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Potential of Aleppo pine as a vegetative barrier to airborne metal and metalloid pollutants: diachronic and synchronic studies

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Keywords :

plant barrier, trace metals and metalloids, non-destructive methods, Aleppo pine

Project Goals and Objectives

Role of Aleppo pines as a barrier to the transfer of polluted particles (Fig 1) in the context of the past coal mining activity of Provence territory (Fig 2) :

- Measure the transferred elements from ground to litter and pine bark
- Health Indices of the green needles
- Obtaining a 3D model of the barrier formed by the pine trees on Mangegarri site

Summary

Trees can act as atmospheric filters, removing a large number of particles in suspension and thus improving air quality in polluted environments. Because of epicuticular wax of pine needle, pine bark crevices and increased cohesive properties of fine dust, particles accumulate during several years in these plant parts. What role play pine forests installed on Provence coal mining territory in trapping airborne particles, specially fine particles related to storage of bauxite and red mud residues? For security and stability of measurements, sites with low heavy truck movements were chosen (Fig 2): the bauxite backup storage of Mangegarri, Vitrolles Stadium site as a red mud repository which ceased operations in 1953. The reference site located next to the neighbourhood of Roy d'Espagne is a control site for low metal pollution.

Material and Methods:

Contamination of soil, pine litter (OLn horizon of the year) and bark, was evaluated non-destructively by mobile XRF (Niton XL3t GOLDD). We combined the XRF use in situ and ex situ and ICP-AES measurements after acid mineralization, ex situ to increase the sensitivity of the analysis after grouping individual, sieving the soil then drying, and grinding the soil and plant samples. The physiological state of the pines at the individual and population levels was estimated using a fluorescence and reflectance sensor Multiplex[®]5 (FORCE-A[®], Orsay) on green needles, comparing them with uncontaminated needles from reference site on the territory of the Calanques national park. To evaluate the use of the terrestrial laser scanner (LIDAR Optech ILRIS-3D) to estimate biomass and plant barrier porosity, a 3D model of the bauxite deposit of Mangegarri was performed. 3D models were built with Innovmetric's Polyworks and Cloudcompare Softwares.

Results

The most important detected elements related to industrial process are marked in green (Table 1). Aluminium is more concentrated on the ore storage site of Mangegarri. Iron remaining in the residue after extraction of aluminium are more concentrated in the red mud of Vitrolles. The difference is not significant for Titanium in storage sites. Other traces elements are present on three sites. The only noteworthy point is the lack of detection of an essential nutrient for plants: potassium in deposits of Vitrolles, the most rain-leached area of the sites.

The concentrations of Al, Fe, Cr and Ti measured in bark and litter go in ascending order of the Roy d'Espagne to Mangegarri and Vitrolles (Fig 3). This is explained by the fineness of red mud from Vitrolles (Fig 8) compared to ore Mangegarri and soil of the Roy d'Espagne that promotes their flight and their adsorption and possibly their penetration into the plant parts.

Element accumulation factors in bark and litters as % compared to the ground surface, are presented on Fig 4. Results can be grouped into airlifted elements (Al, Fe, Ti) and absorbed by roots (Cu, Zn, Mn, Cr).

Significant differences of fluorescence and reflectance indices are measured for the 3 sites but control with a light soil dusting shows the optical effects of deposits only (Fig 6). Titanium oxide has the property of re-emitting light as in the case of the fluorescence pigments of the plant tissues. Moreover iron oxide reflected red light which disturbs the measurement of anthocyanins and chlorophyll.

LIDAR applications on the site of Mangegarri may:
 1) Conduct to an inventory of Mangegarri by a 3D model (Fig 7)
 2) Calculation of volume and mass of wood and foliage from the heights and circumferences, obtained from literature references equations after slaughtering trees. Example presented: 12-14 kg of leaf, area of 8-9 m²/year
 3) Measurement accuracy on small objects has shown that it is possible, according to Steinvall et al. (2004), to estimate the relative tree occlusion by placing several identical targets at increasing depths from the edge of the wood during the LIDAR measurements.

CONCLUSION

- Pine litter and bark are good traps for the red mud particles
- Differences in the physiological state of the pines are minimal or can be explained by optical artifacts caused by TiO₂ and FeO₂.
- LIDAR scanning can be used for biomass estimates and relative occlusion
- practical conclusions = Pines cover should be preserved for its role of proved barrier, or alternatives plant barriers and mulching must be found

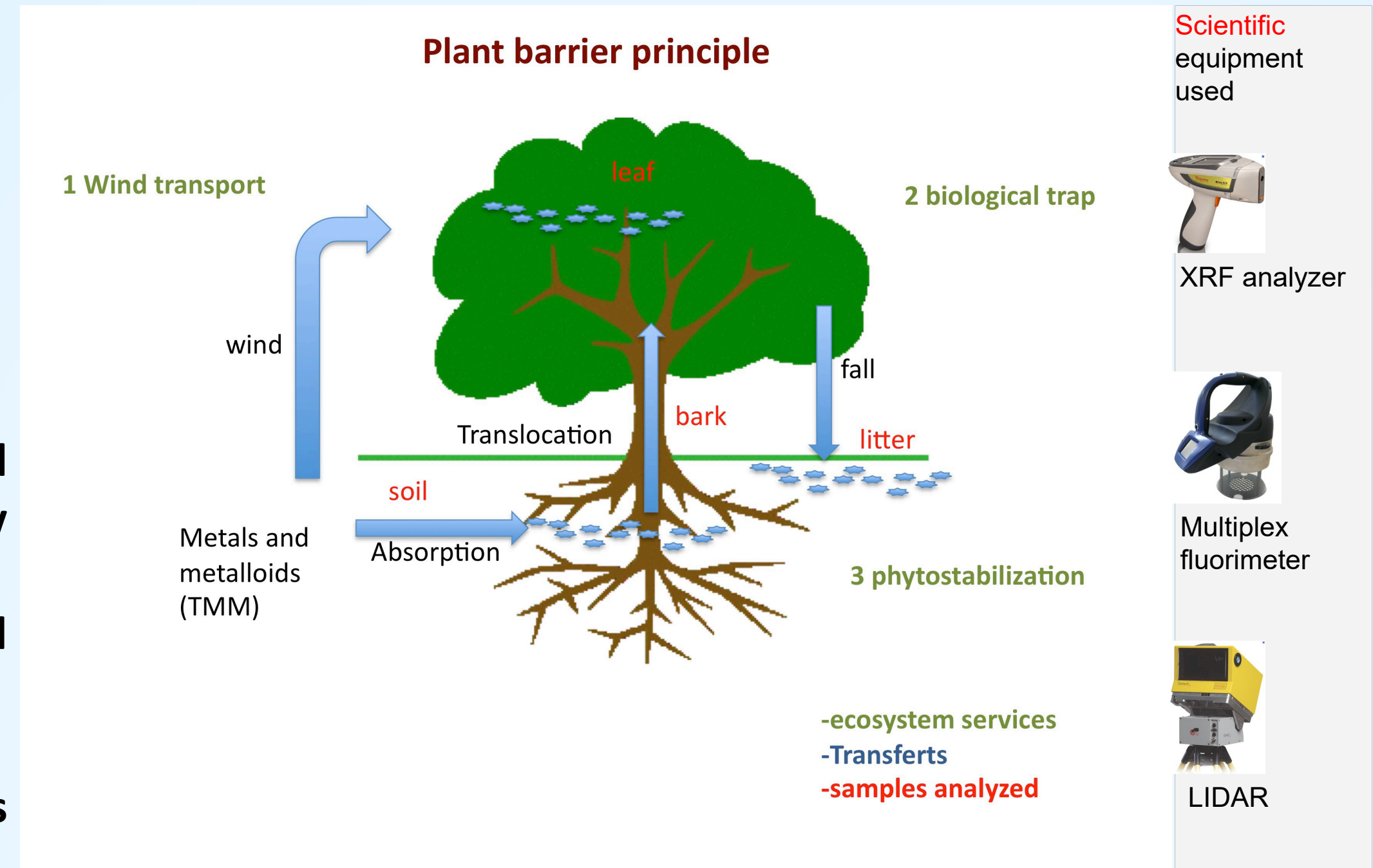


Fig 1: Plant barrier principle and techniques used

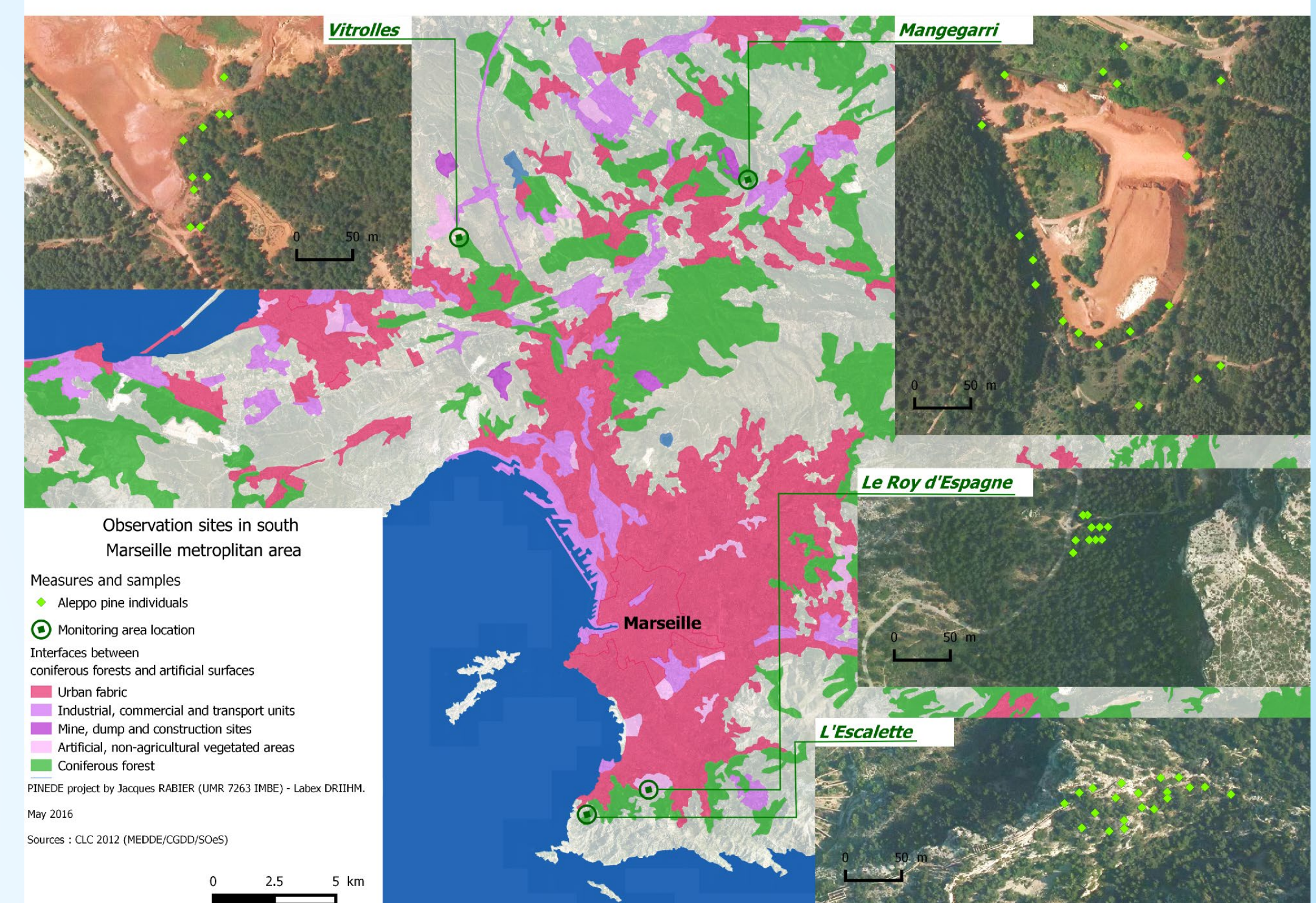


Fig 2: Location of the pine sampled in the study sites (green dots)

Table 1: Soil elemental analysis: average concentration in mg/kg±SD in dry weight, different letters mean significant difference (n=10, p<0.05, Wilcoxon test) and technique used.

Site	Mangegarri	Roy d'Espagne	Stadium Vitrolles	Analysis
Fe	51450±14100b	62520±25420b	127000±21000a	XRF
Ca	139000±33000a	37000±17000b	73000±24000b	XRF
Al	73500±1500	9600±700	32800±1300	ICP-AES
Na	ongoing analysis	ongoing analysis	ongoing analysis	GF-AAS
Ti	14439±3492a	6659±2999b	20685±3787a	XRF
Zr	530±100a	400±170a	720±110a	XRF
Cr	112±62a	236±100a	364±117a	XRF
V	96±67a	221±107a	359±148a	XRF
Mn	199±56a	148±67a	324±59a	XRF
Zn	48±10b	159±44a	187±80a	XRF
Sr	110±20ab	67±14b	150±20a	XRF
Pb	50±15a	186±90a	81±13a	XRF
Nb	34±6b	23±8b	59±8a	XRF
As	20±6b	63±18a	49±8b	XRF
Cu	4±5b	136±136a	32±9a	XRF
W	UDL	107±88a	19±14a	XRF
Mo	4±1b	10±2a	7±1ab	XRF
Rb	13±4a	11±3a	6±1a	XRF
K	13000±500b	3200±2100a	UDL	XRF

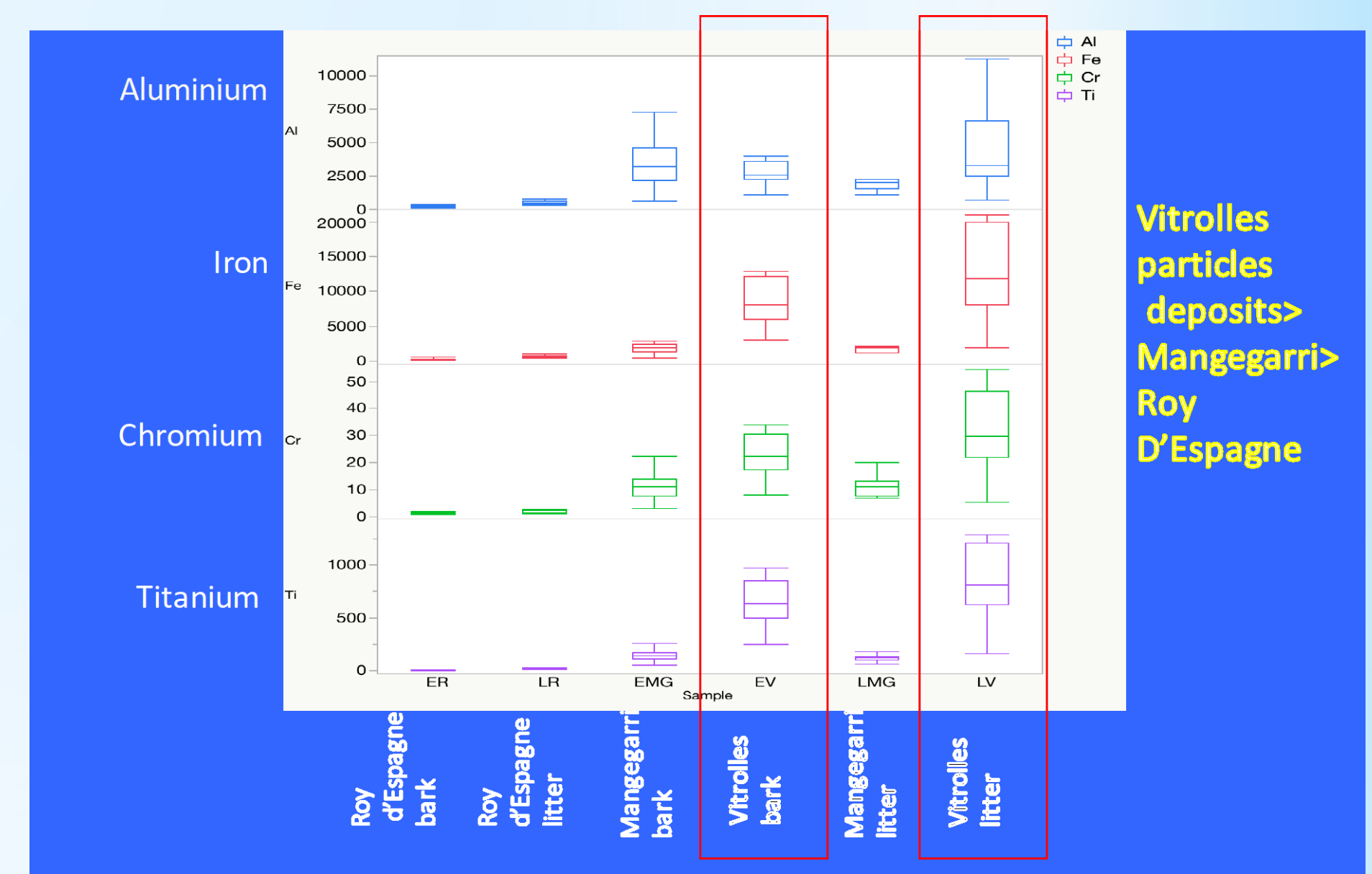


Fig 3: Composition of the main metallic elements in litter and bark of different sites (mg/kg dry weight, ICP-AES)

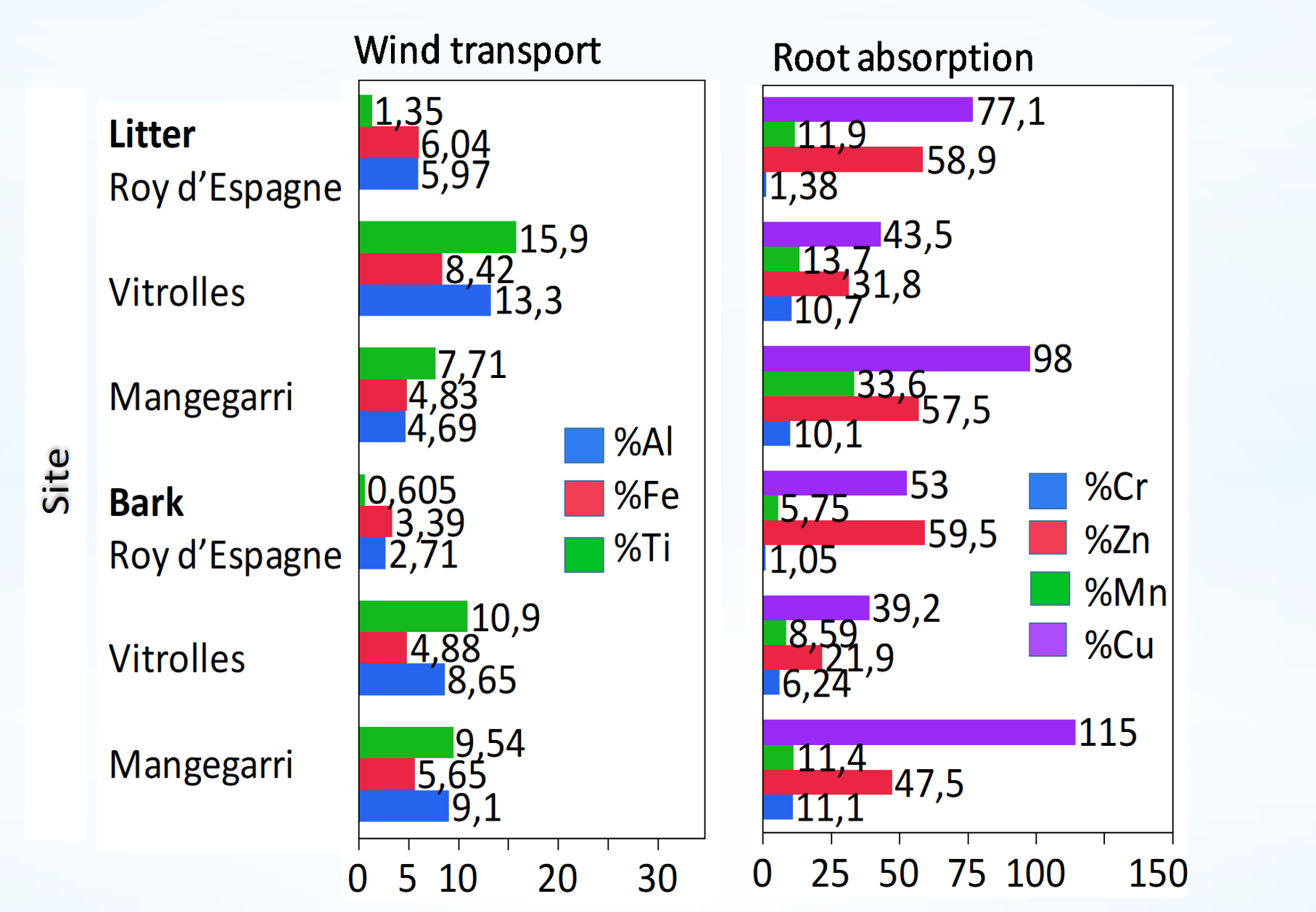


Fig 4: Accumulation factors of elements in % in the bark and litter compared with the surface soil

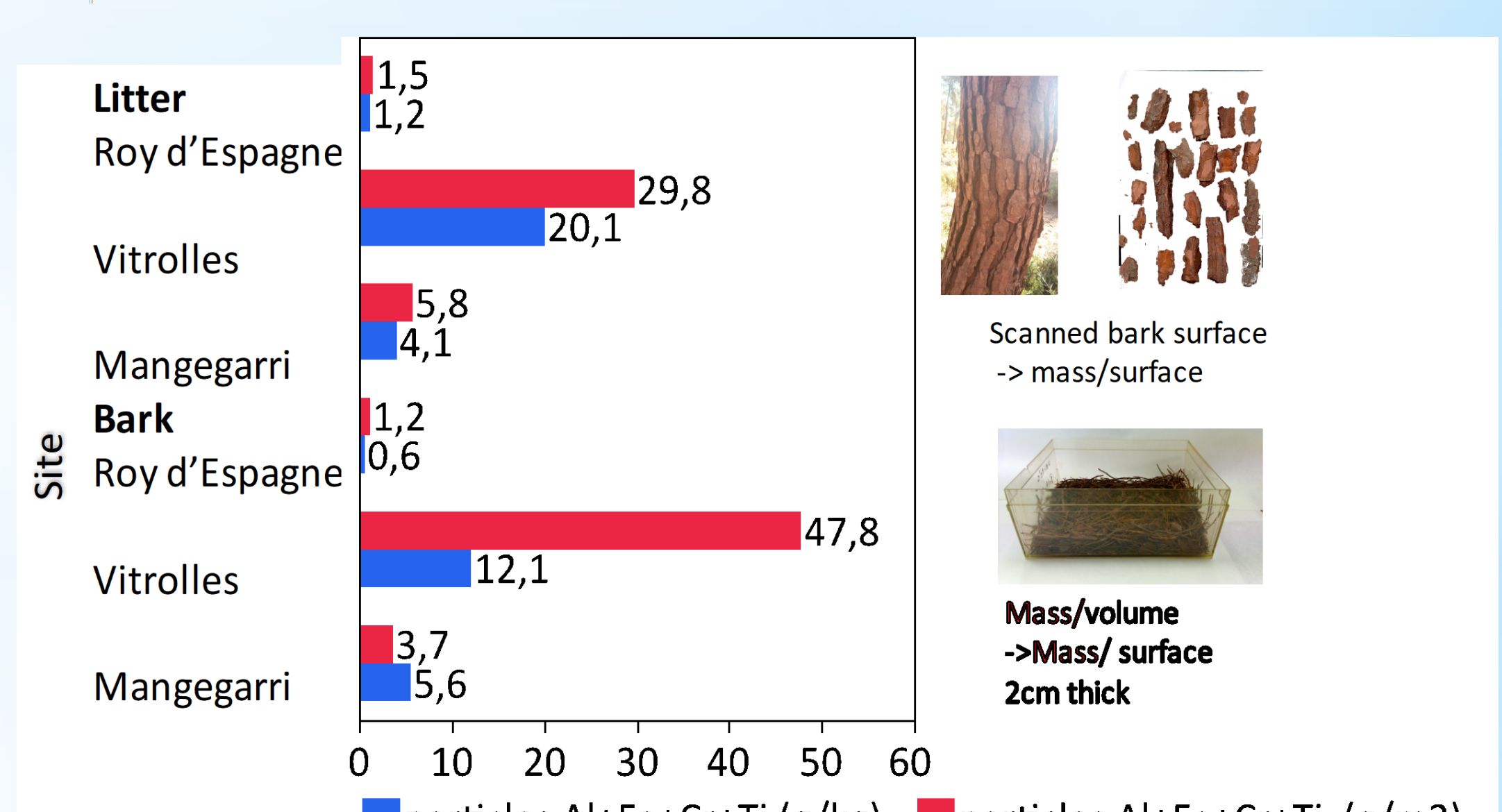


Fig 5: Total mass estimate of the 4 metal atmospheric particles incorporated in the litter and bark (g/m² and kg)

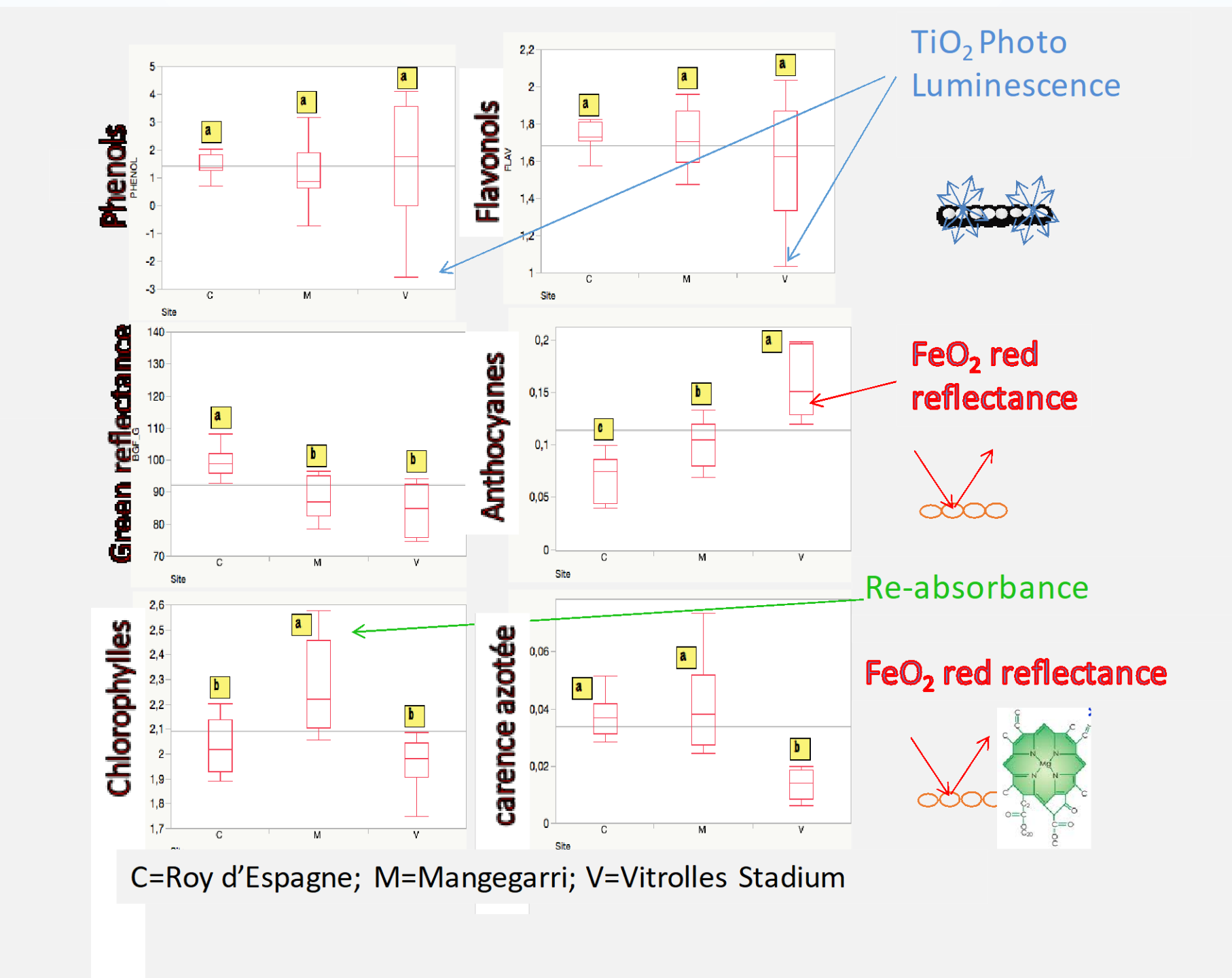


Fig 6: Comparison of the mean physiological indices of 10 pines for the 3 sites



Fig 7: LIDAR applications on the site of Mangegarri



Fig 8: View of the « Stadium Vitrolles » brownfield (with no viable responsible party) after the fire of 10/08/2016