



Contaminations atmosphériques et redistributions paysagères des éléments traces

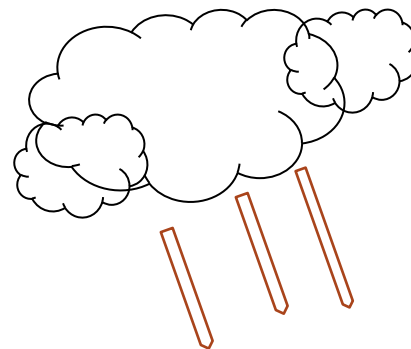
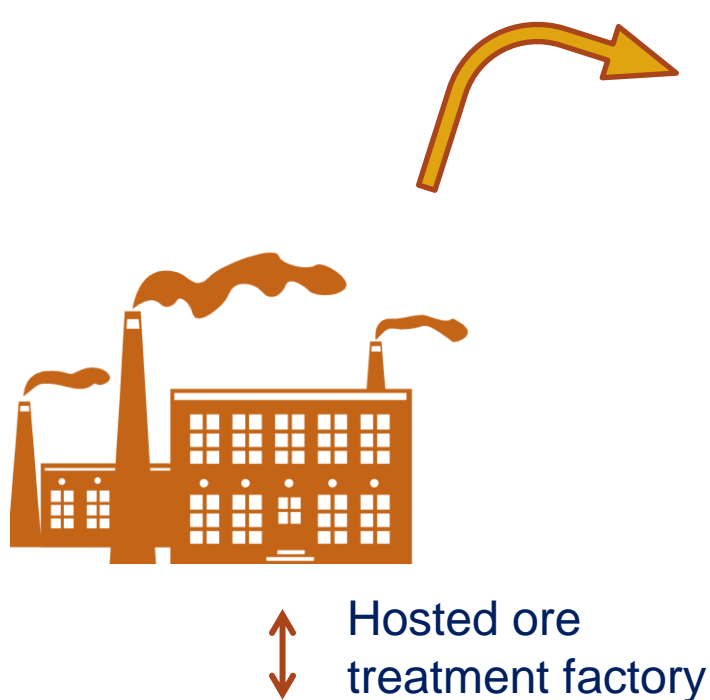
Leçons d'études menées autour d'anciennes usines de traitement des minerais de blende en Région wallonne

Beauvais, 27 mars 2014

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Université de Liège – Gembloux Agro-Bio Tech – Unité “Systèmes Sol-Eau”

Contexte général

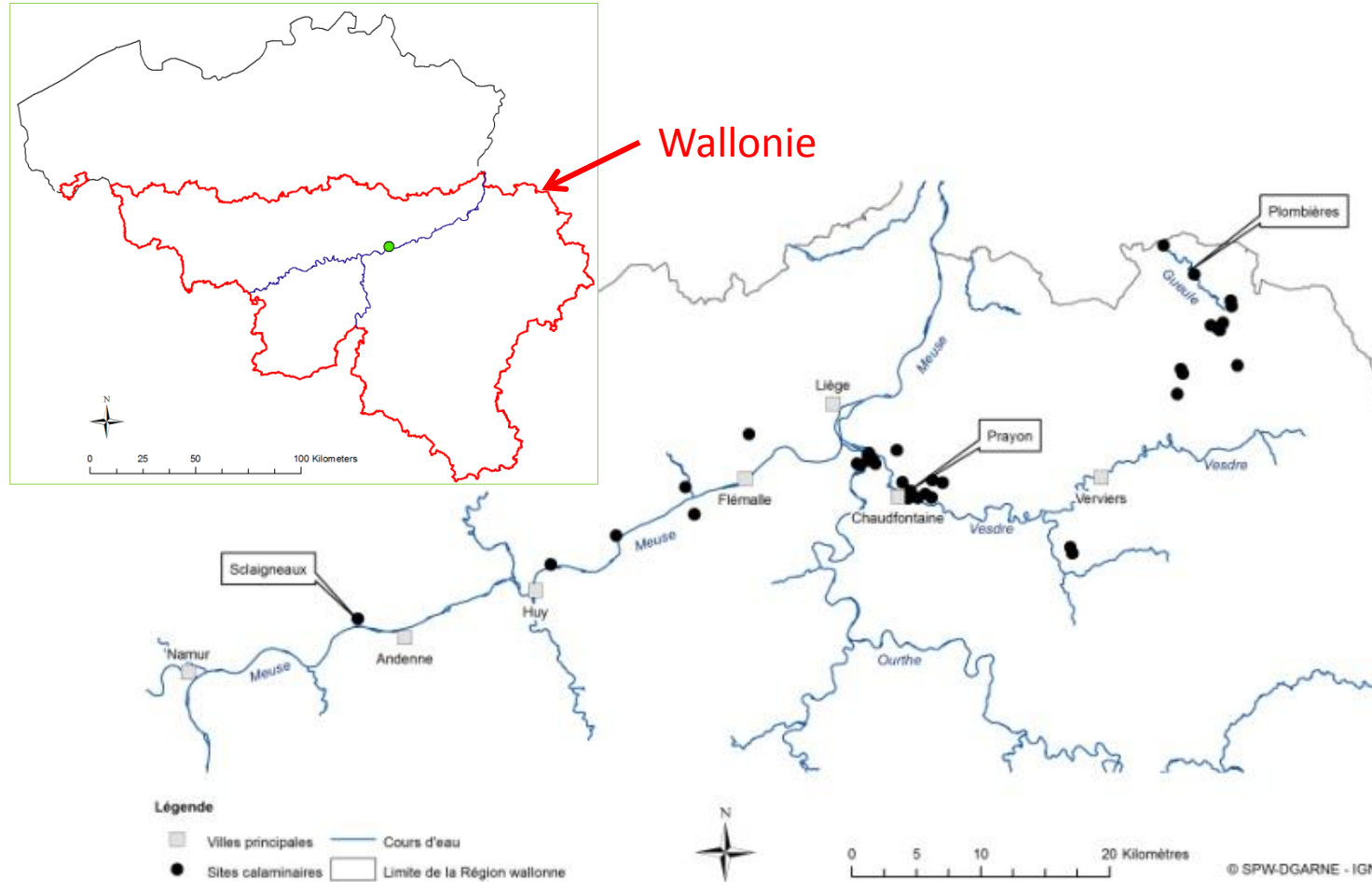


Contaminations of ecosystems by fallouts of particulate metallic trace elements (MTE)

Cd-Pb-Zn



Localisation des sites calaminaires



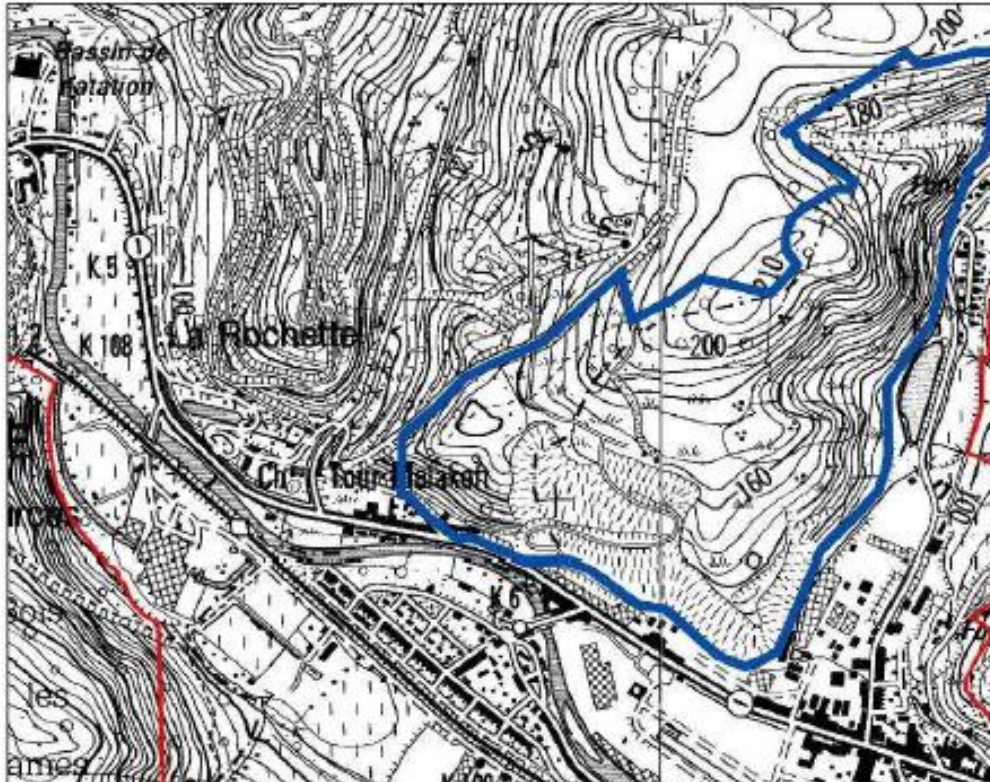
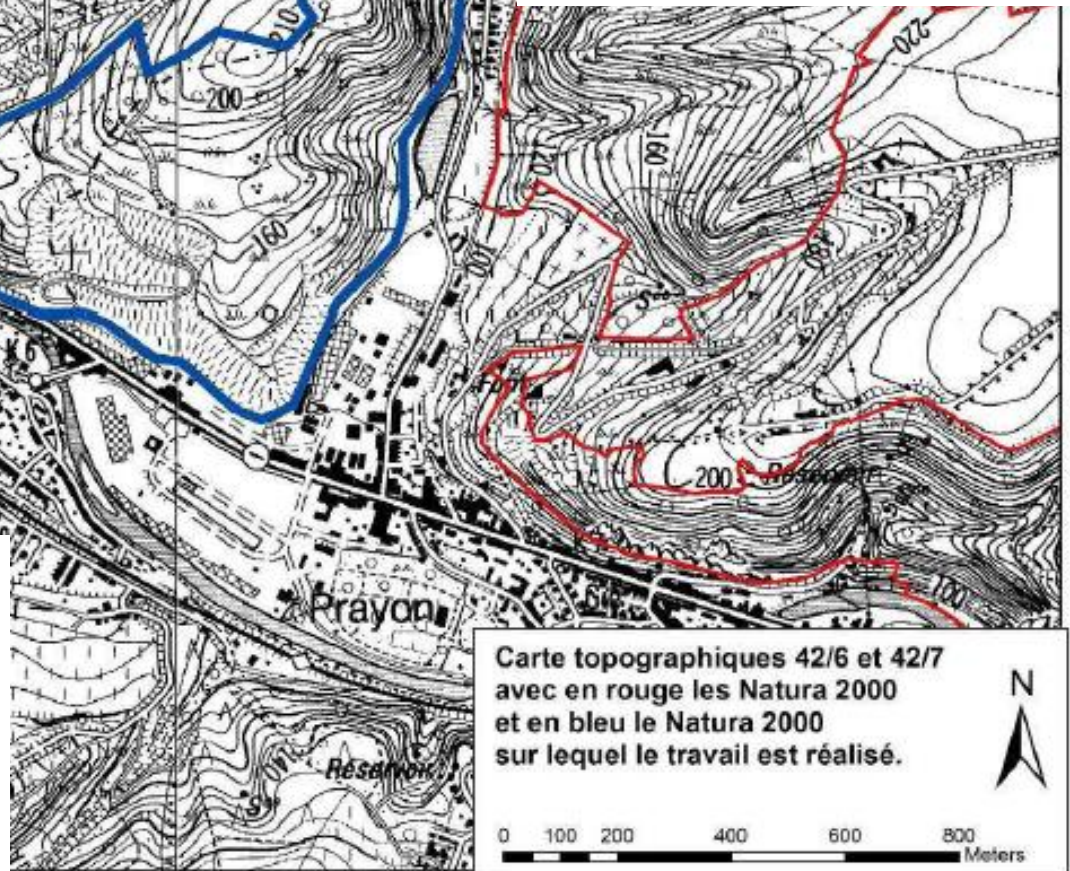


Photo 13 : tabouret calaminaire (*Thlaspi caerulescens* subsp. *calaminare*)



Carte topographiques 42/6 et 42/7
avec en rouge les Natura 2000
et en bleu le Natura 2000
sur lequel le travail est réalisé.

0 100 200 400 600 800
Meters



Photo 12 : *Viola calaminaria* (pensée calaminaire)

Carte 2 : carte topographique 42/6 et 42/7 (IGN) (site de Prayon en bleu)

Des contaminations en ETM dans les sols qui débordent largement des sites NATURA 2000

Carte de Krigeage: Pb pseudo-total

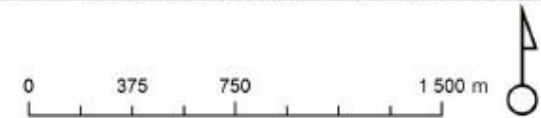


Cartographie réalisée dans le cadre du mémoire de MICHEL Brieuc
Source: Carte IGN (Institut Géographique National)

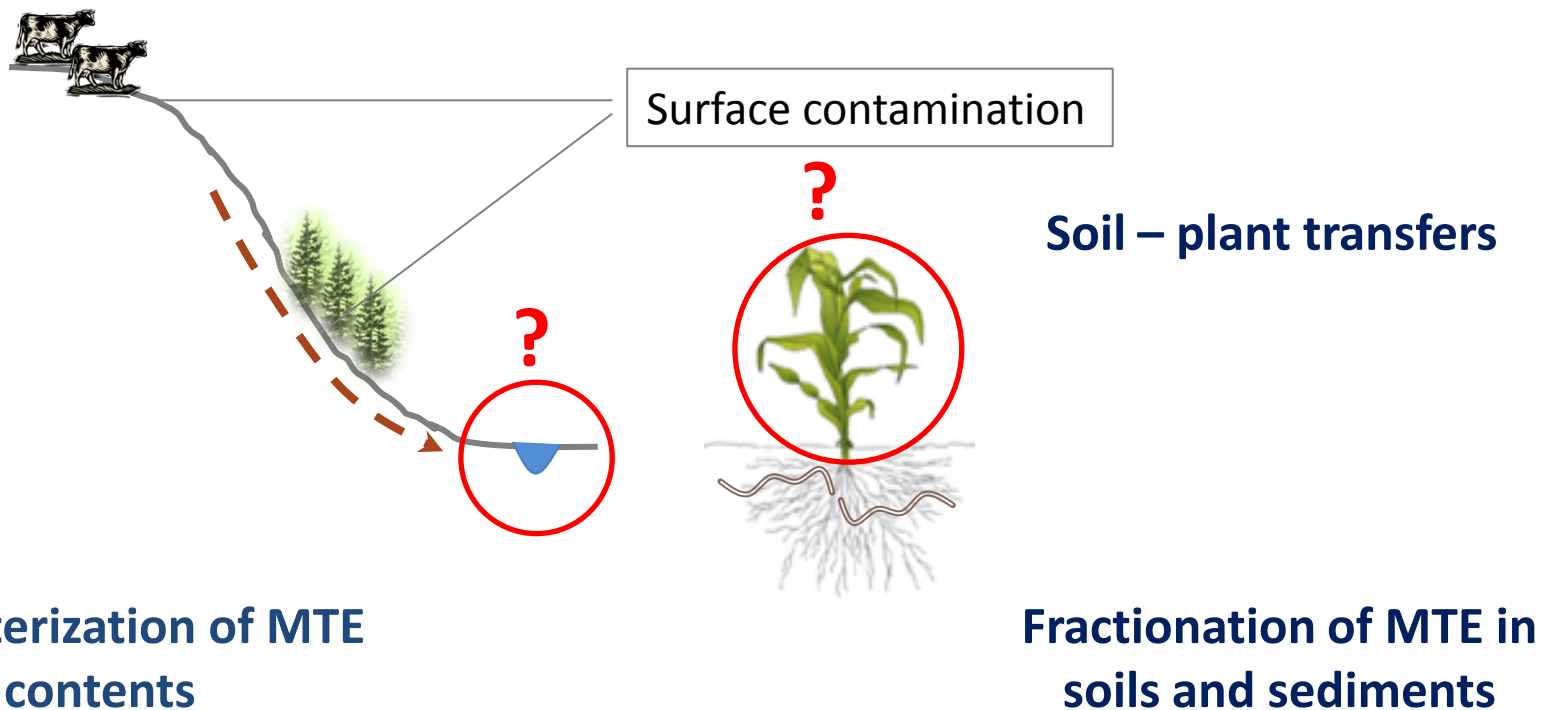


Légende

Pb_ER (ppm)	Filled Contours		
65 - 120		200 - 400	
120 - 200		400 - 700	
		700 - 4 600	
			Point_terrain

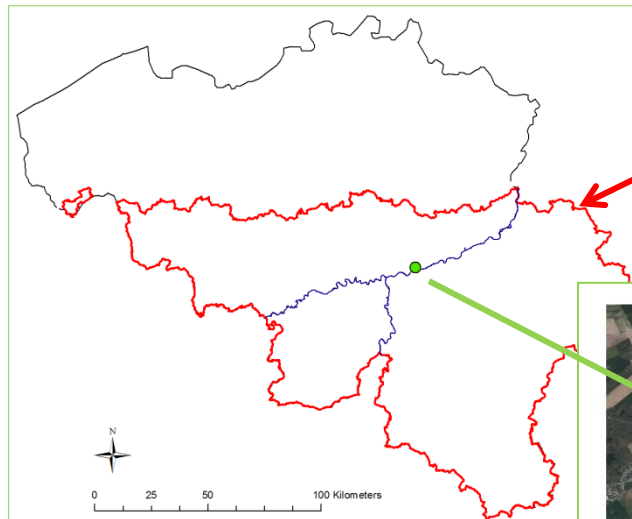


Devenir des contaminants dans les paysages contaminés



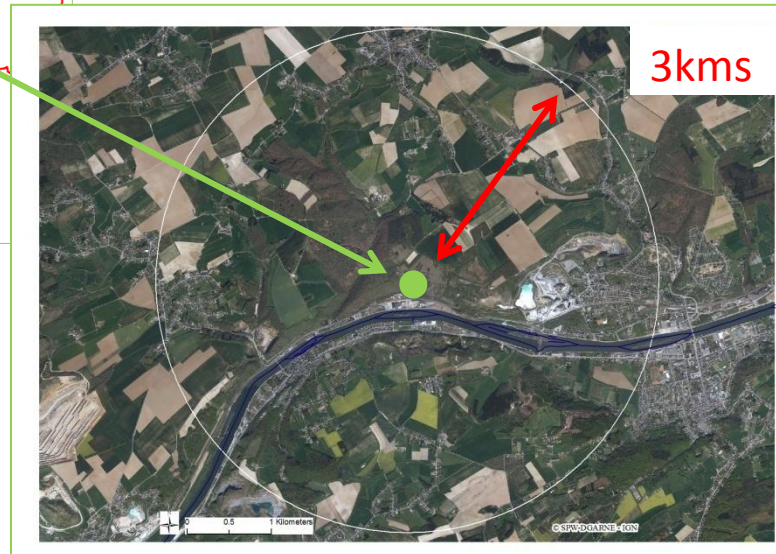
Factors of variation of MTE content in soils and sediments

Localisation des sites d'étude



Sclaigneaux

Wallonie



Caractéristiques du site de Sclaigneaux

Forests



Crops



Loyse river

Situation of old chimney

Meuse valley



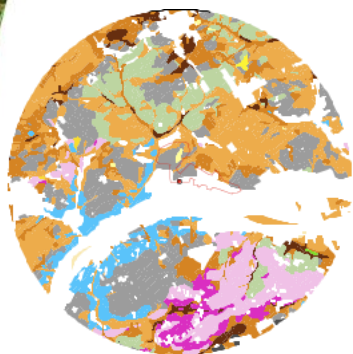
Grasslands



Village

Etude des contaminations de surface

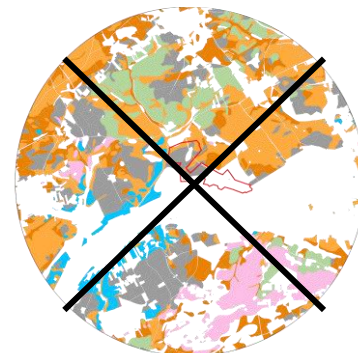
Stratégie d'échantillonnage



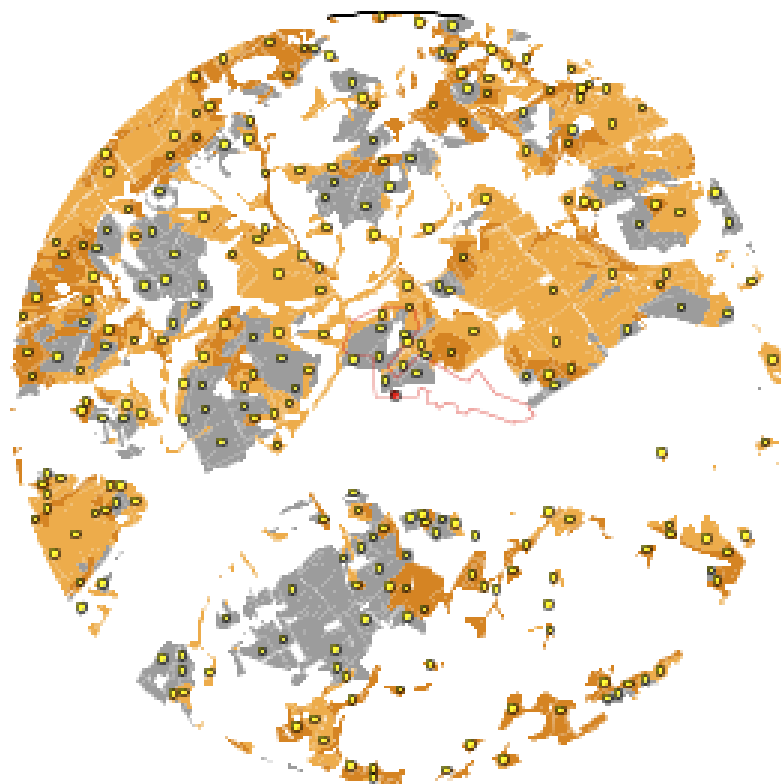
1. Main soil types



2. Land use



3. Wind directions



Sampling points are distributed between 3 distinct soil types, 3 land uses and 4 wind directions (36 combinations)



Loamy soil with good drainage

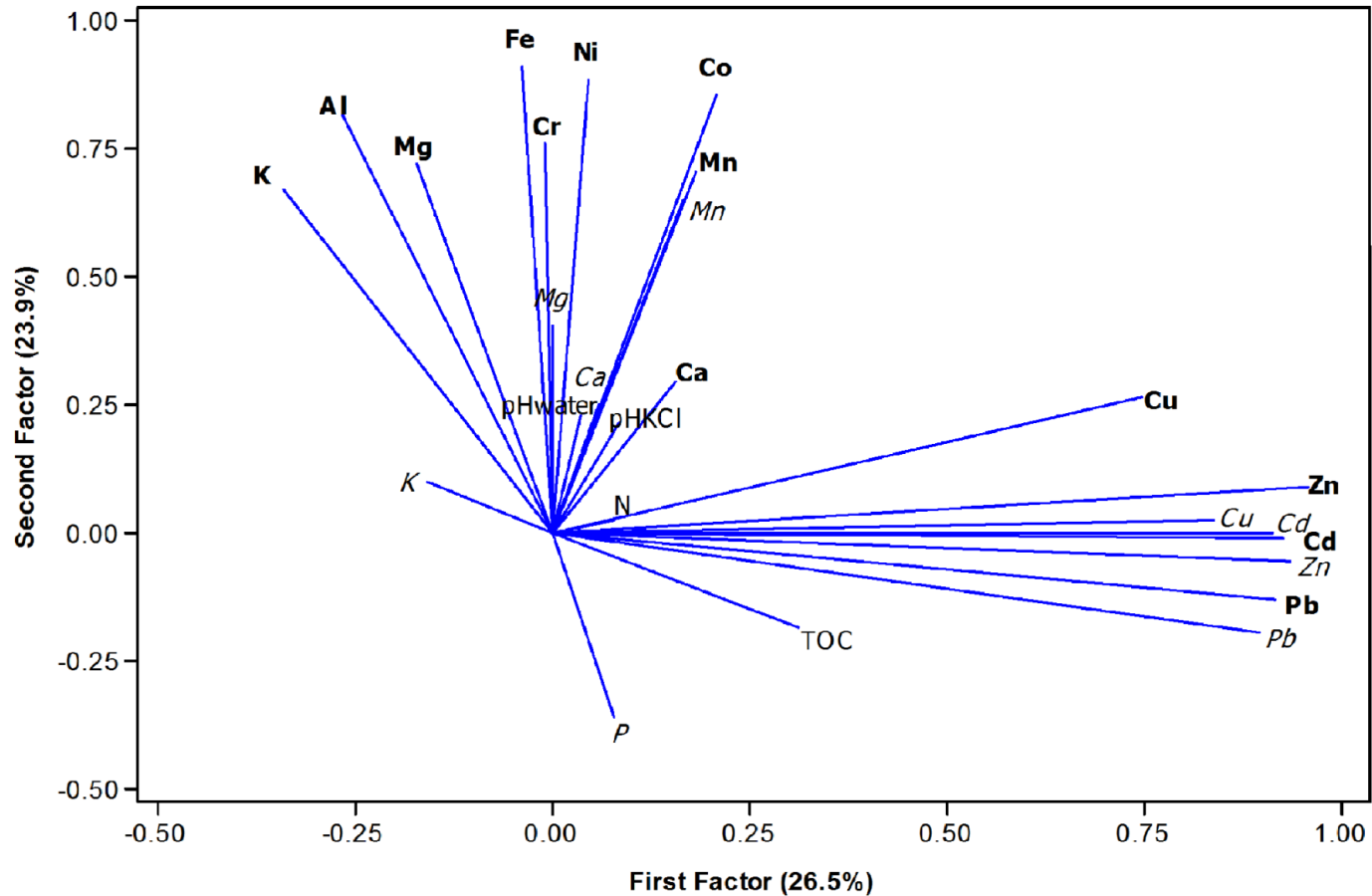


Loamy soil with imperfect drainage

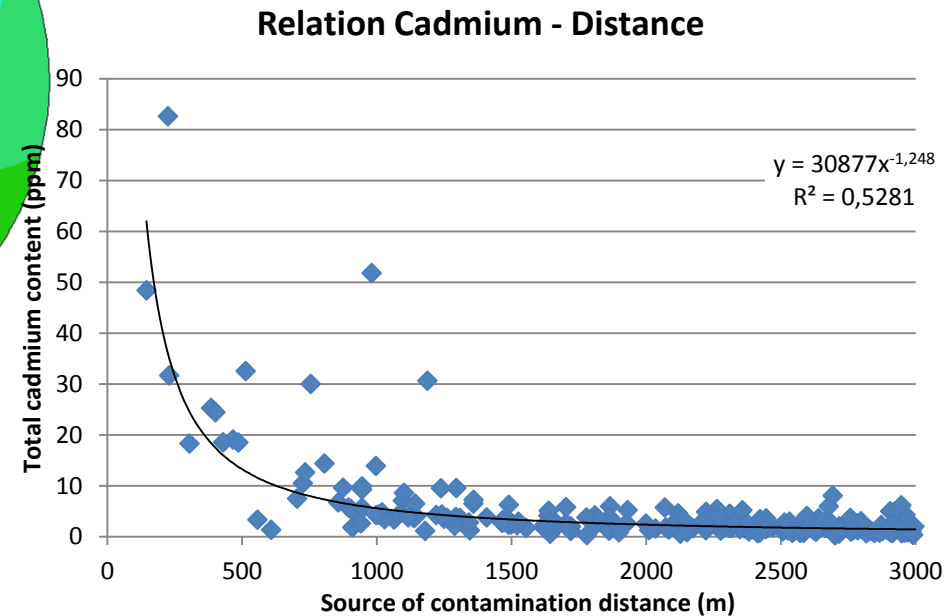
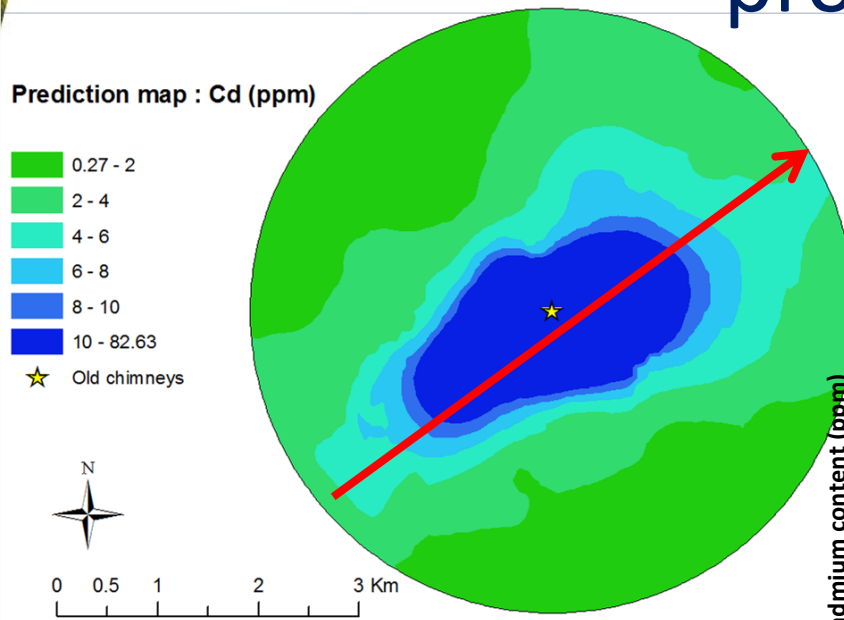


Loamy stony soil with silexite and gravels

Propriétés physico-chimiques des sols de Sclaigneaux



Teneur en Cd en dehors de la zone protégée



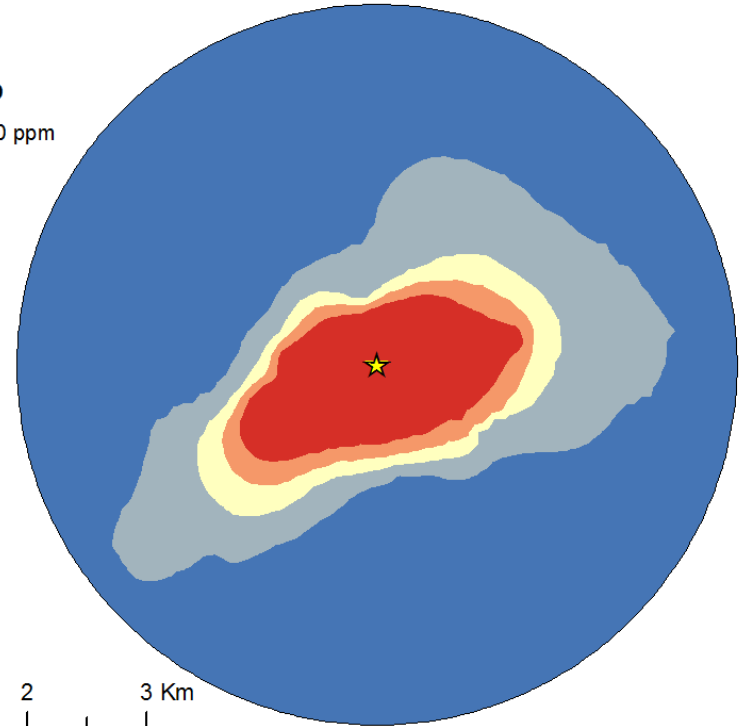
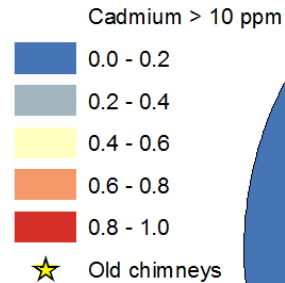
1. Content in each MTE decreases with **distance**

2. P-value < 0.001 and $R^2 > 0.5$

Evaluation de la dangerosité de la contamination

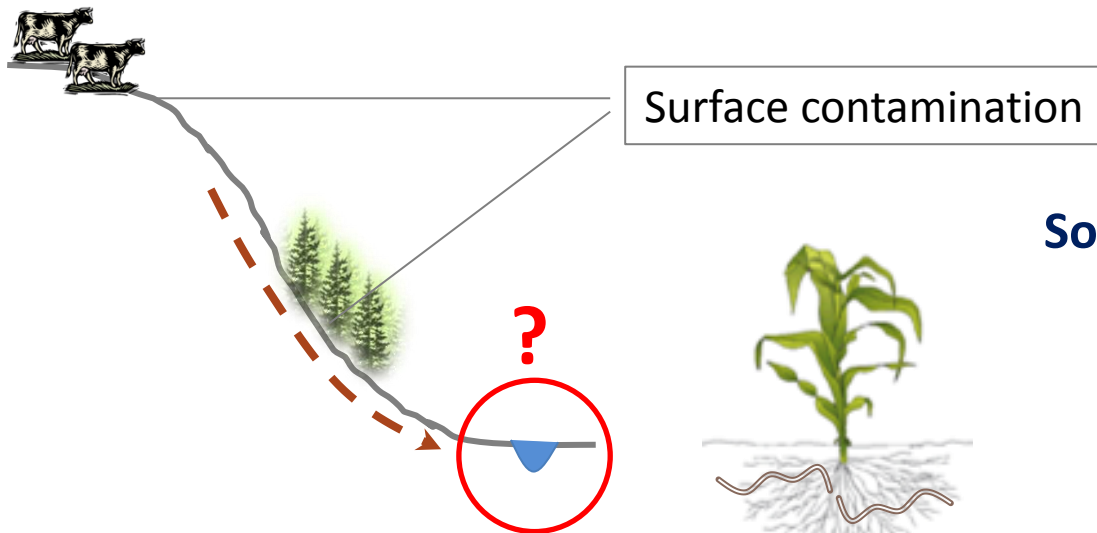
In a 1km radius around the source, there is 80% probability for each contaminant to be above the allowed regional intervention value

Probability Map



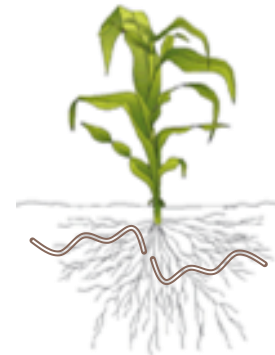
	Cadmium	Lead	Zinc
Natural reference	0.2	25	67
Critical level	1	200	155
Intervention value	10	400	300

Devenir des contaminants dans les paysages contaminés



Surface contamination

Soil – plant transfers



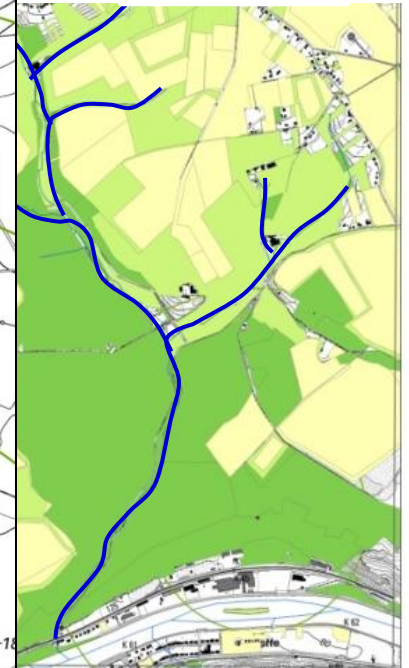
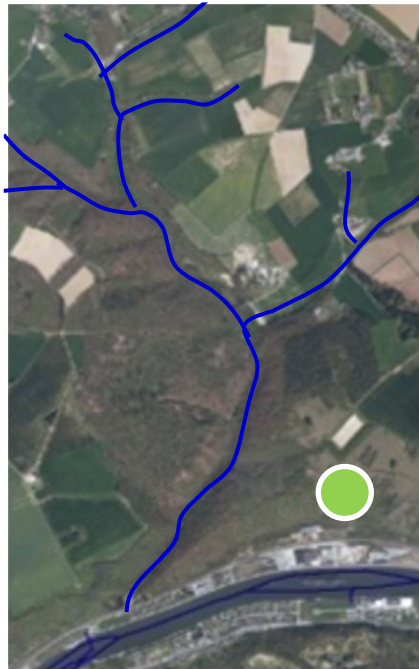
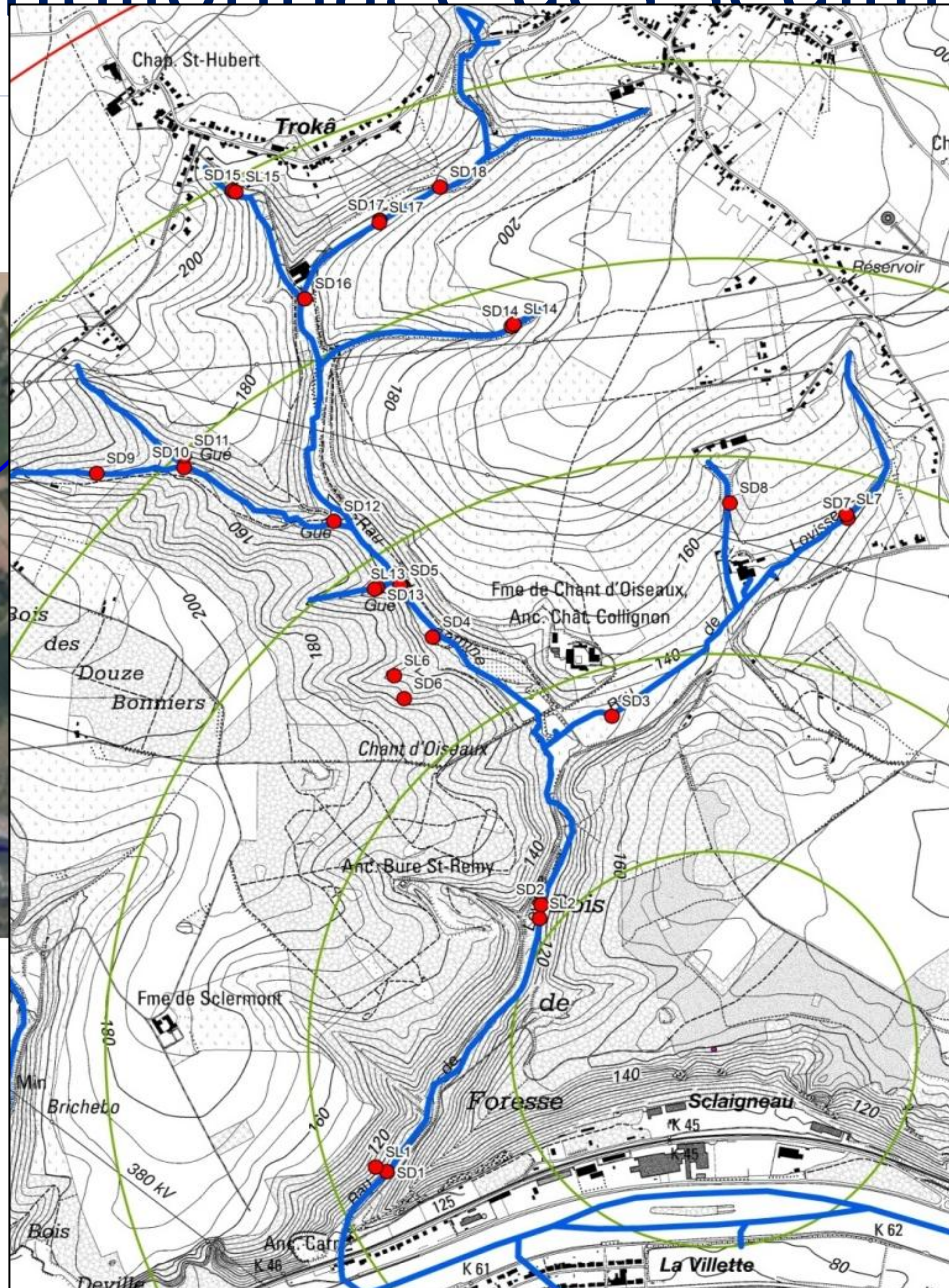
Fractionation of MTE in soils and sediments

Characterization of MTE contents

Factors of variation of MTE content in soils and sediments

Echantillonnage des sédiments

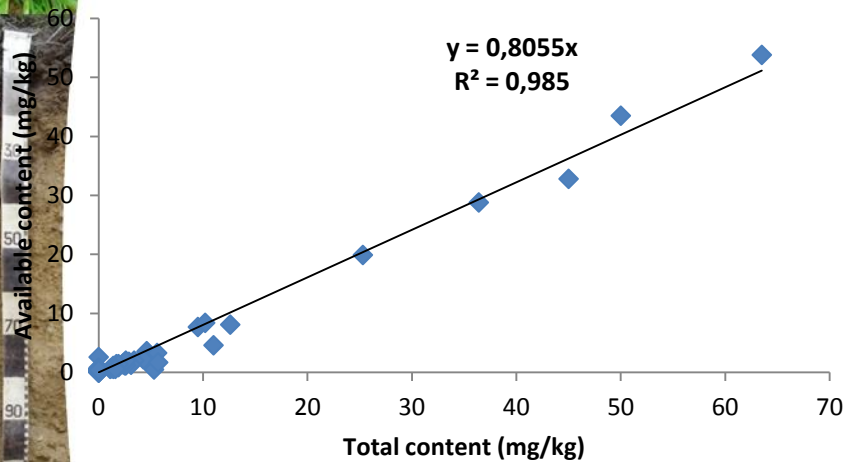
2. Land use



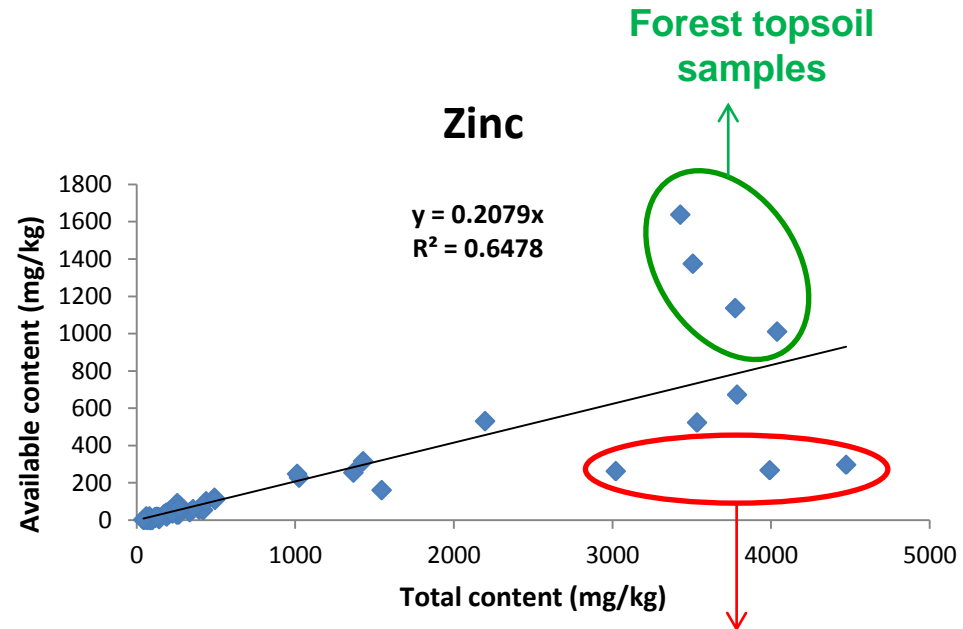
Caractérisation physico-chimique

Disponibilité des ETM

Cadmium



Zinc



- Cd ; Cu ; Pb : significant linear relationships ($p < 0.001$ and $R^2 > 0.95$)
- Zinc : correlations are less significant from 3000 ppm of pseudototal

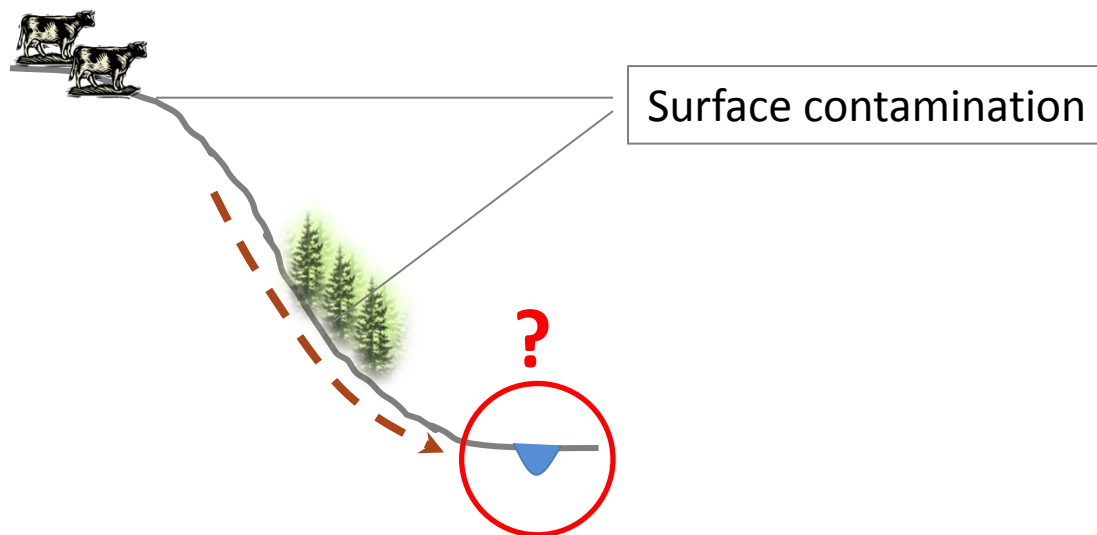
Corrélations entre teneurs disponibles, pH et COT

	Zn	Pb	Cd	Cu	pH KCl
Pb	0,846 ***				
Cd	0,956 ***	0,740 ***			
Cu	0,084	-0,028	-0,026		
pH KCl	0,298 *	0,239	0,194	0,157	
COT	0,637 ***	0,437 ***	0,621 ***	0,081	0,365 **

- High correlation between Cd-Pb-Zn, $p < 0.001$ and $r > 0.7$
- No relation between available Cu and the other MTEs
- pH is not correlated with MTEs unlike COT ($p < 0.001$ for Cd-Pb-Zn)

Sol - sédiments

Fate of MTE in contaminated landscapes



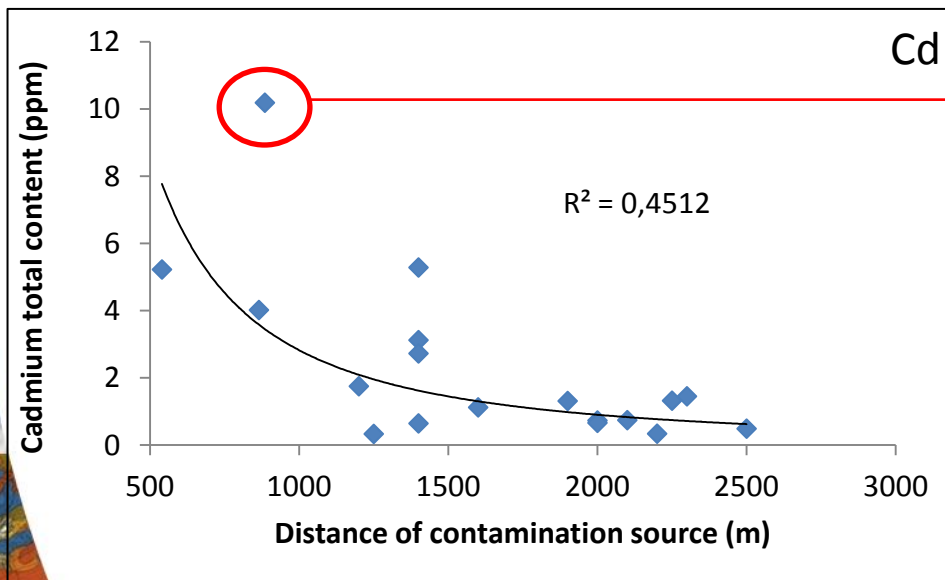
Characterization of MTE contents

Fractionation of MTE in soils and sediments

Factors of variation of MTE content in soils and sediments

Distance à la source de contamination

- Only an effect of distance can “explain” pseudototal content in MTEs (Cd-Pb-Zn) for sediments
- This explanation doesn't work for copper content



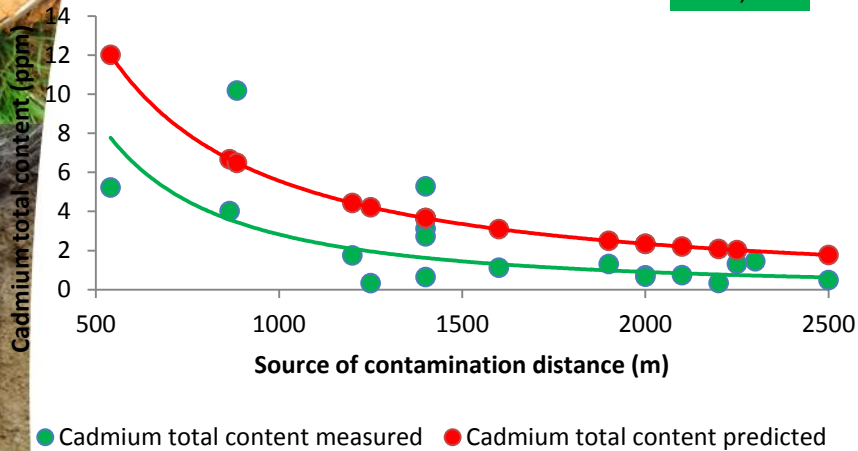
- Sediment sampled downstream the former chimney

- Evidence of redistribution by sediment transport ?

Comparaison entre teneurs mesurées et prédites

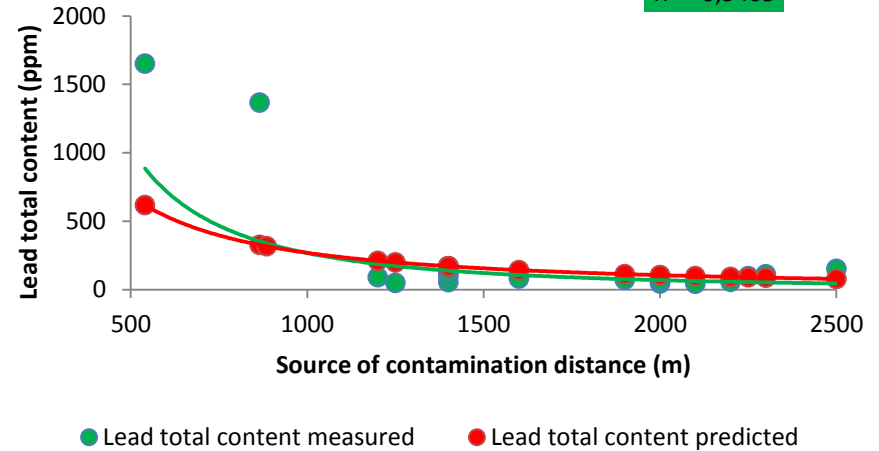
Cadmium

$R^2 = 0,4512$



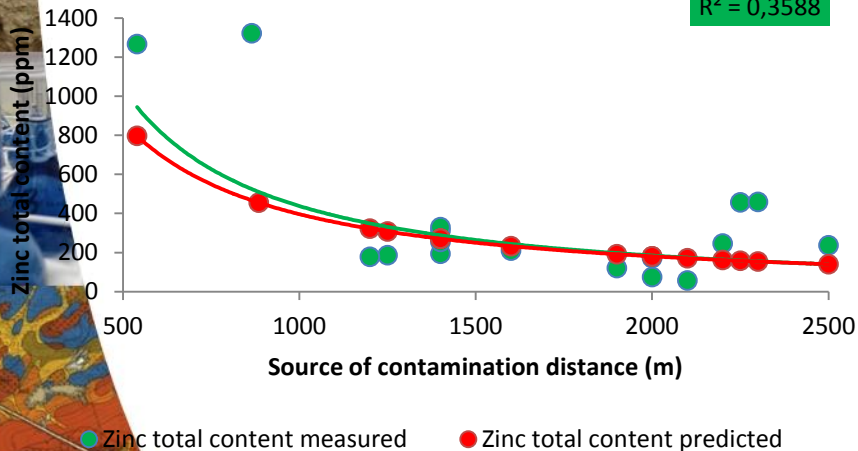
Lead

$R^2 = 0,5405$



Zinc

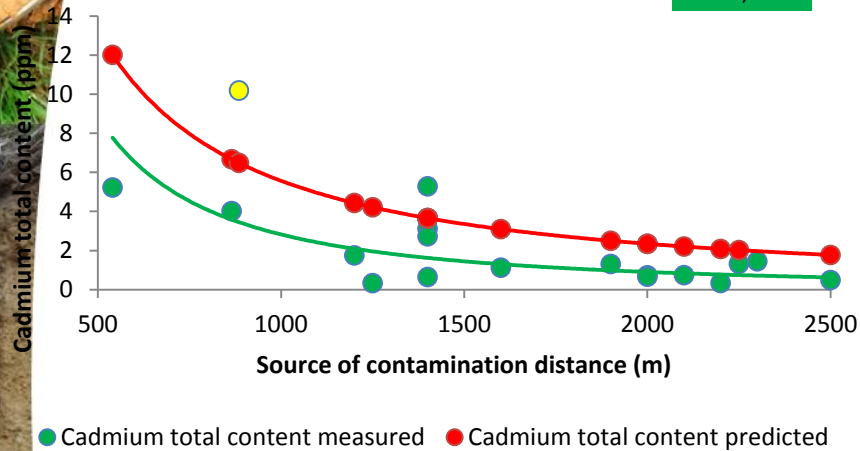
$R^2 = 0,3588$



Comparaison entre teneurs mesurées et prédites

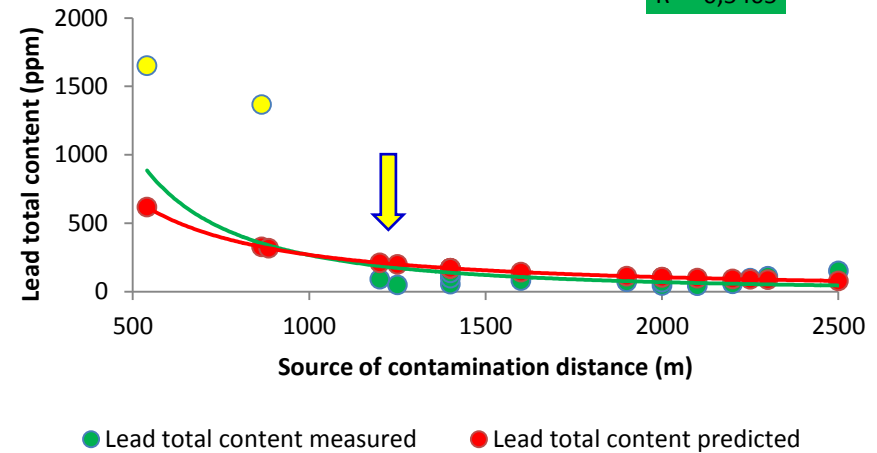
Cadmium

$R^2 = 0,4512$



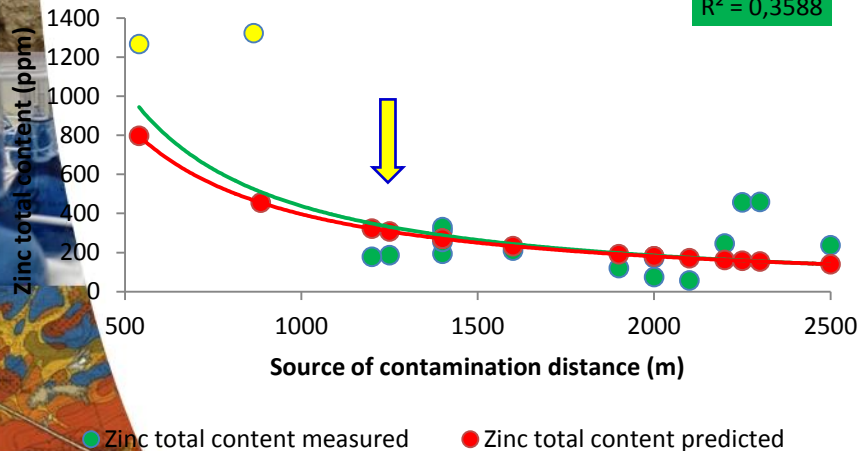
Lead

$R^2 = 0,5405$



Zinc

$R^2 = 0,3588$

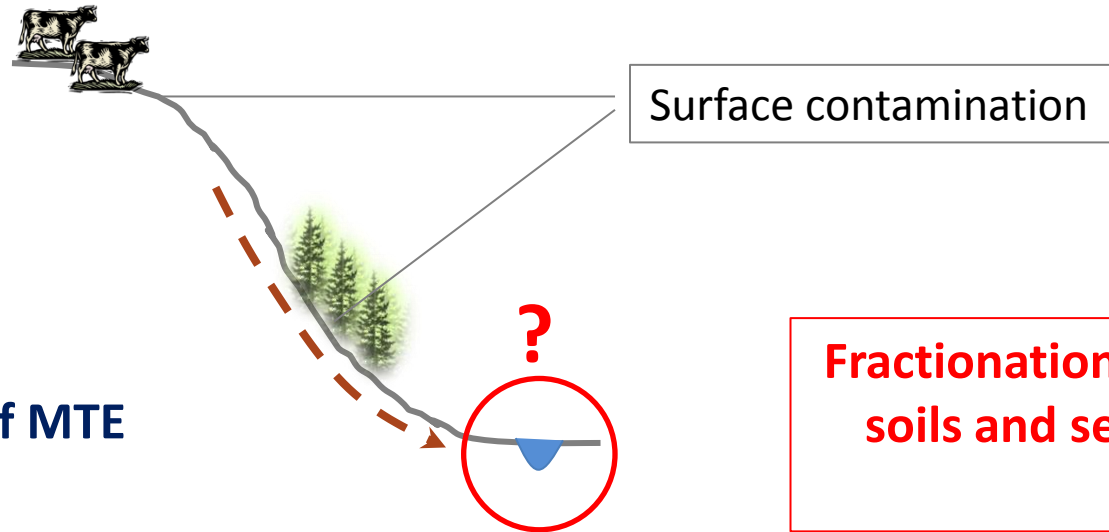


-Cd : the prediction based on the "soil" data overestimates measured values of about 200%

- Pb – Zn : the estimate is consistent with reality as 1,250 m

Sol-sédiments

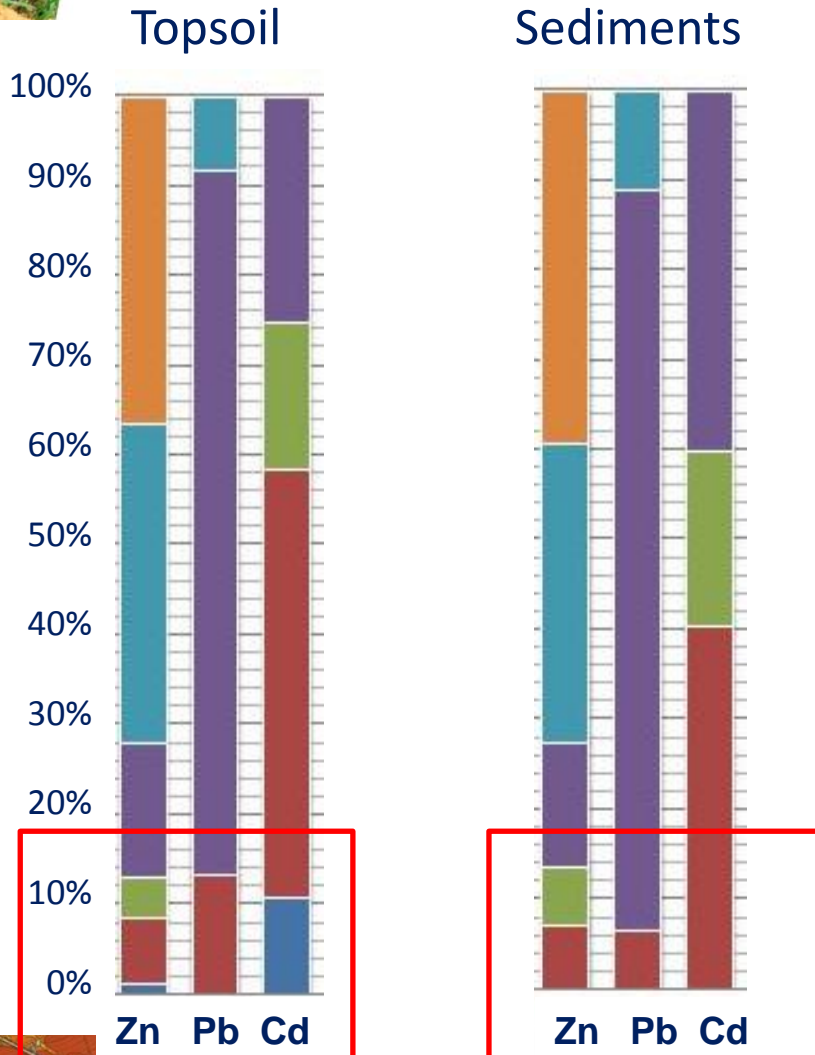
Fate of MTE in contaminated landscapes



Characterization of MTE contents

Factors of variation of MTE content in soils and sediments

Fractionnement chimique des ETM



- Cd : fractionation is different between topsoil and sediments → lost of exchangeable fraction
- Pb : no possible major transfer toward water
- Zn : a small amount may be leached but this is small relative on the total amount

F1	Exchangeable
F2	Bound to carbonates
F3	Bound to amorphous oxides
F4	Bound to organic matter
F5	Bound to crystallized oxides
F6	Residuals

Conclusions sol-sédiments

Fate of MTE in contaminated landscapes

Characterization of MTE contents



Availability of MTE depends on total content of MTE and organic matter

Variation factors of MTE in soil and sediments



The distance is the main factor but possible transport



Can explain the overestimation of cadmium amounts in the sediments

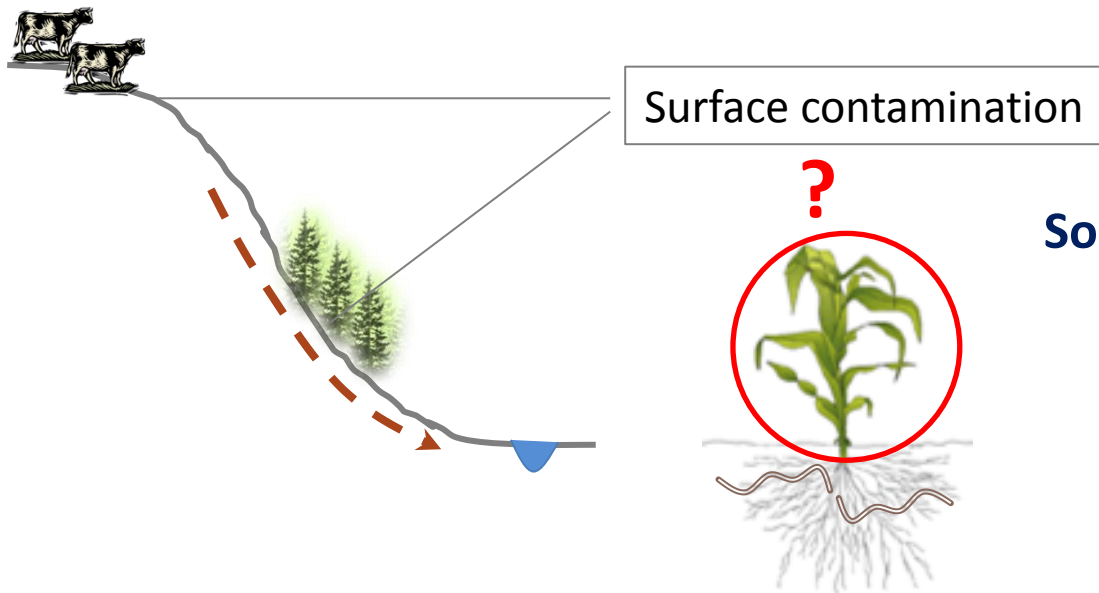
Fractionation of MTE in soils and sediments



Leaching of exchangeable cadmium?



Devenir des contaminants dans les paysages contaminés



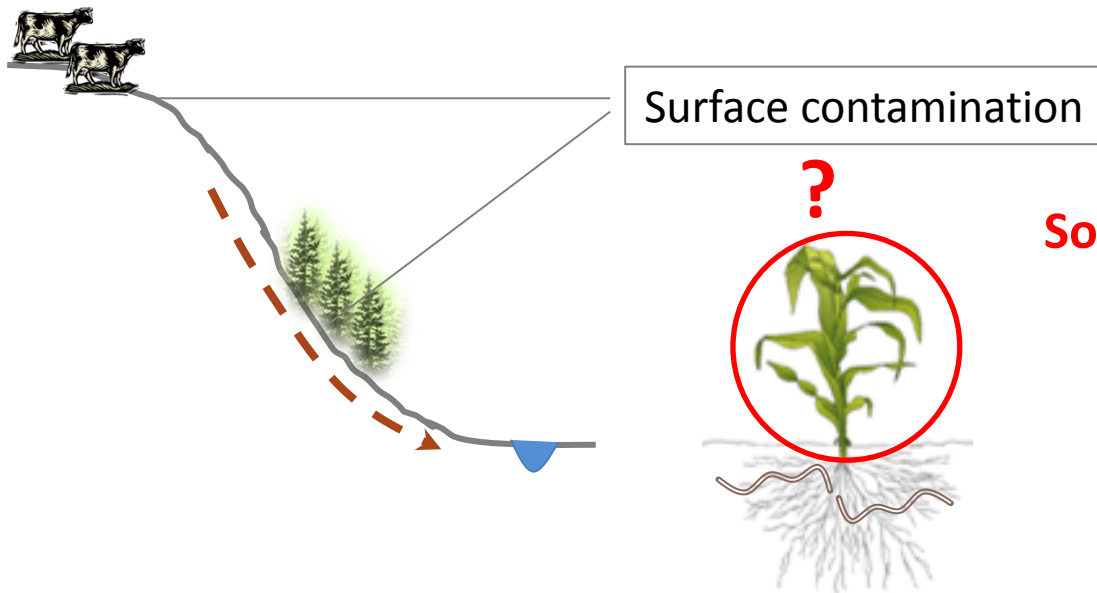
Soil – plant transfers

Characterization of MTE contents

Fractionation of MTE in soils and sediments

Factors of variation of MTE content in soils and sediments

Devenir des contaminants dans les paysages contaminés



Soil – plant transfers

- Crops;
- Grasslands;
- Vegetables

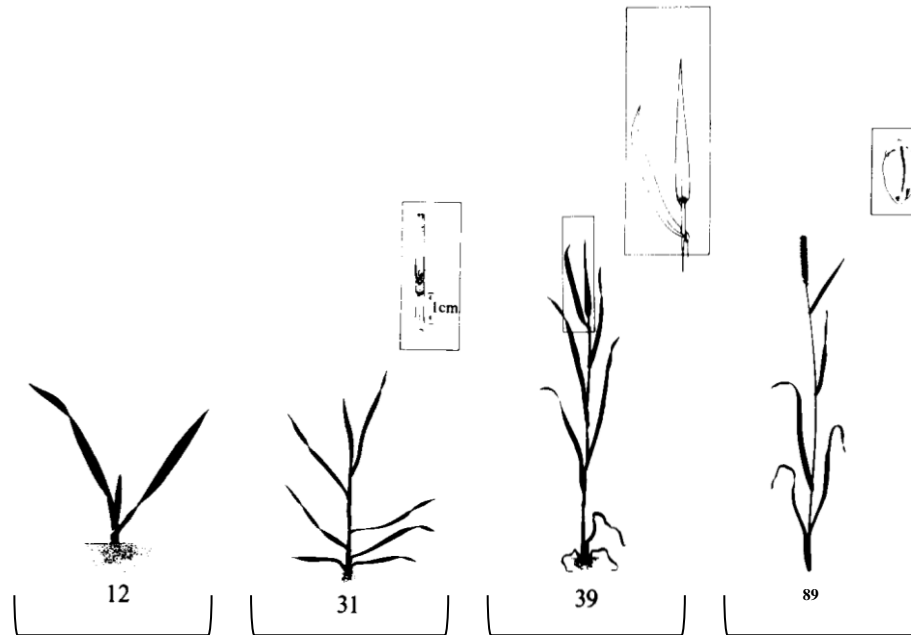
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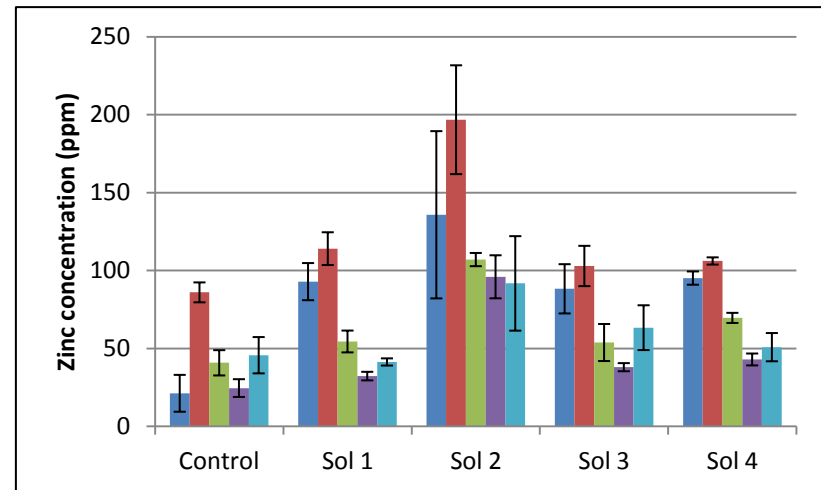
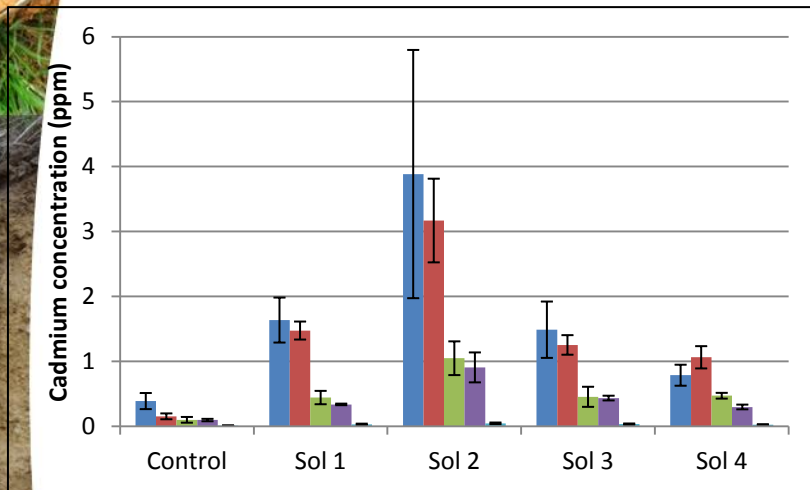
Qualité des cultures

We harvested plants at four phenologic stages and to compare the uptake of MTE according to the stage. We set up 4 replicates by combination (soil-stage).



Qualité des cultures

Cd and Zn uptake in *Hordeum vulgare*

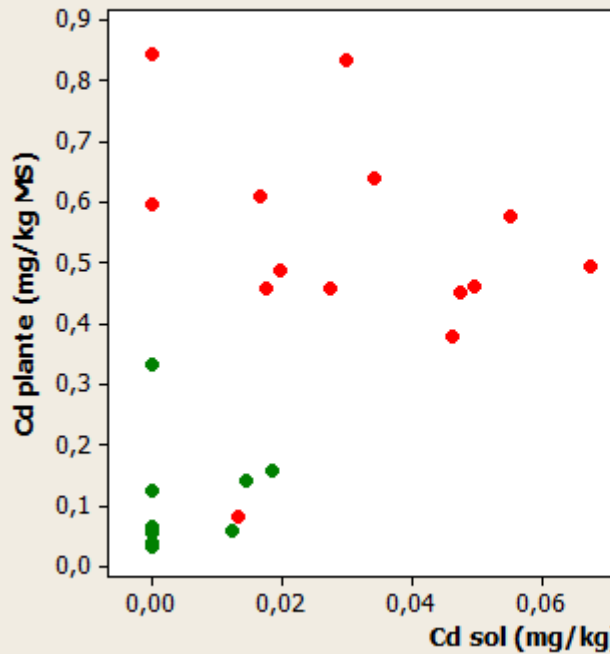


■ Stade 1 ■ Stade 2 ■ Stade 3 ■ Stade 4 - Plant ■ Stade 4 - Seeds

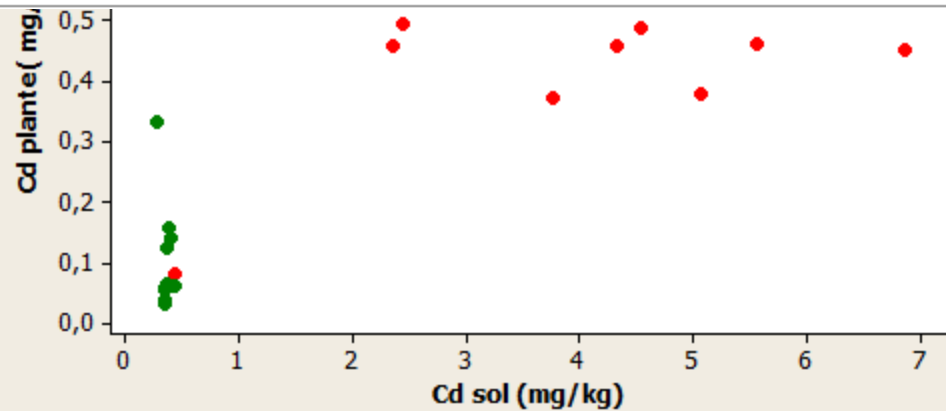
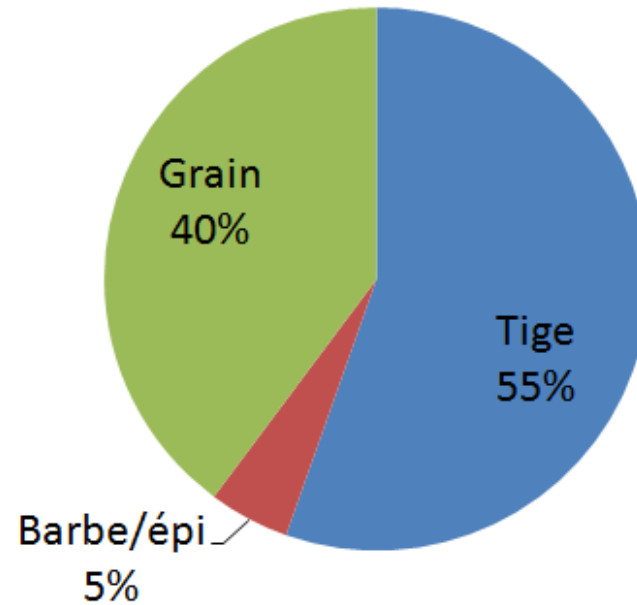
- The highest concentration of Cd is measured in stade 1 (three leaves) while the highest concentration of Zn is measured in stade 2 (2 nodes).
- At the end of growth, Zn is stored in the seeds while Cd remains in the plant (leaves and stem) and is found only in small quantities in seeds.
- Cd and Zn have a different behavior because the first is a contaminant and the second is an oligo-element.

Qualité des cultures : terrain

Cd plante vs Cd



Minéralomasse du Cd dans l'orge



Qualité des fourrages

Map of sampling places realized in grassland around the metalliferous site of Plombières

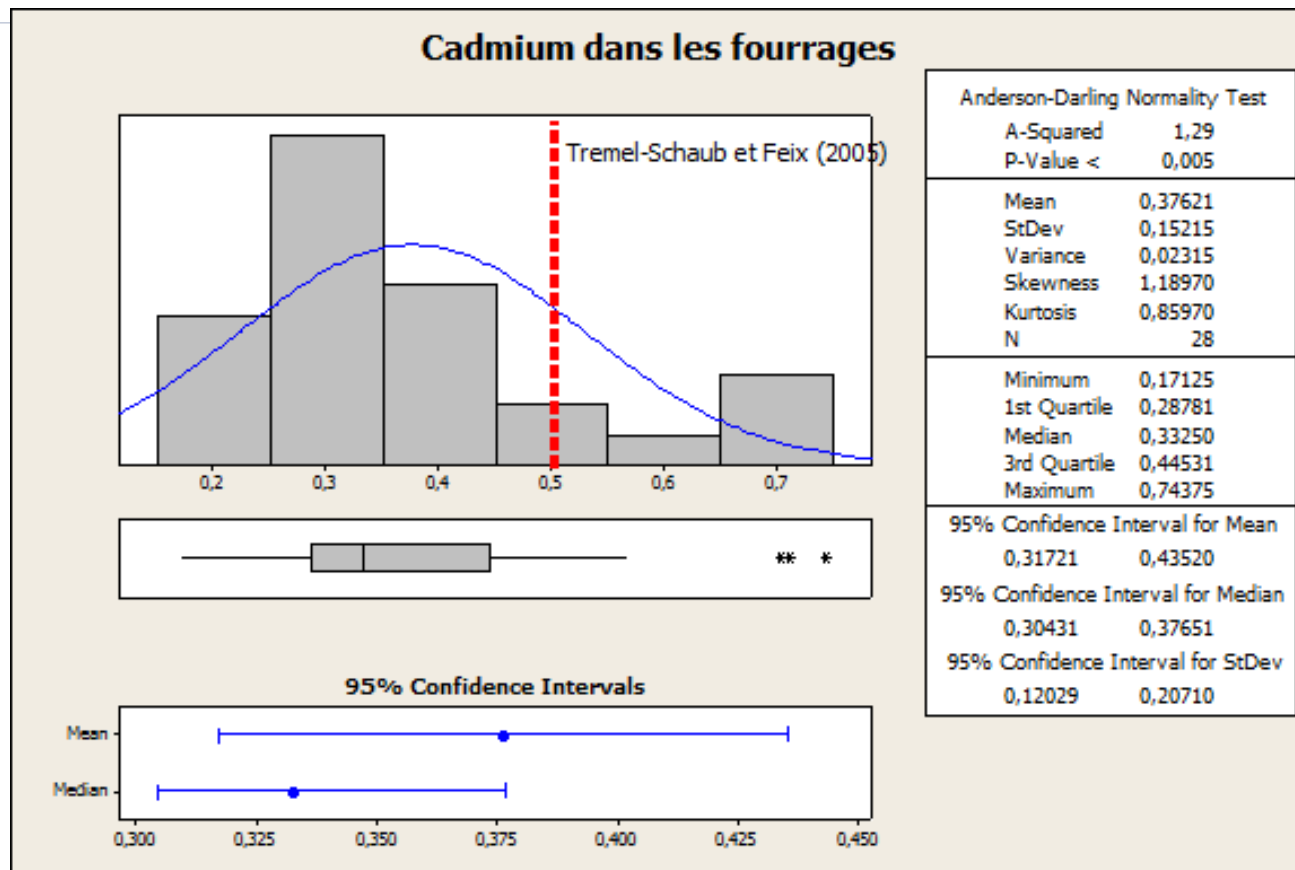


- Sample
- ★ Metalliferous
- ▭ Grassland (soil type ADa)



0 125 250 500 m

Qualité des fourrages



- The MTE uptake by plants can be estimated by some MTE contents in soils :
 - $[Cu]_{Plant}$ is correlated with $[Cd]_{soil}$ and $[Pb]_{soil}$
 - $[Pb]_{Plant}$ is correlated with $[Pb]_{soil}$ and $[Zn]_{soil}$ (ER)
 - $[Cd]_{Plant}$ is only correlated with $[Zn]_{Plant}$

Qualité des légumes



Lettuce sp. and *Endive sp.* were cultivated on 10 contaminated garden soils (Meuse valley) and 2 control soils during 2 months.

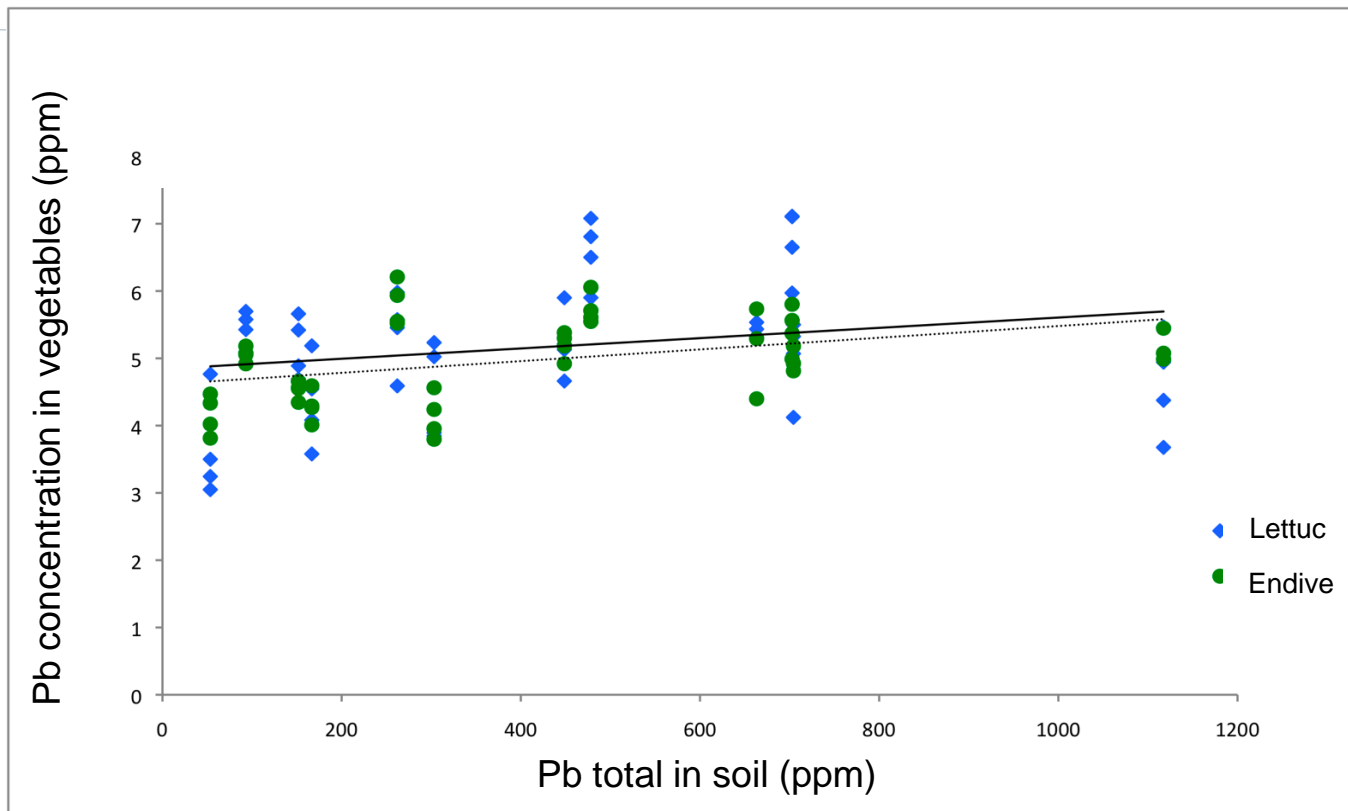
Range of MTE concentration of the 10 contaminated gardens soils:

- Cd: 0,9 – 22 ppm
- Cu: 20 – 250 ppm
- Pb: 55 – 1120 ppm
- Zn: 240 – 5840 ppm

This range is representative of levels found in Liège province.

We investigated the MTE uptake of the two vegetable species when they grow on this range of contamination.

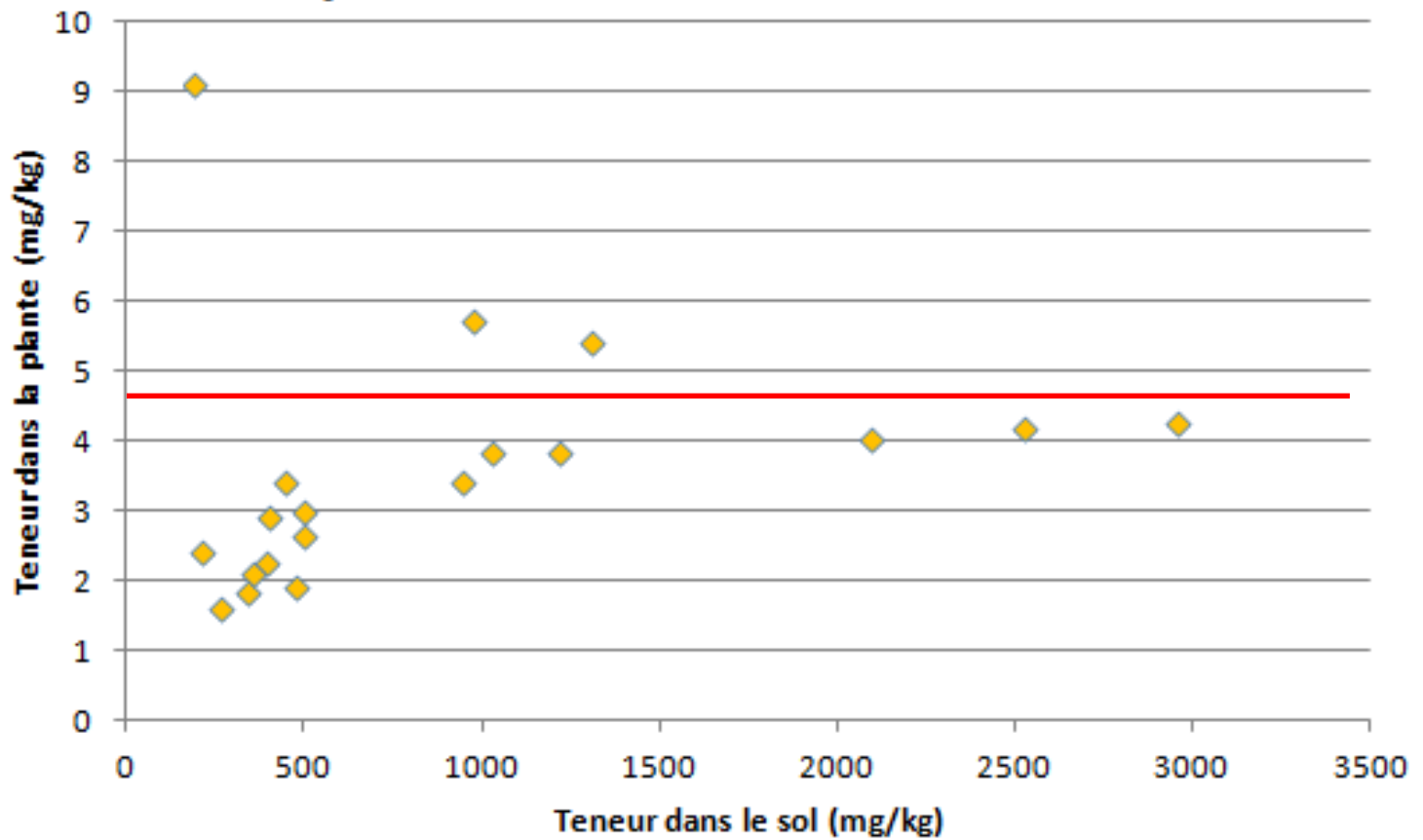
Qualité des légumes



- Statistically, both species accumulate the same concentration of cadmium, copper, lead and zinc.
- Positive significant relationships were found between plant and soil content for studied MTE.
- The risks for people linked to MTE ingestion seem therefore significant and do not depend on the species studied.

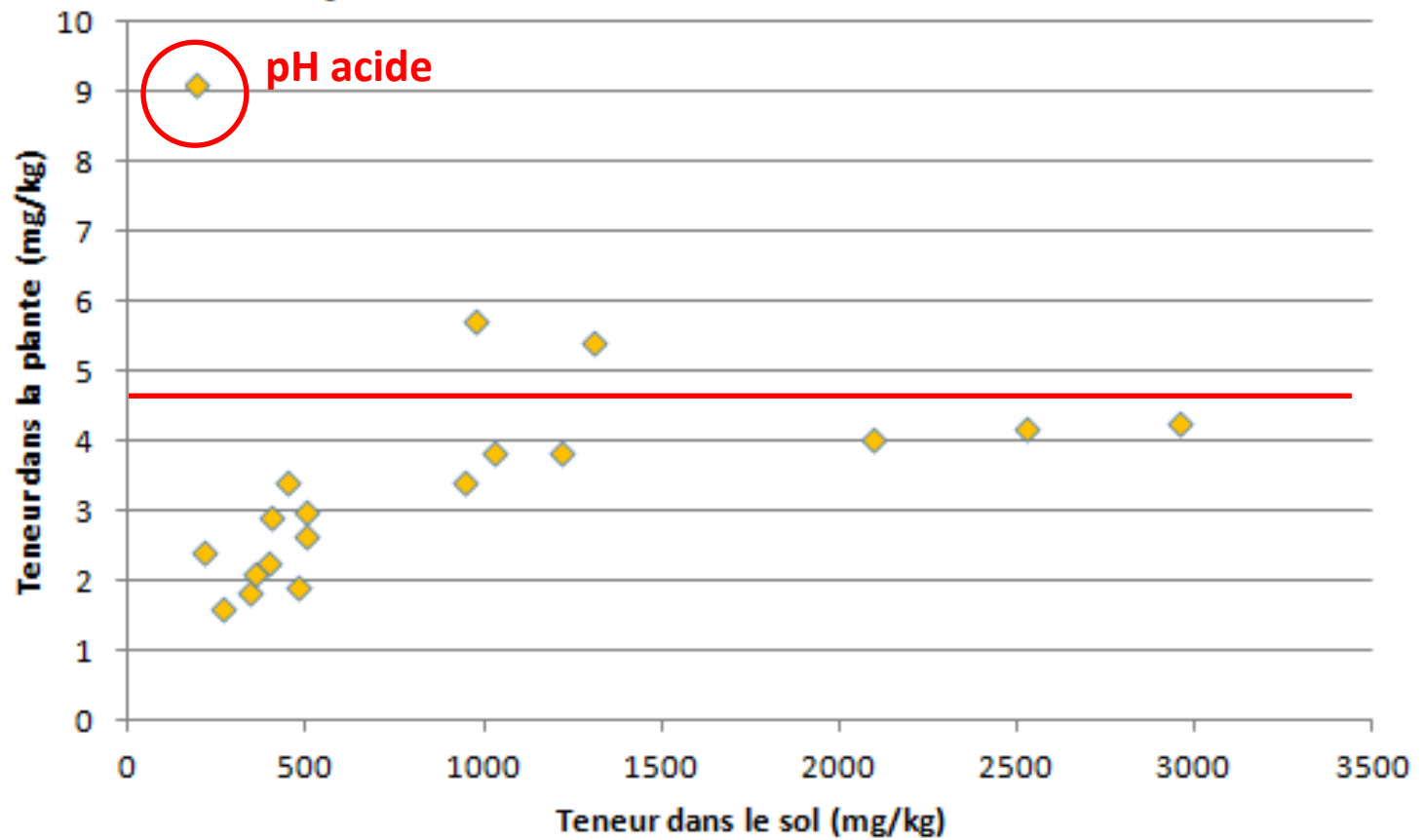
Qualité des légumes

Relation entre teneurs dans le sol et dans la plante : Zn dans des carottes



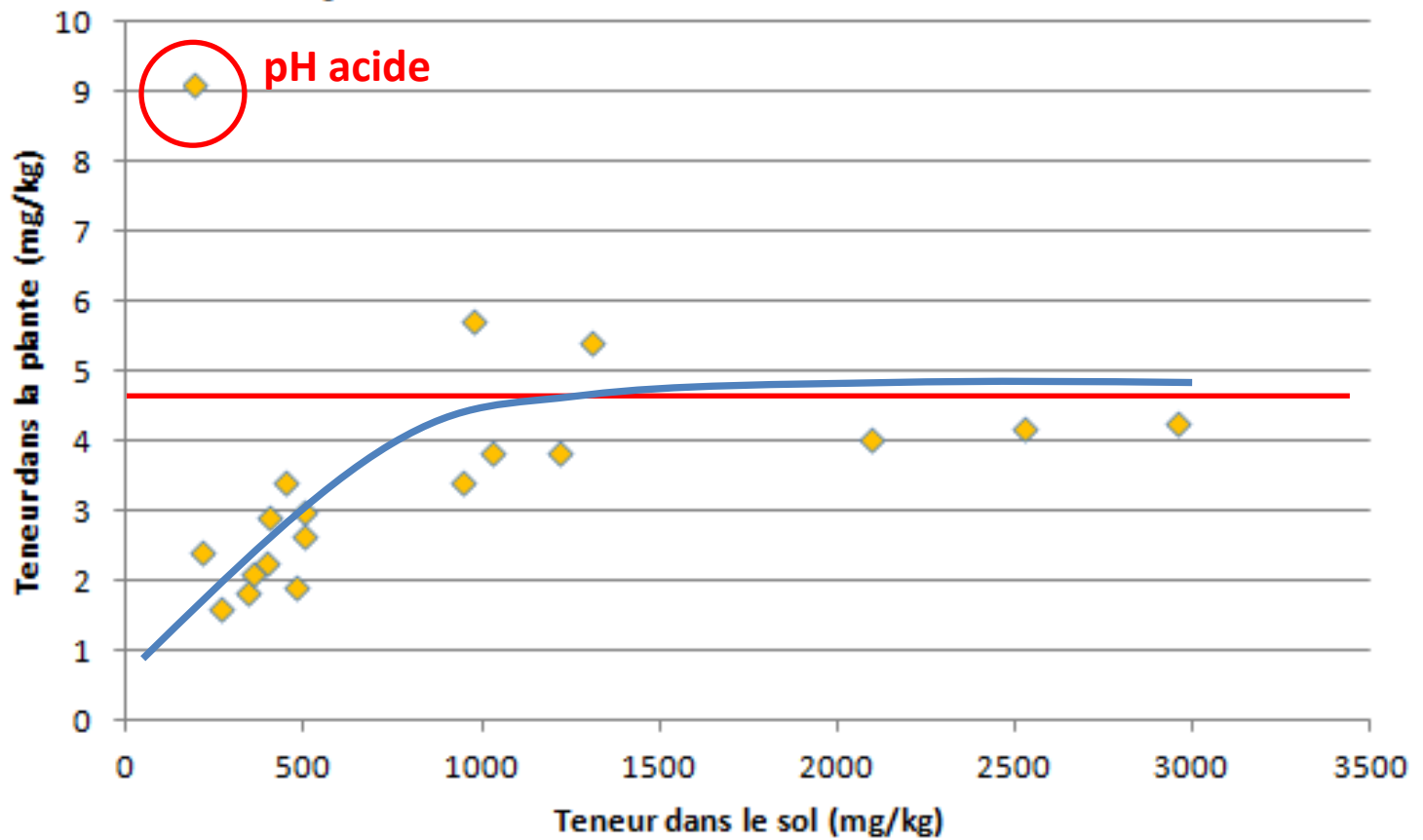
Qualité des légumes

Relation entre teneurs dans le sol et dans la plante : Zn dans des carottes



Qualité des légumes

Relation entre teneurs dans le sol et dans la plante : Zn dans des carottes



Conclusion

Que retenir de nos expérimentations?

- ✓ Les contaminations débordent des sites classés
- ✓ Les teneurs en ETM sont fortement corrélées entre elles et à travers les méthodes d'extraction chimique
- ✓ Les éléments sont potentiellement mobiles au sein des paysages
- ✓ Les risques de contamination des productions agricoles sont réels → études intégrées
- ✓ Attention aux comparaisons entre conditions expérimentales
- ✓ Comment communiquer ?

Merci

