

# Interreg



# Sudoe



European Regional Development Fund

RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT IN SOUTHWEST EUROPE

## Effects of the long-term phytomanagement of Cu mine-soils on microbial diversity and soil quality

Petra Susan Kidd, A. Lanzén, C. Trasar-Cepeda, B. Rodríguez-Garrido, C. Monterroso, Á. Prieto-Fernández, V. Álvarez-López, M. Mench, I. Martín and C. Garbisu

Consejo Superior de Investigaciones Científicas (CSIC), Spain  
NEIKER, Basque Institute of Agricultural Research and Development, Spain  
UMR BIOGECO INRA 1202, Bordeaux University, France



## PhytoSUDOE

**Demonstrating improvements in soil biodiversity, functionality and ecosystem services of contaminated and degraded land under (phyto)management within the Interreg Sudoe region.**

### Project objectives:

- Establish a network of contaminated/degraded sites under phytomanagement within the Interreg Sudoe region
  - Maintaining medium- to long-term field sites
  - Implementing new sites
- Characterise and demonstrate enhancements in biodiversity, soil functionality and ecosystem services through the phytomanagement

RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT IN SOUTHWEST EUROPE

**Industrial zones**

(wood treatment facility)

- Rhizoremediation
- Phytostabilization
- Phytoextraction

Network of field sites



**Urban / Peri-urban areas**

- Phytostabilization
- Sustainable re-vegetation

**Mining areas**

- Phytostabilisation
- Phytoextraction



# Touro Cu mine – (Galicia, NW Spain)

RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT IN SOUTHWEST EUROPE

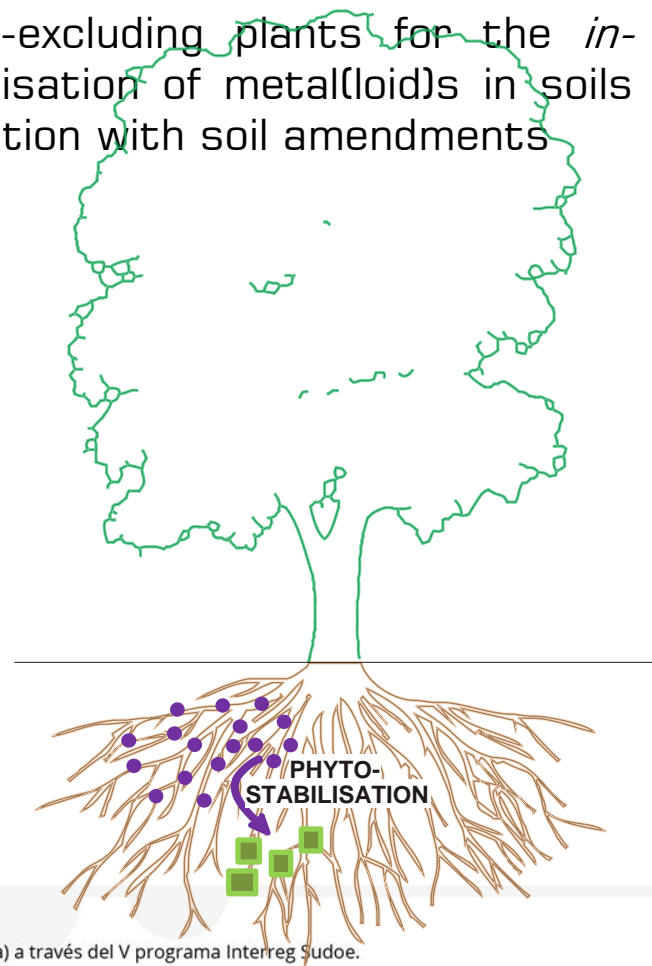
- Active from 1974 – 1988
- Now confined to extraction of material for road construction
- Mine tailings 550 ha
- Geological substrate is amphibolite metal sulphides (pyrite, pyrrhotite, and chalcopyrite).
- Spolic Technosols (Episkeletic)
- Climate Atlantic (oceanic)
- Mean annual precipitation 1900 mm
- Mean annual temperature of 12.6°C.



## RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT IN SOUTHWEST EUROPE

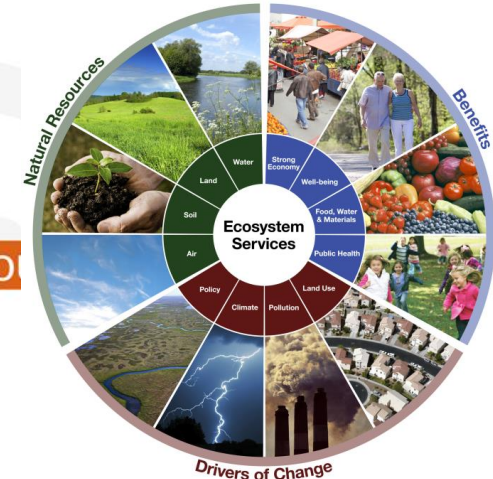
### Aided Phytostabilisation

Metal(loid)-excluding plants for the *in-situ* stabilisation of metal(loid)s in soils in combination with soil amendments



- Established end of 2010
- FP7 Greenland project (Gentle remediation of trace element contaminated land)
- Tratamientos Ecológicos del Noroeste s.l. (TEN s.l.)
- SME company (established 2004)
- Recycling and valorisation of non-toxic waste products
- Organic amendments (based on organic residues and waste products)





## RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT IN SO

- Phytomanagement using short rotation coppice system (for biomass production) and different organic amendments

### Soil quality

- Plant nutrients
- Organic matter
- Physical properties
- Reduce Cu phytotoxicity
- Microbial diversity



### Ecosystem services

- Carbon sequestration
- Nutrient cycling
- Habitat and gene pool
- Water storage and purification
- Biomass production



# Mine tailings soil properties before implementing phytostabilisation trials (Time=0)

•Sulphide oxidation: hyperacidic, hyperoxidising soils/waters

• High [metal sulphates], PTE.

Untreated soil	Mean	Range
pH	3.1	2.7 – 3.6
%C	0.60	0.10 – 1.08
%N	0.10	0.08 – 0.13

Texture Sandy loam

	Mean (mg/kg)	Range (mg/kg)
CEC (cmol(+)/kg)		
Exc. Al (cmol(+))		
Exc. H (cmol(+))		
P olsen (mg/kg)		
Cu	598.0	308 - 1155
Mn	823.0	650 - 1142
Ni	43.0	27 – 181
Cr	96.0	68 – 140

## 3 experimental blocks - 500 m<sup>2</sup>

- PC: amended with compost
- PT1: waste mixture 1
- PT2: waste mixture 2
  
- Sub-plots 5 x 5m
- Spacing 1 m between sub-plots;  
4 m between blocks



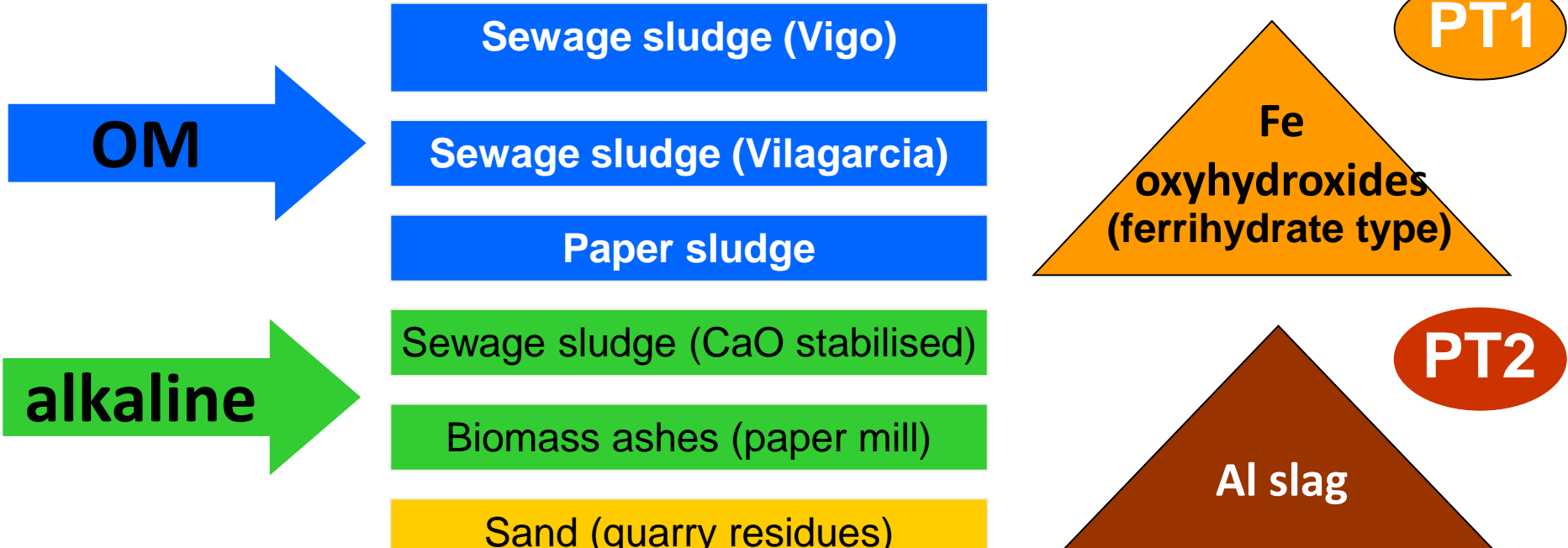
**PC:** composted sewage sludges, pine bark chips



**Less durable effect?**



**Waste mixtures (PT1 and PT2):**



- Stabilise organic material (organo-mineral complexes)

- Different reactive surfaces for Cu immobilisation

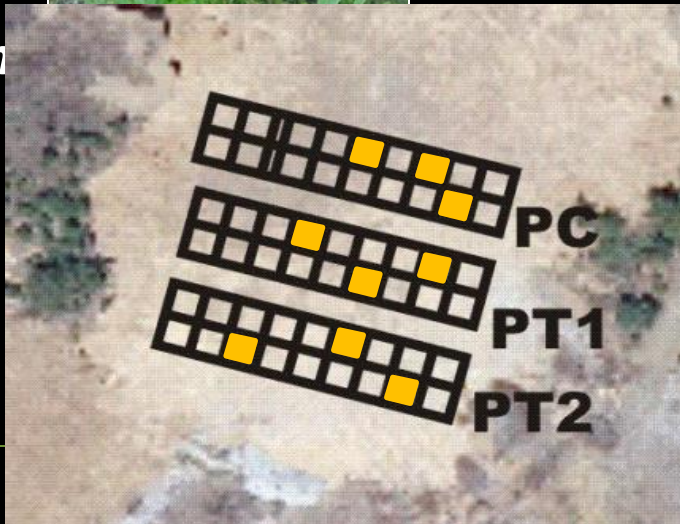
# Plant species



*Salix viminalis*



*Agrostis capillaris* cv. Highland



3 replicate sub-plots per species and per amendment

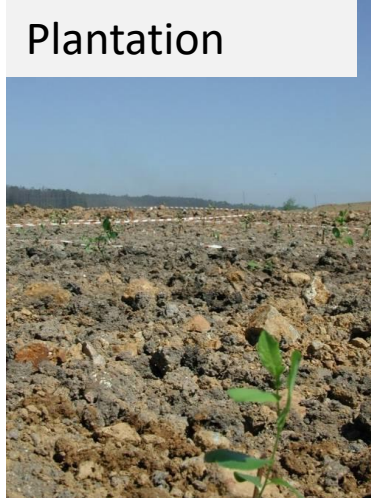
# Salix - 2017



## Progress



Incorporation amendment



# Plant-microbial-soil system

## Soil physico-chemical properties

General properties

pH, texture, CEC, C, N, pseudo-total [metal], organo- and Fe/Al (hydro)oxides

Metal availability

H<sub>2</sub>O-, NH<sub>4</sub>NO<sub>3</sub>-extractable [metal], BCR fractionation

Nutrient availability

Available P (olsens), water-extract: DOC, TN, anions (NO<sub>3</sub><sup>-</sup>, NH<sub>4</sub><sup>+</sup>, K<sup>+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup>)

## Soil biological properties

Structural diversity (Bacteria, Archaea, Fungi)

Functional diversity (enzyme activities, respiration, Biolog Ecoplate); NGS shotgun

## Plant growth

Biomass production

Nutrition, metal accumulation

# Plant-microbial-soil system

## Soil physico-chemical properties

Gene

Meta



Monitoring T=0, 1 yr, 2 yr, 3 yr,  
6 yr

## PHYTOMANAGED MINE-SOIL

- Different amendments (PC, PT1, PT2)
- Different plant covers (*Salix*, *Agrostis*)

- 1-3 years general amendment effect no plant species effect
- Soil biological properties (microbial diversity and activity)

Soil biology

Structure  
Archaea

Function  
activities

Ecoplate); NGS shotgun



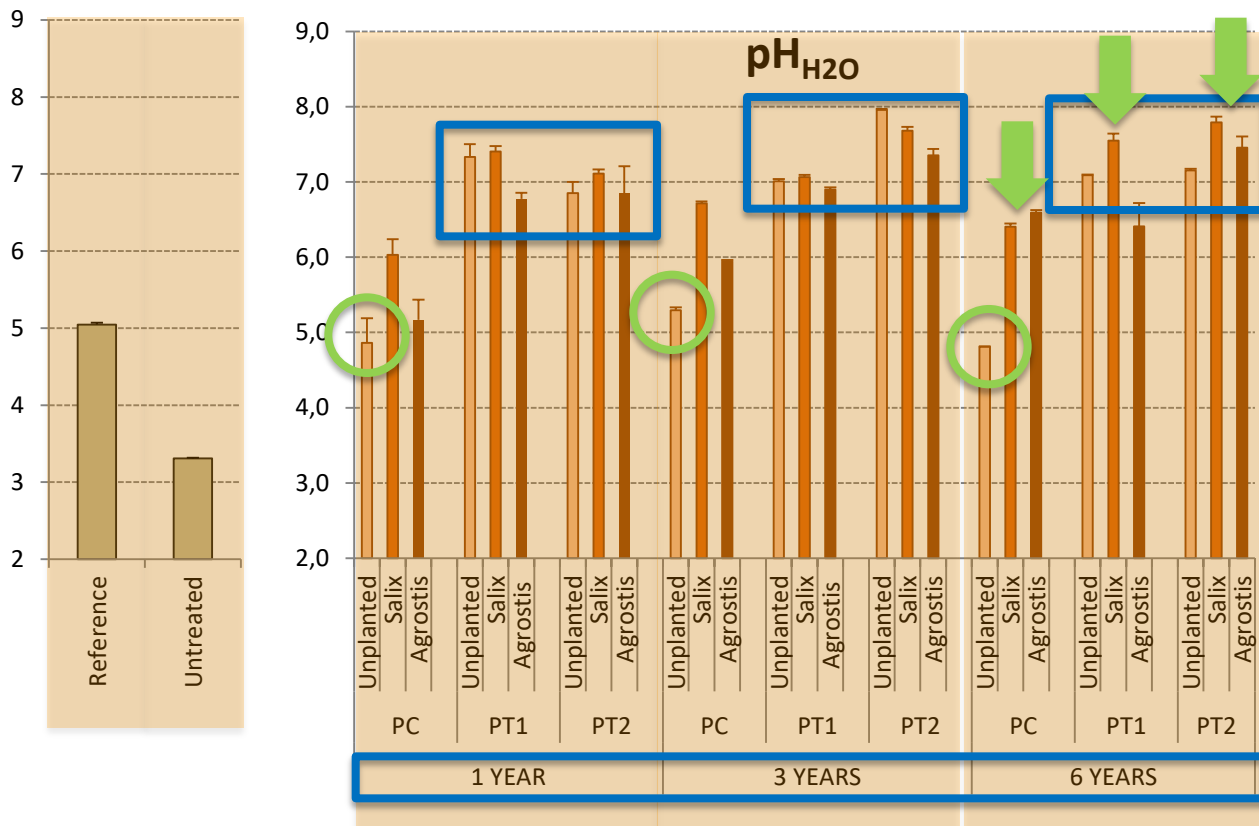
- Untreated soils (UNT)

## NON-CONTAMINATED SOIL

- Reference soil (Oak forest, similar geological substrate (amphibolite))

# Improvements in soil fertility

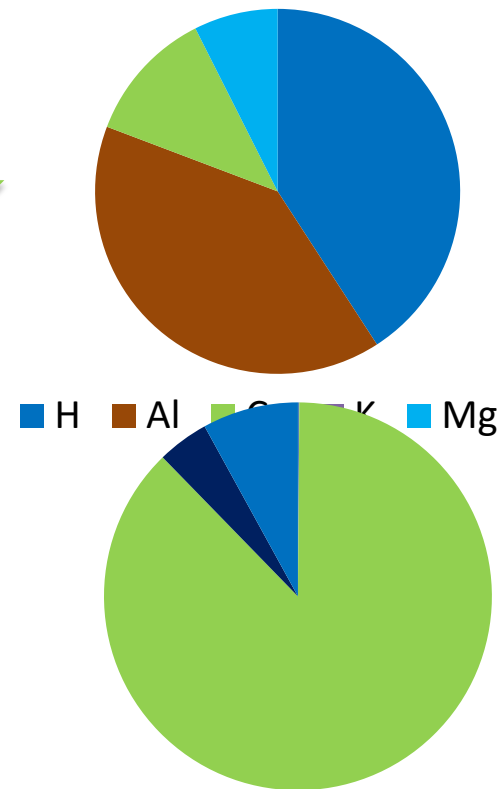
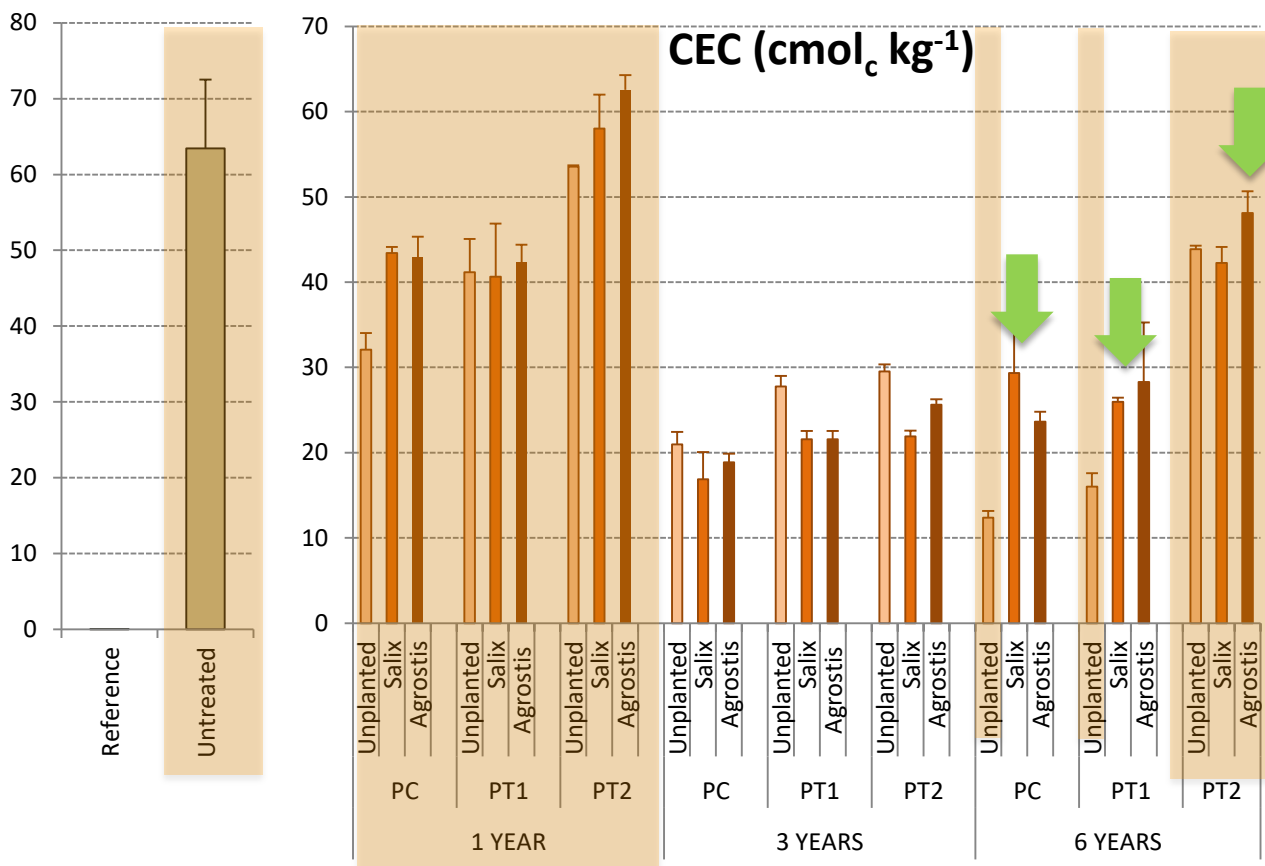
## RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT IN SOUTHWEST EUROPE



- PT1/PT2 > PC
- Durable pH effect
- PC UNP < pH
- 6 yrs: >pH under plant cover

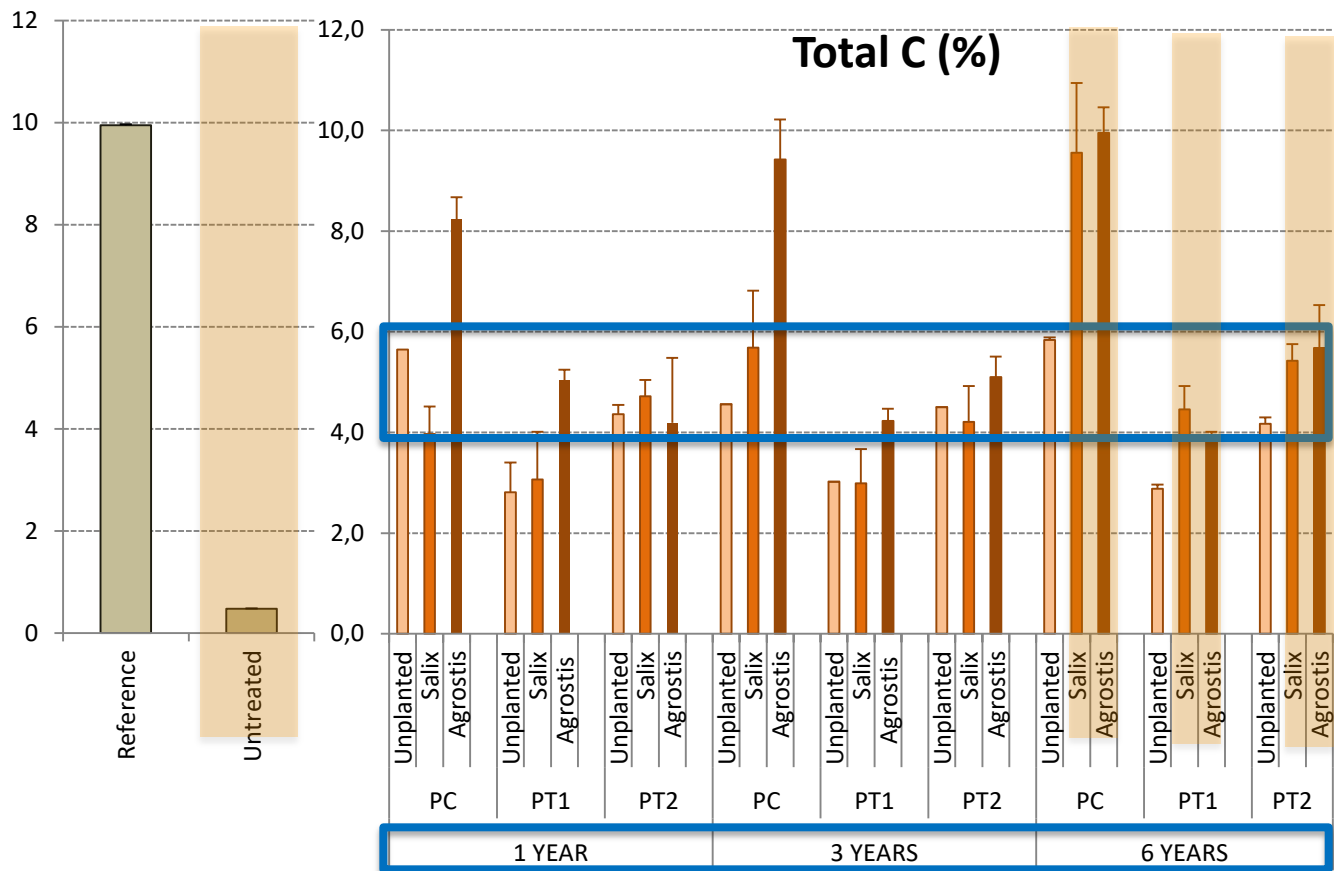
# Improvements in soil fertility

RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT IN SOUTHWEST EUROPE



# Improvements in soil fertility

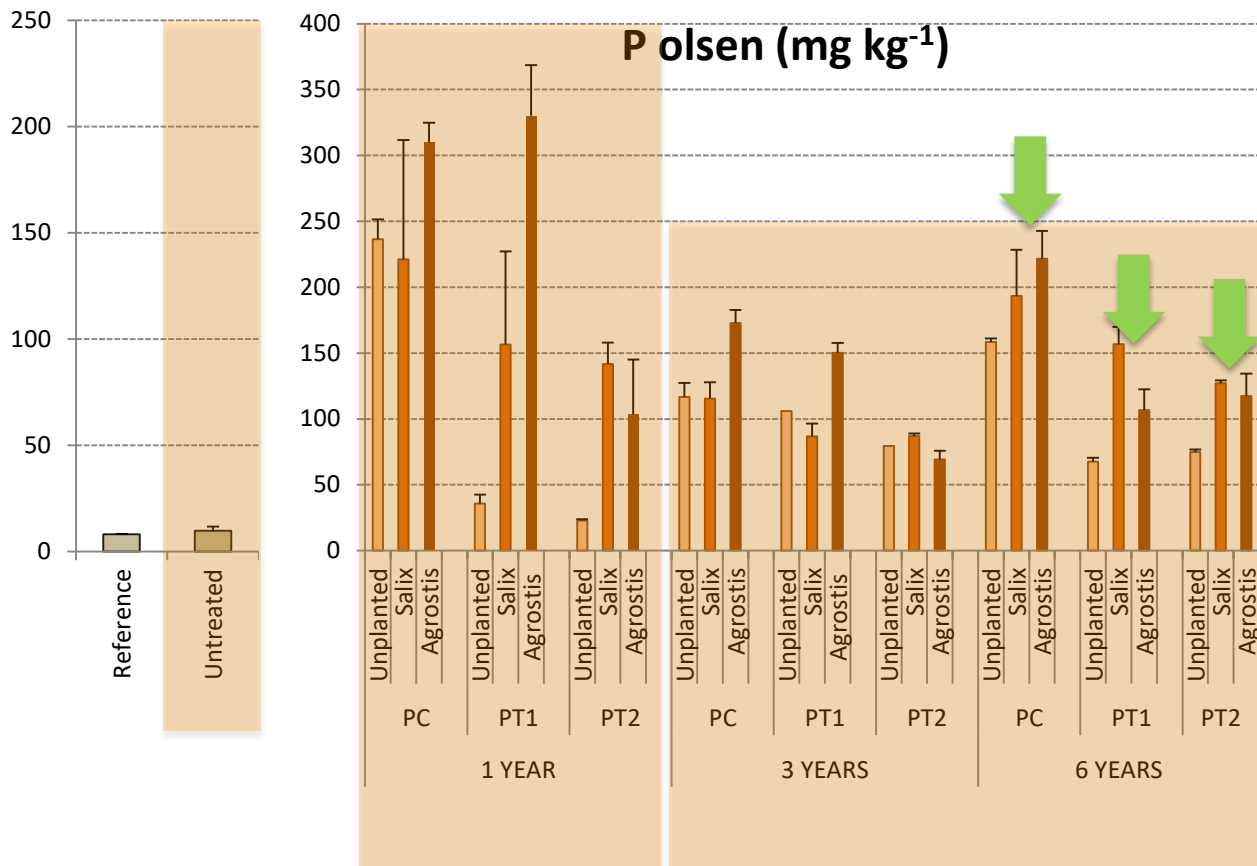
## RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT IN SOUTHWEST EUROPE



- Same trends observed in total N

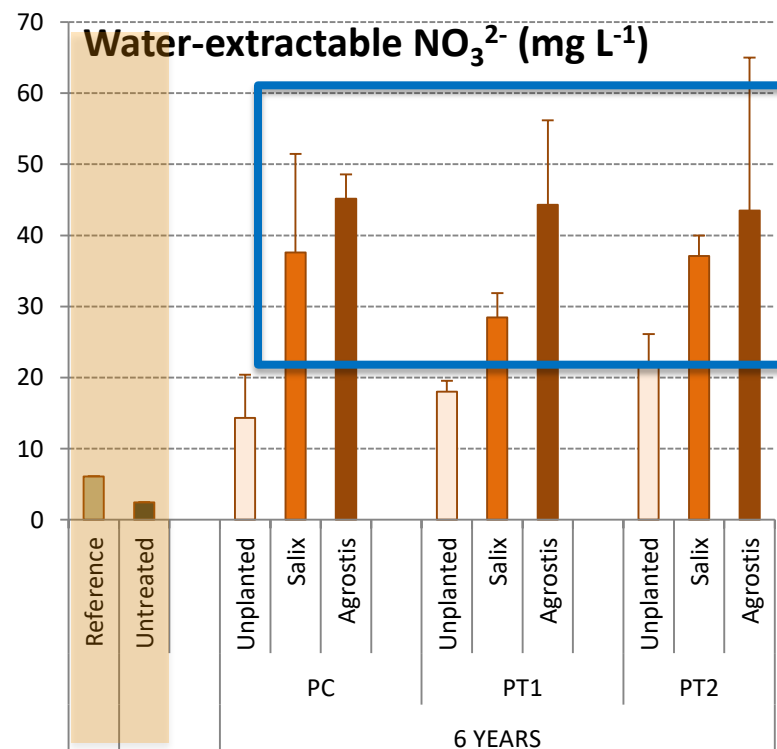
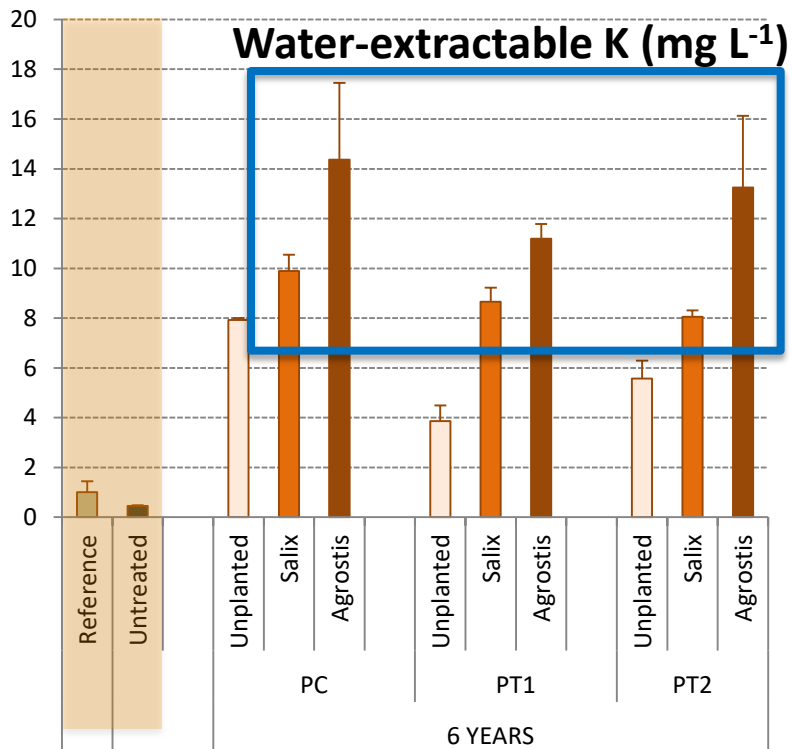
# Improvements in soil fertility

## RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT IN SOUTHWEST EUROPE



# Improvements in soil fertility

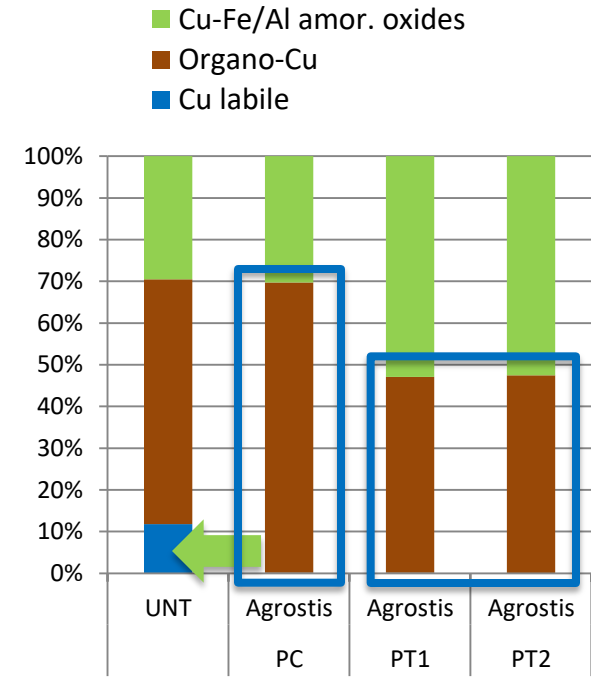
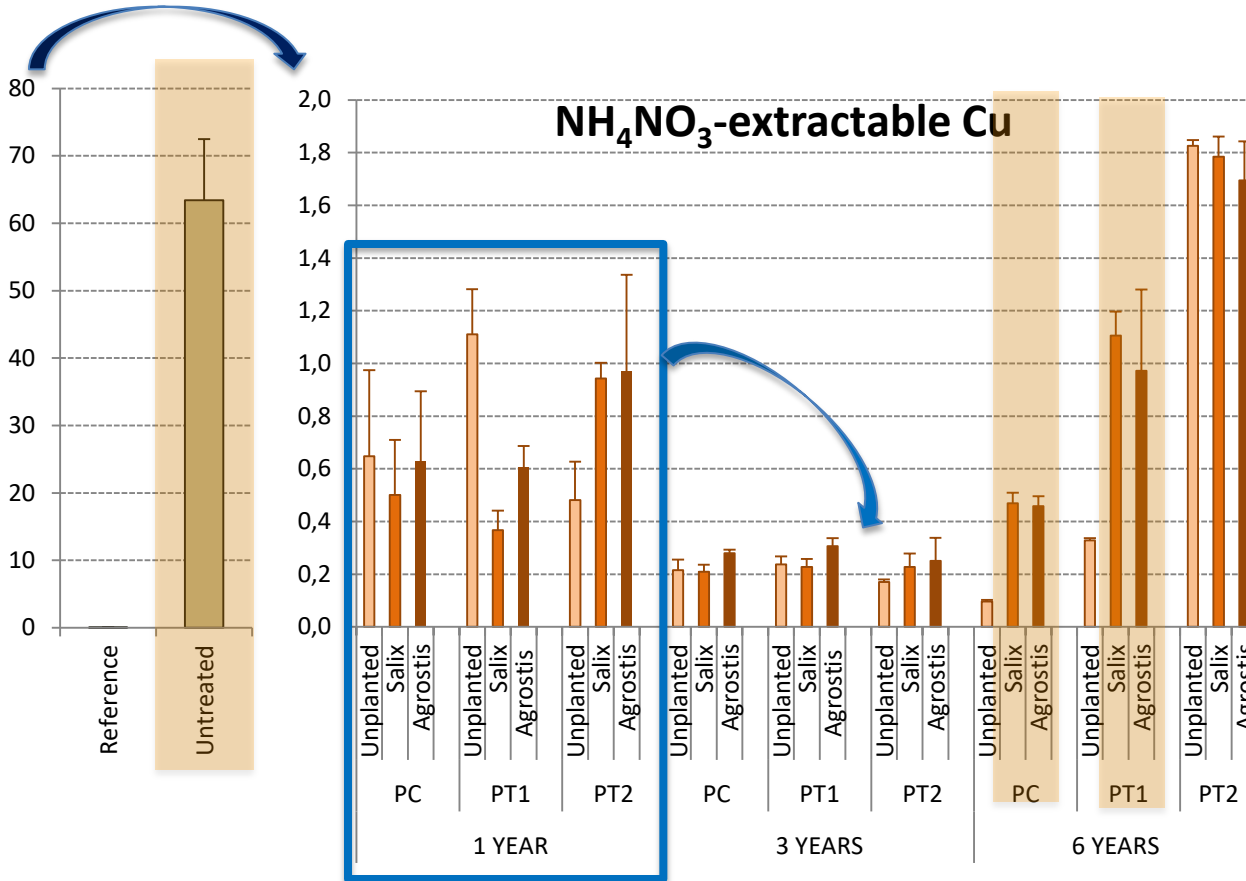
RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT IN SOUTHWEST EUROPE



# Reduction in Cu availability

RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT IN SOUTHWEST EUROPE

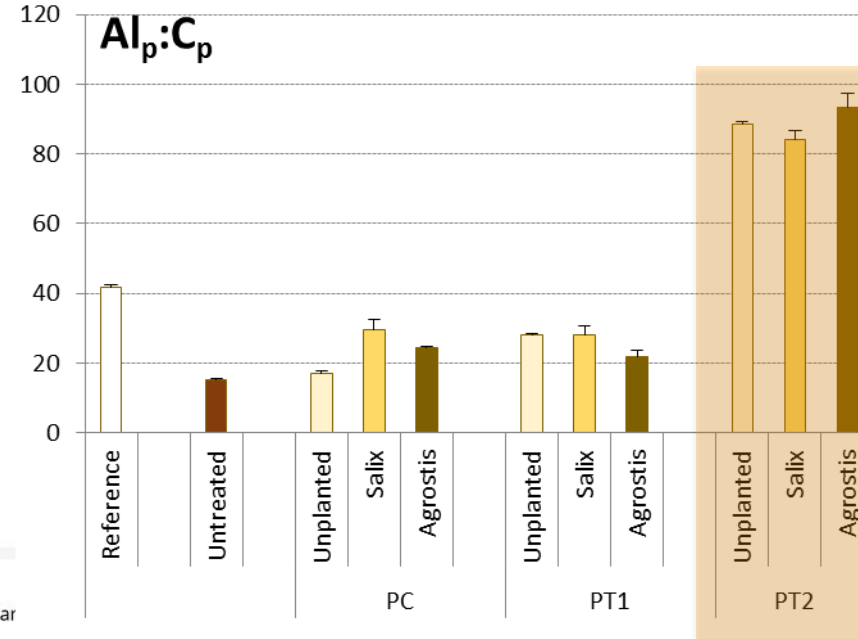
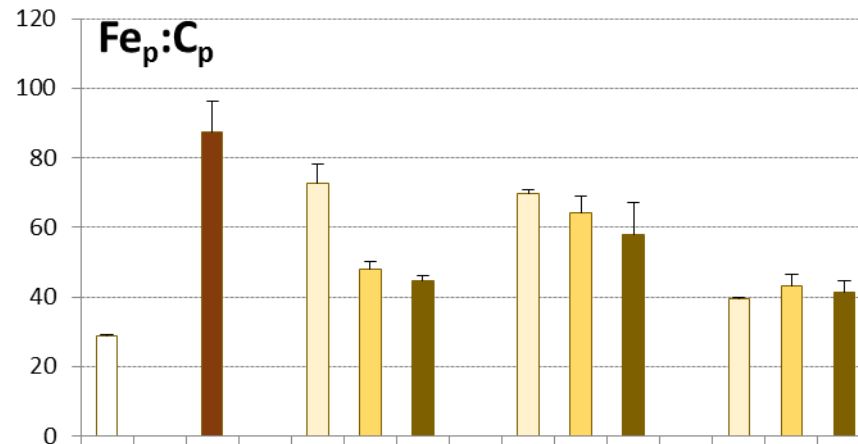
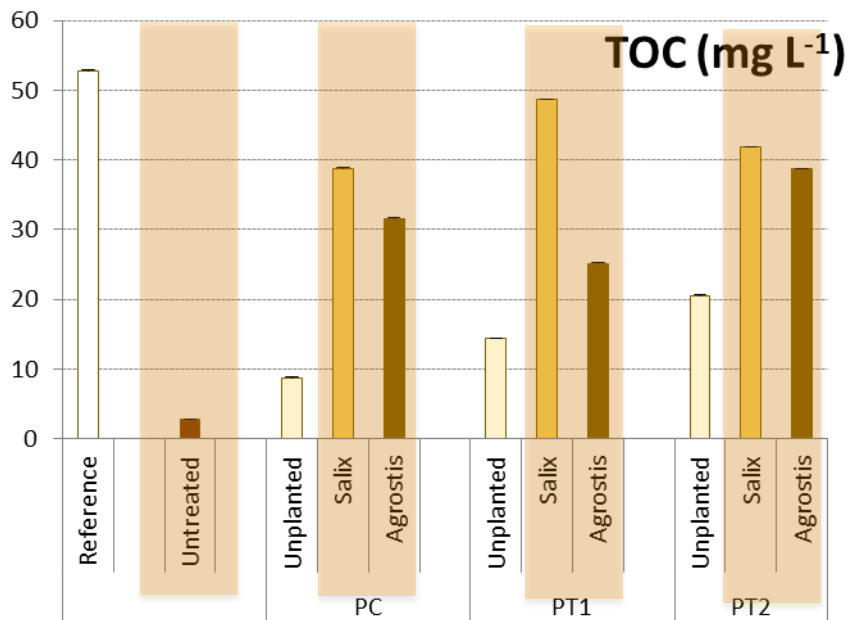
## Immobilization



Co bl PT1/2-amended blocks: Cu associated with amorphous Fe/Al oxides

# C stabilization processes

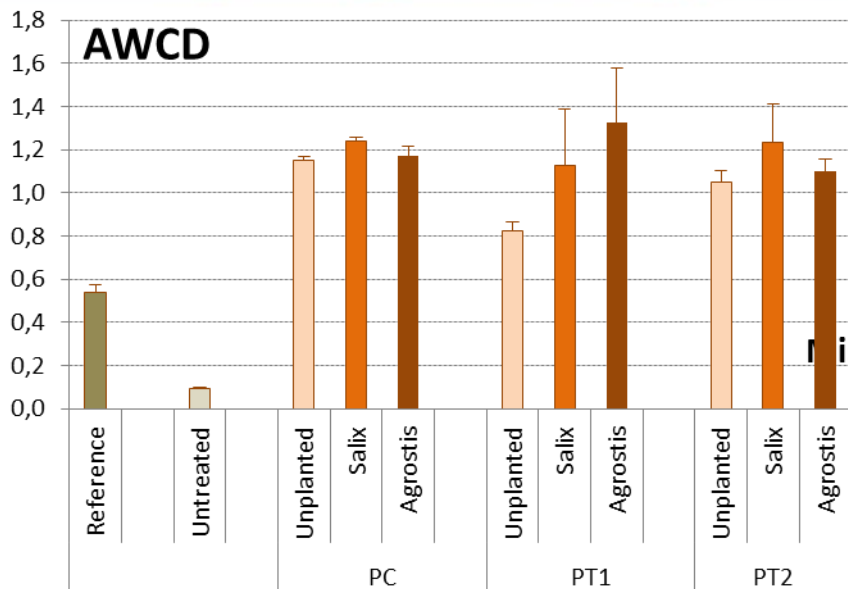
## RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT IN SOUTHWEST EUROPE



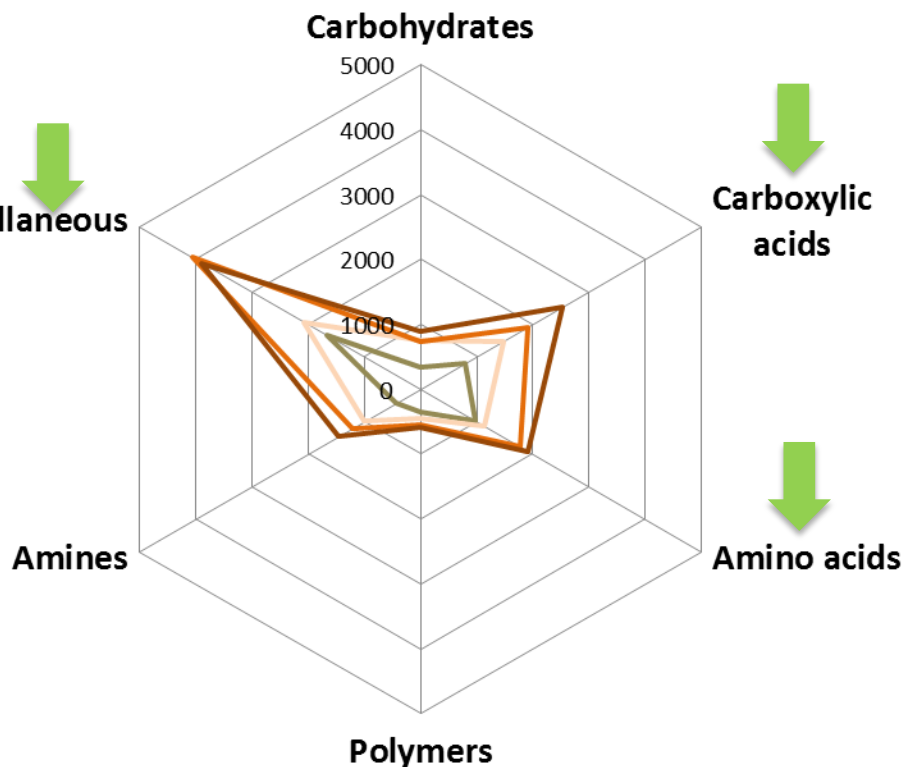
- DOC > under plant cover
- Reactive Fe phases present in all amended soils (in line with geology)
- Important phase of organo Al complexes in PT2

# Improvements in soil microbial activity

## RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT IN SOUTHWEST EUROPE



- C substrate usage compared to UNT

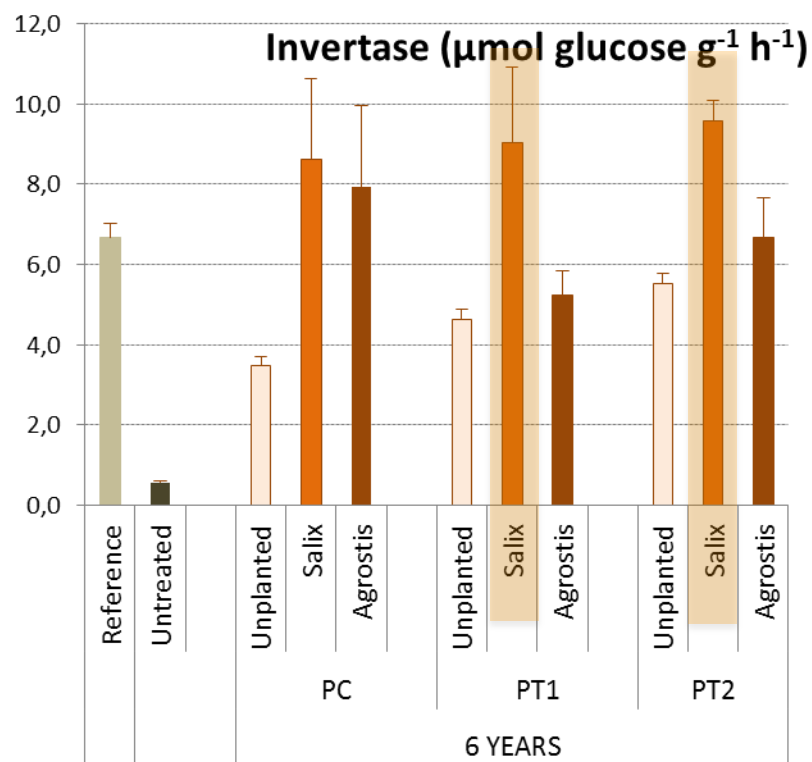
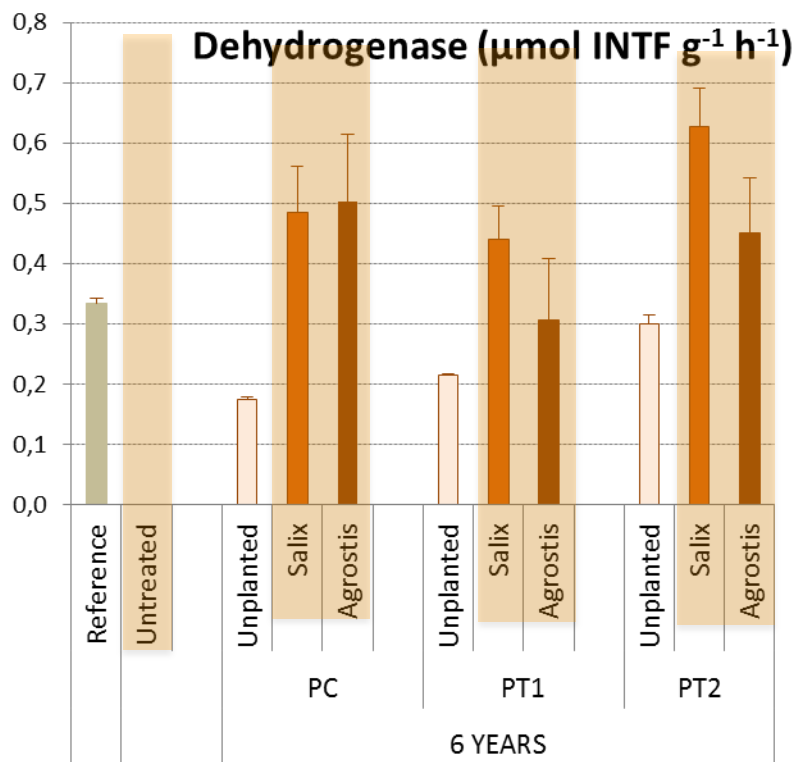


- Community level physiological profiling (Biolog Ecoplates)
- AWCD > phytomanaged soils
- AWCD and C substrate use > under plant cover

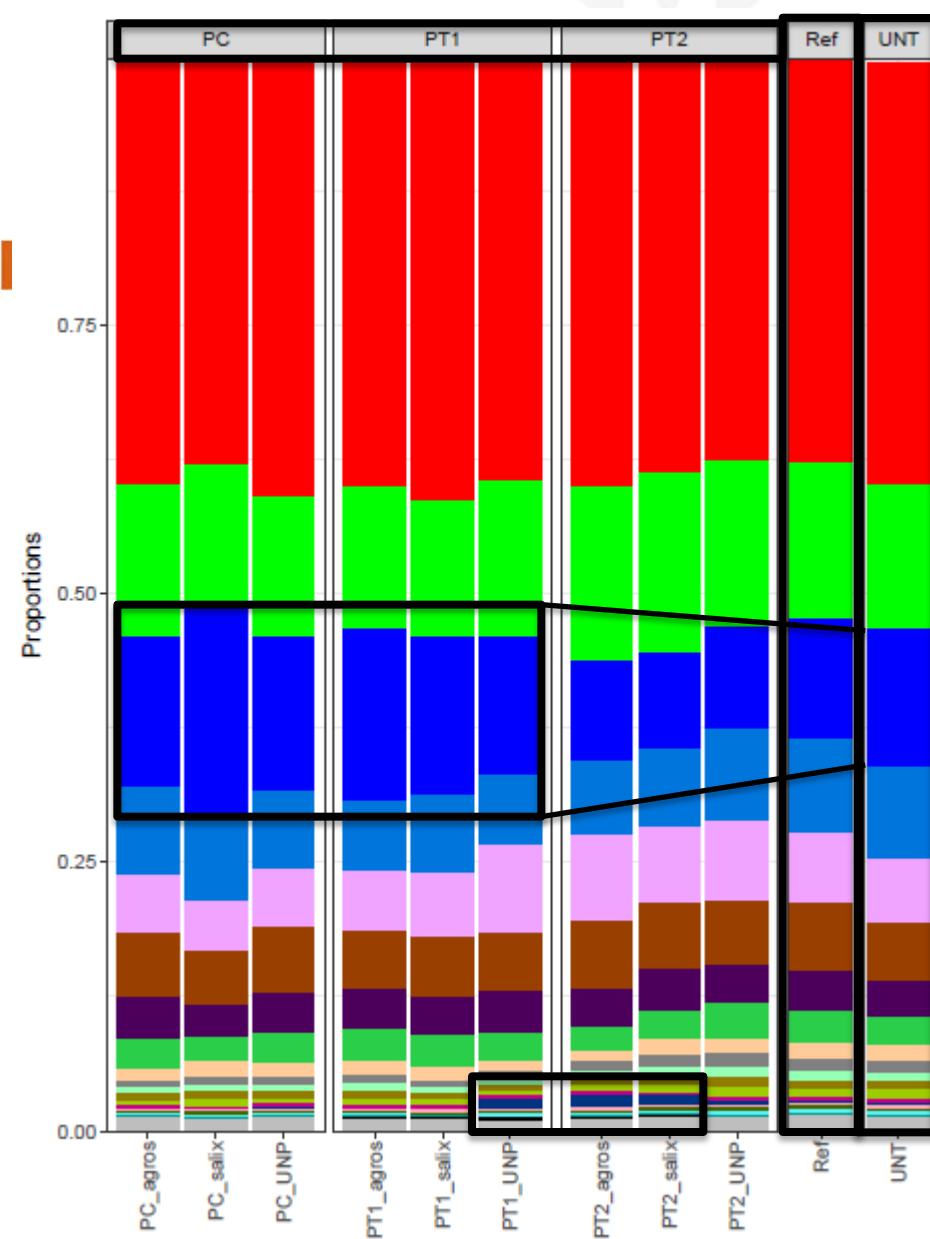
— Reference   
 — PT1 UNP   
 — PT1 Salix   
 — PT1 Agrostis

# Improvements in soil microbial activity

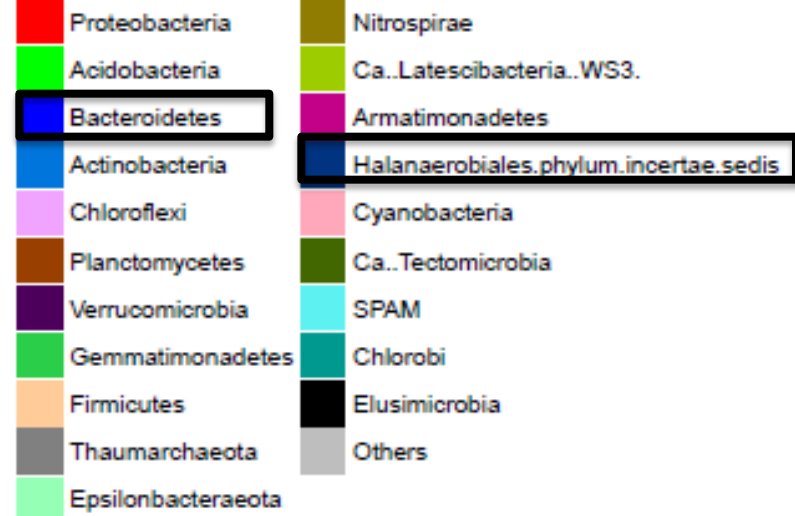
## RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT IN SOUTHWEST EUROPE



# Changes in soil microbial diversity (NGS sequencing illumina)



## Taxa

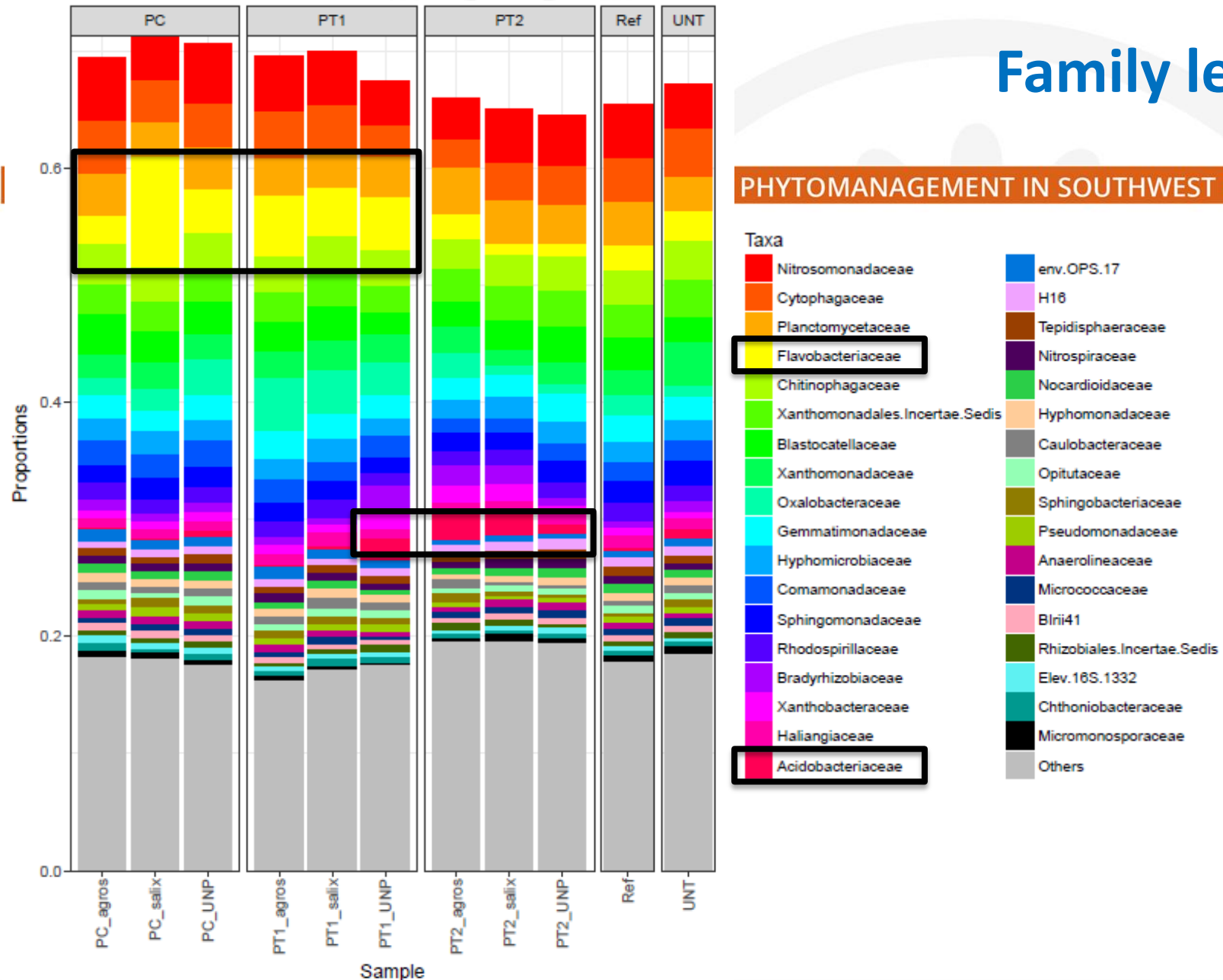


- Assignment of sequences to phyla
- Dominant phyla: Proteobacteria, Acidobacteria, Actinobacteria
- Increase relative abundance of bacteroidetes PC/PT1
- Increase halanaerobiales



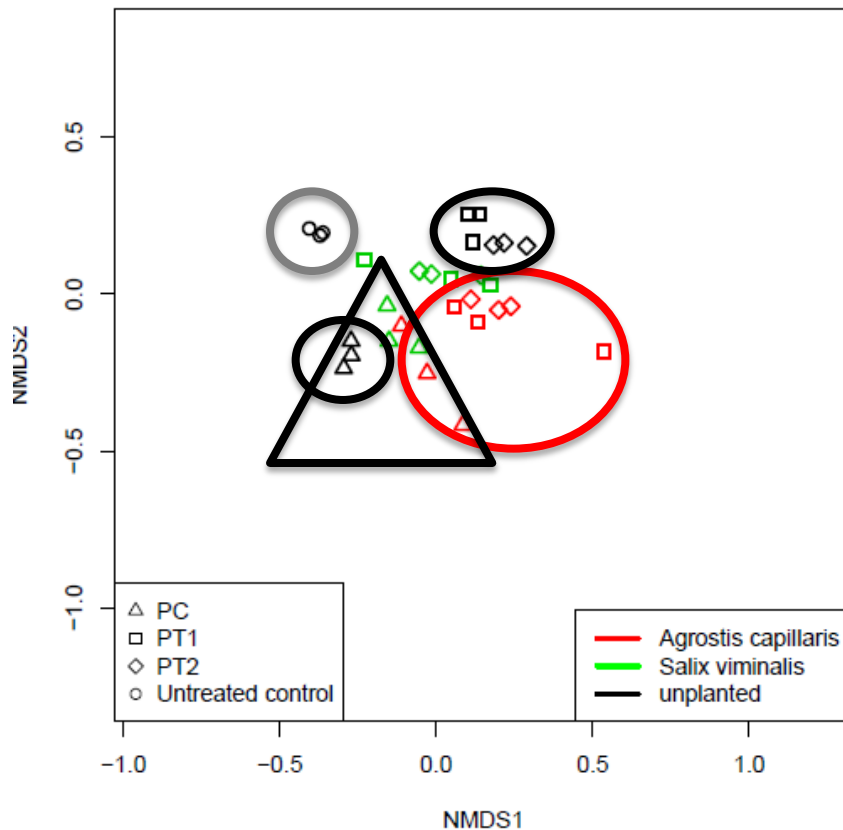
# Family level

## PHYTOMANAGEMENT IN SOUTHWEST EUROPE



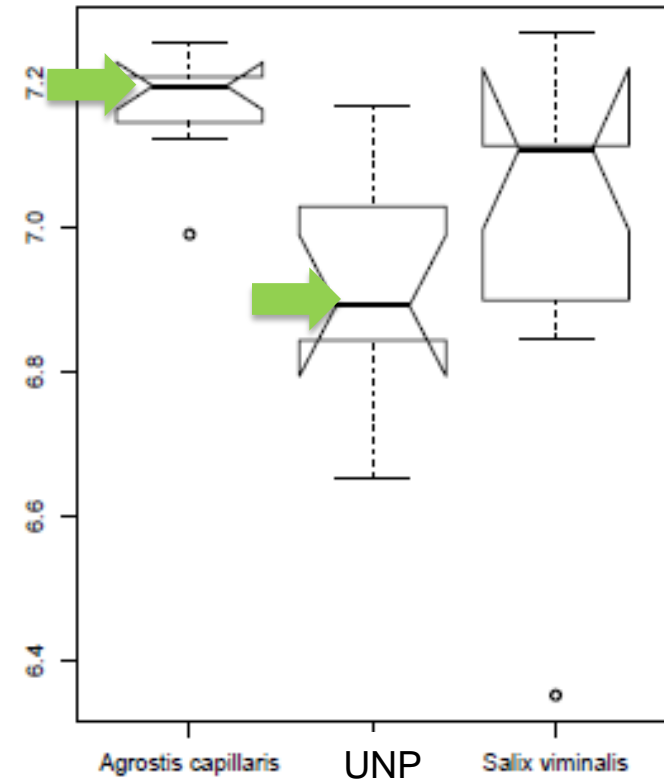
## RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT IN SOUTHWEST EUROPE

### Non-metric multidimensional scaling (NMDS) ordination plot:



### Shannon diversity > under plant cover

$H, p = 0.028$



- Separation of plant species/treatments