Phytotechnologies: recent experiences in France

1- Deployment of aided phytostabilisation at field scale: set up and monitoring lessons

2- Integration of phytotechnologies in cities

Valérie Bert

1- Deployment of aided phytostabilisation at field scale: set up and monitoring lessons

Specific objectives :

- To reduce environmental risks using **aided phytostabilisation** (plants and amendments)

- To allow economic valorization of the land through the **sale of produced biomass for bioenergy purposes** (bioenergy plantation)

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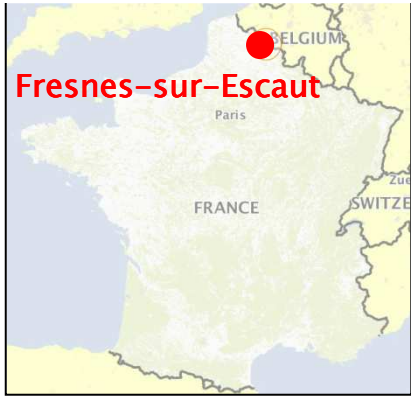
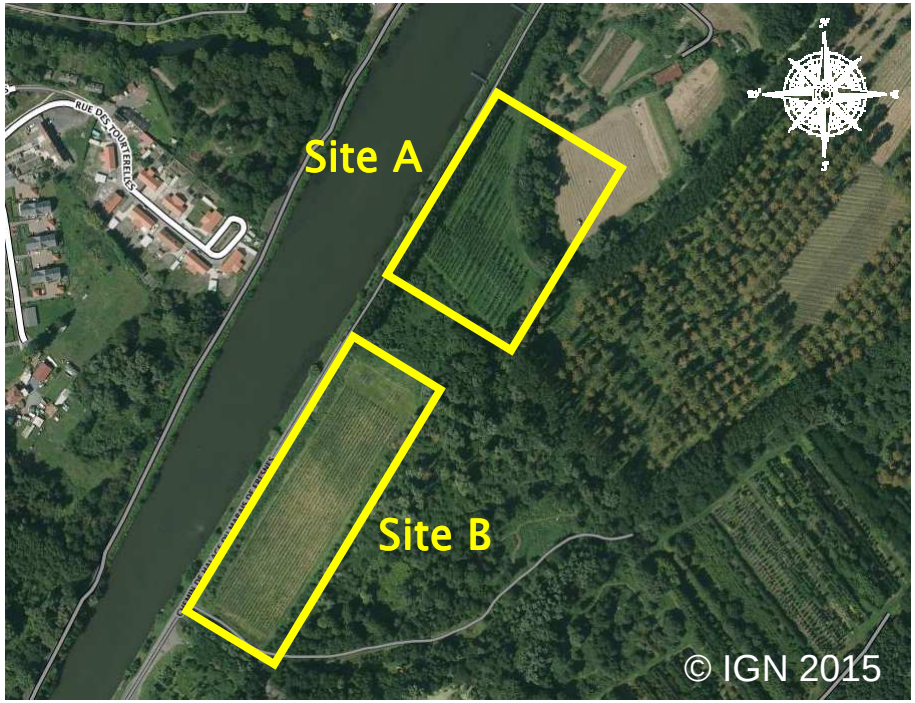
SITE DESCRIPTION



- 2 field trials set up in 2011 – sediment landfill sites – national French waterway manager :
  - site A, 1 ha
  - site B, 1 ha
- Contaminated by various organic and inorganic pollutants



Parameters (0 – 20 cm depth)	Site A	Site B
Texture	Silt loam	Loam
pH $_{(H2O)}$	7.6 ± 0.1	7.3 ± 0.1
CEC ($cmol^+/kg$)	17	24
Organic matter (%)	5.7	31
Organic carbon (%)	3.3	15
Total $CaCO_3$ (%)	4.0	5.3
C/N	9	31
Cd (mg/kg)	11.0 (2.00 – 67.1)	9.74 (6.48 – 15.6)
Cu (mg/kg)	78.6 (19.6 – 126)	110 (37.7 – 193)
Pb (mg/kg)	541 (41.5 – 8,154)	956 (146 – 1830)
Zn (mg/kg)	1,506 (79.0 – 2,710)	6,089 (372 – 12,800)

Site A : SRC poplar plantation (2,200 trees per ha)

April 2011

Field preparation

Plantation of poplars cuttings;

2 cultivars: Skado and I214

Inoculation of mycorrhizal fungi at the foot of the cuttings

AIDED PHYTOSTABILISATION ✚ BIOENERGY CROP FOR ECONOMIC VALORIZATION

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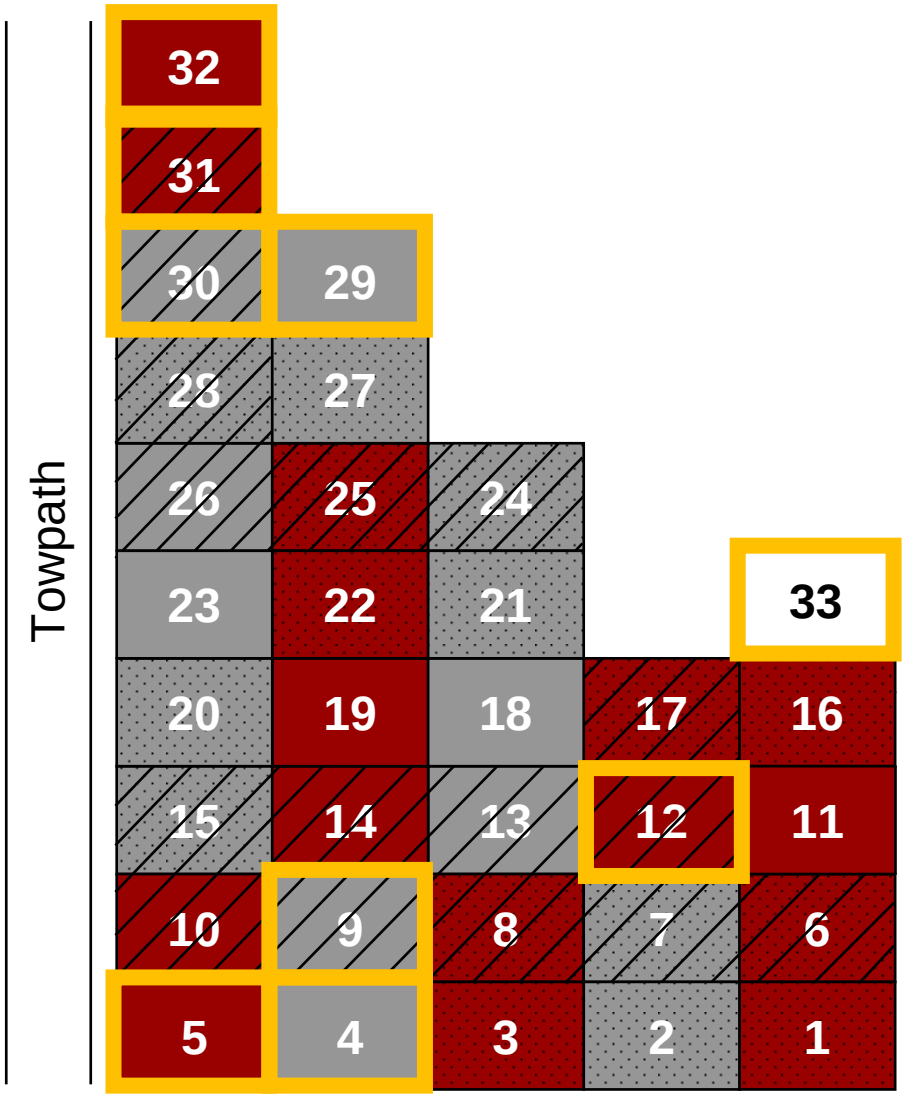
Site A : SRC poplar plantation

- Skado
- I214
- Skado + alder
- I214 + alder
- Inoculated trees
- Non inoculated trees

- 33 Plot without trees
- Sampled plots



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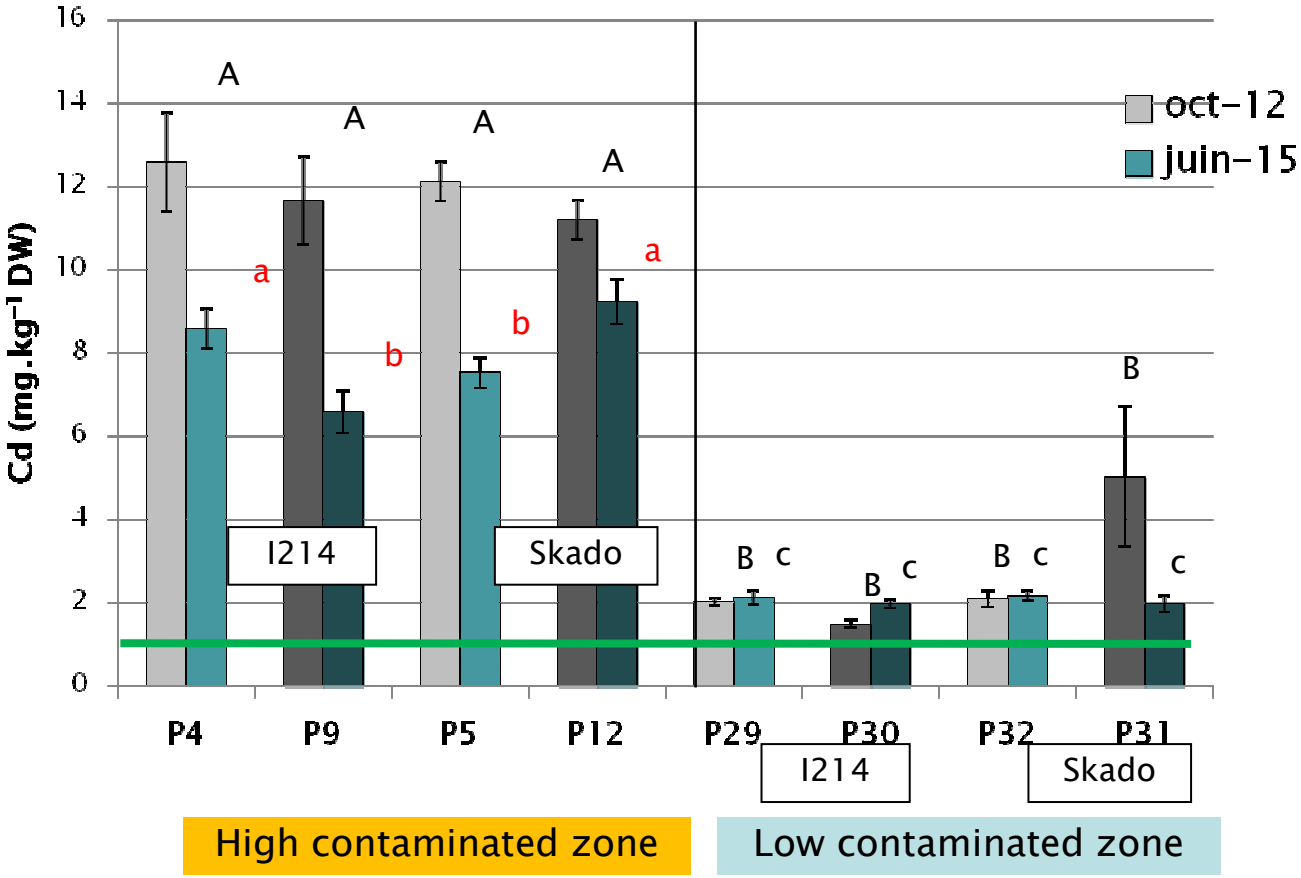
Site A

Cd accumulation in poplar leaves

- Site A



- High Cd concentrations compared to physiological concentrations

  –even in low contaminated zone
  –for both poplars

- inoculation has no clear effect on Cd accumulation

- similar Cd accumulation for both poplars

- seasonal effect?

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SITE DESCRIPTION

Site B : VSRC willow plantation (12,000 willows per ha)

September – October 2011
Field preparation

Spreading of a basic mineral amendment ("OPTISCOR")

Sowing of grass seeds (*Deschampsia cespitosa*)

March 2012

Laying of plastic mulches

Plantation of willow cuttings;

2 cultivars: Inger and Tordis

AIDED PHYTOSTABILISATION

+

BIOENERGY CROP FOR ECONOMIC VALORIZATION

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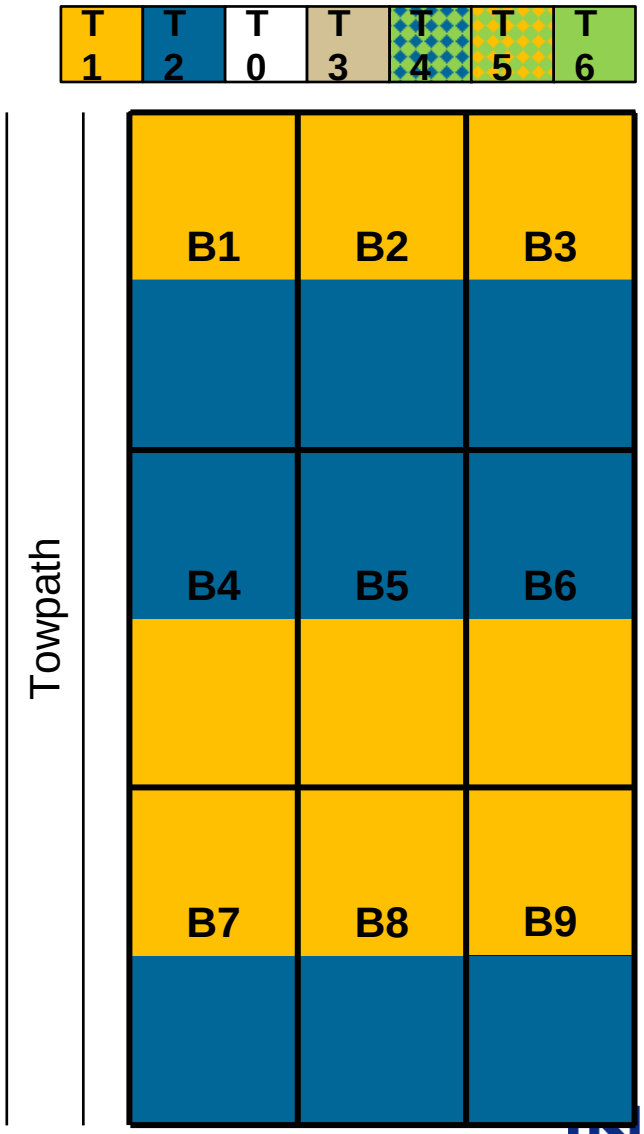
Site B : VSRC willow plantation

Plots amended with a basic mineral amendment

- Tordis + grass
- Inger + grass

Untreated plots

- Tordis, bare ground
- Inger, bare ground
- Tordis + grass
- Inger + grass
- Bare ground
- Lime
- Grass



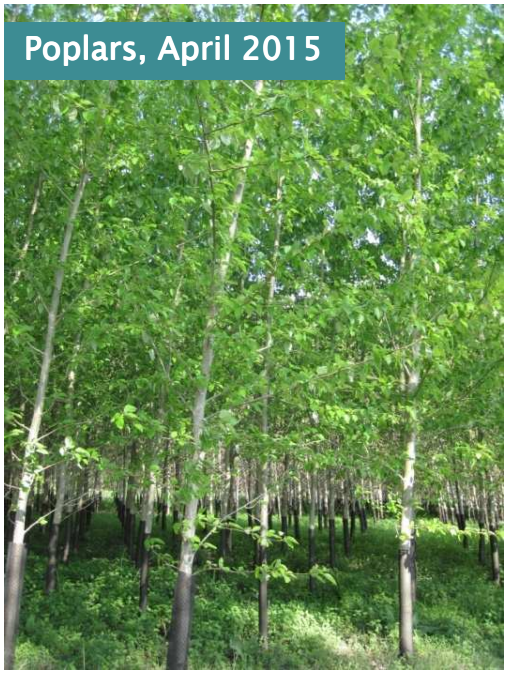
Performance of plants and vegetation dynamics

- Survival rate of trees (Sites A and B)

Survival rate (June 2015)

Year	Site A	Site B
June 2014	98 %	73 %
June 2015	98 %	34 %
		Tordis 38 %
		Inger 29 %


Willows, April 2015


Poplars, April 2015


Willows,

Site B

Untreated Plots	Survival rate
T1	100 %
T2	81 %
T4	47 %
T5	86 %

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Performance of plants and vegetation dynamics

- Botanical survey (June 2015)
  - Species richness:
    - Site A: 21 species
    - Site B: 35 species
  - Identification of 5 dominant species: characteristics of wetlands (site B) and forest (site A)

Site A	Site B
Urtica dioica	*Symphytum officinale*
Glechoma hederacea	*Urtica dioica*
Ranunculus repens	*Rubus caesius*
Galium aparine	*Glechoma hederacea*
Epipactis helleborine	*Ranunculus repens*

➢ Potential role of colonizing species in phytostabilisation ?

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Site B: aided phytostabilisation and willow plantation protocols

September – October 2011

March 2012

Plant removal

Sediment leveling

Decompaction

Amendment spreading (9t/ha)

Grass seeds sowing

Sediment covering

Willow plantation

Duration of preparation and deployment: 3 weeks

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Aided phytostabilisation and willow plantation protocols

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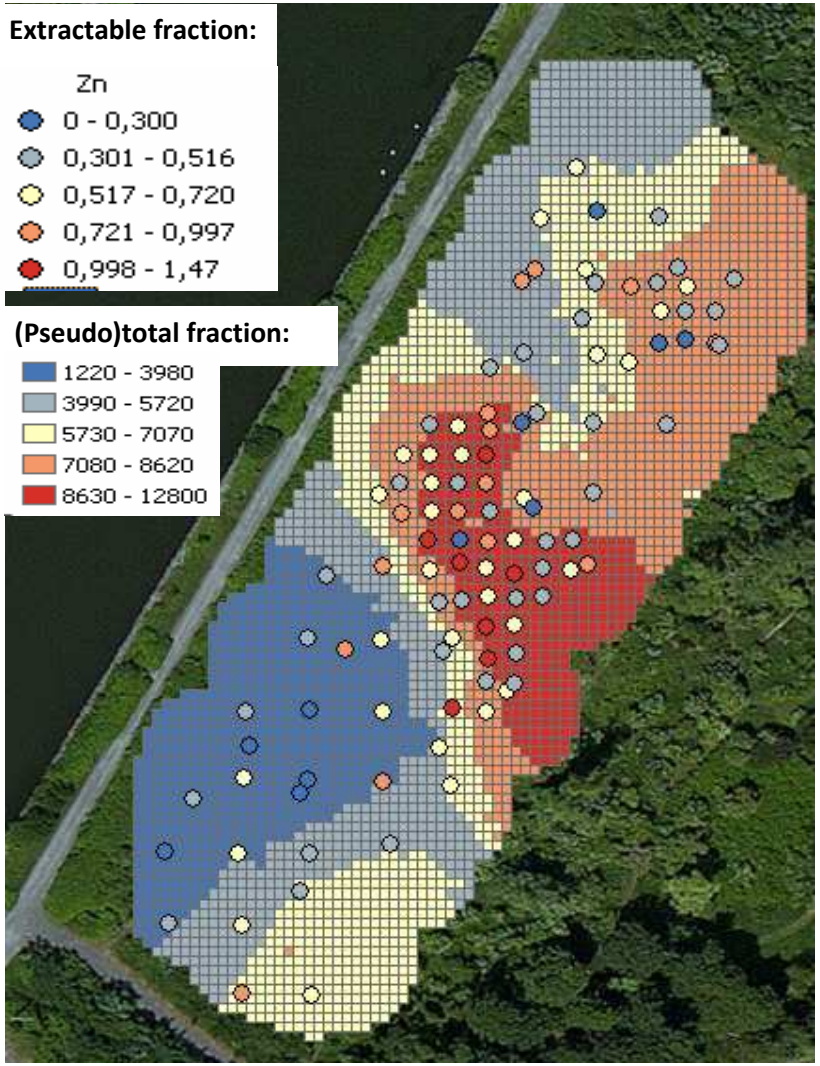
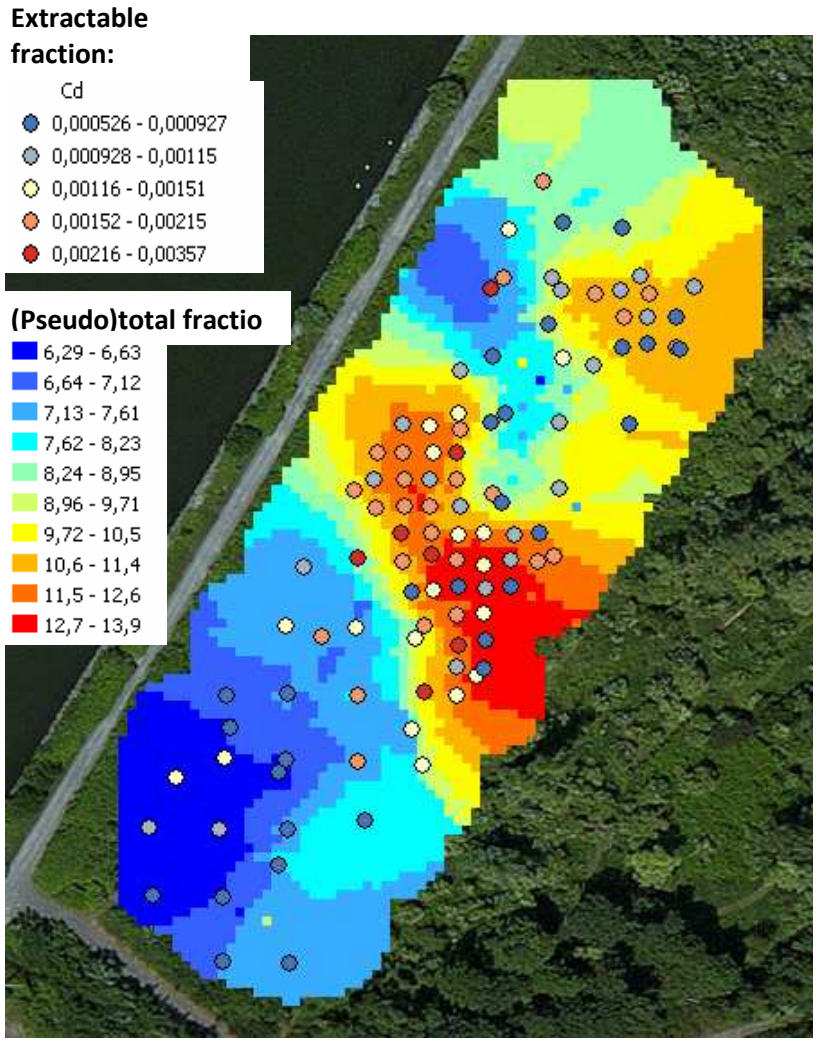
TE mapping





- Spatial heterogeneity of the pollution
- High concentration values (Cd, Zn)

- No correlation between Zn and Cd extractable and (pseudo-total) concentrations

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Aided phytostabilisation ⇨ *Barchampsia cespitosa* as plant cover?

- 100% dense sediment covering
- No toxicity symptoms
- Flowering stage reached

Growth and spread of the invasive species, *Fallopia japonica,* reduced with phytostabilisation

Year	Spot 1 (m²)	Spot 2 (m²)	Total surface (m²)
2011	90	1 200	1 290
2013	24	918	942
2015	16	46	62

– 1 228 m²

- Reduction of the area covered by the Japanese knotweed by 95%
- Reduction of the vigour of the plant
- B. cespitosa competes with F. japonica
- Phytostabilisation is a working strategy

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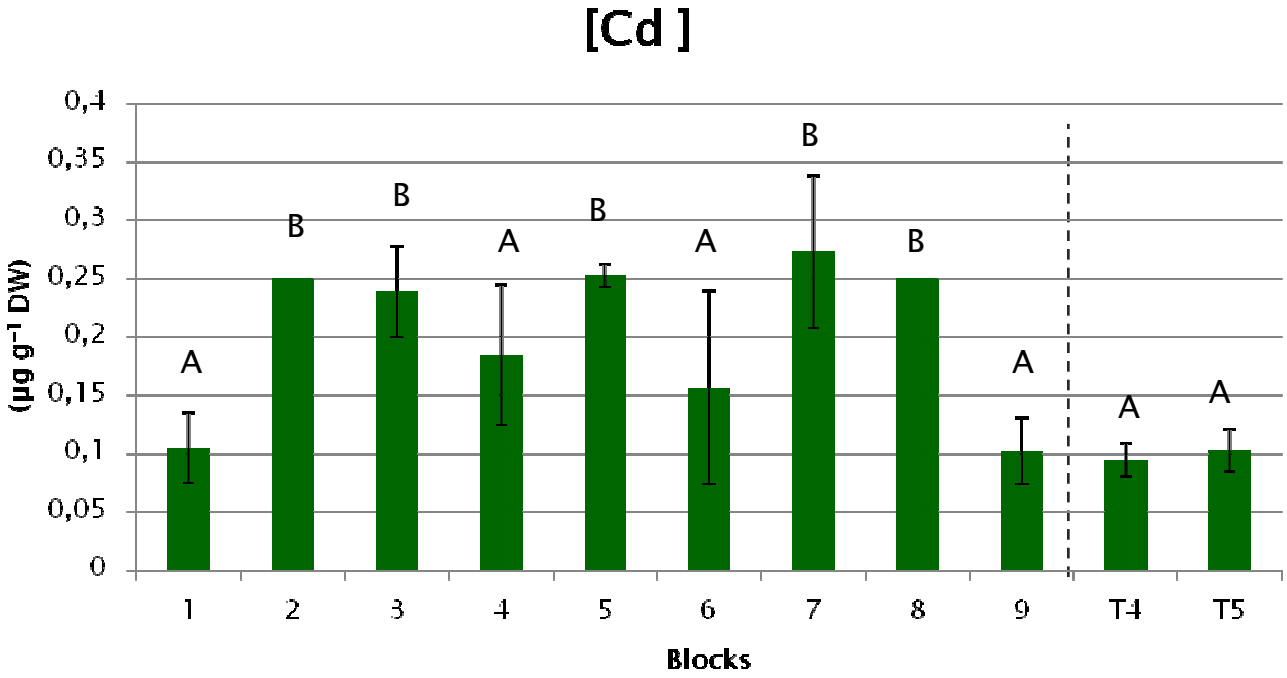
TE concentrations in *Barcampsia cespitosa*



- Frequent (**0,05–0,2** mg kg^{-1}) and toxic (**5–30** mg kg^{-1}) values (Kabata-Pendias, 2010)
- Significant difference between blocks ($p < 0{,}001$)

→ No amendment effect on Cd shoot concentrations

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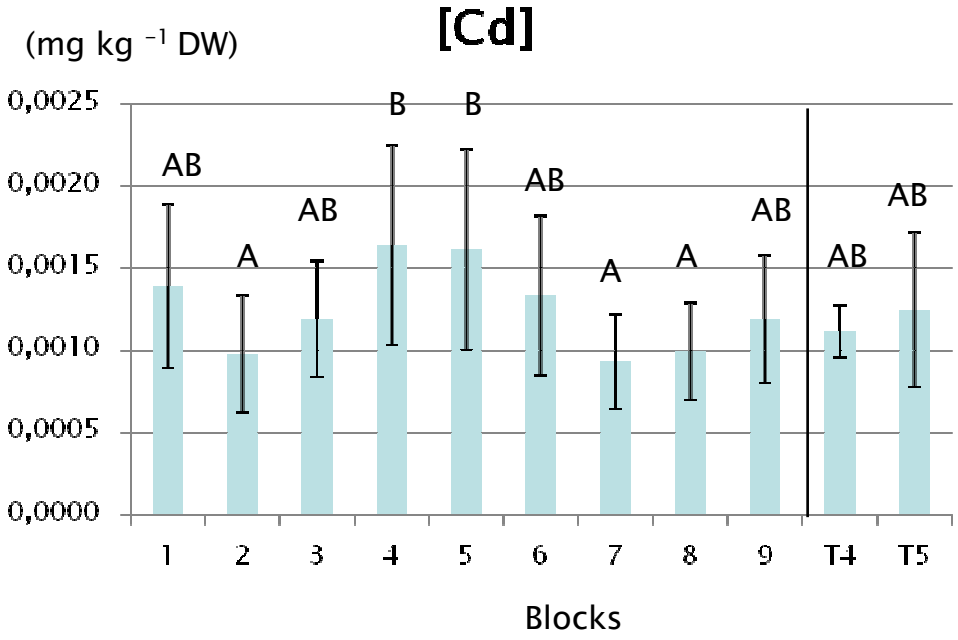
Extractable TE concentrations in sediments



- For Cd, significant differences between blocks ($p < 0,05$)

→ No amendment effect on TE extractable concentrations

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Aided phytostabilisation with *Barcampsia cespitosa?*

- Success of the plant cover
- Tolerance to the sediment conditions
- TE concentrations approximate frequent values for grasses on uncontaminated soil
- Growth reduction of the invasive species

↳ The commercial cultivar, *B. cespitosa*, is a good candidate for phytostabilisation

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Aided phytostabilisation with *Optiscor?*

- Until now, no efficiency on the decrease of the TE labile pool and shoot concentrations. Present work is addressing the mechanisms (speciation, OM, $CaCO_3$ stock, etc.).

- Monitoring to be continued the next years

Valuation of the sediment deposit site
↳ *Salix* cultivation to produce valuable biomass for bioenergy

Salix cultivation in combination
with risk management by aided phytostabilisation

Relationship between the grass and the willows

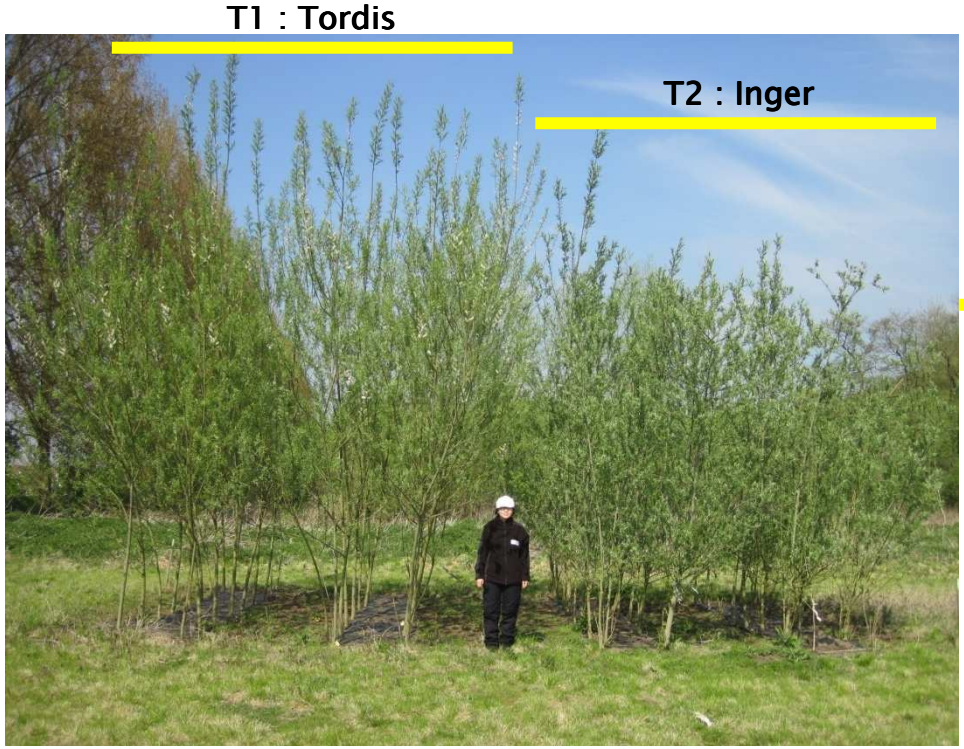
- The grass is competing for water and nutrients

⇨The survival rate of willows decreases time after time (2013: 90% – 2014: 73%)
⇨The height and diameter are not increasing, as well as biomass

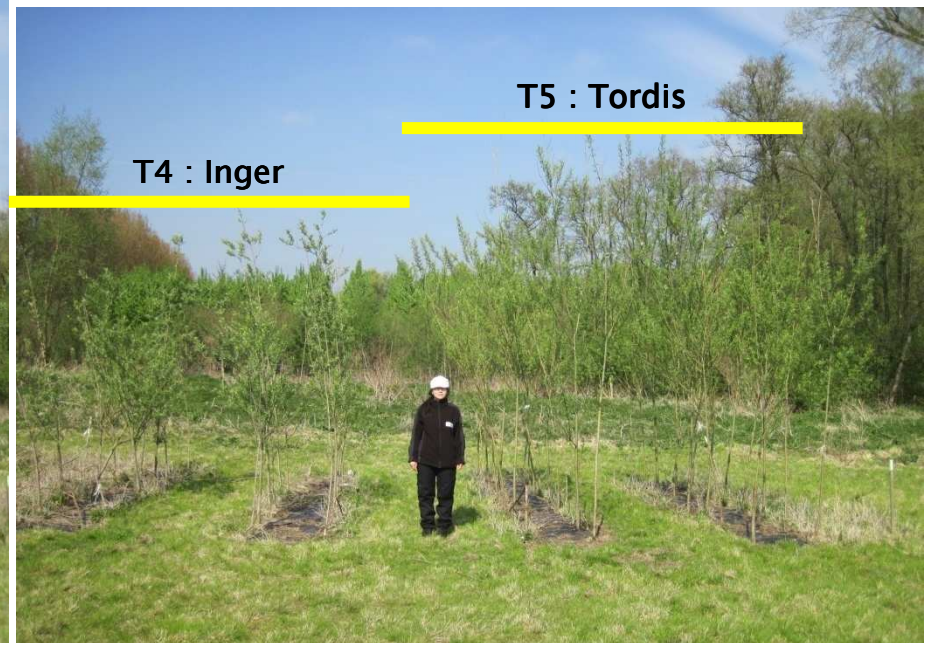
- Clear evidence when looking at the roots: without versus with the grass

Relationship between the grass and the willows?

April 2015



Untreated and unvegetalized plots



Untreated plots with vegetation cover (tufted hair grass)

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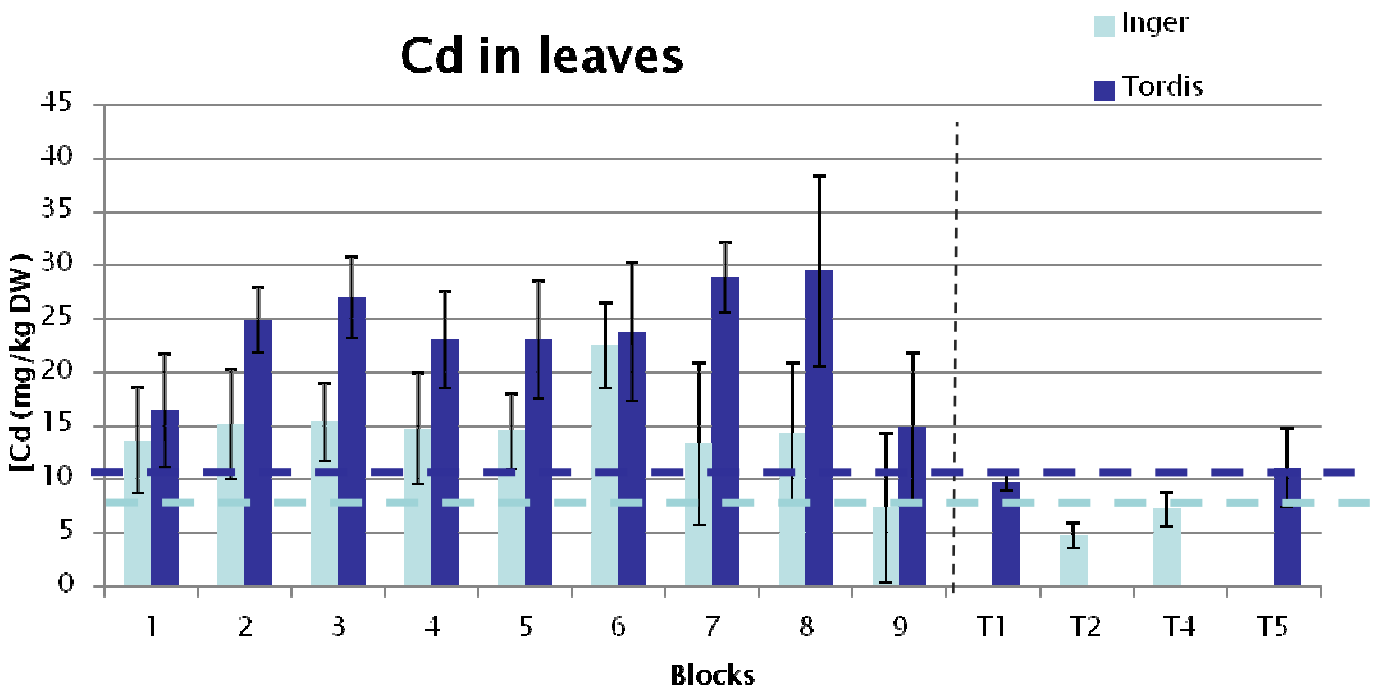
TE concentrations in leaves of willows



- Cd concentrations >> frequent willow leaves concentrations [<2 mg kg^{-1} DW] → phytotoxicity?
- 'Tordis' > 'Inger'
- Cd concentrations on amended plots are higher than those on control plots

→ inefficiency of soil amendment

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Lessons after 4 years of monitoring

↳ In our case, the combination of aided phytostabilisation using a grass cover with the plantation of willows to produce biomass for bioenergy is not successful:

- grass and willow competition for water and nutrients

- sensitivity of the selected willow clones to pollution and other factors (willow leaf beetle, herbivores…)

Present work:

↳ Test other option to avoid grass competition:
Replace grass by mulch

↳ Test poplar instead of willow

↳ Use herbivore protections on trees

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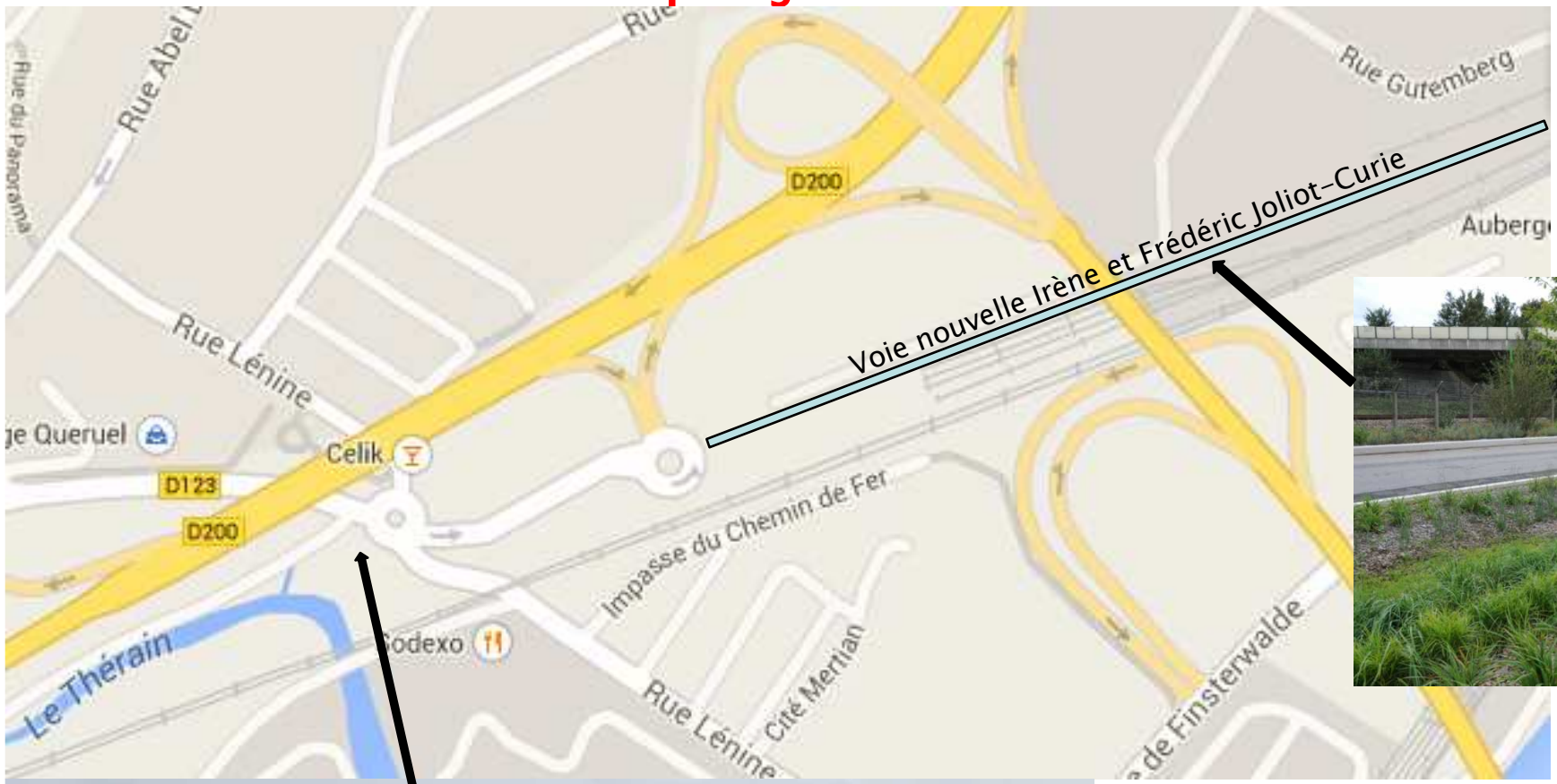
PHYTOAGGLO

Integration of phytotechnologies in cities
Polluted soil management

Location of the project



Phytostabilisation

Set up:
June 2013

Phytoextraction

Set up:
March 2013

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Phytoextraction

- selection of willow
(*Salix viminalis)* and hyperaccumulating plant
(Arabidopsis halleri)

↳ significant transfer of Zn and Cd in aerial parts
↳ metal tolerance

↳ suitable species with vegetation objective (vegetation area)

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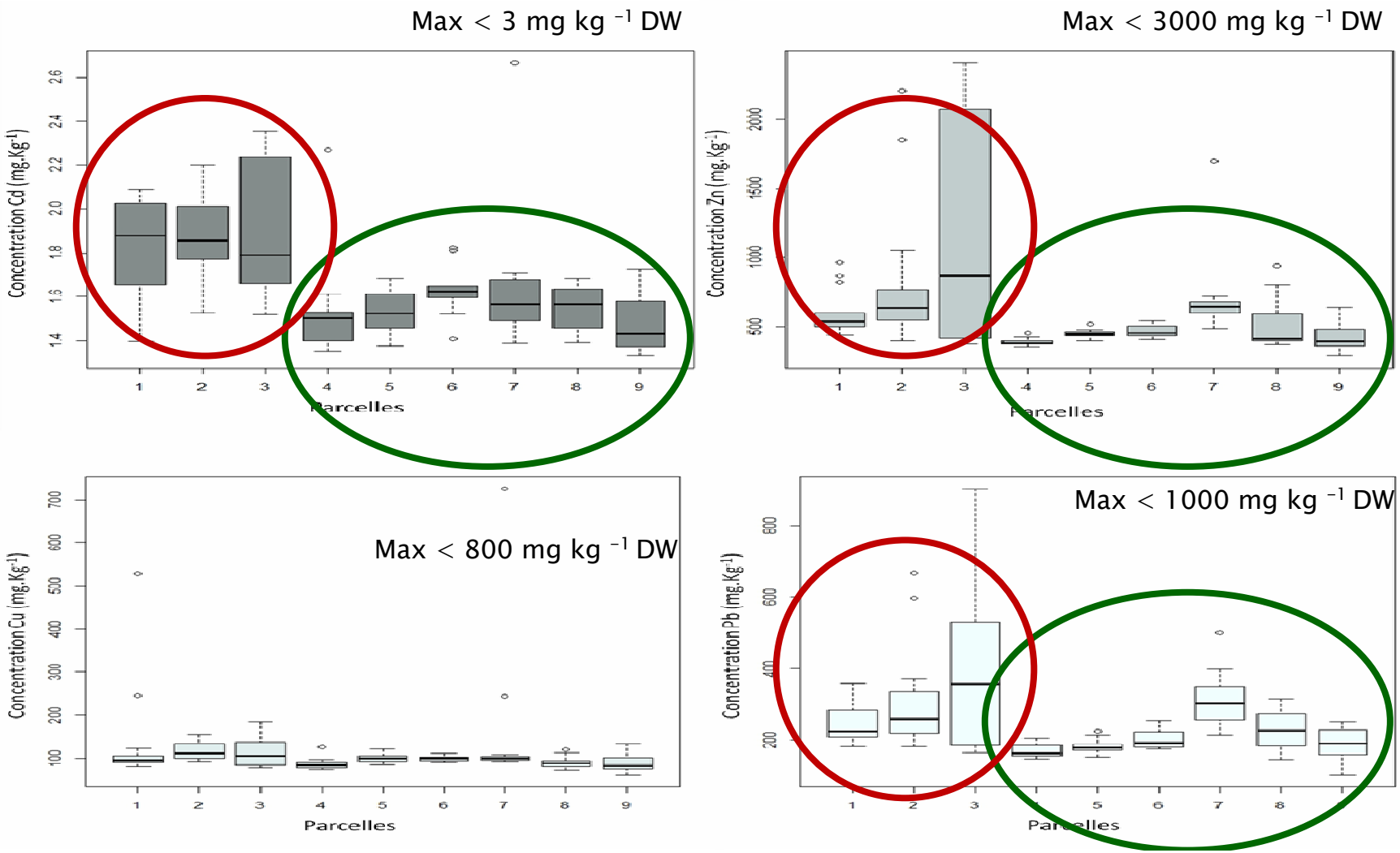
pH et concentrations en métaux dans les sols

- alcaline pH (8,09 ± 0,17) a priori not optimal for phytoextraction
- spatial heterogeneity of the pollution(Cd, Zn et Pb)



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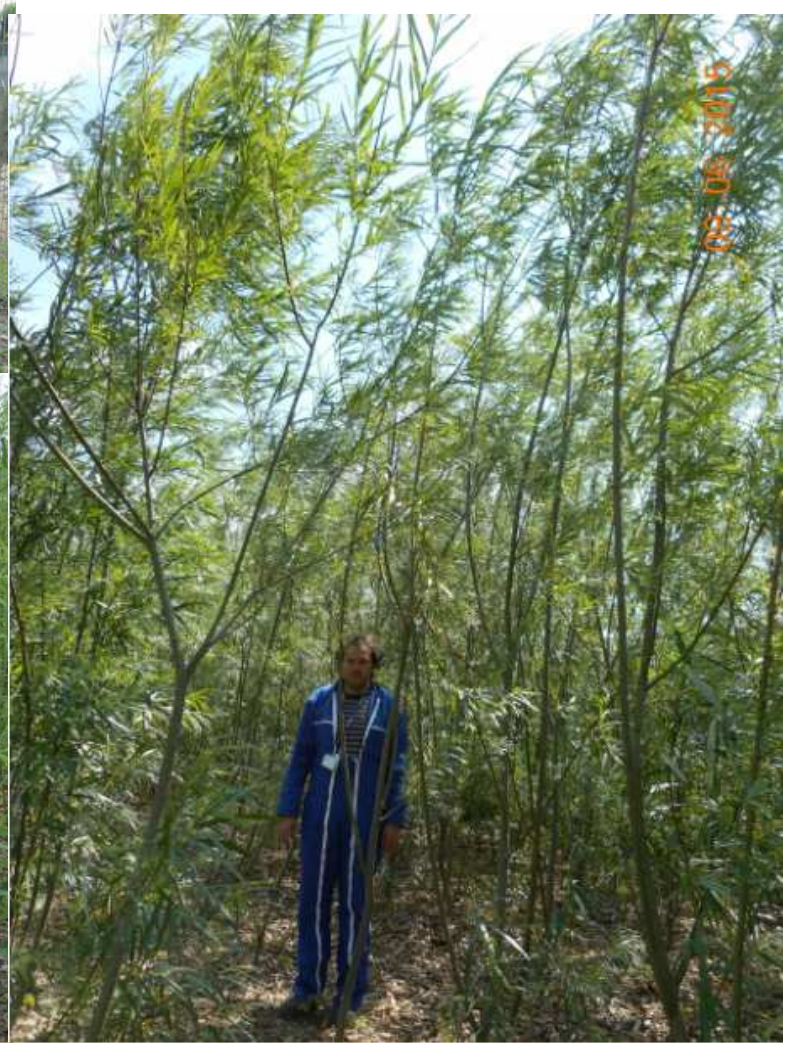
June 2015 willow plantation-successful growth



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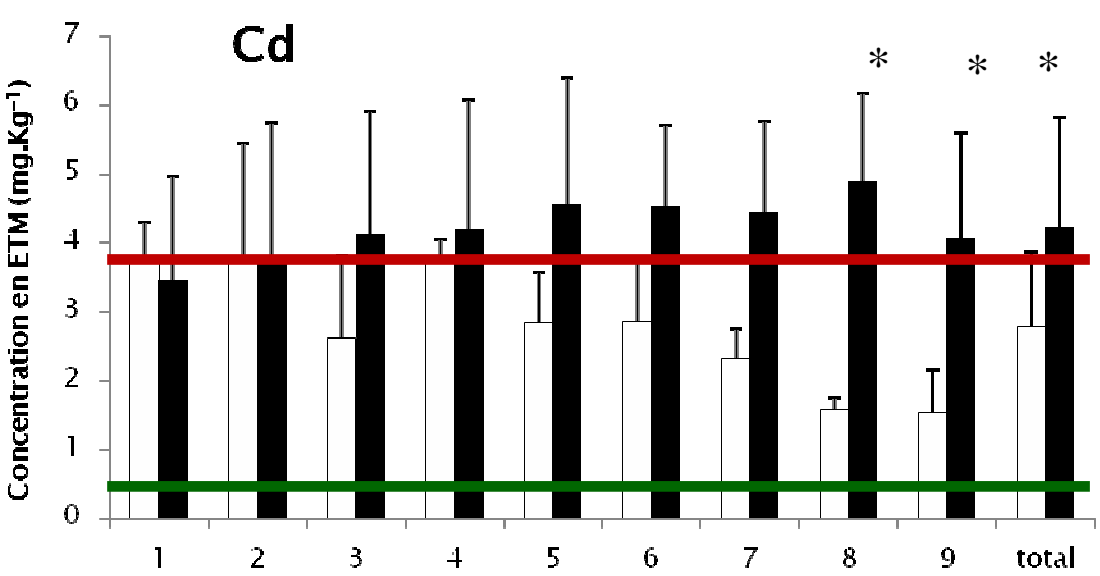
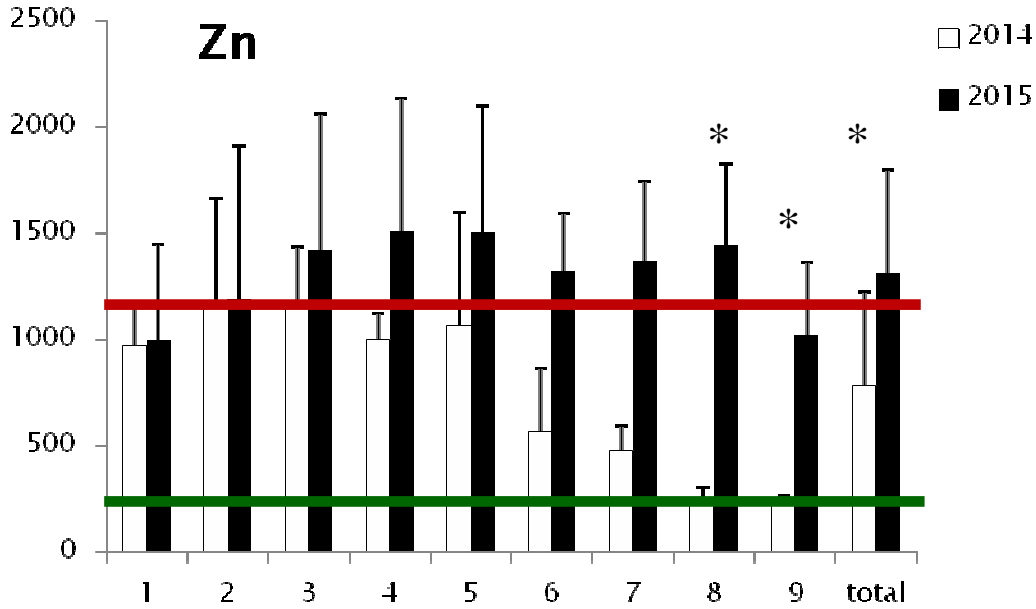
June 2015 – metal concentration in willow leaves

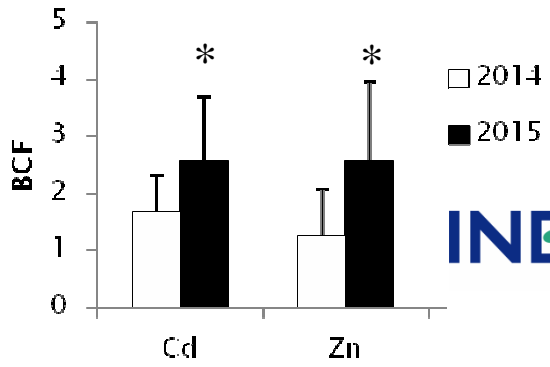




- Zn and Cd accumulation at non physiological levels (Zn > 200; Cd > 0,5)

- higher metal concentration in 2015 than in 2014 (1.5 times more Cd and 1.6 times more Zn)

- BCF: foliar concentration / soil concentration
BCF ~ 2,5 interest for phytoextraction
(accumulating behavor)



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in situ growth of A. halleri

Growth
Flowering
stage

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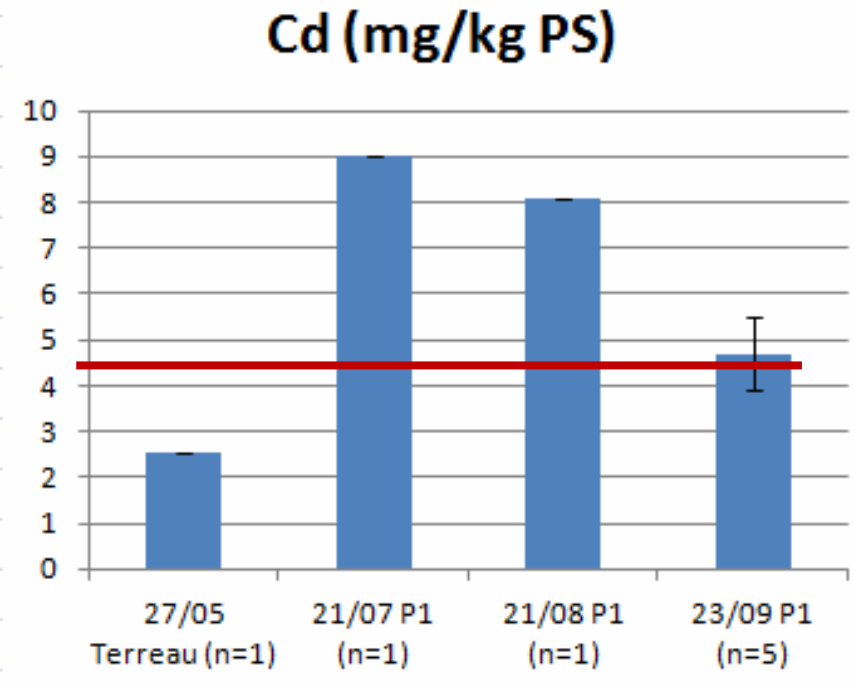
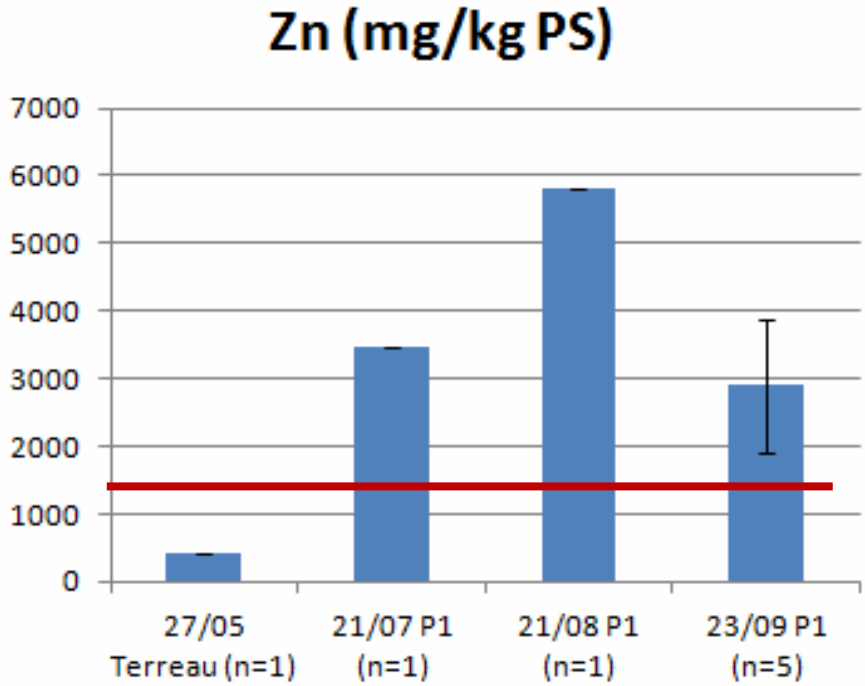
TE concentrations in A. halleri





- A. halleri concentration > willow concentration (Cd: 4,2; Zn: 1310 mg/kg PS)
- Interest of the co-culture willow/A. halleri

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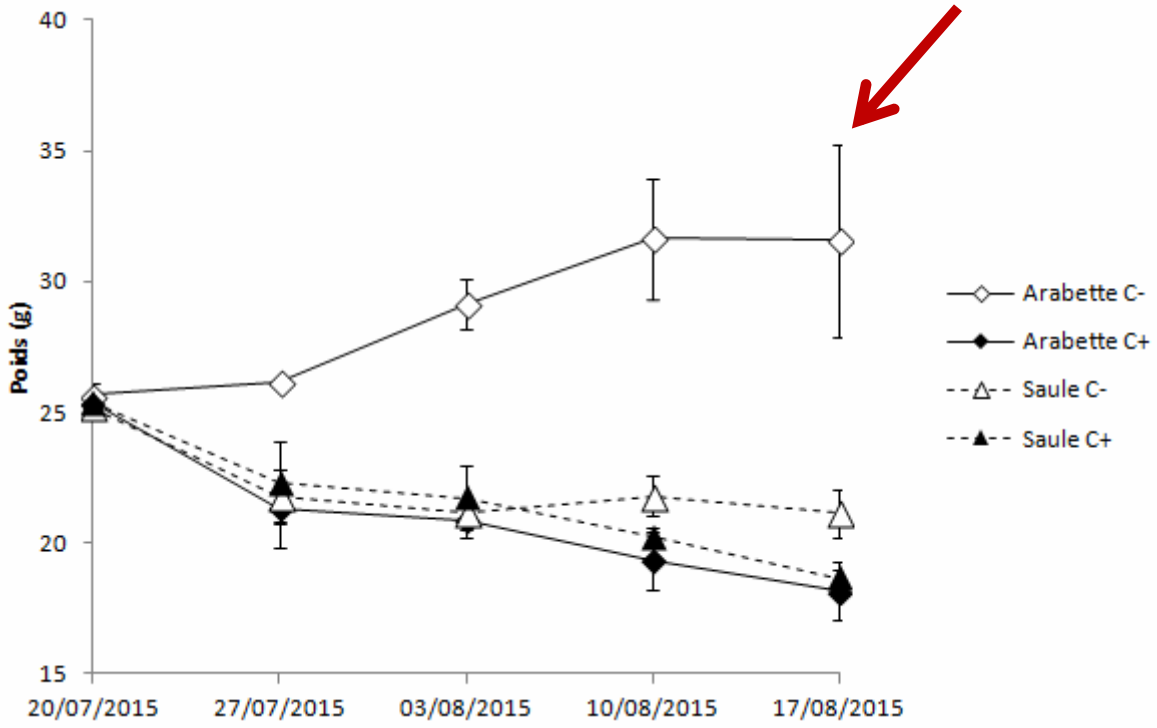
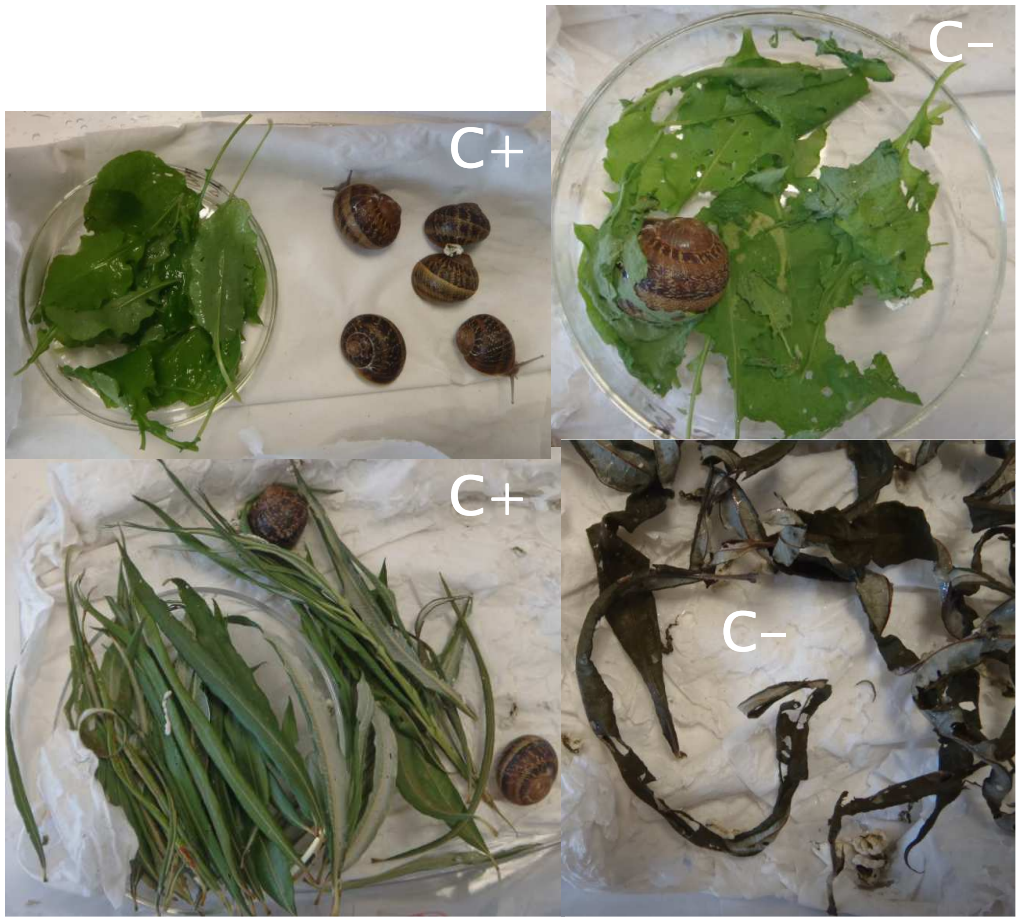
Do snails eat A. halleri or willows?

Snails in contact with plants more/less enriched with Zn and Cd
Regular weight measurement

A. Halleri Auby (enriched Zn/Cd: C+) vs control (C–)
Willows phytoagglo (enriched Zn/Cd: C+) vs control (C–)

C– A. halleri





Conclusions after 2 years of monitoring

Phytoextraction

- Success of the willow plantation (growth and vegetation image)

- Success of the A. halleri growth

Besides the alcaline pH :
- increase of foliar accumation of Cd/Zn in willows
- Zn/Cd foliar accumulation in A. halleri better than willow

Present work
↳ Continuation of monitoring
↳ Increase phytoextraction performance by collecting leaves of willows

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Willow leaves collection – production of Zn ecocatalyst (green chemistry– Phytochem project)

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