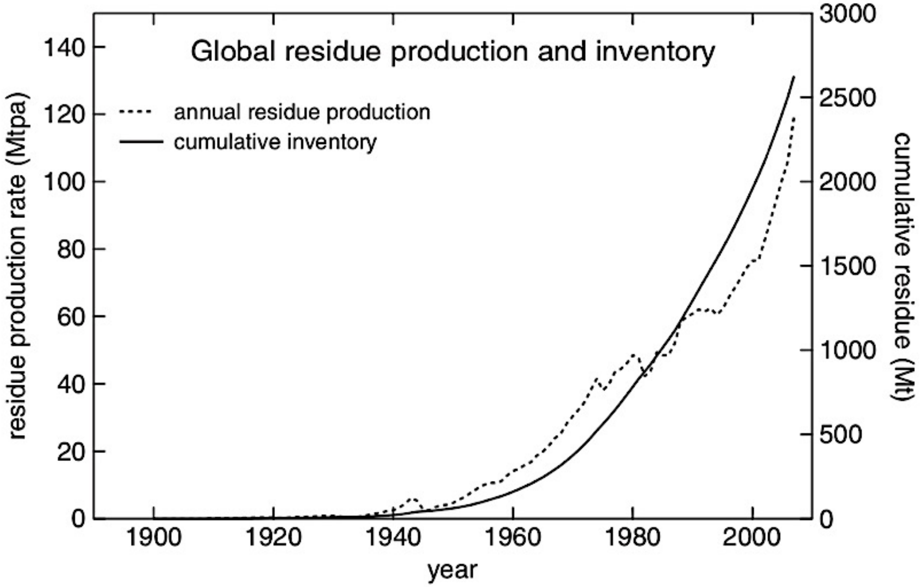
Potential of Aleppo pines as a vegetative barrier to reduce transfer of particles in and around storage sites of bauxite and its residues, in the Bouches-du-Rhône (France)

I. Laffont-Schwob, J. Rabier, V. Masotti, H. Folzer, M.-D. Salducci, M. Maignan, Y. Noack, J.C. Raynal, L. Vassalo, C. Demelas, P. Prudent

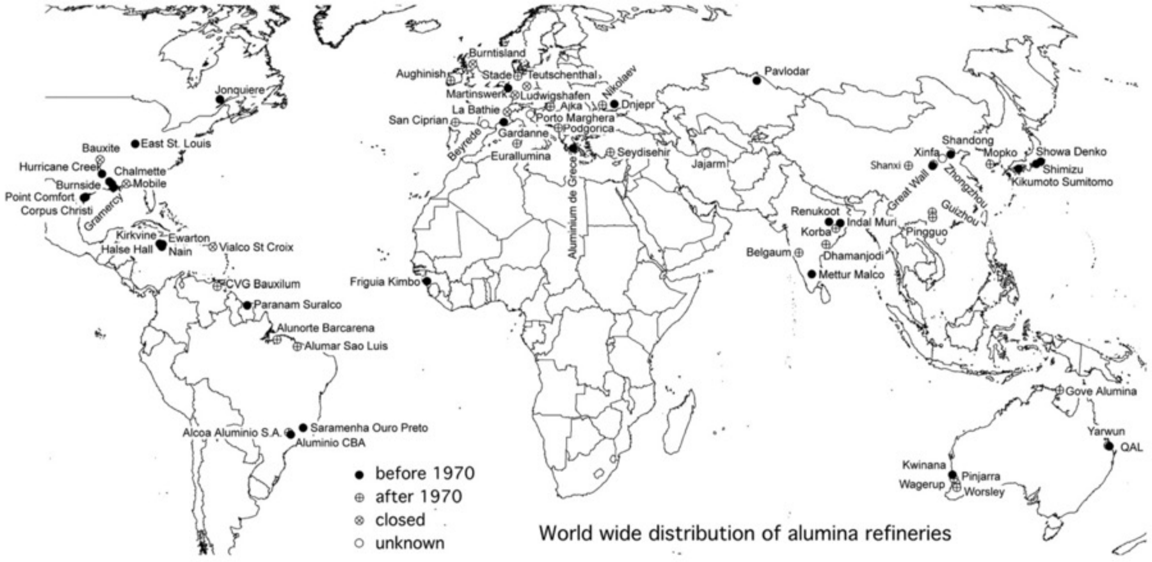
Journées Scientifiques : "Bauxite Résidues"
Aix-en-Provence, du 08 au 09 juin 2021

Storage of bauxite residues: an increasing issue



Global production rate and cumulative inventory of bauxite residue

(Power et al., 2011)



World map showing the distribution of alumina refineries based on establishment date (before or after 1970), closed or unknown

(Power et al., 2011)

From lagooning and sea disposal to dry stacking

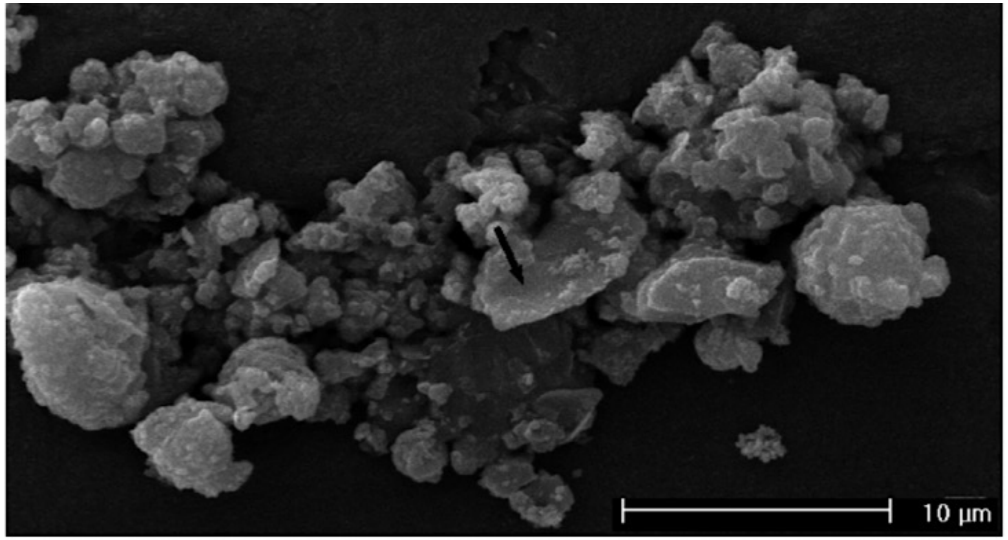
Dry stacking impacts

Bauxite residue: fine fraction waste remaining after Al extraction from bauxite using the Bayer Process

Dust: the majority (~80%) of particles in red mud may be less than 100 µm

pH 9–13

determinand	red mud leachate
pH	12.6
selected elements ($\mu g\ L^{-1}$)	
Al	833500
As	6325
B	1693
Cr	65
Cu	429
Fe	288
Ga	3820
Mo	7883
Ni	35
Pb	405
Si	9133
V	8977

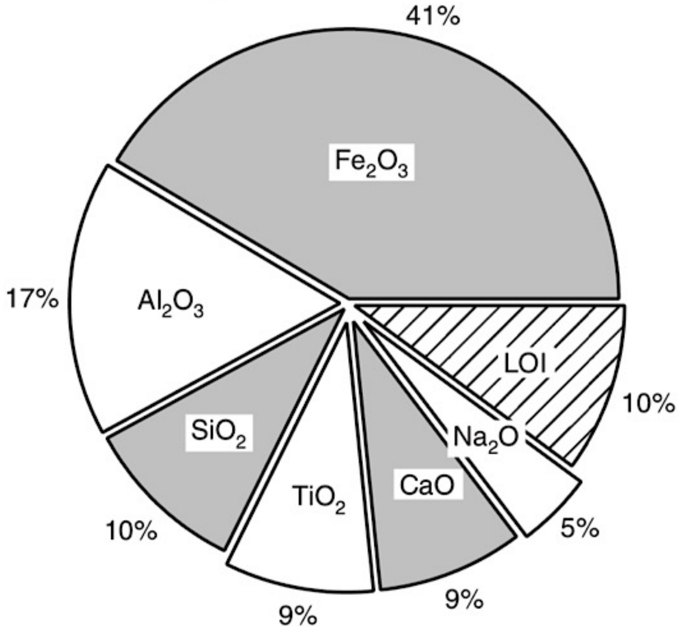


Grain size distribution : SEM image of the PM(10-1) fraction of resuspended red mud dust. Most particles are fluffy aggregates with diameters smaller than ~5 µm (Gelencsér et al., 2011)

Environmental Science & Technology ARTICLE pubs.acs.org/est

The Red Mud Accident in Ajka (Hungary): Characterization and Potential Health Effects of Fugitive Dust

András Gelencsér,† Nóra Kováts,† Beatrix Turóczi,† Ágnes Rostási,† András Hoffer,† Kornélia Imre,† Ilona Nyirő-Kósa,† Dorottya Csákberényi-Malasics,† Ádám Tóth,† Aladár Czitrovszky,§ Attila Nagy,§ Szabolcs Nagy,† András Ács,† Anikó Kovács,† Árpád Ferincz,† Zsuzsanna Hartyáni,† and Mihály Pósfai*,†



Composition of bauxite residue: metallurgical view

Hydrometallurgy 108 (2011) 46–59
Contents lists available at ScienceDirect
Hydrometallurgy
journal homepage: www.elsevier.com/locate/hydromet

Bauxite residue issues: IV. Old obstacles and new pathways for *in situ* residue bioremediation

M. Gräfe, C. Klauber *

Environmental Science & Technology Article pubs.acs.org/est

Speciation of Arsenic, Chromium, and Vanadium in Red Mud Samples from the Ajka Spill Site, Hungary

Ian T. Burke,*,† William M. Mayes,‡ Caroline L. Peacock,† Andrew P. Brown,§ Adam P. Jarvis,‖ and Katalin Gruiz⊥
†Earth Surface Science Institute, School of Earth and Environment, University of Leeds, Leeds LS2 9JT, U.K.
‡Centre for Environmental and Marine Sciences, University of Hull, Scarborough, YO11 3AZ, U.K.
§School of Process, Environmental and Materials Engineering, University of Leeds, Leeds LS2 9JT, U.K.
‖School of Civil Engineering and Geosciences, Newcastle University, Newcastle upon Tyne, NE1 7RU, U.K.
⊥Department of Applied Biotechnology and Food Science, Budapest University of Technology and Economics, 1111 Budapest, St. Gellért sq. 4, Hungary

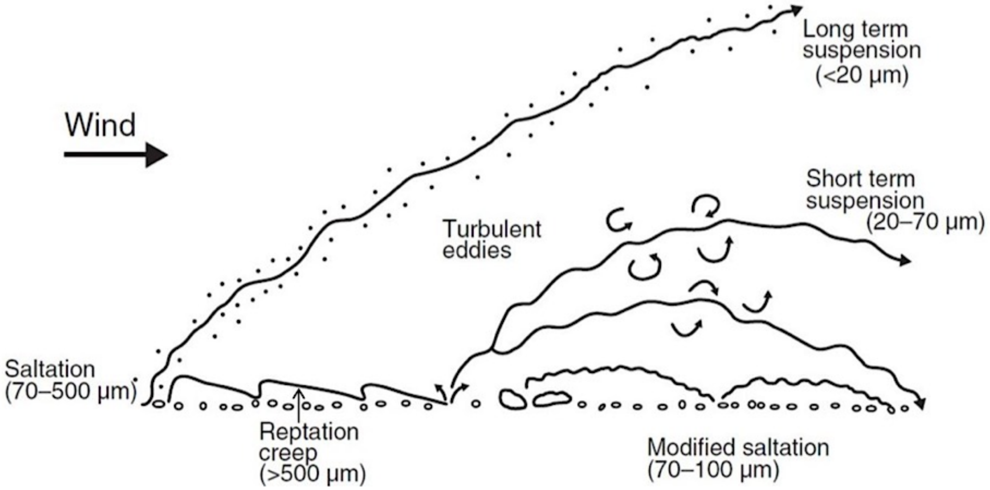
Dry stacking impacts

Red muds : fine fraction waste remaining after Al extraction from bauxite using the Bayer Process

Emission of fine and extra-fine particles (PM10 and PM2.5), which sometimes include inhalable hazardous compounds

+ sedimentable particles

Unfavorable meteorological conditions (high temperature, low humidity, intense solar radiation, and wind speed)



Schematic of the different modes of aeolian transport.
(Kok et al 2012)

Stadium (Vitrolles, October 2015)

minerals MDPI

Article

Experimental Evaluation of PM Emission from Red Mud Basins Exposed to Wind Erosion

Valentina Dentoni *, Battista Grosso and Francesco Pinna

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* Correspondence: vdentoni@unica.it

The physics of wind-blown sand and dust

Jasper F. Kok[1], Eric J. R. Parteli[2,3], Timothy I. Michaels[4], and Diana Bou Karam[5]

[1]Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY, USA
[2]Departamento de Física, Universidade Federal do Ceará, Fortaleza, Ceará, Brazil
[3]Institute for Multiscale Simulation, Universität Erlangen-Nürnberg, Erlangen, Germany
[4]Southwest Research Institute, Boulder, CO USA
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Science of the Total Environment 426 (2012) 359–365

Contents lists available at SciVerse ScienceDirect

Science of the Total Environment

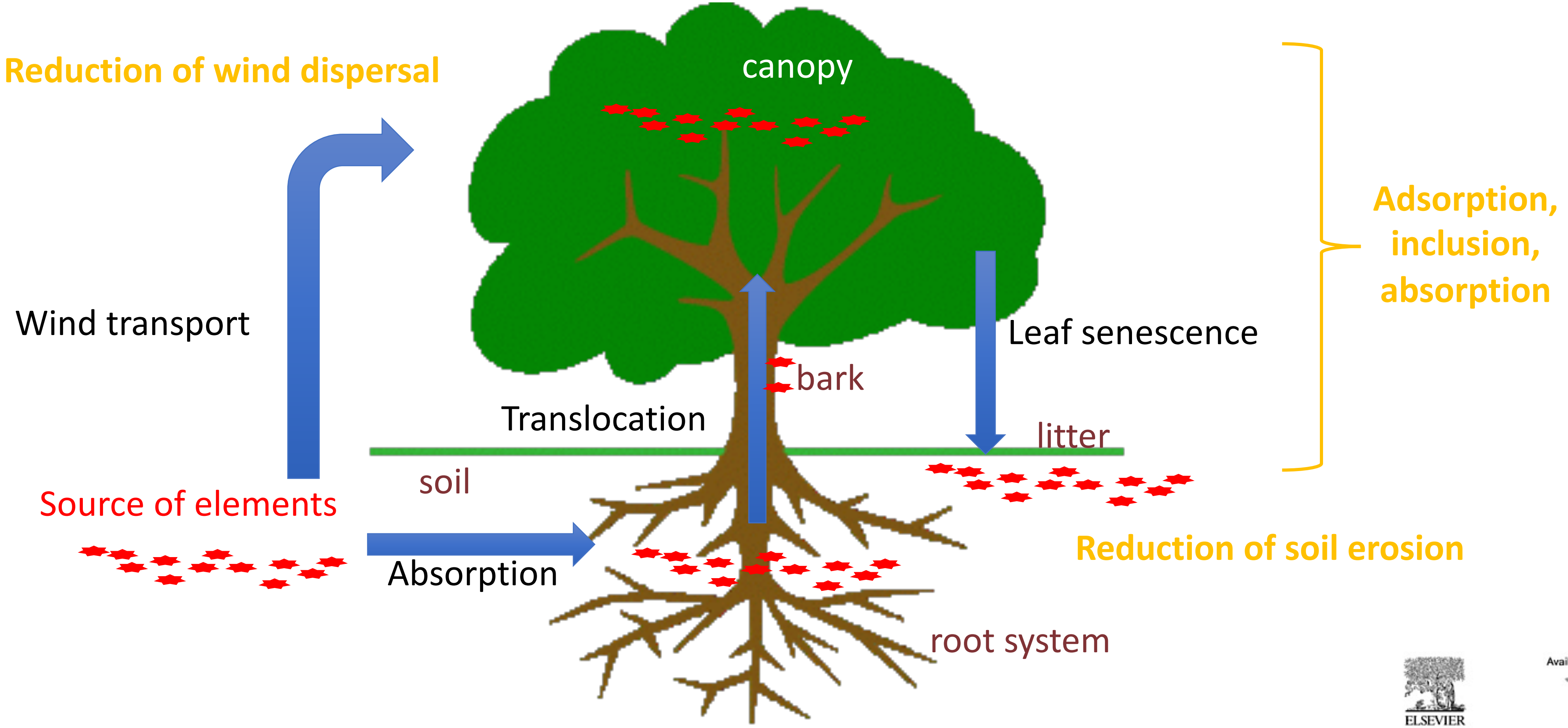
journal homepage: www.elsevier.com/locate/scitotenv

Environmental impact of toxic elements in red mud studied by fractionation and speciation procedures

Radmila Milačič *, Tea Zuliani, Janez Ščančar

Department of Environmental Sciences, Jožef Stefan Institute, Jamova 39, 1000 Ljubljana, Slovenia

Vegetative barriers: a nature-based solution to lower particle transfer



Ecotechnologies with proven results in urban environments

ELSEVIER
Available online at www.sciencedirect.com
ScienceDirect
Aerosol Science 39 (2008) 40–47
Journal of Aerosol Science
www.elsevier.com/locate/jaerosci

Collection of ambient particulate matter by porous vegetation barriers: Sampling and characterization methods

Abhishek Tiwary[a], Adam Reff[b,*], Jeremy J. Colls[c]
[a]School of Chemical Engineering and Analytical Sciences, Environment and Sustainable Technology Division, The University of Manchester, P.O. Box 88, Sackville St., Manchester M60 1QD, UK
[b]Atmospheric Modeling Division, US Environmental Protection Agency, E243-03, Research Triangle Park, NC 27711, USA
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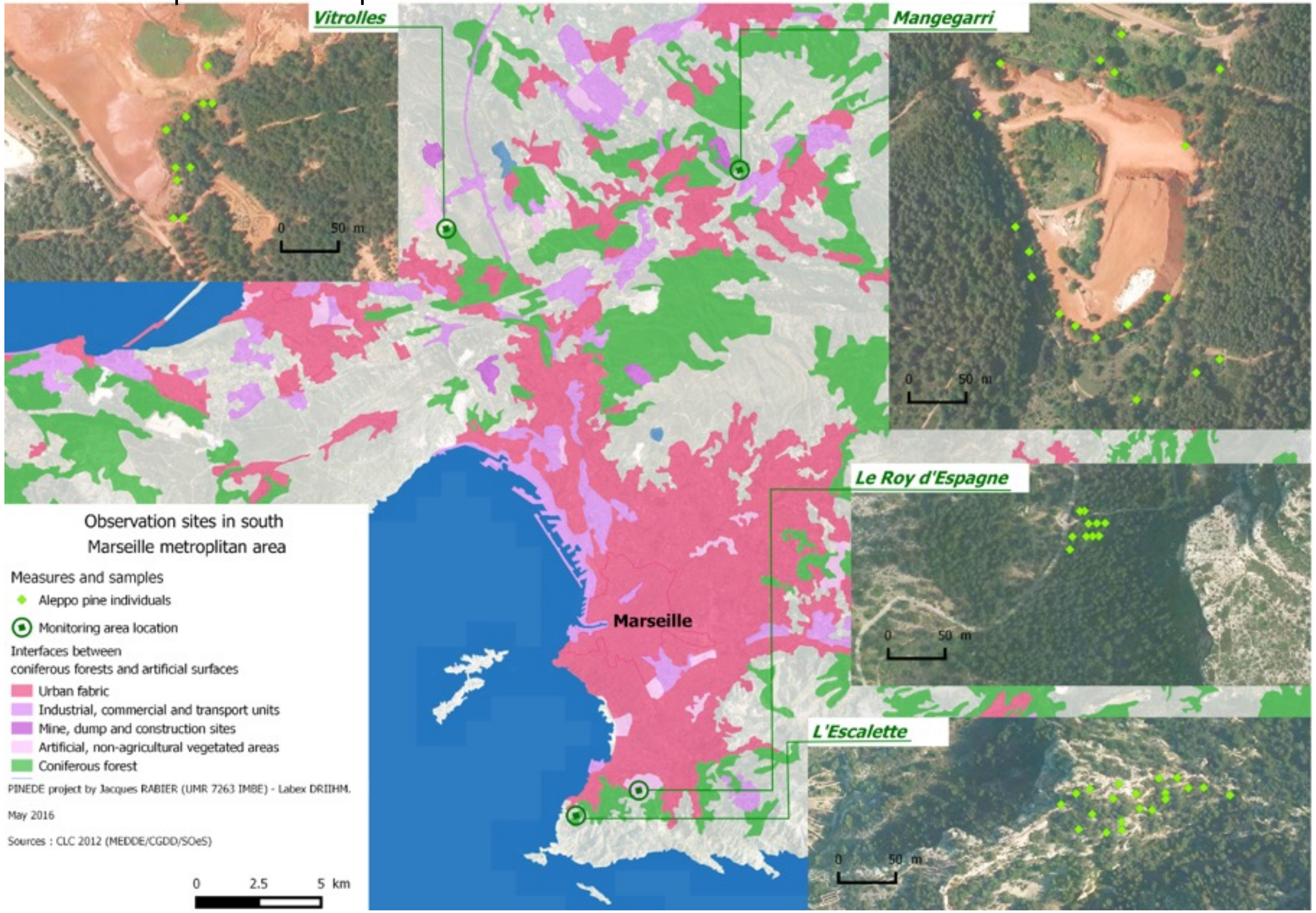
Our hypothesis: Aleppo pine trees occurring nearby bauxite residue deposit may play a role to reduce wind and soil erosion and prevent particles dispersion in the surrounding

Four sites chosen:

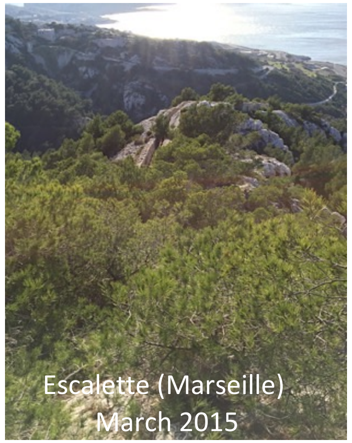
- 2 bauxite and their residues deposits (Mangegarri and Stadium)
- 1 reference site (Roy d'Espagne) in the National park of Calanques
- 1 brownfield site (Escalette) in the National park of Calanques


Stadium (Vitrolles) October 2015




Mangegarri (Bouc-Bel-Air)
June 2015


Roy d'Espagne (Marseille)
March 2015


Escalette (Marseille)
March 2015

10 pine trees on each site with 10 m of distance between each one

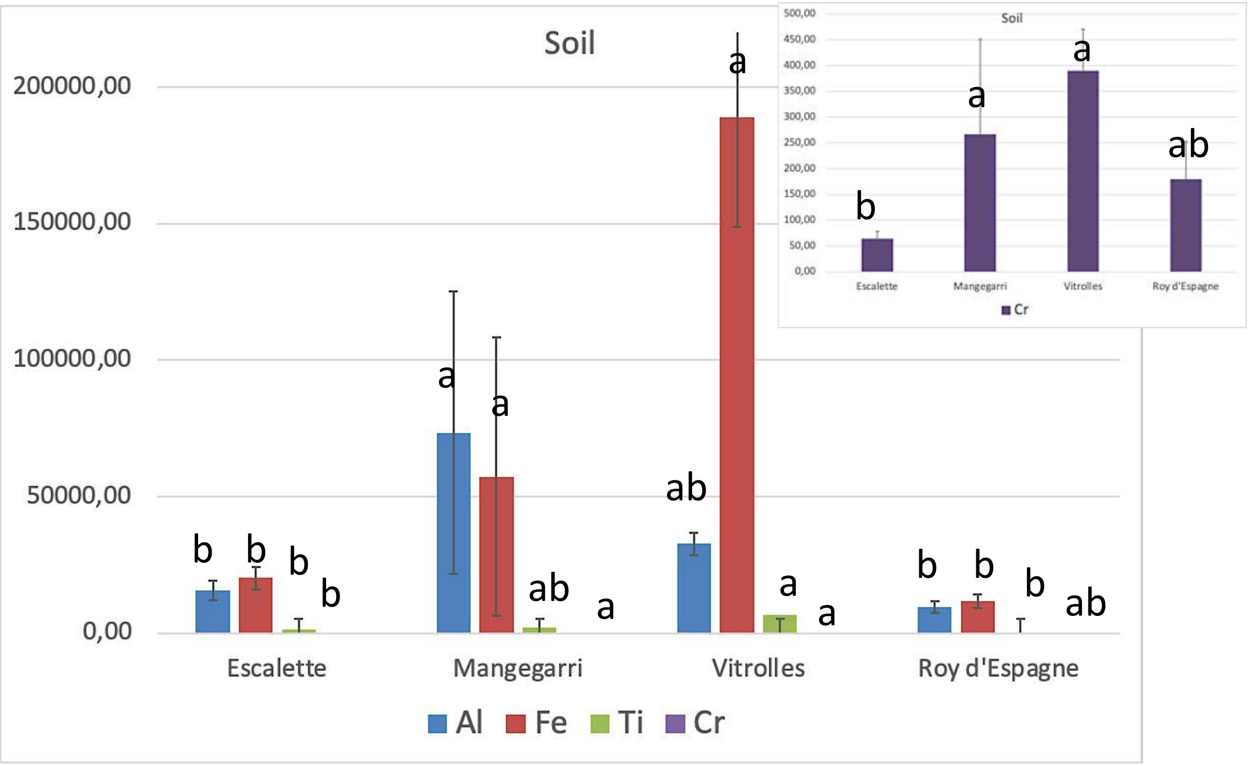
Non-destructive measurements of plant compounds with a portative fluorimeter

All samples dried and grinded, and soils sieved at 2mm beforehand

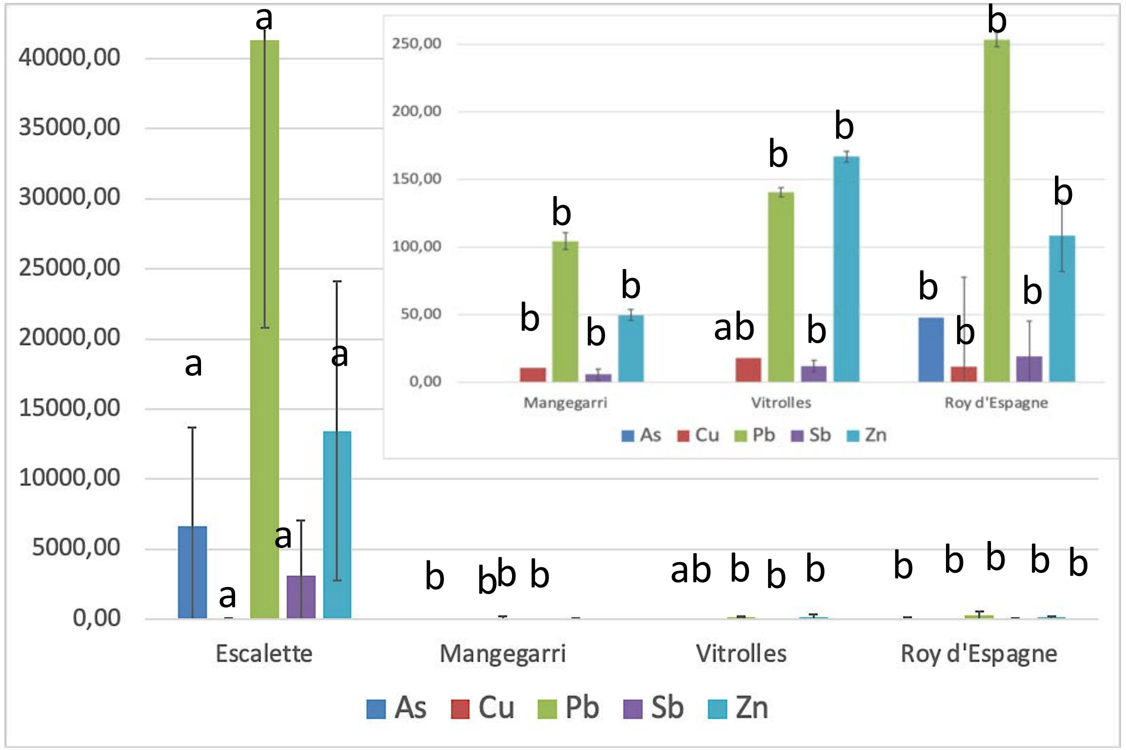
X-ray fluorescence & Coupled Plasma - Atomic Emission Spectrometry analyses

Soil

Element mg/kg



(Mean ± SD, n=10, Dunn test, p≤0.01)



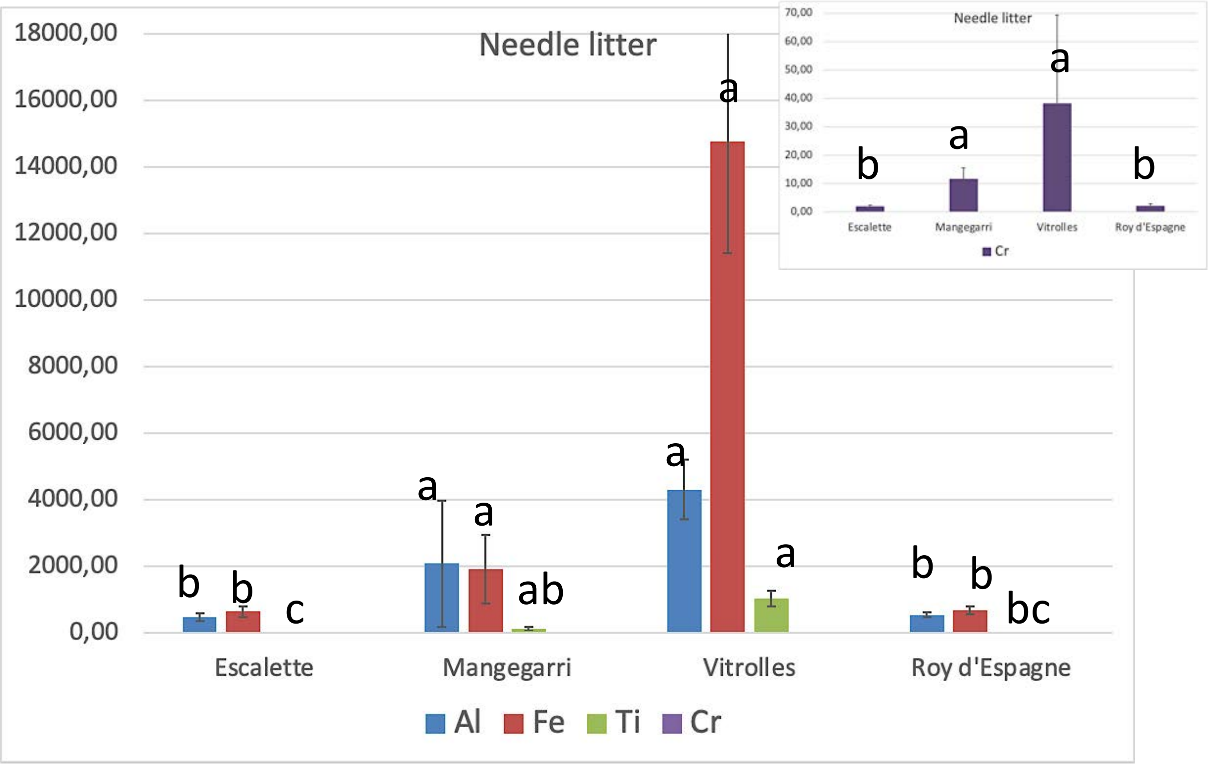
(Mean ± SD, n=10, Dunn test, p≤0.01)

Soils in Mangegarri with higher **Al** content (bauxite storage)
Fe significantly higher in Mangegarri and Vitrolles soils than Escalette and Roy d'Espagne (bauxite and its residues)
Ti significantly higher in Vitrolles than Escalette and Roy d'Espagne
Cr significantly higher in Mangegarri and Vitrolles soils than Escalette

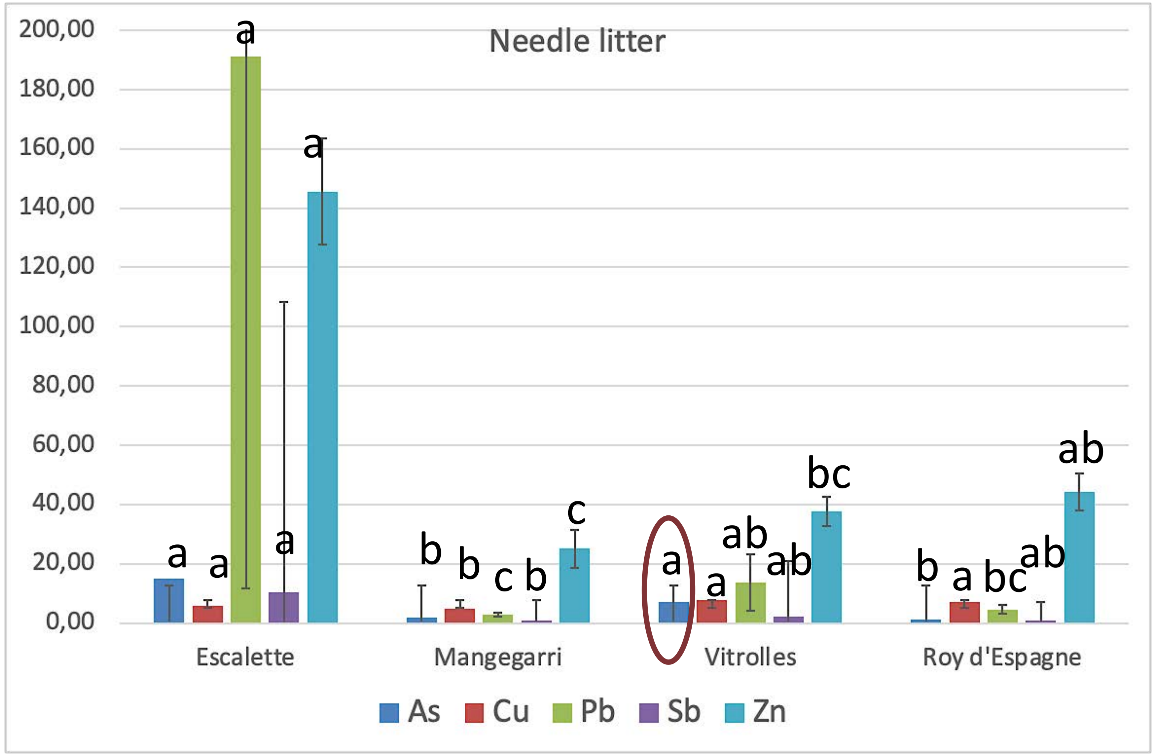
As only detected in Escalette and Roy d'Espagne (< LD for other soils)
Pb, **Sb** and **Zn** significantly higher in Escalette than other soils

Needle litter

Element mg/kg



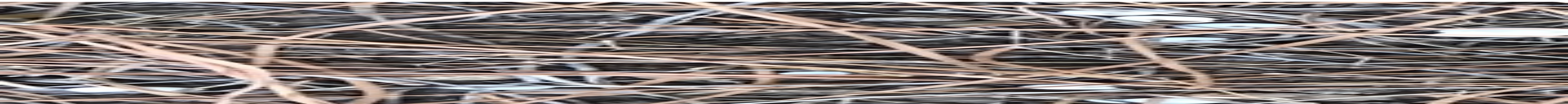
(Mean ± SD, n=10, Dunn test, p≤0.01)



(Mean ± SD, n=10, Dunn test, p≤0.01)

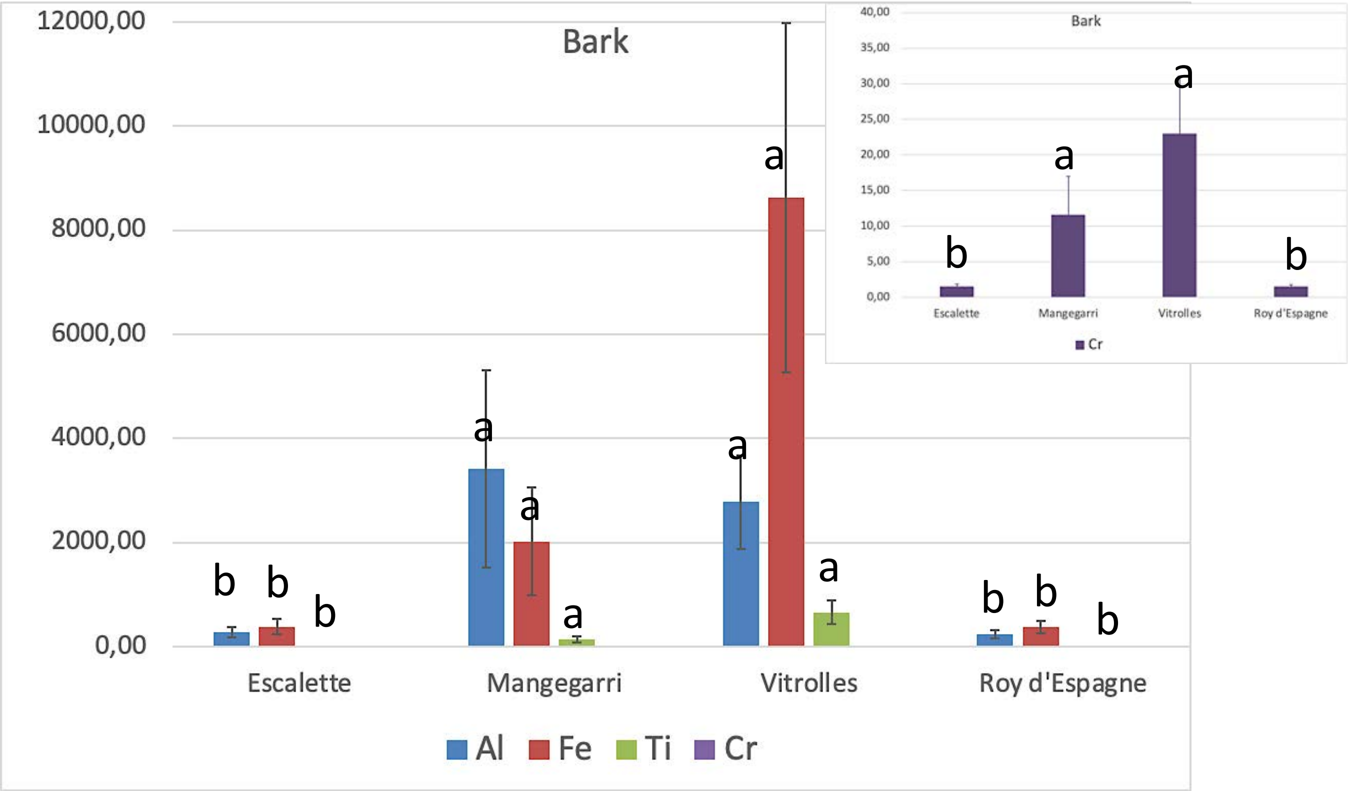
Al, **Fe**, and **Cr** significantly higher in Mangegarri and Vitrolles litters than Escalette and Roy d'Espagne litters
Ti signficantly higher in Vitrolles than Escalette and Roy d'Espagne litters

As in litter significantly higher in Vitrolles and Escalette than in Mangegarri and Roy d'Espagne
Pb in litter significantly higher in Escalette than Mangegarri and Roy d'Espagne

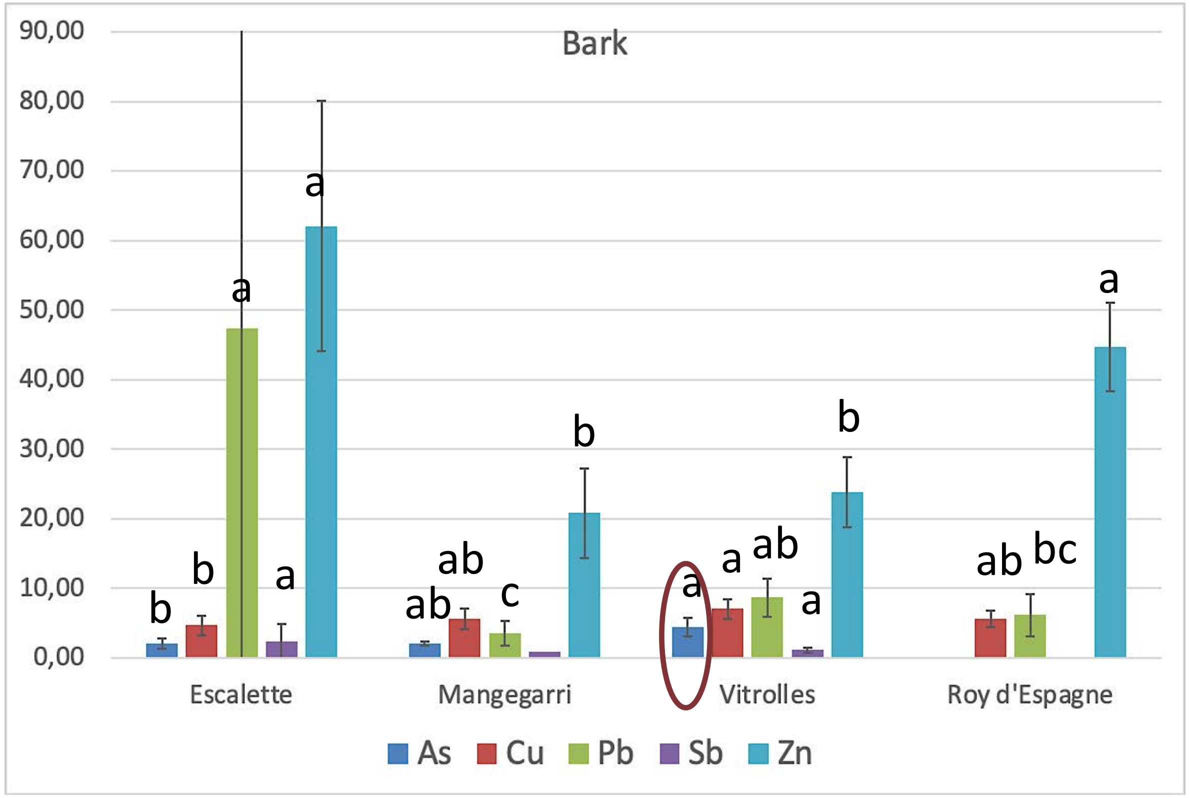


Bark

Element mg/kg



(Mean ± SD, n=10, Dunn test, p≤0.05)

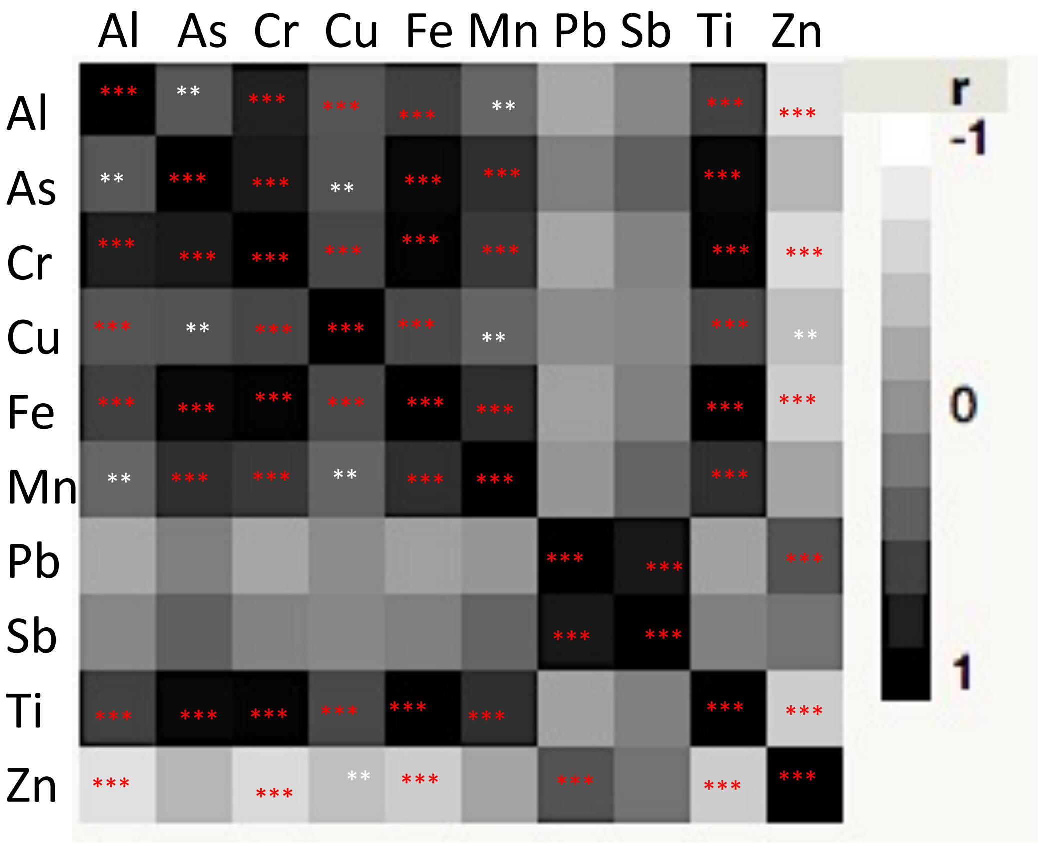


(Mean ± SD, n=10, Dunn test, p≤0.05)

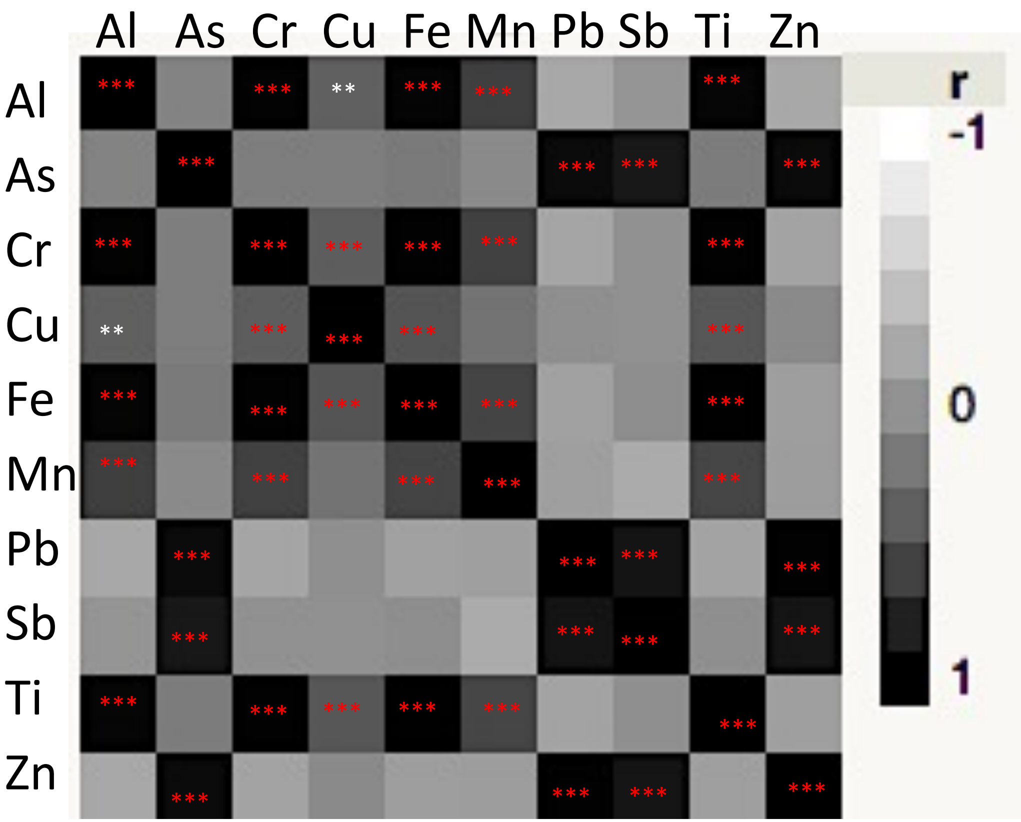
Al, **Fe**, **Ti** and **Cr** significantly higher in Mangegarri and Vitrolles barks than Escalette and Roy d’Espagne barks

As in bark significantly higher in Vitrolles than Escalette
Pb in bark significantly higher in Escalette than Mangegarri and Roy d’Espagne

Correlation between elements in **bark**



Correlation between elements in **needle litter**



*** ≤0.001
**≤0.05

No significant correlation detected between Pb and Sb or As with other elements except Pb/Zn in barks
High positive correlations between Ti, Fe, Al, Cr

High positive correlations between Pb, As, Sb, Zn
High positive correlations between Ti, Fe, Al, Cr, Mn

Linked to the type of particles

Linked to the industrial context

What did we expect?

Bark and litter are able to trap particles ☑

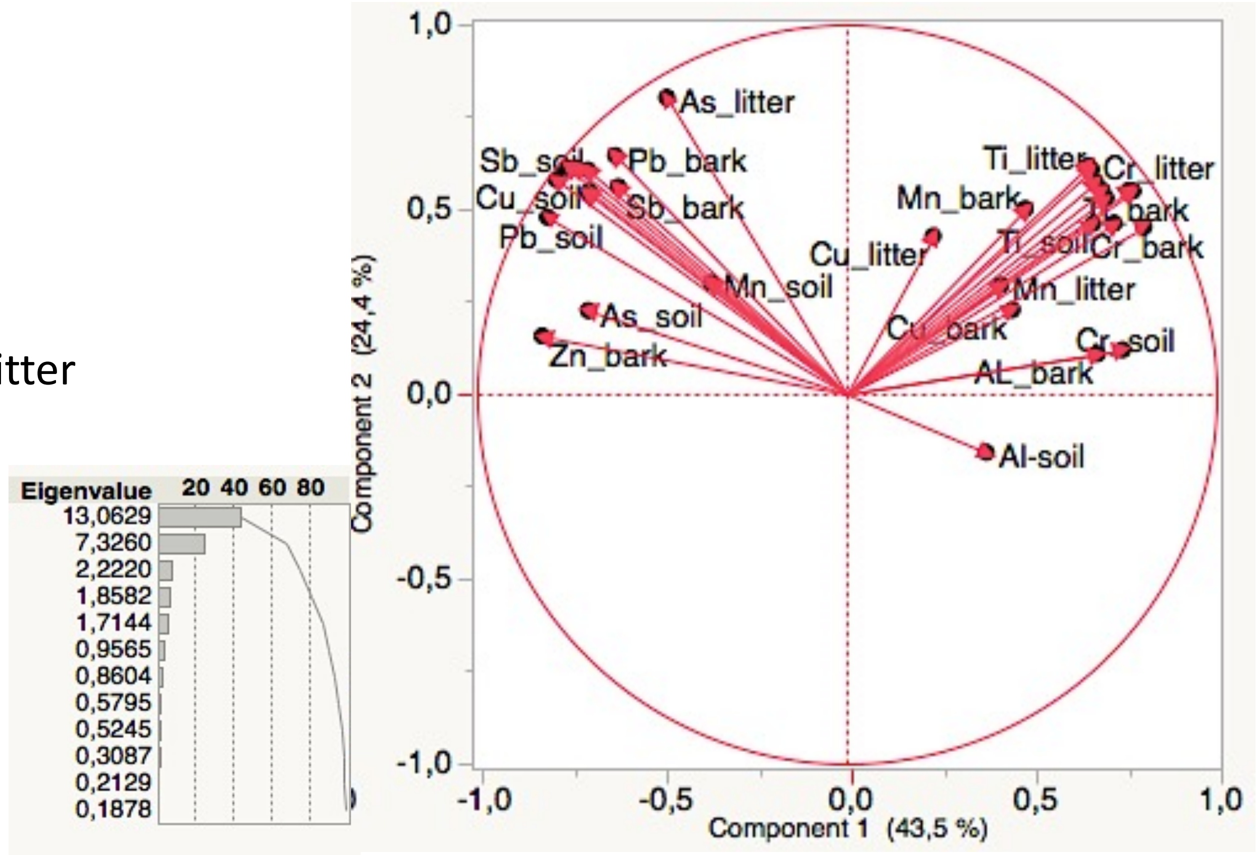
Bark and litter contents are linked to their soil environment ☑

For **Al,** no significant correlation between Al contents in soil and litter
But $R_{soil, bark}$= 0.52 ($p \leq 0.0001$)

For **Fe**, $r_{soil, litter}$= 0.67 and $r_{soil, bark}$= 0.84 ($p \leq 0.0001$)

For **Ti**, $r_{soil, litter}$= 0.72 and $r_{soil, bark}$= 0.77 ($p \leq 0.0001$)

For **Cr**, $r_{soil, litter}$= 0.45 and $r_{soil, bark}$= 0.62 ($p \leq 0.005$)



Principal component analysis

Different modes of aeolian transport depending on elements and size of particles?

For **As,** $r_{soil, litter}$= 0.49 and $r_{soil, bark}$= - 0.51 ($p \leq 0.05$)

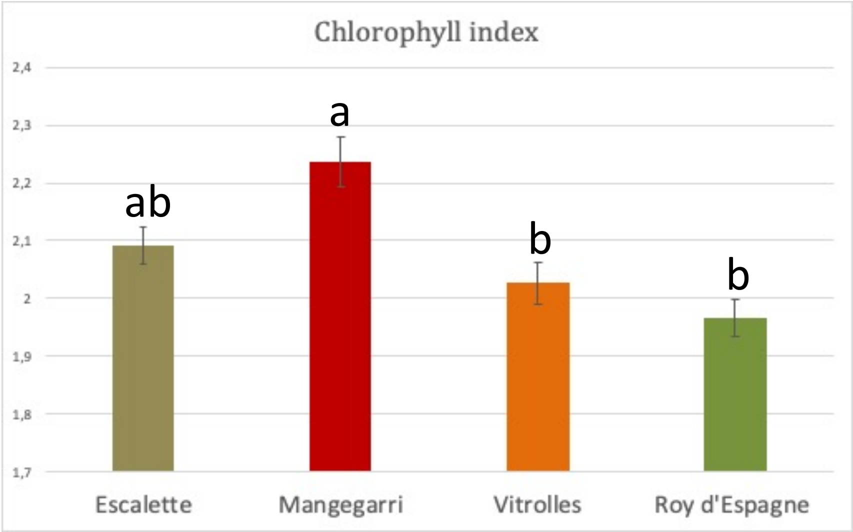
For **Pb**, $r_{soil, litter}$= 0.88 and $r_{soil, bark}$= 0.75 ($p \leq 0.0001$)

For **Sb**, $r_{soil, litter}$= 0.78 and $r_{soil, bark}$= 0.87 ($p \leq 0.0001$)

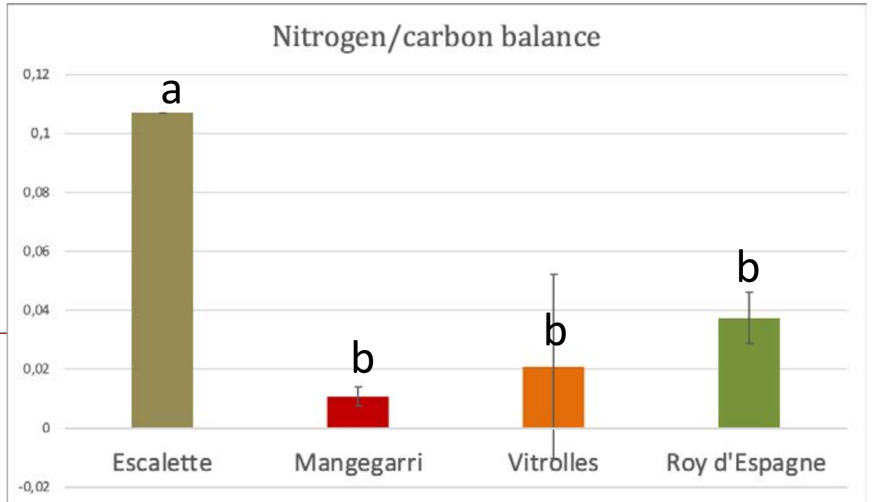
For **Zn**, $r_{soil, litter}$= 0.95 and $r_{soil, bark}$= 0.66 ($p \leq 0.0001$)

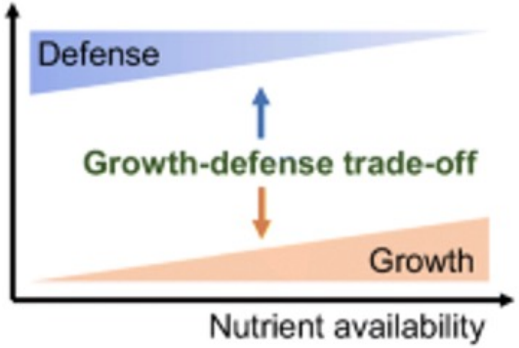
Green needles

Non-destructive analysis of plant primary and secondary compounds



(Mean ± SE, n=10, Dunn test, p≤0.05)



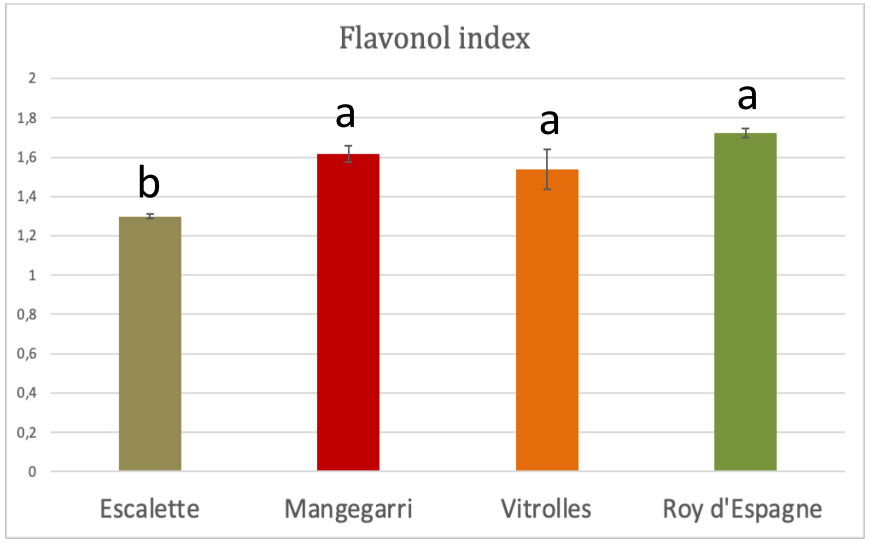


Our hypothesis:
exposure to metals and metalloids
↓ chlorophyll content for growth
↑ secondary compounds for defense

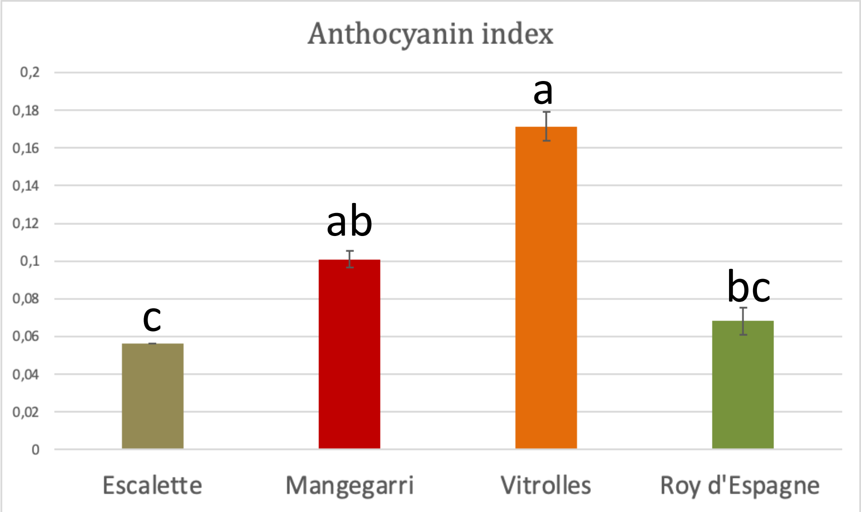
Not confirmed

physiological responses
or
optical responses?

Treated data to limit interference of TiO_2
But potential FeO_2 interaction that overestimates indices

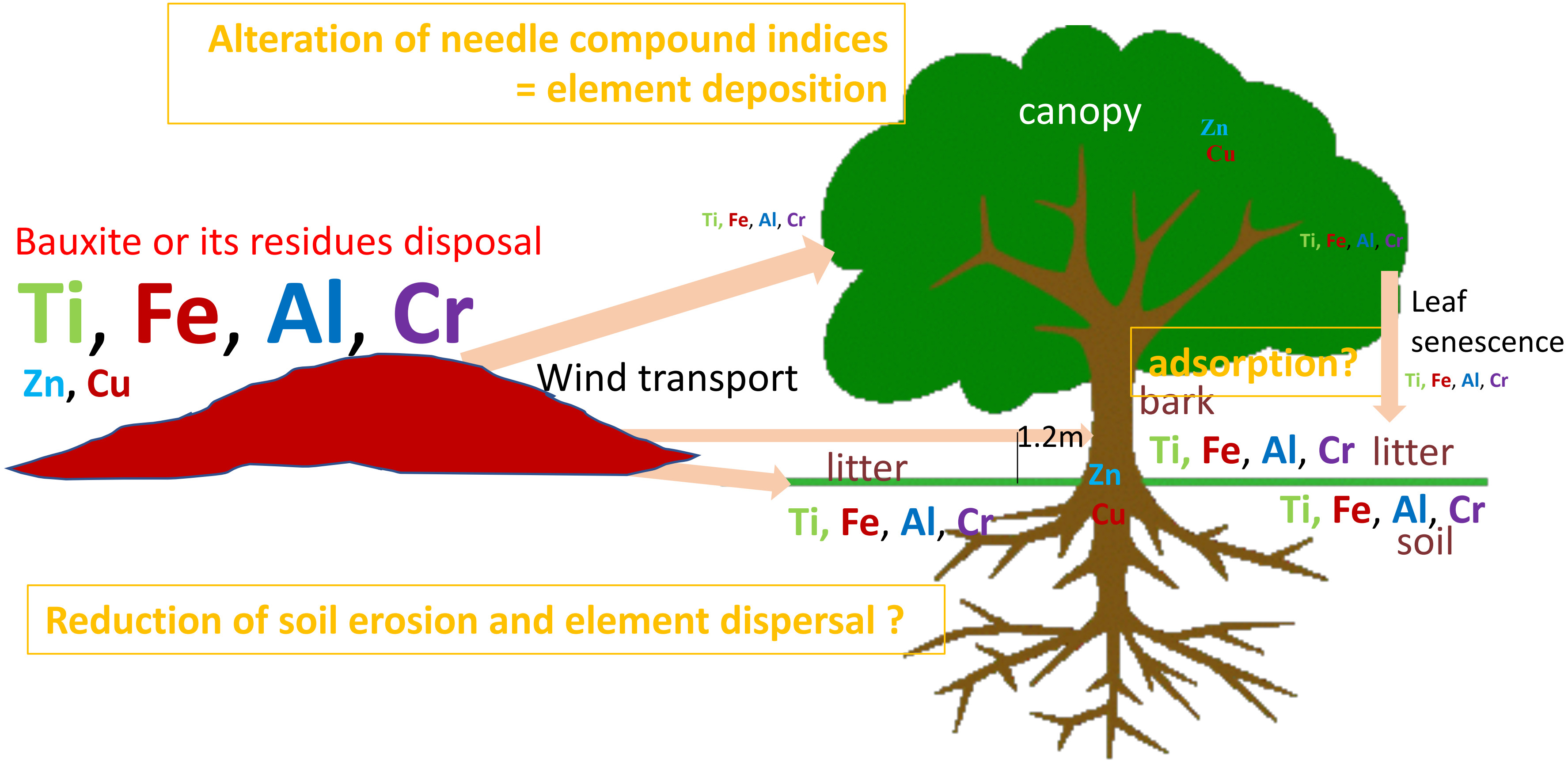


(Mean ± SE, n=10, Dunn test, p≤0.05)



Return to our conceptual model

Hypothesis in Mangegarri and Vitrolles



Green needles, bark, litter:
- trap particles
- retain Ti, Fe, Al, Cr

Modes of wind transport may differ between particles:
- no significant correlation between Al contents in soil and litter
- low positive correlations for other elements between soils and litters

Two ways of trapping in litters:
- needle senescence after particle exposure
- aeolian deposits on litter

A complex model

Potential role of Aleppo pine as vegetative barrier confirmed
but flammable species in an industrial context under Mediterranean climate raises questions

Many thanks to all contributors to this work, particularly our students, to OHM BMP for financial support, to ALTEO society, Vitrolles Town hall and CD13 for enabling access to the study sites, and to J. Viglione (Eco-Med) for his linking people's action