LE PROJET PHYTEO : PERTINENCE DE LA FILIÈRE CULTURE DE PLANTES AROMATIQUES PRODUCTRICES D'HE POUR LE PHYTOMANAGEMENT DE SOLS POLLUÉS PAR LES ÉLÉMENTS TRACES MÉTALLIQUES

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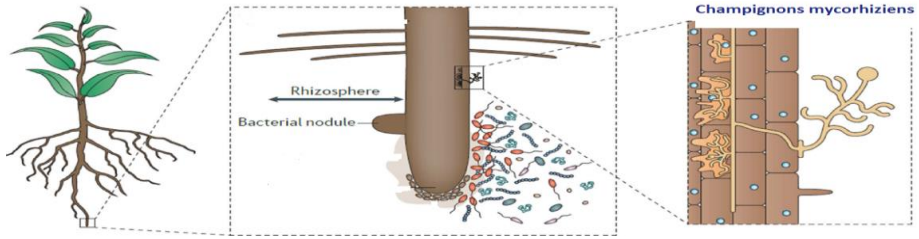
07/09/2021

Phytomanagement of contaminated areas

Aided phytostabilization channel at field scale

Use of natural plant ability and its associated soil microorganisms to stabilize inorganic pollutants

Biological Amendments **Arbuscular Mycorrhizal Fungi**



- Exploration of more important soil volume by the AMF
- Better water and mineral nutritions for the plant
- Better plant growth and stress tolerance
- Contribution to pollutant stabilization

Valorization of the biomass produced on polluted soils (essential oil production)

PhytEO Phytostabilization and Essential Oil

Project objectives

Valorization channel => non-food perspective - vegetable biomass produced on agricultural contaminated soils - combination of aided phytostabilization (aromatic plants) and essential oil production

Setting up of a large scale *in situ* assay

-

Initial characterization

Aromatic plant growth & development monitoring

Amendment

(biological)

contribution on :

- biomass and EO's yields

- TE immobilisation

(INERIS collaboration)

Trace Elements :

Time monitoring in soil and plant aerial parts

- Total content

- Easily-extractable fraction

- EO distillation

- EO quality assessment

TE contamination? (INERIS collaboration)

Chemical composition?

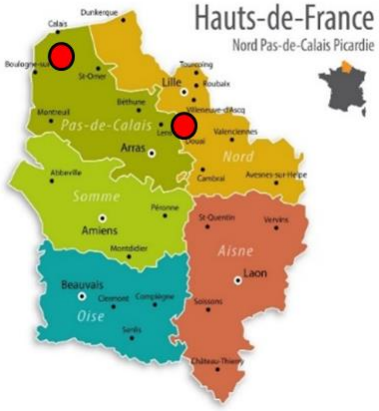
Techno-economic viability assessment

-

Social acceptance

In situ experimental site - Metaleurop

Two experimental plots of 2 hectares :

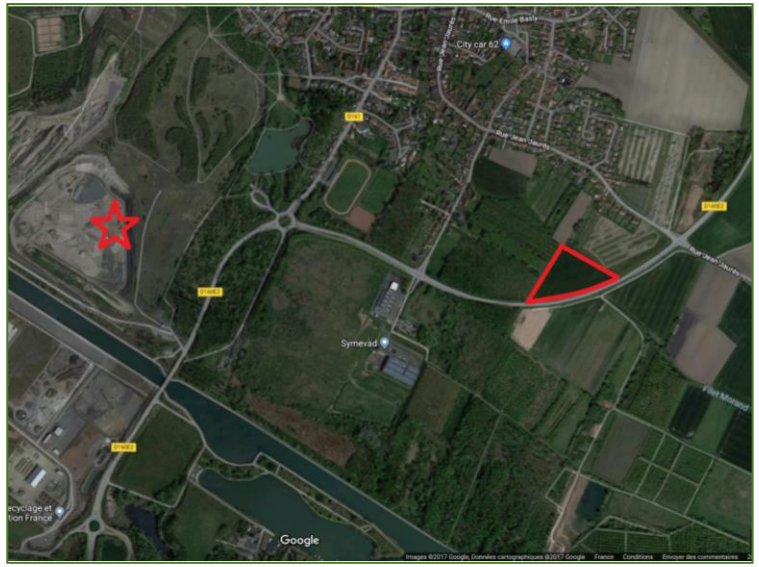


Unpolluted plot

Rodelinghem

TE-polluted plot

Evin-Malmaison



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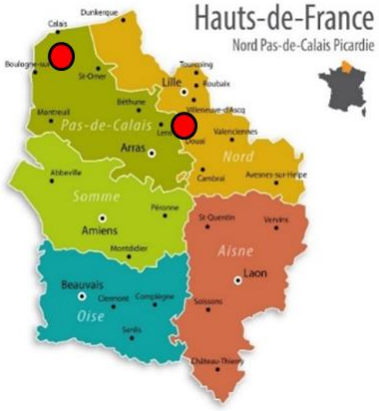

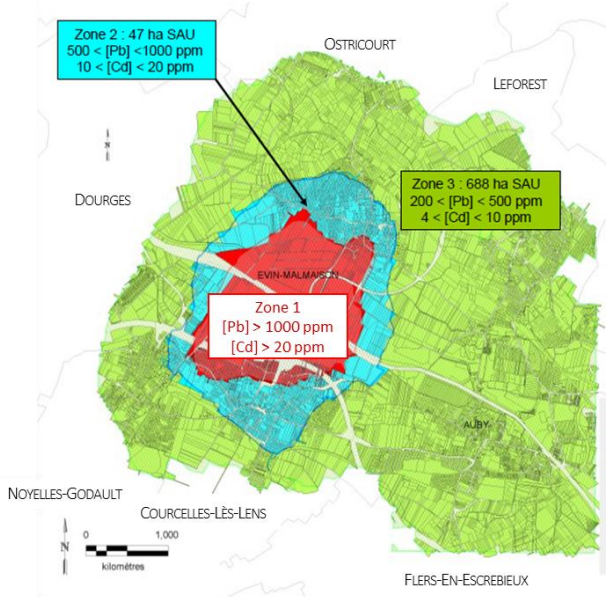

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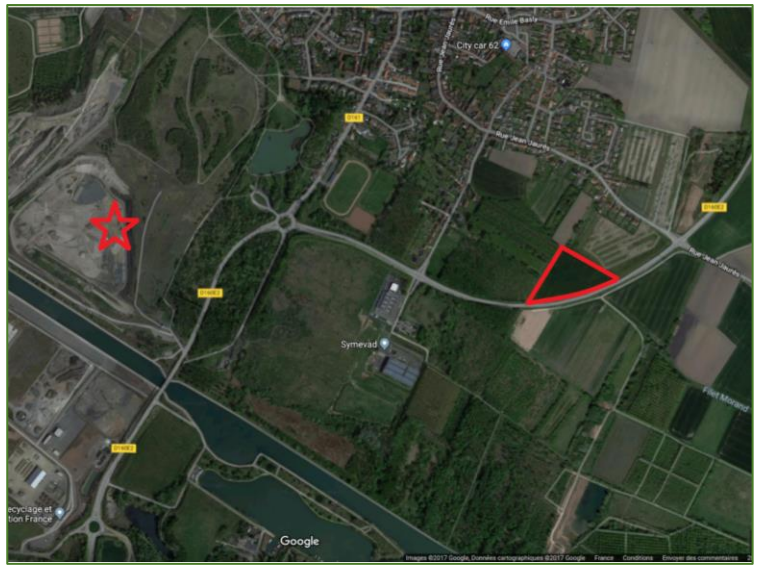

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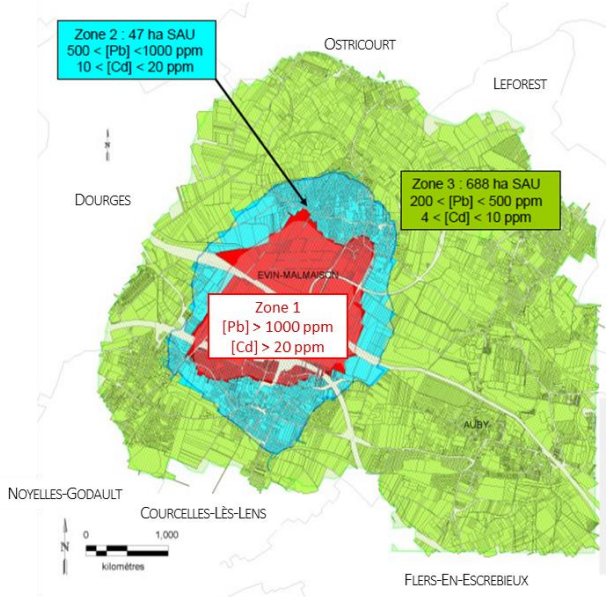

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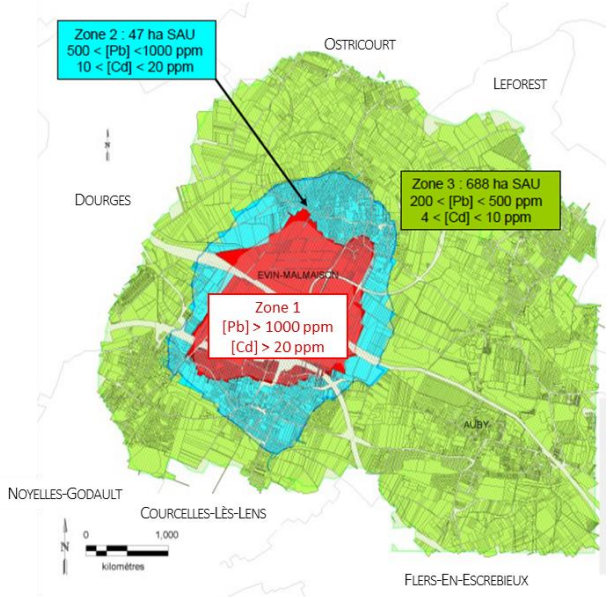


- Monitoring of 9 TE (As, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Zn)

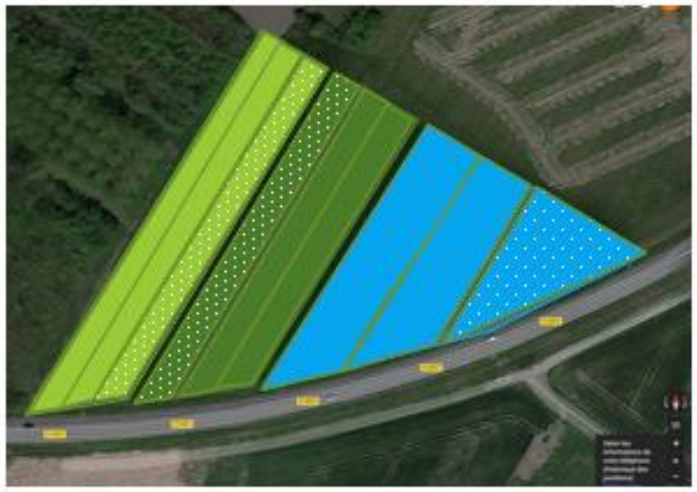
TE amount	Unpolluted		Polluted		
	Total ($mg.Kg^{-1}$)	Echangeable ($\mu g.g^{-1}$)	Total ($mg.Kg^{-1}$)		Echangeable ($\mu g.g^{-1}$)
Cd	0,4 ± 0,03	0,009 ± 0,001	7 ± 0,4	X17	0,11 ± 0,06
Pb	22 ± 2	0,015 ± 0,006	394 ± 16	X11	0,079 ± 0,004
Zn	48 ± 2	0,61 ± 0,10	443 ± 12	x6	0,93 ± 0,07

In situ experimental site - conditions

Two successive years (2017 - 2019)

Unpolluted plot

TE-polluted plot



Not amended - control

Amended with a biological inoculum (mycorrhizal fungi)

Angelica

Coriander

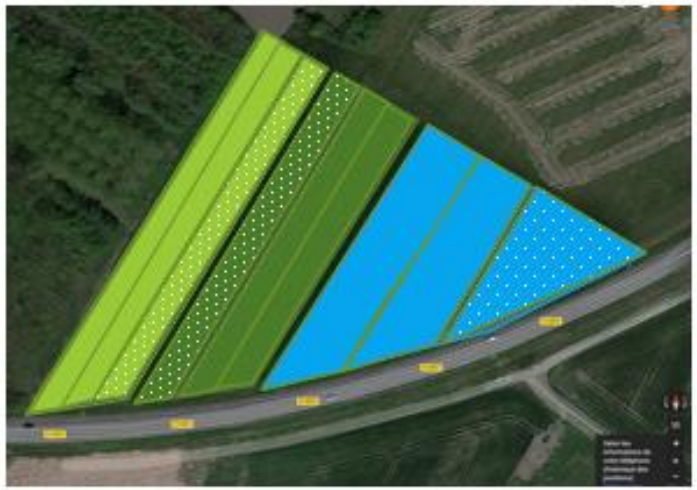
Sage

In situ experimental site - conditions

Two successive years (2017 - 2019)

Unpolluted plot

TE-polluted plot



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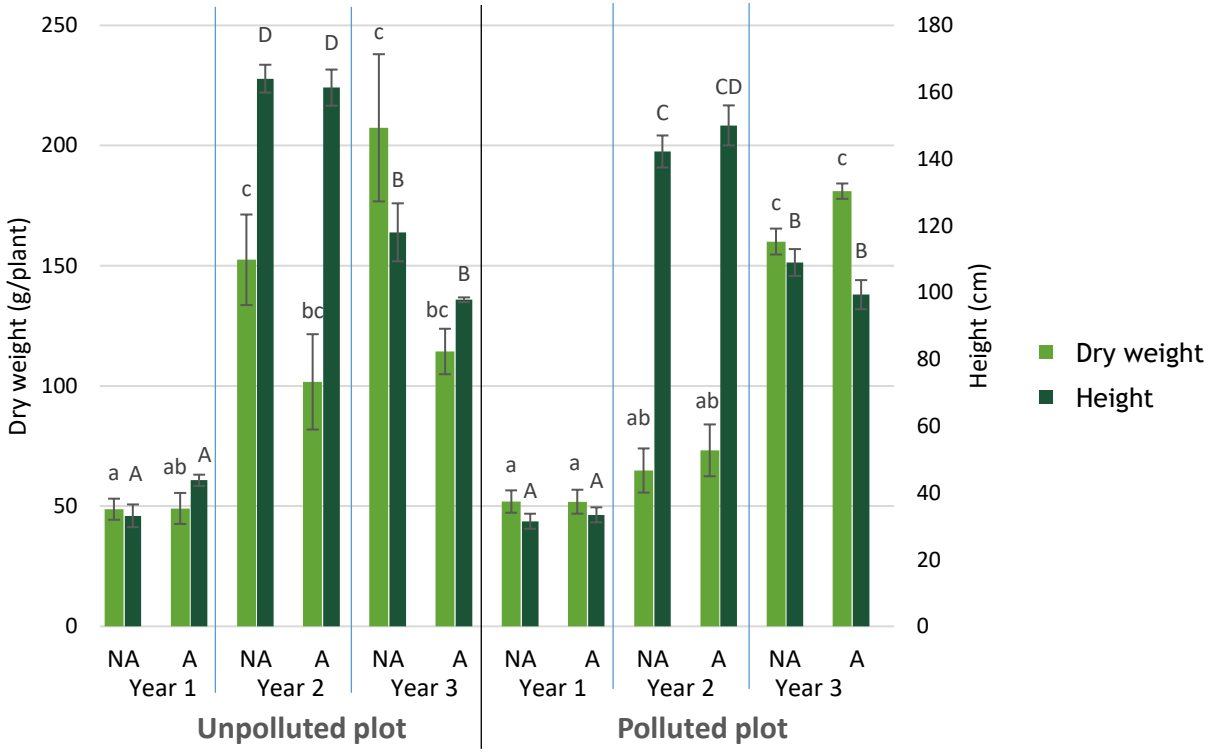
Angelica Coriander Sage

Selection criteria

- Life cycle (annual / biennial / perennial) – plant species acclimatization – agricultural practices – harvested parts
- Phytostabilization potential
- Commercial potential in a non-food valorization channel (Seed prices and availability – EO selling price – market opportunities)

Clary sage emergence & growth

Clary sage emergence & growth

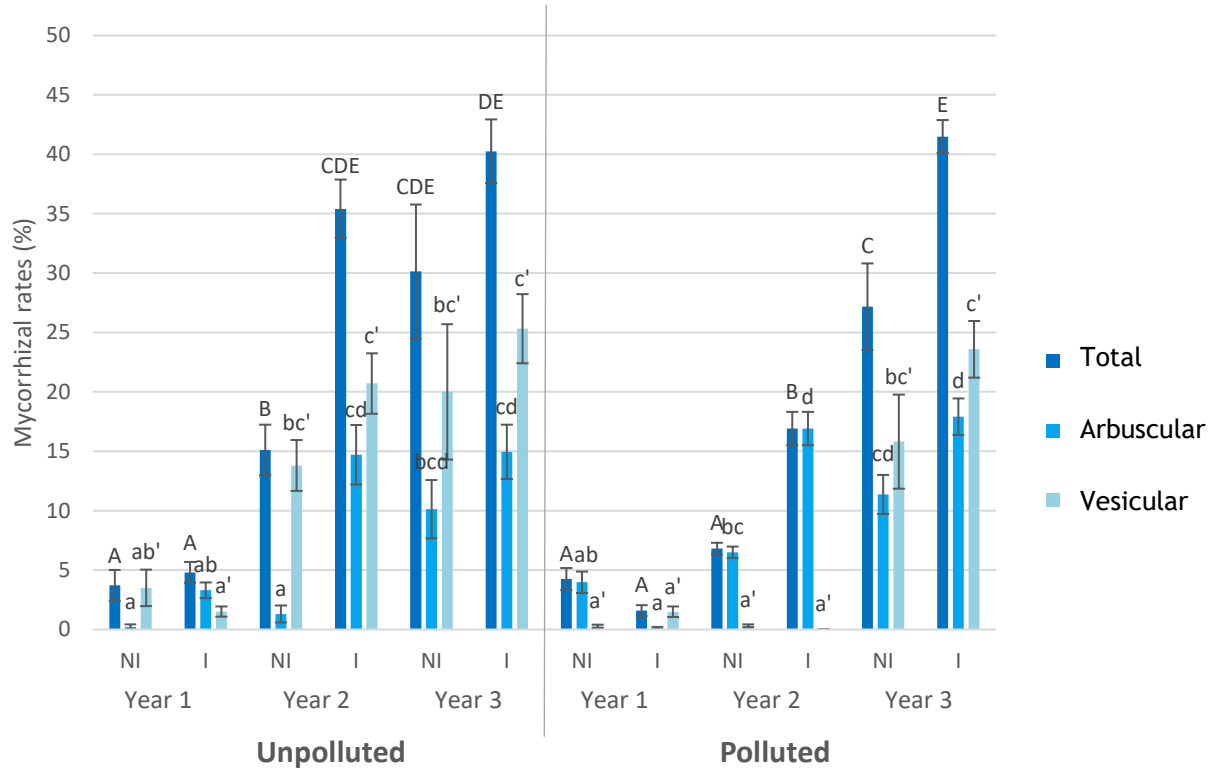


NA : Not amended

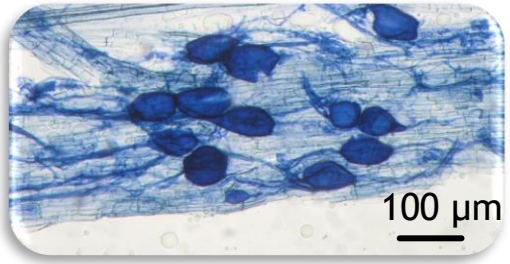
A : Amended

Multiple comparison, ANOVA-2F (n=6)

Clary sage root mycorrhization



Vesicles



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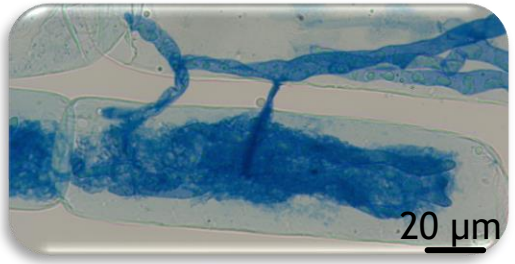

Hyphae

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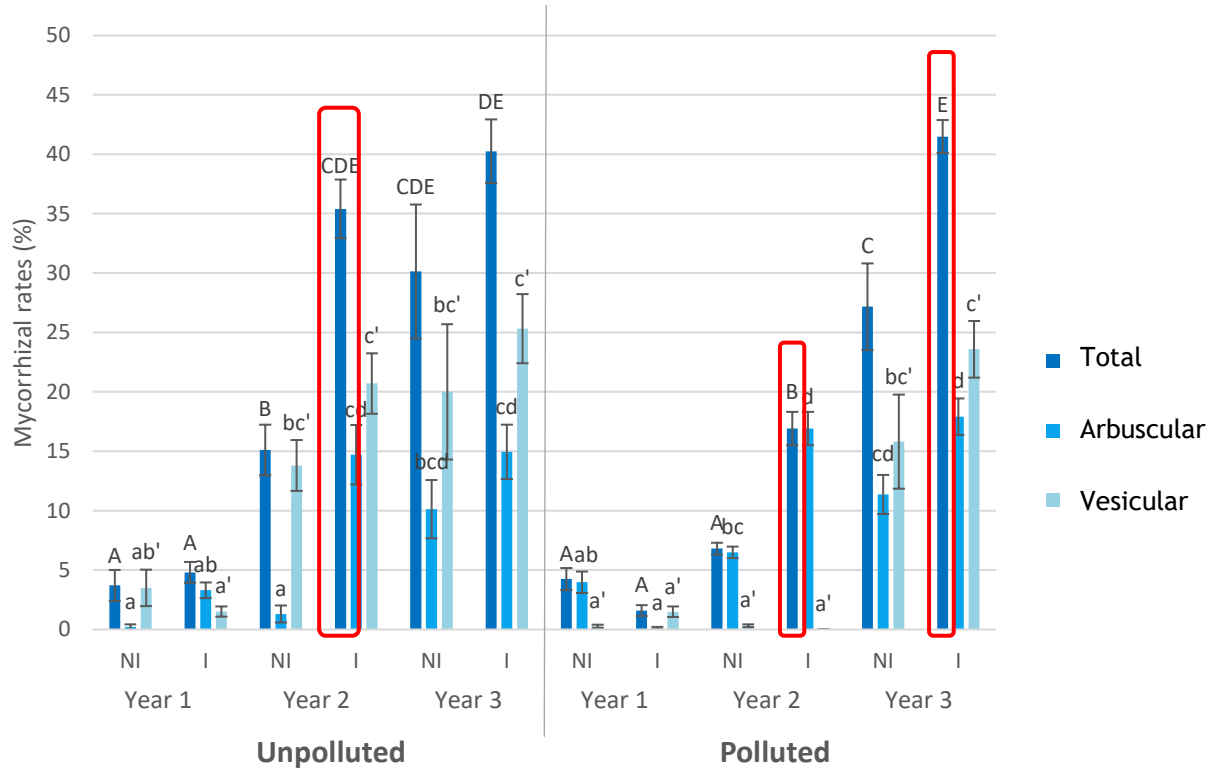

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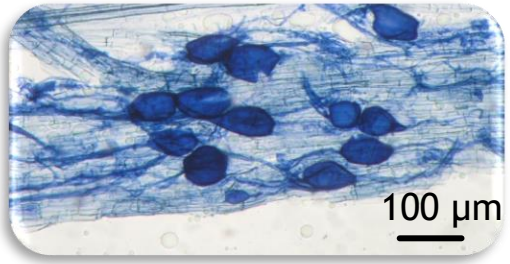

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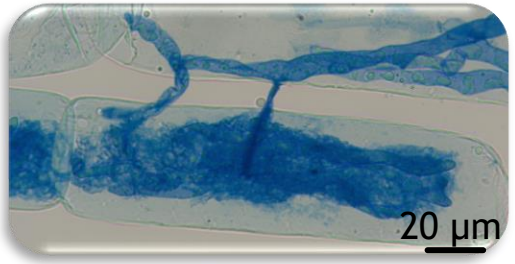

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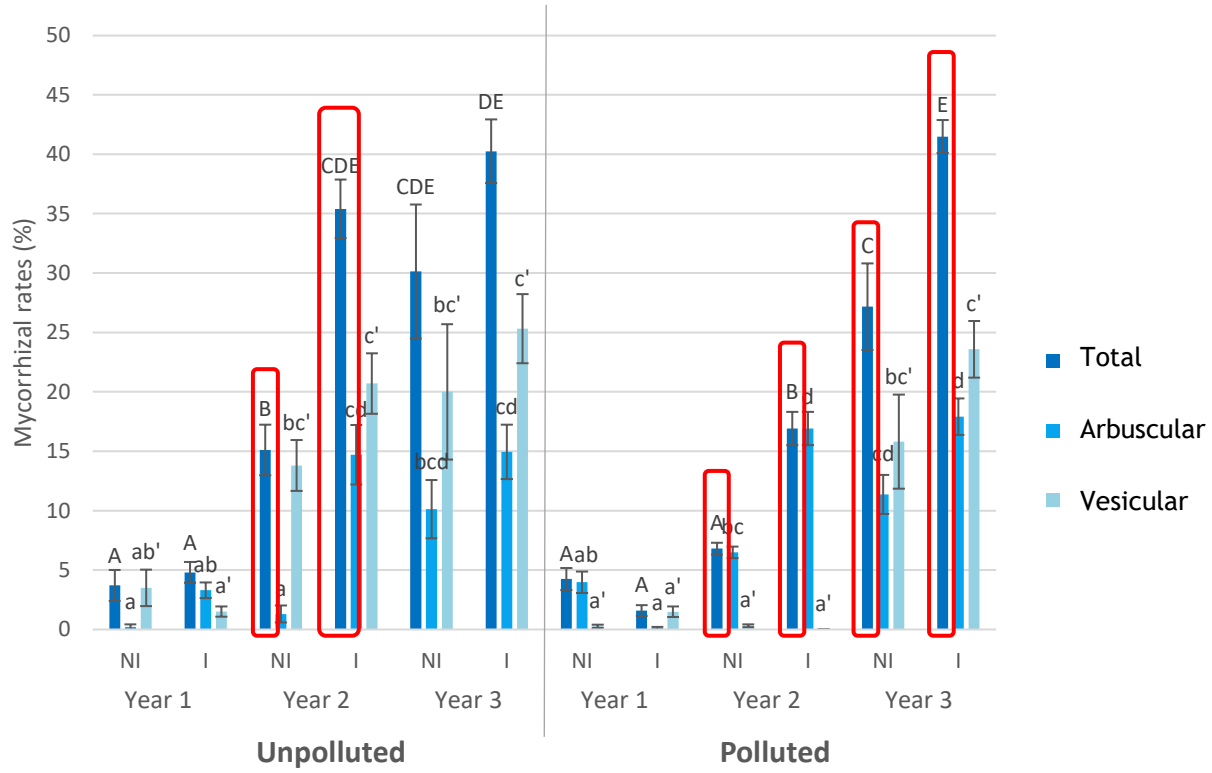

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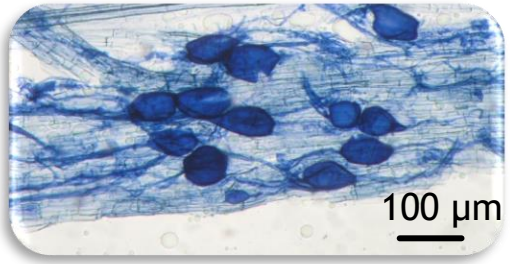

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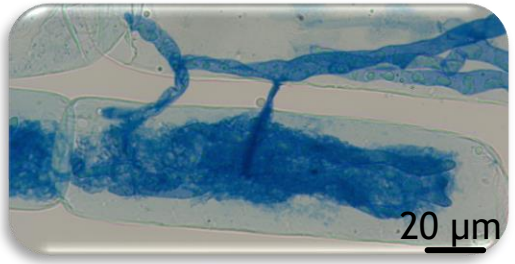

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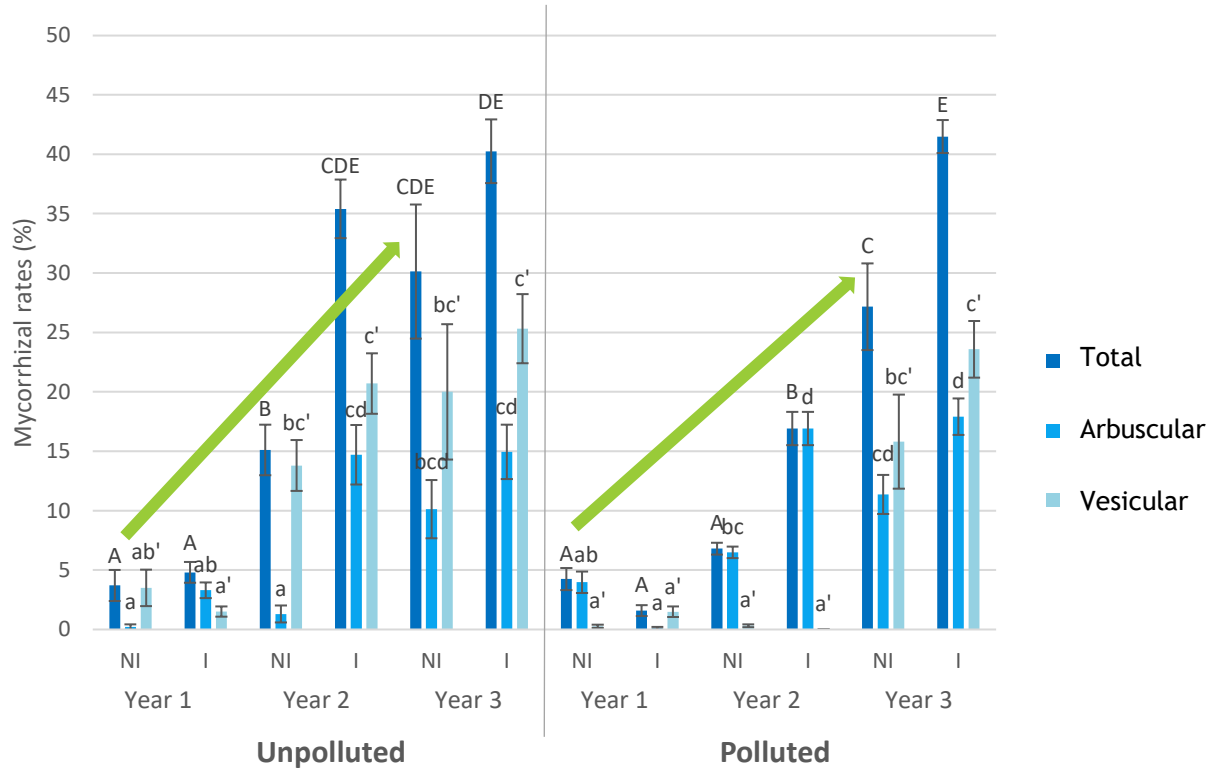

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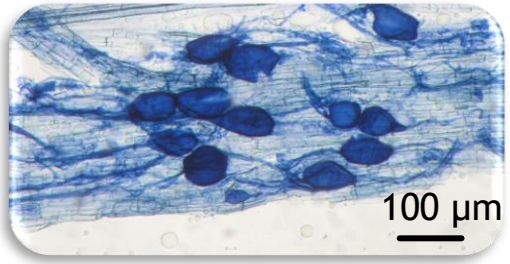

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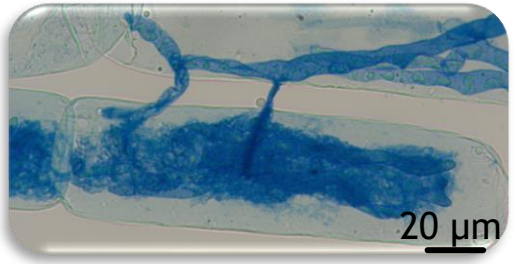

Hyphae

Essential oil production & quality



Conditions		Year 1	Year 2	Year 3
		EO yield (kg/ha)	EO yield(kg/ha)	EO yield (kg/ha)
Unpolluted	NA	0,93	12,9	0,48
	A	0,53	20,3	2,7
Polluted	NA	0,17	33,7	1,4
	A	0,15	24,2	2,3

NA : Not amended - A : Amended

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	Clary sage inflorescences	
	Unpolluted	Polluted
Cd	< LoQ	< LoQ
Pb	< LoQ	< LoQ
Zn	< LoQ	0,086

LoQ : Limit of quantification

- TE in EO lower than the LoQ in most samples

Essential oil production & quality





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	Clary sage inflorescences		
	Unpolluted	Polluted	Market
Cd	< LoQ	< LoQ	**< LoQ**
Pb	< LoQ	< LoQ	**0,01**
Zn	< LoQ	0,086	**0,11**

LoQ : Limit of quantification

- TE in EO lower than the LoQ in most samples
- Lower TE amounts than those in marketed products

TE monitoring in sage aerial parts

TE	Reference : salad on unpolluted soil (µg.g^{-1} DW)	BCF	Washing effect	Mean [TE] in Year 1	Mean [TE] in Year 2	Inoculum effect - Year 1	Inoculum effect - Year 2	Time monitoring
Cd	0,029 – 0,4	< 1	-	I: 0,8 NI: 1,32	**I: 0,69** NI: 0,9	Reduction	Reduction	↘ 2018
Pb	2,4	< 1	-	I: 7,03 NI: 12,02	**I: 2,03** NI: 1,48		-	
Zn	44 - 73	< 1	-	I: 110,9 NI: 141,9	**I: 62,4** NI: 55,3		-	

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- Reduction of Cd, Pb and Zn accumulation in aerial parts in year 2 (same in year 3)

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- No washing effect
- Reduction of Cd, Pb and Zn accumulation in aerial parts in year 2 (same in year 3)
- Significant inoculation effect - reduction of Cd accumulation

Techno-economic viability

Determination of production costs

- Seeds
- Cultivation practices
  - Sowing, fertilization, harvest
- Farm inputs

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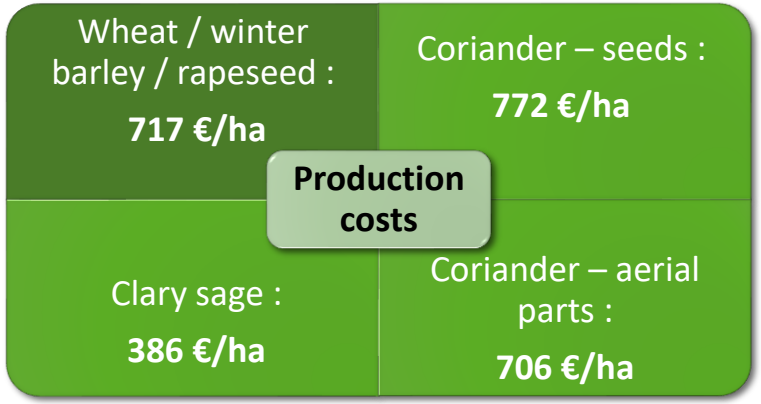

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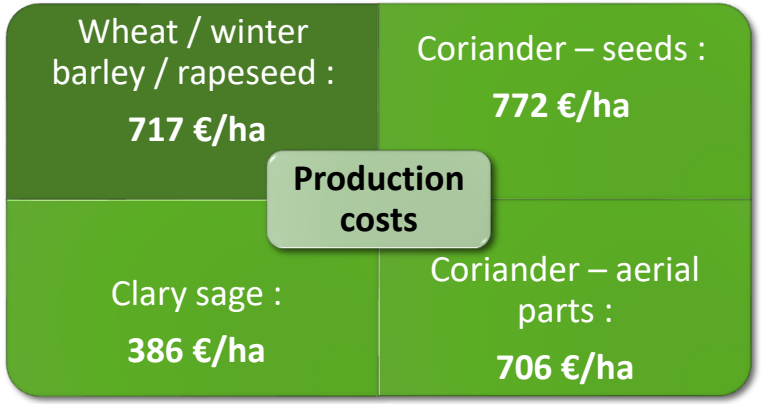

- Lower or similar production costs / field crops

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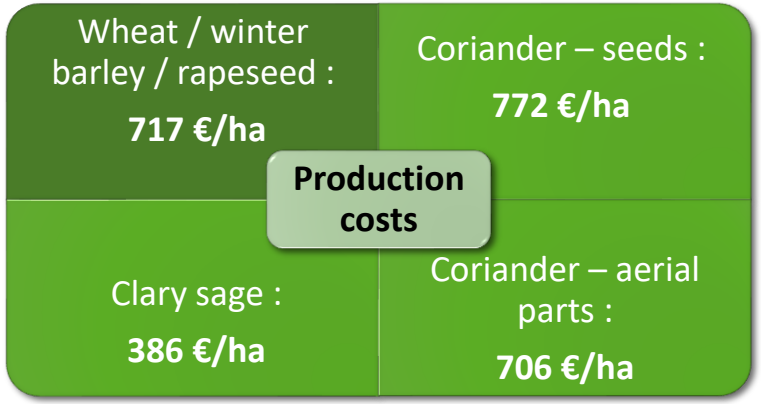

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Physico-chemical remediation

=> 500 000 €/ha

(Zhang, 2019)

Phytomanagement methods

=> 700 à 10 000 €/ha

(Wan *et al.,* 2016; Włóka *et al.,* 2019)

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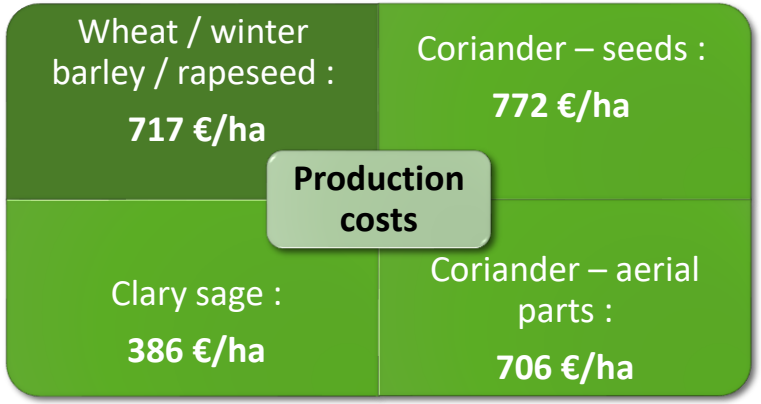

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Production costs + Distillation costs → Techno-economic viability ?

Techno-economic viability

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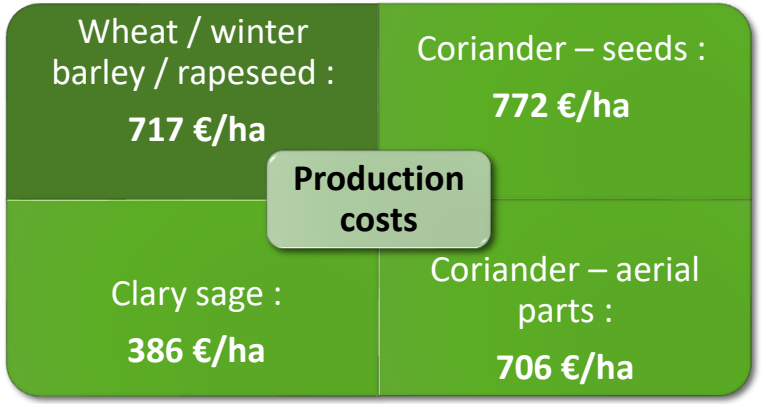

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⇒ Coriander ⛔

⇒ Clary sage ➕➕

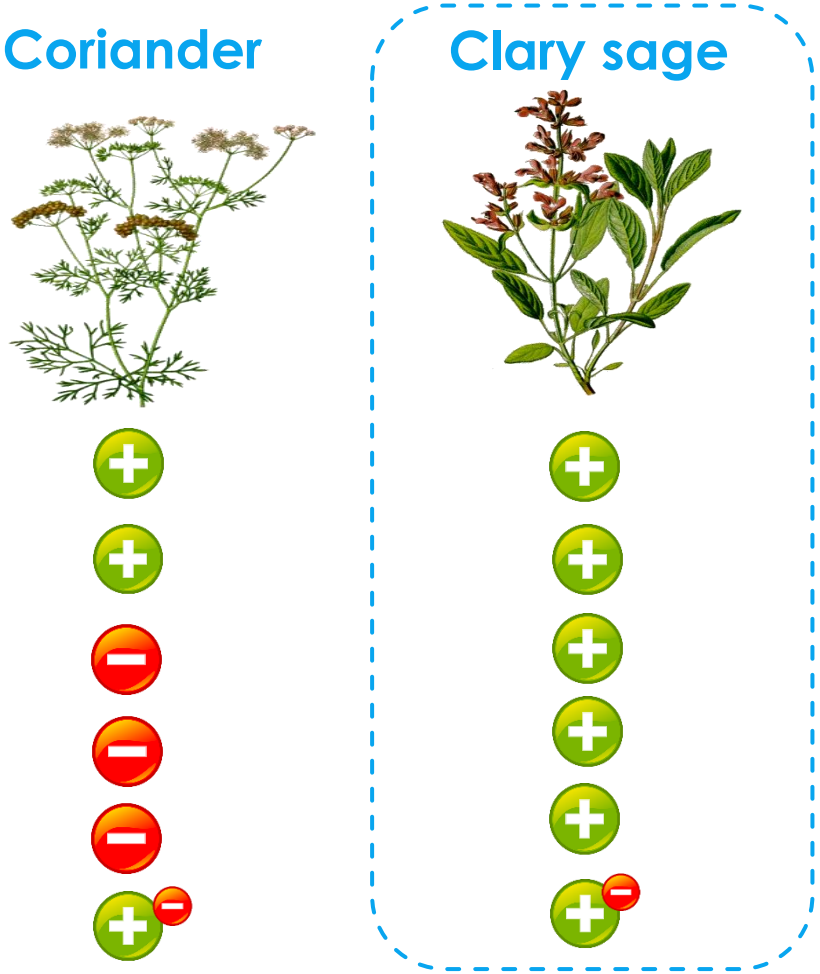
Conclusion

Conclusion

	Coriander	Clary sage
		
• Growth, biomass production, and EO yields	+	+
• EO quality (composition, contamination, biological properties)	+	+
• Aided phytostabilisation potential	−	+
• Distillation residue valorization	−	+
• Techno-economic viability	−	+
• Social acceptance	+−	+−

Conclusion

- Growth, biomass production, and EO yields
- EO quality (composition, contamination, biological properties)
- Aided phytostabilisation potential
- Distillation residue valorization
- Techno-economic viability
- Social acceptance



Clary sage

=

A promising option for the phytomanagement of TE-polluted soils

Thank you

UCEIV

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Consortium PhytEO – Steering committee

Funders

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Site web Phyteo Project: https://phyteo.univ-littoral.fr

Raveau *et al.*, 2020 - https://doi.org/10.3389/fmicb.2020.586050
Raveau *et al.*, 2021 a - https://doi.org/10.3390/microorganisms9061333
Raveau *et al.*, 2021 b - https://doi.org/10.1016/j.scitotenv.2021.147944