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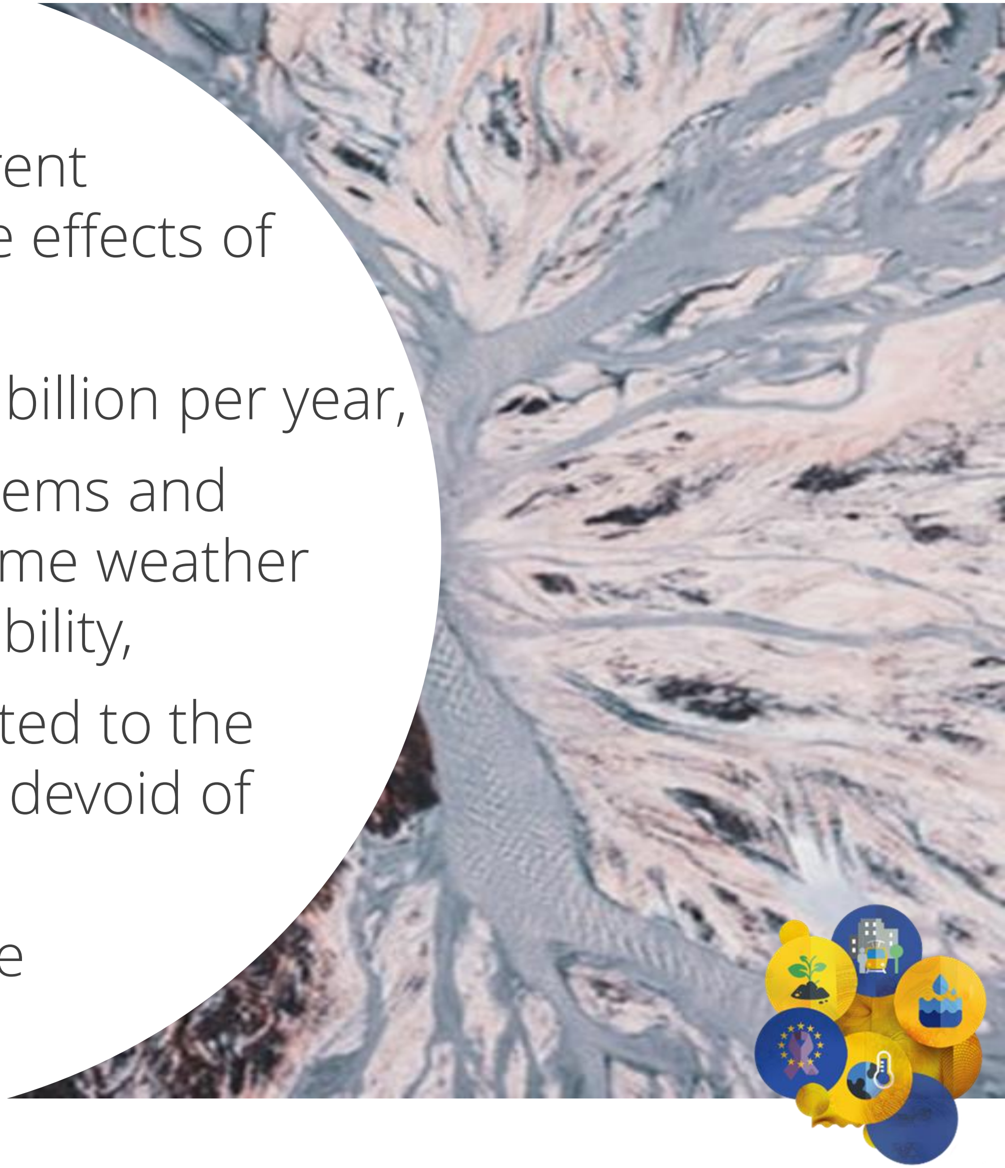
PHYTOREMEDIATION AS A SOLUTION FOR HEAVY METAL CONTAMINATED LAND - POLISH CASE STUDIES

Marta Pogrzeba, PhD, DSc, IETU
Associate profesor
Director of Institute for Ecology of Industrial Areas (IETU)

SOILS ARE UNDER THREAT ACROSS EUROPE AND WORLDWIDE

- 2.8 million potentially polluted sites,
- 60-70% of all soils in Europe are unhealthy due to current management practices, pollution, urbanization and the effects of climate change,
- the cost of soil degradation in the EU can exceed € 50 billion per year,
- soil degradation can lead to the destruction of ecosystems and landscapes, making societies more vulnerable to extreme weather events, threats to food security and even political instability,
- contaminated soils are a source of health hazards related to the secondary emission of wind-borne dust from surfaces devoid of vegetation,
- soluble forms of metals leach from the soil and migrate to surface and groundwater.



A SOIL DEAL FOR EUROPE
WHAT WE MUST ACHIEVE BY 2030

Reduce soil degradation, including desertification and salinisation:

- recover 50% of degraded land to achieve soil degradation neutrality.

Protect soil organic carbon stocks (e.g. forests, permanent pastures, and wetlands):

- increase organic carbon on cropland from 0.1 to 0.4% per year,
- reduce the area of peatlands losing carbon by 30% to 50%.

Reduce soil sealing and increase reuse of urban soils (the current urban soil reuse rate is to be increased from 13% to 50%).

www.kierunekenergetyka.pl/artykul,35306,problemy-skazenia-gleby-podczas-produkcji-energii-w-zawodowych-zakladach-energetycznych,0.html

HEAVY METAL CONCENTRATIONS IN TOPSOIL IN EUROPE

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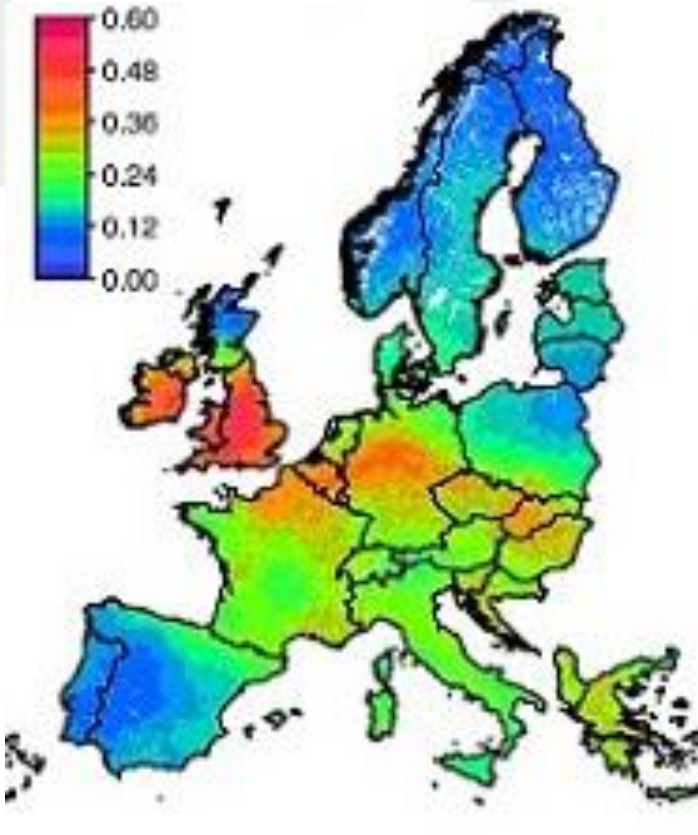
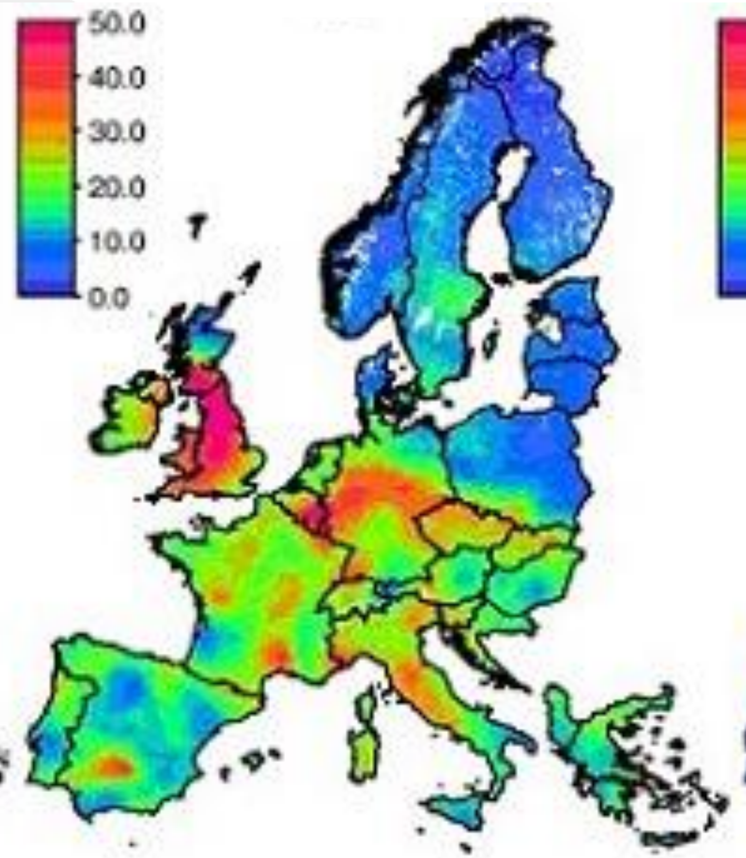
Maps of heavy metal concentrations in topsoil in Europe (mg kg^{-1}) interpolated using block regression-kriging (support size=5km)

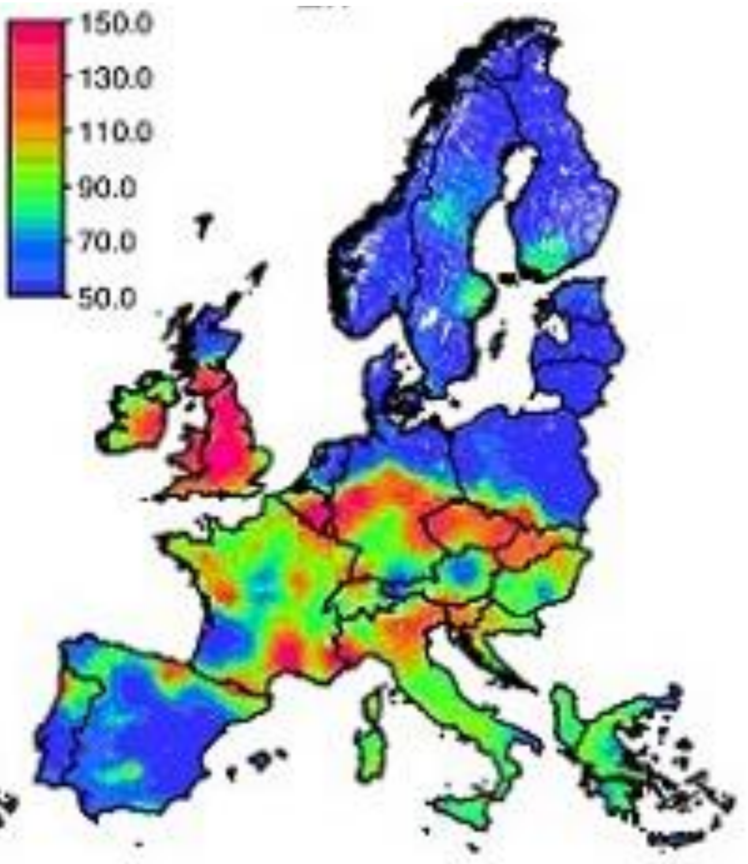
Cd



Pb



Zn



Lado L.R., Hengl T., Reuter H.I., (2008) : Heavy metals in European soils. A geostatistical analysis of FOREGS Geochemical database, Geoderma 148, 189–199.

MANAGEMENT OF DEGRADED AREAS

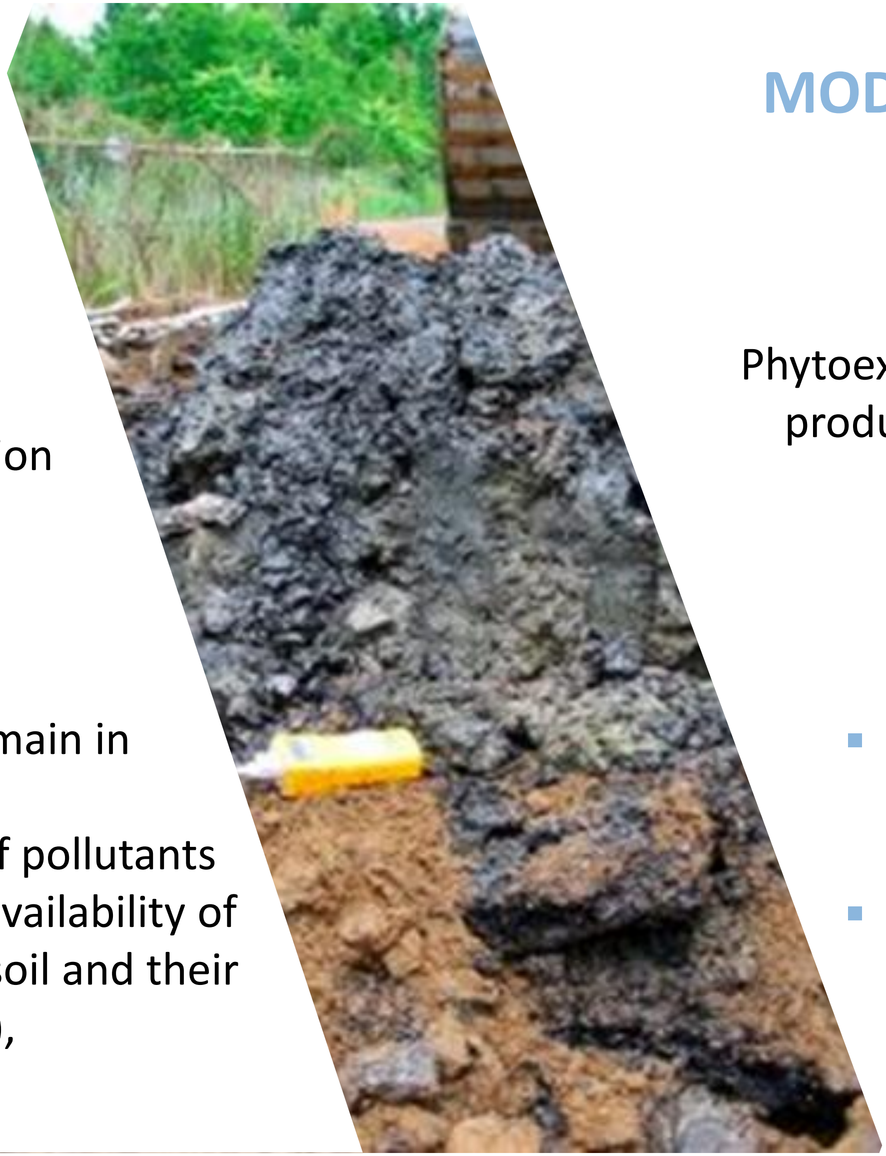
HEAVILY POLLUTED AREAS

Induced phytoextraction or assisted phytovolytilization

- clean soil,
- contaminated crop yield,
- the release of pollutants into the atmosphere,

Phytostabilization
or
Assisted phytostabilization

- contaminants remain in the soil,
- immobilization of pollutants (limiting the bioavailability of elements in the soil and their uptake by plants),

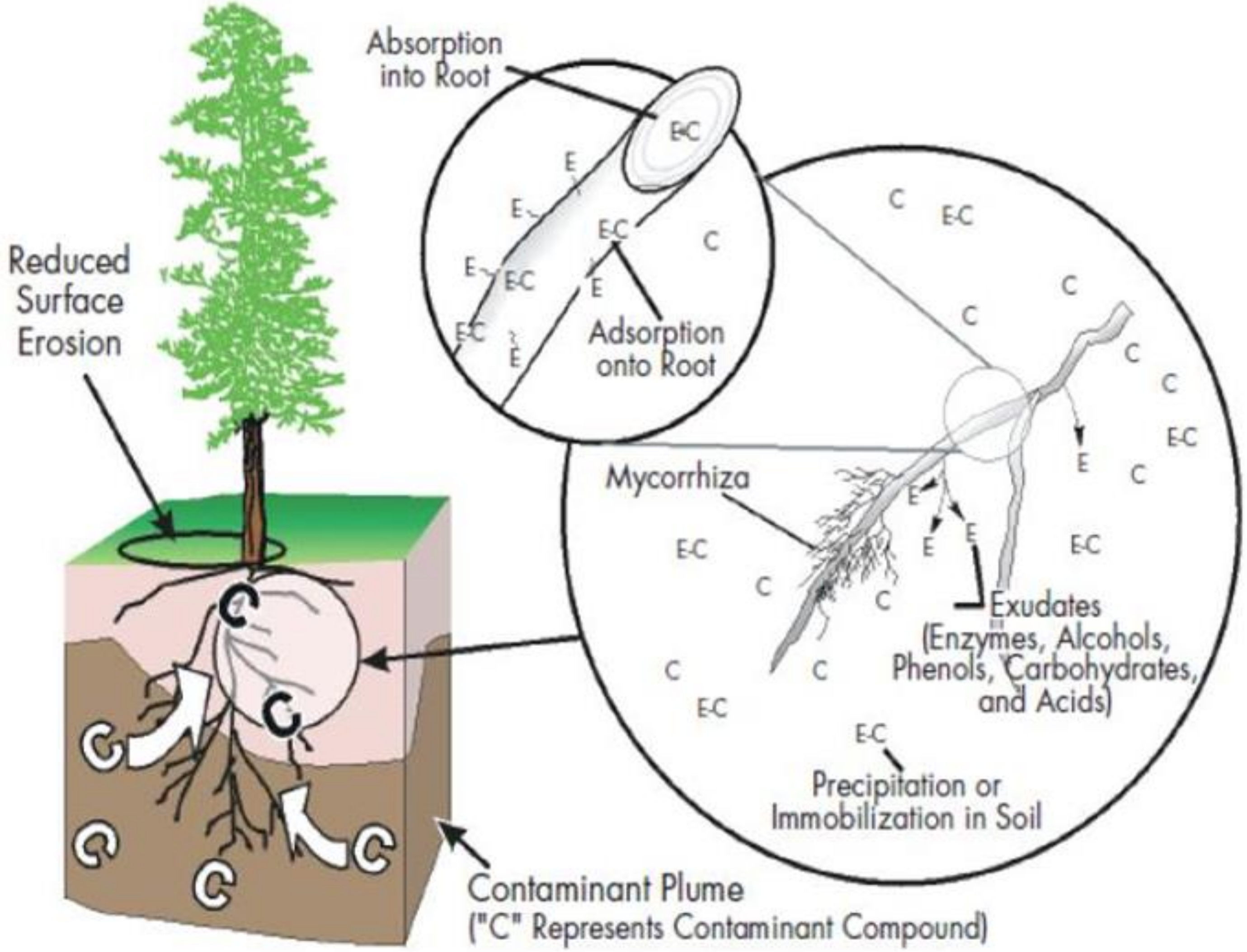


MODERATELY POLLUTED AREAS

Phytoextraction associated with the production of a crop for energy purposes

- production of uncontaminated biomass and its use for energy purposes,
- development of areas excluded from agricultural production due to pollution

MANAGEMENT OF HEAVILY POLLUTED AREAS



PHYTOSTABILIZATION

- The use of plants to immobilize pollutants in the soil by absorption and accumulation in the roots, adsorption on the root surface or precipitation in the rhizosphere.

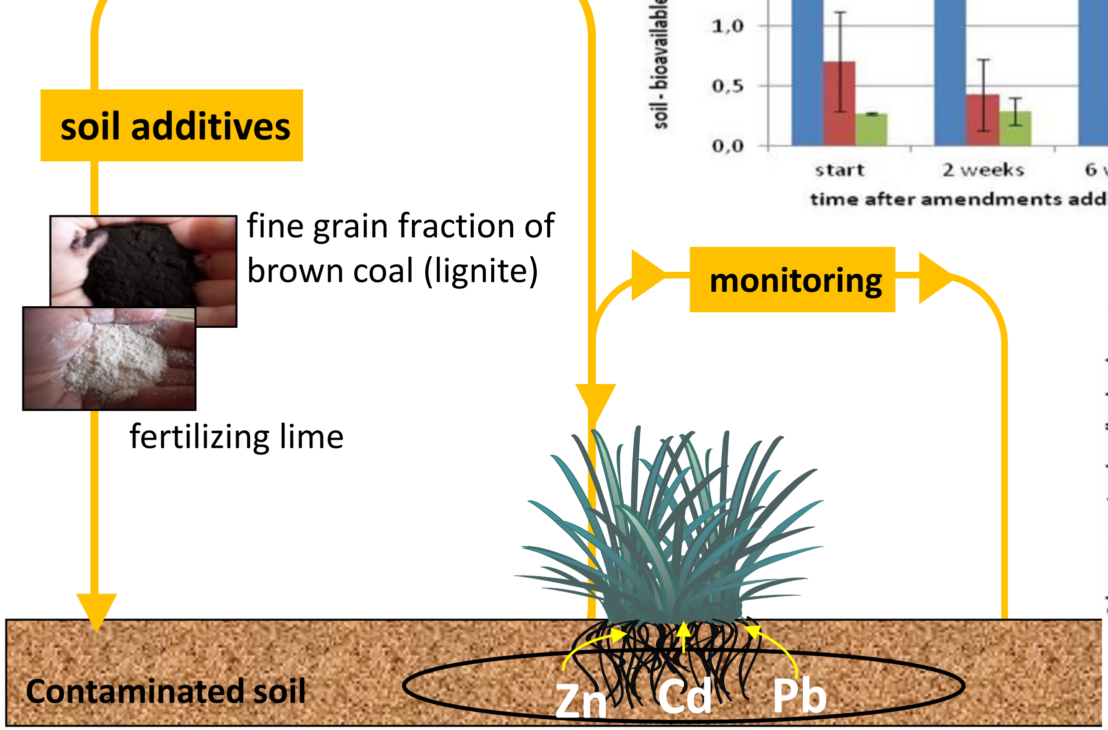
AIDED PHYTOSTABILIZATION

- The use of soil additives immobilizing metals with appropriately selected plant species.

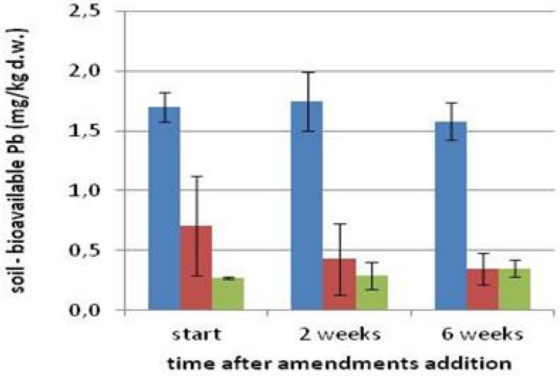
The immobilization of pollutants in the soil is based on the processes of absorption and accumulation in the roots, adsorption on the surface of the roots or their transformation within the rhizosphere into sparingly soluble compounds.

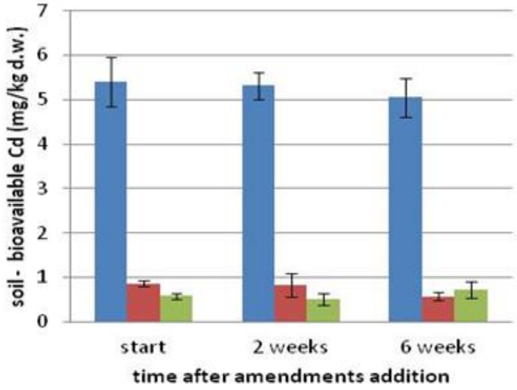
REVITALIZATION OF THE POST-ZINC DUMP IN THE CENTER OF RUDA ŚLĄSKA - APPLICATION OF SUSTAINABLE LAND MANAGEMENT IN INTEGRATED ENVIRONMENT MANAGEMENT IN URBAN FUNCTIONAL AREAS

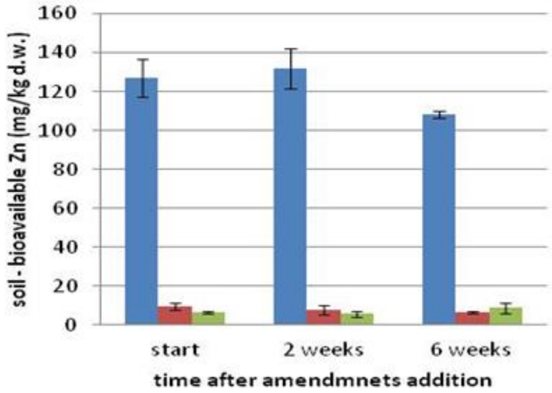
Application of the phytostabilization method developed in IETU at the top of the heap - additives limiting the bioavailability of heavy metals were used and specially selected species of grasses that did not collect pollutants were sown



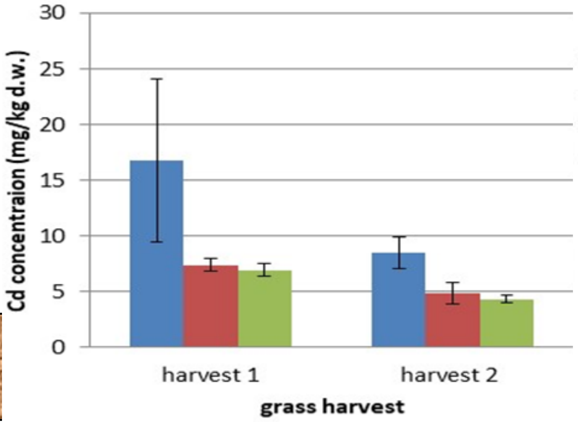
The content of the bioavailable fraction of heavy metals in the soil

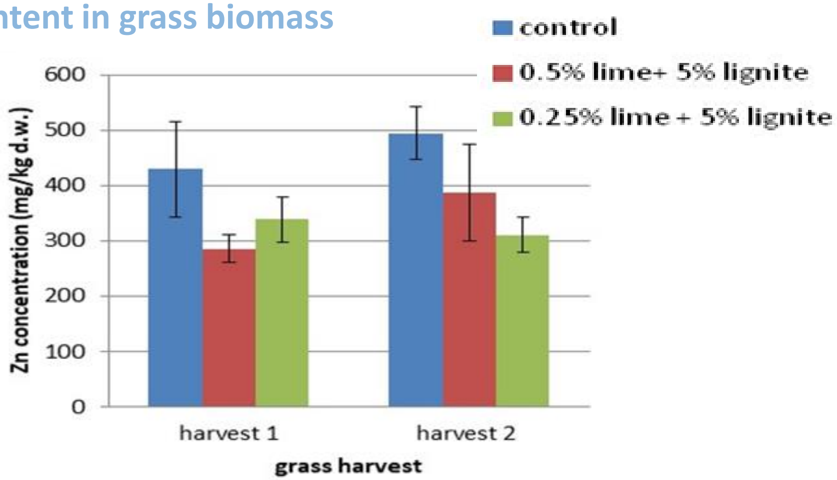






Heavy metals content in grass biomass





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REVITALIZATION OF THE POST-ZINC DUMP IN THE CENTER OF RUDA ŚLĄSKA - APPLICATION OF SUSTAINABLE LAND MANAGEMENT IN INTEGRATED ENVIRONMENT MANAGEMENT IN URBAN FUNCTIONAL AREAS


NORTH SLOPE OF THE HEAP BEFORE THE REVITALIZATION PROCESS, VISIBLE CRACKS AND EXPOSED CONTAMINATED SOIL

Interreg CENTRAL EUROPE European Union European Regional Development Fund LUMAT

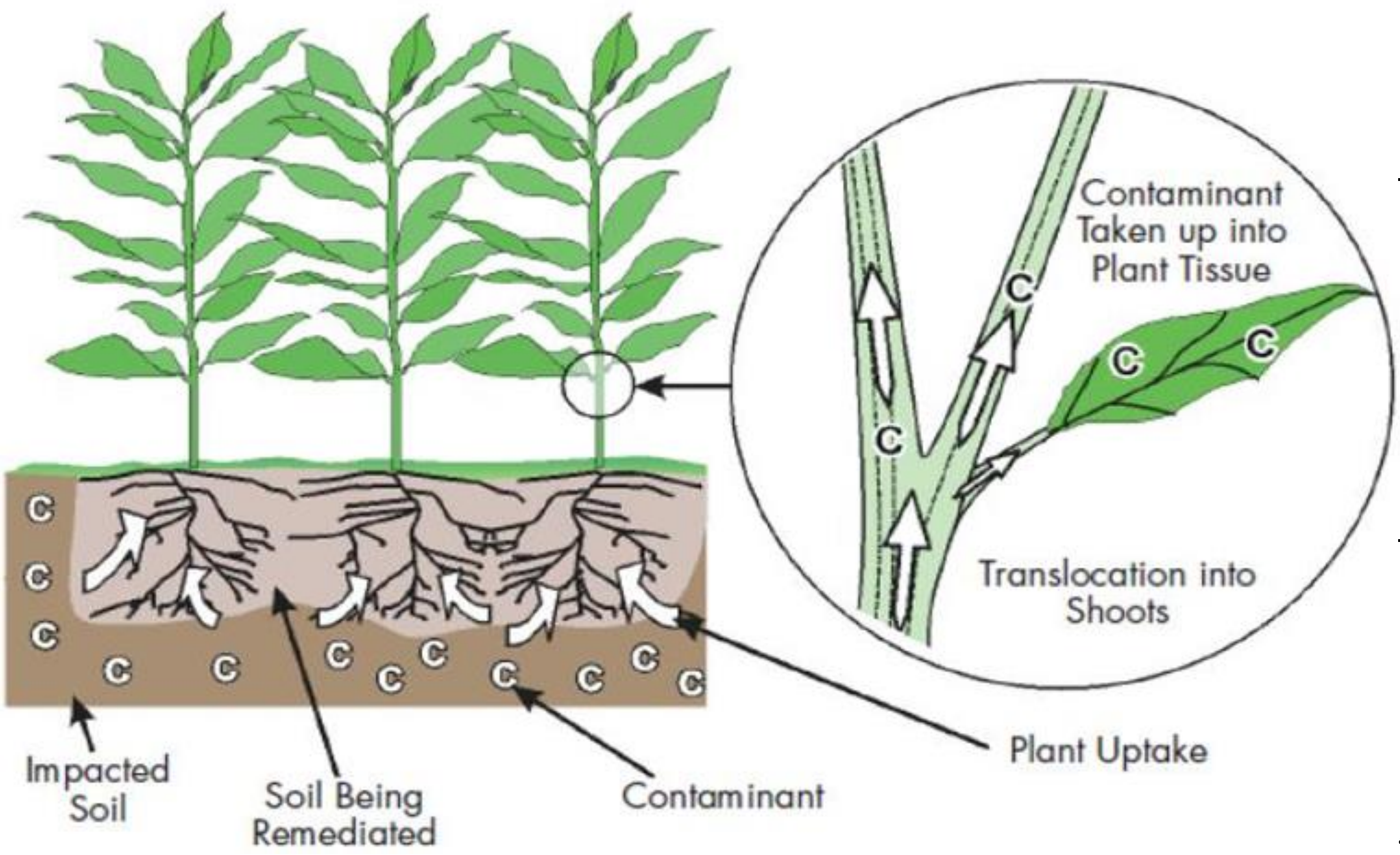

THE REVITALIZED SPOIL HEAP TO THE SOUTH-WEST DIRECTION


2016, VIEW OF THE HEAP IN THE NORTH DIRECTION, BEFORE THE REVITALIZATION PROCESS


CONCRETE HAMMOCKS HANGERS IN REVITALIZED AREA

www.interreg-central.eu/

MANAGEMENT OF MODERATELY POLLUTED AREAS



PHYTOEXTRACTION

– The use of plants capable of absorbing heavy metals to transport these metals or organic compounds from the soil and their accumulation in the above-ground parts of plants.

– Possibility of associating phytoextraction with the production of a crop for energy purposes.

INDUCED PHYTOEXTRACTION

- The use of chemical reagents to enchance plant metal uptake

GROWING ENERGY CROPS IN AREAS EXCLUDED FROM FOOD AND FODDER PRODUCTION

MARGINAL SOILS - soils which, due to unfavorable natural, anthropogenic and economic conditions, have relatively low productivity or are not suitable for safe food production

Problem: heavy metal contaminated agricultural soil, poor quality soil

Objective: sustainable management of the land excluded from agricultural production, obtaining vegetation cover and production of biomass

PHYTO2ENERGY – BIOMASS ON MARGINAL LAND

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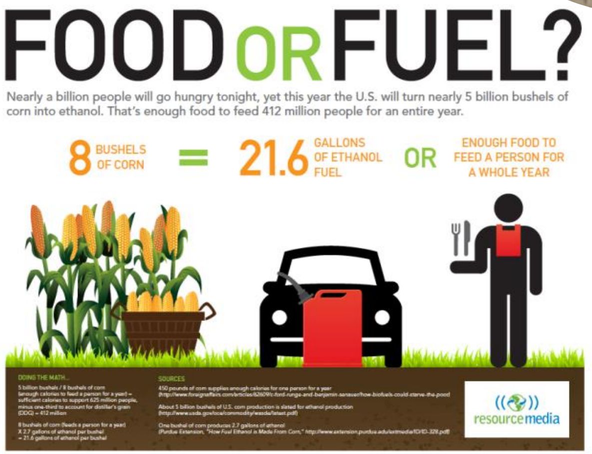
About 10% of arable lands across Europe seems to be marginal

Renewability of biomass makes it an attractive source of energy

About 100 million to 1 billion ha of marginal lands are theoretically available for production worldwide



PHYTO2ENERGY

Phytoremediation driven energy crops production on heavy metal degraded areas as local energy carrier

Use of land for biomass production should not compete with its use for food production

About 800 thousand km² of soils in Europe are considered polluted or potentially polluted in that 30% with heavy metals

Some energy crop species demonstrate potential for heavy metal removal

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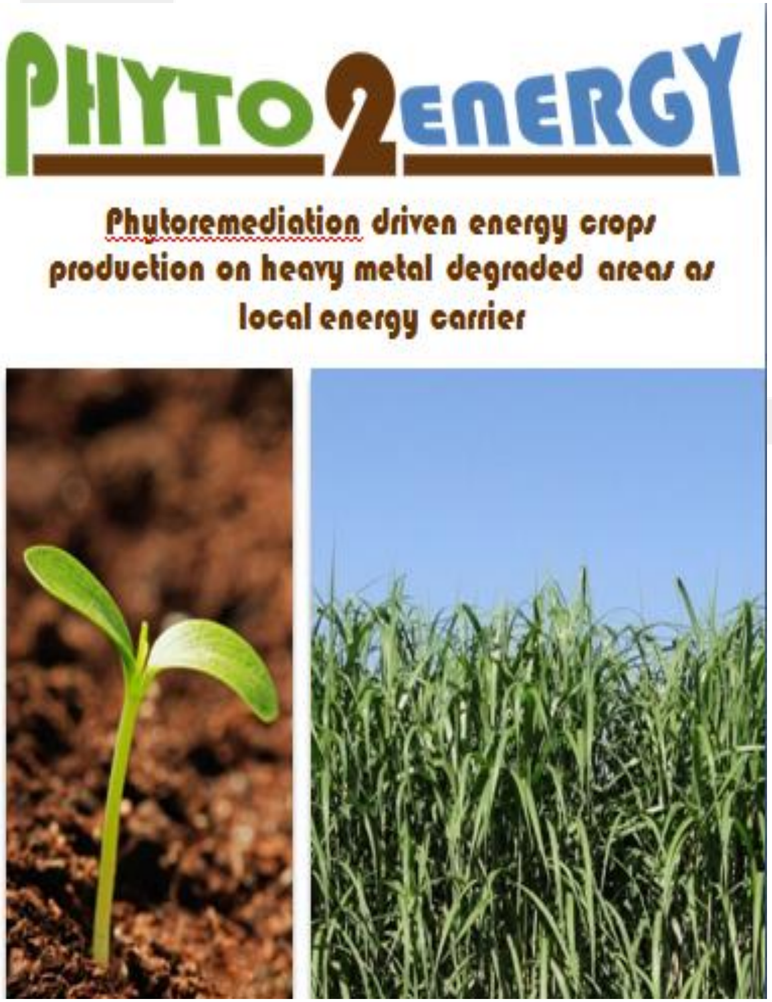
EXAMPLE OF MARGINAL LAND – BYTOM IETU EXPERIMENTAL SITE

Soil characteristic

Property	Value
pH (1 : 2.5 soil/KCl ratio)	6.79 ± 0.01
Electrical conductivity (μS/cm)	127 ± 0.002
Organic matter content (%)	4.0 ± 0.03
Sand (1 – 0.05 mm), %	28
Silt (0.05 – 0.002 mm), %	56
Clay (< 0.002 mm), %	16
Total heavy metal concentration (extraction with aqua regia)	
Pb (mg kg^{-1})	547.0 ± 27.92
Cd (mg kg^{-1})	20.84 ± 1.17
Zn (mg kg^{-1})	2174 ± 103
$CaCl_2$ extractable metal fraction [a]	
Pb (mg kg^{-1})	0.39 ± 0.03 (0.07) [b]
Cd (mg kg^{-1})	1.20 ± 0.03 (5.76) [b]
Zn (mg kg^{-1})	46.52 ± 1.51 (2.13) [b]

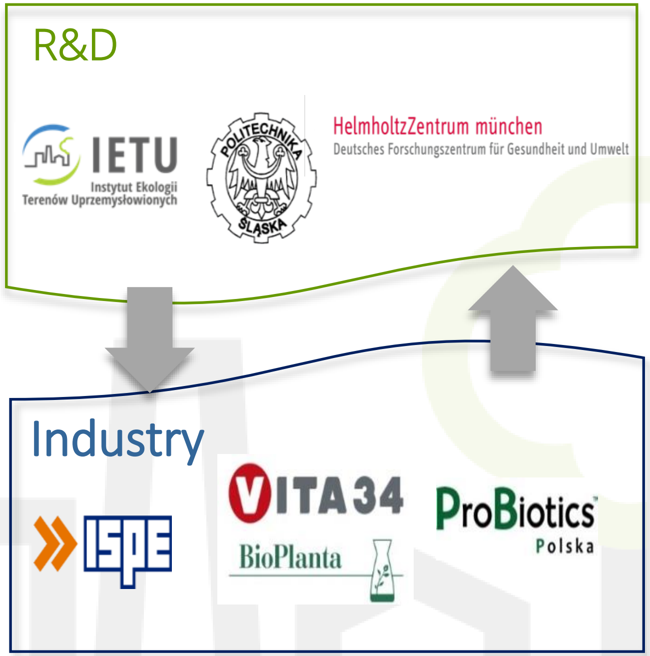
Values represent mean of three replicate samples ± SE, [a] – extraction with 0.01 M $CaCl_2$, [b]– in parentheses percentages of total metal concentrations are presented

PHYTO2ENERGY – BIOMASS ON MARGINAL LAND



Expected results:

- obtain information which energy crop species are optimal in terms of biomass yield, robustness and relative site management goal,
- develop a simple guidance on phytoremediation driven energy crop production to be used in HMC sites management practice.



Financed by: Industry Academia Partnerships and Pathways under Maria Skłodowska Curie Actions of the 7FP

SELECTION OF OPTIMAL ENERGY CROP SPECIES SUITABLE FOR BOTH BIOMASS PRODUCTION AND PHYTOREMEDIATION PURPOSES OF HMC SITES AND FOUND THE POSSIBLE WAYS OF RESIDUES UTILIZATION AFTER BIOMASS GASIFICATION

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PHYTO2ENERGY

Phytoremediation driven energy crops production on heavy metal degraded areas as local energy carrier

Giant miscanthus (*Miscanthus × giganteus*)

Switchgrass (*Panicum virgatum*)

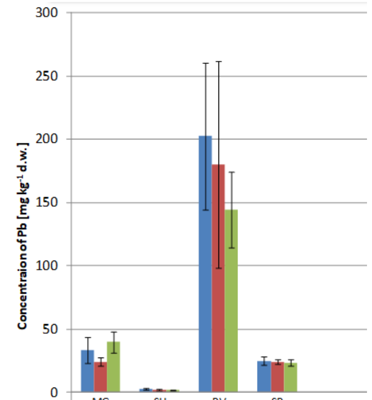
Cordgrass (*Spartina pectinata*)

Virginia mallow (*Sida hermaphrodita*)

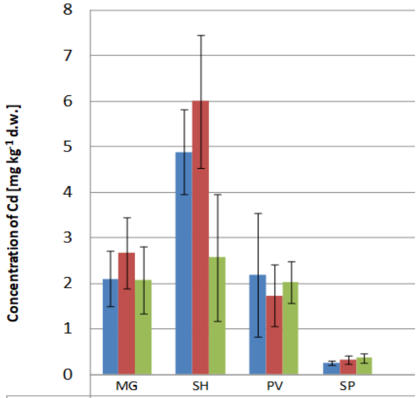
They demonstrate promising performance in terms of biomass yield and metal uptake

Heavy metals plant uptake

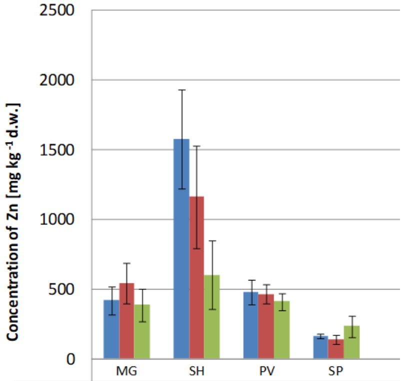
MG: *Miscanthus* x *giganteus*
SH: *Sida hermaphrodita*
PV: *Panicum virgatum*
SP: *Spartina pectinata*



	MG	SH	PV	SP
Control	33,44	2,68	202,45	25,11
NPK	24,25	2,15	179,83	24,27
Inoculum	39,73	1,90	144,02	23,60

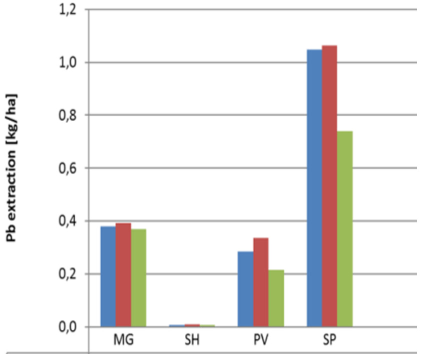


	MG	SH	PV	SP
Control	2,10	4,89	2,18	0,26
NPK	2,67	6,00	1,74	0,32
Inoculum	2,07	2,57	2,02	0,36

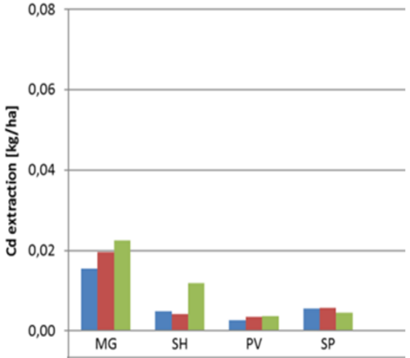


	MG	SH	PV	SP
Control	420,32	1577,50	479,74	168,74
NPK	545,69	1162,59	467,60	142,11
Inoculum	389,78	604,50	411,94	234,77

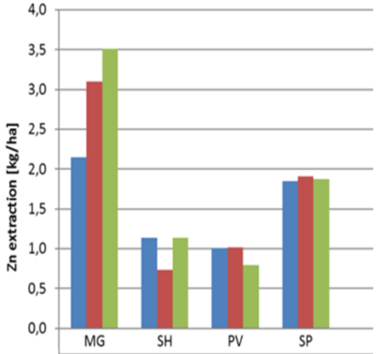
Extraction after 3rd vegetation season (kg per ha)



	MG	SH	PV	SP
Control	0,38	0,01	0,28	1,05
NPK	0,39	0,01	0,34	1,06
Inoculum 1	0,37	0,01	0,22	0,74

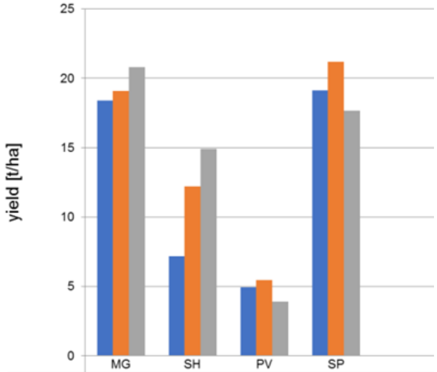


MG	SH	PV	SP
0,02	0,005	0,003	0,01
0,02	0,004	0,003	0,01
0,02	0,01	0,004	0,00



MG	SH	PV	SP
2,15	1,14	1,01	1,85
3,10	0,73	1,02	1,90
3,51	1,14	0,79	1,87

Yield after 3rd growing season



	MG	SH	PV	SP
Control	18,4	7,2	5,0	19,1
NPK	19,1	12,2	5,5	21,2
Inoculum 1	20,8	14,9	3,9	17,7

MISCOMAR AND MISCOMAR +

Miscanthus spp. (seed based hybrid)

miscomar

Miscanthus biomass options for contaminated and marginal land: quality, quantity and soil interactions.

Project start date: May 2016

Duration of the project: 36 months

miscomar+

Miscanthus biomass from marginal and polluted areas - MISCOMAR PLUS

Project start date: July 2020

Duration of the project: 36 months

Areas under interest

soils contaminated with heavy metals

marginal and fallow soils

soils depleted under intensive agriculture

MISCANTHUS BIOMASS OPTIONS FOR CONTAMINATED AND MARGINAL LAND: QUALITY, QUANTITY AND SOIL INTERACTIONS

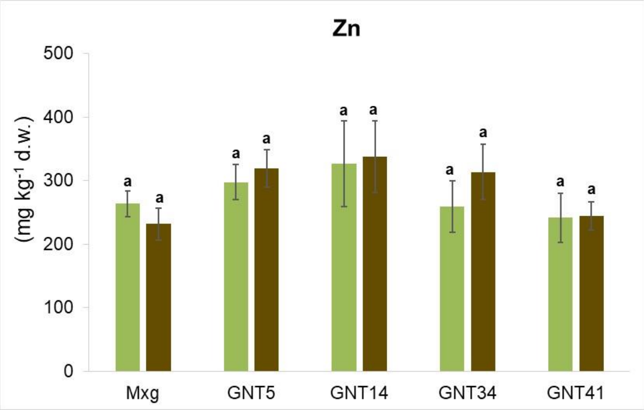
50th anniversary IETU 1972 - 2022

miscomar

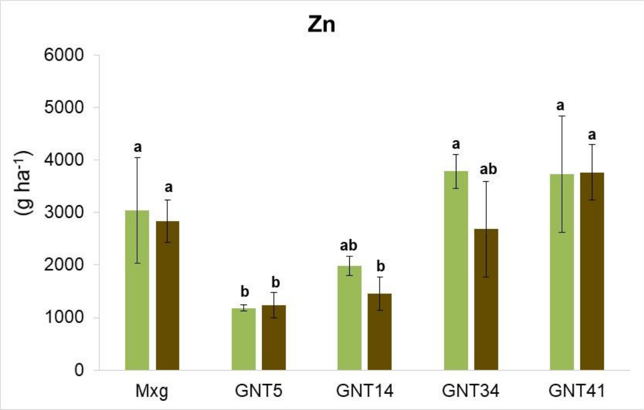
Goals:

- **investigate the field performance** of novel, stress tolerant *Miscanthus* hybrids in comparison to the standard genotype *M.* x *giganteus* on economically marginal and heavy metal contaminated soils,
- **quantify the impacts** of *Miscanthus* production on soil parameters,
- **identify utilisation options** for biomass and study the impact of varying environmental conditions on potential *Miscanthus* end uses,
- **develop concepts** for the integration of *Miscanthus* into existing landscapes, crop rotations and farming systems.

Metal accumulation in biomass (mg kg $^{-1}$ d.w.)



Extraction potential from soil (g ha^{-1})



Integrating *Miscanthus* into farming systems: improving environmental and economic performance

	Biomass management	Biomass production costs [€ (t DM)$^{-1}$ a^{-1}]	Biomass yield [t DM ha^{-1}a^{-1}]	Sales revenue [€ ha^{-1} a^{-1}]	Gross margin [€ ha^{-1} a^{-1}]
Green harvest (October)	anaerobic digestion	55	10-20	2,200	1,500
Brown harvest (March)	animal beeding	64	10-20	9,000	8,100
	combustion	47	10-20	1,500	800

MISCANTHUS BIOMASS FROM MARGINAL AND POLLUTED AREAS - MISCOMAR PLUS

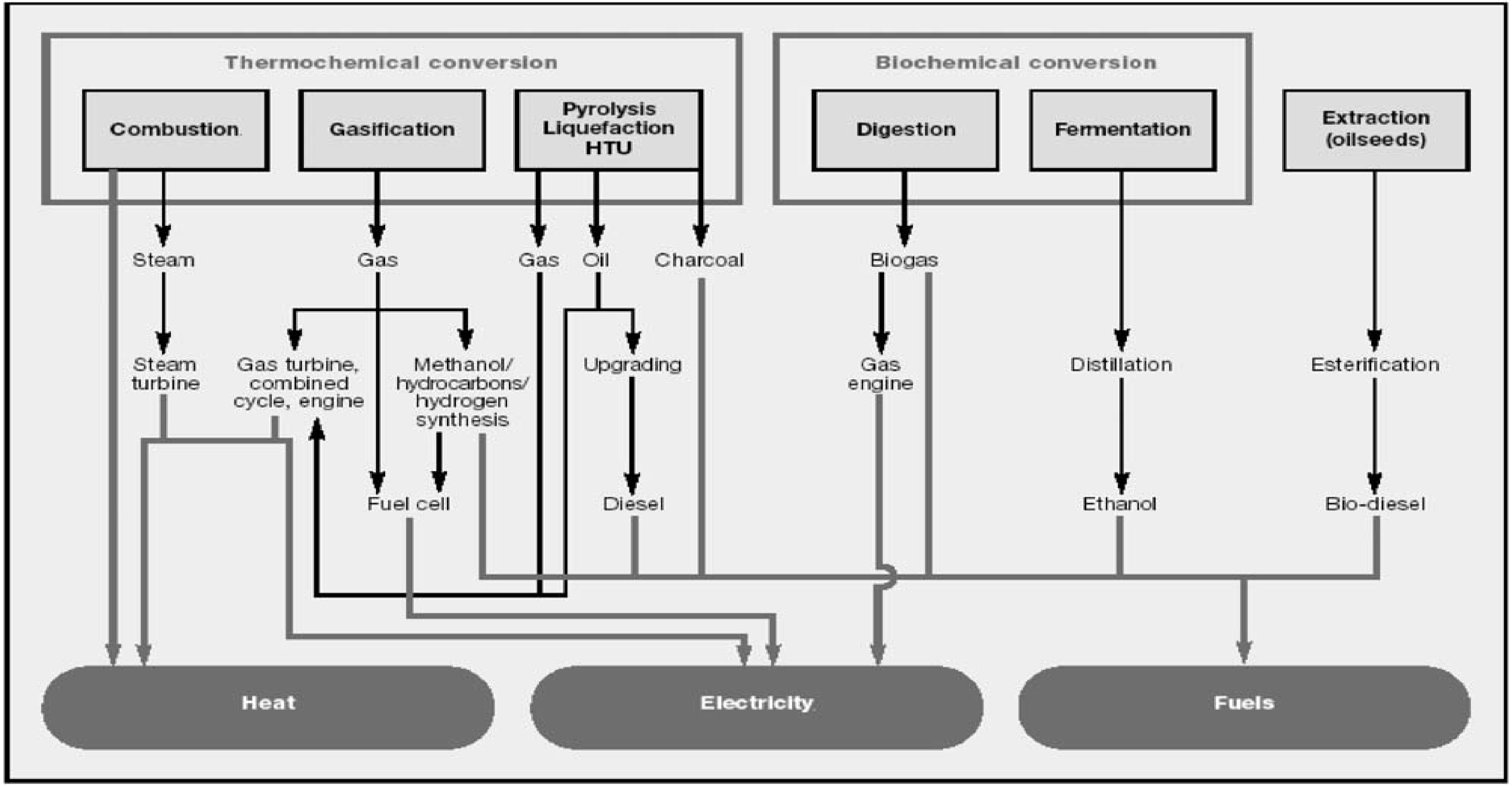
Project Goals

- MISCOMAR+ will extend the evidence-base for *Miscanthus* as a leading perennial bioenergy crop for Marginal, Contaminated, and industrially damaged Land (MaCL)

- Using interdisciplinary academic and industrial expertise, with novel *Miscanthus* hybrids bred for climate change resilience

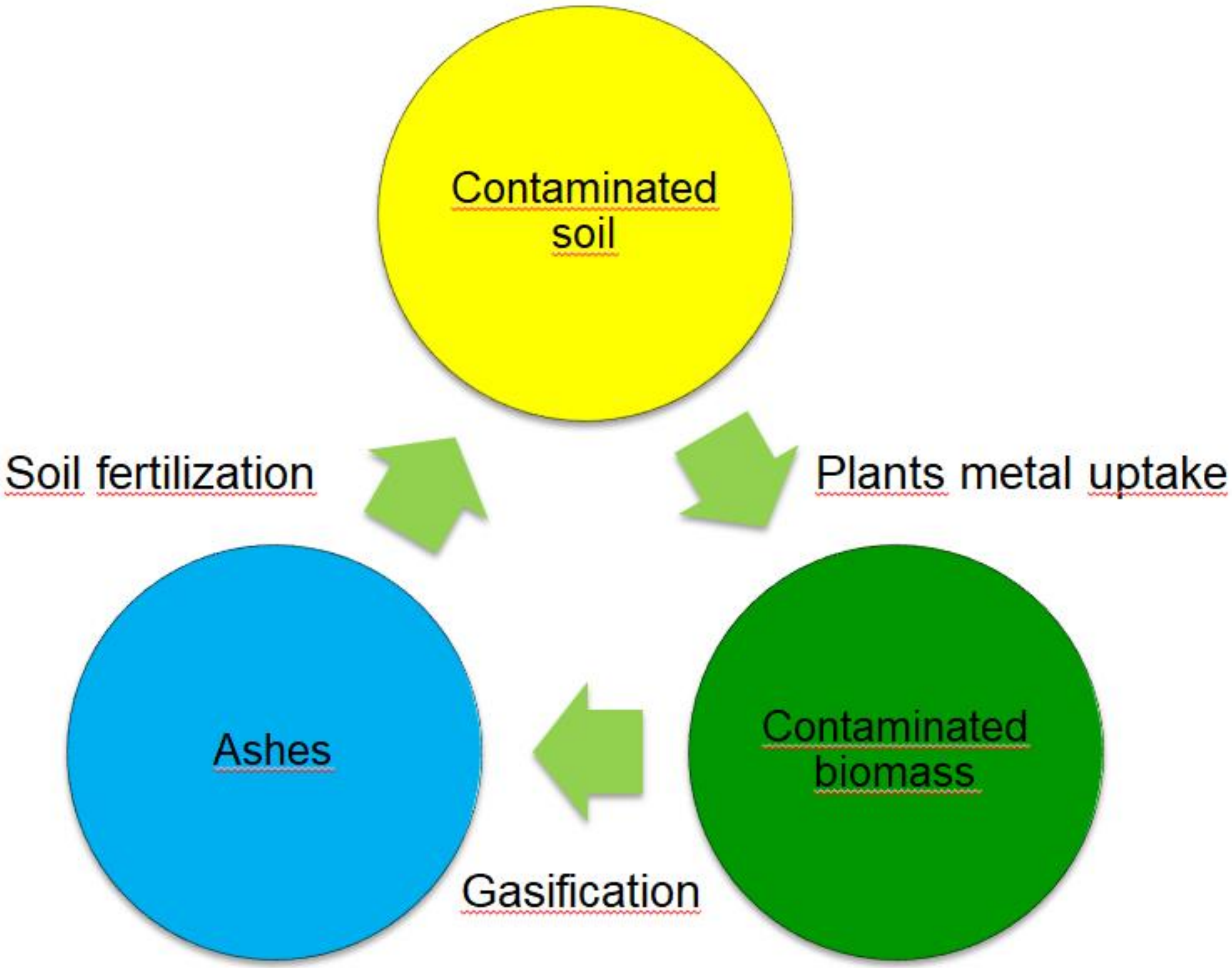
- *Miscanthus* on MaCL represents smart bioenergy because biomass is produced by the most sustainable means on land that is currently unsuitable for food production. Our approaches have potential to boost productivity from poorly functioning land whilst improving ecosystem services

MAIN CONVERSION OPTIONS FOR BIOMASS INCLUDING ENERGY PRODUCTION



Data from Faaij A.P.C, 2006, Energy Policy, 34, 322–342.

ENERGY CROP PRODUCTION CYCLE AT CONTAMINATED AREAS



ASH COMPOSITION AFTER GASIFICATION PROCESS

	Variants	Pb	Cd	Zn	P	Fe	K/K_2O	Ca/CaO	Mg/MgO
		(mg kg^{-1})					(% w/w)		
Poland	MG control	1342	<0.60	3308	2449	9555	2.46	2.90	0.794
Poland	MG fertilization	947	<0.60	3603	2320	5073	2.63	3.99	0.778
Poland	MG inoculum	1164	<0.60	2909	4115	6379	3.07	2.62	0.766
Poland	SH control	171	<0.60	2471	4139	2050	2.96	12.80	2.09
Poland	SH fertilization	81	<0.60	5805	3957	3265	3.63	17.10	2.30
Poland	SH inoculum	296	<0.60	2370	2114	1178	2.76	13.10	1.78
Poland	SP control	599	<0.60	2511	1917	3058	3.29	4.77	0.382
Poland	SP fertilization	584	<0.60	3003	2057	4424	2.51	4.06	0.381
Poland	SP inoculum	477	<0.60	1918	1596	2596	2.63	3.32	0.258
Germany	SH control	<6.60	<0.60	502	7490	799	0.578	27.50	1.06
Germany	SH fertilization	11.10	<0.60	629	10305	929	0.608	23.80	1.50
Germany	SH inoculum	<6.60	<0.60	539	1629	74	1.88	14.20	0.851

Na < 83 mg/kg — Fertilizer in agriculture (green) — Brownfield reclamation (grey)

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Thank you for your attention

Marta Pogrzeba, PhD, DSc, IETU Associate professor

Director of Institute for Ecology of Industrial Areas (IETU), Katowice, Poland

Mobile: +48 602 484 667

Fax: +48 32 254 17 17

E-mail: m.pogrzeba@ietu.pl

IETU

Institute for Ecology of Industrial Areas

6, Kossutha Str., 40-844 Katowice, Poland

www.ietu.pl

ietu@ietu.pl