Gentle remediation of trace element contaminated land Greenland (FP7-KBBE-266124)

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

Valérie Bert, Anaïs Buffard, Assiya Cherifi-Alaoui, Antoine Hoste, Nicolas Manier, Michel Mench, Pierre Boucard

WP1 Sustainable management adapted to TE contaminated soil and deployment of gentle remediation options at field scale

Objectives

- To gain practical information on deployment
- To assess performance and long term efficiency
- To produce plant biomass for transformation processes

Objectives of the study

• Aided phytostabilisation *in situ*

↳ association of plants and soil amendment to reduce the TE labil pool in soil and the TE transfer in plants

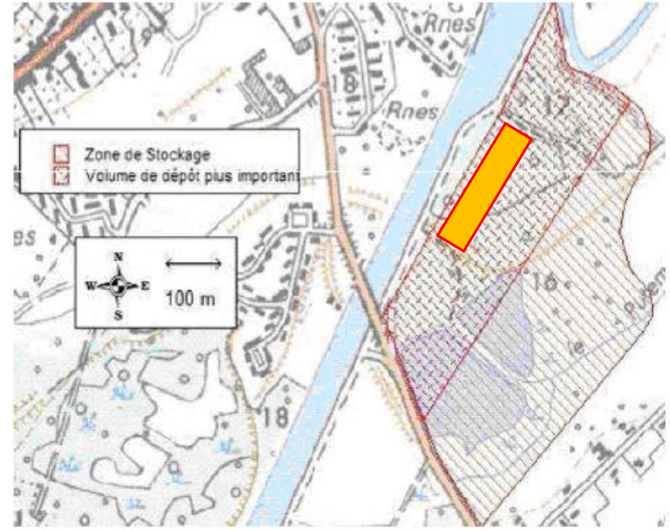
• To test this strategy to reduce the growth and spread of the invasive species, *Fallopia japonica*

• Valuation of the site

↳ *Salix* cultivation to produce valuable biomass for bioenergy

• To make a technico-economical analysis of aided phytostabilisation and biomass production

Field site before deployment



1 ha contaminated (Cd, Zn, Pb, Cu) dredged sediment landfill site with no usage

Presence of Japanese knotweed

INERIS
maîtriser le risque
pour un développement durable

Aided phytostabilisation and willow plantation protocols

September – October 2011

March 2012

Plant removal

Sediment leveling

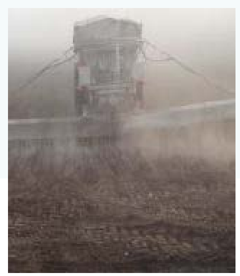
Decompaction

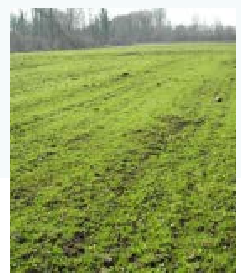
Amendment spreading (9t/ha)

Grass seeds sowing

Sediment covering

Willow plantation





Duration of preparation and deployment: 3 weeks

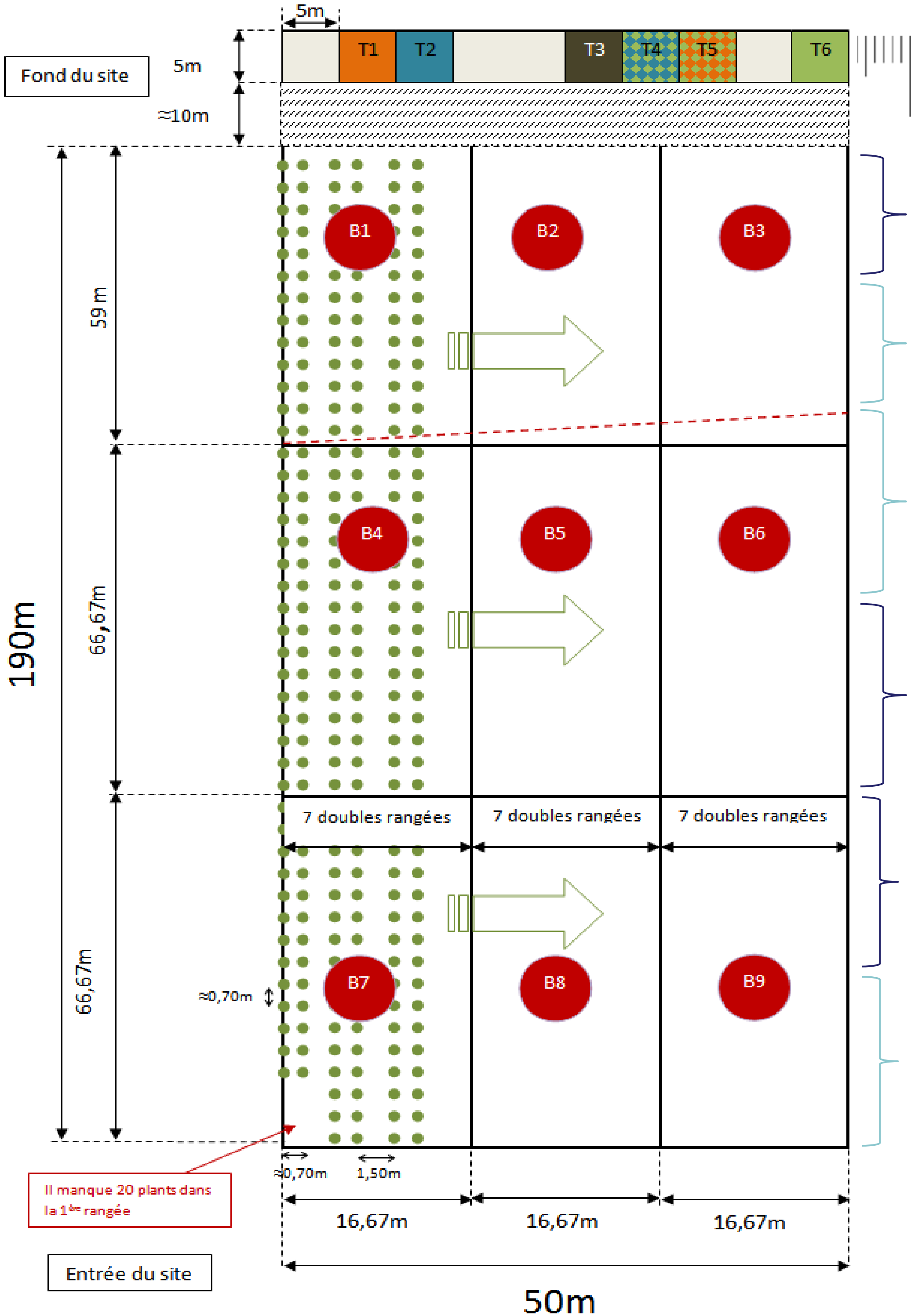
INERIS
maîtriser le risque
pour un développement durable

Aided phytostabilisation and willow plantation protocols






Planting design



38 rows (TORDIS)

37 rows (INGER)

48 rows (INGER)

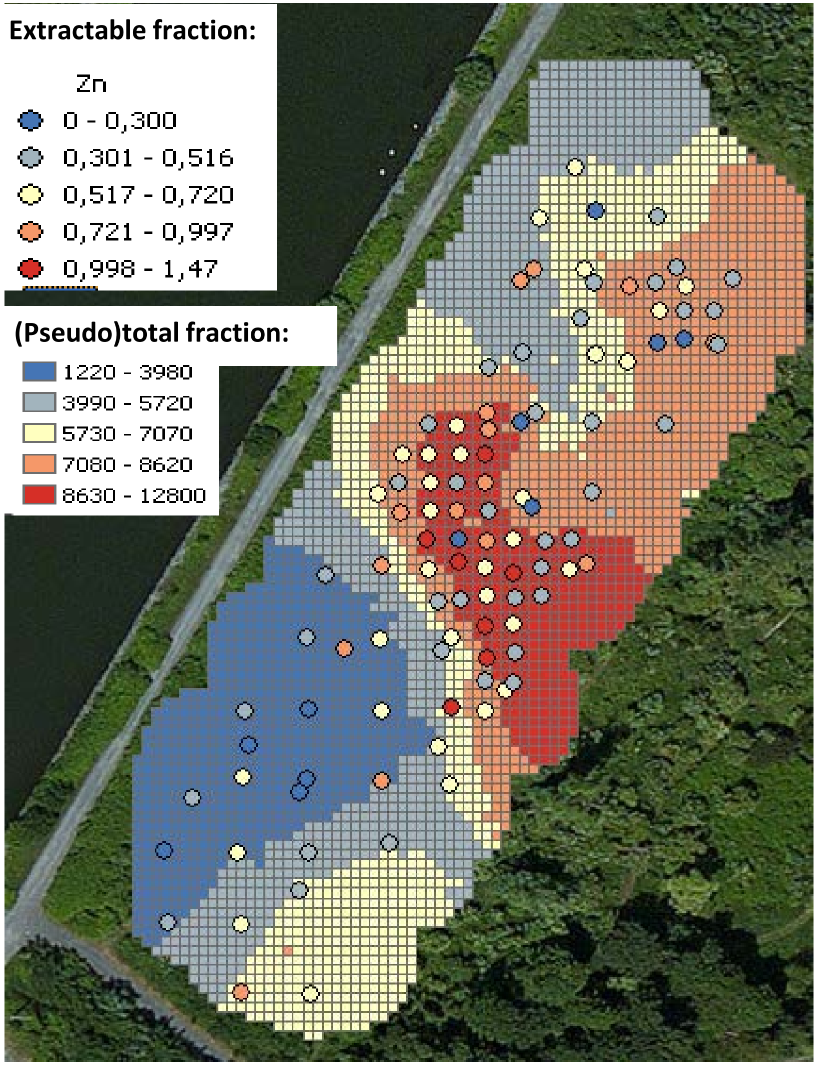
47 rows (TORDIS)

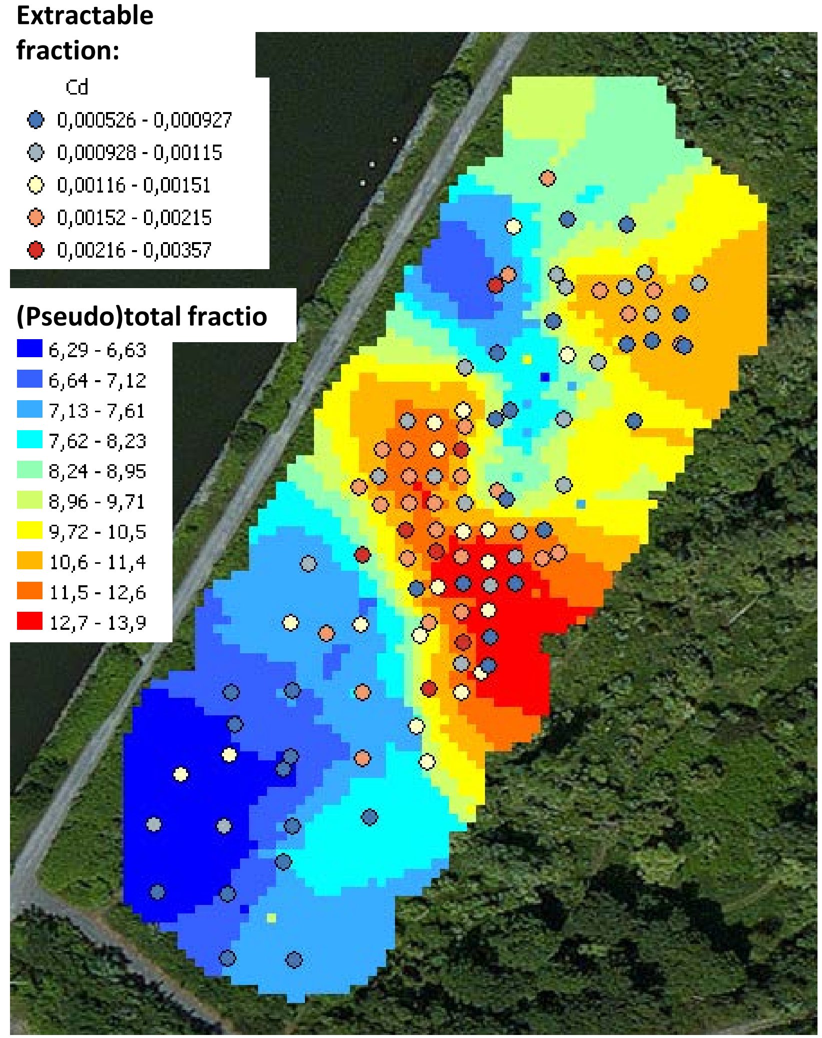
47 rows (TORDIS)

48 rows (INGER)

INERIS
maîtriser le risque
pour un développement durable

TE mapping





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

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

INERIS
maîtriser le risque
pour un développement durable

Aided phytostabilisation ⇨ *Barchampsia cespitosa* as plant cover?

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

Were the growth and spread of the invasive species, *Fallopia japonica,* reduced with phytostabilisation?

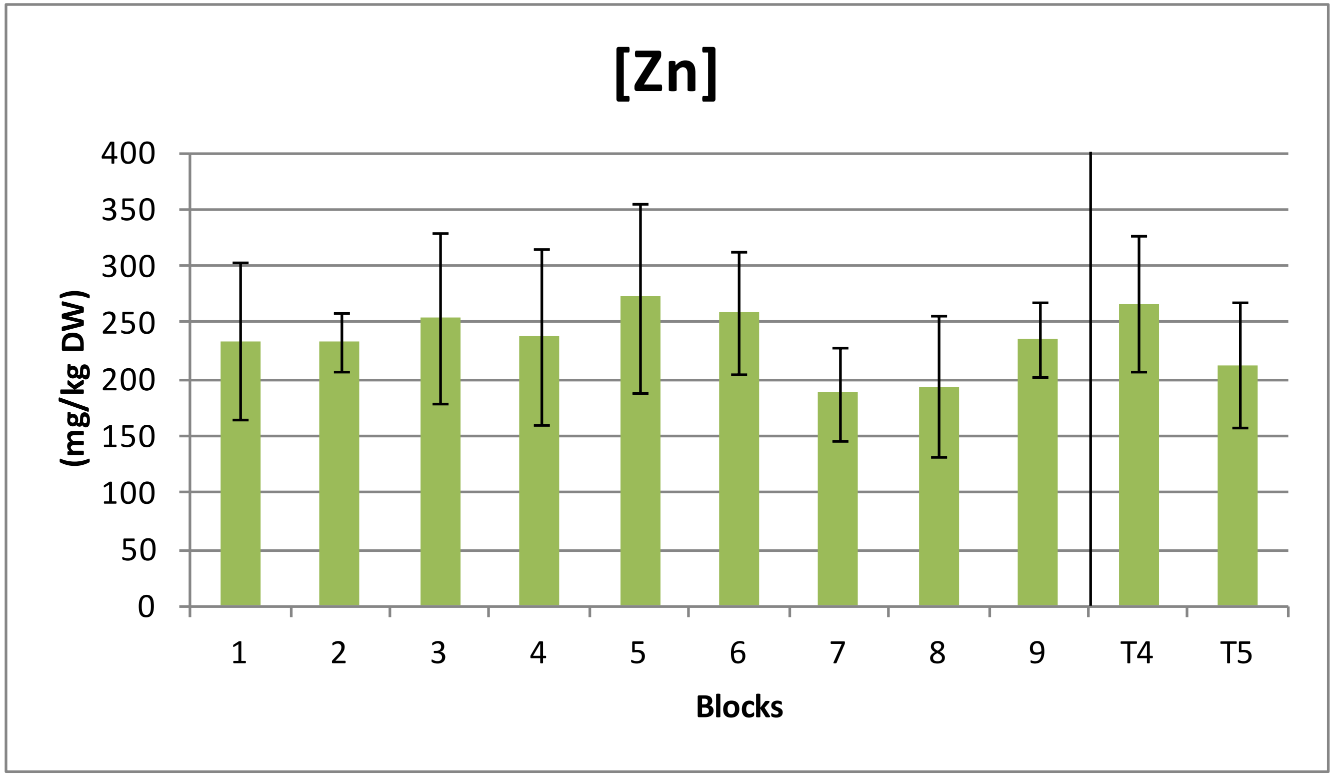
- coverage reduction of 27% of the surface area in one year

↳ *F. japonica* is less competitive in presence of *B. Cespitosa*

↳ its growth decrease accounts for a beneficial effect of phytostabilisation

INERIS
maîtriser le risque
pour un développement durable

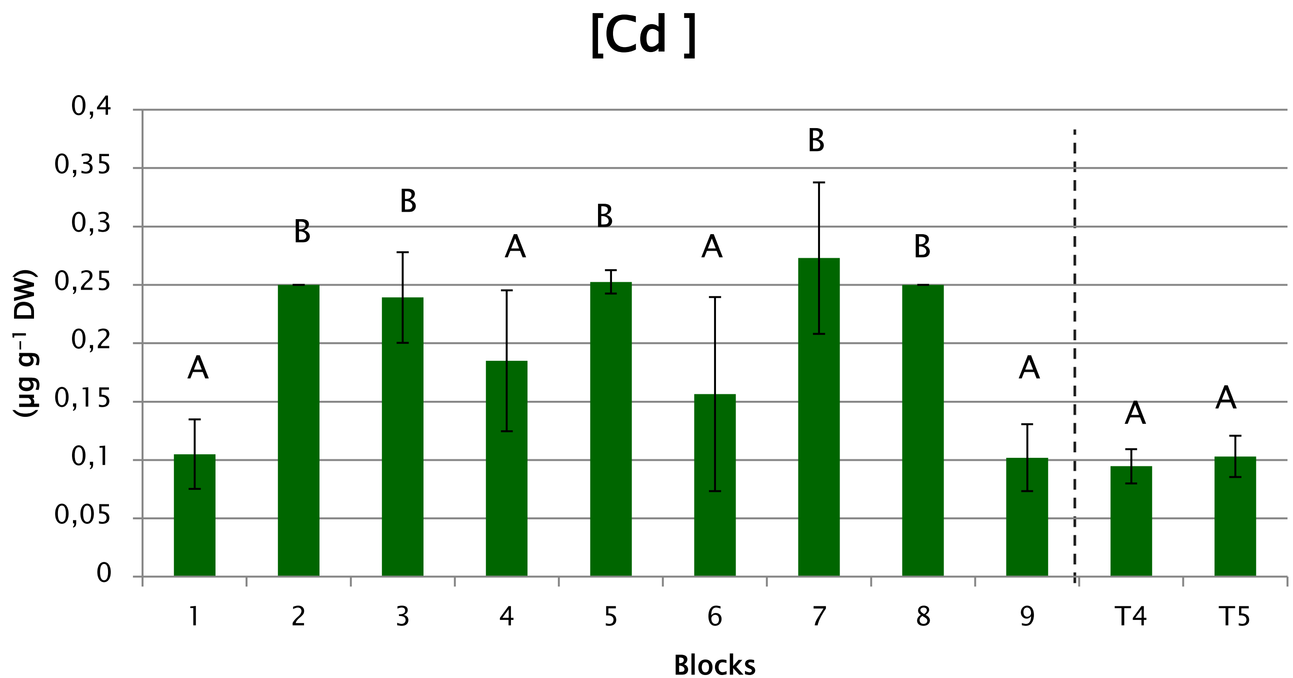
TE concentrations in *Barcampsia cespitosa*



- Frequent (**27–150** mg kg^{-1}) and toxic (**100–400** mg kg^{-1}) values (Kabata-Pendias, 2010)
- No significant difference between blocks ($p > 0{,}05$)

→ No amendment effect on Zn shoot concentrations

TE concentrations in *Barcampsia cespitosa*

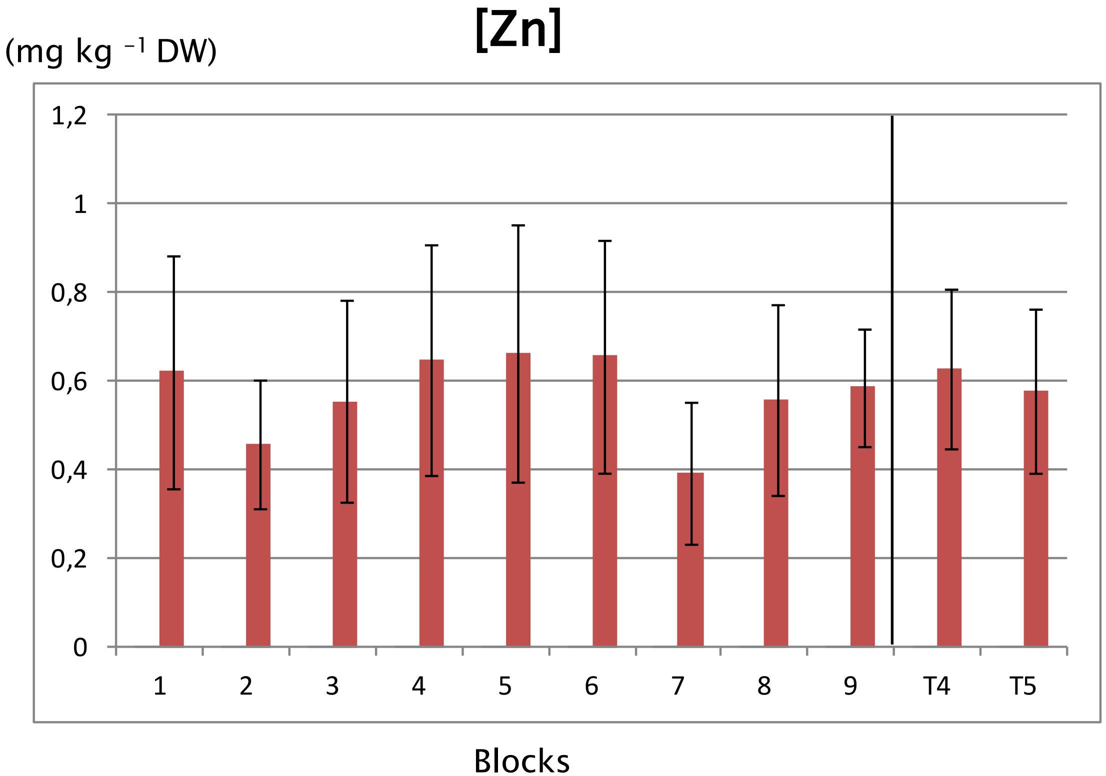


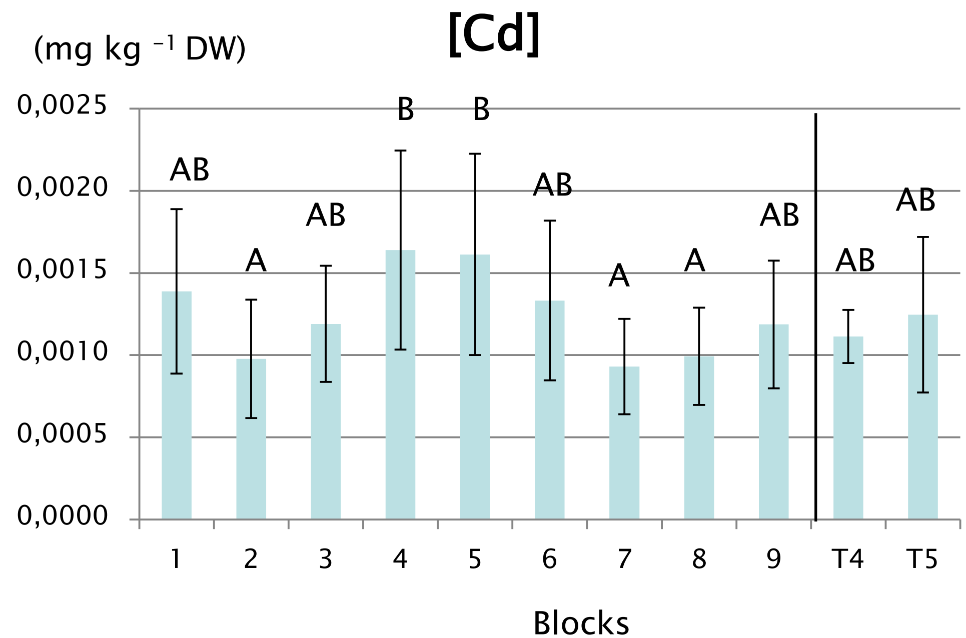
- Frequent (**0,05–0,2** mg kg^{-1}) and toxic (**5–30** mg kg^{-1}) values (Kabata-Pendias, 2010)
- Significant difference between blocks ($p < 0{,}001$)

→ No amendment effect on Cd shoot concentrations

INERIS
maîtriser le risque
pour un développement durable

Extractable TE concentrations in sediments





- For Zn, no significant difference between amended and non amended blocks ($p > 0,05$)
- For Cd, significant differences between blocks ($p < 0,05$)

→ No amendment effect on TE extractable concentrations

INERIS
maîtriser le risque
pour un développement durable

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 (Cd >>Zn)

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

Aided phytostabilisation with *Optiscor?*

- Until now, no efficiency on the decrease of the TE labile pool and shoot concentrations

- Monitoring to be continued the next years

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

Is it possible to combine *Salix* cultivation
with risk management by aided phytostabilisation?

Is it possible to combine *Salix* cultivation with risk management by aided phytostabilisation?

- Relationship between the grass and the willows?
- Choice of ‘Inger’ and ‘Tordis’ related to TE concentrations in shoots?
- Role of the soil amendment to decrease the TE transfer in willow shoots?

Relationship between the grass and the willows?

- The grass is competing for water and nutrients

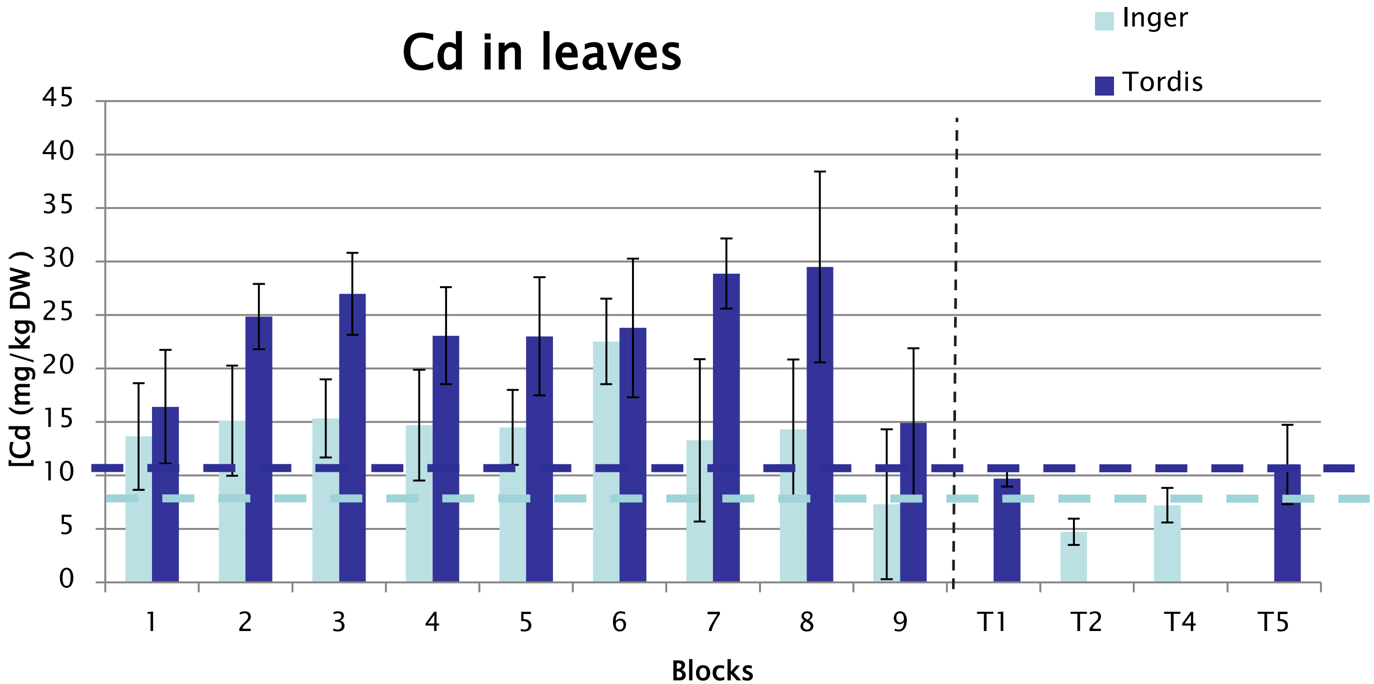
⇨The survival rate of willows decreases time after time (2013: 90% – 2014: 73%)
⇨The height and diameter are not increasing, as well as biomass

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






Choice of ‘Inger’ and ‘Tordis’ related to TE concentrations in shoots?

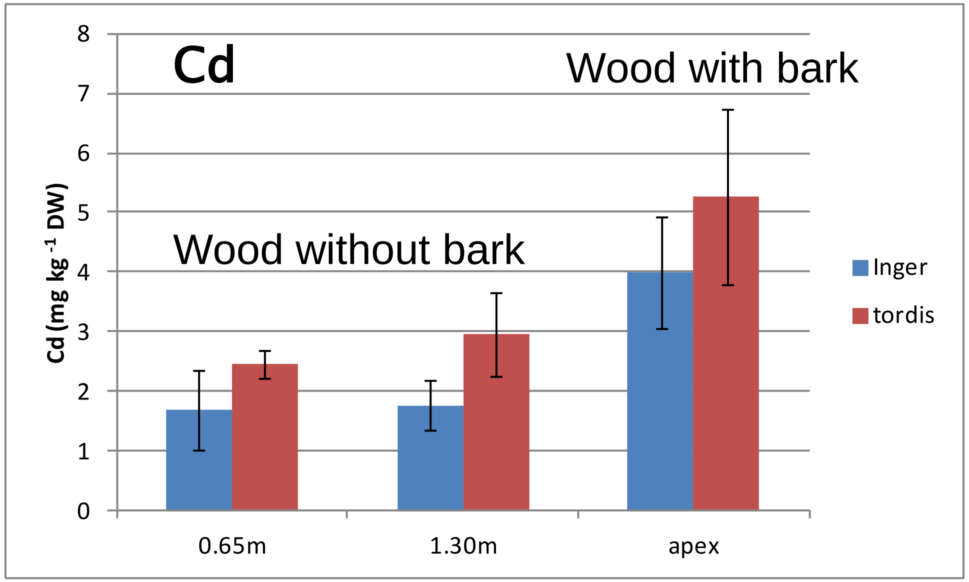


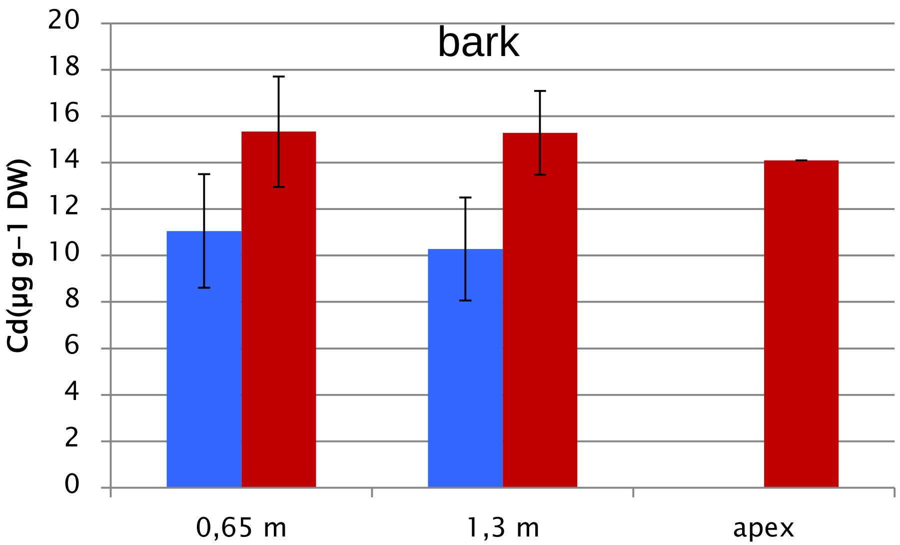
- Cd concentrations >> frequent willow leaves concentrations [<2 mg kg^{-1} DW] → phytotoxicity?
- ‘Tordis’ > ‘Inger’
- Cd concentrations on amended plots are higher than those on control plots

→ inefficiency of soil amendment

INERIS maîtriser le risque pour un développement durable

Choice of ‘Inger’ and ‘Tordis’ related to TE concentrations in shoots?





- wood and bark Cd concentrations << leave concentrations
- ‘Tordis’ concentrations ~ ‘Inger’ concentrations
- Increased concentrations compared to those measured before the plantation (2 mg kg^{-1} DW in wood)

⇨inefficiency of soil amendment

⇨ what will be the metal concentrations at harvest?
(smallest concentrations as possible)

INERIS
maîtriser le risque
pour un développement durable

Preliminary economical study of aided phytostabilisation and biomass production: overview of costs and revenues to set up 1ha (field owner perspective)

Investment Costs		
Field preparation (plant removal, tillage, tarpaulin set up, etc.)	34	k€
Soil Amendment	850	€
Salix (purchase, planting)	18	k€
Barchampsia cespitosa (purchase, sowing, rolling)	1.5	k€
Operating costs		
Monitoring (analyses)	3	k€/year
Maintenance (mowing, insect treatment)	679	€/year
Biomass costs		
Trees harvesting (to wood ships)	35	€/t FW
Site repairing (after 24 years)	2	k€
Biomass revenues		
Sale of wood ships	40	€/t FW

The removal of the invasive species is very costly (18,888€)

The purchase of stems instead of cuttings is very costly (13,000 €)

Numerous analyses are performed due to the high pollution level of the site

Forest cooperative price

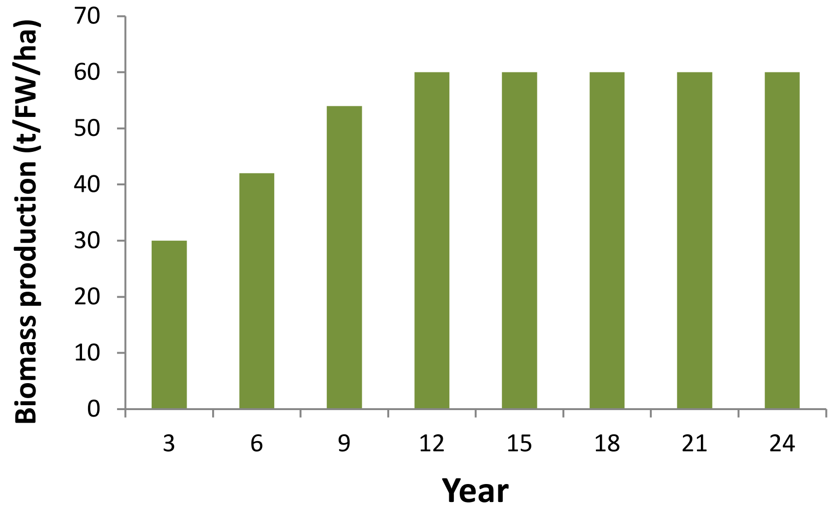
Wood bioenergy network price

INERIS
maîtriser le risque pour un développement durable

Preliminary economical study of aided phytostabilisation and biomass production: overview of costs and revenues to sep up 1 ha (field owner perspective)

- Duration : 24 years (8 harvests)
- Biomass production (40% humidity)

Biomass costs		
Trees harvesting (to wood ships)	35	€/t FW/3y
Site repairing (after 24 years)	2	k€
Biomass revenues		
Sale of wood ships	40	€/t FW/3y



Preliminary economical study of aided phytostabilisation and biomass production: overview of costs and revenues to set up 1 ha (field owner perspective)

Investment Costs		
Field preparation (plant removal, tillage, tarpaulin set up, etc.)	34	k€
Soil Amendment	850	€
Salix (purchase, planting)	18	k€
Barchampsia cespitosa (purchase, sowing, rolling)	1.5	k€
Operating costs		
Monitoring (analyses)	3	k€/year
Maintenance (mowing, insect treatment)	679	€/ha/year
Biomass costs		
Trees harvesting (to wood ships)	35	€/t FW/3 y
Site repairing (after 24 years)	2	k€
Biomass revenues		
Sales of wood ships	40	€/t FW/3 y

Discounted cost
(24 years duration, 4% discount rate) :
107 k€

Aided phytostabilisation (costs) : 90 k€

Costs of biomass production : 27 k€

Revenues of biomass production : 10 k€

Costs– Revenues : 17 k€

⇨ In our case, biomass production does not allow to decrease the cost of contamination management

INERIS
maîtriser le risque
pour un développement durable

Lessons after 2 years of monitoring

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

↳ *B. cespitosa* competes very well against the invasive species (beneficial effect).

↳ Until now, the selected soil amendment did not succeed. Future work will address the expected mechanisms (speciation, OM, $CaCO_3$ stock, etc.).

INERIS
maîtriser le risque
pour un développement durable

Lessons after 2 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...)

- generation of costs rather than economical benefits



INERIS
maîtriser le risque
pour un développement durable

Lessons after 2 years of monitoring

What are the alternatives?

• Put the grass several years after the willow plantation? Is it technically feasible?
• What about the risks in this case?

• Replace grass by mulch? Is it economically viable?

• Found other fast growing trees (than willows and poplars) or cultivars with no or very low accumulation capability? Do they exist?

• In our study, benefits of biomass production do not compensate costs linked to set up and monitoring of both aided phytostabilisation and willow plantation. Are we able to decrease these costs?

↳ Recalculate cost and benefits with other protocols.

INERIS
maîtriser le risque
pour un développement durable

Lessons after 2 years of monitoring

What's the future of biomass production ?

- Decrease of harvesting costs
- Increase of purchasing price

Is the economical study exhaustive ?

- Need to include external effects (environmental and health issues, impact on land prices, carbon storage…)

Benefit – cost < 0 : should we stop ?

- What is the benchmark scenario (dig and dump)?

→ Future work...

INERIS maîtriser le risque pour un développement durable