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
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
Aided phytostabilisation and willow plantation protocols

September – October 2011

- Plant removal
- Sediment leveling
- Amendment spreading (9t/ha)

March 2012

- Grass seeds sowing
- Sediment covering
- Willow plantation

Duration of preparation and deployment: 3 weeks
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)

Il manque 20 plants dans la 1ère rangée

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

- No correlation between Zn and Cd extractable and (pseudo–total) concentrations
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
• 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
• 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
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
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
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)
Preliminary economical study of aided phytostabilisation and biomass production: overview of costs and revenues to set up 1ha (field owner perspective)

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<td>Soil Amendment</td>
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**Operating costs**

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**Biomass costs**

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

- Duration: 24 years (8 harvests)

- Biomass production (40% humidity)

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

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### 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.
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.).
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
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.
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...