Bioremediation (*in broad sense*): the use of biological resources for remediate contaminated soils

Massimo Fagnano (fagnano@unina.it)

Limits:

Contaminant concentrations are too high for allowing the survival of plants and microbia

Contaminated soil layer is too deep to be reached by roots or microbia

Sanitary risks are too high for waiting the time required by bio-, phyto-remediation

According to the Italian legal definitions the bioremediation techniques for recovering degraded soils are aimed to:

a) **Environmental restoration:** transforming landfills in parks

b) **Securing:** avoiding contaminant movements

Concrete Platform

Dense meadow

c) Remediation (to reduce risks below the thresholds): biodegrading organic contaminants, extracting PTEs and reducing PTE mobility and bioavailability.

Dig and dumping

Poplar and Brassica juncea for phytoexctraction of bioavailable Cd

Poliannual crops allow to achieve all these objectives, also providing other ecosystem services

PROVISIONING S.: biomasses for energy or bioplastic

REGULATING S.: climate (C sequestration in soils), water (groundwater protections), erosion, biodiversity

CULTURAL S.: educational, recreational,

In this context, we defined and validated at pilot scale an assisted phytoremediation protocol based on biomass crops fertilized with compost from MSW

Agriculture, Ecosystems and Environment 141 (2011) 100–107

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

Environmental and agronomic impact of fertilization with composted organic fraction from municipal solid waste: A case study in the region of Naples, Italy

Massimo Fagnano[a,*], Paola Adamo[b], Mariavittoria Zampella[b], Nunzio Fiorentino[a]

[a] Dipartimento di Ingegneria agraria e Agronomia, Università di Napoli Federico II, Via Università 100, 80055 Portici, Italy
[b] Dipartimento di Scienze del Suolo, della Pianta, dell'Ambiente e delle Produzioni Animali, Università di Napoli Federico II, Via Università 100, 80055 Portici, Italy

ARTICLE INFO

Article history:
Received 7 September 2010
Received in revised form 8 February 2011
Accepted 11 February 2011
Available online 5 March 2011

Key words:
Compost fertilization
Municipal solid waste
Heavy metal
Nitrate
Lettuce yield

ABSTRACT

In large urban agglomerations, composting of organic waste is a possible solution to the long-s rubbish problem, limiting the amount of waste going to final disposal. Fertilization with composte from Naples city was studied with the aim to evaluate the possibility of recycling waste thr agricultural use after composting. The best agronomic (soil fertility, quantity and quality of lettu and environmental (C storage in stable SOM, low risk of potentially toxic metal and nitrate po results were obtained using the 30 Mg ha^{-1} dose of compost. In compost and soil, total concen of Cu, Cr, Pb and Zn were always below European pollutant limits. However, after plant gro compost fertilization at the highest dose (60 Mg ha^{-1}), the amounts of EDTA-extractable Pb and Z significantly increased, suggesting a role of composted organics and root exudates in metal bioava Fertilization with composted waste could have positive agronomic and environmental effects if t are balanced against the N requirements of crops. However, further researches are needed to as long-term effect of repeated compost application to soil and the potential cumulative effects.

Compost fertilization increases:

- PTEs uptake (as it increases bioavailability and plant growth)
- Organic contaminant biodegradation

Italian Journal of Agronomy 2013; volume 8:e29

pagepress

Assisted phytoextraction of heavy metals: compost and *Trichoderma* effects on giant reed (*Arundo donax* L.) uptake and soil N-cycle microflora

Nunzio Fiorentino, Massimo Fagnano, Paola Adamo, Adriana Impagliazzo, Mauro Mori, Olimpia Pepe, Valeria Ventorino, Astolfo Zoina

Dipartimento di Agraria, Università di Napoli Federico II, Portici (NA), Italy

Abstract

Little information is available as to the real effectiveness of the phytoextraction remediation technique, since laboratory experiments are still the most common way in which this is measured. Given this, an experiment on a cadmium-polluted soil was carried out in open field conditions in Southern Italy with the aim of assessing the growth and the phytoextraction potential of giant reed (*Arundo donax* L). Compost fertilisation and *Trichoderma harzianum* A6 inoculations were used to verify the possibility of increasing the metal uptake of the crop. Biomass yield of giant reed in the first growth season (average 12.8 Mg ha^{-1}) was not affected by the Cd concentration in the soil and this increased significantly with compost fertilisation (13.8 Mg ha^{-1}). Both compost fertilisation and *T. harzianum* inoculation increased cadmium uptake and translocation in leaves. Nitrifying bacteria was shown to be a useful tool to biomonitor soil quality. These results proved the suitability of the giant reed for assisted-phytoremedation with the use of compost fertilisation and *T. harzianum*.

industrialised areas is well documented (Glass, 1998; Black, 1999) and represents an important environmental concern due to their potential accumulation in the food chain. Human activities such as industrial plants, mining, road transport and the unwise application of sewage sludges, fertilisers and pesticides to agricultural soils are recognised to be the main sources of PTE pollution (do Nascimento *et al.*, 2006; Lado *et al.*, 2008). A large number of methods are available to remediate soils, such as soil washing with synthetic surfactants. However, these are extremely expensive, such that a large number of sites remain contaminated (Ensley, 2000). Moreover, *ex situ* soil reclamation techniques lead to a big reduction in soil fertility due to the soil disturbance and to the toxicity of synthetic surfactants. Soil washing with humic substances extracted from composted organic matter or from geochemical deposits represents a reliable alternative (Conte *et al.*, 2005) and phytoextraction is a valuable complementary technique. It is low cost and environmentally safe (Wu *et al.*, 2006) and is able to both remove heavy metal pollutants from the soil and to offer important economic and agronomic advantages (Mattina *et al.*, 2003). It involves the utilisation of plants to remove heavy metals from soil and concentrate them in the biomass. For years now, metal hyperaccumulating plants such as *Alyssum murale, Berkheya coddii, Brassica juncea* and *Thlaspi caerulescens* have been considered the most suitable tool

Among the different species, we consider giant reed particularly interesting because it:

Bioenerg. Res. (2015) 8:415–422
DOI 10.1007/s12155-014-9532-7

Agronomic and Environmental Impacts of Giant Reed (*Arundo donax* L.): Results from a Long-Term Field Experiment in Hilly Areas Subject to Soil Erosion

M. Fagnano · A. Impagliazzo · M. Mori · N. Fiorentino

1) completely covers the soil (also with crop residues),
2) completely cancels soil erosion (and dispersion of soil particles),
3) increases C storage into the soil, thus improving soil fertility,
4) produces high biomass yield with low inputs (no irrigation, low N doses)

Dense poplar stands are also interesting since they:

- uptake great amount of PTEs and accumulate them in roots and wood
- reduce ground wind speed since reducing risk of resuspension of soil particles

N.B.: PTEs accumulated in leaves return in the soil but they are recirculated from the deep to top soil layers, thus protecting groundwater from leaching. The effects on PTE bioavailability must be better studied

Contaminated wood can be pyrolysed for concentrating and immobilizing PTEs in the char (and producing energy from syngas)

Waste Management 85 (2019) 232–241

Contents lists available at ScienceDirect

Waste Management

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

CHEMICAL ENGINEERING TRANSACTIONS

VOL. 58, 2017

Guest Editors: Remigio Berruto, Pietro Catania, Mariangela Vallone

ISBN 978-88-95608-52-5; **ISSN** 2283-9216

Steam assisted slow pyrolysis of contaminated biomasses: Effect of plant parts and process temperature on heavy metals fate

Corinna Maria Grottola [a,*], Paola Giudicianni [a], Stefania Pindozzi [b], Fernando Stanzione [a], Salvatore Faugno [b], Massimo Fagnano [b], Nunzio Fiorentino [b], Raffaele Ragucci [a]

[a] Istituto di Ricerche sulla Combustione – C.N.R., p. le V. Tecchio, 80, 80125 Naples, Italy
[b] Department of Agricultural Science, University of Naples Federico II, Via Università 100, 80055 Portici (NA), Italy

Effect of Feedstock and Temperature on the Distribution of Heavy Metals in Char from Slow Steam Pyrolysis of Contaminated Biomasses

Paola Giudicianni[a], Stefania Pindozzi*[b], Corinna Maria Grottola[a,c], Fernando Stanzione[a], Salvatore Faugno [b], Massimo Fagnano [b], Nunzio Fiorentino [b], Raffaele Ragucci[a]

Waste Management 61 (2017) 288–299

Contents lists available at ScienceDirect

Waste Management

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

Pyrolysis for exploitation of biomasses selected for soil phytoremediation: Characterization of gaseous and solid products

Paola Giudicianni [a], Stefania Pindozzi [b,*], Corinna Maria Grottola [a,c], Fernando Stanzione [a], Salvatore Faugno [b], Massimo Fagnano [b], Nunzio Fiorentino [b], Raffaele Ragucci [a]

[a] Istituto di Ricerche sulla Combustione – C.N.R., p.le V. Tecchio, 80, 80125 Naples, Italy
[b] Department of Agricultural Science, University of Naples Federico II, Via Università 100, 80055 Portici (NA), Italy
[c] DICMaPI, University of Naples Federico II, p.le V. Tecchio, 80, 80125 Naples, Italy

Wood can also be used in smelters as substitute of pet-coke

Dense meadows perform different functions:

- Avoiding contaminated soil resuspension and risk of inhalation or deposition in surrounding fields
- Reducing percolation and PTE leaching toward watertable
- Stimulating microbial metabolism thank to the rhizosphere effect

Mixing macrothermal species **(i.e. Cynodon dactylon, Paspalum vaginatum)** = salinity and drought resistant
and microthermal species **(i.e. Lolium perenne, Festuca rubra, Poa spp.)** = fast growth and cold resistant

allows to maintain a complete soil cover during all the year

NB. In low fertility soils a N-fixing species can be added (i.e. **Trifolium repens**)

The preliminary floristic survey of contaminated sites allows to:

- assess the risks for biological communities and ecosystems due to PTE pollution;
- evaluate the potential for phytoremediation of native species growing *in situ*.

pagepress

Italian Journal of Agronomy 2018; volume 13(s1)

Use of the native vascular flora for risk assessment and management of an industrial contaminated soil

Donato Visconti,[1] Nunzio Fiorentino,[1] Adriano Stinca,[2] Ida Di Mola,[1] Massimo Fagnano[1]

[1]Department of Agricultural Sciences, University of Naples Federico II, Portici (NA); [2]Department of Environmental, Biological and Pharmaceutical Sciences and Technologies, University of Campania Luigi Vanvitelli, Caserta, Italy

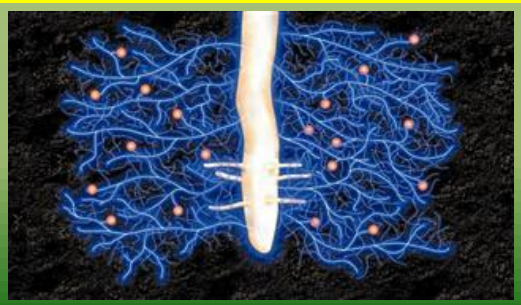
In press on Environmental Pollution

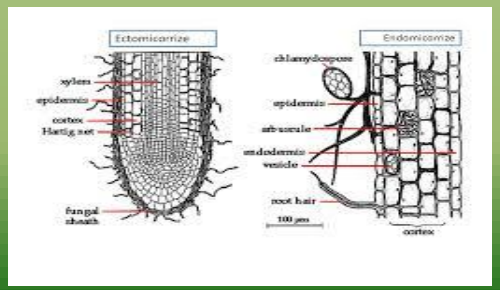
Analysis of native vegetation for detailed characterization of a soil contaminated by tannery waste

Donato Visconti, Nunzio Fiorentino, Antonio G. Caporale, Adriano Stinca, Paola Adamo, Riccardo Motti, Massimo Fagnano

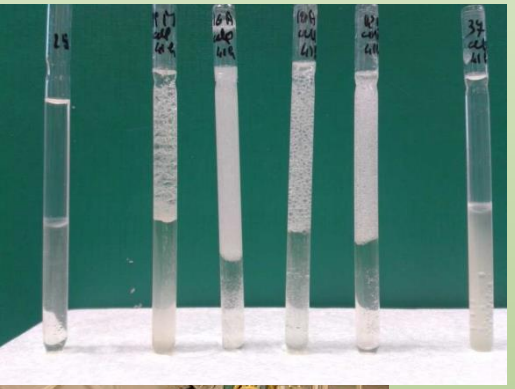
Bio-stimulants improve plant growth, uptake efficiency and tolerance to abiotic stresses

- Humic substances (compost, vermicompost)
- Hydrolysed proteins
- Seaweed extract
- PGPR, arbuscular mycorrhizae





We decided to make also bioremediation (in the strict sense) by using autochthonous microflora because it is already adapted to pedoclimatic and contamination conditions of the site



1) Extraction, selection and characterization of soil microbia for their bio-degradative activity and bio-surfactants production;

2) multiplication of the more interesting strains

3) inoculation in open field for accelerating biodegradation of organic pollutants (es. PAHs, Hydrocarbons C>12)

4) Organic fertilization with compost

5) Poliannual crops transplanting

6a) Rhizosphere effect
6b) Uptake of bioavailable PTEs

FUNCTIONS OF PERENNIAL VEGETATION FOR REMEDIATION AND RISK MANAGMENT

1) To *prevent access and irregular use* of contaminated soils, and thus the health risks, thanks to the presence of perennial and not-grazeable species (i.e. (i.e. eucalyptus, giant reed), eventually green-covered for preventing spread of contaminated dusts;

2) To improve rural landscape and soil fertility, protecting and *improving eco-systemic services of soil*;

3) To allow *analysis of risks for food chain* (i.e. uptake of contaminants by hyperaccumulating crops).

4) To strengthen metabolism of soil microbia (rhizosphere effect) helping them to *biodegrade organic pollutants*

5) To *extract the bioavailable fraction* of mineral contaminants, so reducing the consequent risks for consumer health

6) To represent a technology more *environmental friendly and much more inexpensive* than the physico-chemical remediation techniques (removal, capping, soil washing,….) that destroy soil fertility of soils making them unsuitable for agriculture (but ready for new urbanization).

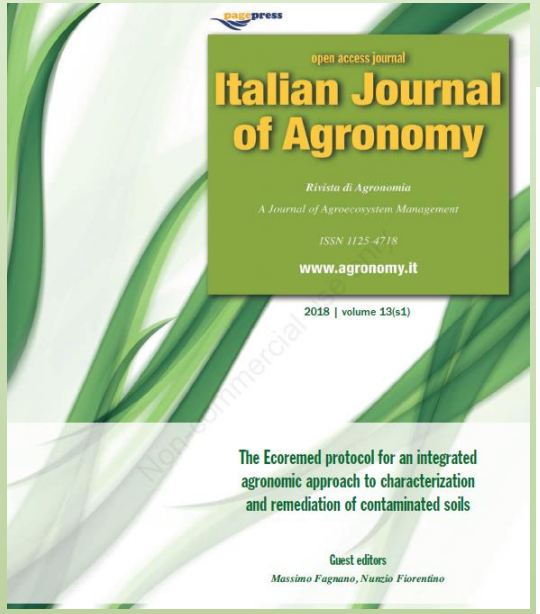


Table of Contents

All articles are also available at http://www.agroengineering.org

pagepress

Italian Journal of Agronomy 2019; volume 14:1176

Linking phytotechnologies to bioeconomy; varietal screening of high biomass and energy crops for phytoremediation of Cr and Cu contaminated soils

Filip Pošćić,[1-3] Guido Fellet,[1] Massimo Fagnano,[2] Nunzio Fiorentino,[2] Luca Marchiol[1]

[1]*DI4A - Department of Agriculture, Food, Environment and Animal Sciences, University of Udine, Italy;*
[2]*Department of Agricultural Sciences, University of Naples Federico II, Portici (NA), Italy;*
[3]*Institute for Adriatic Crops and Karst Reclamation, Split, Croatia*

www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

Comparative assessment of autochthonous bacterial and fungal communities and microbial biomarkers of polluted agricultural soils of the Terra dei Fuochi

Received: 5 March 2018
Accepted: 11 September 2018
Published online: 24 September 2018

Valeria Ventorino[1,5], Alberto Pascale[1], Paola Adamo[2], Claudia Rocco[2], Nunzio Fiorentino[3], Mauro Mori[3], Vincenza Faraco[4,5], Olimpia Pepe[1,5] & Massimo Fagnano[3]

More details about Ecoremed approach will be given:

Wednesday, 5th June (full day)			
9.45 - 10.30	Lecture 5	Valeria Ventorino, Olimpia Pepe	Microbial biodiversity of contaminated soils and identification of microbial bioindicators for the assessment of soil health: from cultural methods to Next Generation Sequencing
Thursday, 6th June (full day)			
12.45 - 13.30	Lecture 12	Nunzio Fiorentino	Use of vegetation for cleaning (phytoextraction) or securing (phytostabilization) contaminated sites: study cases in Southern Italy
14.45 - 17.30	Introduction to case studies and field excursion	Simona Vingiani, Nunzio Fiorentino, Diana Agrelli, Antonio G. Caporale, Valeria Ventorino	• Geo-pedological classification of study areas • Description of environmental surveys • Explanation of bioremediation strategy, aims and phases
17.30 - 18.30	Interaction time 2	Organizing Committee	Student feedbacks
Friday, 7th June (morning)			
8.00 - 14.30	Field excursion	Organizing Committee and Participants	Field excursion to polluted rural and industrial sites under bioremediation. The purpose of the trip will be to examine the pollution that had occurred on the sites, and discuss the remediation strategies being employed.

Thank you !

The Ecoremed methodologies are reported in the handbook downloadable from:

www.ecoremed.it

JUNE 6, 2019
Study cases in Campania region

a) agricultural areas
b) industrial areas

A) AGRICULTURAL SITES

Acerra countryside

A1. GIUGLIANO

Private site, with illegal dumping of wastes

Potentially contaminated by Cu and Zn, but values were < risk thresholds

Journal of Geochemical Exploration 170 (2016) 30-38

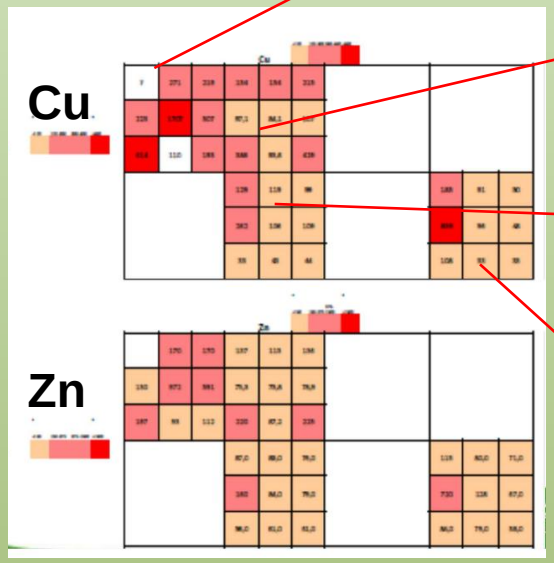
Contents lists available at ScienceDirect

Journal of Geochemical Exploration

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

Composite vs. discrete soil sampling in assessing soil pollution of agricultural sites affected by solid waste disposal

Claudia Rocco [a,b,*], Ida Duro [a], Salvatore Di Rosa [c], Massimo Fagnano [a,b], Nunzio Fiorentino [a,b], Angela Vetromile [c], Paola Adamo [a,b]



Cu

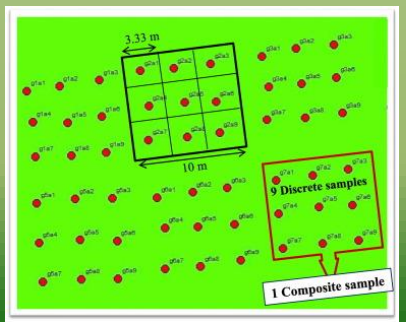
276	ND*	271	219
	223	1707	507
	614	110	193
152	154	154	215
	97.1	84.1	107
	386	93.6	429
114	129	119	99
	262	106	109
	33	43	44
67	185	91	50
	859	96	48
	108	53	33

Zn

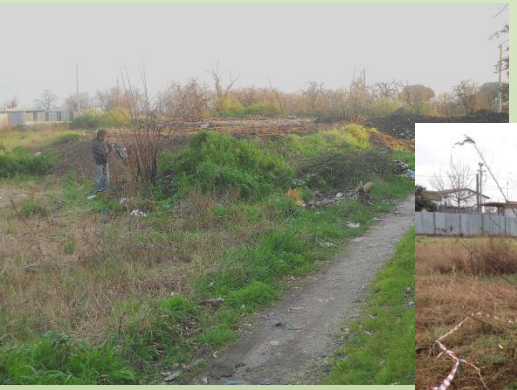
174	ND*	170	170
	130	972	591
	197	93	112
109	137	113	136
	73.5	75.8	79.0
	221	87.2	255
83	87	85	76
	160	84	79
	56	61	61
73	115	80	71
	720	128	67
	84	79	58

Sampling density (from 10x10m to 3x3m) influences (of course) quality of data.

let's imagine 100 x 100 m, as Italian law requires



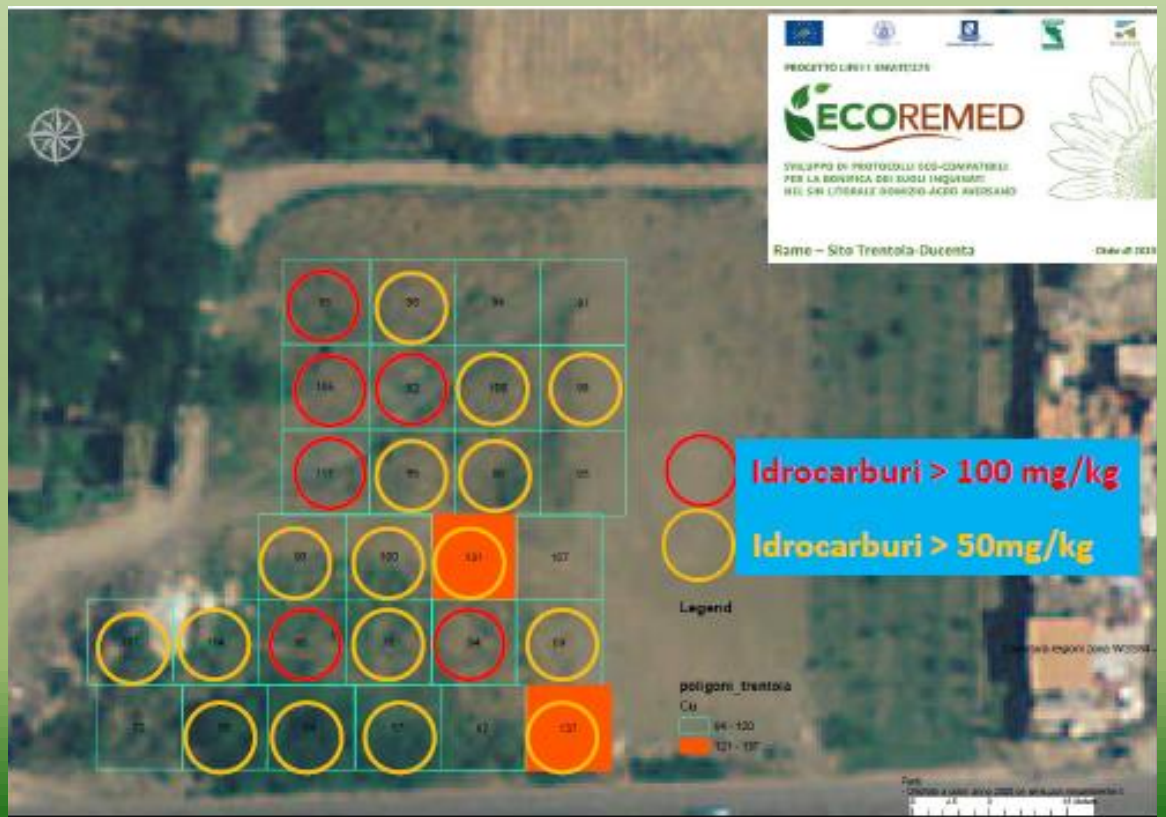
A2. Abandoned temporary landfill of Trentola-Ducenta Municipality



Widespread presence (22/28) of hydrocarbons C>12, but with moderate concentrations (max 186 mg/kg)

Punctual presence (2/28) of Cu and low values (max = 157 mg/kg)

Risk assessment= no direct or indirect risks for human health or environment



Soil degradation was due to a severe soil compaction that impeded regular water infiltration and plant growth

Science of the Total Environment 514 (2015) 298–306

Contents lists available at ScienceDirect

Science of the Total Environment

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

Photogrammetry for environmental monitoring: The use of drones and hydrological models for detection of soil contaminated by copper

Alessandra Capolupo [a], Stefania Pindozzi [a], Collins Okello [b], Nunzio Fiorentino [a], Lorenzo Boccia [a,*]

[a] University of Naples Federico II, Department of Agricultural Sciences, via Università 100, 80055 Portici Naples, NA, Italy
[b] Gulu University, Department of Biosystems Engineering, P.O. Box 166, Gulu, Uganda

Photogrammetry allowed to identify micro-basins in which the accumulation of copper is more probable (and where to concentrate soil samplings)

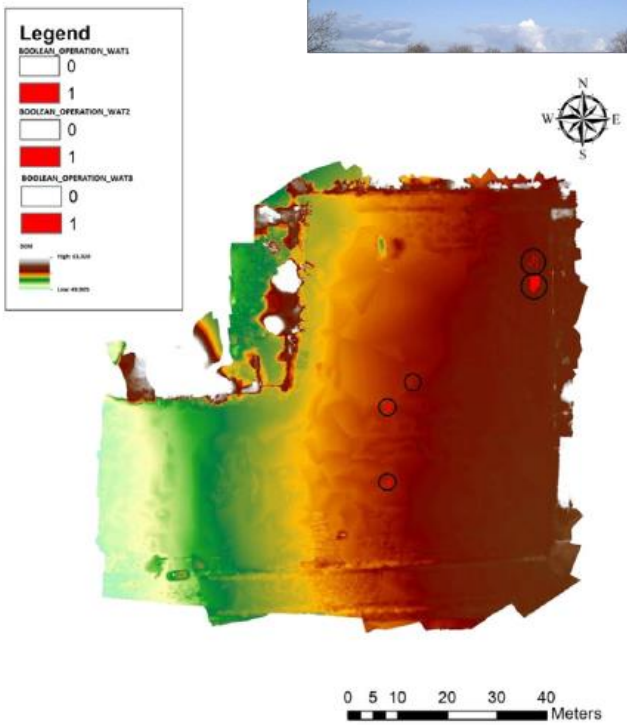
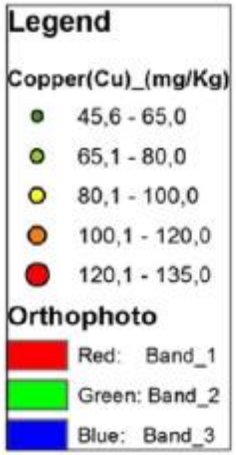


Fig. 11. Boolean And Operation between TI and interpolated copper concentration map.



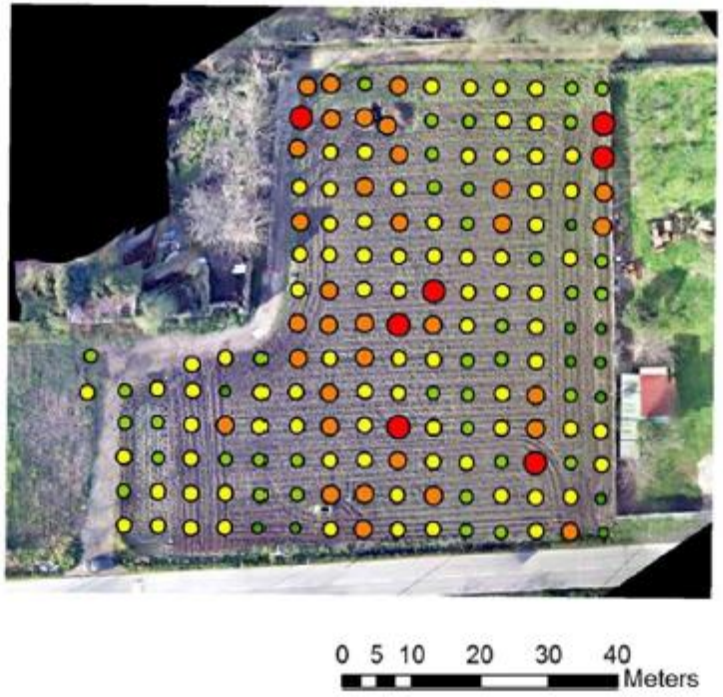
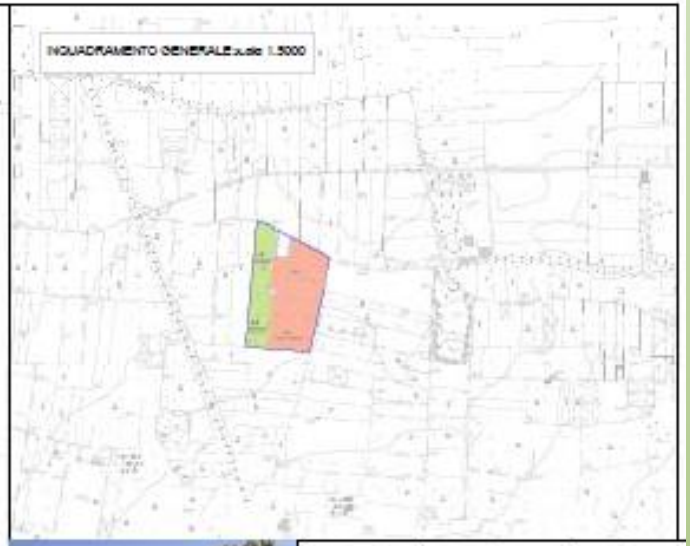
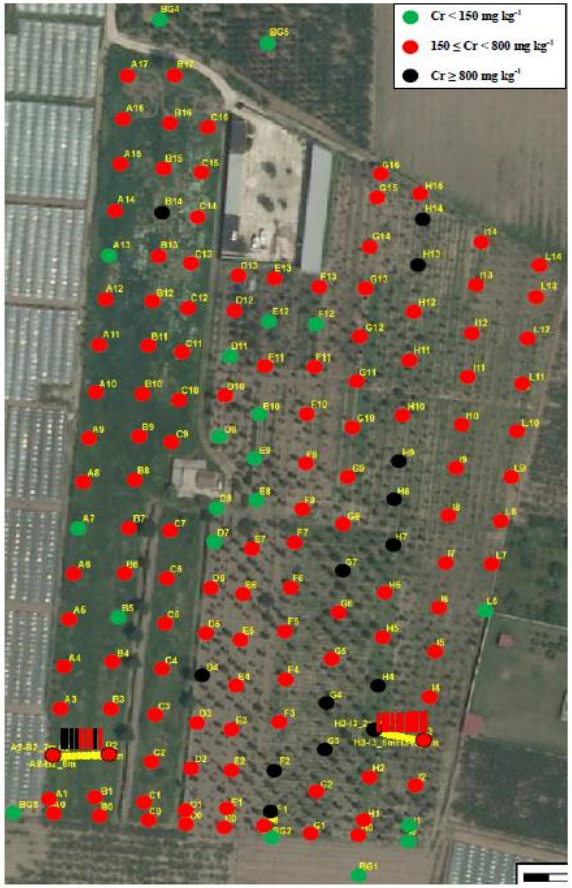


Fig. 3. Copper concentration classes (in mg/kg) over the obtained orthophoto map.

A3. Site confiscated to a criminal for illegal dumping of tannery sludge and hides coming from Toscana Region

Max values
Cr = 1705 mg/kg
Zn = 609 mg/kg





Contaminazione da cromo (Cr) nello **strato 0-20cm** dell'area di San Giuseppiello.

Range di conc.	N. camp.	% sul totale	Conc. media	Dev. std.
Cr < 150	15	8,8 %	116,7	28,1
150 ≤ Cr < 800	136	80,0 %	440,8	166,4
Cr ≥ 800	19	11,2 %	1110,9	357,9
Tot strato 0-20	170	100 %	487,1	305,8

150 = soglia di contaminazione da cromo totale per siti ad uso verde pubblico, privato e residenziale (D.Lgs. 152/06).
800 = soglia di contaminazione da cromo totale per siti ad uso commerciale e industriale (D.Lgs. 152/06).

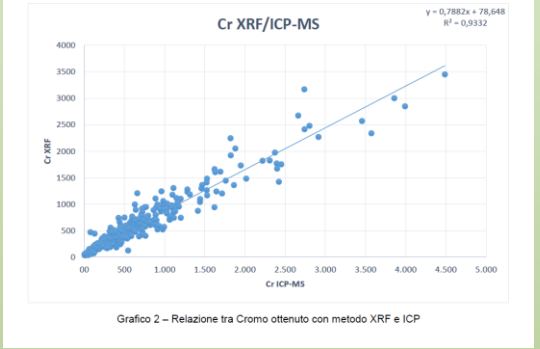


Grafico 2 – Relazione tra Cromo ottenuto con metodo XRF e ICP

Cor
Cro
Cromo &

Expeditious (and cheap) methods (i.e. XRF) can orient the following sampling scheme (i.e. soil samples in the red areas).

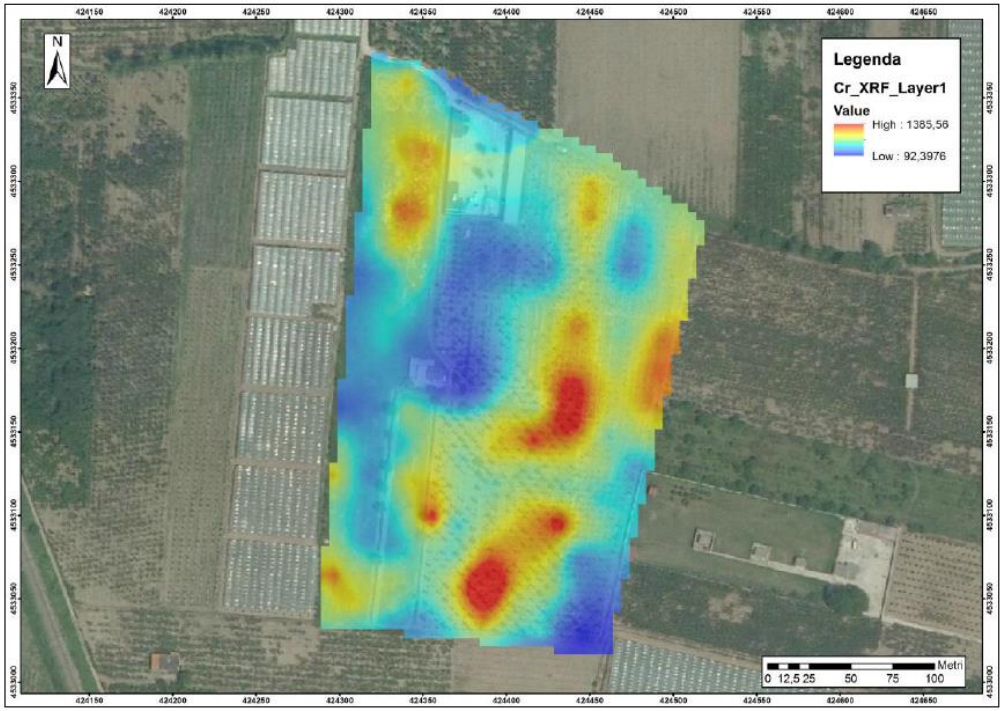


Figura 23- Mappa del Cromo ottenuto tramite misure XRF relativa al primo layer campionato (0-20 cm)

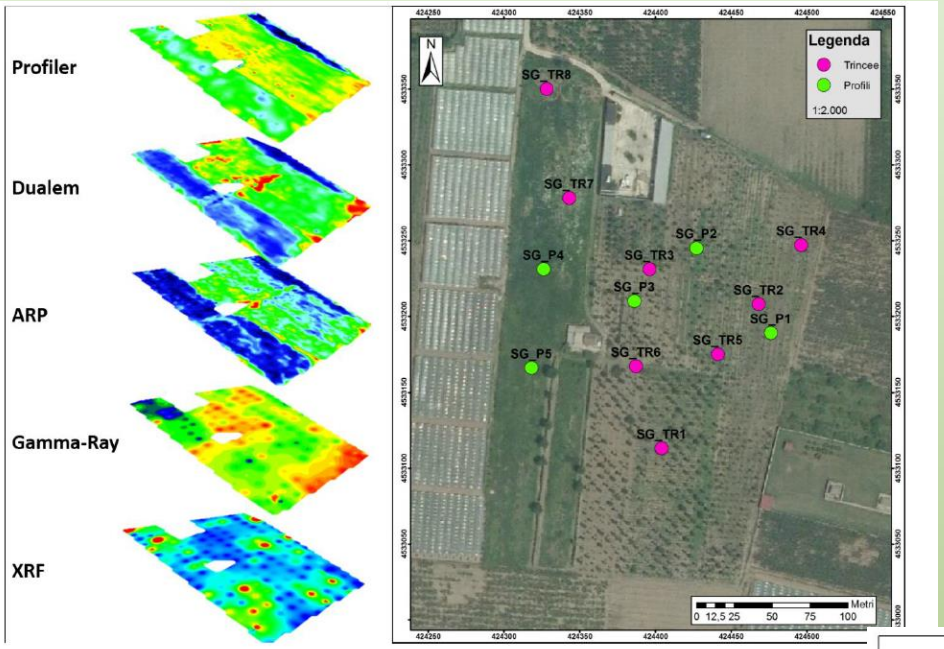


Figura 36 – Ubicazione profili e trincee

vedi cap. 5 manuale Ecoremed (Terribile et al.)

L'interpolazione di tutte le misure geofisiche ha consentito anche di identificare le anomalie da indagare con scavi di trincee e profili

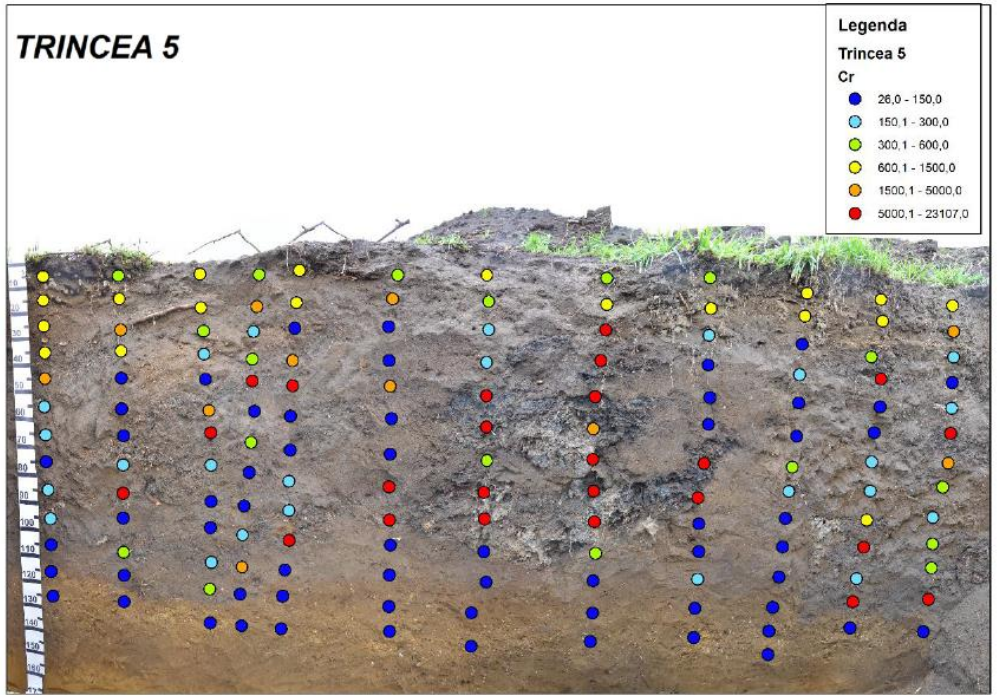
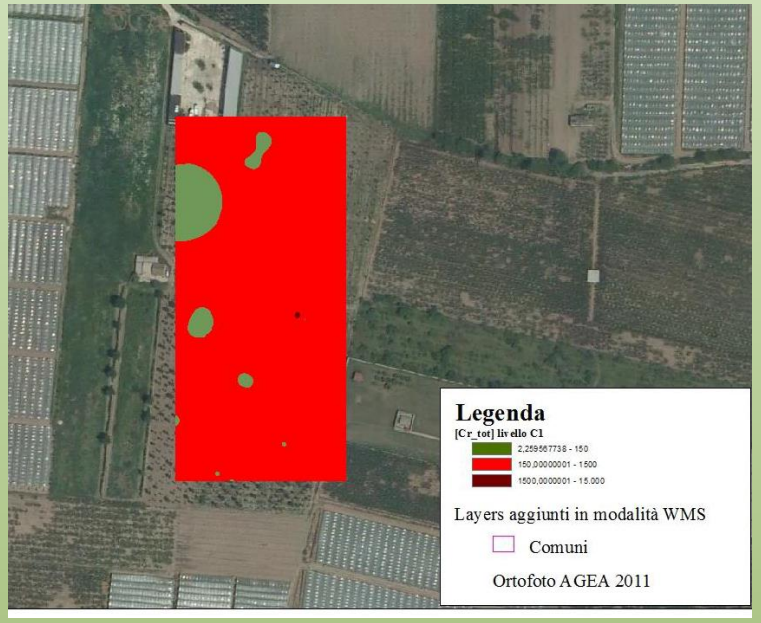


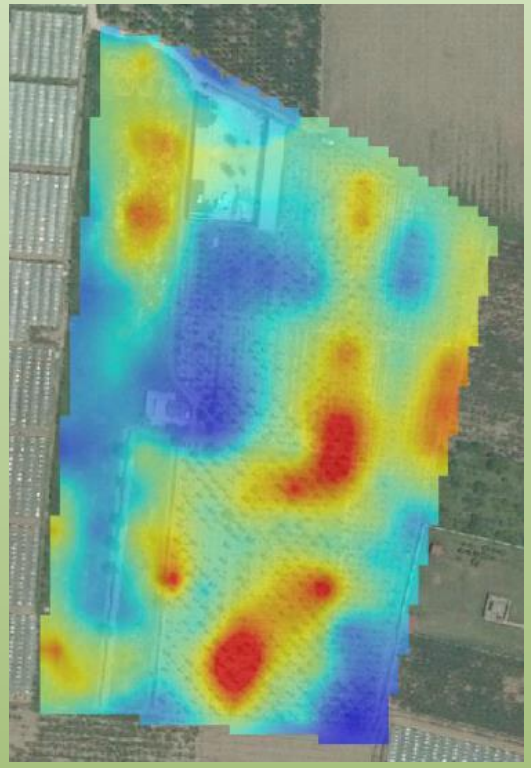
Figura 52 – Misure XRF su mosaico della Trincea 5

La caratterizzazione a «norma di legge*» indicava in 125.000 m^3 i volumi potenzialmente contaminati, con un valore massimo di 1700 ppm di Cr.



***11 punti di prelievo randomizzati; campioni medi compositi dello strato 0-1 m.**

La caratterizzazione «di precisione*» indica in 30,000 m^3 i volumi potenzialmente contaminati, con un valore massimo di 23,000 ppm di Cr.



***mappatura preliminare (XRF); campionamenti mirati (ICP-MS); campioni puntuali di strati di 20-30 cm.**

April 2016

July 2016

October 2016

Note the dense meadow that prevents dispersion of contaminated soil particles

The collection of soils from the hot spots with the highest PTE concentration and the cultivation of metallophyte crops (rocket salade, lettuce, chicory) allowed to exclude risks for consumers as regards Cr, Zn, Pb, As,

Only Cd (in an area of 3000 m2) was accumulated in such crops at levels potentially toxic for consumers

Phytoextraction of poplar was enhanced by consociation with the annual Brassica juncea (indian mustard): estimated reclamation time = 5 y

Furthermore, a site where criminals discharged wastes, becoming a symbol of land degradation and illegality……..

…has been transformed in an open-air laboratory where to carry out researches and to show to students and policy maker how it is possible to heal the wounded ecosystems

AGRICULTURAL SITES: CONCLUSIONS

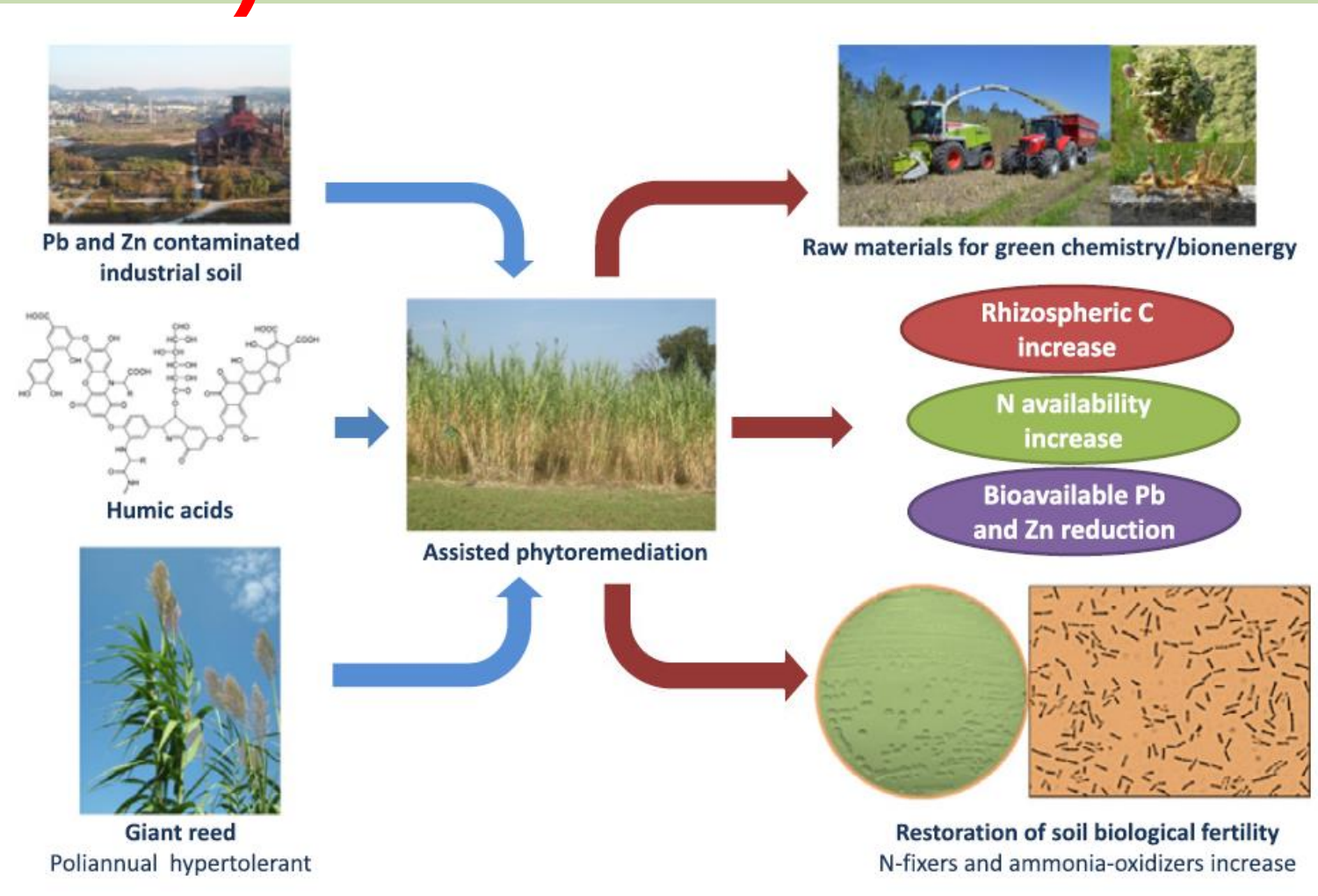
1- In most cases removal of wastes was sufficient for restoring cropland quality

2- Physical anomalies (i.e. compacted or unstructured soil) were the most spread threaths to soil fertility (solved with deep tillage and compost fertilization)

3- In no case we were able to find contaminated food or biomasses (also in the 30 ha classified as potentially contaminated)

2° phase: for finding contaminated biomasses and for studying problems related to their conversion in energy or biopolymers (aim nr. 3 of the project) we addressed our attention to:

B) INDUSTRIAL SITES



B1. Battery recycling plant heavily contaminated by Pb (3,5 ha)

Risk analysis identified a not tolerable risk linked to wind erosion (scattering of contaminated soil particles lifted by wind)
(Groundwater was protected by 6 wells as hydraulic barrier)

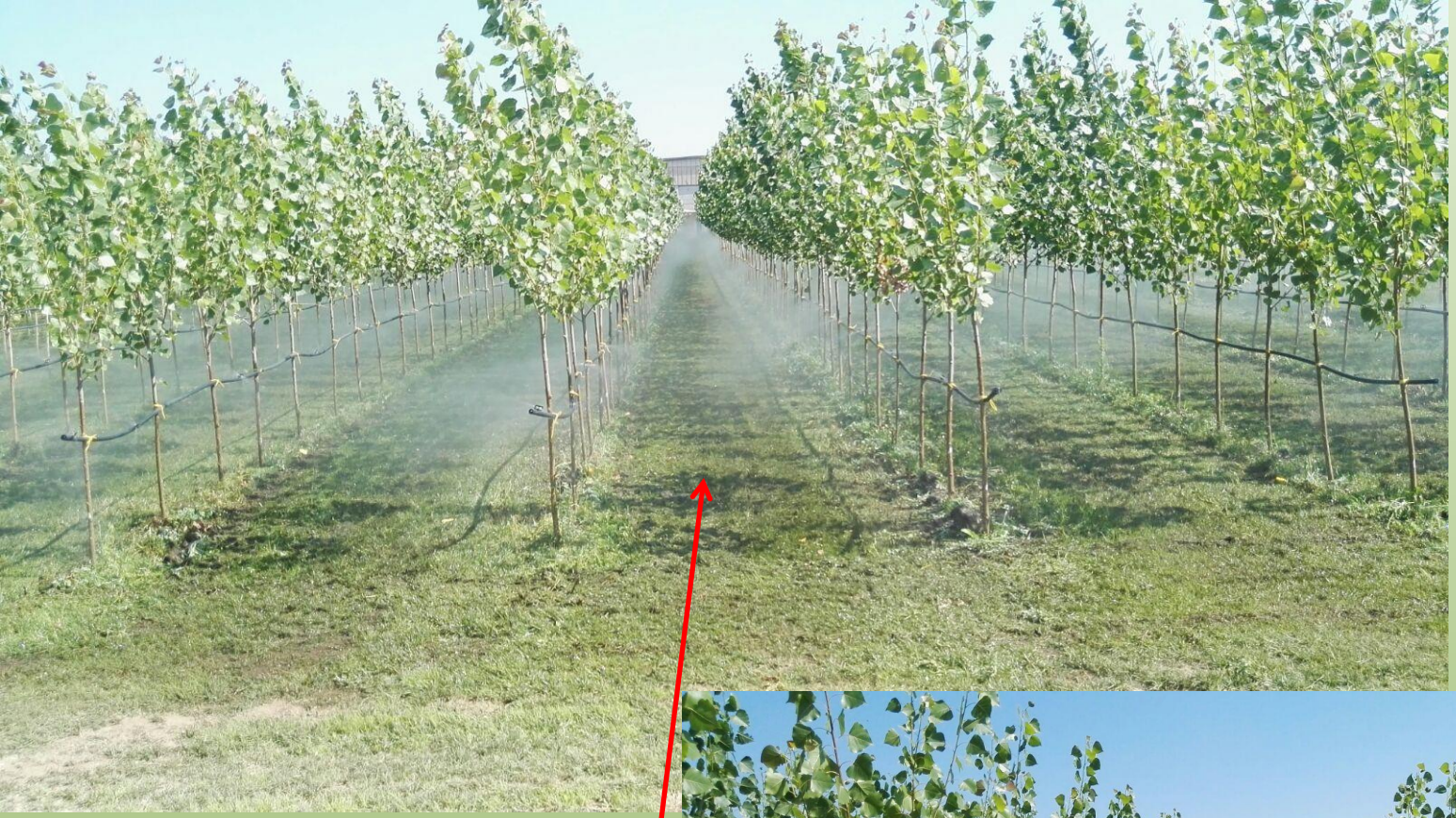
Soil detachment and lifting will be avoided by:
- improving soil aggregate stability (compost),
- permanent meadow with macro-thermal species (i.e. C.dactylon, P. vaginatum),
- poplar stand that reduces wind speed at ground.

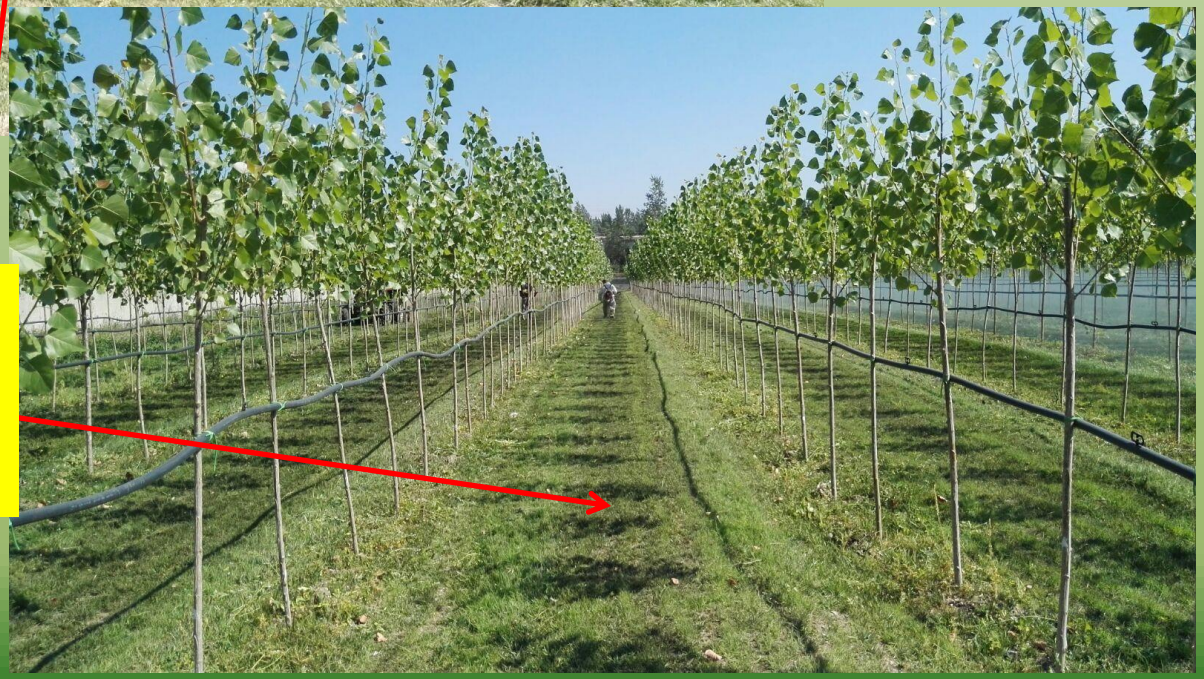
Wooden chips produced by poplar will be used in the smelters of the same plant as reducing agent in substitution of Petroleum-Coke

October 2015

April 2016

July 2016





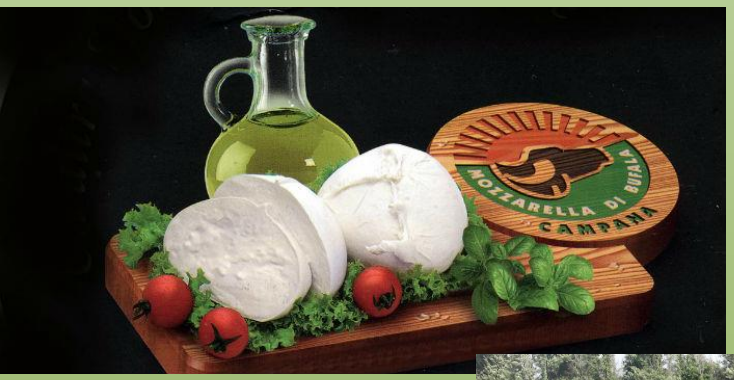
Note the dense meadow that in 3 months prevented dispersion of contaminated soil particles

September 2016

Conclusions

1. <u>Contaminated agricultural</u> soils in plain area of Campania region are too few (30 ha !!!) for satisfying the exigence of a bio-refinery (≈10.000 ha).

The so called “Terra dei Fuochi” produces high-value, healthy and safe vegetables and water buffalo mozzarella cheese, that are exported worldwide and thus, **there aren’t perspectives for biomass cultivation.**



Thank you !!!

Many dissemination materials are downloadable from the website www.ecoremed.it

Scientific publications can be requested to fagnano@unina.it