced an increase of the soil TOC content, which distributed dominantly in the two coarser size-fractions of the soil.

Compost and clover treatments of the soil induced a strong aggregation of the finest soil constituents, thus modifying its spatial structure and copper accessibility to plants.

The size fractions of the five soils were shown to present very different trace elements composition, thus constituting differentiated habitats of very different copper retention capacities.

The most reactive fractions of the five soils were the finest (<20µm) and the coarser (>250µm) fractions, which accumulated about 80% of the total Cu content.

Copper speciation and bioavailability to bacteria and plants varied significantly between soil treatments:

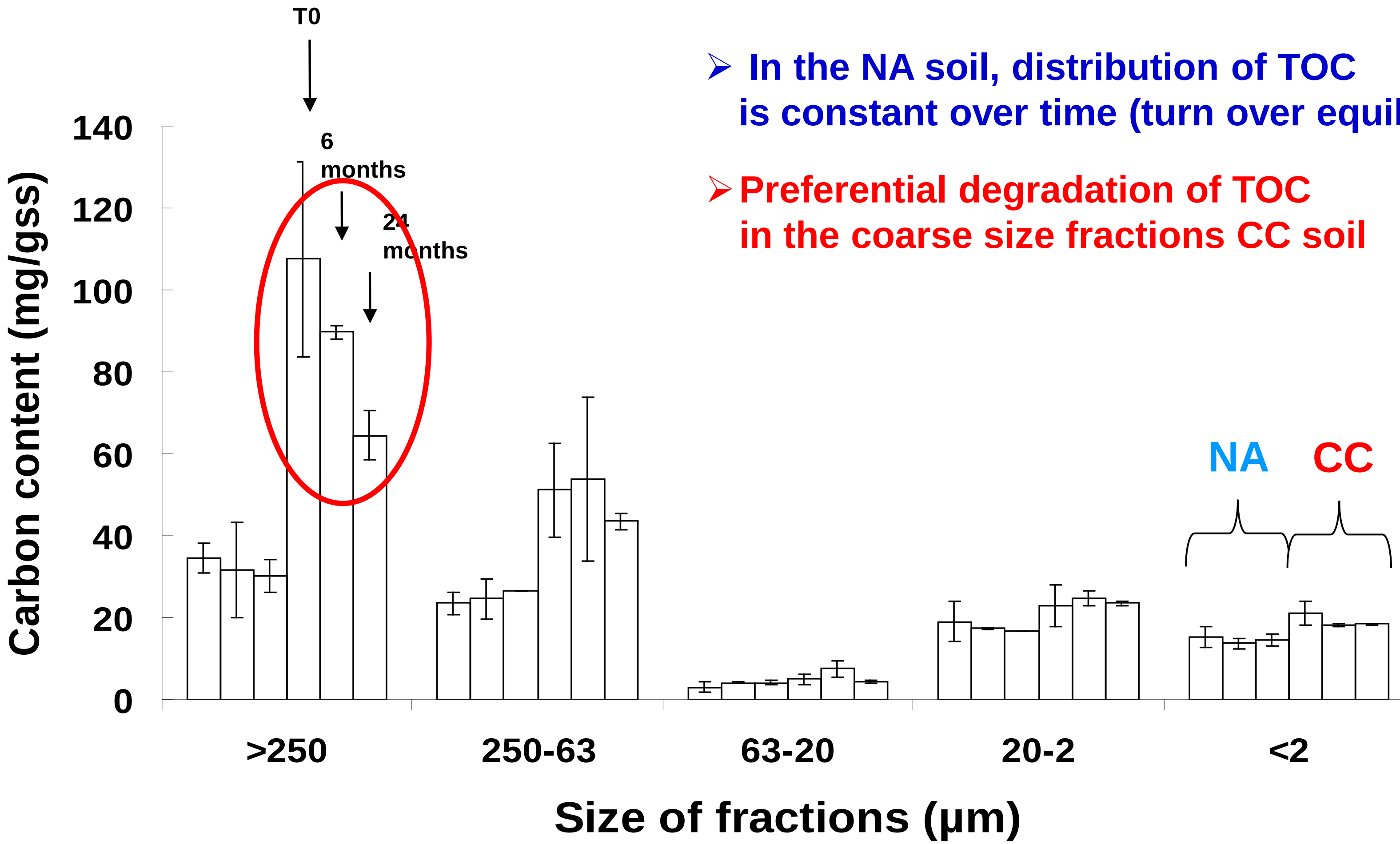
- organic amendments reduced strongly the concentrations of Ca-exchangeable and bioavailable copper (toxic) by Cu-complexation with organic ligands

- clover vegetation modified the soil pH, which increased copper solubility and bioavailability to bacteria

The field scale organic management of vineyard soils controls copper distribution and bioavailability at the micro-aggregate scale through differential effects

Temporal evolution of the TOC contents in size-fractions of the soils

➢ the coarser fractions of the 2 soils present the higher OM contents



➢ In the NA soil, distribution of TOC is constant over time (turn over equilibrium)

➢ Preferential degradation of TOC in the coarse size fractions CC soil

Conclusions

Le projet MOBIPO n'est pas un échec !

=> Meilleure compréhension du fonctionnement des sols (boite grise?) :

Les amendements organiques des sols modifient

1/ la **distribution du cuivre** à microéchelle

2/ la structure des communautés microbiennes à macro et à microéchelle

=> Impact différentié du cuivre sur les communautés microbiennes selon les compartiments structuraux (fonctionnels?) des sols et l'amendement en MO.

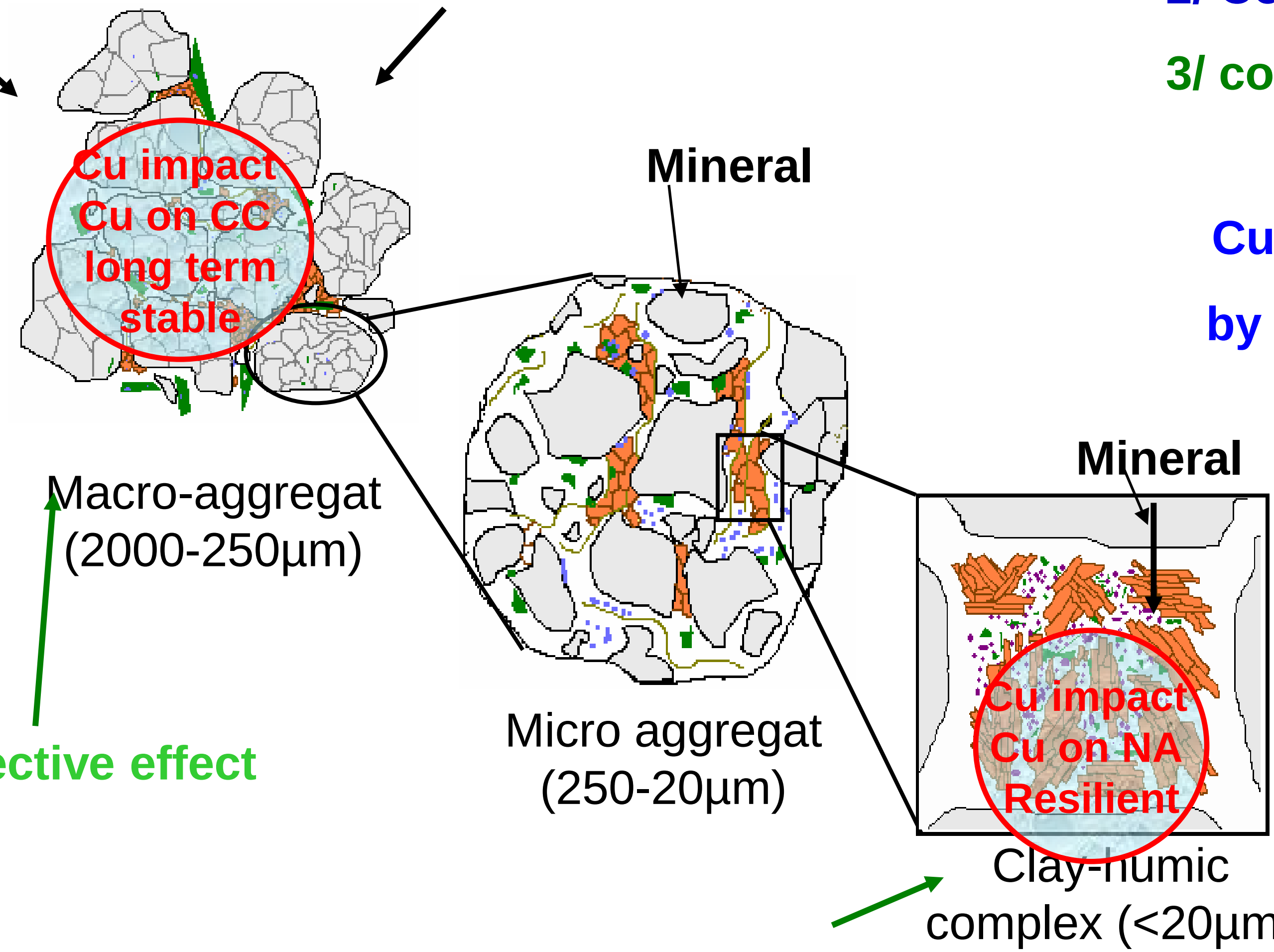
The compost amendment modified Cu speciation, distribution and ageing in the soil and reduced its impact on the microbial compartment

Conclusions

1/ Carbon dynamics

2/ Copper dynamics

3/ copper impact



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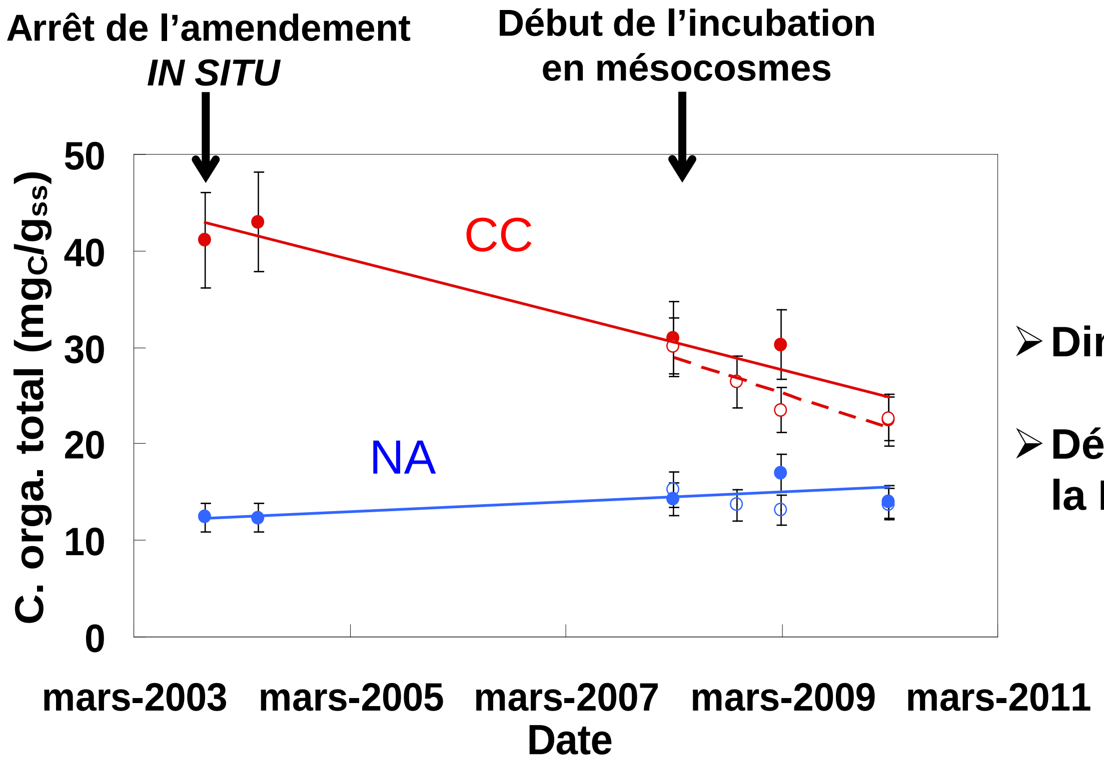
Evolution temporelle du COT dans les sols



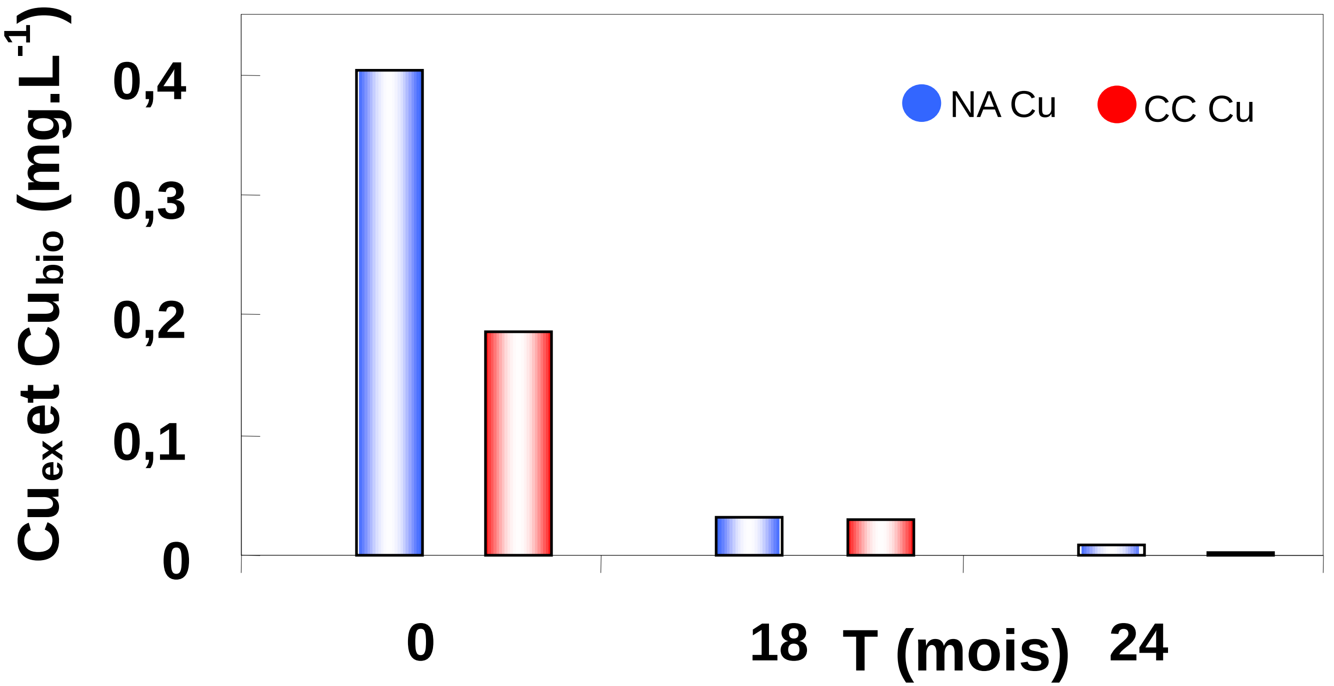
- Diminution du C_{org} dans le sol CC in situ
- Dégradation légèrement plus rapide de la MO en conditions contrôlées.

Rôle des MO dans la relation spéciation/biodisponibilité/impact?

Quel(s) est le compartiment fonctionnel clé?

Dynamics of bioavailable copper in soil solution

Cu-biosensor (*P. fluorescens* DF57)

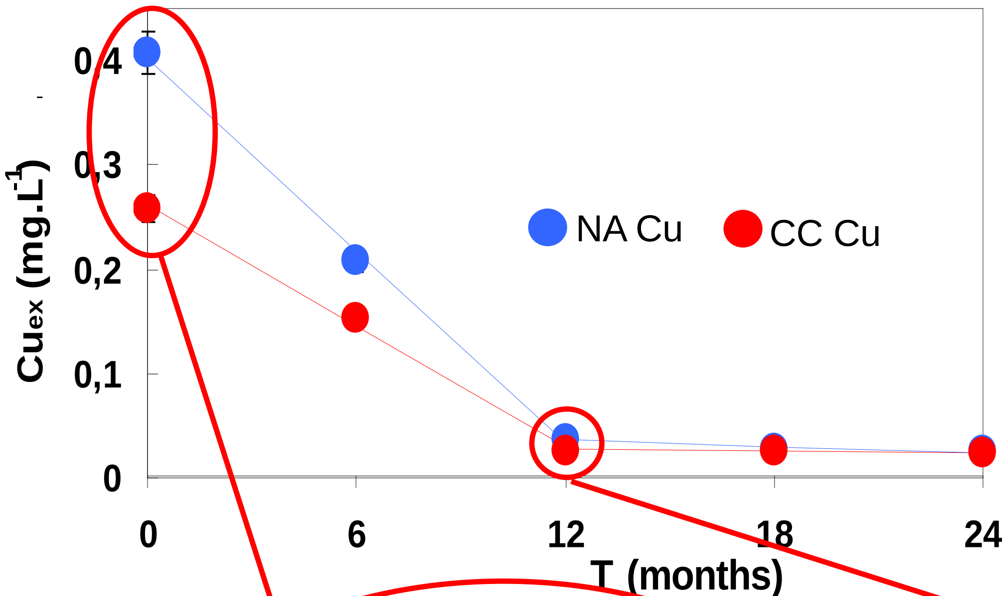


Copper is more bioavailable in the NA than in the CC soil.

➔ **Confirms the protective effect of added OM**

These results indicate that Cu will probably be more toxic in the non amended soil

Speciation and dynamics of Ca-exchangeable copper in soil solution

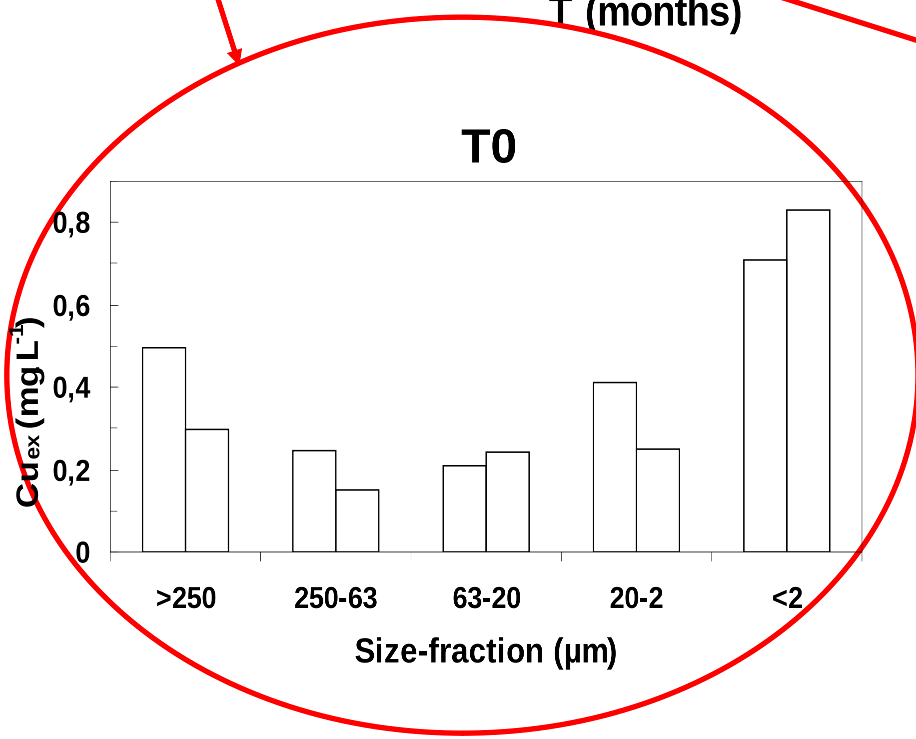


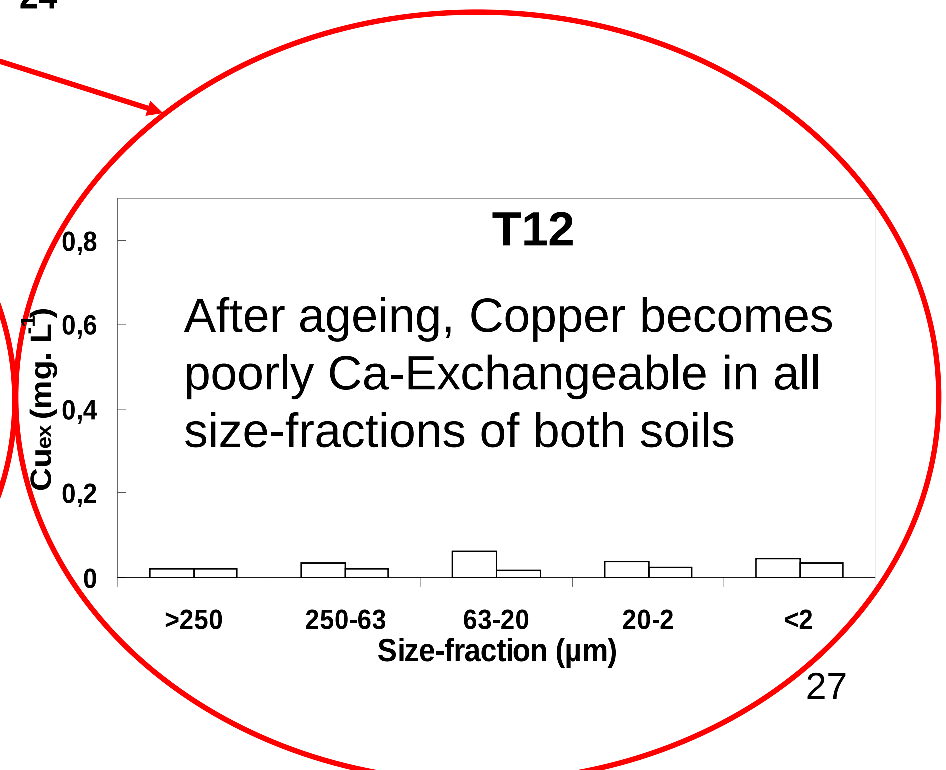
- Only 0.1% of Cu exchanges with Ca !

- **NA** exchanges more Cu than **CC**

➔ **protection effect of the OM**

- Fast ageing of the Cu contamination





After ageing, Copper becomes poorly Ca-Exchangeable in all size-fractions of both soils

Results

1- Effect of amendments and vegetation on the particle size distribution and aggregation of soils

2- Effect of amendments and vegetation on Cu speciation and bioavailability

3- Effect of amendments and vegetation on the mass distribution of total carbon, copper and soils size-fractions

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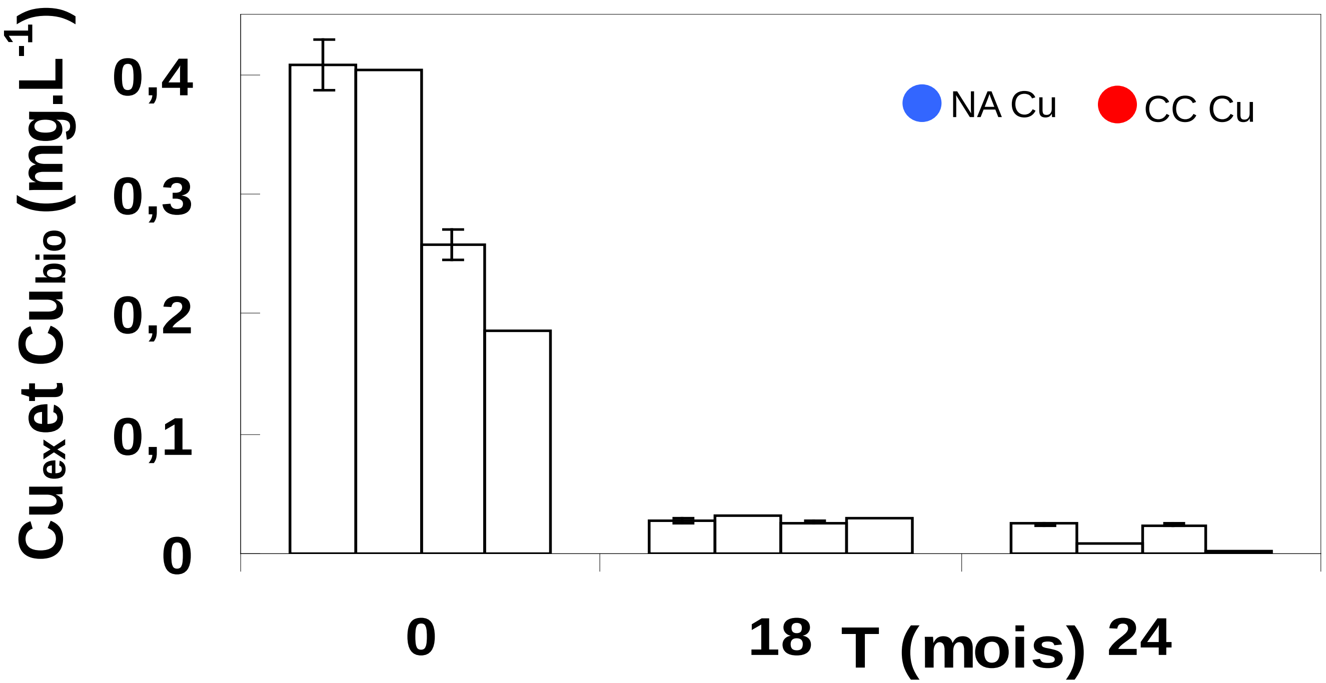

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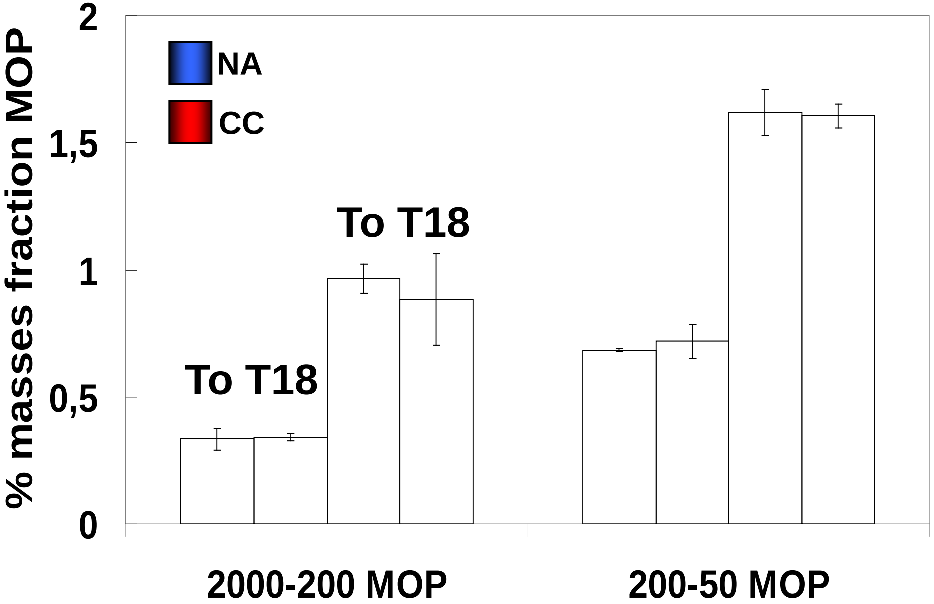
Evolution sur 2 ans des Matières Organiques Particulaires (MOP)

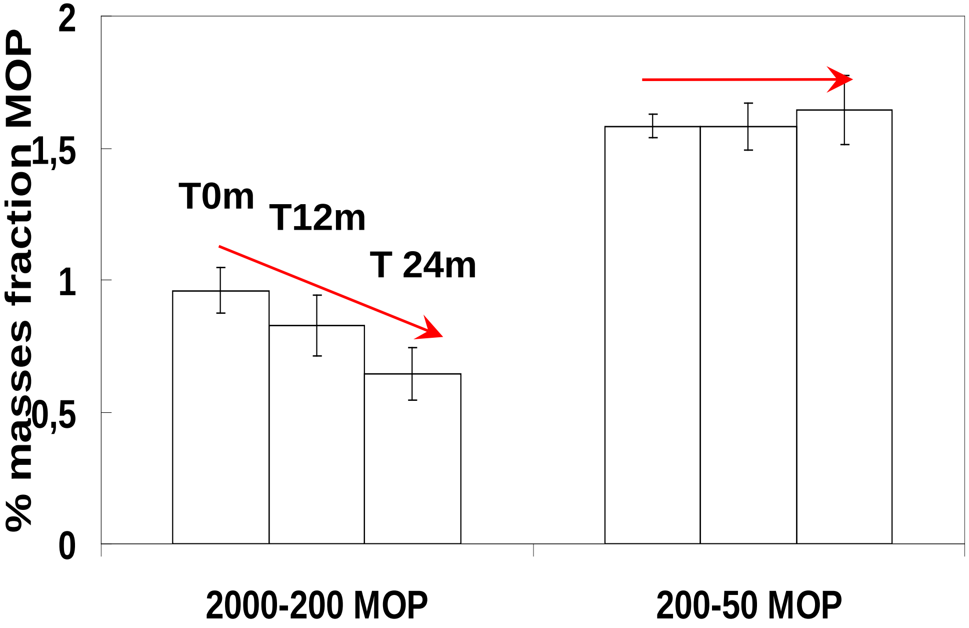
- Cu



Plus de MOP dans le sol CC

Dominance de la fraction 200-50 µm.

+ Cu

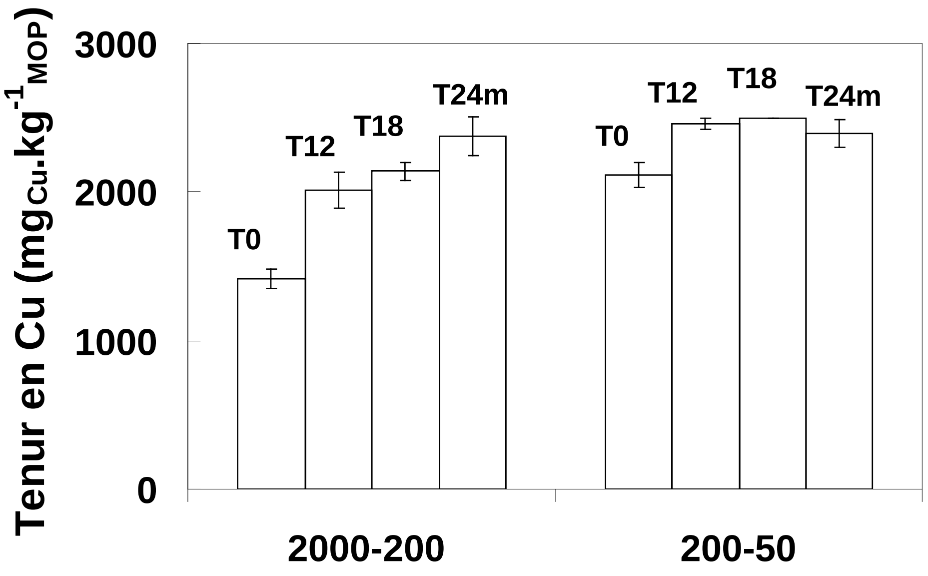


Pas d'évolution significative dans NA !

Le cuivre stimule la dégradation

des MOP !!

Evolution des teneurs en Cu dans les MOP
sol amendé en compost de conifère



Sol CC

contaminé au Cu

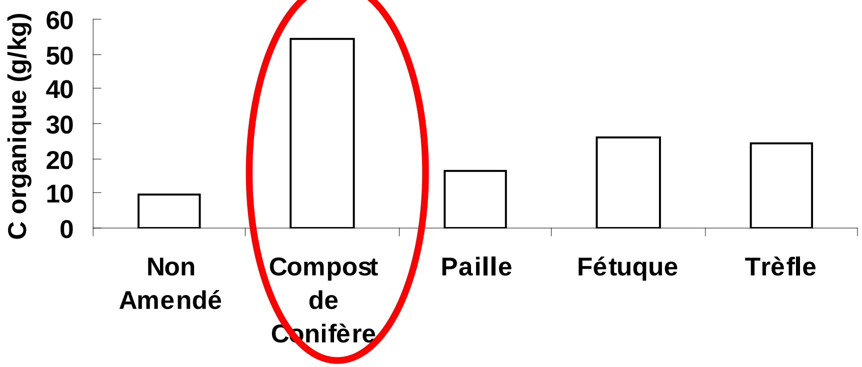
(+/- 300 ppm)

- $[Cu]_{MOP}$ très élevées (7 x la moyenne).
- Enrichissement des MOP > 200µm en Cu au cours du temps (dégradation des MOP)
- Dynamique de puits de cuivre différente selon la taille des MOP

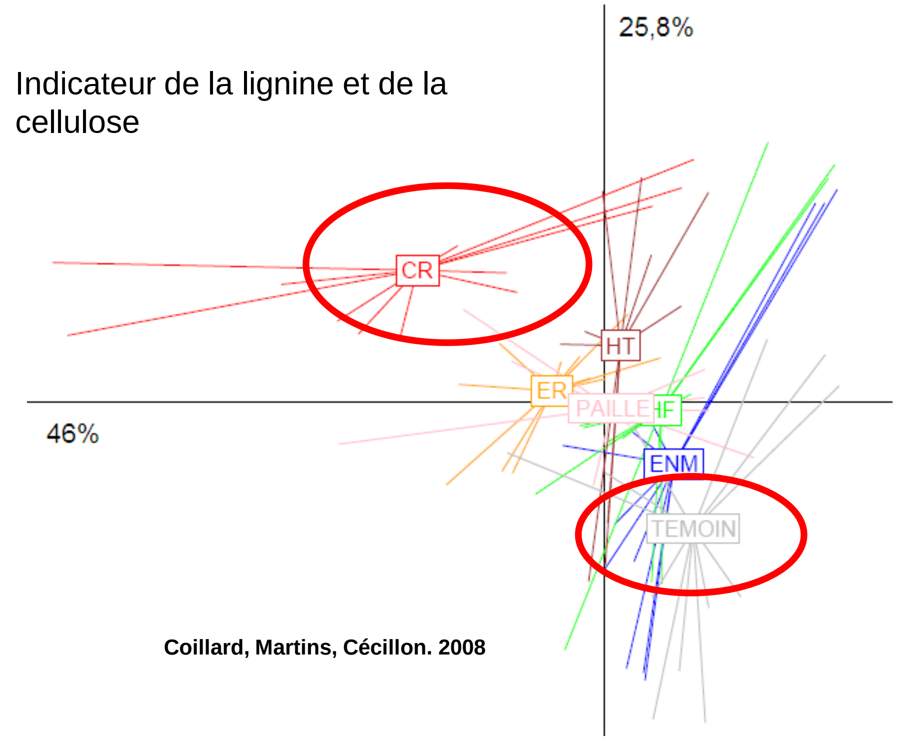
Choix de 2 sols parmi les 5 statuts organiques

Caractérisations Bio-géo-chimiques

Teneur en C organique

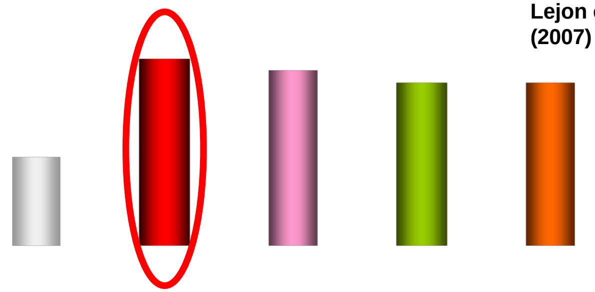


Effet de la nature de la Matière organique (Analyse NIRS)



Teneur en biomasse microbienne

Lejon et al., (2007)



NA ≠ CC, P, F et T

➔ Choix du traitement de MO :

1 contrôle : NA

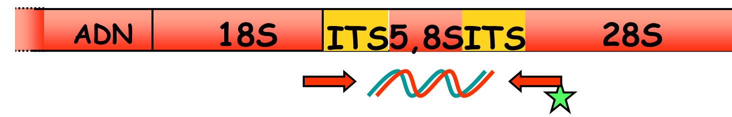
1 amendement : CC

ARISA Analysis of bacterial community structures (INRA Dijon)

ARISA
(Automated Ribosomal Intergenic Spacer Analysis)
(Fisher et Triplett, 1999; Ranjard *et al.*, 2001)

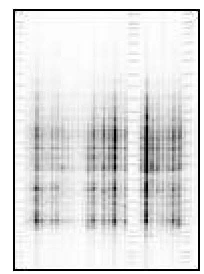
Extraction *in situ* of DNA of microbial communities
(Ranjard, Lejon *et al.*, 2003)

IGS (intergenic spacer) or ITS controlled PCR amplification

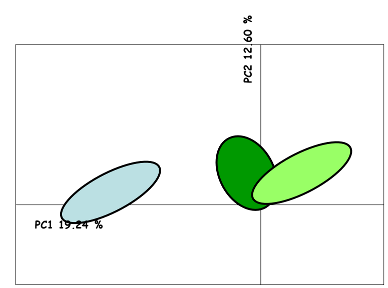


Electrophoretic (LiCOR-type gel)

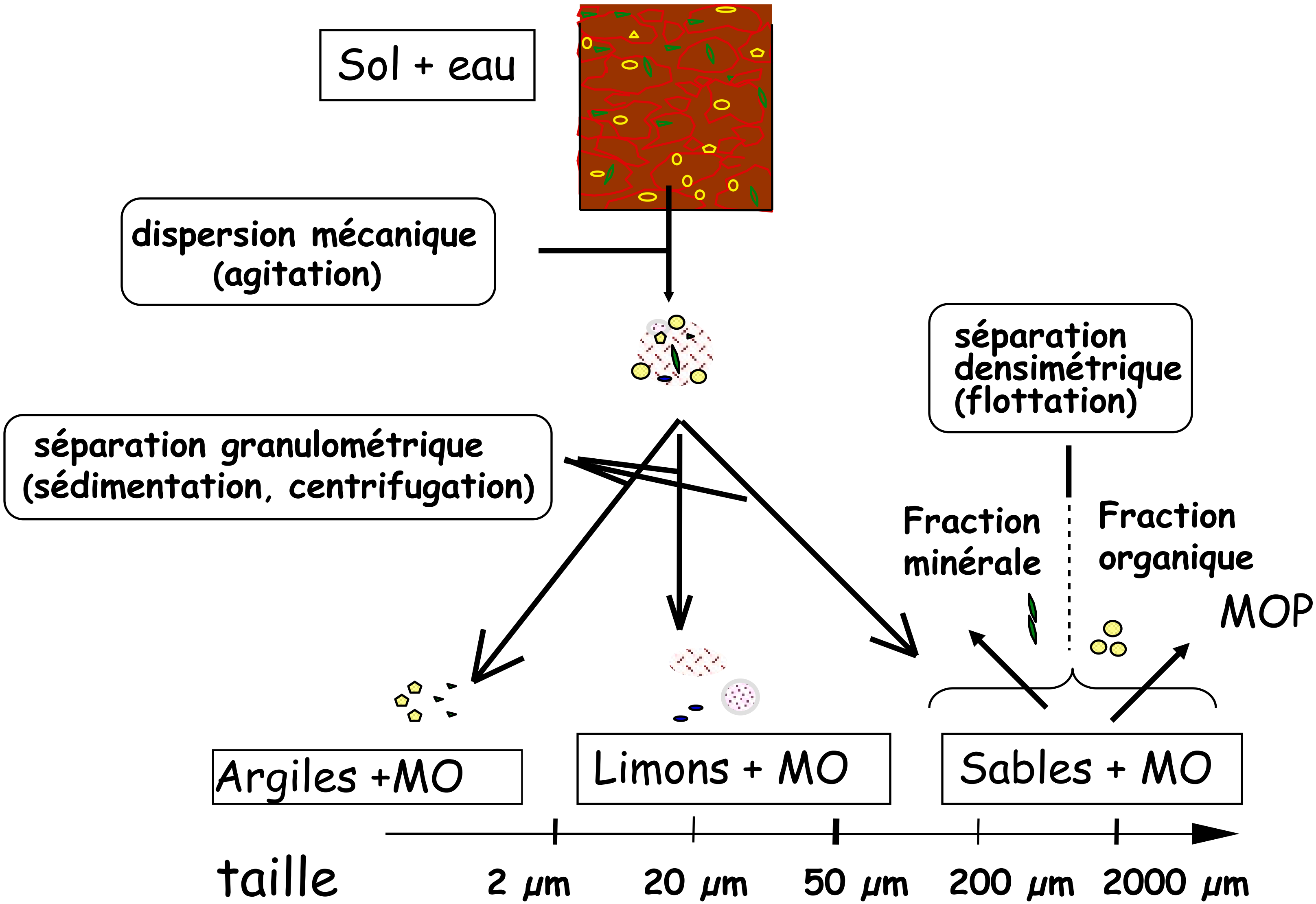
DNA ("*fingerprint*") of bacterial communities

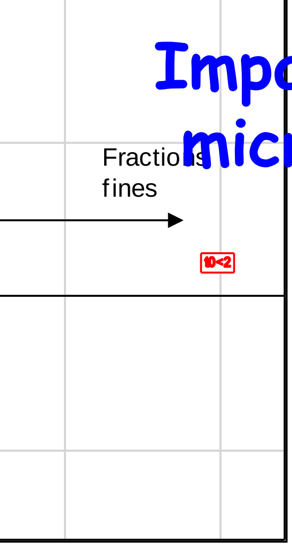


Numerical analysis of profiles – Principal Component Analysis (PCA)



Fractionnement granulo-densimétrique





Impact du Cuivre sur la structure des communautés microbiennes dans les compartiments structuraux.

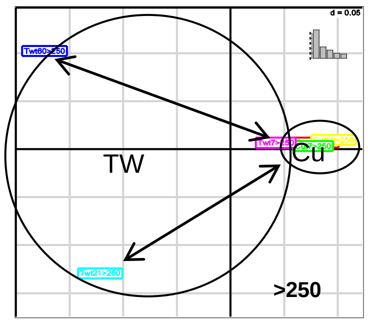
Différence de structure initiale de communautés dans les fractions et le sol total.

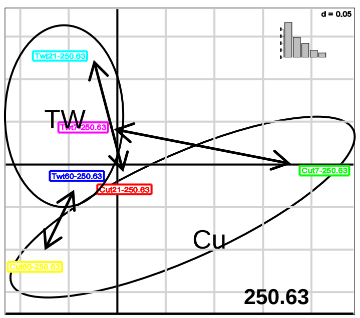
→ impact différent du Cuivre ?

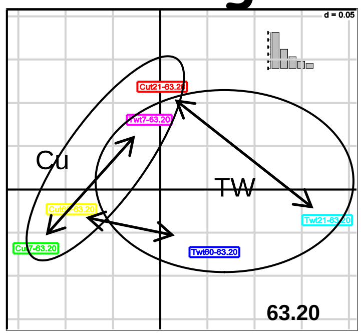
Partie Lionel Ranjard

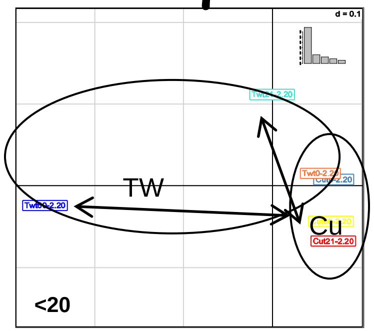
Biodiversité microbienne dans les fractions granulométriques

Impact Cu NA









Impact Cu CC