EuroGeoSurveys
European Geoscience for Society
The Geological Surveys of Europe

GEMAS: A European scale geochemical atlas for environmental management and mineral exploration

GEMAS
Geochemical Mapping of Agricultural and Grazing Land Soil in Europe

Clemens Reimann


EuroGeoSurveys
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IMOA
INTERNATIONAL MOLYBDENUM ASSOCIATION
THE VOICE OF THE MOLYBDENUM INDUSTRY
Zinc
...essential for life
ila
International Lead Association
EUROPE
EUROMETAUX
EUROPEAN ASSOCIATION OF METALS
ITRI
IMnI
International Manganese Institute
Nickel
INSTITUTE
knowledge for a brighter future
VANADIUM
CONSORTIUM
european
COPPER
institute
RioTinto
ARCHE
ASSESSING RISKS OF CHEMICALS
International
ANTIMONY
Association
MFGI
LNEG
GeoZS
GTK
EBA
epmf
GSI
REACH Selenium & Tellurium Consortium
skog+
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GEUS
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brgm
BGR
Instituto Geológico
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GEOLOŠKI
ZAVOD
BWG
OFEG
UFAEG
UFAEG
FOWG
LIETUVOS GEOLOGIJOS TARNYBA
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WAGENINGEN UR
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BGS
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NATURAL ENVIRONMENT RESEARCH COUNCIL
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HGI
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HRVATSKI GEOLOŠKI INSTITUT
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SGL
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NABO
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Observatoire national des sols
Osservatorio nazionale dei suc
Swiss Soil Monitoring Networ
Università
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del Sannio
SGU
Sveriges Geologiska Undersökning
Geological Survey of Sweden
ŠTÁTNY GEOLOGICKÝ ÚSTAV
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STUDIORVM
ALMA MATER STUDIORUM
A.D. 1088
NGU
Norges geologiske undersøkelse
Geological Survey of Norway

GEMAS – the start

2007: Eurometaux contacts EuroGeoSurveys:

Land-use related geochemical data needed at the European scale for

REACH (**R**egistration, **E**valuation, **A**uthorisation and restriction of **CH**emical substances)

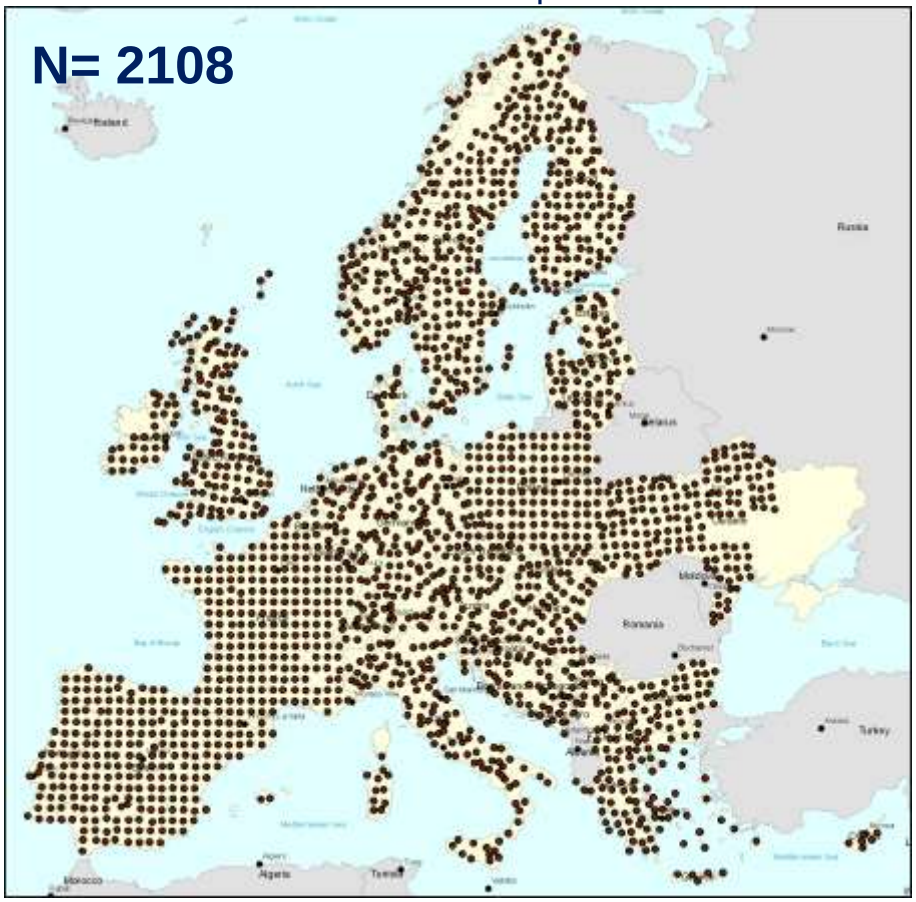
2 sample materials at 1 site/2500 km²

<2 mm fraction

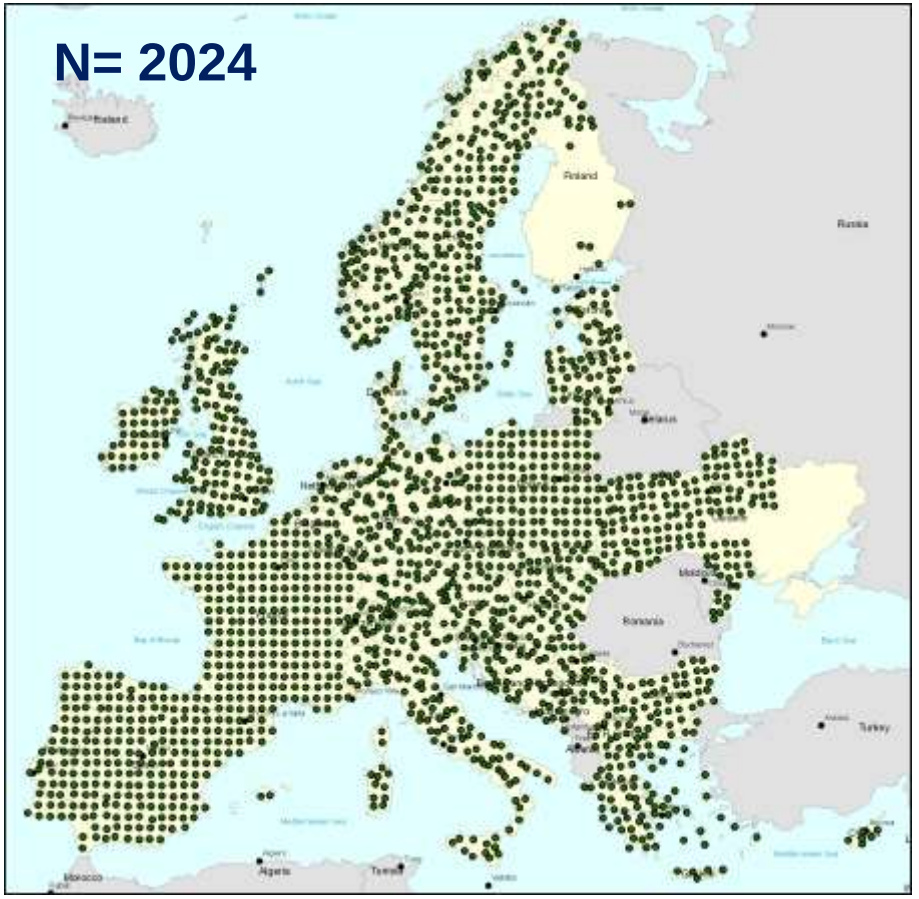
aqua regia extraction

GEMAS - 2008

Agricultural soil (A_p) 0-20 cm

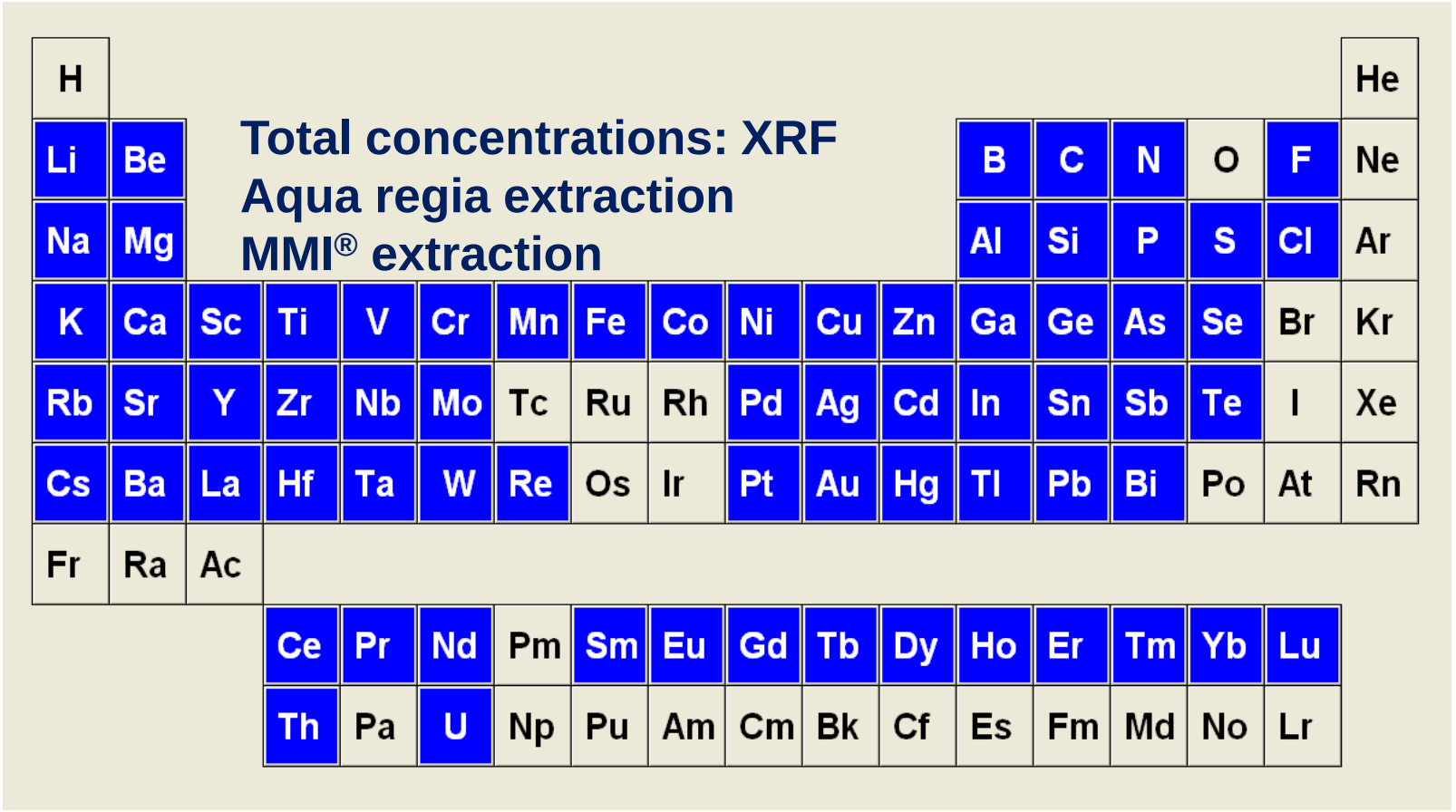


Grazing land soil (Gr) 0-10 cm



33 countries - 5.6 million km^2 - 4132 samples in total

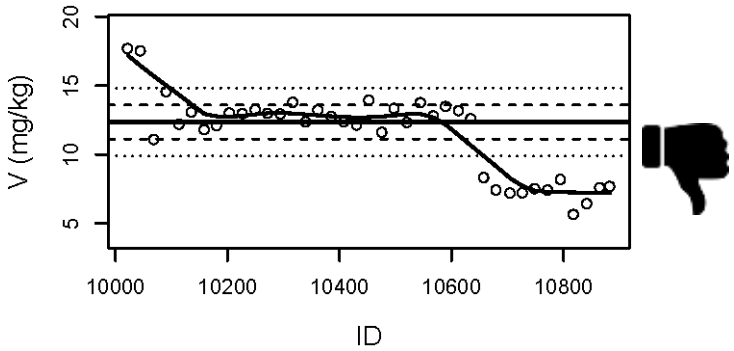
GEMAS : Analytical Programme



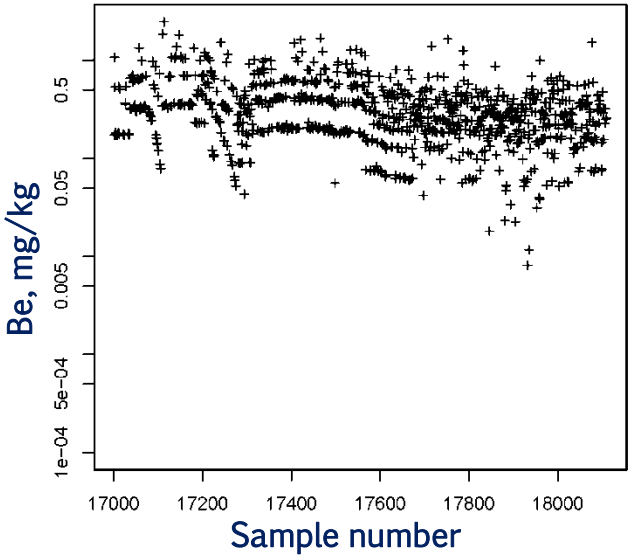
+ pH_$CaCl_2$, CEC, TOC, LOI, grain size, Pb isotopes (7N HNO_3 extraction, Ap-samples), **Sr isotopes** (in progress), **Magnetic susceptibility** (Ap-samples), **Kd-values** (for 14 metals), **MIR spectra**

Accreditation or External Quality Control?

- Randomised samples
- Project standard(s)
- Duplicates

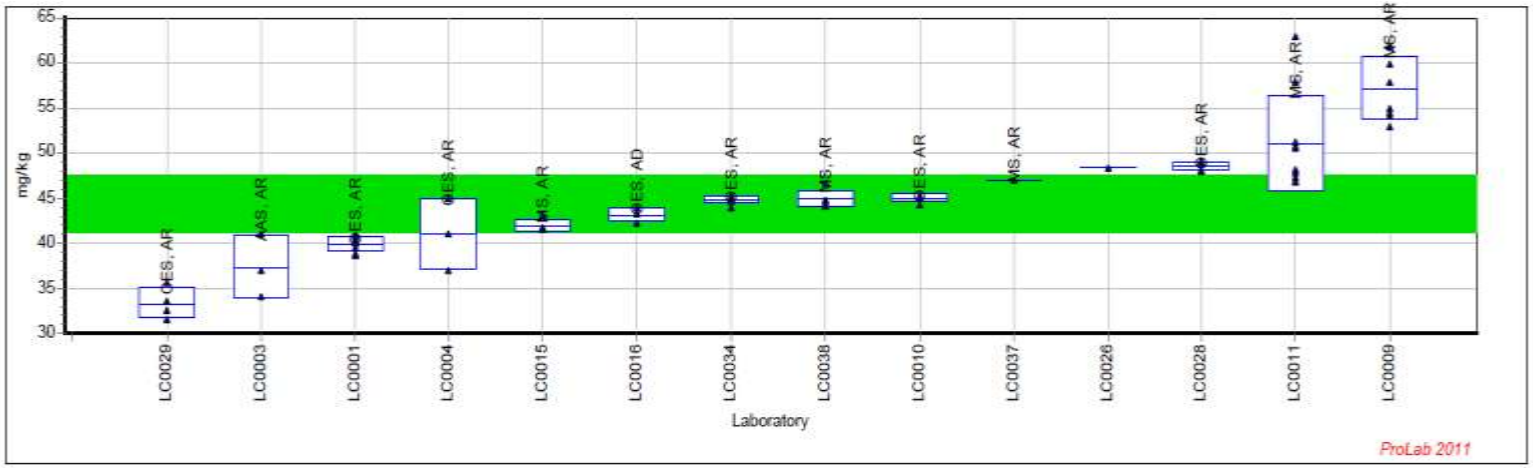


X-Chart for the project standard

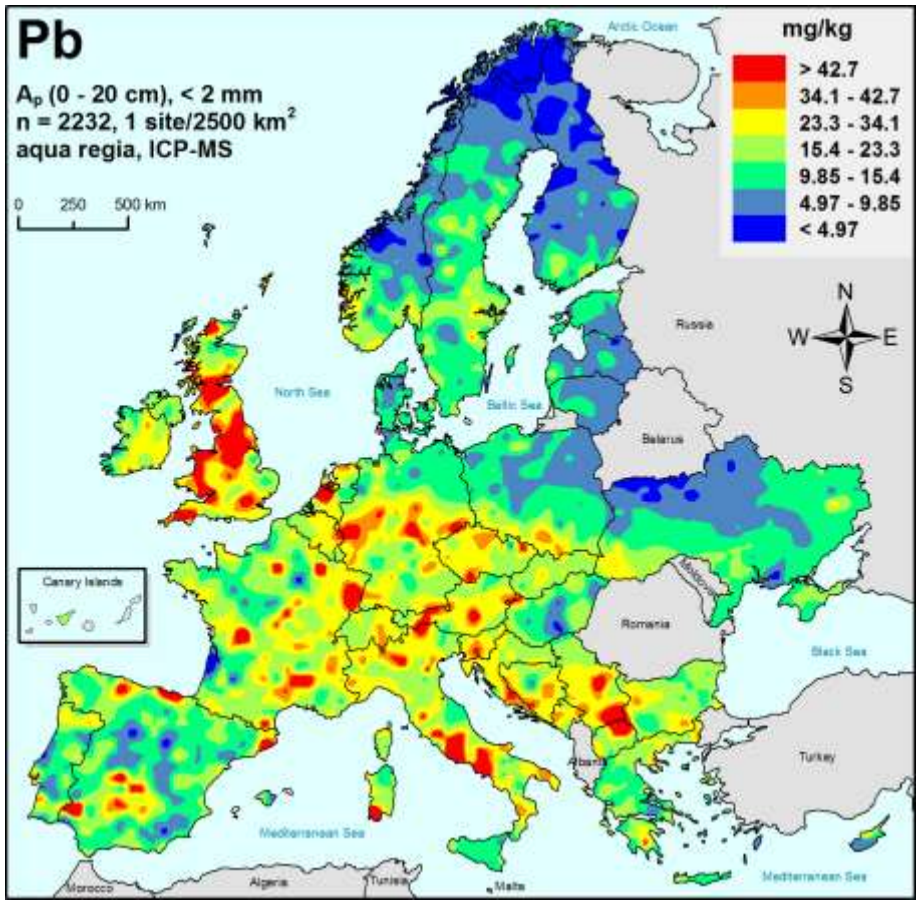


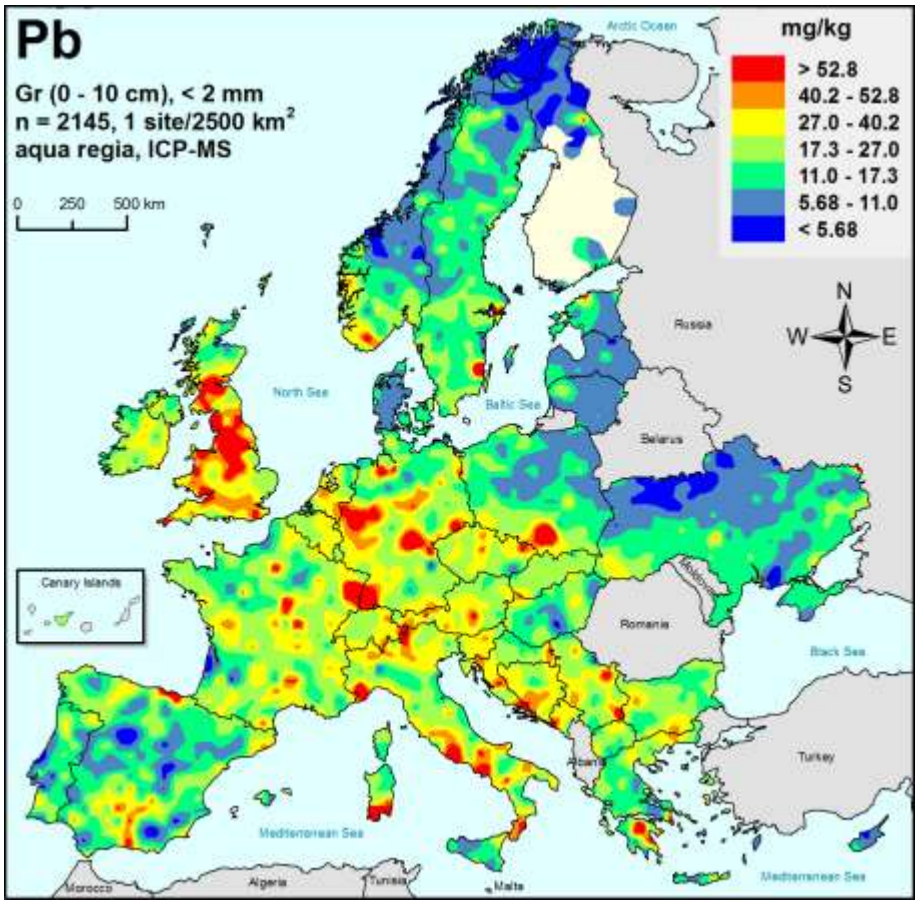
Random plot should show random variation

Ring test: results from14 laboratories on the same sample. True value? Bias?



GEMAS: the maps are robust





Lead: Two independent sample materials show comparable patterns.
Large difference between N- and S-Europe

GEMAS: supporting information

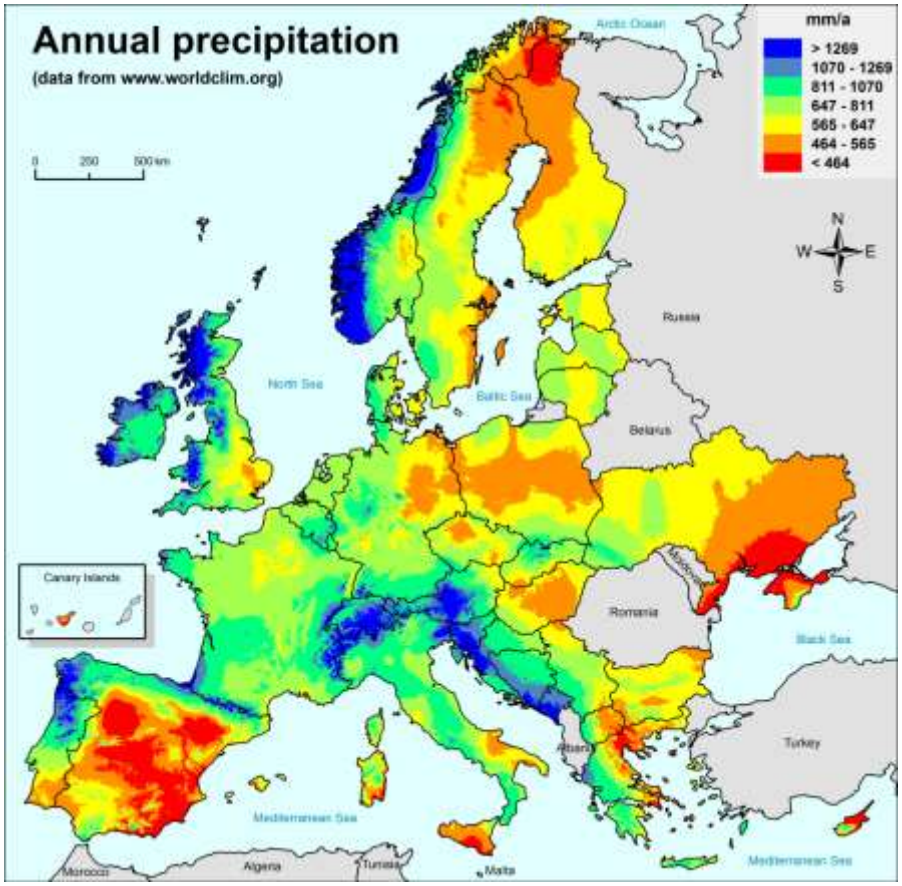
Soil parent material (based on the European Soil Geographical Database 1:1 Million)

- alluvium/colluvium
- calcearous rocks
- clayey materials
- crystalline rocks
- detrital formations
- glaciofluvial materials
- loamy/silty
- marl
- other/organic
- sandstone/flysch/molasse
- sandy materials
- schists
- volcanic rocks

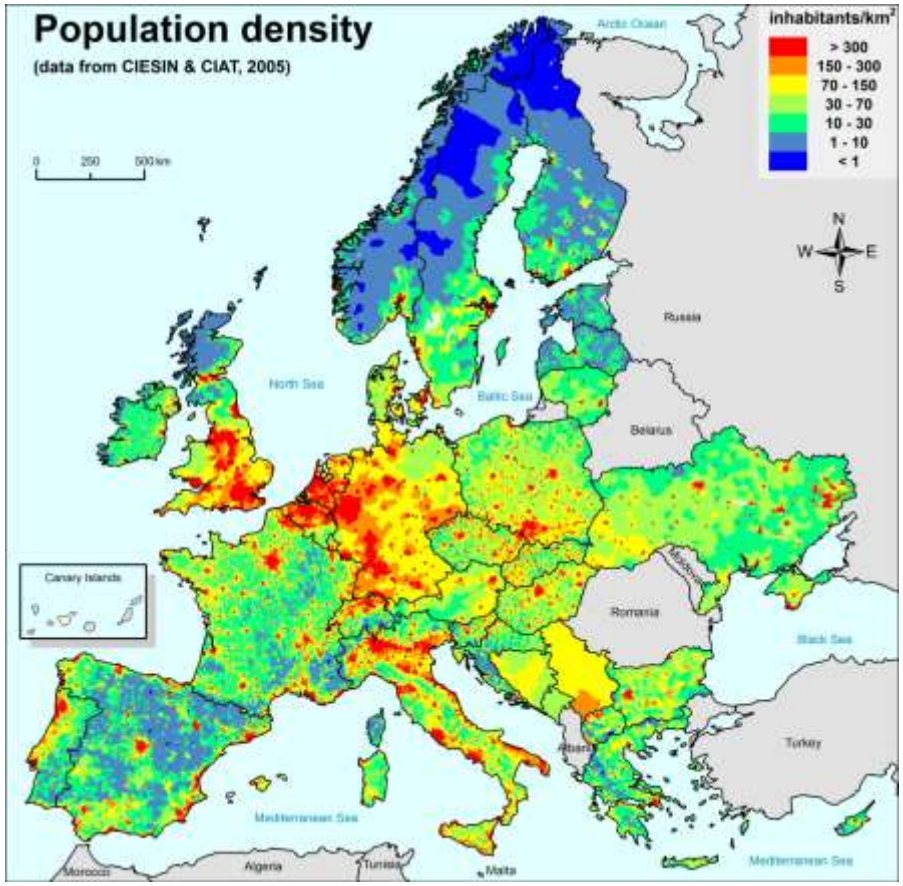
(C) Günther et al., 2013

GEMAS: supporting information

Precipitation (+ temperature + snow cover, etc.)

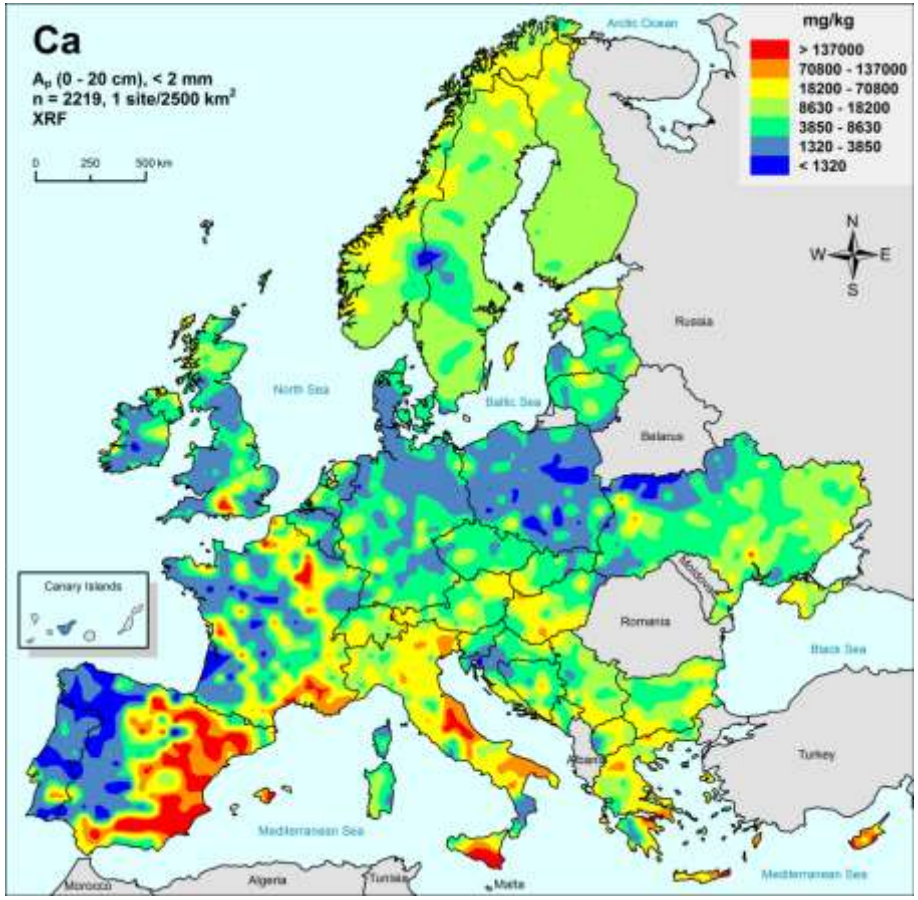


Population density (+ road network + mineral deposits + location of metal smelters, power plants, etc.)

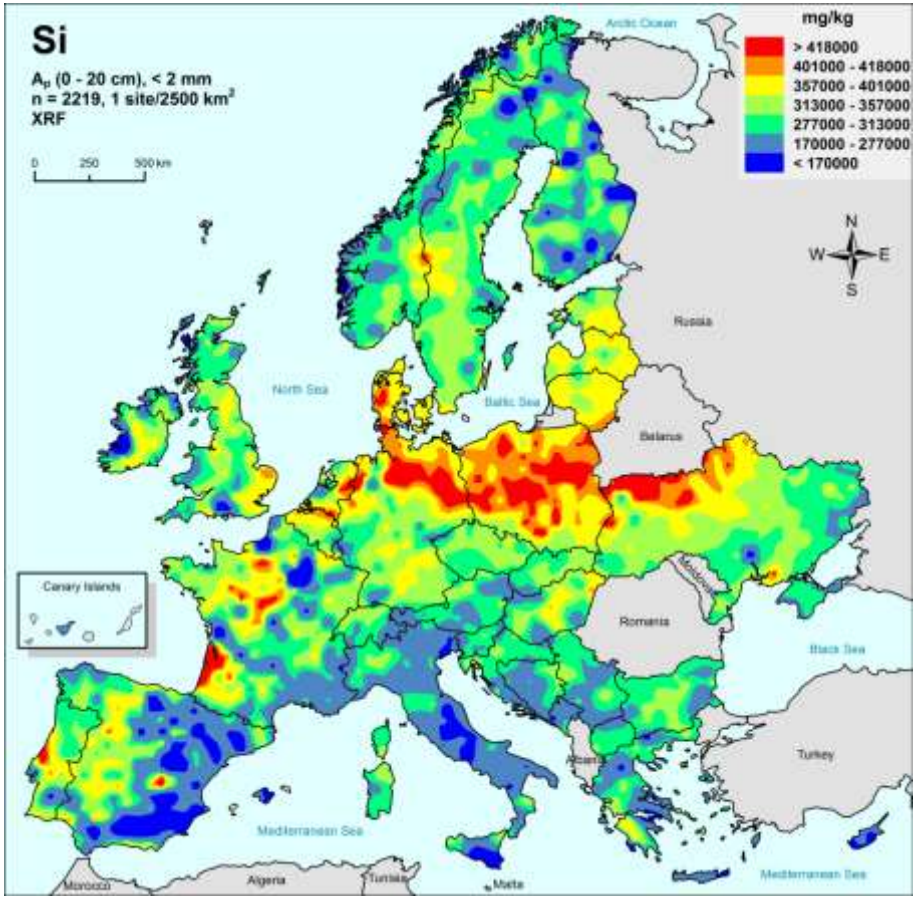


GEMAS: total concentration, major elements

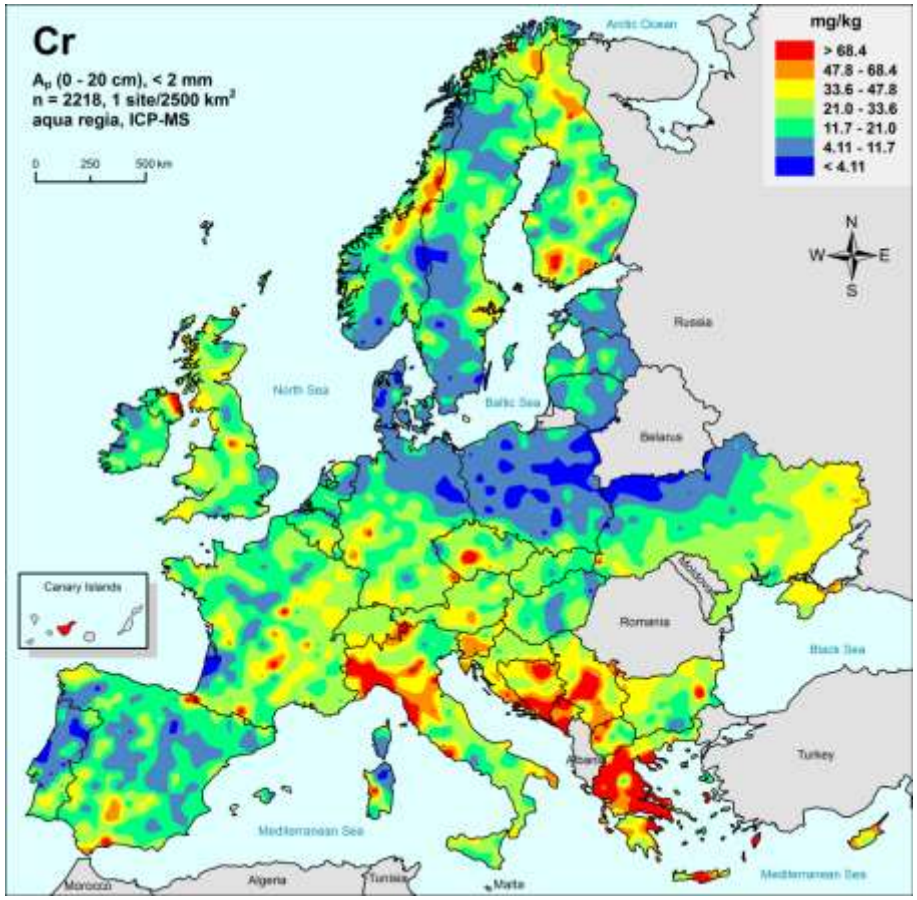
Calcium (XRF): limestone, note Fennoscandia

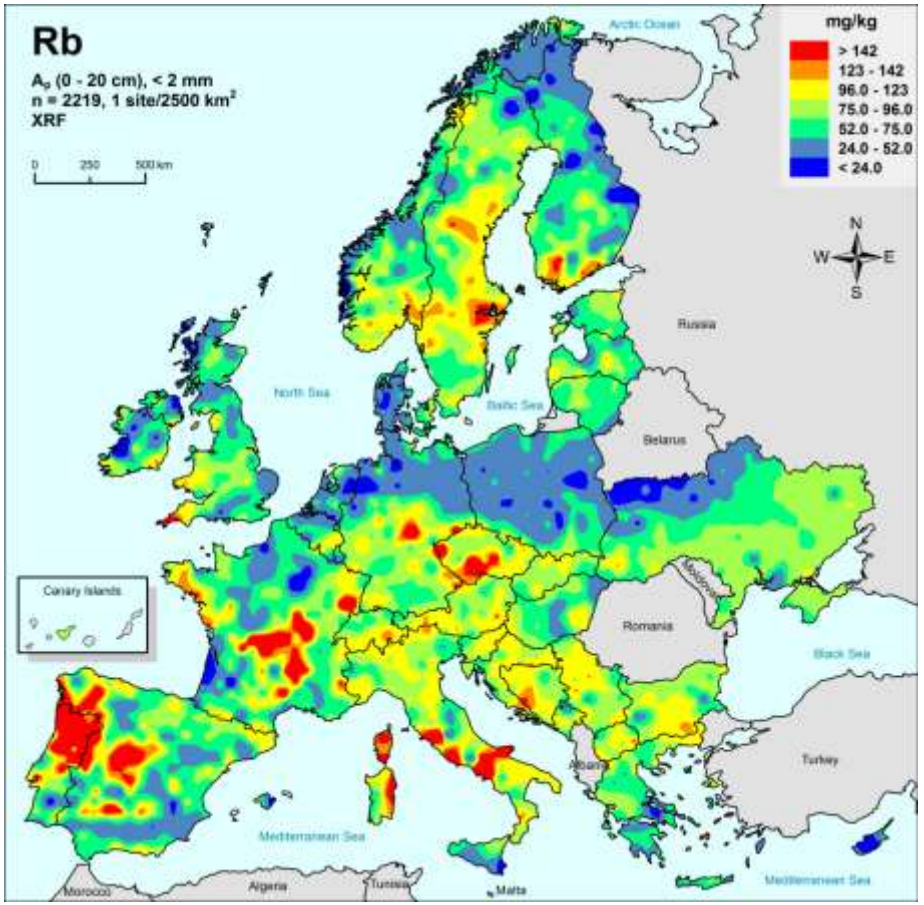


Silicon (XRF): sandstone, coarse-grained sandy soil



GEMAS: distribution of rock types in Europe

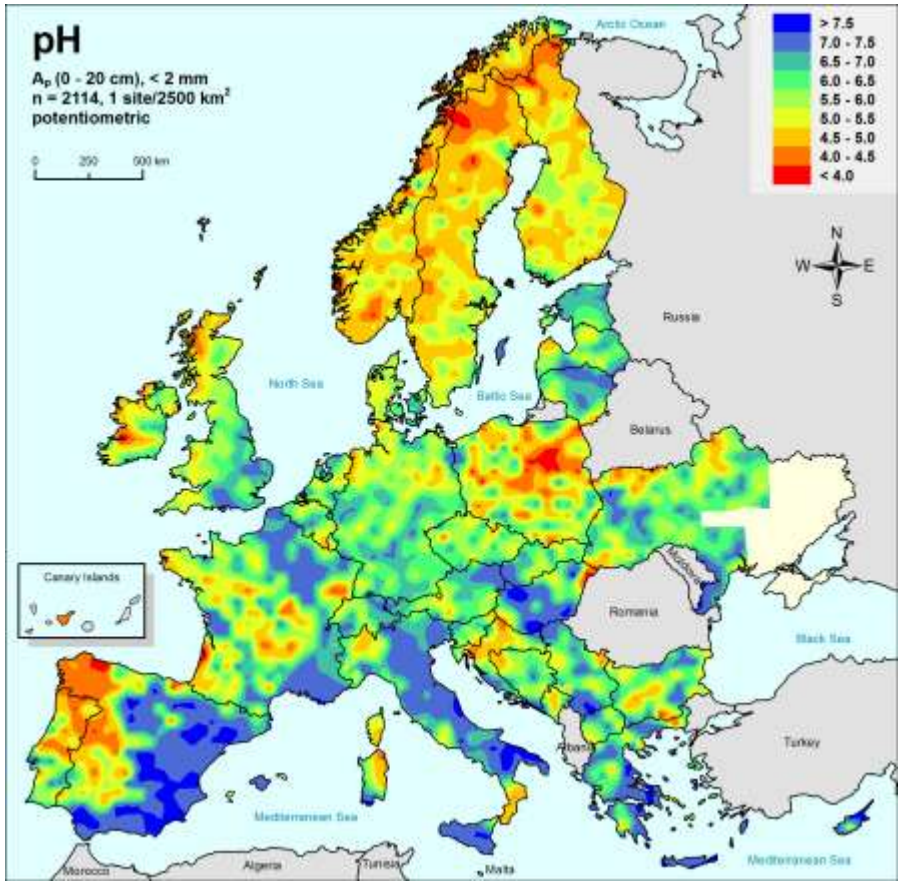


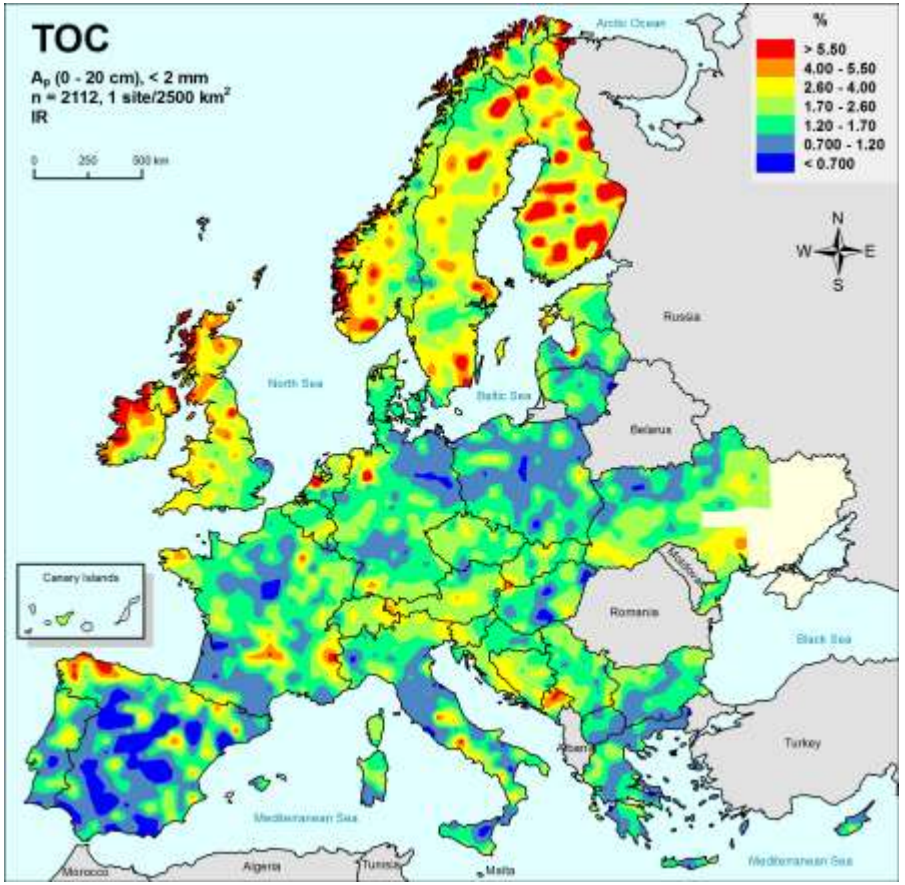


Cr (aqua regia) : ophiolite, greenstone belts, mafic volcanic rocks

Rb (XRF): granitic intrusions

GEMAS: soil properties

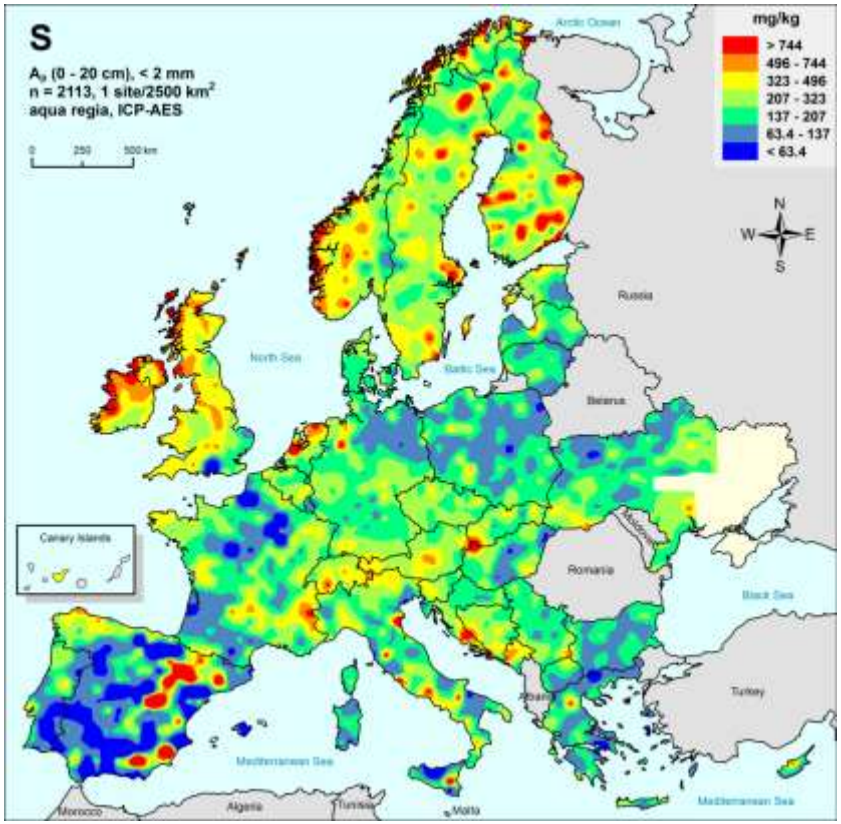




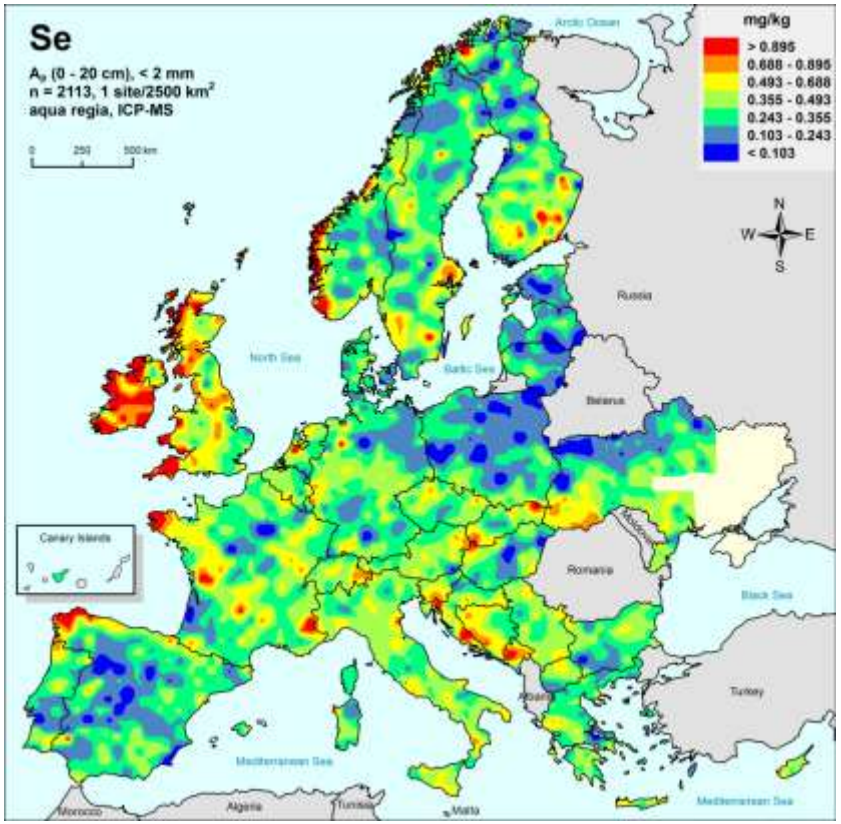
+ eCEC + clay + Kd... – these parameters determine the availability of metals in soils

GEMAS: climate

Sulphur (aqua regia): coast and organic material in soil

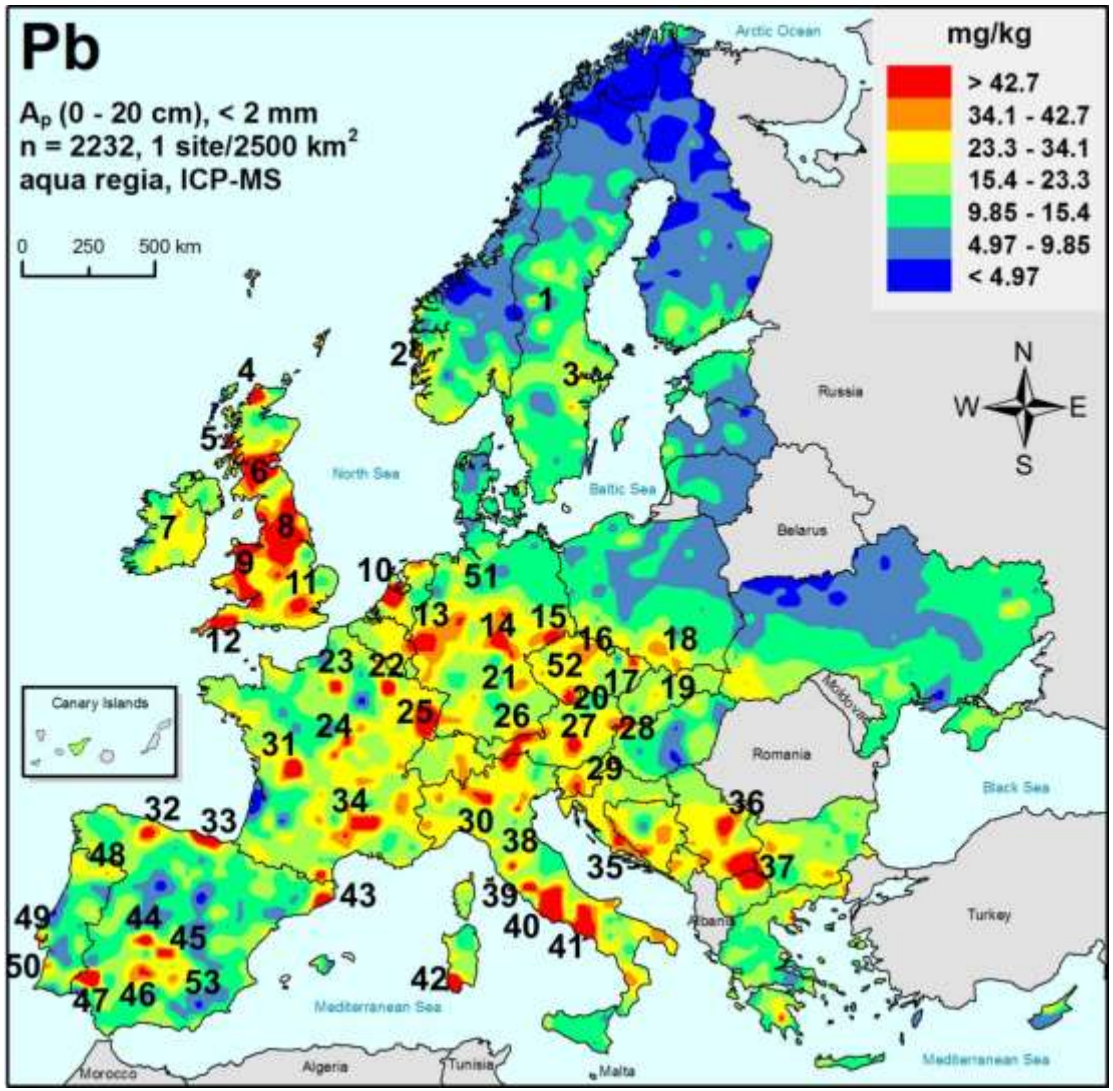


Selenium (aqua regia): strong coastal effect



At the European scale climate is important, e.g. element enrichment in organic soil in coastal areas.

GEMAS: source of anomalies



Ore deposits:

1, 3, 7, 8, 9, 12, 13, 14, 15, 16, 18, 19, 21, 24, 25, 26, 27, 20, 31, 33, 34, 35, 36, 37, 38, 39, 42, 44, 47, 53

Geology:

5, 20, 28, 29, 40, 41, 43, 46, 48

Cities:

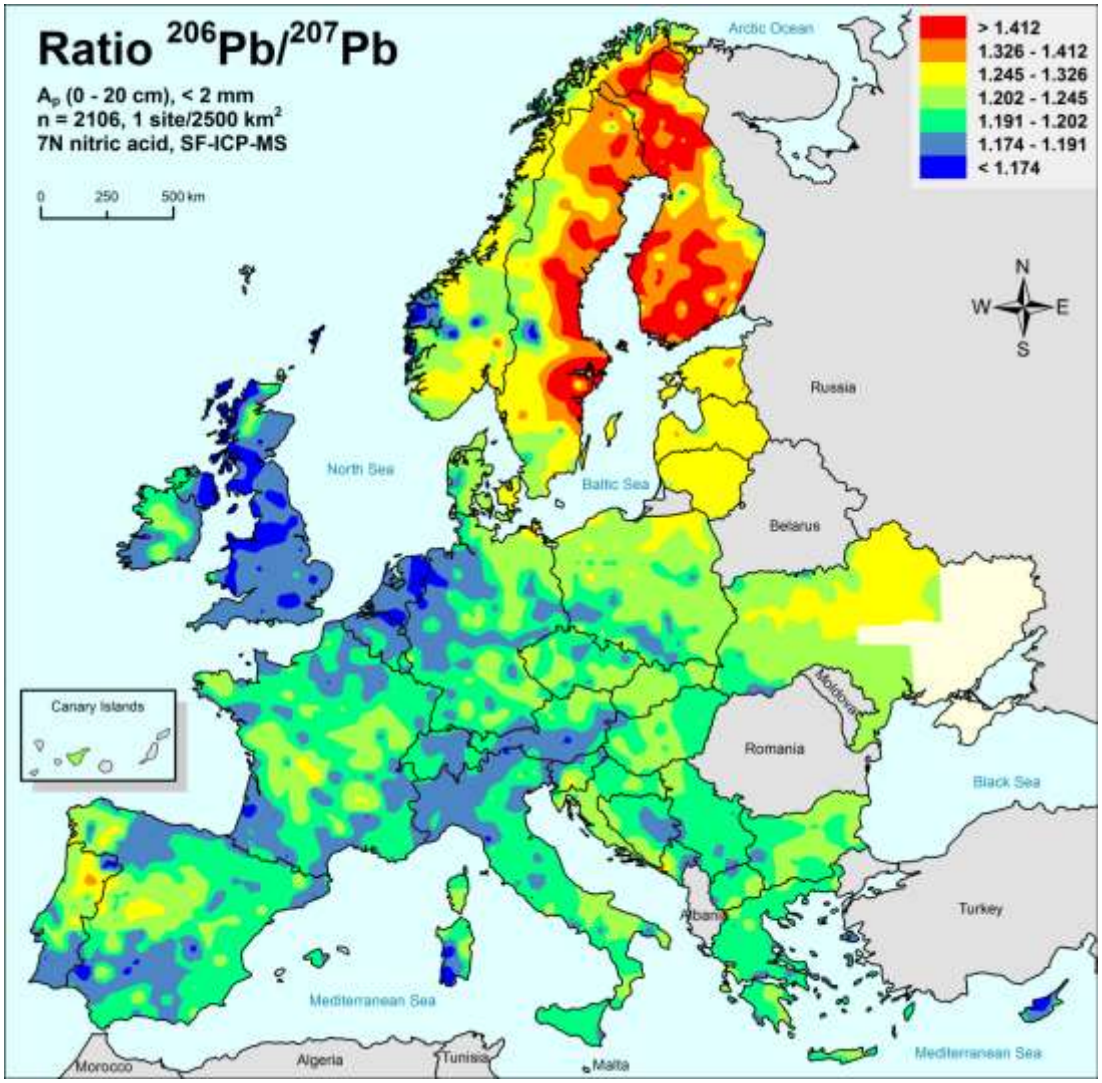
2, 10, 11, 23, 49

Contamination:

6, 17, 32, 50, 51, 52

Unexplained: 4, 22, 45

GEMAS: isotopes show geological history



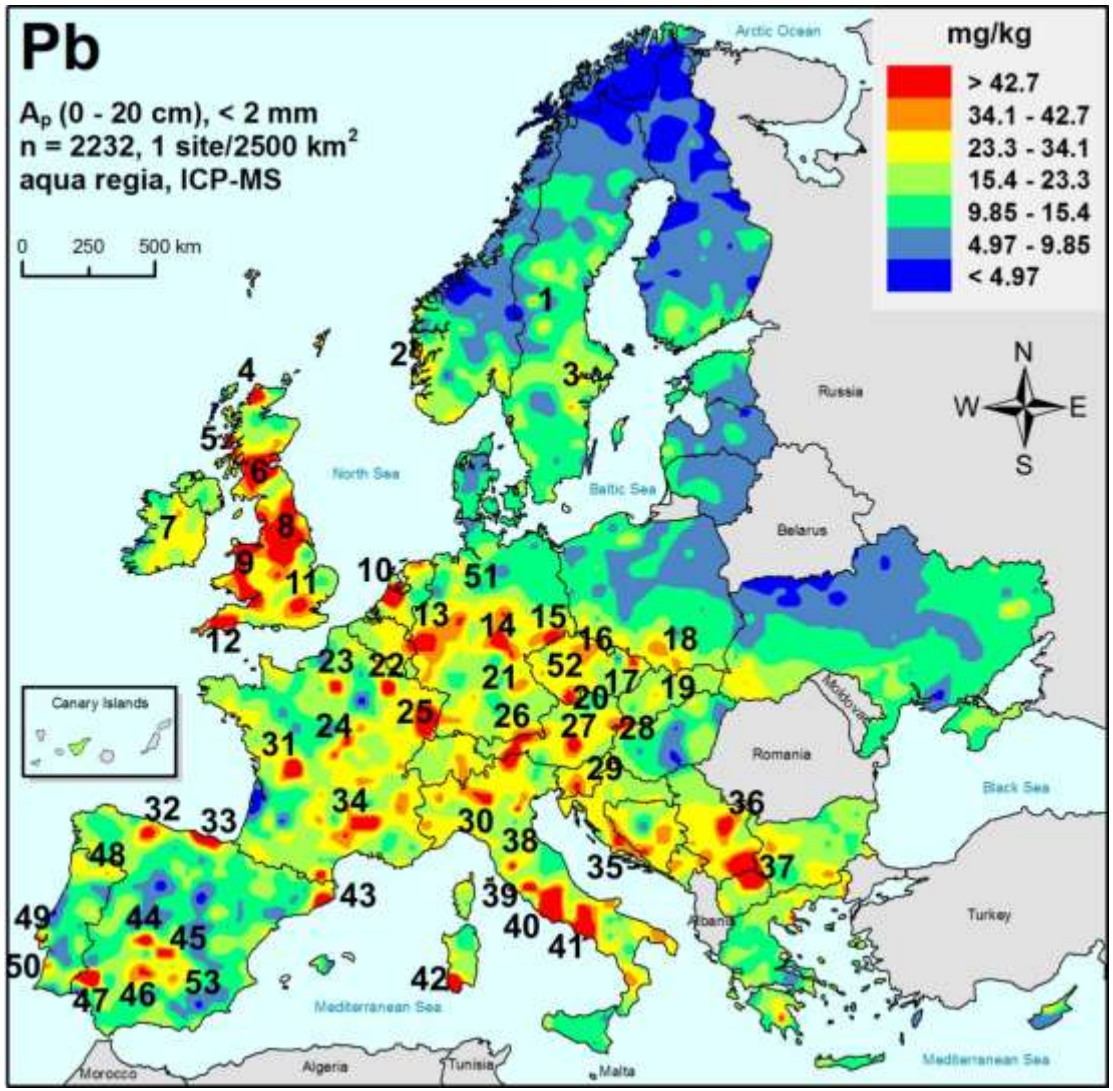
$^{206}Pb/^{207}Pb$ lead isotope ratio

- depicts geology

- some minor anthropogenic signals may be discernible (e.g., London, Paris, Amsterdam?)

- note the overall low values for the UK

GEMAS: source of anomalies



Ore deposits:

1, 3, 7, 8, 9, 12, 13, 14, 15, 16, 18, 19, 21, 24, 25, 26, 27, 20, 31, 33, 34, 35, 36, 37, 38, 39, 42, 44, 47, 53

Geology:

5, 20, 28, 29, 40, 41, 43, 46, 48

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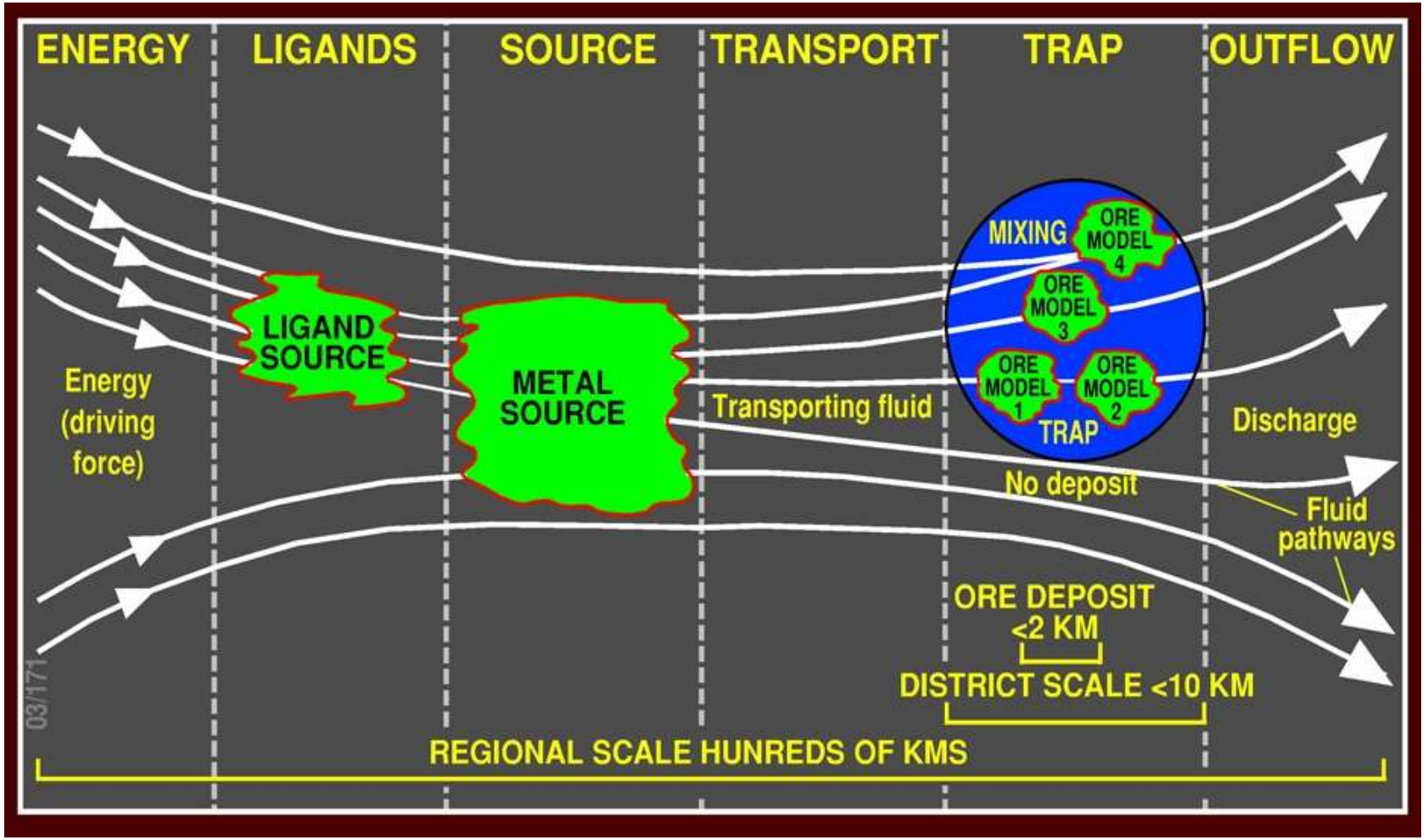
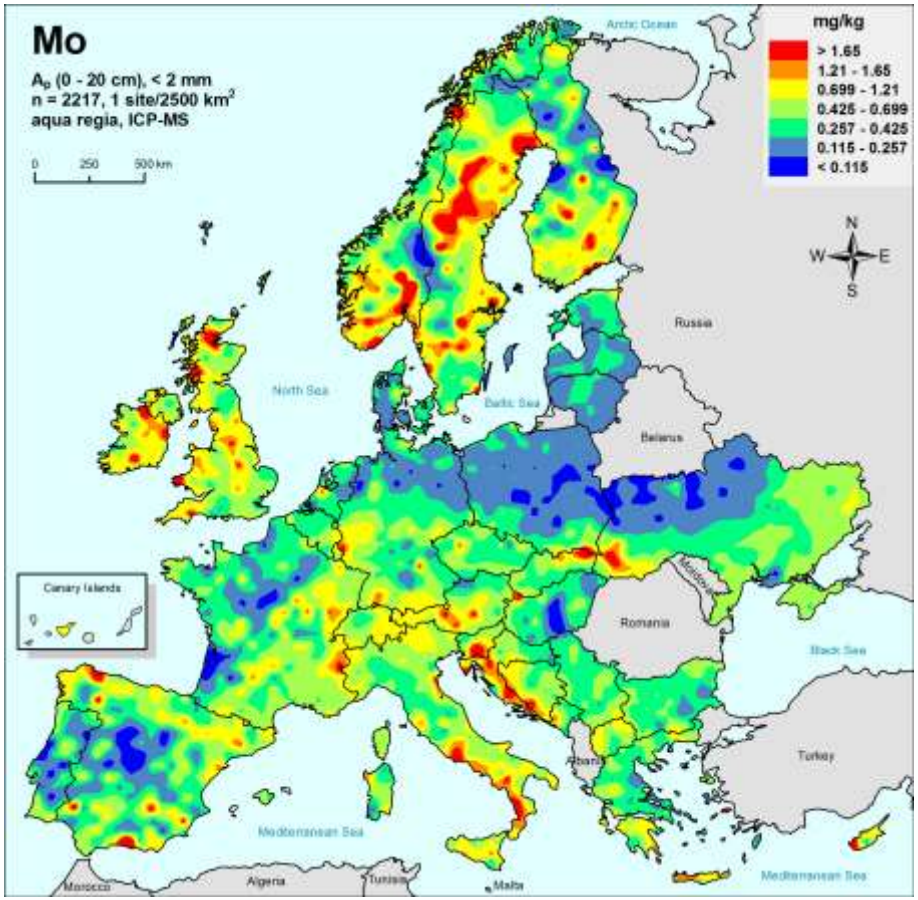
GEMAS: mineral exploration



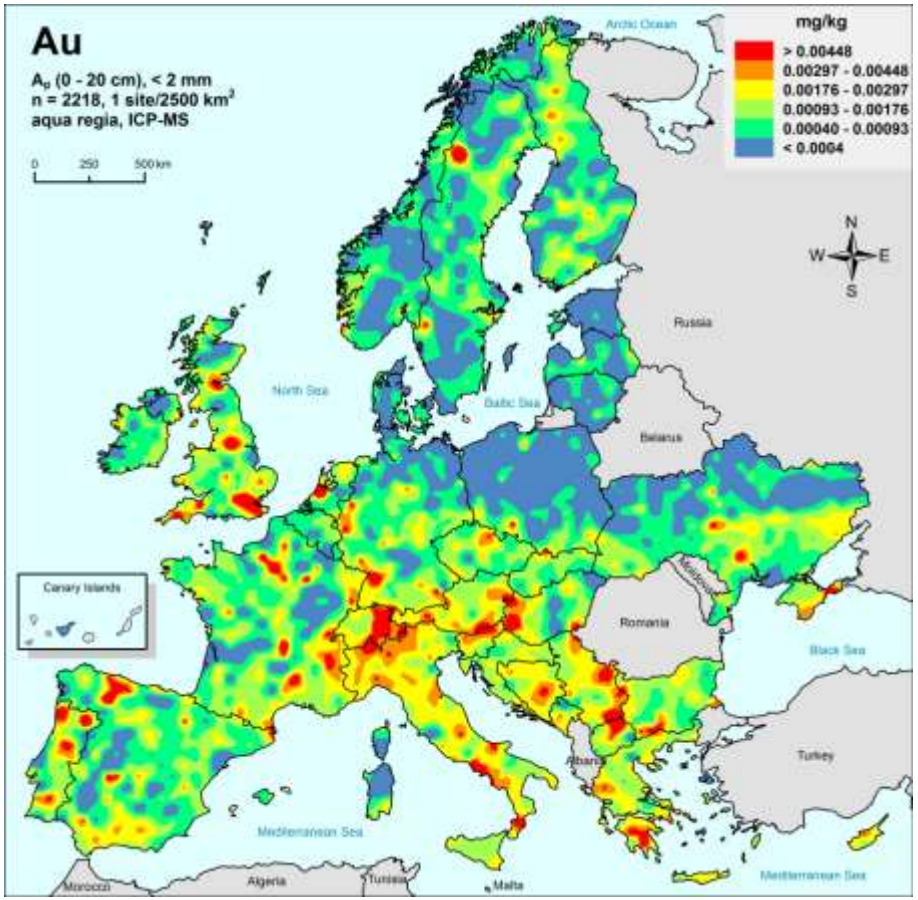
The mineral system model (Knox-Robinson &Wyborn 1997)

GEMAS: mineral exploration

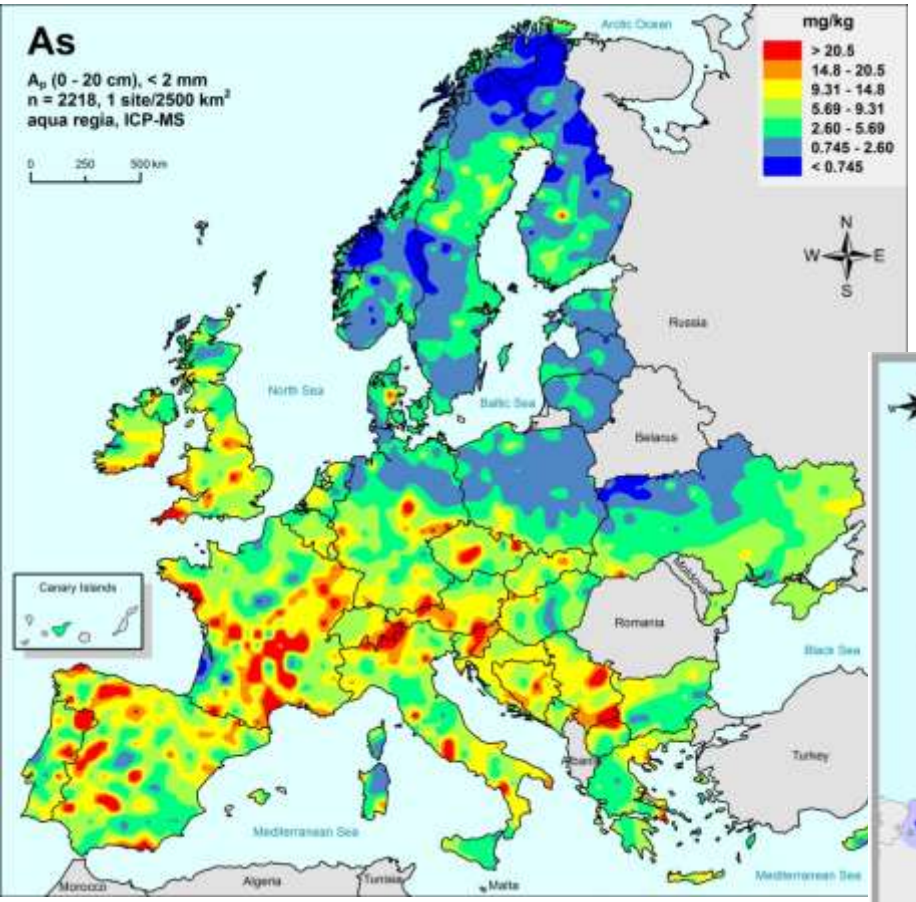
Mo: interesting anomalies in northern Europe – indications for ore deposits?



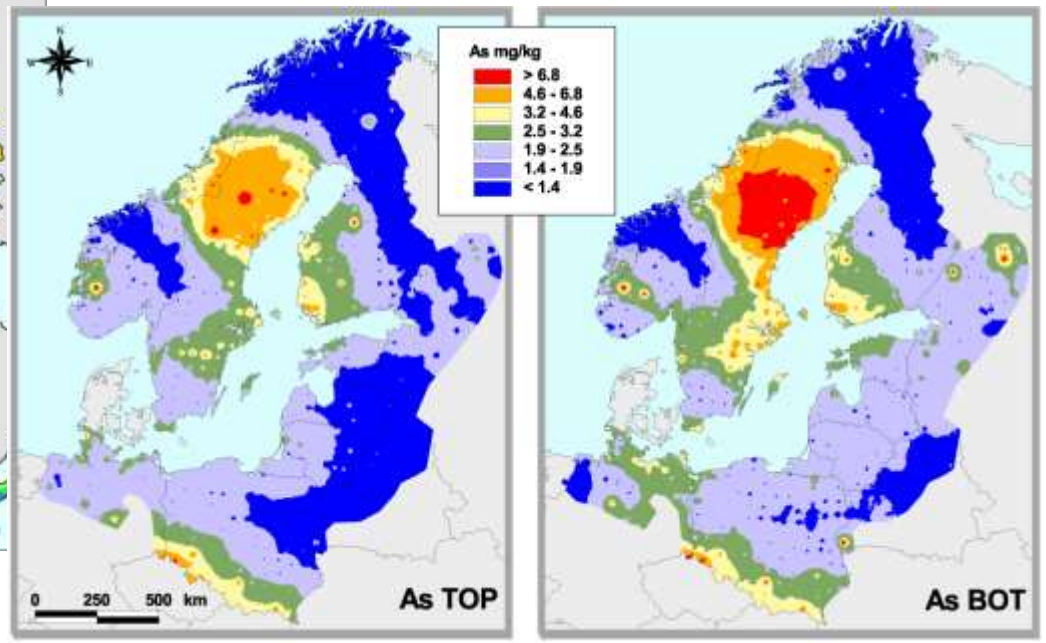
Au: the „gold line“ in Scandinavia is visible



GEMAS: mineral exploration



Arsenic: central Scandinavia - since 2003 eleven new massive sulfide deposits were found along the fringes of this 200.000 km^2- anomaly– the pattern is underlain by a heat flow anomaly

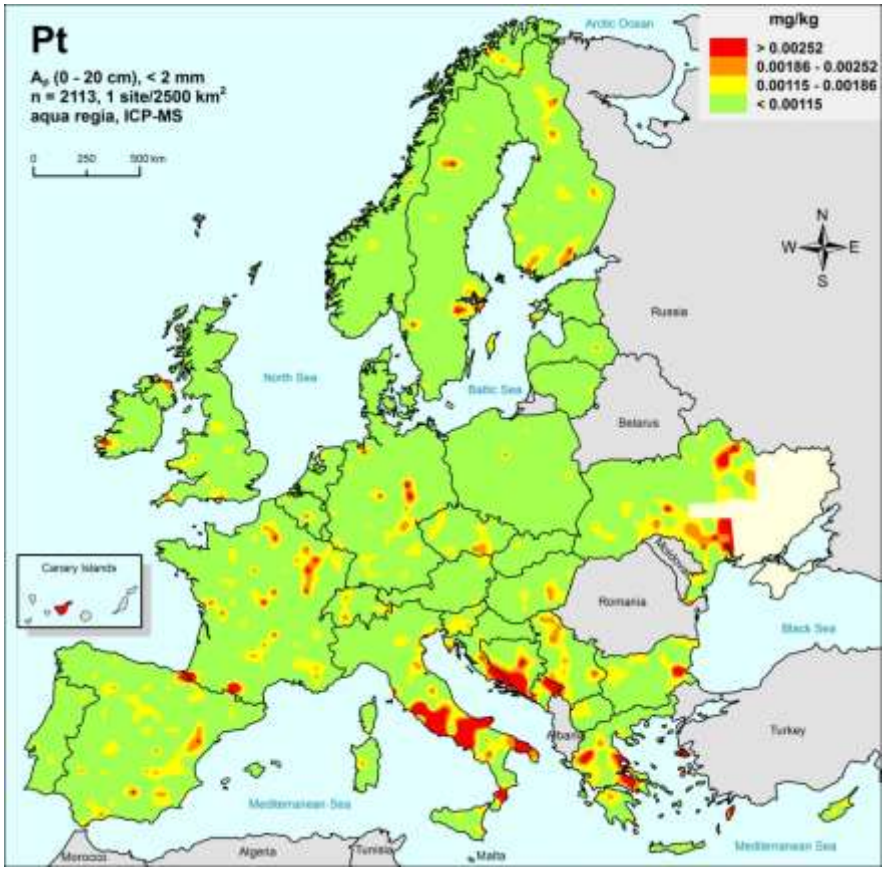


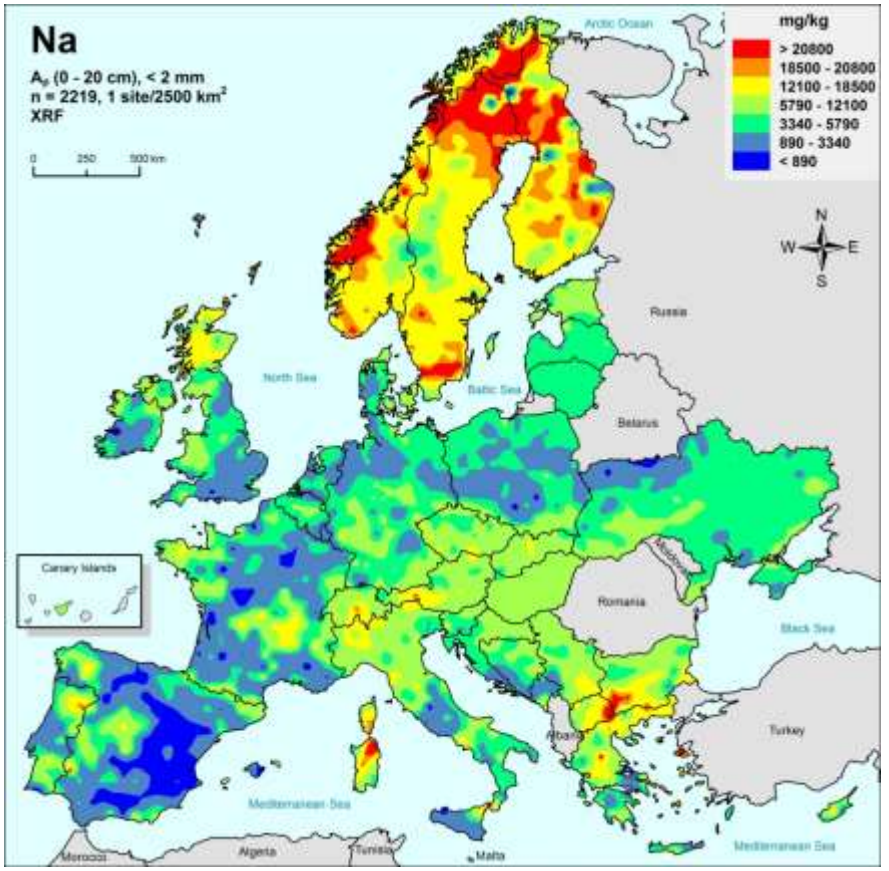
Source: Baltic Soil Survey, Reimann et al. 2003

GEMAS: mineral exploration

Pt: Italian alkaline volcanic province causes the largest anomaly

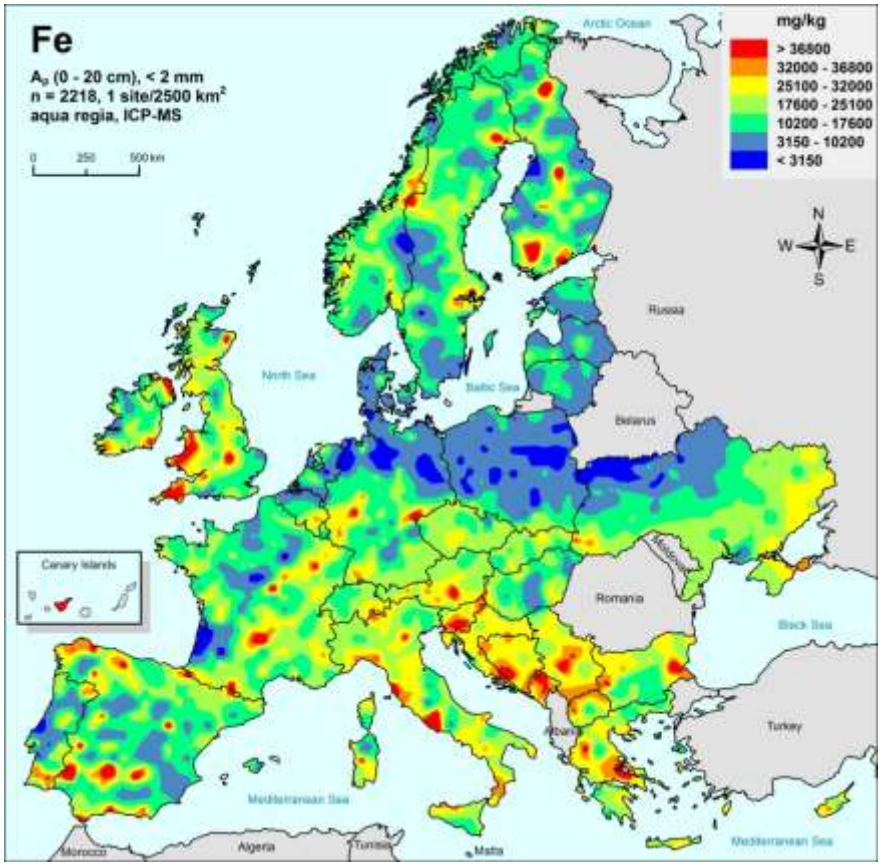
Na: displays a major anomaly in N-Scandinavia, in the most prospective area



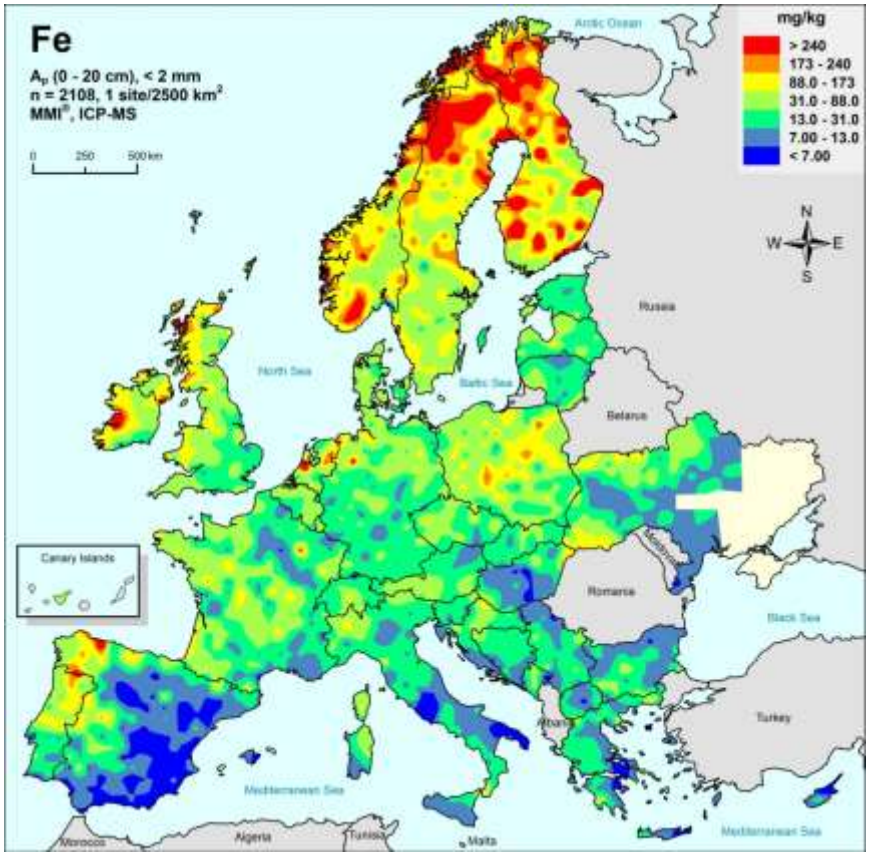


GEMAS: mineral exploration

Aqua regia Fe: no sign of the major iron ore provinces in N-Europe

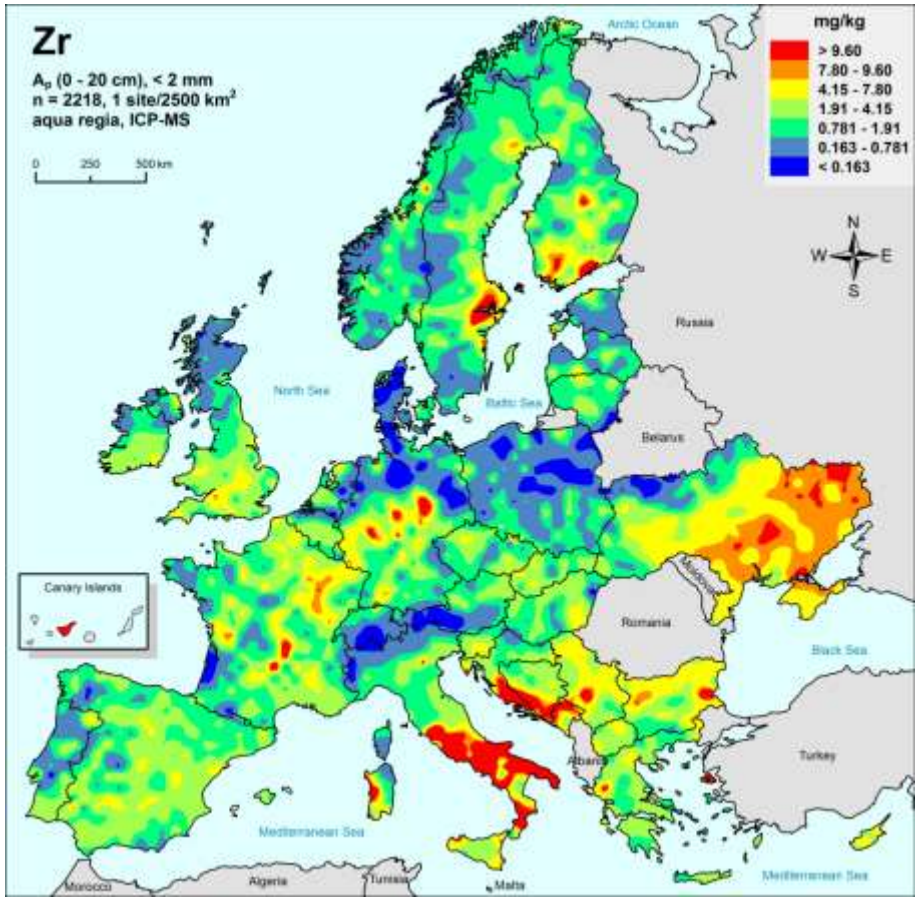


MMI-available Fe: a major anomaly in N-Scandinavia

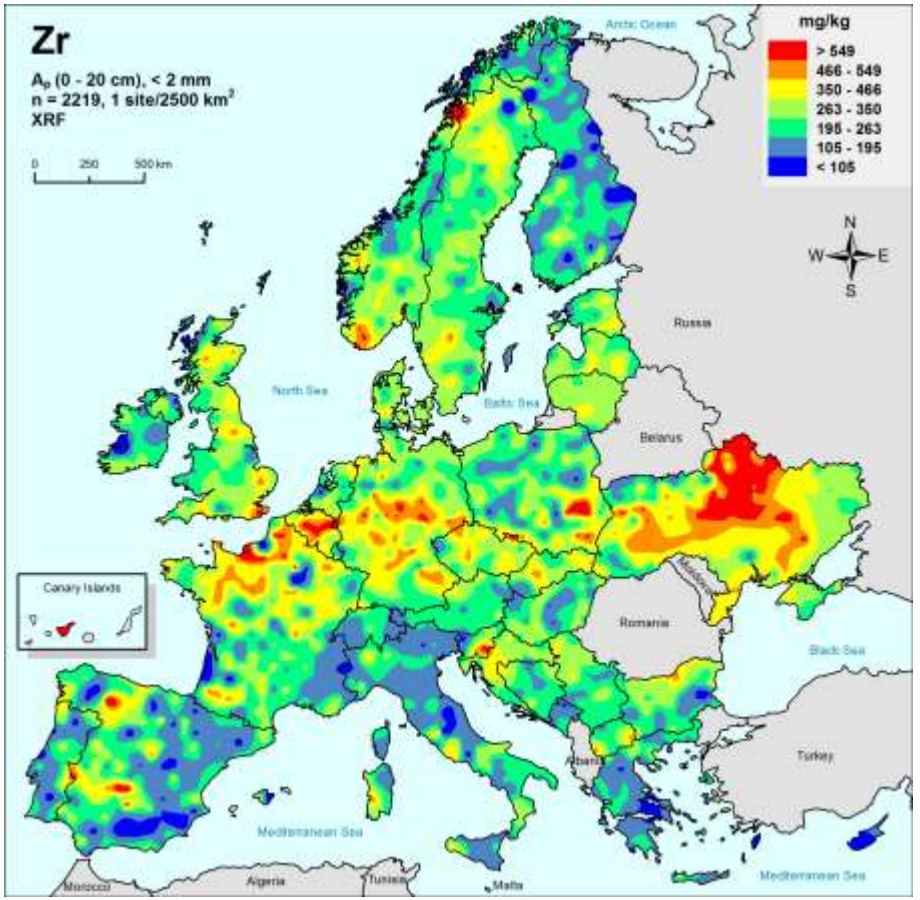


GEMAS: different analytical methods

Zr (aqua regia): note the Italian alkaline volcanics



Zr (XRF): the central European loess belt is visible



Pinatubo eruption in 1991

within 2 days:

10,000,000,000 t magma

20,000,000 t SO_2

2,000,000 t Zn

1,000,000 t Cu

550,000 t Cr

300,000 t Ni

100,000 t Pb

10 ,000t As

5,500t Cd

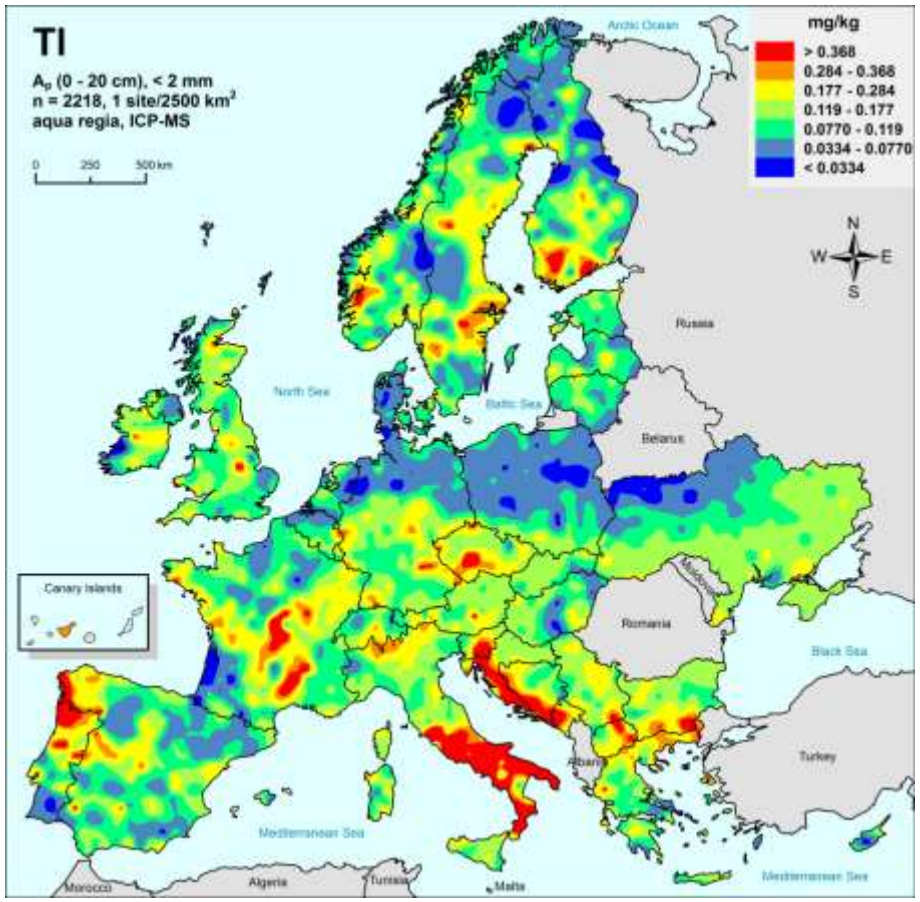
800t Hg

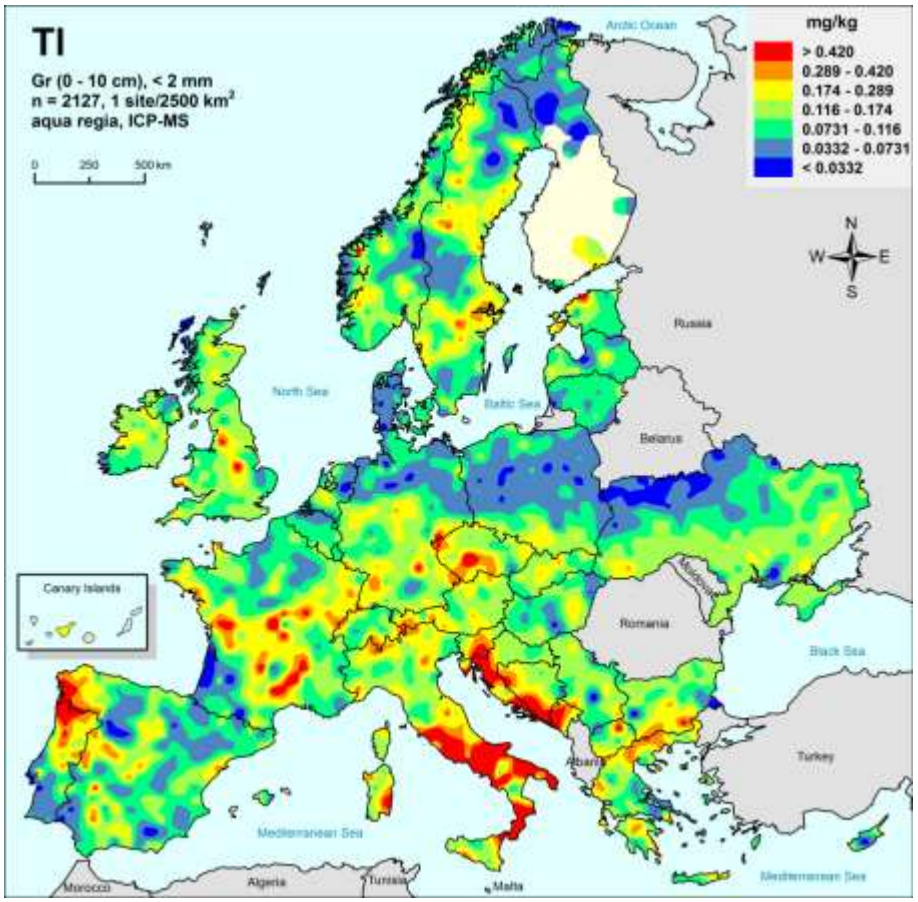
60 volcanic eruptions per day

>3000 active vent fields at mid- ocean ridges

Photo: ©Daniela Szczepanski

GEMAS: volcanic impact

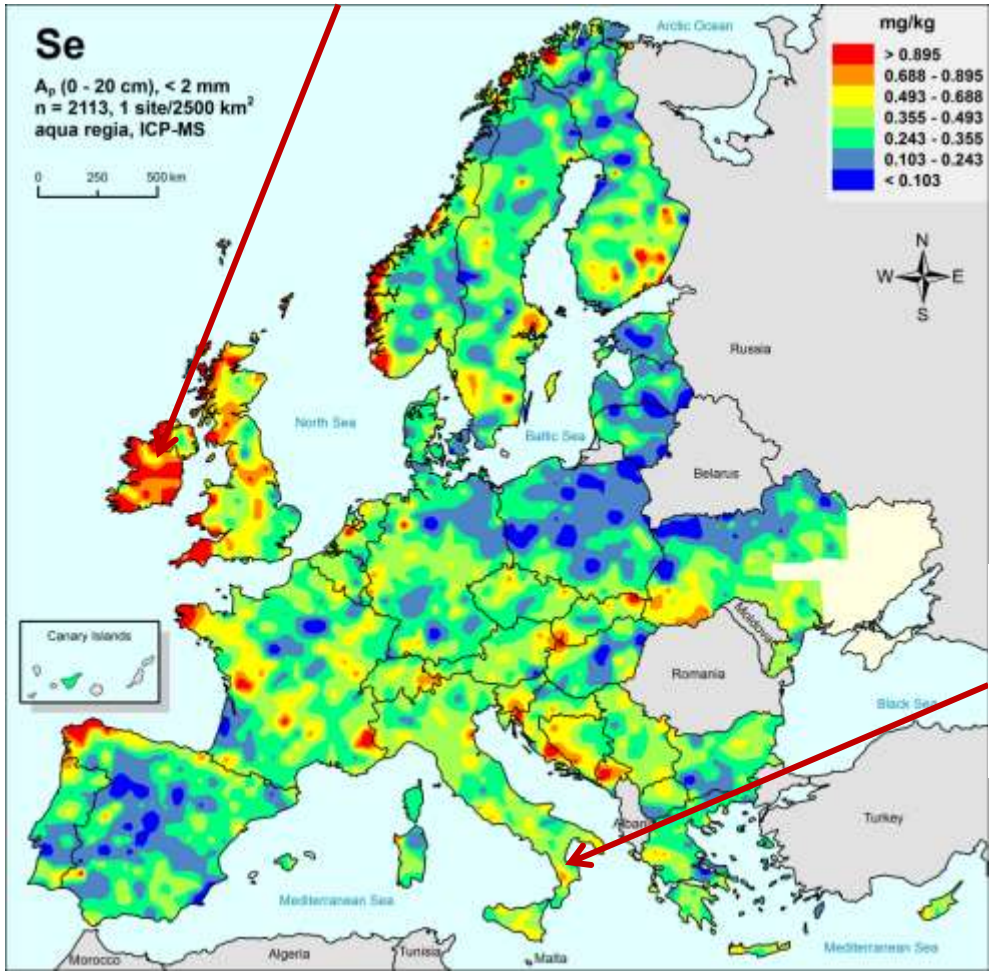




Tl (aqua regia): note the Italian alkaline volcanic province

Selenium: health aspects

Selenosis in Limerick (cattle, horses)



Se deficiency is widespread in Finland, Sweden, Denmark

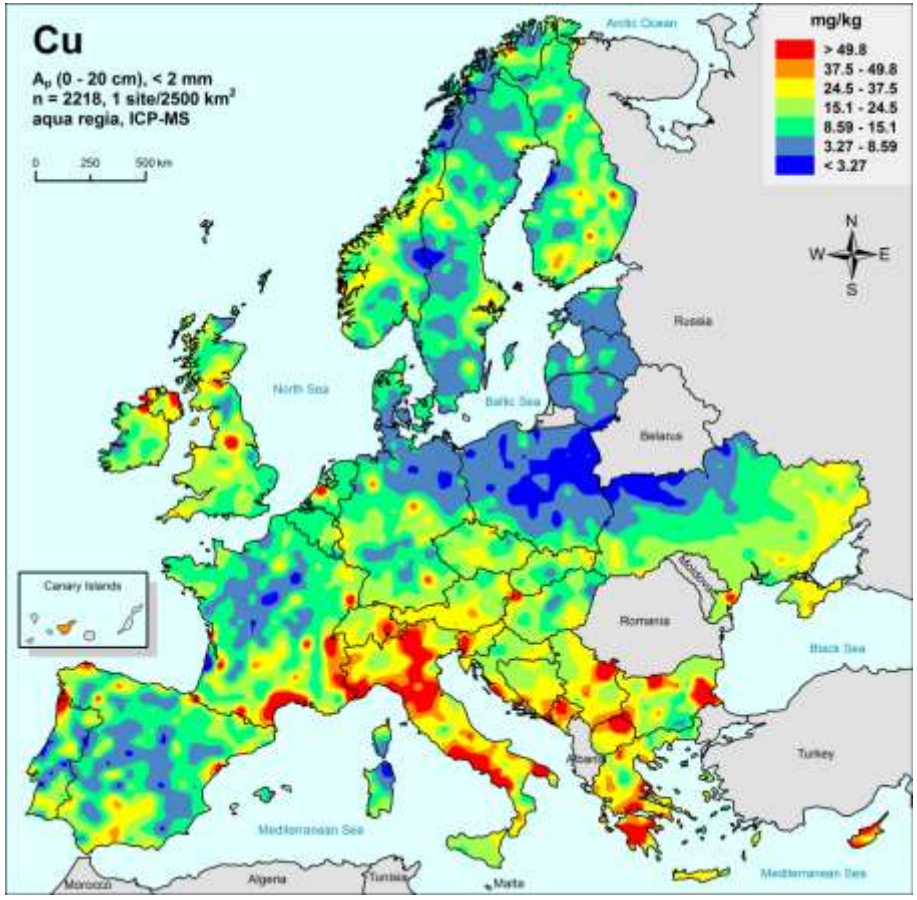
Se toxicity is more of a problem in animal husbandry

Se toxicity in drinking water (Reggio)

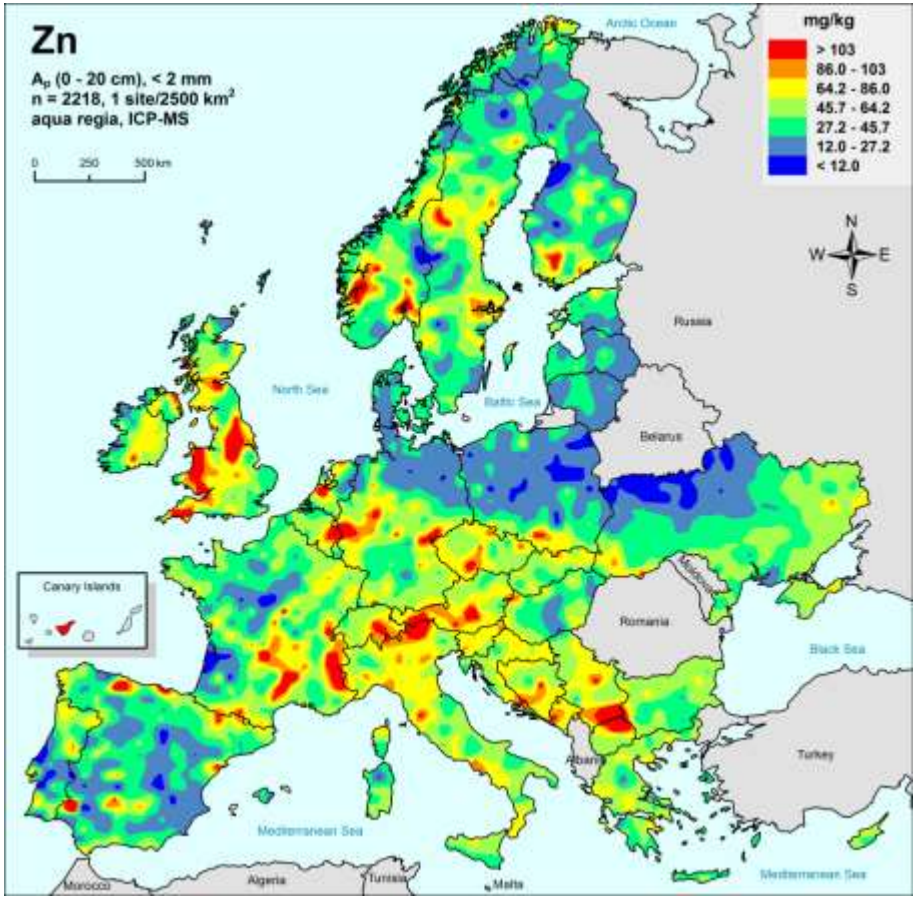
Practically no anthropogenic impact detected (note Finland!)

GEMAS: element deficiency

Copper (aqua regia): >10% of all values <10 mg/kg



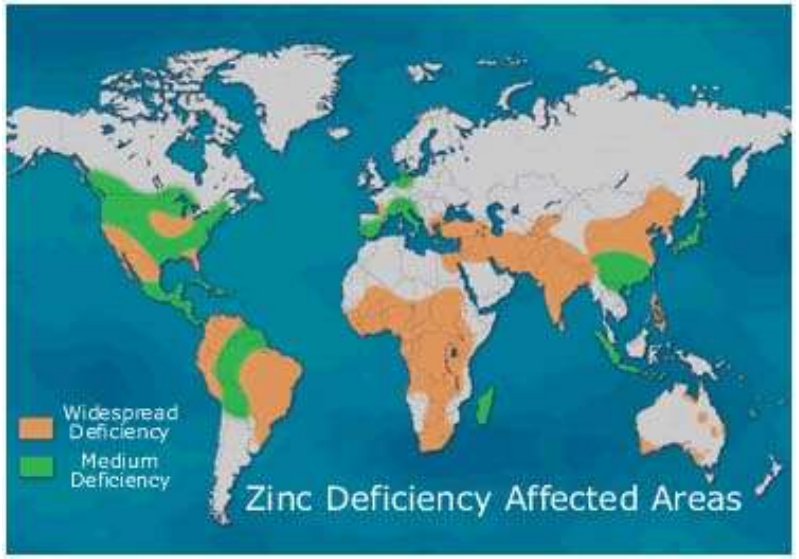
Zinc (aqua regia): 5% of all values <12 mg/kg



Zinc

- Zinc (Zn) is an essential micronutrient
- Zinc deficiency is widespread in soil

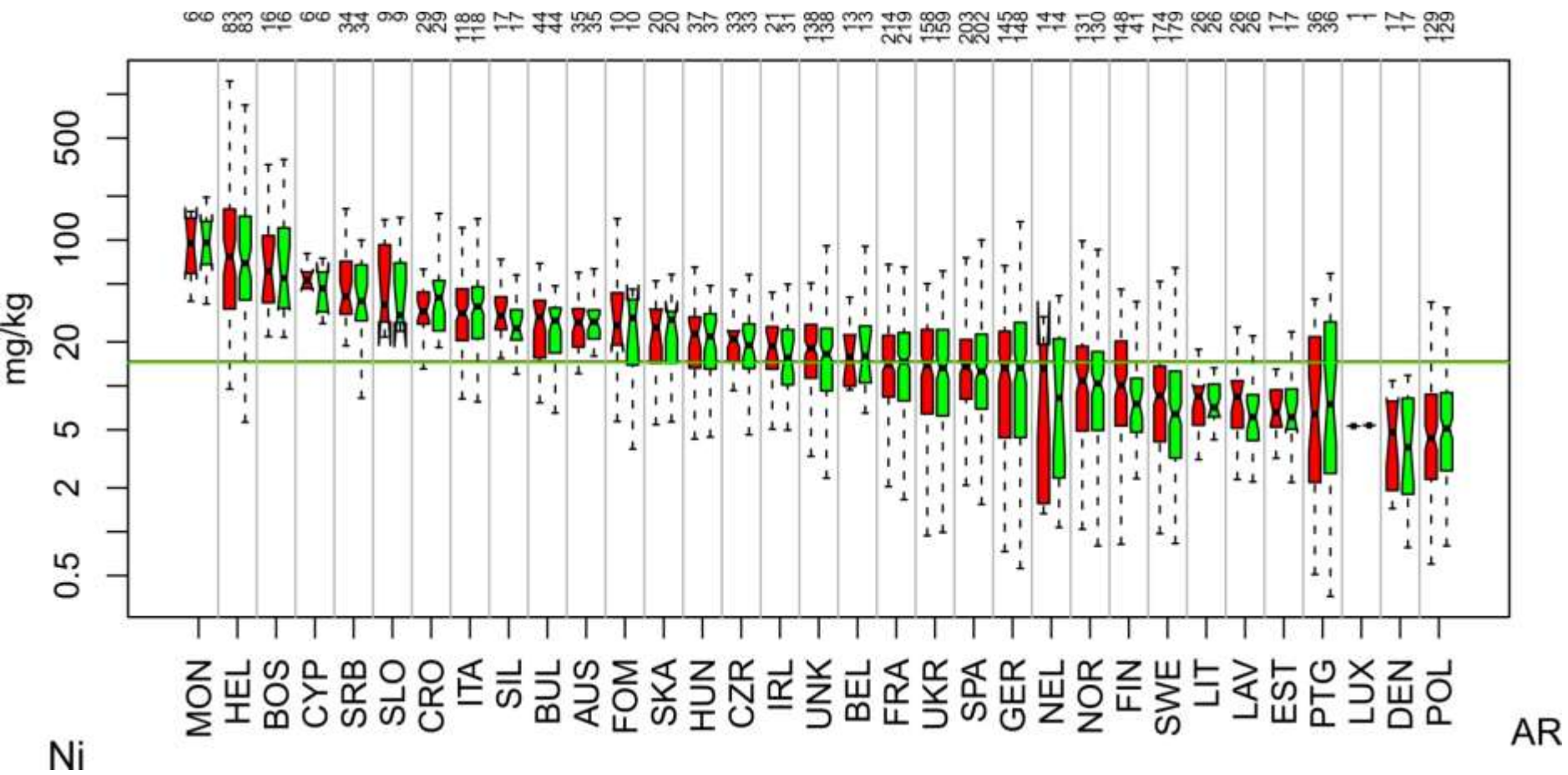
Nearly 50% of the soil on which cereals are grown have levels of available Zn low enough to cause Zn deficiency – <1% of the samples reach possibly toxic values



Source: Alloway (2008)

Zinc deficiency symptoms in plants

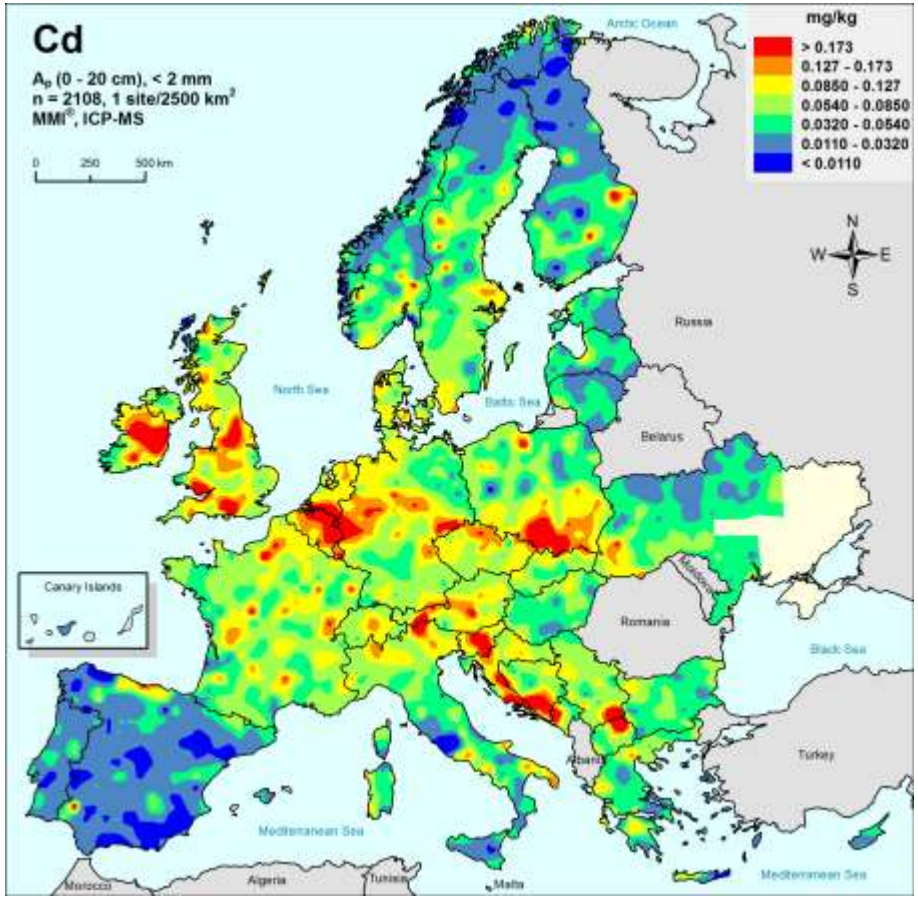
GEMAS: political decision making



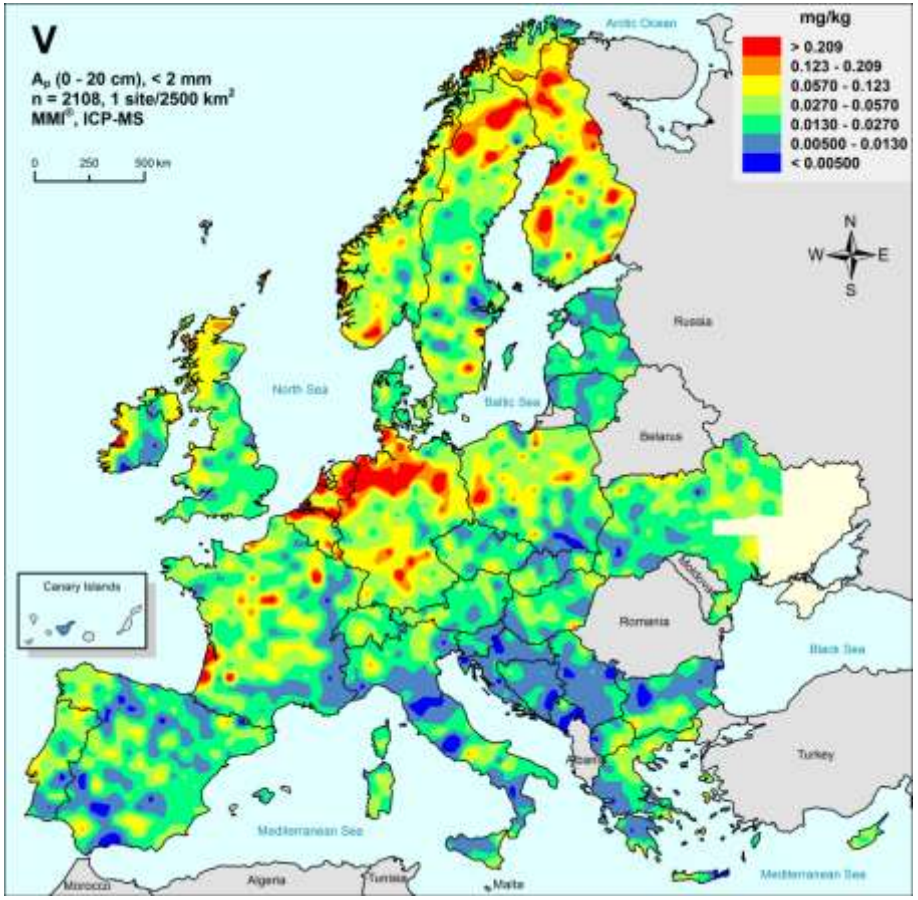
Boxplot comparison of nickel concentrations (aqua regia) in the participating countries (red: Ap, 0-20 cm; green: Gr, 0-10 cm)

GEMAS: anthropogenic impact

Cd (MMI extraction): anthropogenic pressure becomes visible



V (MMI extraction): input via sewage sludge? (+ Fe deposits in Scandinavia)



GEMAS: the most recent results

GEMAS Ap samples:
Magnetic measurements at Kazan Federal University, Tartastan, Russia - magnetic measurements provide an extremely detailed picture of the iron mineralogy which in soils is a sensitive fraction indicating lithology and environmental conditions

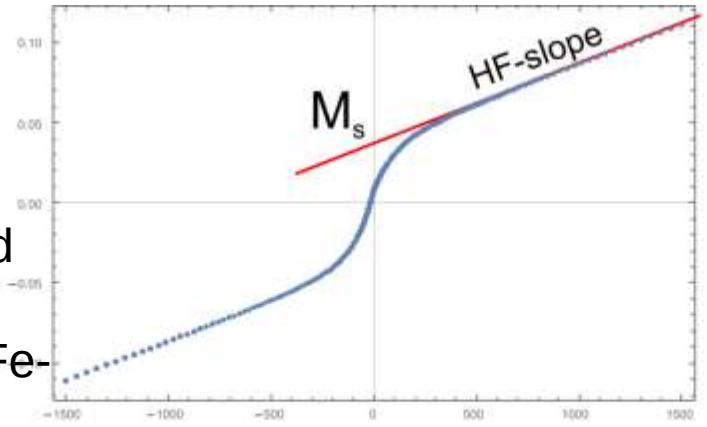
Acquired data
- Magnetic susceptibility
- Magnetic hysteresis curves up to 1.5 T
- Magnetic remanence acquisition up to 1.5 T

The measured data provide many different magnetic parameter sets that can be mapped.

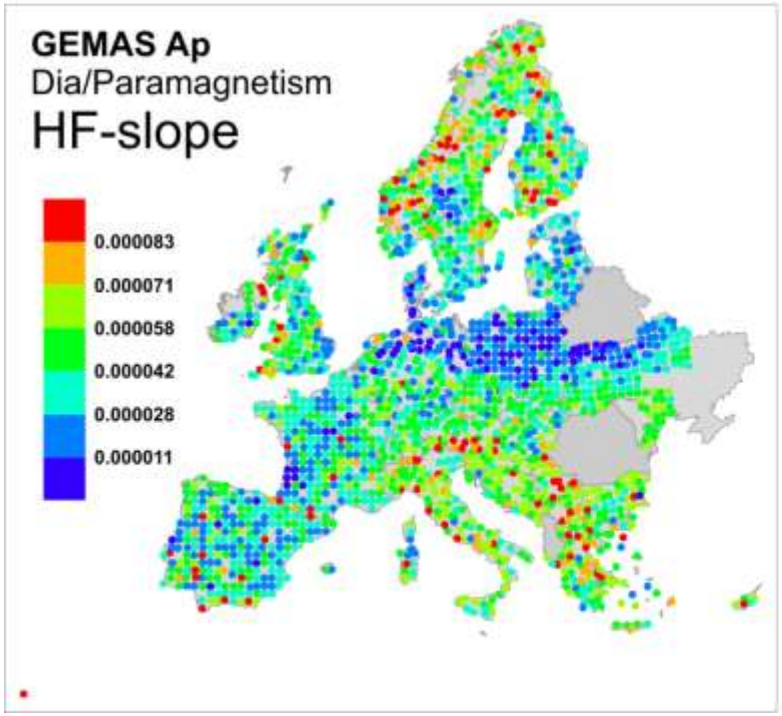
Fascinating maps are emerging, demonstrating that low density sampling & mapping functions not only for geochemistry

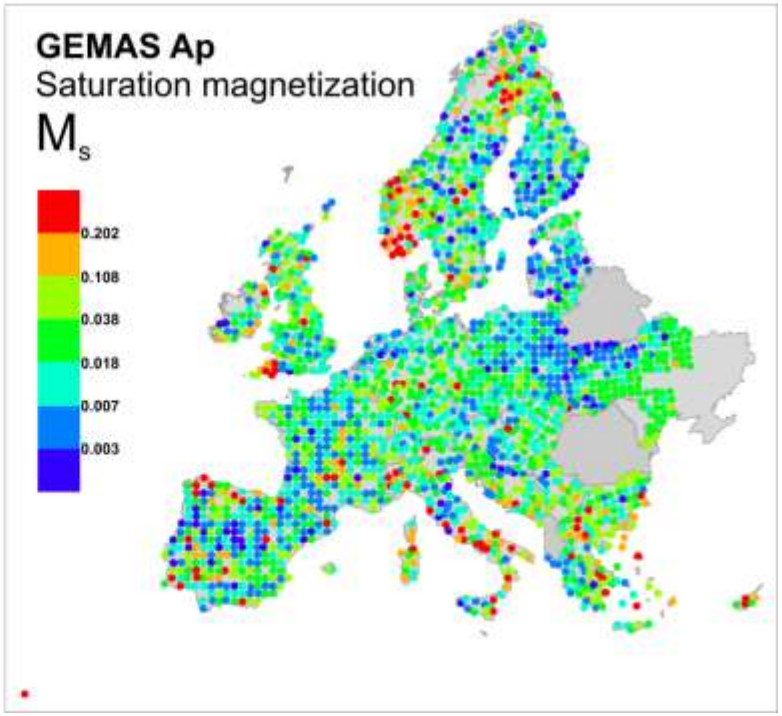
GEMAS Project - new data

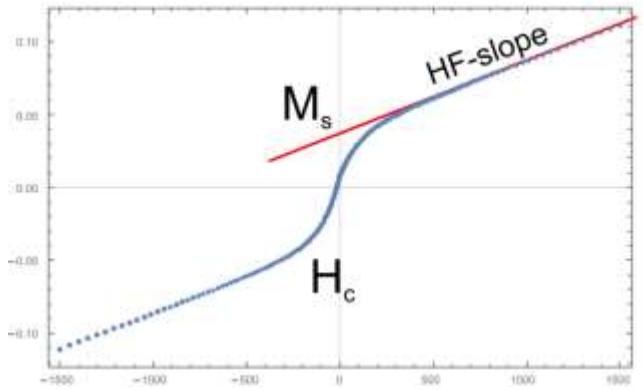
High field slope indicates the dia/paramagnetic minerals; it is probably dominated by non-ferrimagnetic Fe-minerals

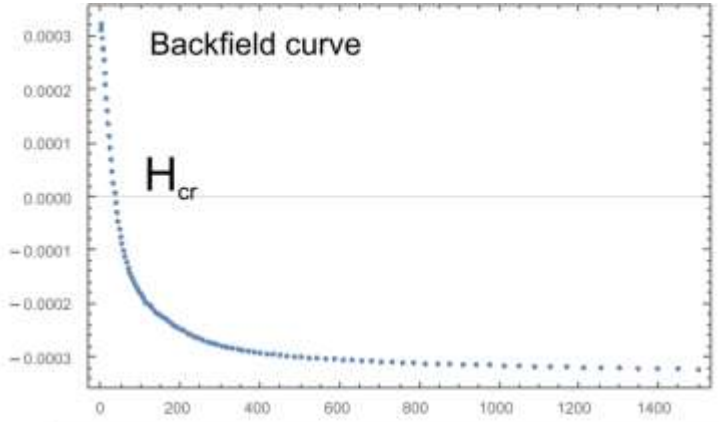


Saturation magnetization Ms reflects the ferrimagnetic mineral concentration; it is probably dominated by magnetite-titanomagnetite content

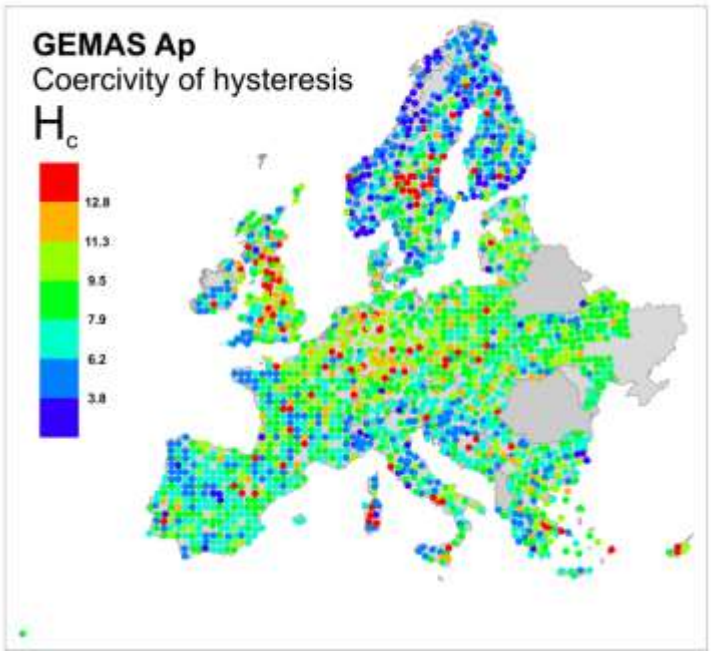


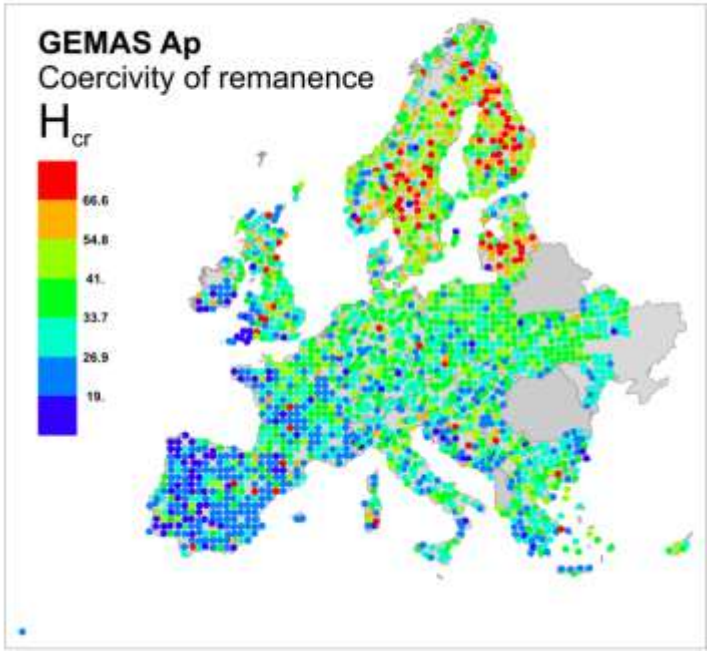






GEMAS Project - new data



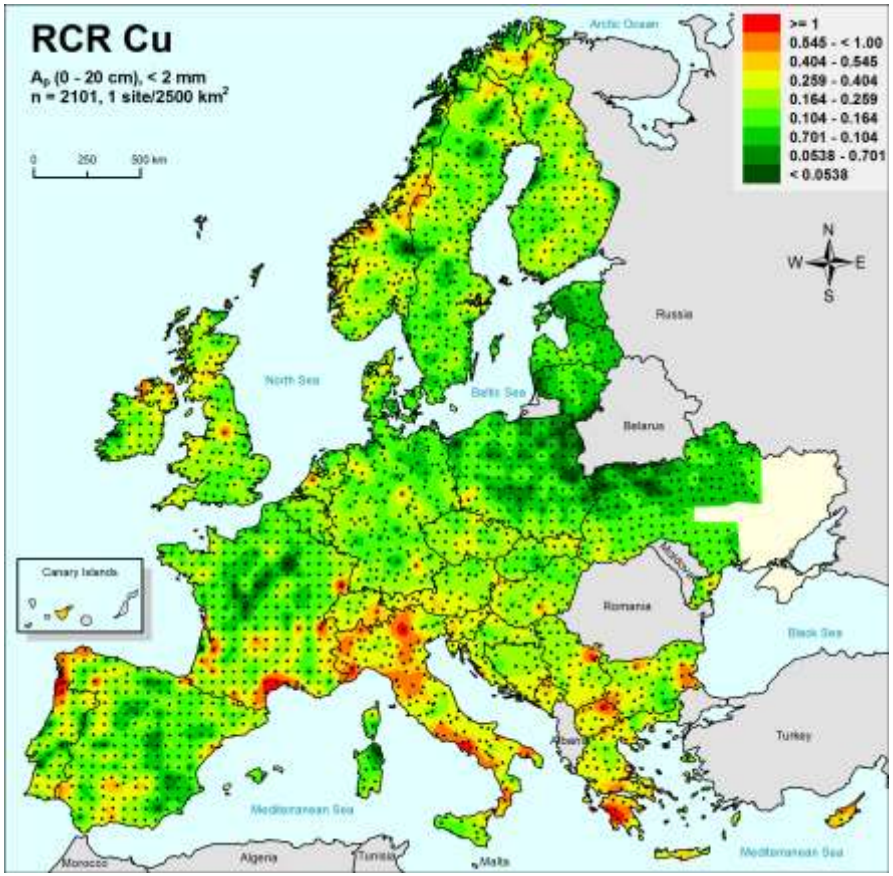


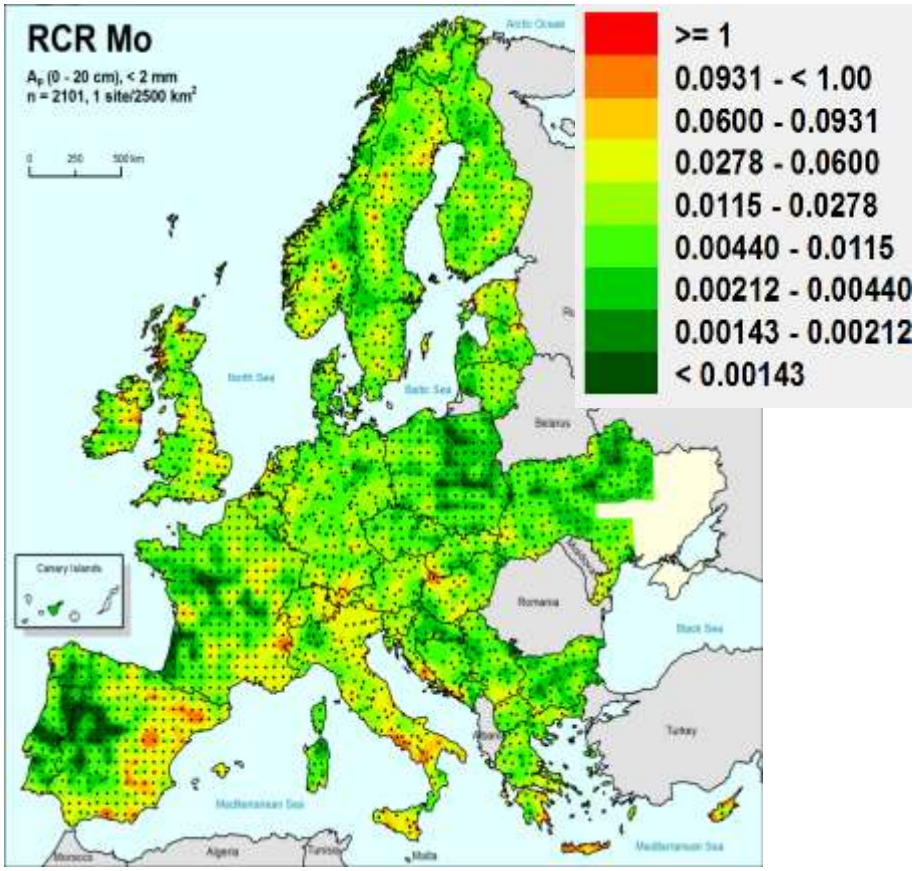
Hc and Hcr are intensive quantities (independent of material concentration) - they reflect the average magnetic hardness of the ferrimagnetic phase (Hc) and the remanence carriers (Hcr).

GEMAS: risk assessment

Cu (Ap): 1.3% of samples at risk (RCR>1) – mostly soil in vineyards

Mo (Ap): only 1 site at risk – location of Europe's largest Mo deposit



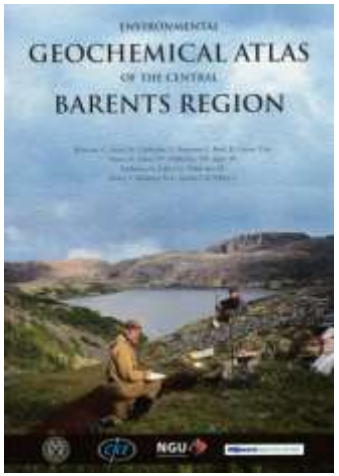


GEMAS: some key results

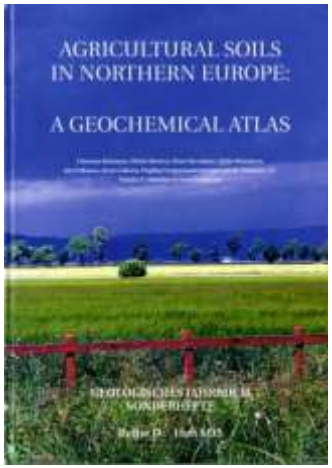
- Evidence for diffuse industrial contamination?
- Evidence of other anthropogenic impacts?
- What levels of potentially harmful elements?
- Element deficiencies?
- Differences between the European countries?
- Geology and/or climate reflected?
- Consequences for mineral exploration?

Successful Large Scale Mapping Projects

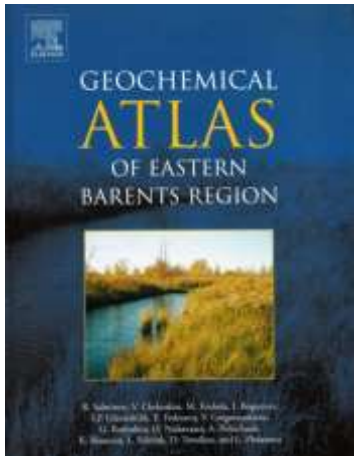
1992



1998

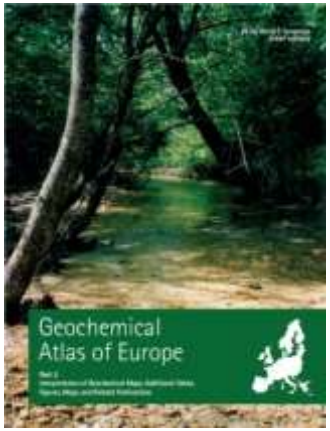


2003



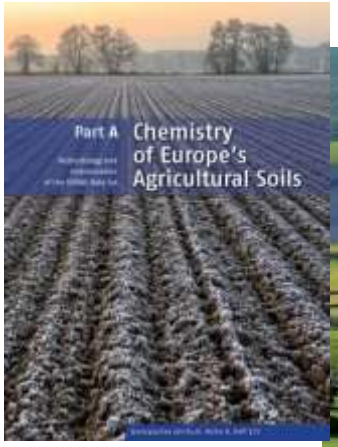
2004

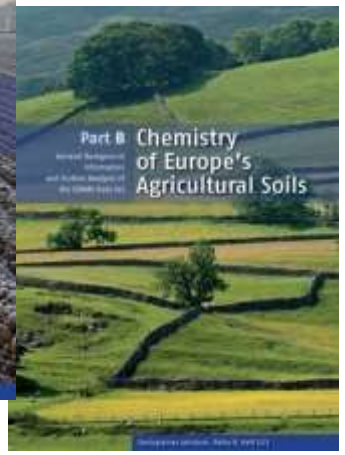
2005



2006

2010





2014

Thank you for your attention!

GEMAS
Geochemical Mapping of Agricultural and Grazing Land Soil in Europe

EUROMETAUX
EUROPEAN ASSOCIATION OF METALS

EuroGeoSurveys
European Geoscience for Society
The Geological Surveys of Europe