SEGH Society for Environmental Geochemistry and Health Live

SEGHLive: Fellowship Seminars

GEMAS:

Geochemistry of Agricultural and Grazing land soil for healthy food production in Europe

Alecos (Alexandros) Demetriades, BSc(Hons), MSc, PhD, FAAG

and

*The GEMAS Project Team**

**The GEMAS Project Team*: S. Albanese, M. Andersson, R. Baritz, M.J. Batista, B. Flem, A. Bel-lan, M. Birke, D. Cicchella, B. De Vivo, W. De Vos, E. Dinelli, M. Ďuriš, A. Dusza-Dobek, O.A. Eggen, M. Eklund, V. Ernstsen, P. Filzmoser, D.M.A. Flight, S. Forrester, M. Fuchs, U. Fügedi, A. Gilucis, M. Gosar, V. Gregorauskiene, W. De Groot, A. Gulan, J. Halamić, E. Haslinger, P. Hayoz, R. Hoffmann, J. Hoogewerff, H. Hrvatovic, S. Husnjak, L. Janik, G. Jordan, M. Kaminari, J. Kirby, J. Kivisilla, V. Klos, F. Krone, P. Kwećko, L. Kuti, A. Ladenberger, A. Lima, J. Locutura, D. P. Lucivjansky, A. Mann, D. Mackovych, J., Matschullat, M. McLaughlin, B.I. Malyuk, R. Maquil, R.G. Meuli, G. Mol, P. Négrel, P. O'Connor, R.K. Oorts, R.T. Ottesen, A. Pasieczna, W. Petersell, S. Pfleiderer, M. Poňavič, S. Pramuka, C. Prazeres, U. Rauch, S. Radusinović, C. Reimann, M. Sadeghi, I. Salpeteur, R. Scanlon, A. Schedl, A.J. Scheib, I. Schoeters, P. Šefčik, E Sellersjö, F. Skopljak, I. Slaninka, A. Šorša, R. Srvkota, T. Stafilov, T. Tarvainen, V. Trendavilov, P. Valera, V. Verougstraete, D. Vidojević, A. Zissimos and Z. Zomeni.

Presentation structure

- GEMAS project objective
- Participating countries
- Requirements for the development of uniform and homogeneous pan-European geochemical databases
- Kick-off meeting and testing of field methods; Final version of Field Manual; Collected Agricultural and Grazing land soil samples
- Sample preparation
- Laboratory analyses
- Quality Control Reports
- Results (Median differences; Robust patterns; Impact of geology & climate; Risk assessment; Health implications; European Black Soil region)
- The GEMAS Periodic Tables
- Final advice for early-career researchers
- References
- Abstract

GEMAS project objective: To produce a land-use related geochemical database needed at the European scale for the REACH regulation (***R**egistration, **E**valuation, **A**uthorisation and restriction of **CH**emical substances*) by the companies of the European Association of Metals (Eurometaux). REACH addresses the production and use of chemical substances, and their potential impacts on both human health and the environment.

Eurometaux companies submitted their dossiers to the European Chemicals Agency (ECHA), for examination and approval, as they had to prove that their chemical products (imported or produced) do not present any risk to human health and the environment in their use in agricultural and animal rearing.


Grazing land soil, 0-10 cm


Agricultural soil (A_p-horizon), 0-20 cm

GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe

First step was to secure the participation of European countries in the GEMAS project.

33 Countries participating:

Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, F.Y.R.O.M., Germany, Hellas, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Montenegro, The Netherlands, Norway, Poland, Portugal, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine and The United Kingdom

Source: Birke *et al.*, 2014, Fig. 10.1, p.94

EuroGeoSurveys
European Geoscience for Society
The Geological Surveys of Europe

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

ARCHE
ASSESSING RISKS OF CHEMICALS

International ANTIMONY Association

MFGI

RioTinto

EBA

epmf

GSI

LNEG
Laboratório Nacional de Energia e Geologia, I. P.

GeoZS

GTK

REACH Selenium & Tellurium Consortium

skog+landskap
NORSK INSTITUTT FOR SKOG OG LANDSKAP

Państwowy Instytut Geologiczny
Państwowy Instytut Badawczy

museum

CYPRUS GEOLOGICAL SURVEY 1955

GEUS

Geoscience for a sustainable Earth
brgm

BGR

Instituto Geológico y Minero de España

GEOLOŠKI ZAVOD
Geological Survey of Montenegro

BWG
OFEG
UFAEG
UFAEG
FOWG

LIETUVOS GEOLOGIJOS TARNYBA
LITHUANIAN GEOLOGICAL SURVEY

EESTI GEOLOOGIAKESKUS OÜ
GEOLOGICAL SURVEY OF ESTONIA

TU WIEN

ALTERRA
WAGENINGEN UR

BGS 1835
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

CSIRO

ПІВНІЧ ГЕОЛОГІЯ

LATVIJAS VIDES, ĢEOLOĢIJAS UN METEOROLOĢIJAS AĢENTŪRA

HGI 1909
HRVATSKI GEOLOŠKI INSTITUT
CROATIAN GEOLOGICAL SURVEY

SGL
Service Géologique du Luxembourg

NABO
Nationale Bodenbeobachtung
Observatoire national des sols
Osservatorio nazionale dei suoli
Swiss Soil Monitoring Network

SGU
Sveriges Geologiska Undersökning
Geological Survey of Sweden

Università degli Studi del Sannio

ŠTÁTNY GEOLOGICKÝ ÚSTAV DIONÝZA ŠTÚRA

GEOLOGICAL INSTITUTE OF SERBIA

INSTITUTE OF GEOLOGY & MINERAL EXPLORATION
I.G.M.E

A.D. 1088

NGU
Norges geologiske undersøkelse
Geological Survey of Norway

In total, 72 scientists participated in the GEMAS project.

If the supporting staff is added, then the number exceeds 100 persons.

DEVELOPMENT OF UNIFORM AND HOMOGENEOUS PAN-EUROPEAN GEOCHEMICAL DATABASES demands the standardisation and harmonisation of all procedures, namely:-

- Vital sampling equipment to be purchased centrally and distributed to all participating countries.
- Sampling procedure to be tested in the field before finalisation, and the compilation of a Field Sampling Manual.
- Preparation of two large reference samples (agricultural & grazing land soil).
- Sample preparation of all collected samples at the same laboratory.
- Randomisation of samples and insertion of quality control samples.
- Chemical analysis of all samples to be performed by exactly the same methodologies at the same laboratory.
- Upon receipt of the analytical data sets, their quality is first verified, and a quality control report is compiled. Encountered problems must be reported, and the solutions given.

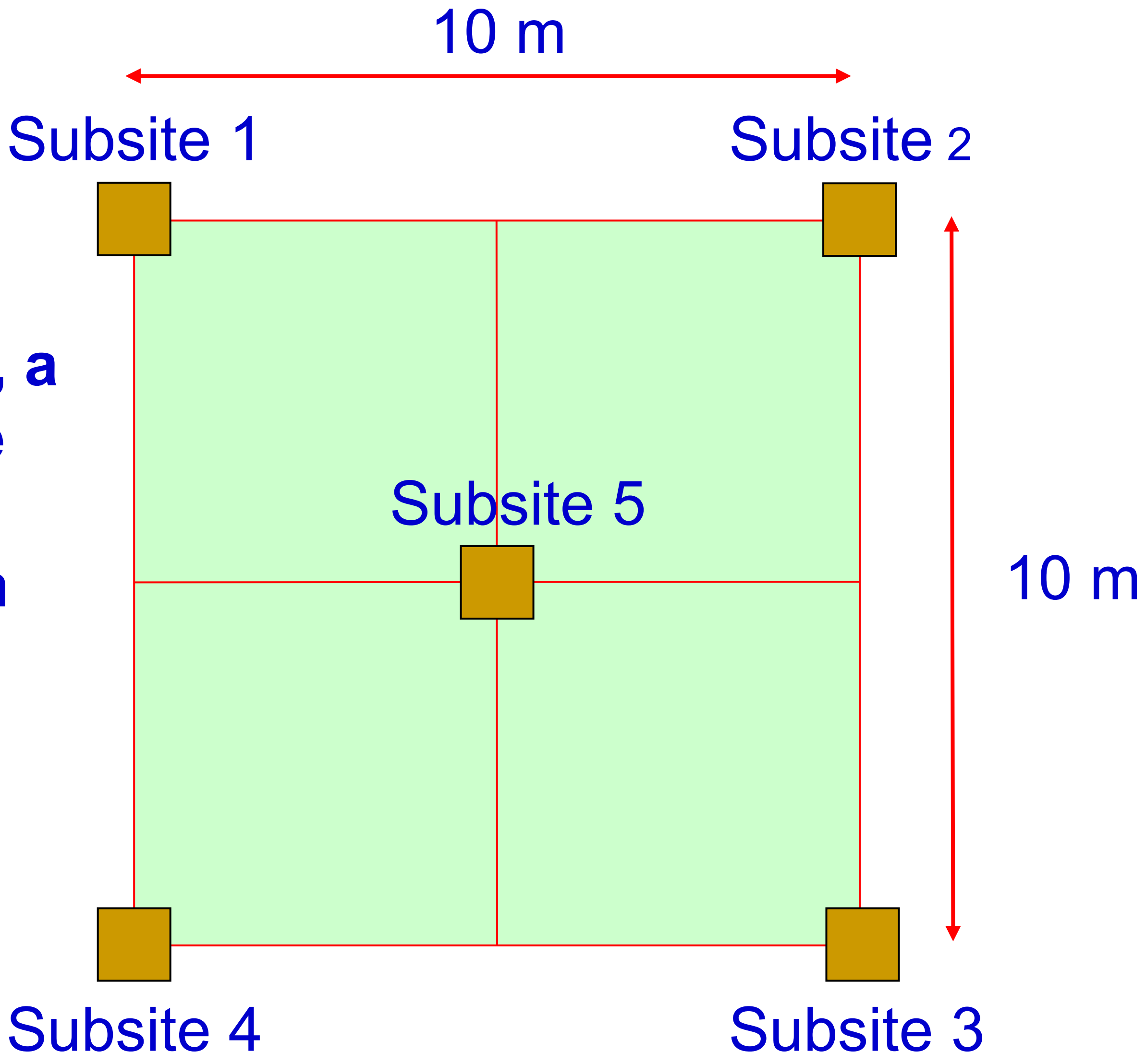
FIELD and KICK-OFF MEETING
Berlin, Germany, March 2008

During this meeting, the draft copy of the field sampling manual was finalised, and other important project management decisions were taken.

FIELD MEETING
Berlin, Germany, March 2008

Clemens Reimann is reading the instructions from the first draft of the Field Manual and Tore Volden is carrying out the sampling

COMPOSITE SAMPLING SCHEME
for agricultural and grazing land soil



At each site, a composite sample is made from 5 subsites

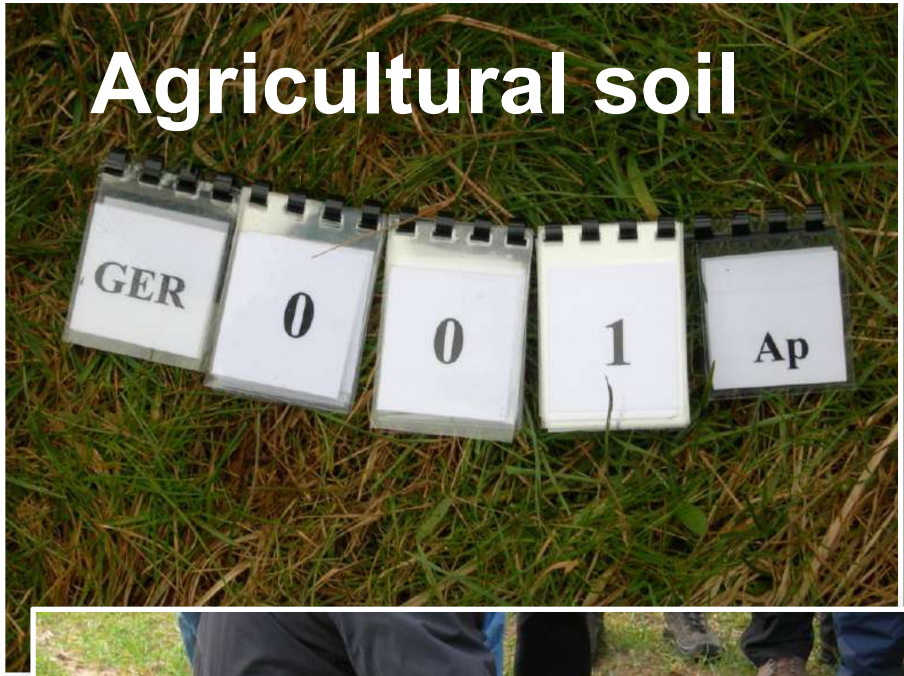
The soil samples were inserted directly into the Rilsan® bags in the field, and the bags were securely closed with a zip-lock strap immediately after collection. The provided Rilsan® bags hold 2 - 2.5 kg of soil.

Duplicate field samples

At every 20^{th} sample site, a duplicate agricultural and grazing land soil sample was collected from the same plot of land, but from different sub-sites.

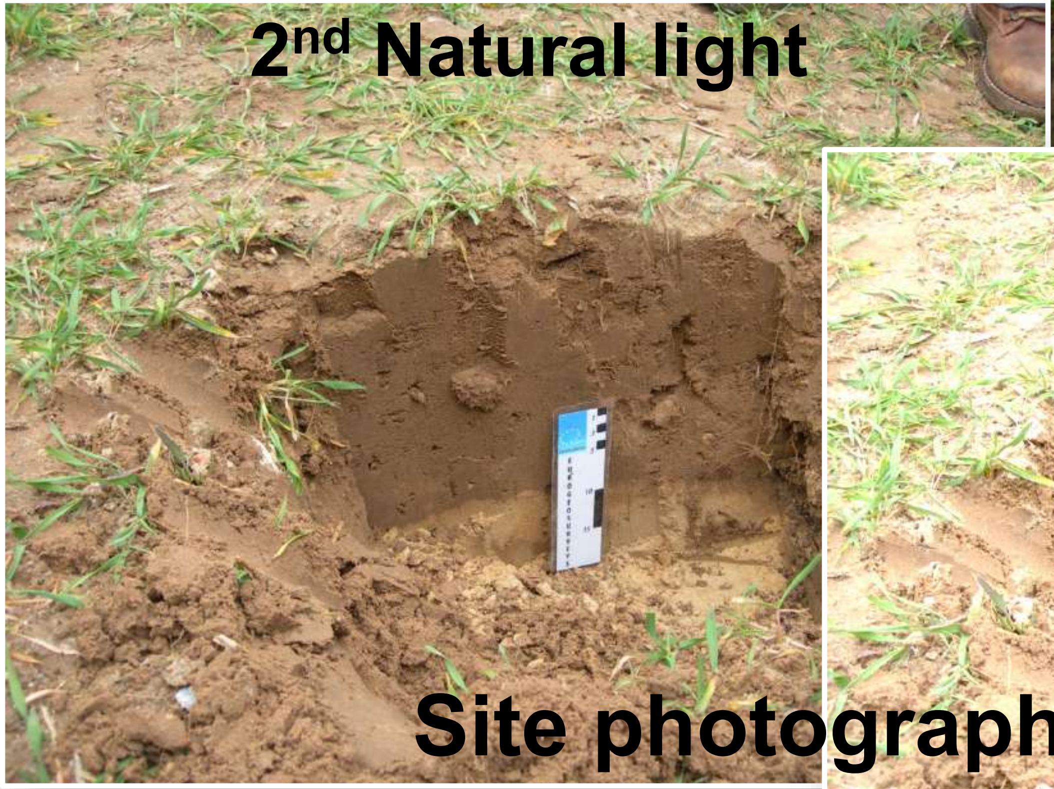
Agricultural soil

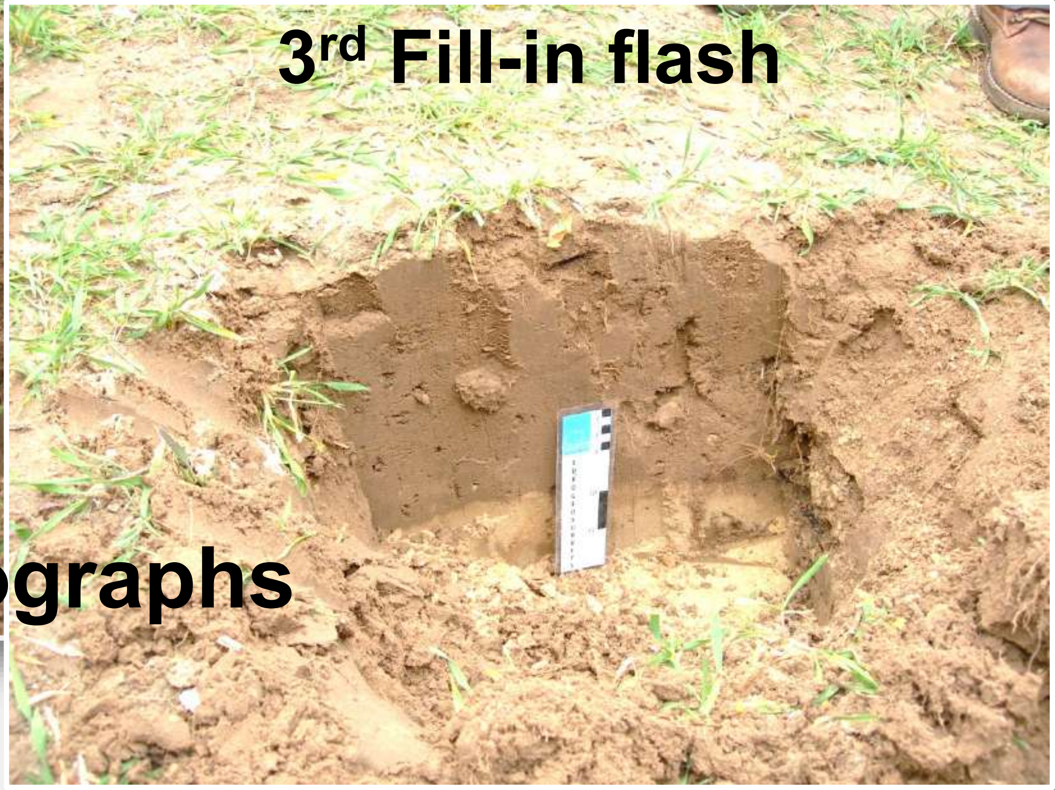
Agricultural soil



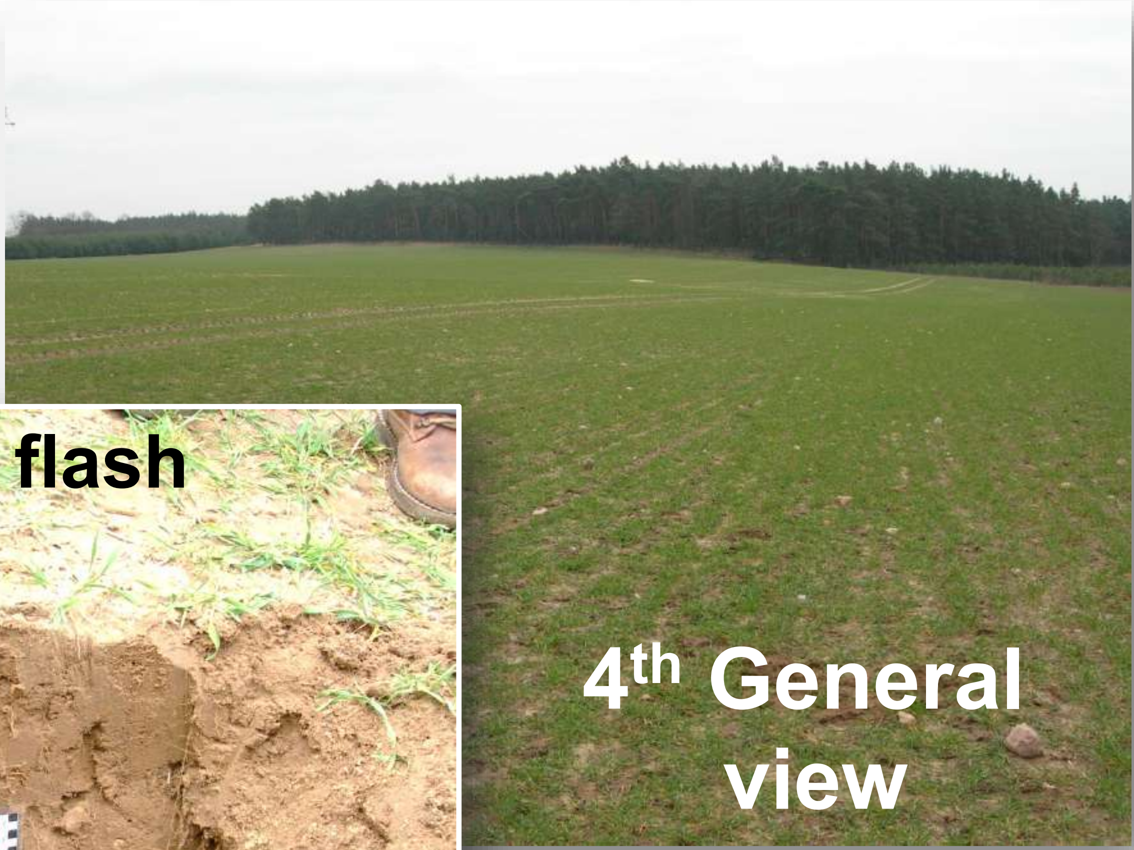
Photographic documentation of each sampling site

1st





Site photographs



Photographs taken in the same order

Grazing land soil (0-10 cm) photographs

1st

2nd Natural light

3rd Fill-in flash

Site photographs

4th close-up of vegetation

5th General view

EuroGeoSurveys GEMAS – GEOCHEMICAL MAPPING OF AGRICULTURAL AND GRAZING LAND SOIL IN EUROPE

Field Observation Sheet **AGRICULTURAL SOIL (Ap-HORIZON)**

Country: ____ Date:______

SAMPLE NO: ___________Ap_________________________

COORDINATES (Use Geographical coordinates WGS84 ONLY in degrees, minutes, seconds)

NORTH: _____º_____'_____" EAST: _____º_____'_____"

ALTITUDE:_____ metres above mean sea level

Size of field selected for sampling: ______x______m

Distance to minor road: _______m Distance to major road: _______m

Last crop: ☐Wheat; ☐Barley; ☐Oat ; ☐Rye; ☐Rice; ☐Maize; ☐Grass; ☐Rapeseed; ☐Sunflower; ☐Sugarbeet; ☐Potato, ☐Unknown

☐Other, specify: ______________________________

Soil Sample depth (0-20 cm) and 5 subsites. If different, specify:___________________

Soil moisture on day of sampling: ☐Dry; ☐Medium; ☐Wet.

Ploughing depth: ____cm

Rockiness of agricultural field: rocks >200 mm: ☐Many; ☐Some; ☐Few; ☐None

Rock fragments 60-200 mm: ☐Many; ☐Some; ☐Few; ☐None; ☐No rocks >60 mm

Main rock type in surroundings of sample location: ☐Metamorphic; ☐Igneous; (☐Plutonic; ☐Volcanic); ☐Sediments, consolidated; ☐Sediments, unconsolidated

☐Greenschist; ☐Gneiss; ☐Phyllite; ☐Marble; ☐Micaschist; ☐Blackschist

☐Granite; ☐Granodiorite; ☐Syenite; ☐Gabbro

☐Rhyolite; ☐Andesite; ☐Tuff; ☐Basalt

☐Limestone; ☐Dolomite; ☐Sandstone; ☐Shale; ☐Marl

Other(s), specify: ______________________________

Landform: ☐Level; ☐Sloping; ☐Steep

Remarks (any unusual observations)

____

____

____

____

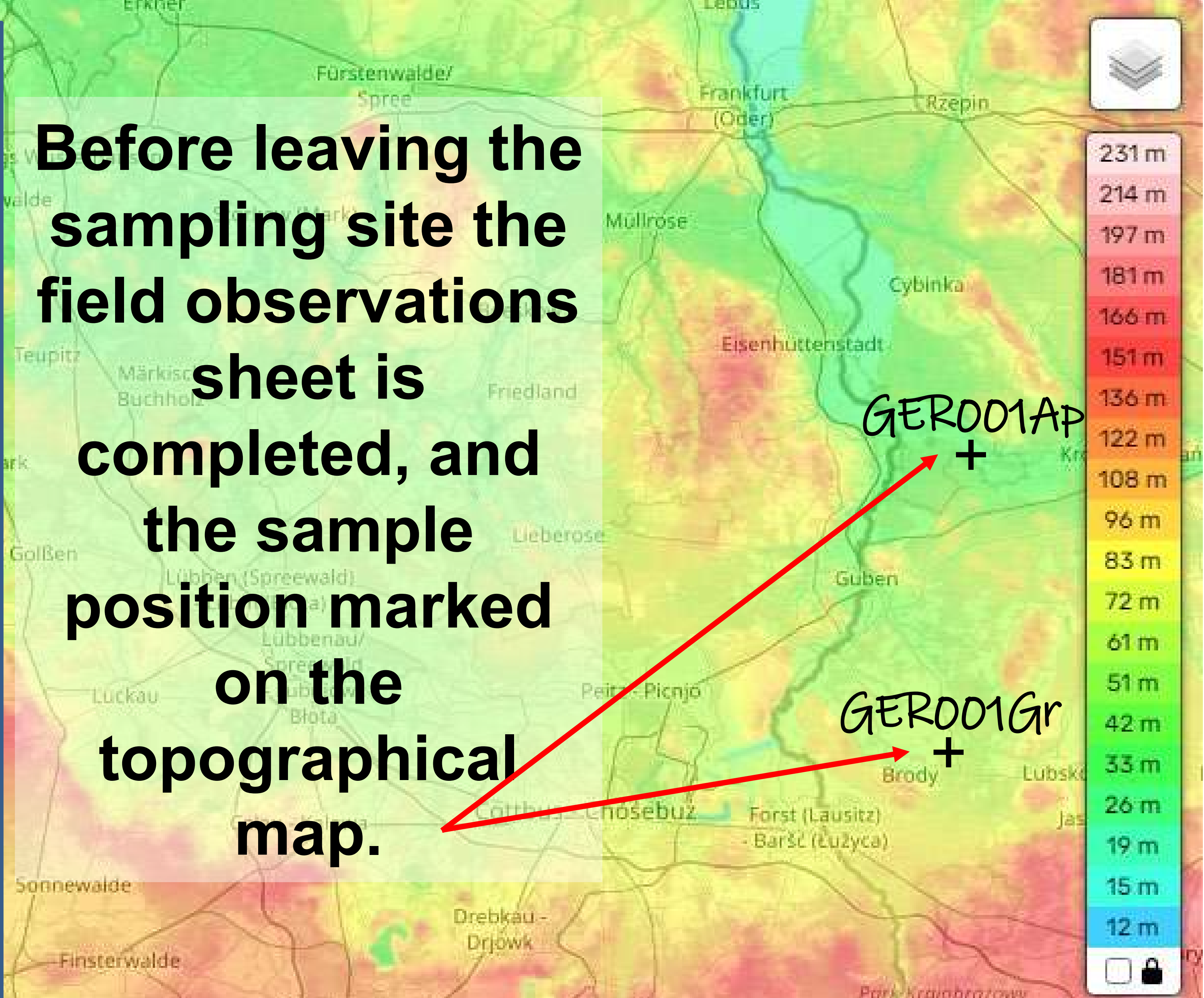
Photos Nr .+ direction (N, NE, E, SE, S, SW, W, NW):

____

Sampler(s): ____

Signature:__________________

Before leaving the sampling site the field observations sheet is completed, and the sample position marked on the topographical map.

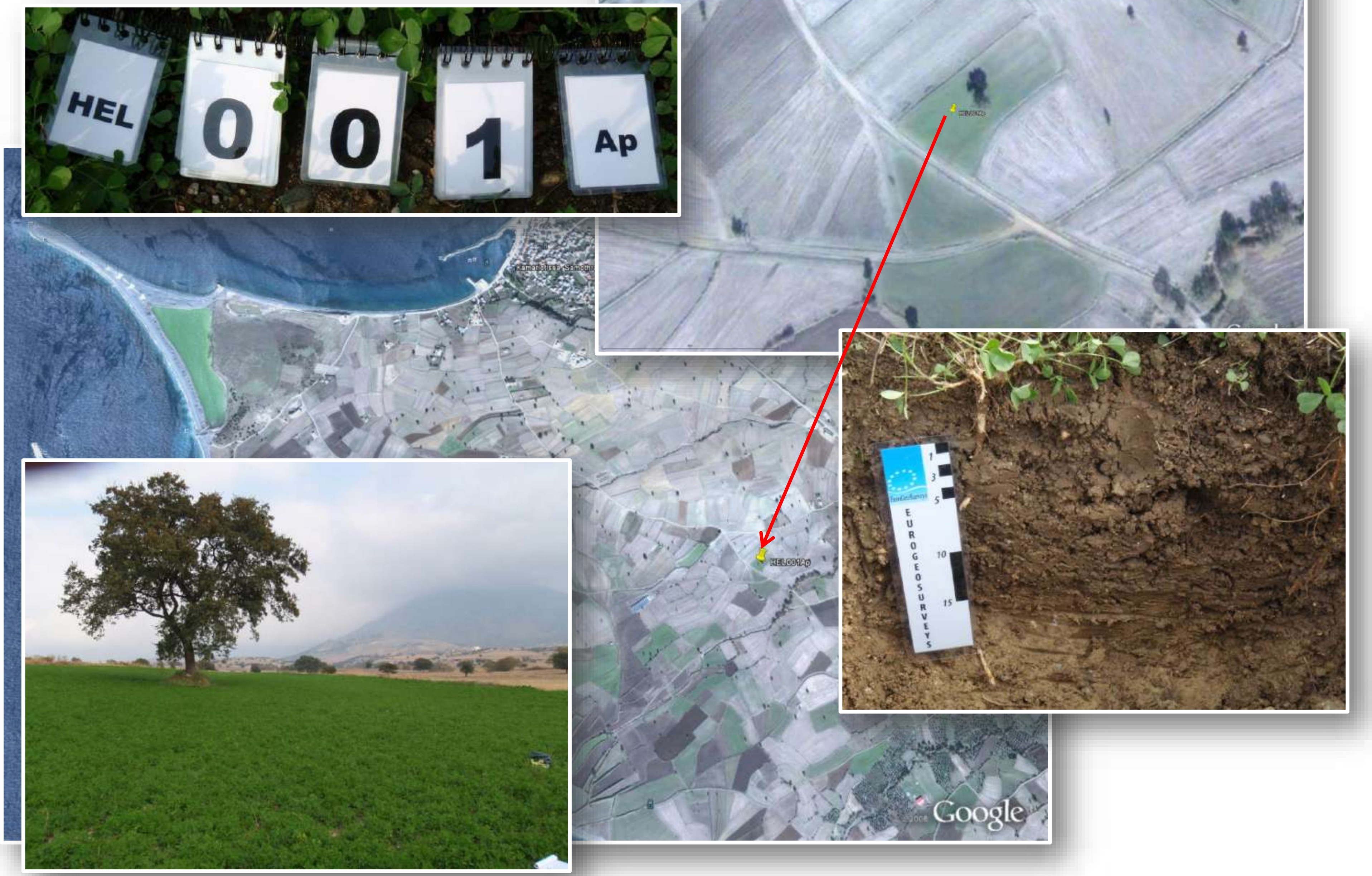


Source: https://en-gb.topographic-map.com/map-35qr18/Berlin/?popup=52.49289%2C13.21037&center=52.75881%2C12.69539

Google Earth photos Hellenic results

Another option is to be online in the field and either use digital topographic maps or Google Earth.

In such cases, a backup must be made in the evening.



Important cautions

ATTENTION: The samples will be analysed for Ag, Au, and Pd –

Therefore, it is not allowed to wear any jewellery or rings when sampling!

Please pay great attention to this "little", but very important, detail.

SMOKING is NOT PERMITTED during sampling.

Intellectual property rights, and authorship of publications

Important issues that were dealt with at the beginning of the project.


Contents lists available at SciVerse ScienceDirect

Applied Geochemistry

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

Lead and lead isotopes in agricultural soils of Europe – The continental perspective

Clemens Reimann [a,*], Belinda Flem [a], Karl Fabian [a], Manfred Birke [b], Anna Ladenberger [c], Philippe Négrel [d], Alecos Demetriades [e], Jurian Hoogewerff [f], The GEMAS Project Team [1]

[a] Geological Survey of Norway (NGU), P.O. Box 6315 Sluppen, N-7491 Trondheim, Norway
[b] Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Postfach 510153, D-30631 Hannover, Germany
[c] Geological Survey of Sweden (SGU), Box 670, S-751 28 Uppsala, Sweden
[d] BRGM, Service Métrologie Monitoring Analyse, 3 Avenue Claude Guillemin, BP 6009, 45060 Orléans Cedex 2, France
[e] Institute of Geology and Mineral Exploration, Entrance C, Olympic Village, Acharnae Athens GR-13677, Greece
[f] Oritain Global Ltd., 8 Pacific Street, Dunedin 9010, New Zealand

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ABSTRACT

Lead isotopes are widely used for age dating, for tracking sources of melts, sediments, Pb products, food and animals and for studying atmospheric Pb contamination. For the first time, a map of a Pb isotope landscape at the continental-scale is presented. Agricultural soil samples (A_p-horizon, 0–20 cm) collected at an average density of 1 site/2500 km^2 were analysed for Pb concentration and Pb isotopes (^{206}Pb, ^{207}Pb, ^{208}Pb). Lead concentrations vary from 1.6 to 1309 mg/kg, with a median of 16 mg/kg. Isotopic ratios of $^{206}Pb/^{207}Pb$ range from 1.116 to 1.727 with a median of 1.202. The new data define the soil geochemical Pb background for European agricultural soil, providing crucial information for geological, environmental and forensic sciences, public health, environmental policy and mineral exploration. The European continental-scale patterns of Pb concentrations and Pb isotopes show a high variability dominated by geology and influenced by climate. Lead concentration anomalies mark most of the known mineralised areas throughout Europe. Some local Pb anomalies have a distinct anthropogenic origin.

1. Introduction

Lead has been mined and used by humans for several thousand years. The accumulated total world Pb production since ancient times is estimated to be 300 Mt (based on Nriagu, 1998 and updated to 2010 according to current world mine production figures). Estimates of the anthropogenic Pb fraction in the environment range from <10% (Strauss, 1978; Kownacka et al., 1990) to >90% (Nriagu, 1979). Detailed studies on environmental samples (e.g., peat bogs, ice cores, sediment cores) has suggested major Pb contamination of the northern hemisphere since ancient times (Komárek et al., 2008; Bindler, 2011). The European Commission has identified diffuse contamination as one of the eight major threats to soil quality (European Commission, 2006).

Because Pb deposits have characteristic Pb isotope compositions (for data on the economically important deposits see: Sangster et al., 2000), Pb concentration and Pb-isotope ratios in combination may in some cases be used as a fingerprint to trace Pb to its source. Natural Pb comprises four stable isotopes (natural abundance in brackets): ^{204}Pb (1.4%), ^{206}Pb (24.1%), ^{207}Pb (22.1%) and ^{208}Pb (52.4%) in varying proportions, uniquely defined by the three ratios $^{206}Pb/^{207}Pb$, $^{208}Pb/^{206}Pb$, $^{206}Pb/^{204}Pb$. The reliable measurement of the isotope ^{204}Pb needs much care and specialised instrumentation and is time consuming. The ratios between the more abundant isotopes ^{206}Pb, ^{207}Pb and ^{208}Pb can be easily determined by inductively coupled plasma mass spectrometry. In environmental sciences the $^{206}Pb/^{207}Pb$ isotope ratio is commonly used to suggest Pb contamination of different compartments of the environment at the local to global scale (for a recent review on the use of Pb isotopes in environmental sciences see Komárek et al., 2008). Data presented in Sangster et al. (2000) demonstrate that the $^{206}Pb/^{207}Pb$ isotope ratio of the most important Pb deposits varies between 0.98 and 1.41. One major producer, Broken Hill in Australia, is characterised by a very low $^{206}Pb/^{207}Pb$ isotope ratio of 1.04, while the largest Pb deposits in the world, the Mississippi

* Corresponding author.
E-mail address: Clemens.Reimann@ngu.no (C. Reimann).

[1] S. Albanese, M. Andersson, A. Arnoldussen, R. Baritz, M.J. Batista, A. Bel-lan, D. Cicchella, E. Dinelli, B. De Vivo, W. De Vos, M. Duris, A. Dusza-Dobek, O.A. Eggen, M. Eklund, V. Ernstsen, P. Filzmoser, T.E. Finne, D. Flight, S. Forrester, M. Fuchs, U. Fugedi, A. Gilucis, M. Gosar, V. Gregorauskiene, A. Gulan, J. Halamić, E. Haslinger, P. Hayoz, G. Hobiger, R. Hoffmann, H. Hrvatovic, S. Husnjak, L. Janik, C.C. Johnson, G. Jordan, J. Kirby, J. Kivisilla, V. Klos, F. Krone, P. Kwecko, L. Kuti, A. Lima, J. Locutura, P. Lucivjansky, D. Mackovych, B.I. Malyuk, R. Maquil, M. McLaughlin, R.G. Meuli, N. Miosic, G. Mol, P. O'Connor, K. Oorts, R.T. Ottesen, A. Pasieczna, V. Petersell, S. Pfleiderer, M. Poňavič, C. Prazeres, U. Rauch, I. Salpeteur, A. Schedl, A. Scheib, I. Schoeters, P. Sefcik, E. Sellersjö, F. Skopljak, I. Slaninka, A. Šorša, R. Srvkota, T. Stafilov, T. Tarvainen, V. Trendavilov, P. Valera, V. Verougstraete, D. Vidojević, A.M. Zissimos, Z. Zomeni.

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Leading and contributing authors

All names of The GEMAS Project Team are mentioned

The GEMAS Field Manual is available from:

http://www.ngu.no/en-gb/hm/Publications/Reports/2008/2008-038/

Fieldwork was carried out in the 33 participating countries from May 2008 to March 2009 as national projects.

Each participating Geological Survey, University or Institution financed the sampling in its country.

Equipment provided centrally to each participating country:

- Certified trace-element free Rilsan® bags

- Strip-locks for the sample bags

- Scalebar for "surface" photographs

- Small cardboard cards for sample number
- Zip-lock bag for sample number card

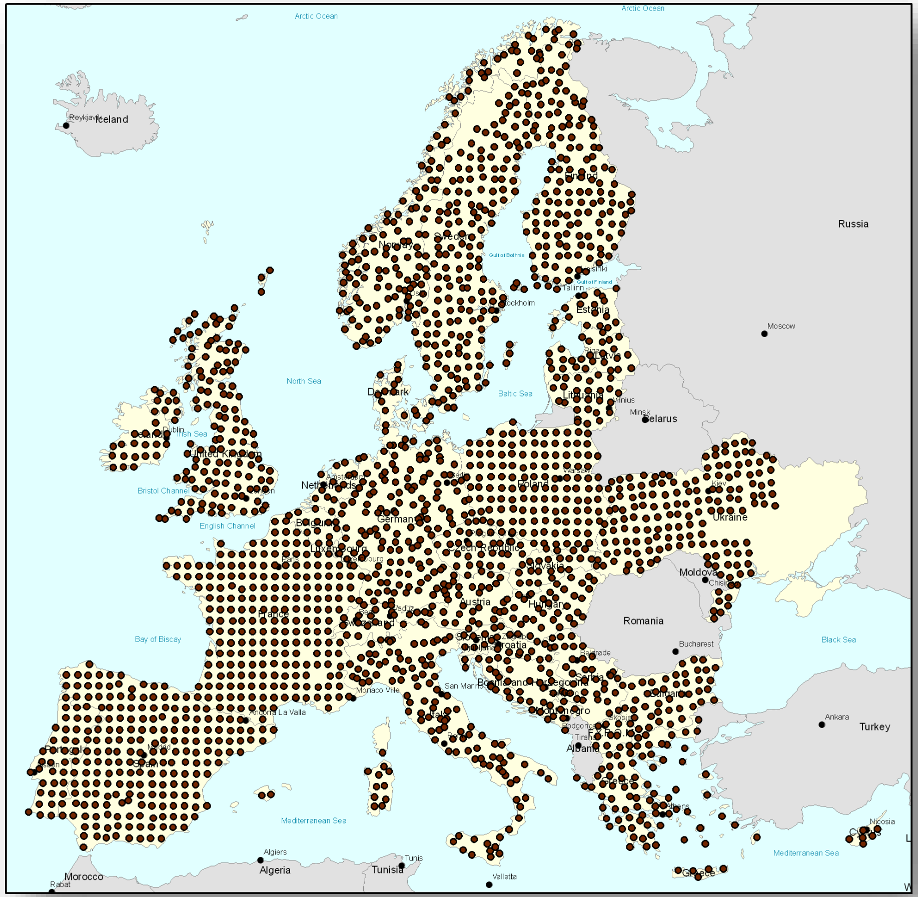
- Black permanent ink markers

Equipment to be purchased by each participating country:

- Stainless steel or Steel spade (if painted the paint must be removed by sandblasting prior to sampling)
- Stainless steel or Steel mattock cutter (if painted the paint must be removed by sandblasting prior to sampling)
- Stainless steel saw knife
- Field observation sheets (printed by each participating country)
- GPS [for recording the sample site coordinates (geographical coordinates: degrees, minutes, and seconds)]
- Maps (topographical maps, preferred scale 1:50,000) for recording sample sites
- Digital camera for required field documentation (minimum 5 megapixels)
- Plastic or heavy-duty cardboard boxes for packing samples.

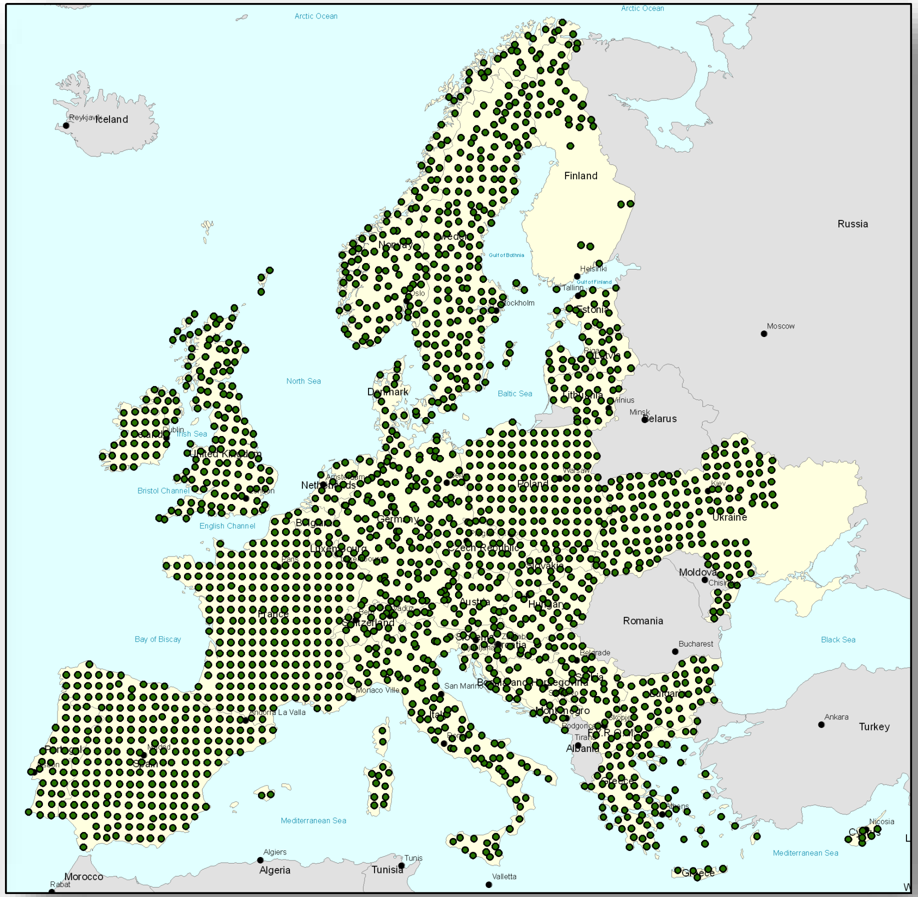
Two different sample types were collected at a sampling density of 1 site/2500 km^2

Agricultural soil (A_p) 0-20 cm (N = 2108)



Source: Reimann *et al.*, 2009, Fig. 1, p.9

Grazing land soil (Gr) 0-10 cm (N = 2024)



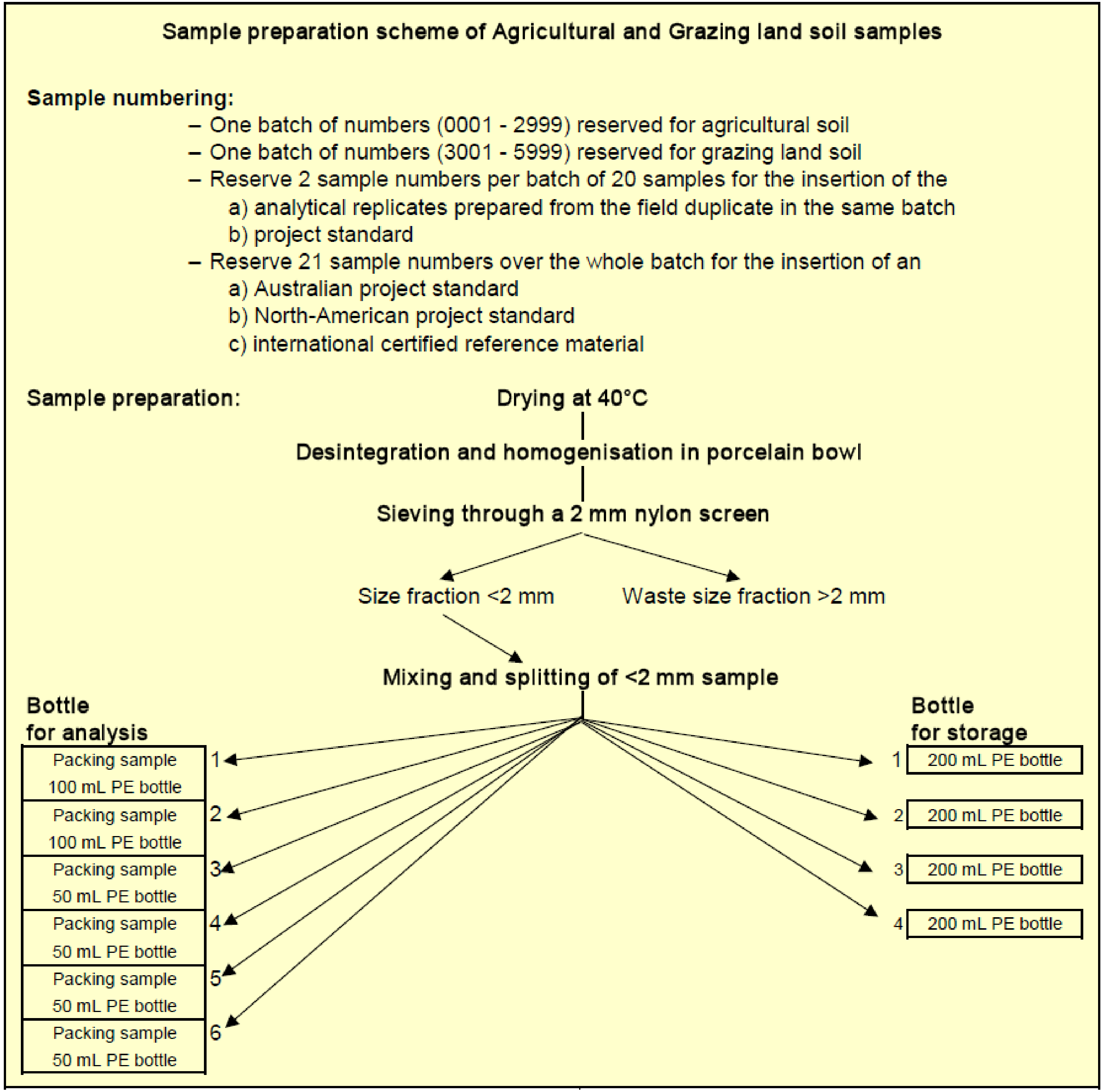
Source: Reimann *et al.*, 2009, Fig. 2, p.9

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

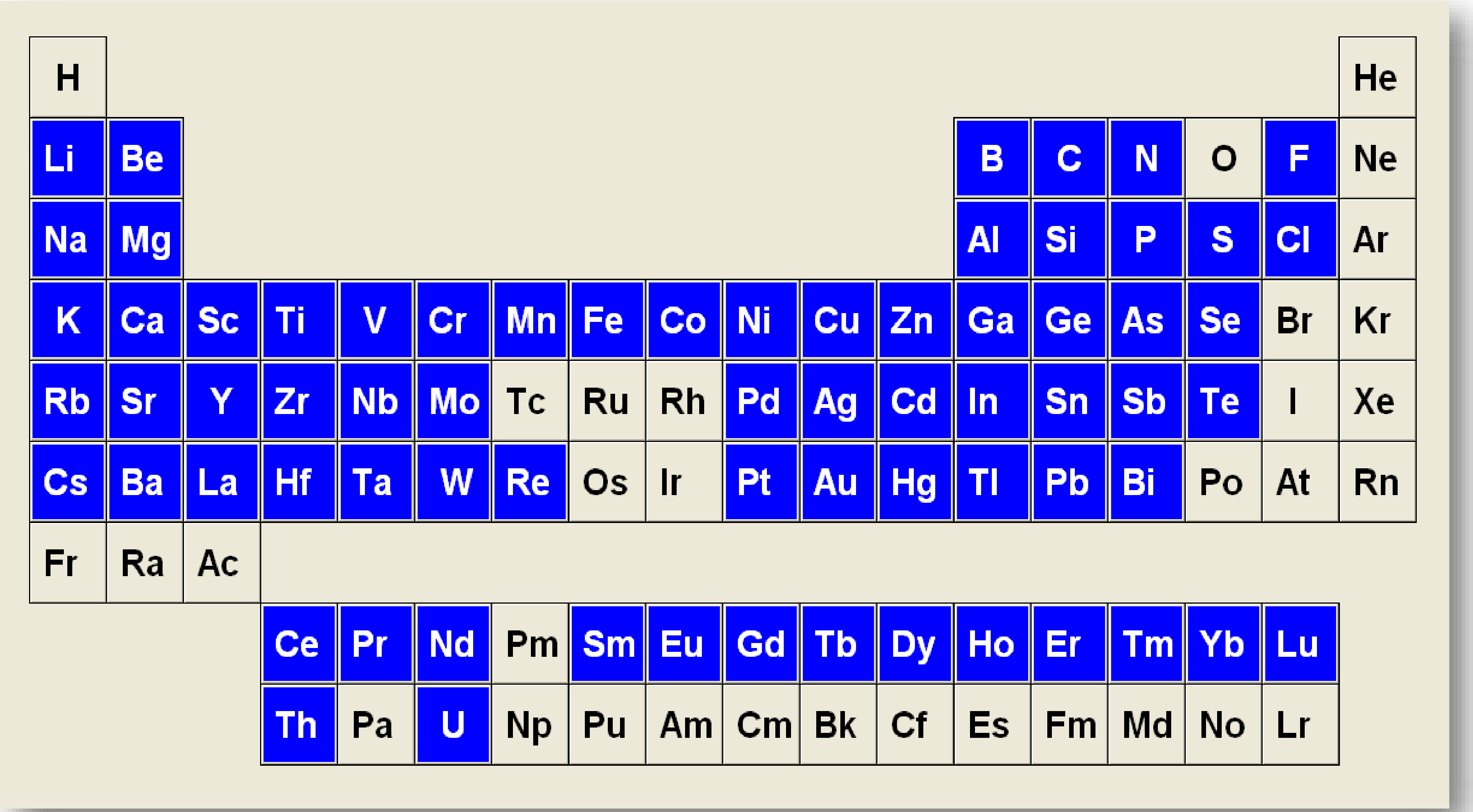
Sample preparation and laboratory analysis

Sample preparation

- All collected agricultural and grazing land soil samples were sent to Slovakia for sample preparation at the State Geological Institute of Dionyz Stur.



GEMAS project – Analytical Programme



GEMAS project – Analytical Programme

- **ACME commercial laboratory: Hot aqua regia extraction on 15 g aliquot of <2 mm soil fraction (53 elements) and determination by ICP-MS/AES**:
  Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Ge, Hf, Hg, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Pd, Pt, Rb, Re, S, Sb, Sc, Se, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, W, Y, Zn and Zr
  (**Condition**: Analytical results to be given without cutting at the laboratory's detection limit – Even sub-zero (negative values) to be reported. Payment to be made after verification of the quality of the analytical results).

.

- **BGR, Germany, Total element concentrations by X-Ray Fluoresence (41 determinands):**
  SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, SO_3, LOI, Cl, F, As, Ba, Bi, Ce, Co, Cr, Cs, Cu, Ga, Hf, La, Mo, Nb, Ni, Pb, Rb, Sb, Sc, Sn, Sr, Ta, Th, U, V, W, Y, Zn and Zr.

- **SGS (Canada) – analysis of the agricultural soil samples only:** Extraction by cold Mobile Metal Ion (MMI®) solution and determination of 53 elements by ICP-MS: Au, Ba, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Hg, In, K, La, Li, Mg, Mn, Mo, Nb, Nd, Ni, P, Pb, Pd, Pr, Pt, Rb, S, Sb, Sc, Se, Sm, Sn, Sr, Ta, Tb, Te, Th, Ti, Tl, U, V, W, Y, Yb, Zn and Zr.

GEMAS – Analytical Programme

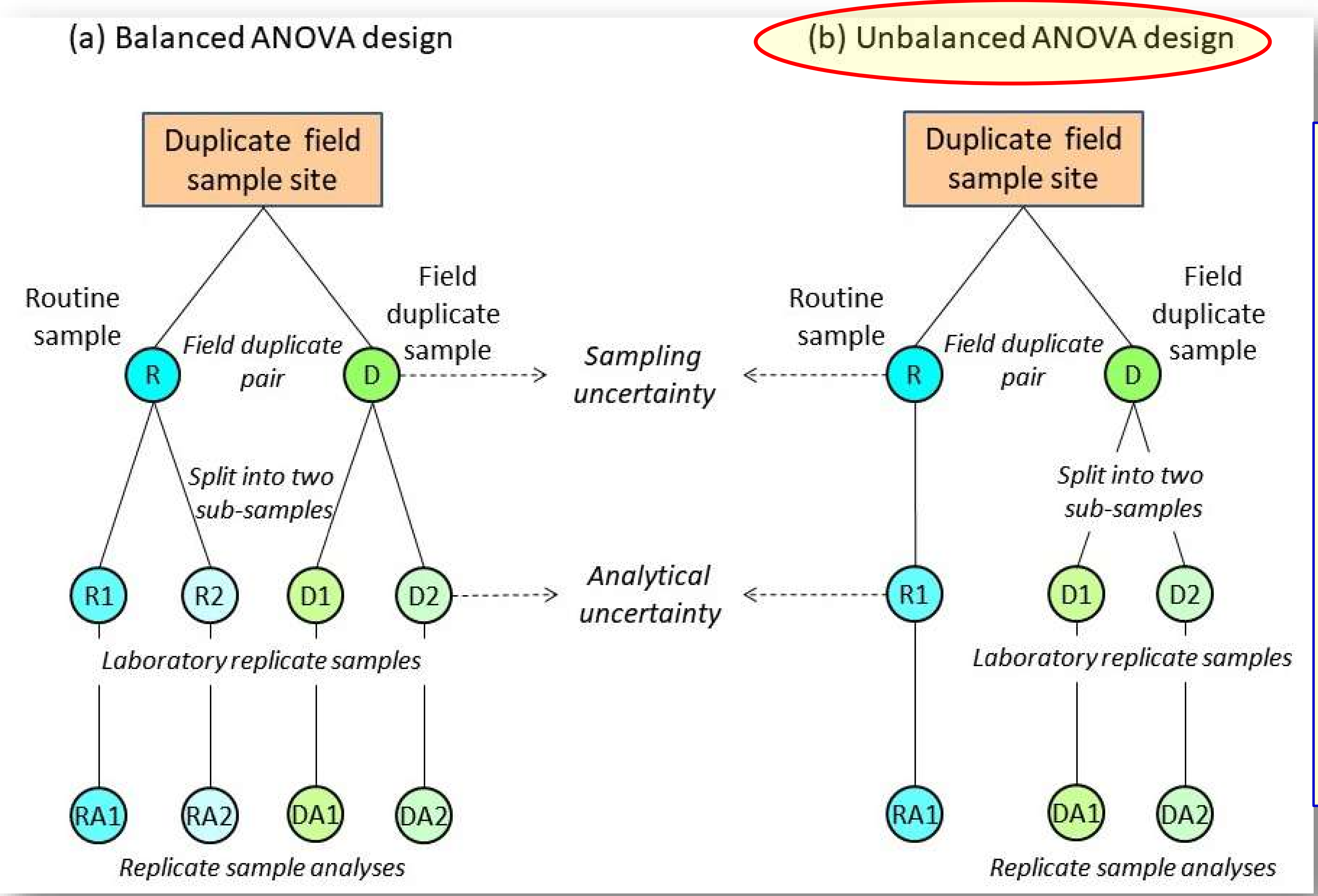
- **Geological Survey of Norway:** pH-$CaCl_2$
- **Geological Survey of Norway (*determinations on the agricultural (Ap) soil samples only*):** Total Carbon and Sulphur, Pb isotopes ($^{206}Pb/^{207}Pb$, $^{206}Pb/^{208}Pb$, $^{207}Pb/^{208}Pb$), Magnetic susceptibility, and soil colour on dry and wet samples.
- **Geological Survey of Slovakia:** Cation Exchange Capacity (CEC).
- **FUGRO (now KIWA):** Total Organic Carbon (TOC) and grain size.
- **Copenhagen & Canberra Universities:** Sr isotopes (*agricultural soil only*).
- **TU Bergakademie Freiberg**: Total C, N, S (*agricultural soil only*).

GEMAS – Analytical Programme

- **Kazan Federal University, Tartastan, Russia:** Magnetic measurements (*agricultural soil only*).

- **CSIRO Land and Water, Adelaide, Australia**: Determination of Partitioning coefficients (K_d) for Ag, B, Co, Cu, Mo, Mn, Ni, Pb, Sb, Se, Sn, Te, V, and Zn by Mid-Infrared Diffuse Reflectance Spectroscopy (MIR).

  Note: In addition, with this method, it is possible to estimate different chemical and physical properties of soil samples, *e.g*., clay, organic matter, moisture, cation exchange, pH, electrical conductivity, mineralogy, *etc*.



The original plan was to use a balanced ANOVA design.

However, due to the cost of:-

- **Sampling equipment,**
- **Sample preparation &**
- **Aqua regia analysis,**

an unbalanced ANOVA design was used.

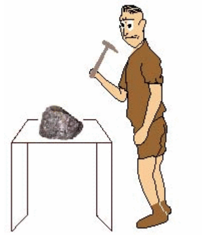
(a) Balanced and (b) unbalanced hierarchical geochemical sampling and analytical schemes for the estimation of geochemical, sampling, and analytical variance and random components of measurement uncertainty.
Source: Demetriades *et al.* (2014, Fig. 6.4, p.56) slightly modified in Demetriades *et al.* (2022, Fig. 7.11, p.407).

Quality of laboratory analyses was first verified

IMPORTANT NOTE: Never start the processing of laboratory analyses before their quality is verified.

PRODUCTION OF HIGH QUALITY HARMONISED GEOCHEMICAL DATABASES

Sampling



Sample preparation

- These are the two most crucial stages of any geochemical survey.
- Any errors during these two stages is carried forward, and can result in the failure of a whole survey.

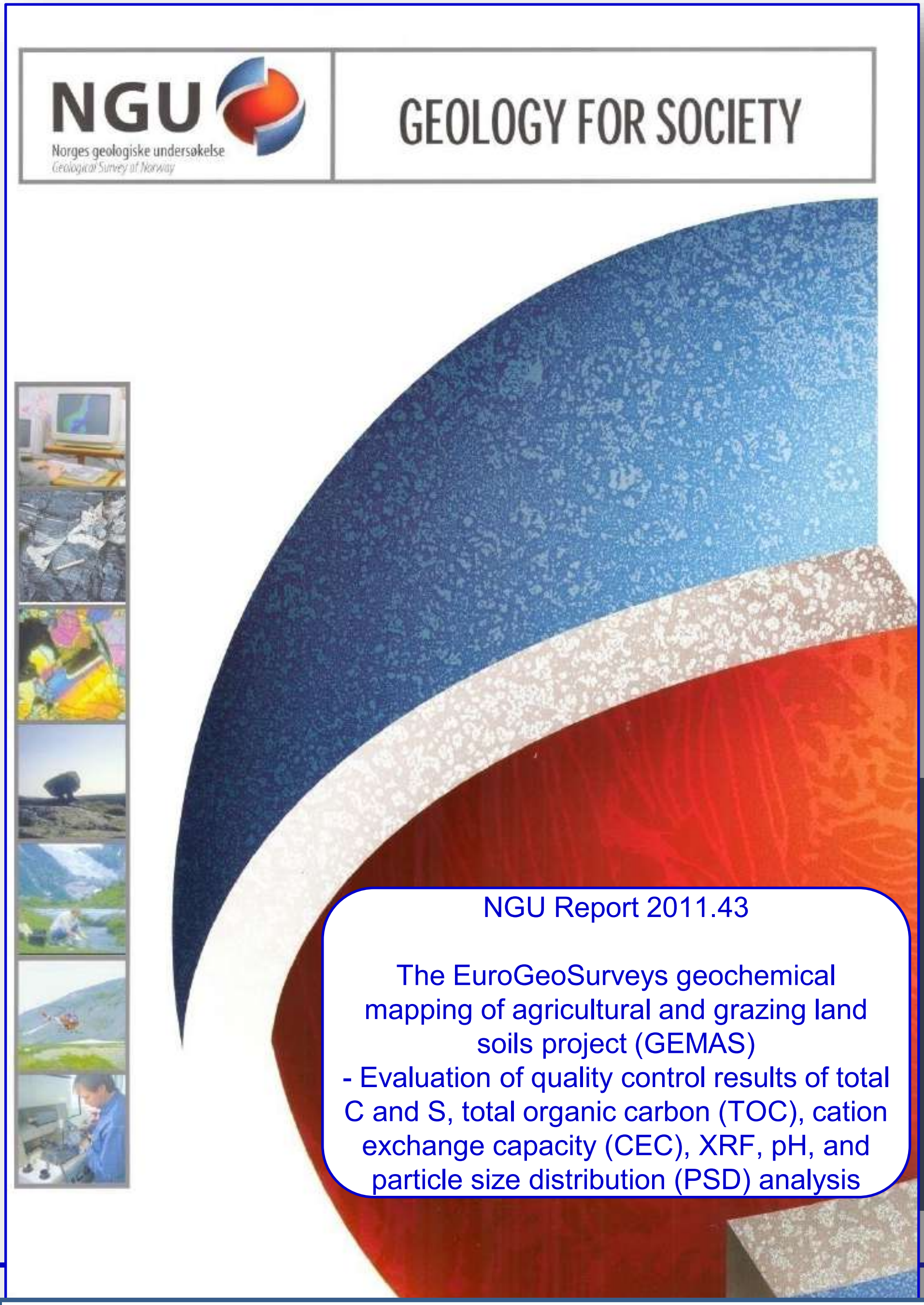
Laboratory analysis

- Errors can be corrected by re-analysis of samples, provided enough sample material is available.

Quality control reports were written for each set of analytical results received

http://www.ngu.no/upload/Publikasjoner/Rapporter/2009/2009_049.pdf

GEMAS Quality control report on the aqua regia extraction analysis results



NGU Report 2011.43

The EuroGeoSurveys geochemical mapping of agricultural and grazing land soils project (GEMAS)
- Evaluation of quality control results of total C and S, total organic carbon (TOC), cation exchange capacity (CEC), XRF, pH, and particle size distribution (PSD) analysis

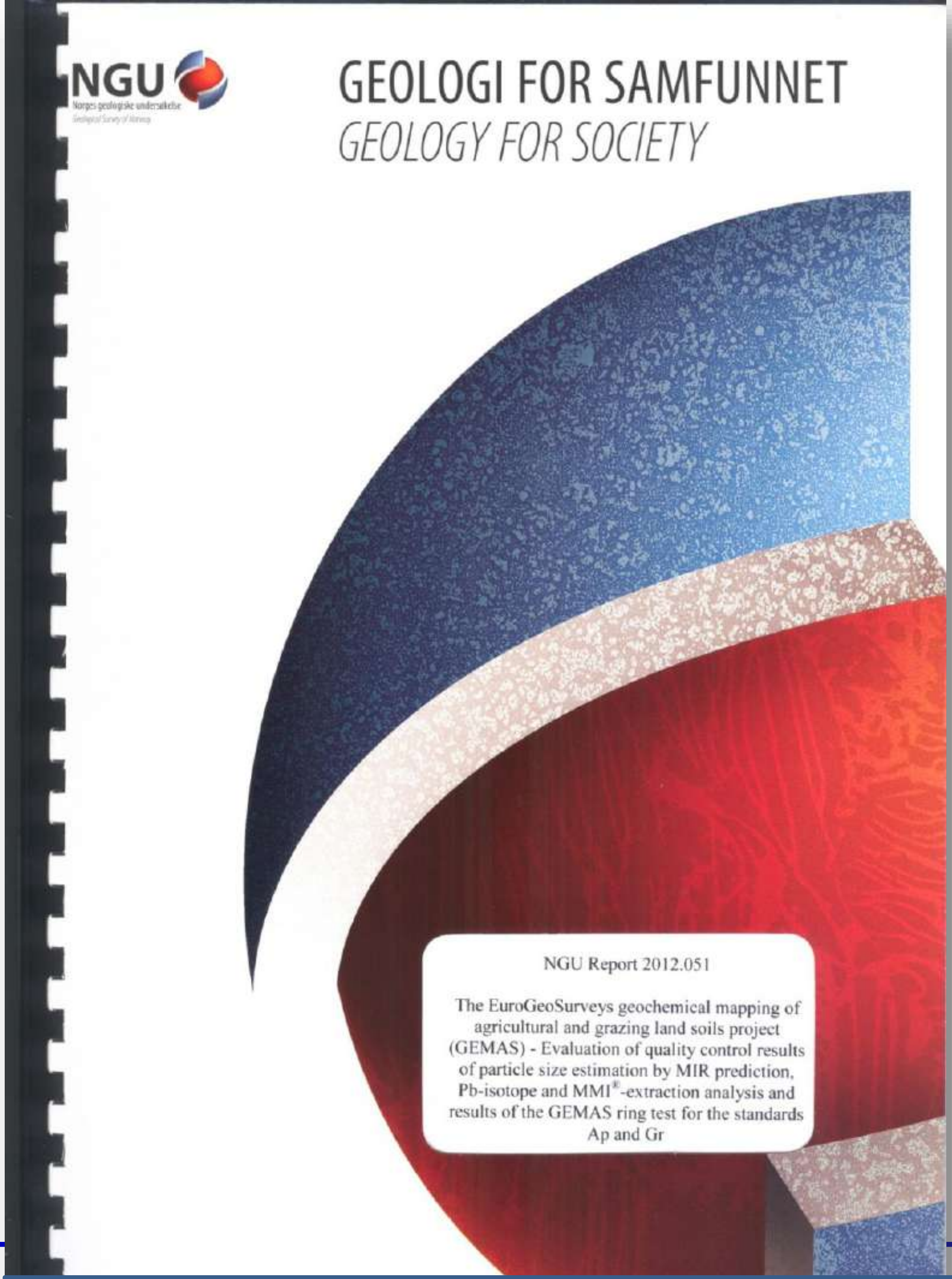
GEMAS Quality control report on the results of

- total C and S (NGU)
- XRF major & trace elements (BGR)
- TOC (FUGRO)
- CEC (Slovak Republic)
- pH in $CaCl_2$-extraction (NGU)
- PSD - particle size distribution (FUGRO)

Particle Size Distribution results are the only GEMAS-results that could not be accepted due to poor quality.

PSD was predicted using CSIRO's MIR-spectra based on a model developed for European soils (cooperation between BGR, CSIRO & ARCHE).

http://www.ngu.no/upload/Publikasjoner/Rapporter/2011/2011_043.pdf



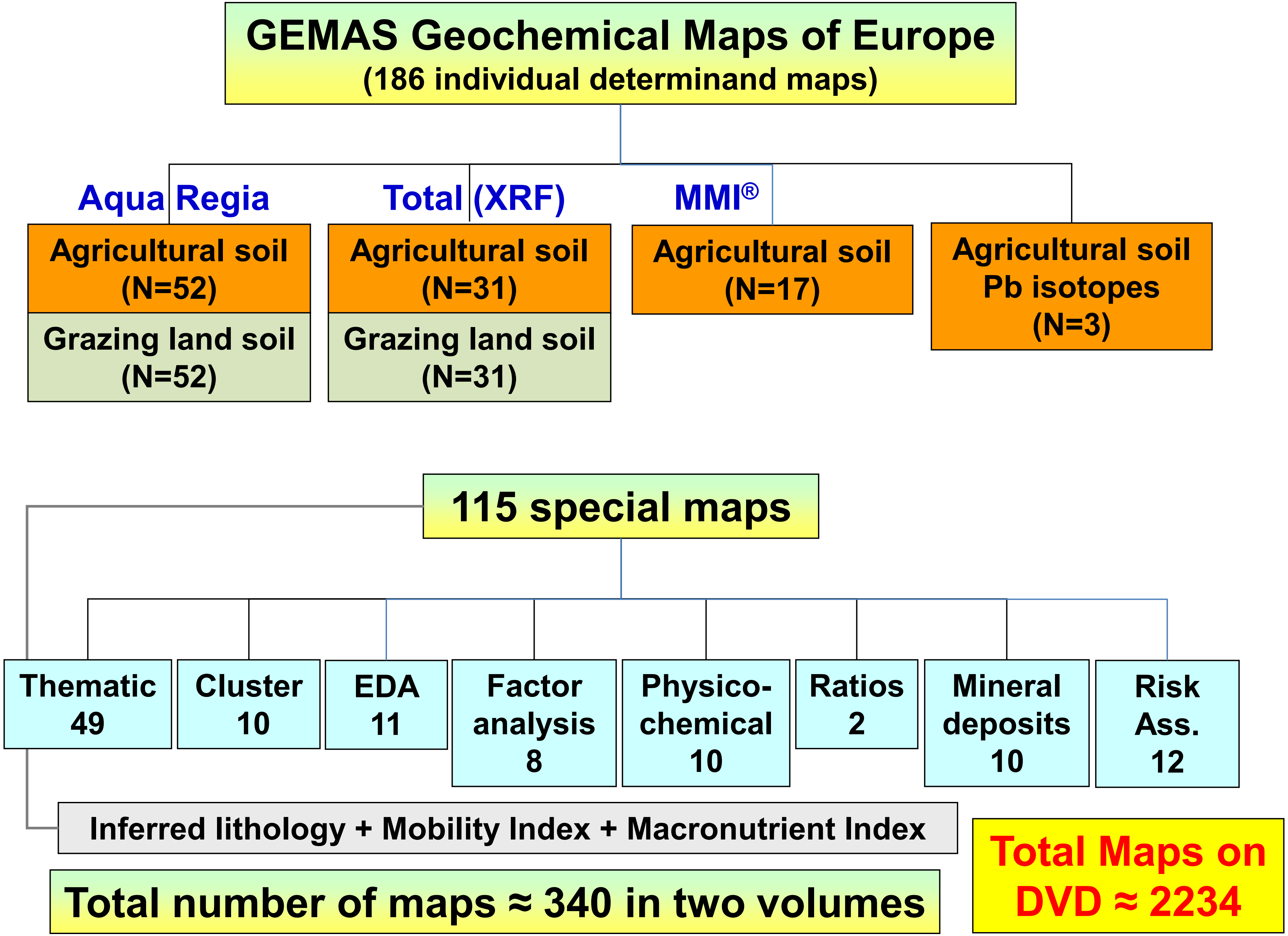
GEMAS Quality control report on the results of

- **Particle size analysis (clay, sand, silt – estimated by MIR)***
- **Lead isotopes**
- **Extraction by Mobile Metal Ions method (SGS)**
- **Quality control of project standards Ap & Gr**

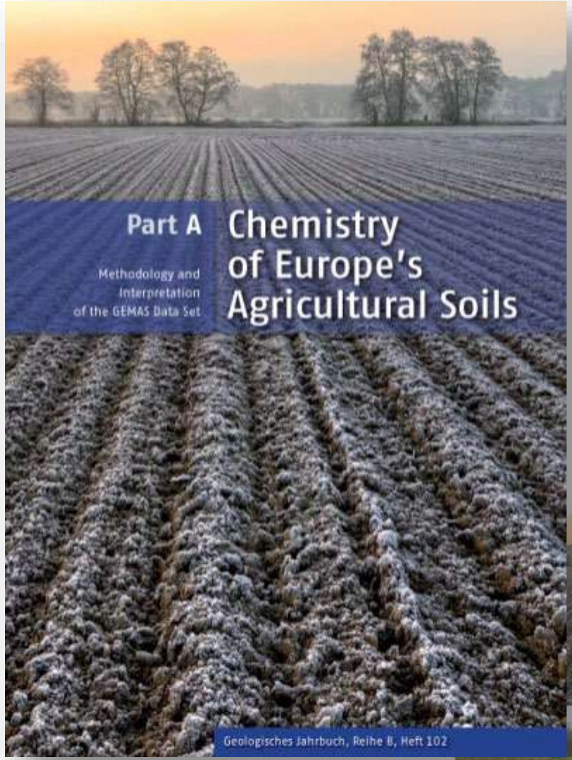
*** Collaboration between BGR, CSIRO & ARCHE for the development of European MIR model**

http://www.ngu.no/upload/Publikasjoner/Rapporter/2012/2012_051.pdf

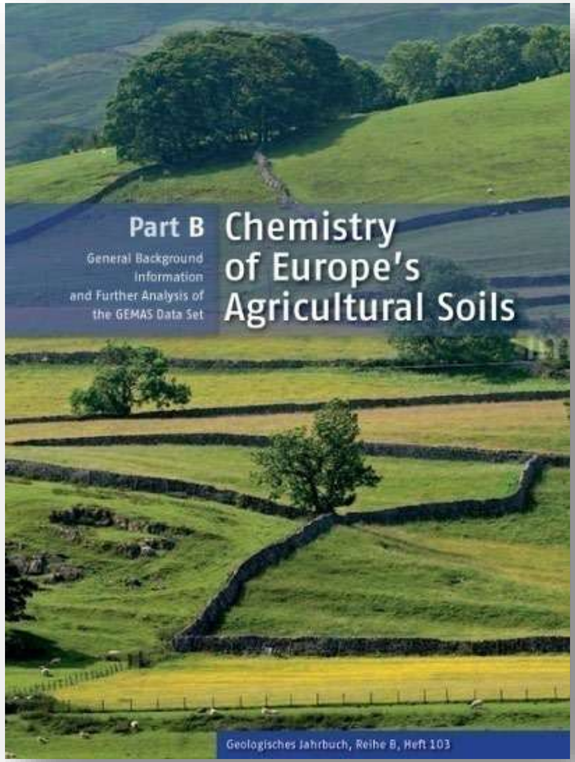
Data processing, Map plotting, Interpretation, writing of book chapters, and Publication of a two-volume atlas accompanied by a DVD with data files, maps and diagrams


GEMAS Geochemical Maps of Europe
(186 individual determinand maps)
Aqua Regia
Agricultural soil (N=52)
Grazing land soil (N=52)
Total (XRF)
Agricultural soil (N=31)
Grazing land soil (N=31)
MMI®
Agricultural soil (N=17)
Agricultural soil Pb isotopes (N=3)
115 special maps
Thematic 49
Cluster 10
EDA 11
Factor analysis 8
Physico-chemical 10
Ratios 2
Mineral deposits 10
Risk Ass. 12
Inferred lithology + Mobility Index + Macronutrient Index
Total number of maps ≈ 340 in two volumes
Total Maps on DVD ≈ 2234

Printed Publications



Reimann *et al.* (2014a)



Reimann *et al.* (2014b)

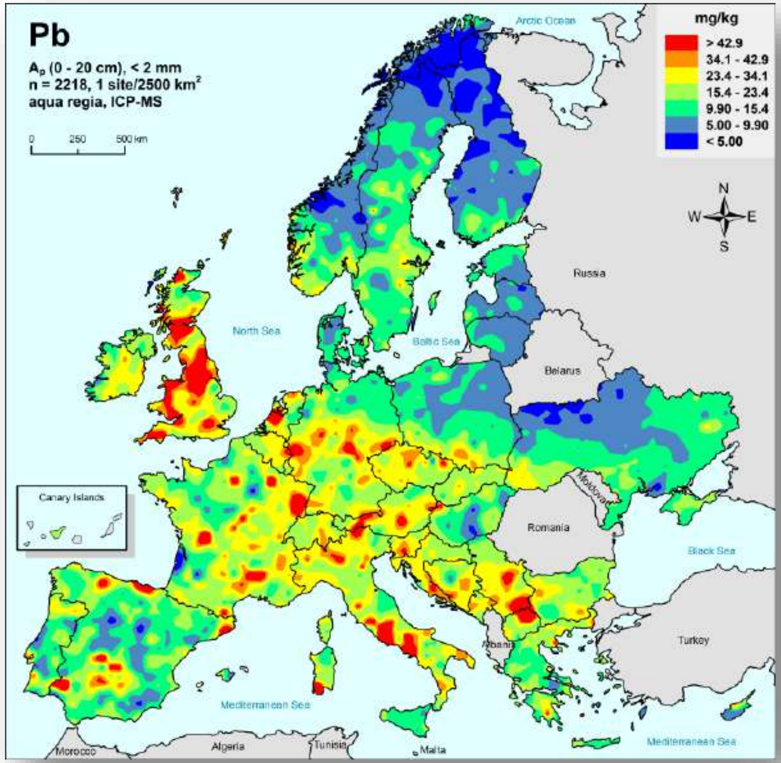
http://www.schweizerbart.de/publications/detail/isbn/9783510968466

The agricultural soil samples were analysed by three different analytical methods

The grazing land soil samples were analysed by two different analytical methods

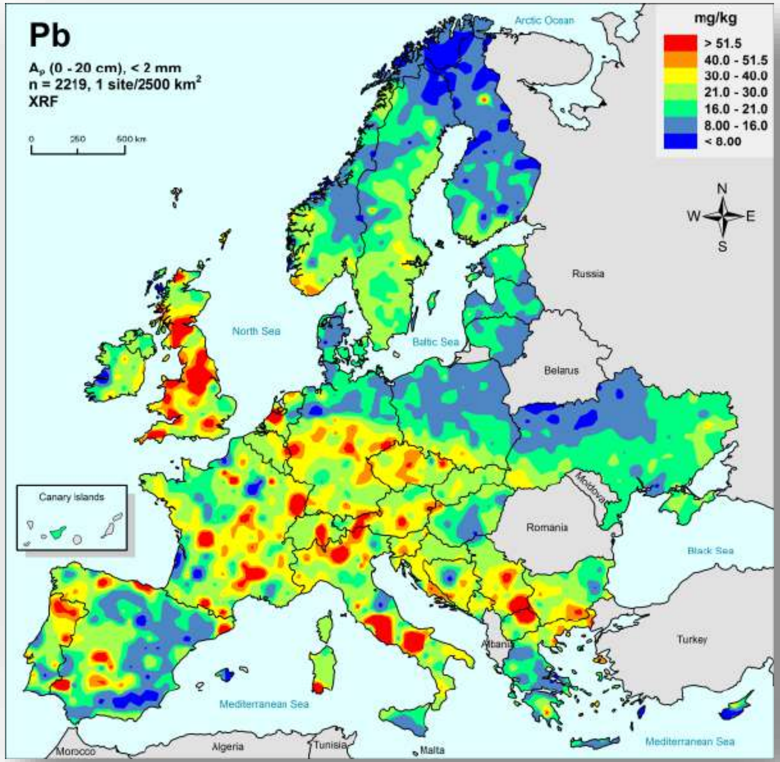
GEMAS atlas –
Geochemical maps showing the distribution of lead (Pb) in agricultural soil (Ap)

Hot *aqua regia* extraction



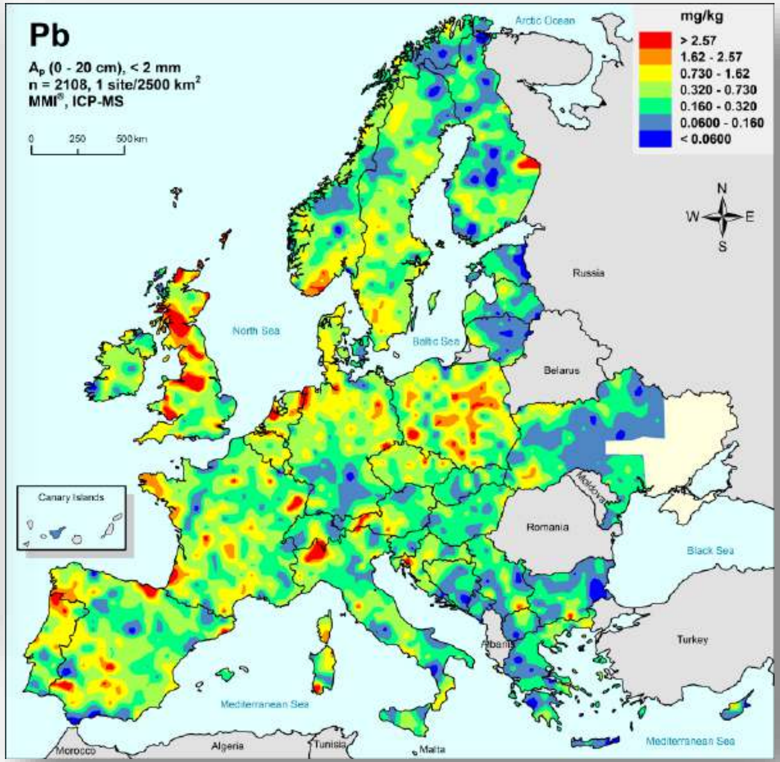
Source: Reimann *et al*., 2014c, Fig. 11.41.5, p.341

Total (XRF)



Source: Reimann *et al*., 2014c, Fig. 11.41.5, p.342

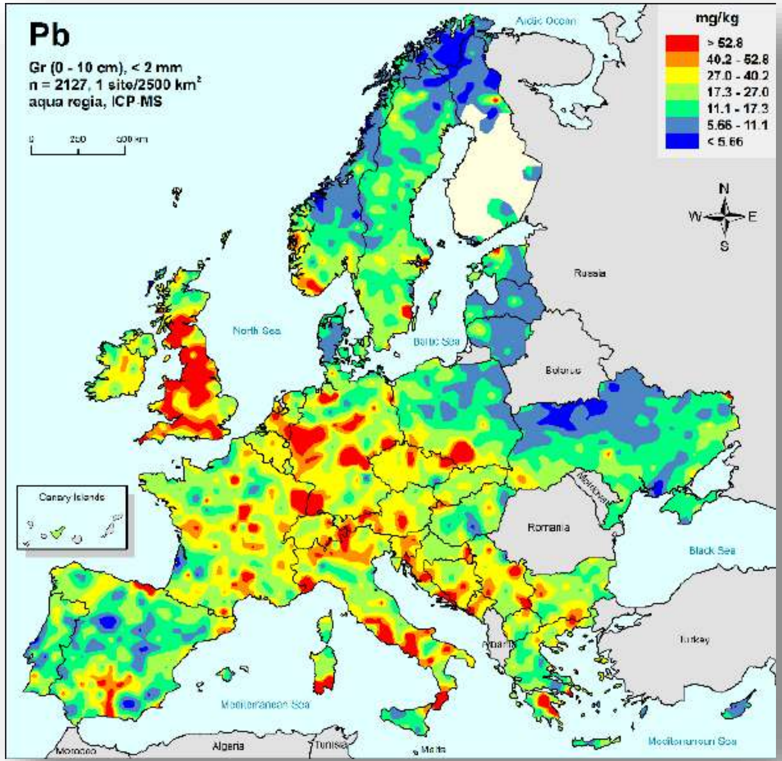
Cold Mobile Metal Ion (MMI®) extraction



Source: Reimann *et al*., 2014a, on DVD

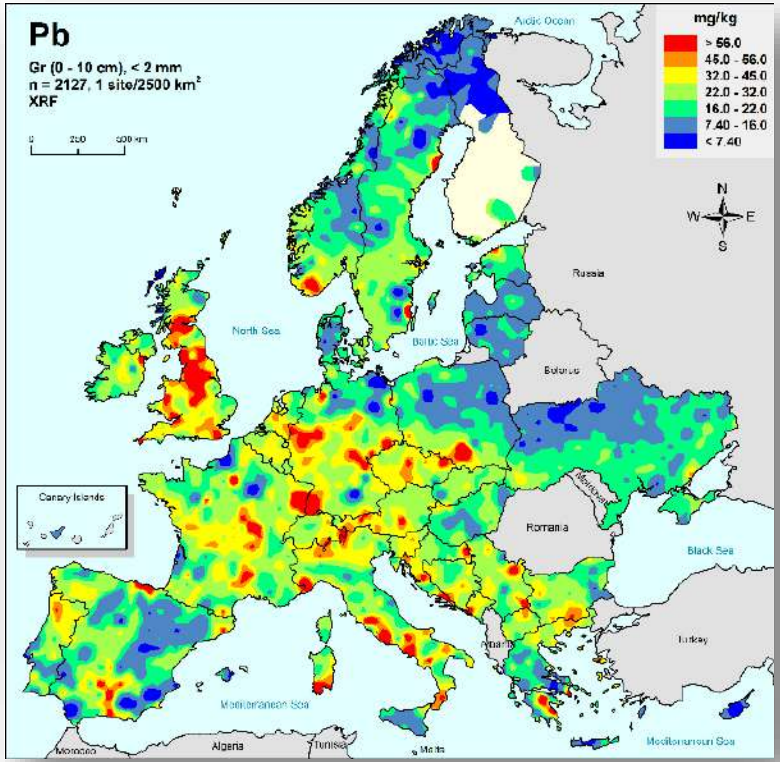
GEMAS atlas –
Geochemical maps showing the distribution of lead (Pb) in grazing land soil (Gr)

Hot *aqua regia* extraction



Source: Reimann *et al*., 2014c, Fig. 11.41.5, p.341

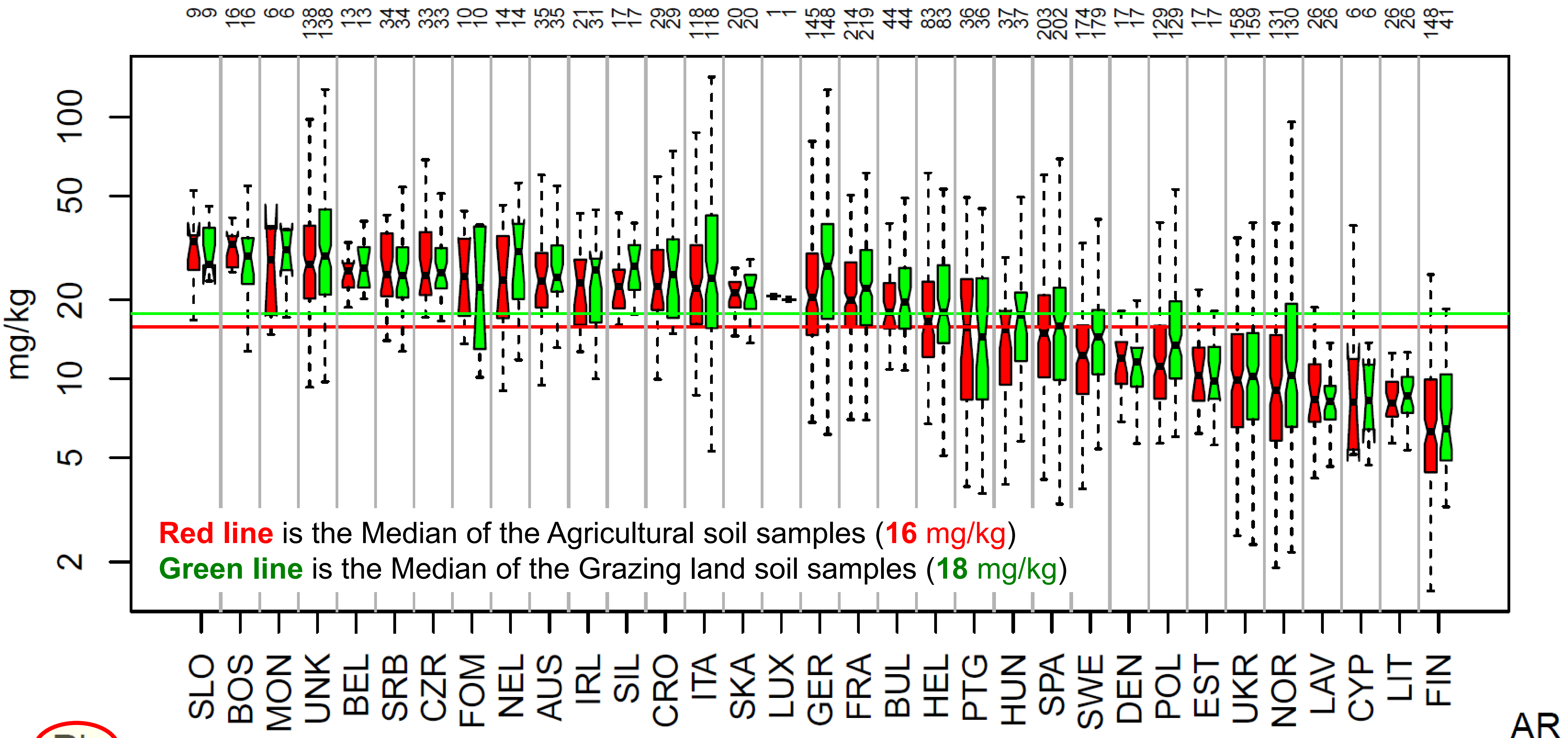
Total (XRF)



Source: Reimann *et al*., 2014c, Fig. 11.41.5, p.342

There are substantial differences among the country soil median values

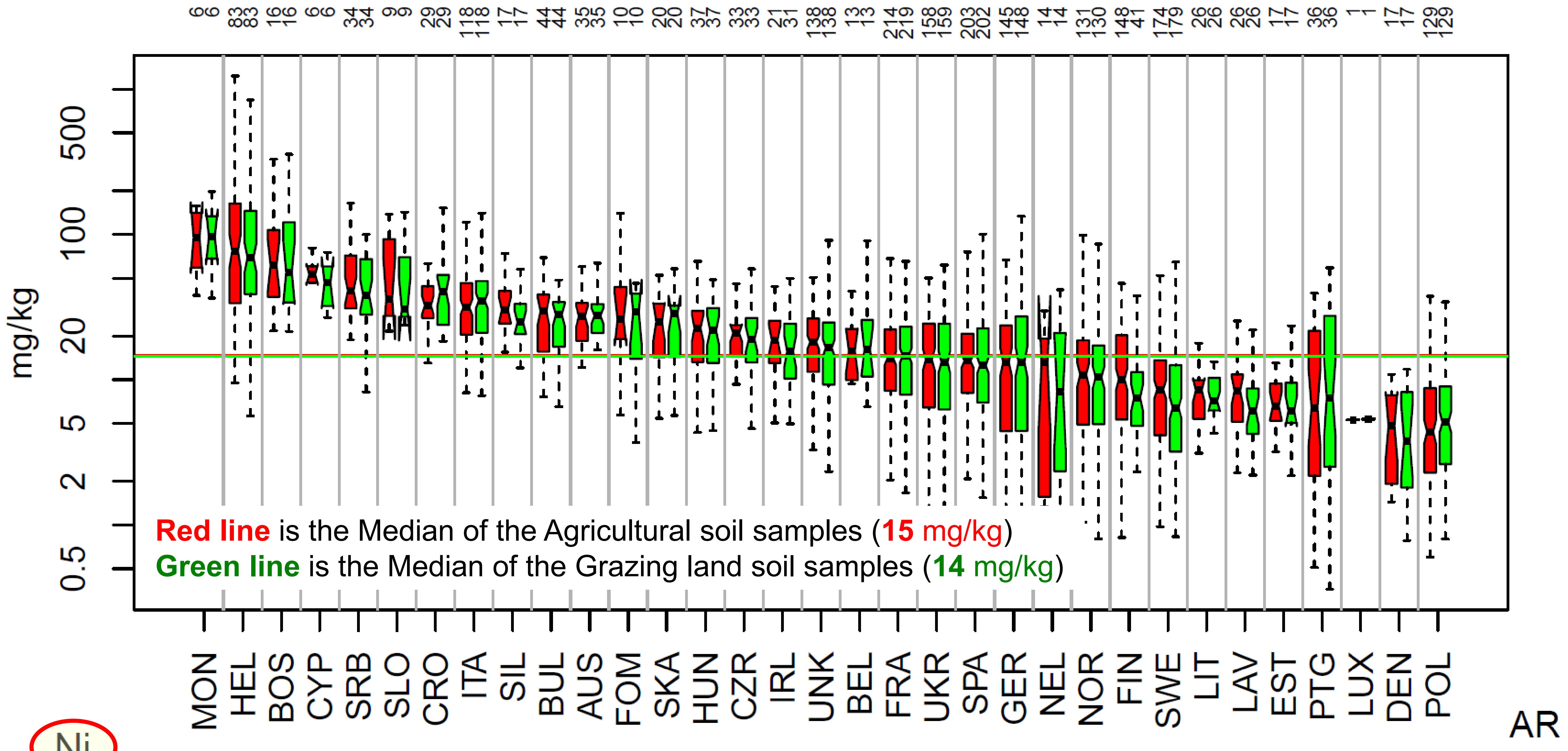
GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



Pb

Source: Reimann *et al.*, 2014c, Fig. 11.41.4, p.339

GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe

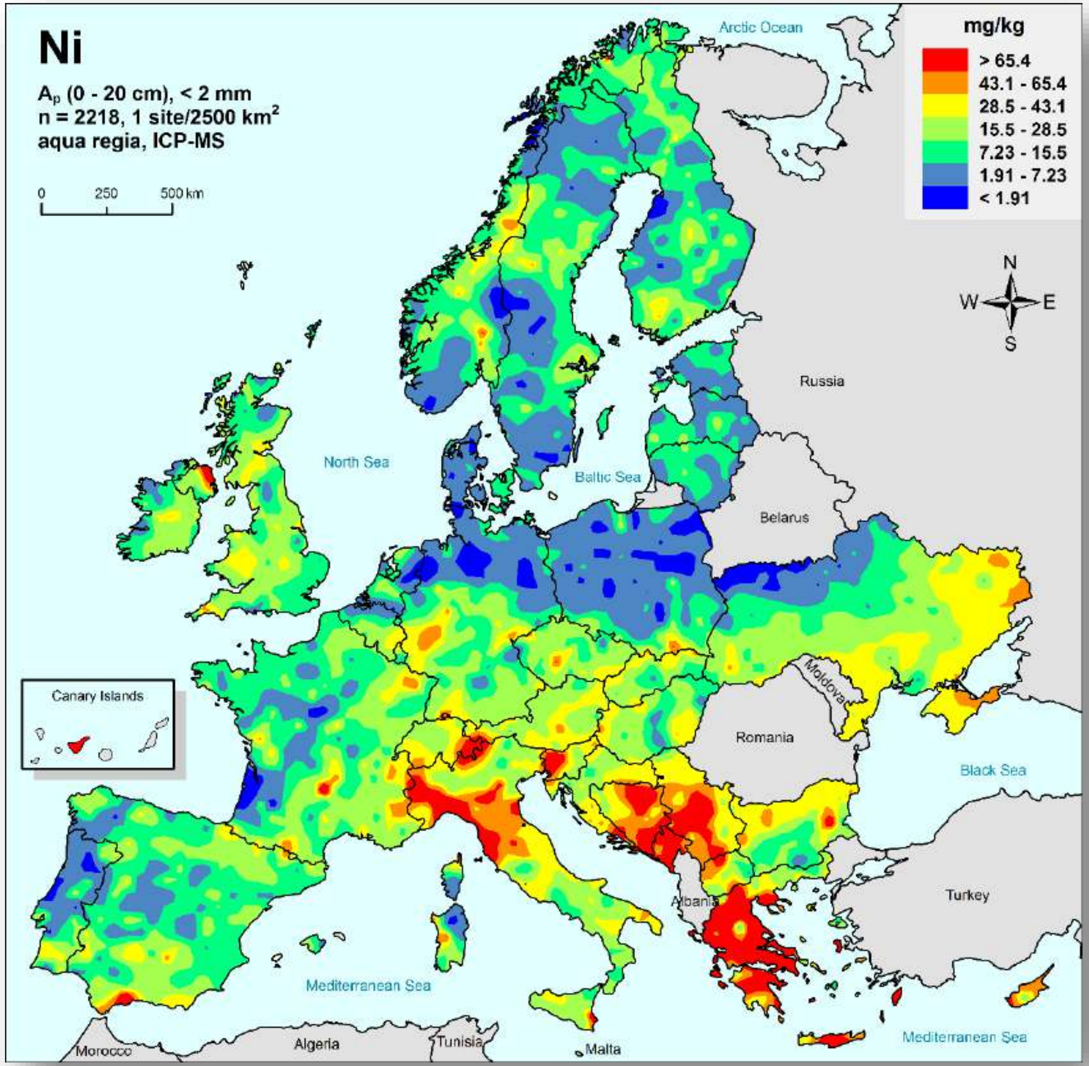


Source: Reimann *et al.*, 2014c, Fig. 11.39.4, p.327

Geochemical patterns of two different sample media are robust

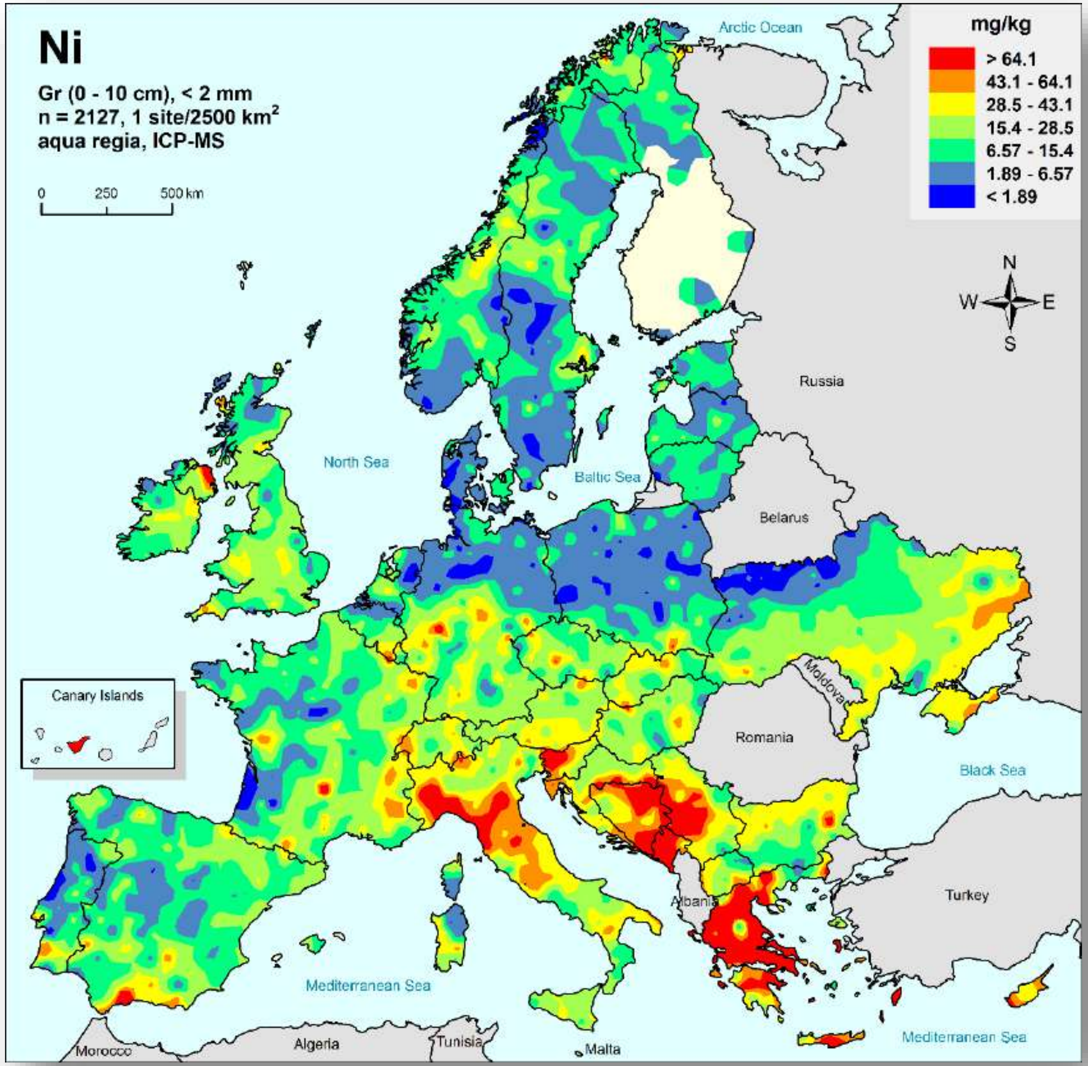
GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe

Agricultural soil, 0-20 cm



Source: Reimann *et al.*, 2014c, Fig. 11.39.5, p.329

Grazing land soil, 0-10 cm

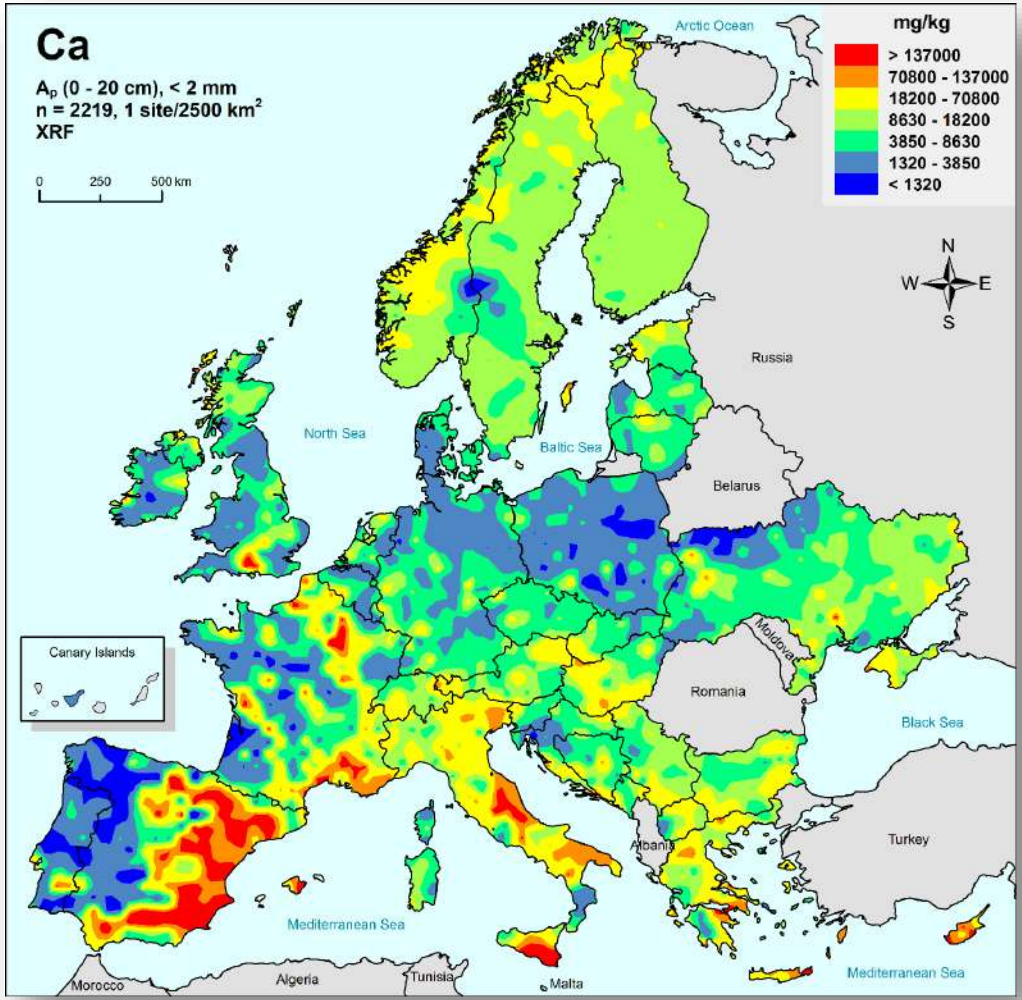


Source: Reimann *et al.*, 2014c, Fig. 11.39.5, p.329

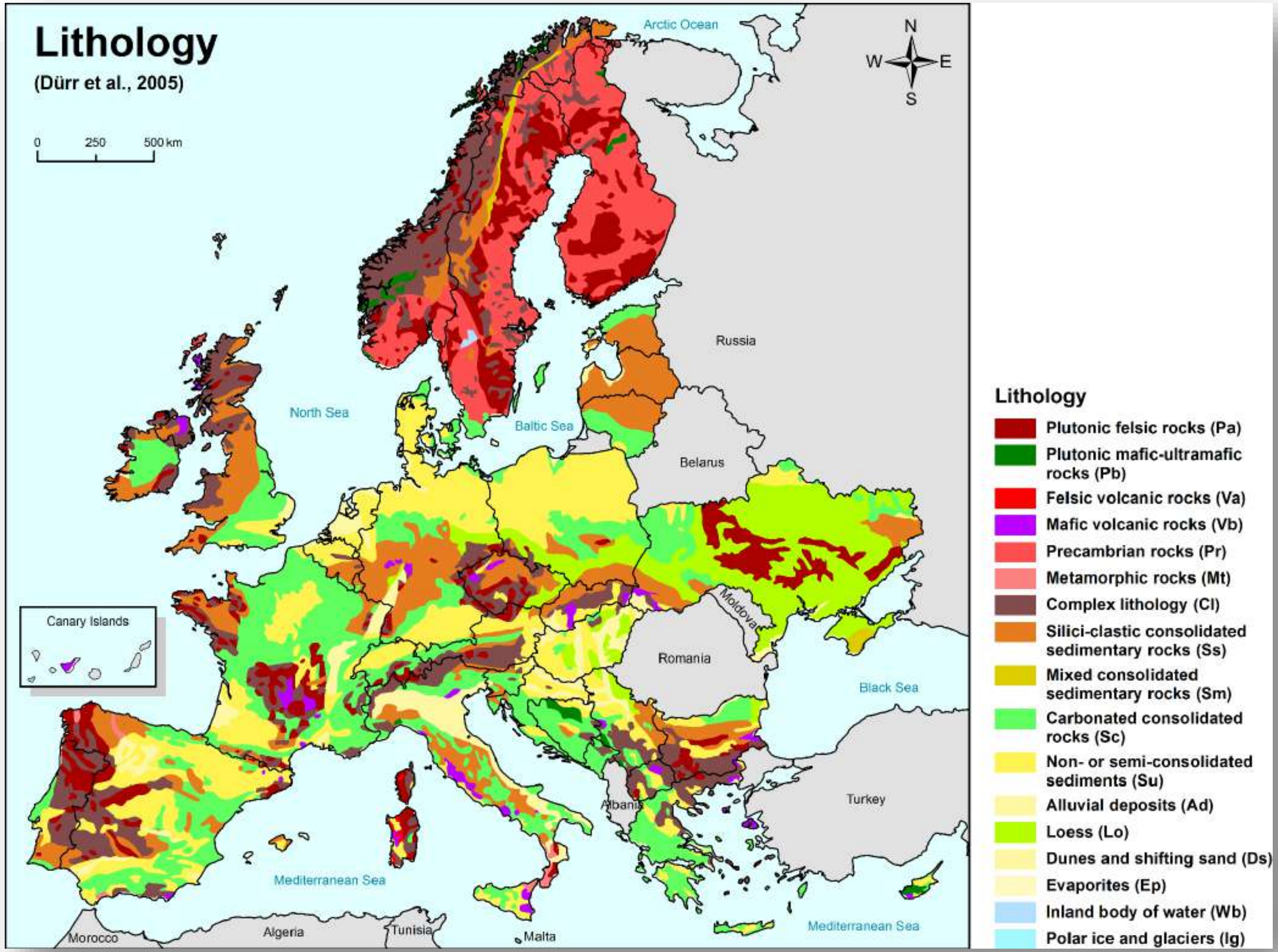
Two different sample types/site, each *ca*. 2100 samples – the maps are robust

The impact of geology or rather lithology

GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe

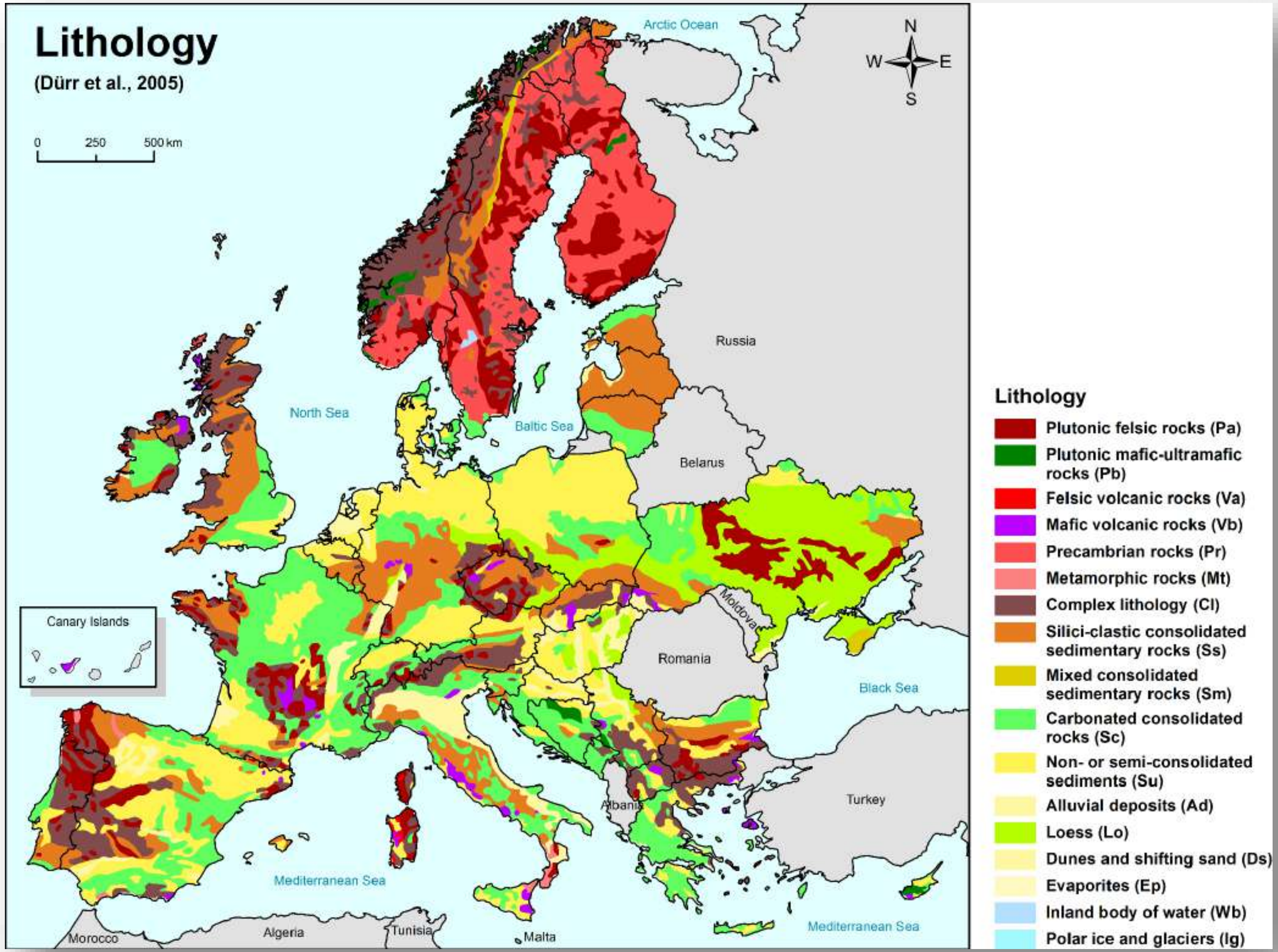


Source: Reimann *et al*., 2014c, Fig. 11.16.5, p.200

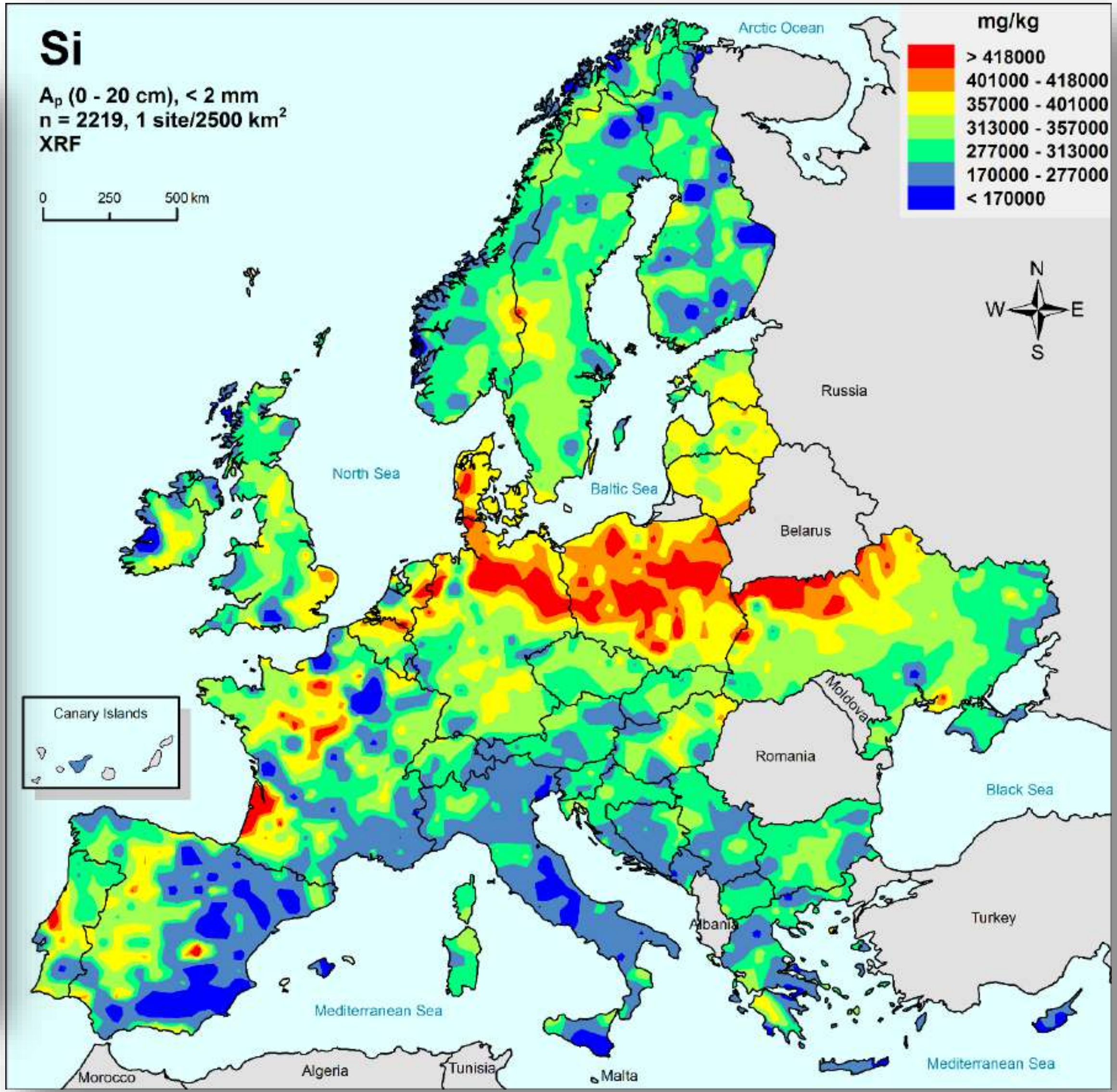


Source: Birke *et al*., 2014, Fig. 10.5, p.96

Carbonated consolidated rocks mapped by Ca.

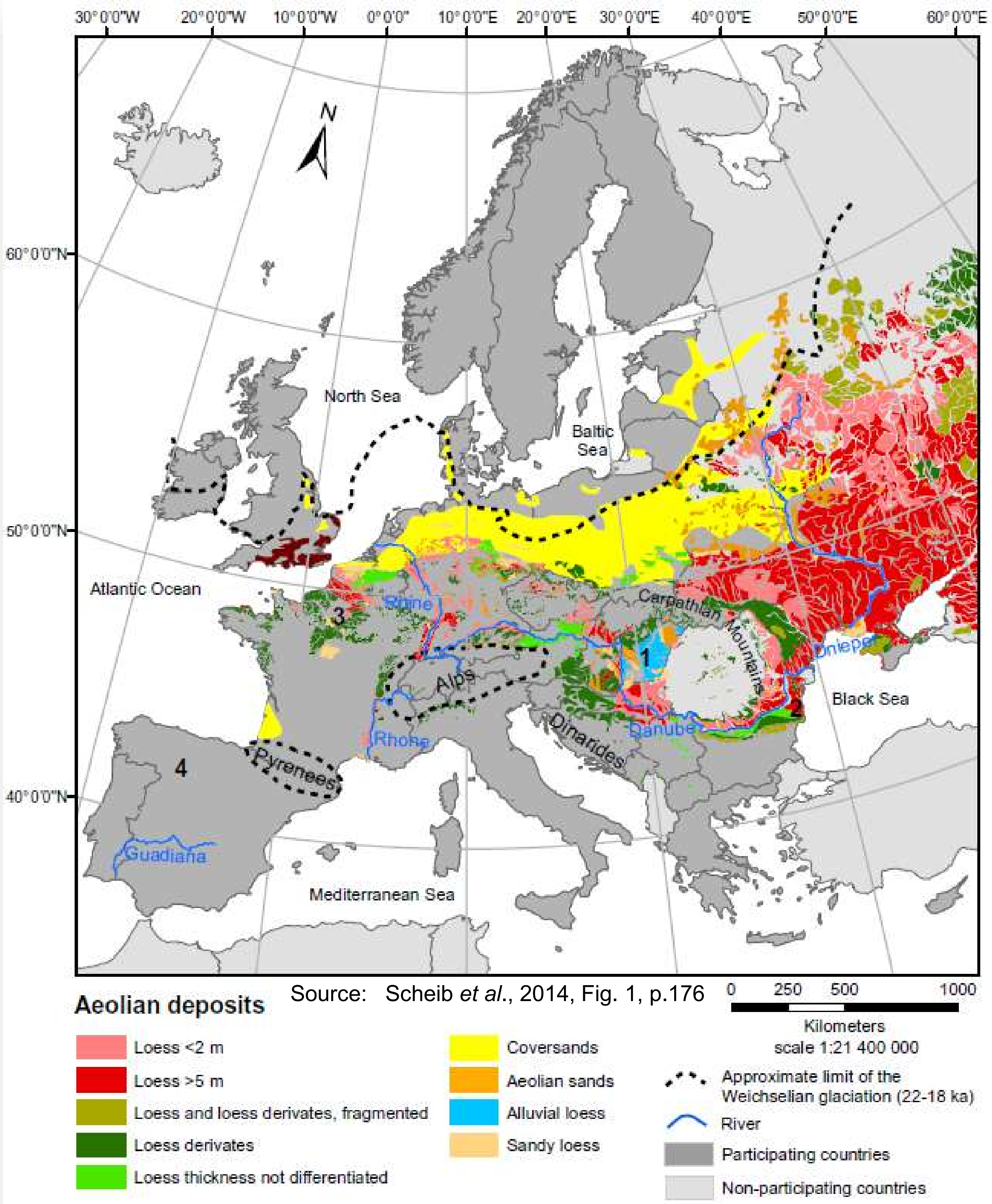


Source: Birke *et al.*, 2014, Fig. 10.5, p.96

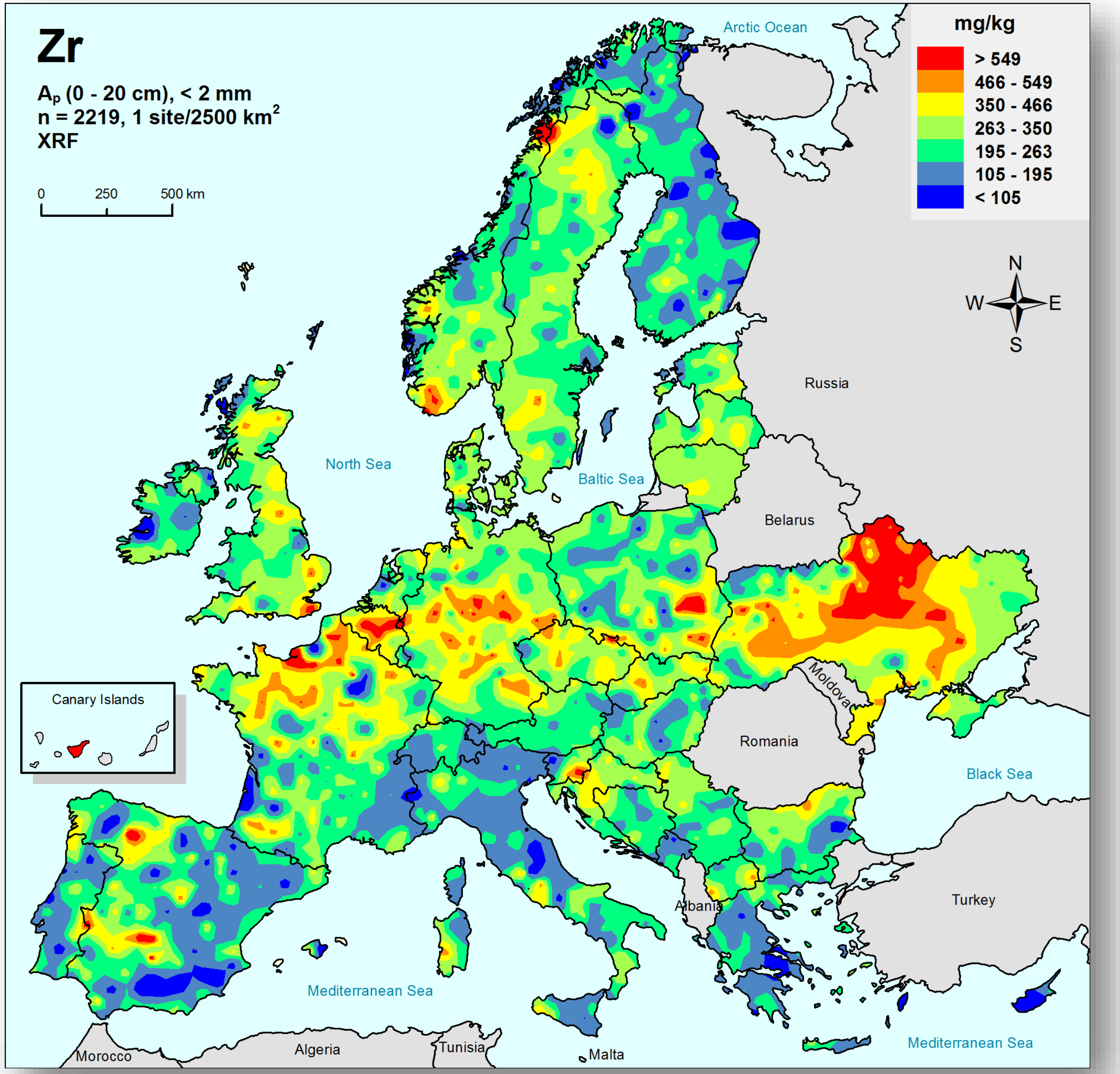


Source: Reimann *et al.*, 2014c, Fig. 11.51.5, p.399

Last glacial sands mapped by Si.

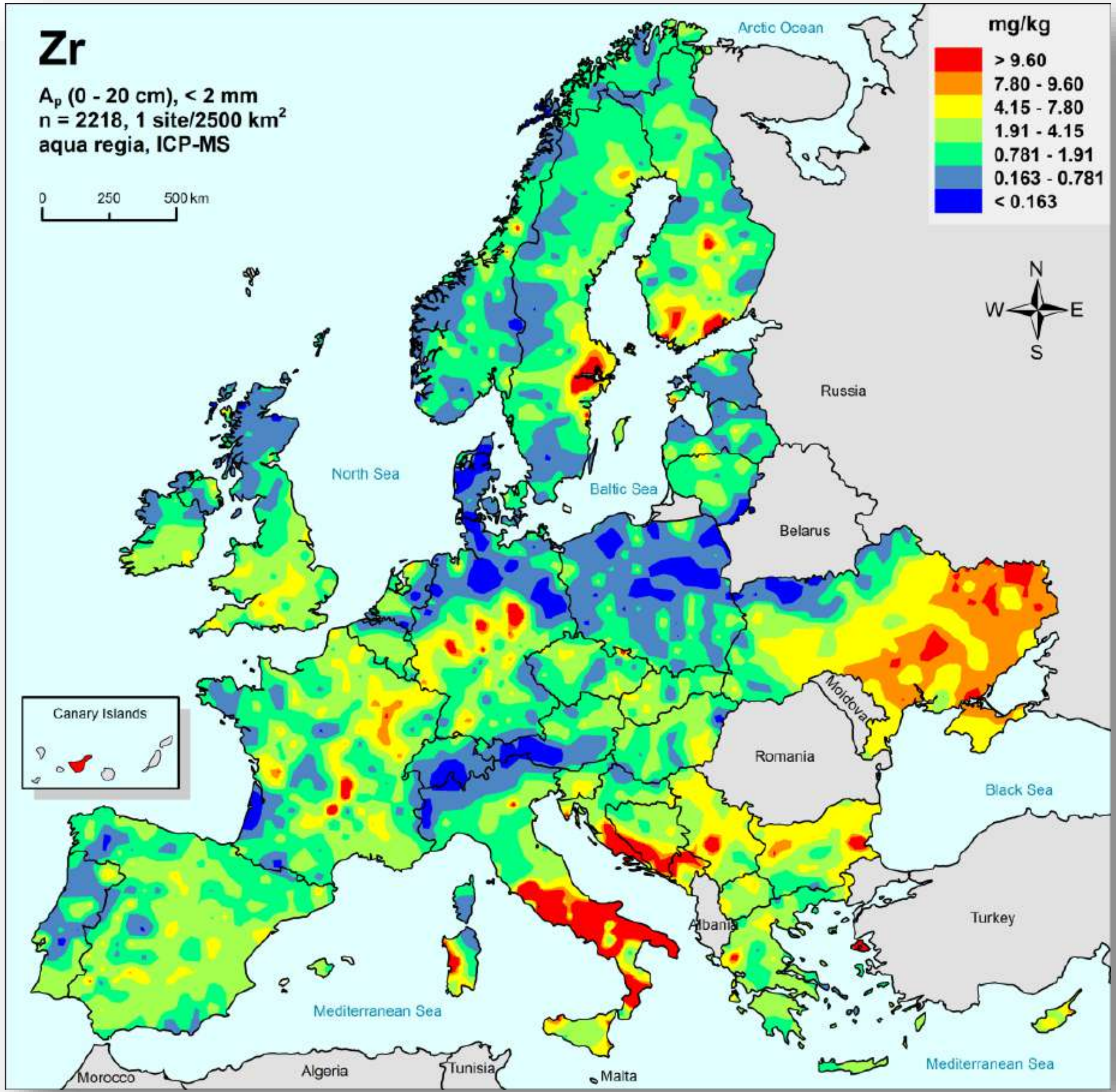


Source: Scheib *et al.*, 2014, Fig. 1, p.176



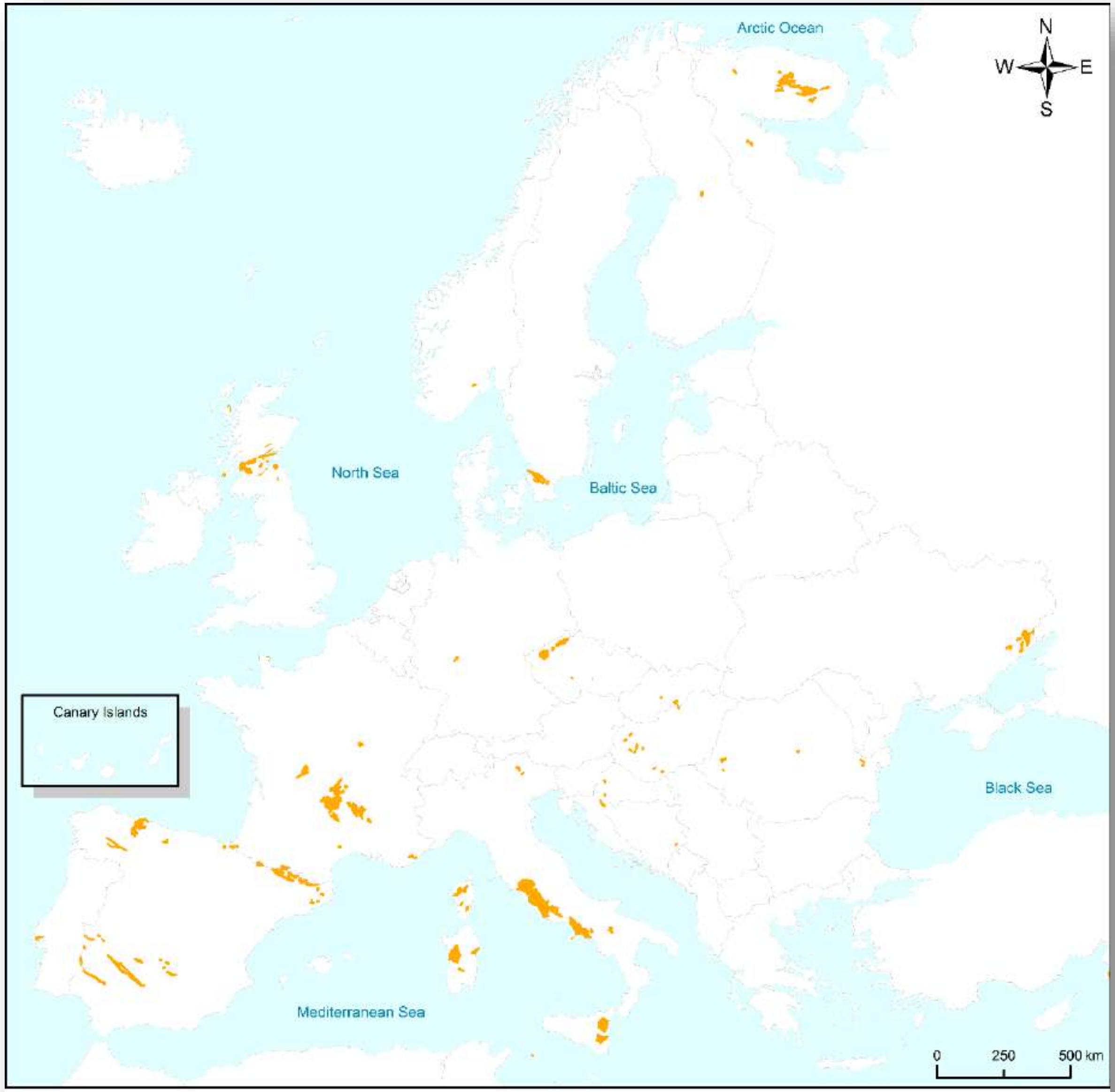
Source: Reimann *et al.*, 2014c, Fig. 11.51.5, p.399

The central European loess belt is mapped by total$_{XRF}$ Zr.



Source: Reimann et al., 2014, Fig. 11.64.5, p.471

The Italian alkaline volcanics are mapped by Zr (aqua regia)



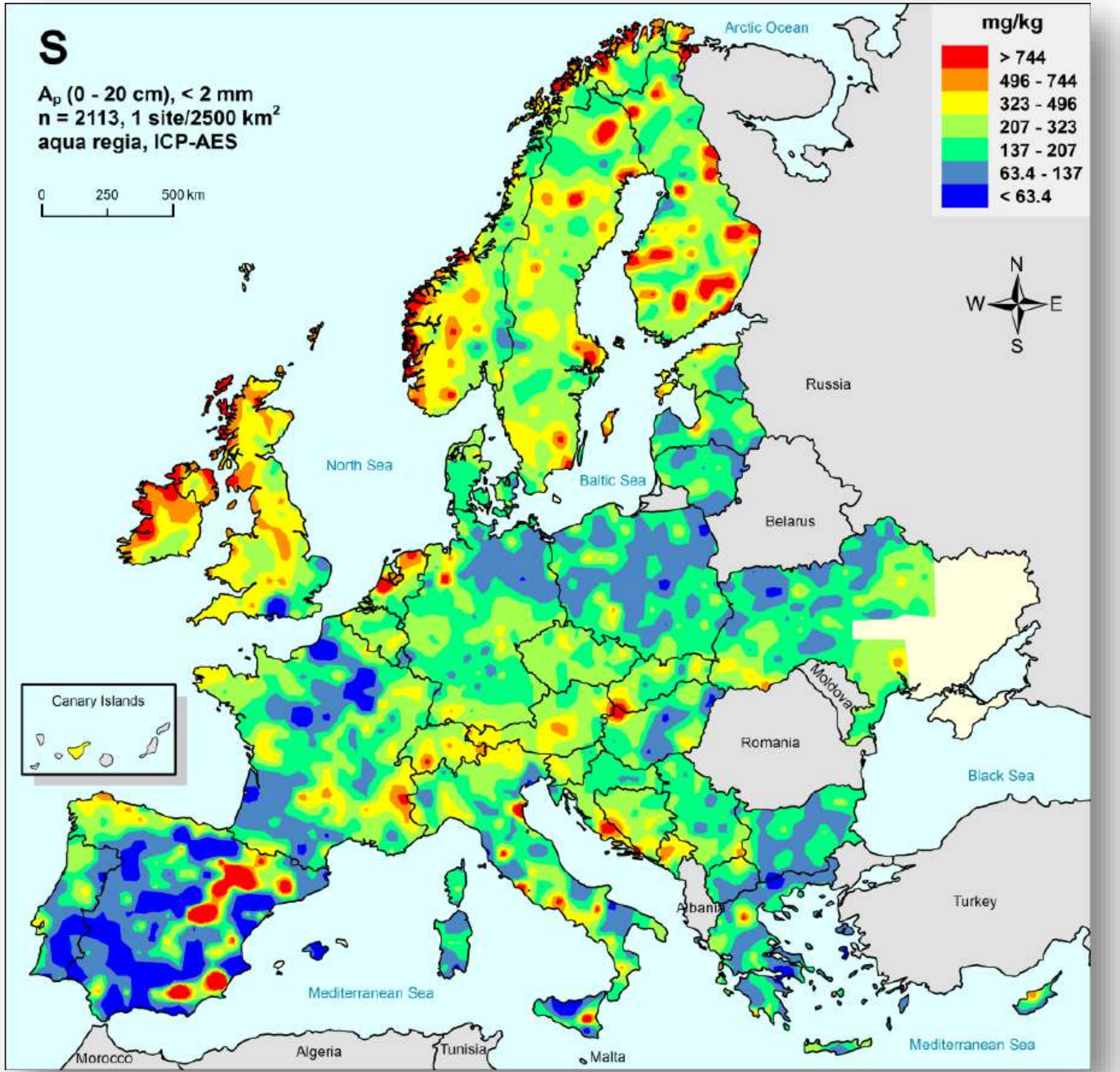
Edited by Jähne F., based on Asch K. (2003). IGME 5000: International Geological Map of Europe and Adjacent Areas

Rock units at the surface with alkaline igneous rocks

Source: Jähne, 2014, Fig. 2.6d, p.60

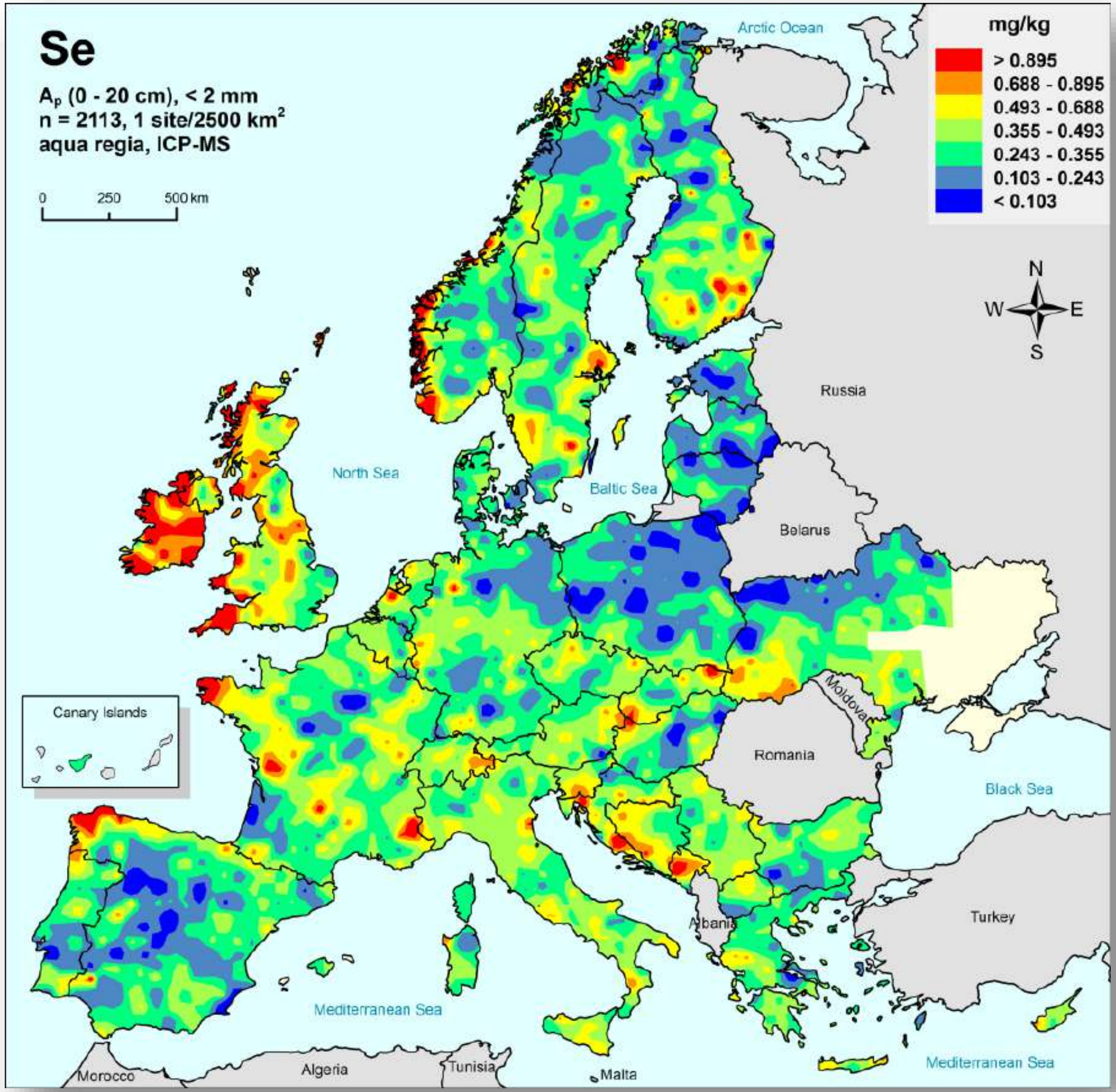
The impact of climate

GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



Source: Reimann et al., 2014, Fig. 11.47.5, p.373

Elevated S contents in soil near coastal areas and in organic material.

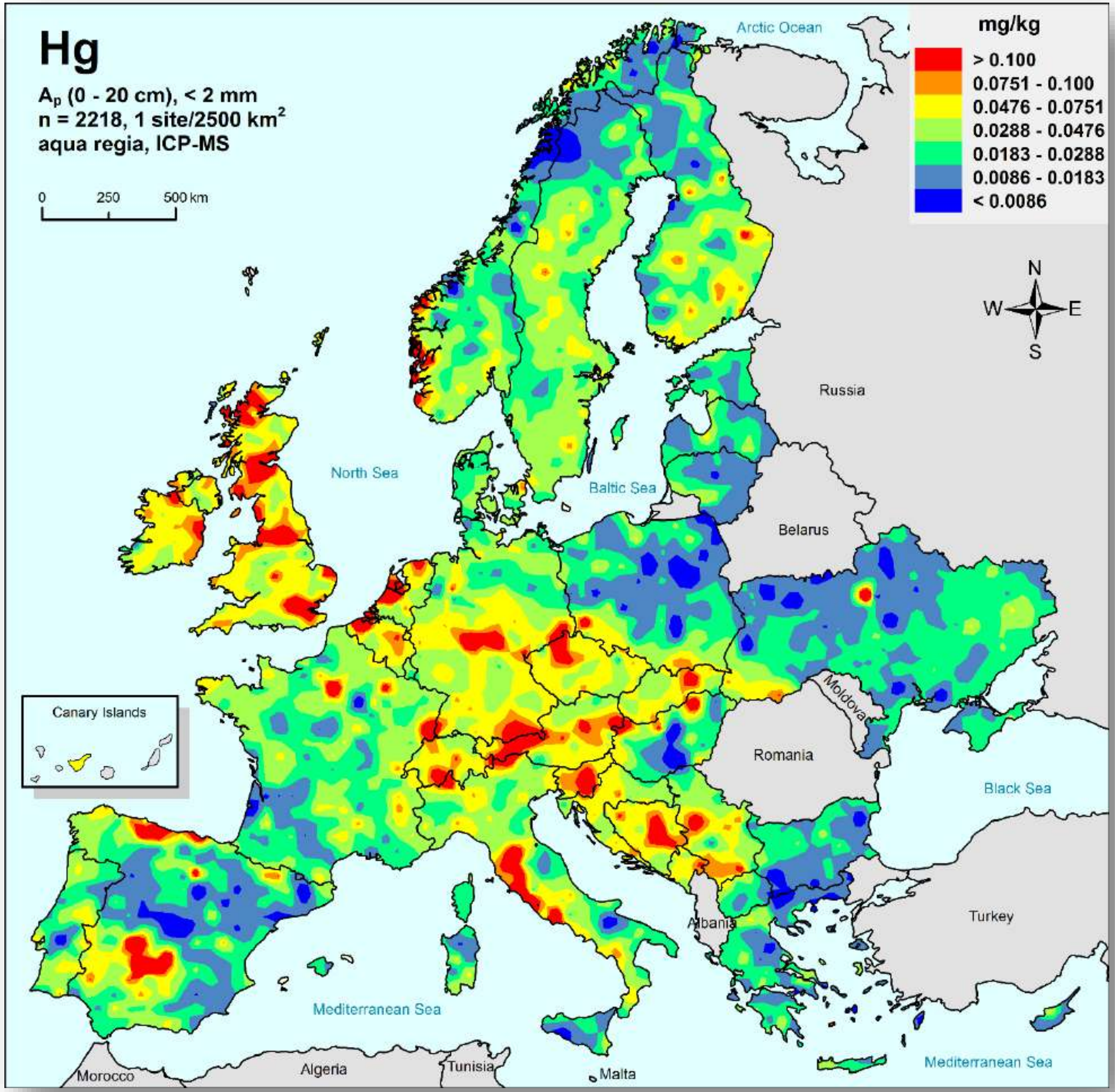


Source: Reimann et al., 2014, Fig. 11.50.5, p.391

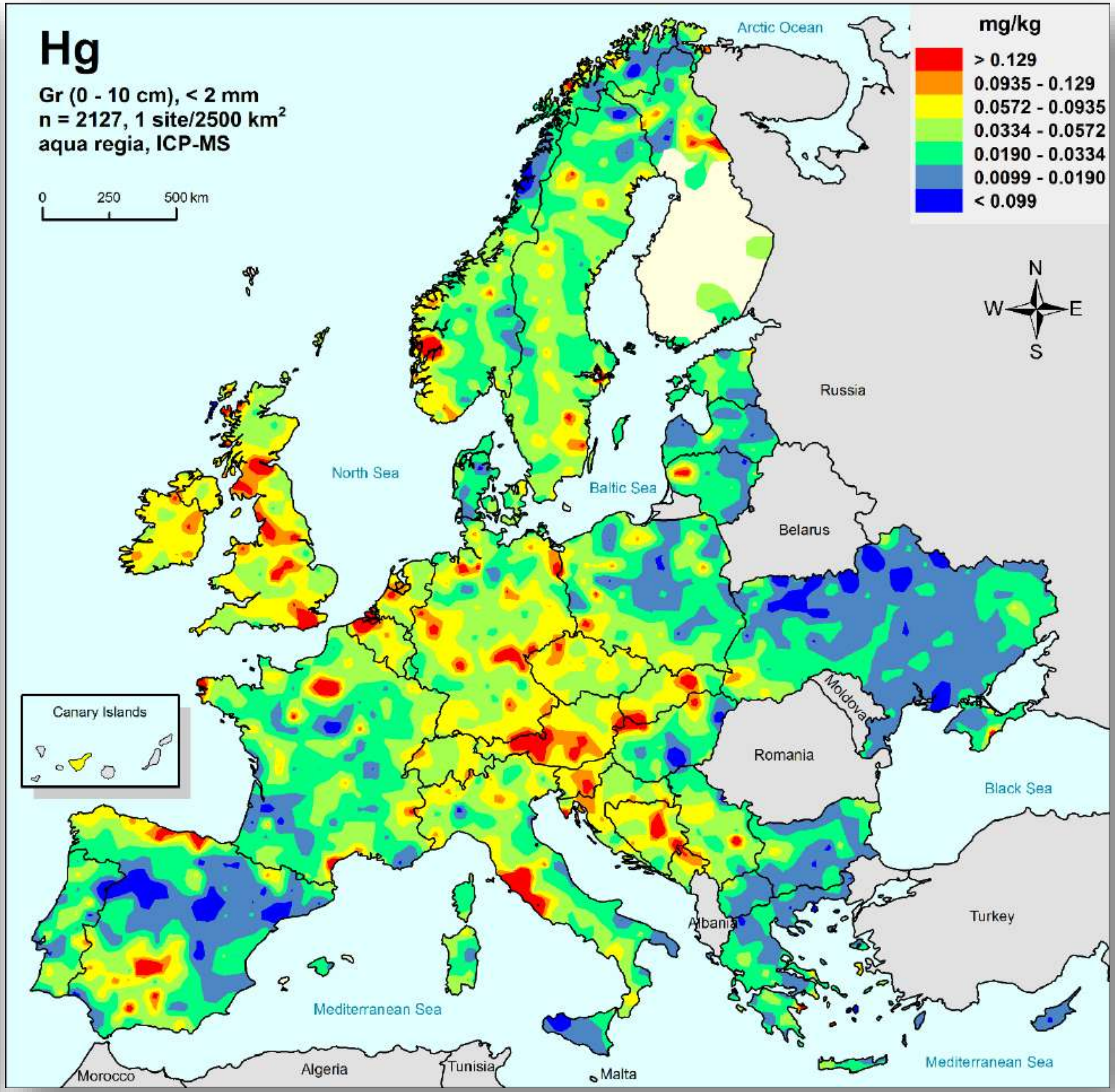
Elevated Se contents showing strong coastal effect.

The impact of human activities

GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe

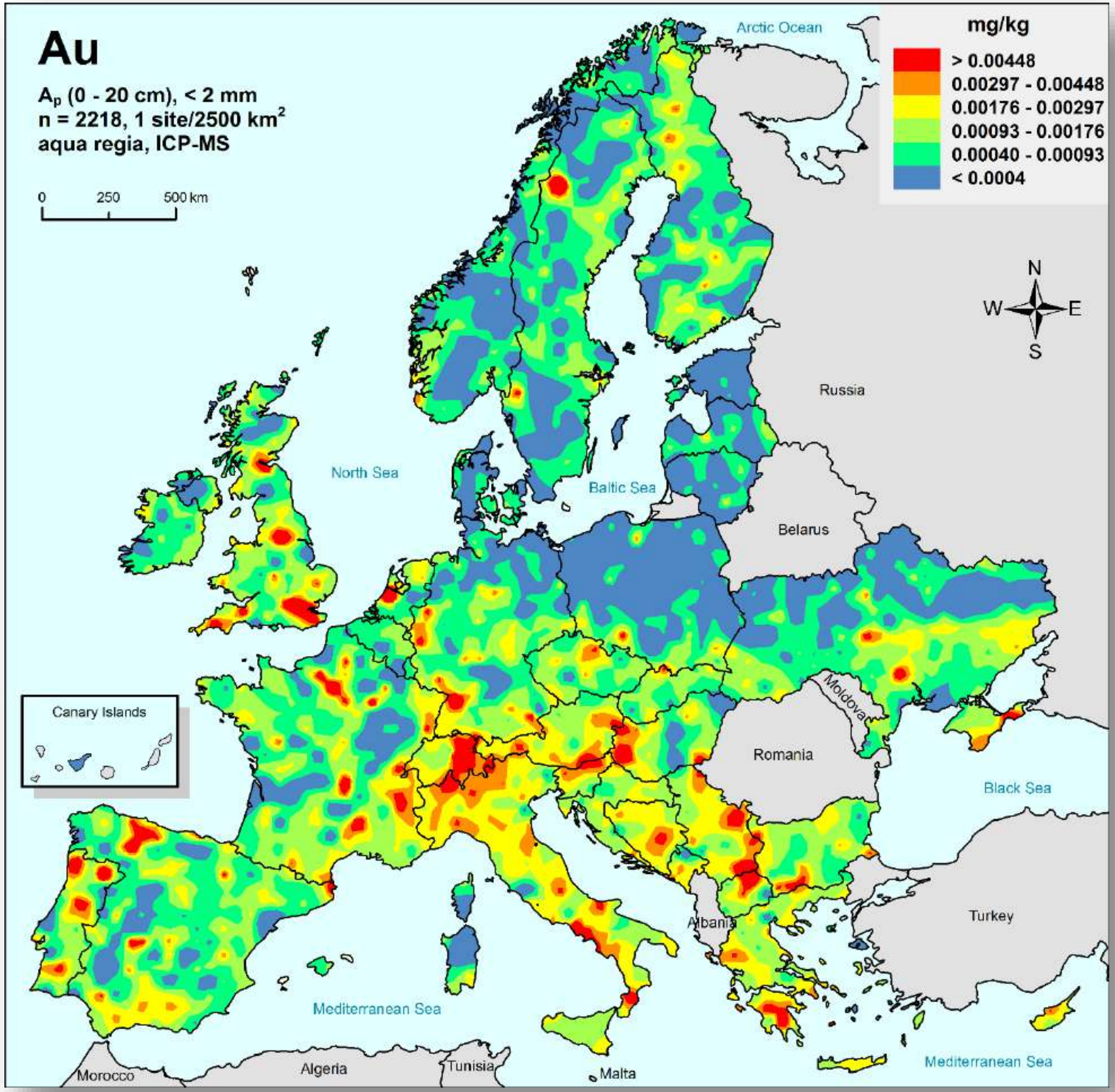


Source: Reimann *et al.*, 2014c, Fig. 11.29.5, p.269

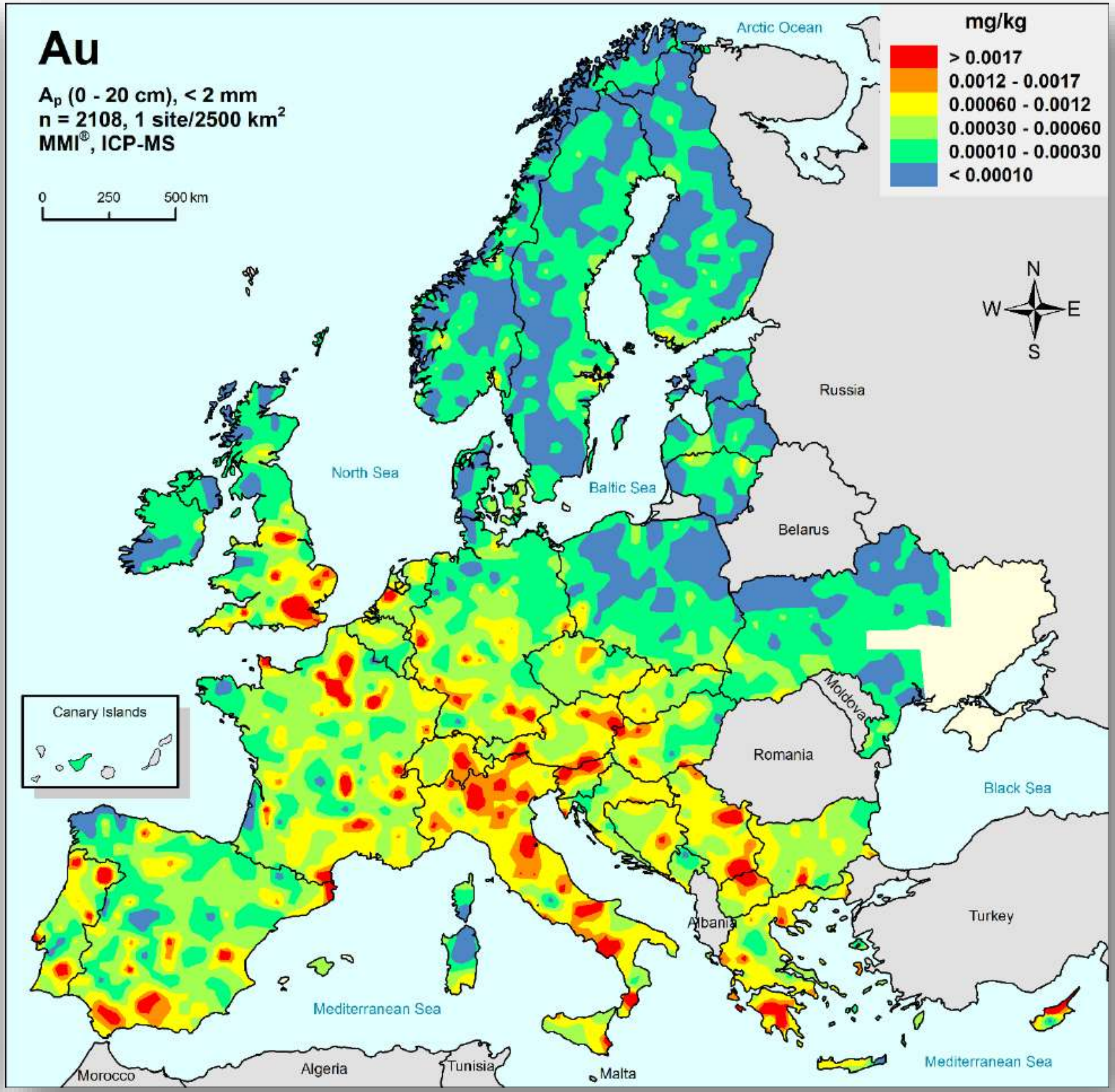


Source: Reimann *et al.*, 2014c, Fig. 11.29.5, p.269

GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



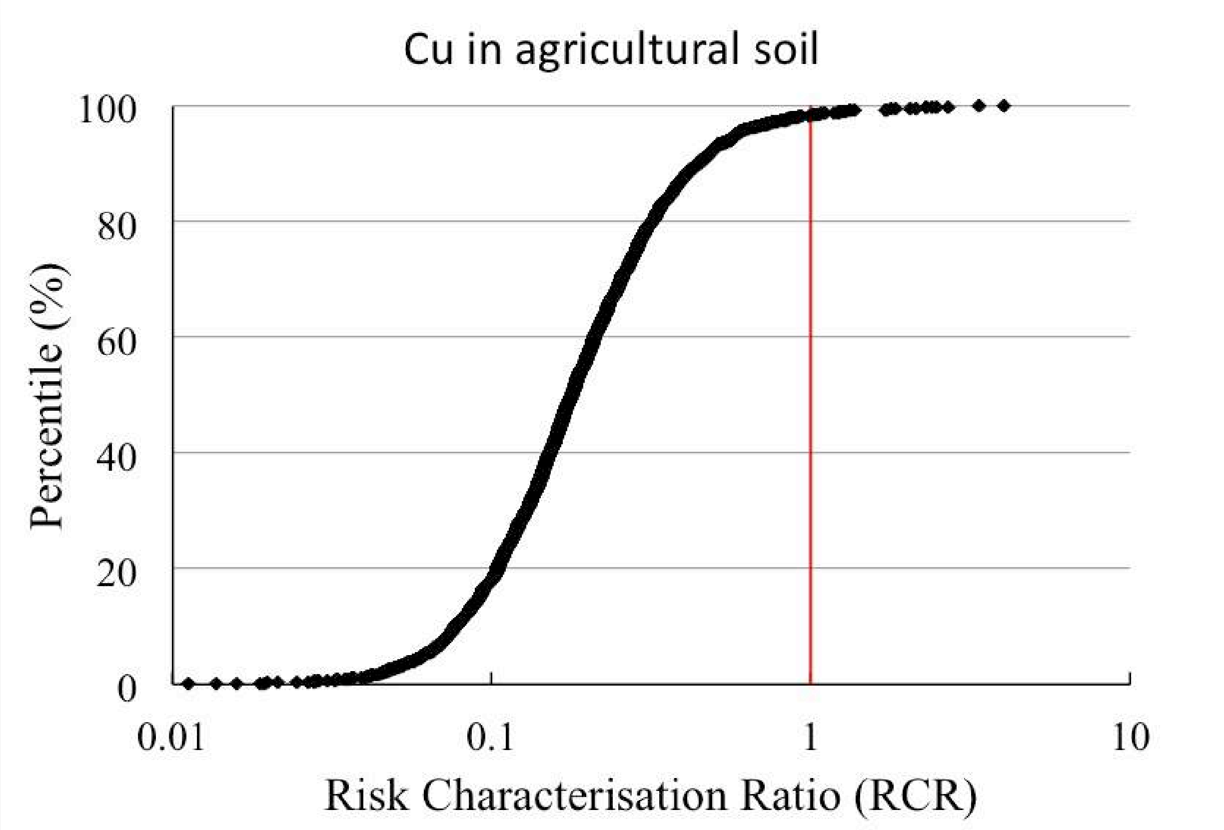
Source: Reimann *et al.*, 2014c, Fig. 11.20.5, p.161

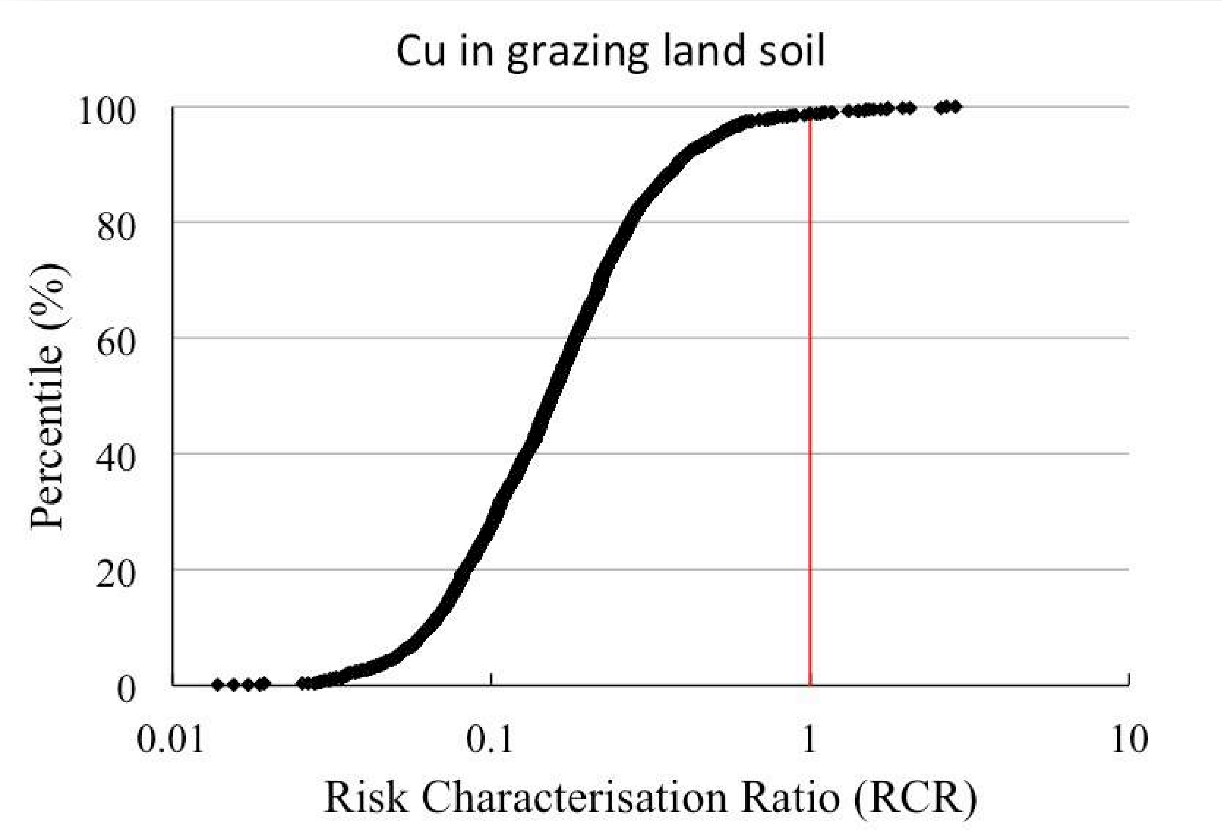


Source: Reimann *et al.*, 2014c, Fig. 11.20.5, p.161

Risk assessment

Risk Characterisation Ratios (RCR) for Cu in agricultural and grazing land soil



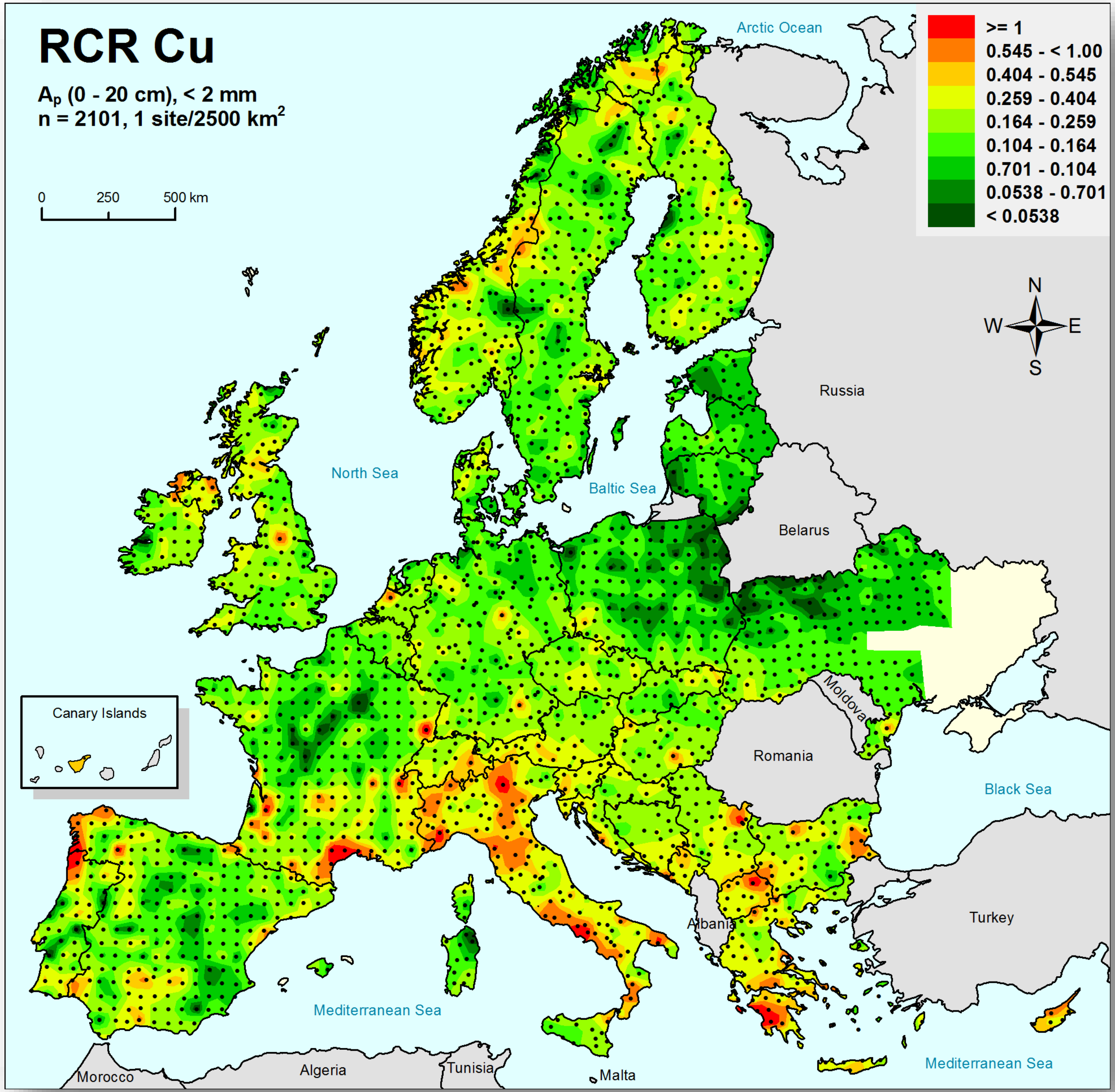


Source: Oorts and Schoeters, 2014, Fig. 12.8, p.200

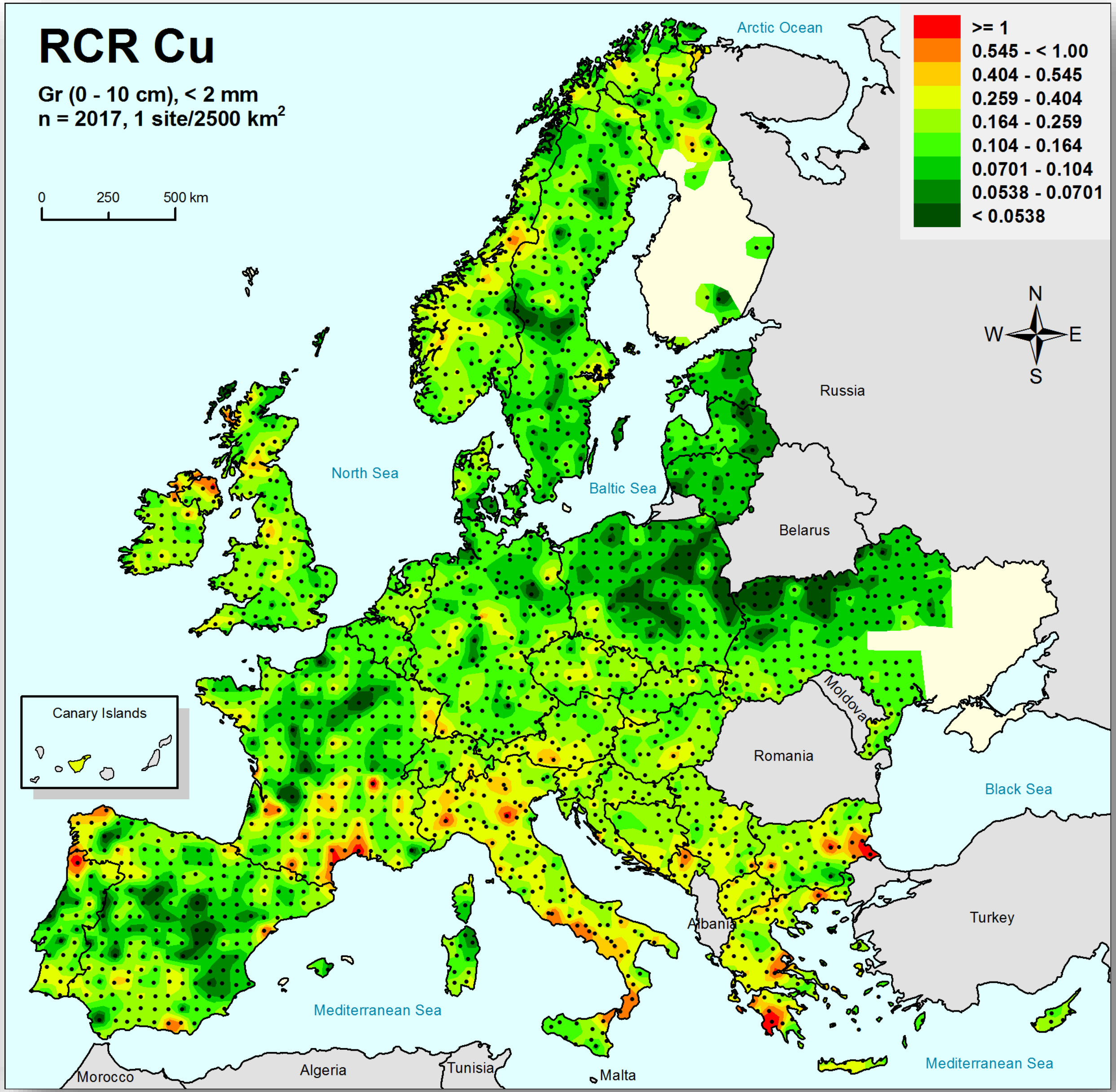
Land use	Minimum	10th percentile	Median	90th percentile	Maximum
Agricultural land	0.01	0.08	0.17	0.43	4.03
Grazing land	0.01	0.06	0.15	0.38	2.85

Source: Oorts and Schoeters, 2014, Table 12.2, p.194

GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



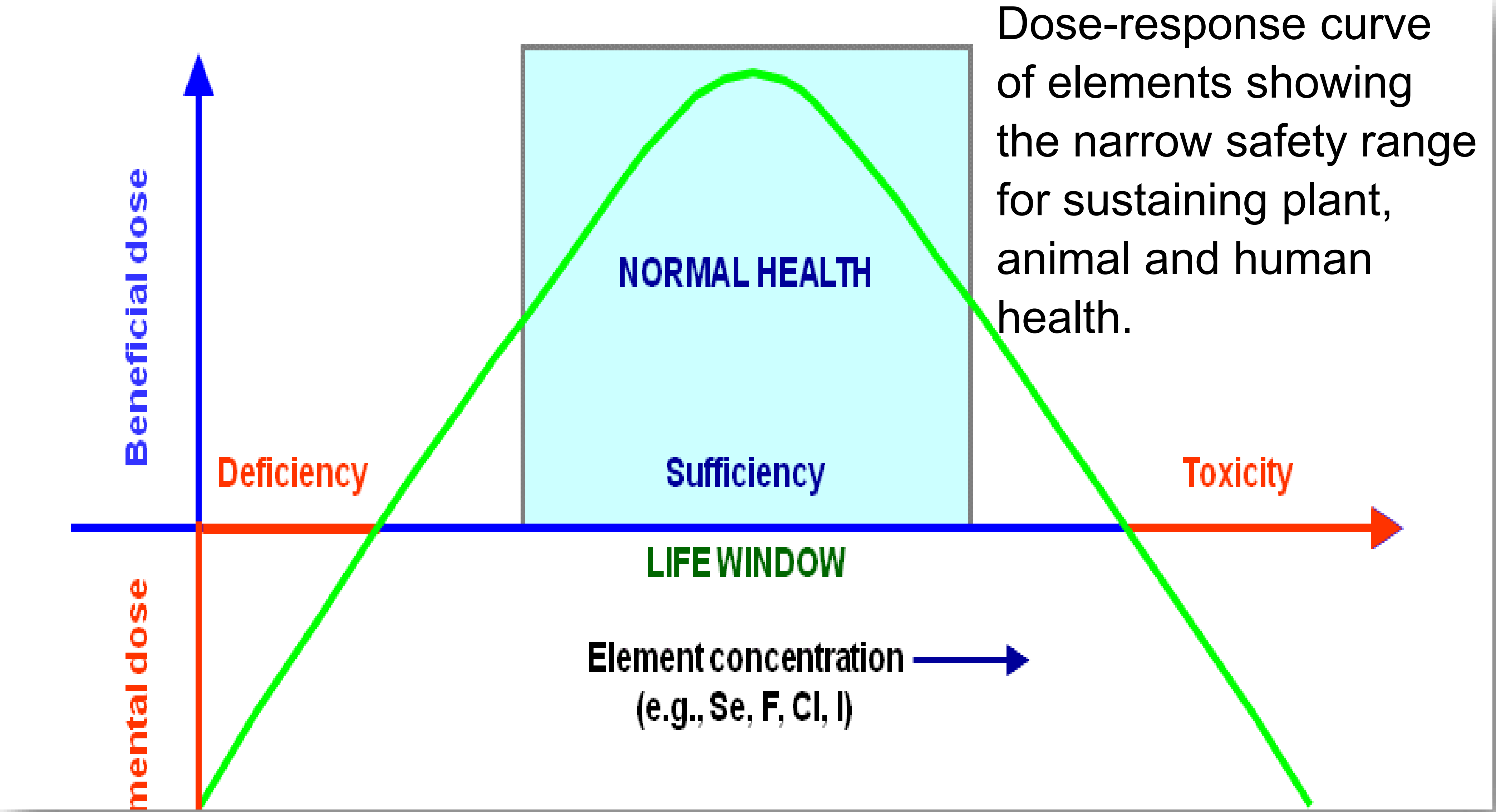
Source: Oorts and Schoeters, 2014, Fig. 12.7, p.198



Source: Oorts and Schoeters, 2014, Fig. 12.7, p.198

Most soil samples at risk were taken in vineyards or near vineyards.

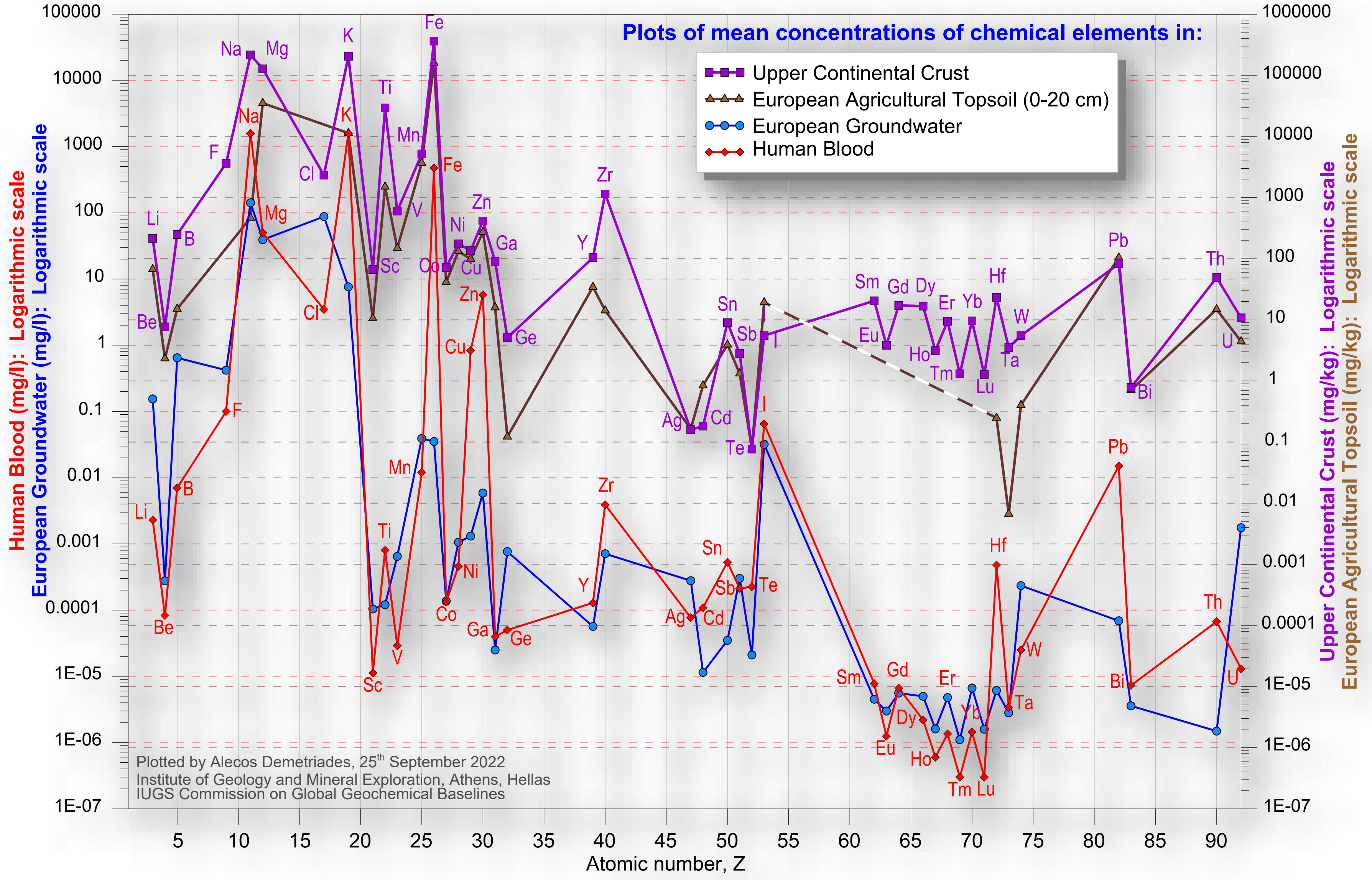
Health implications



Dose-response curve of elements showing the narrow safety range for sustaining plant, animal and human health.

Source: Reimann *et al.*, 2014d, Fig. 12.4, p.495

GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe

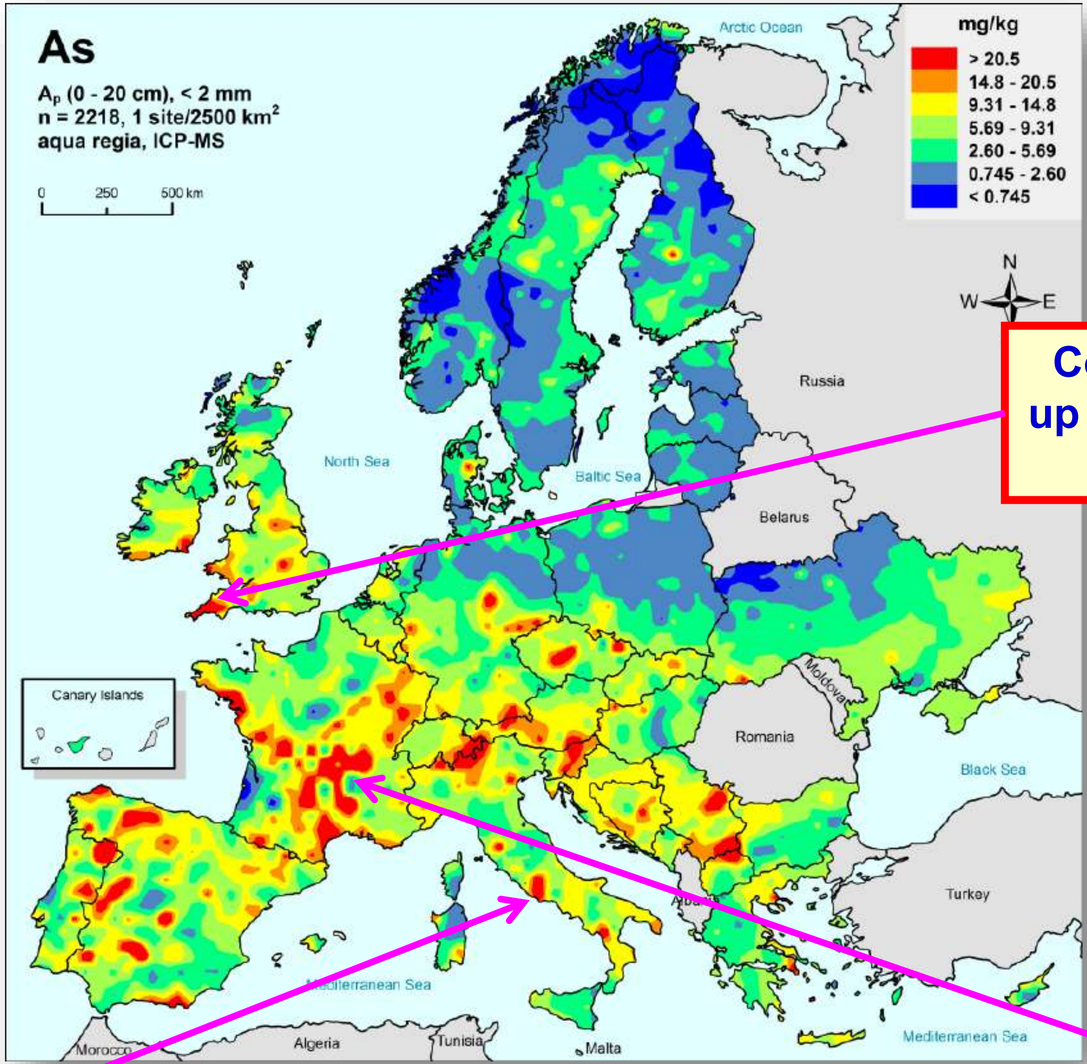


Source: Demetriades, 2024, Fig. 58. p.65

Graph showing the relationship between selected major and trace element mean concentrations in the upper continental crust and human blood. Their similar trend indicates that there is a close relationship between the chemical composition of human blood and the materials of the upper continental crust, although there is a significant difference in magnitude. Data sources: Upper Continental Crust (Reimann et al., 2014c, Table 11.1, p.105); European Agricultural Topsoil (Reimann et al., 2014c); European Groundwater (Reimann and Birke, 2010); Human blood (ALS Global, 2021). Drawn with Golden Software's Grapher™ v21.

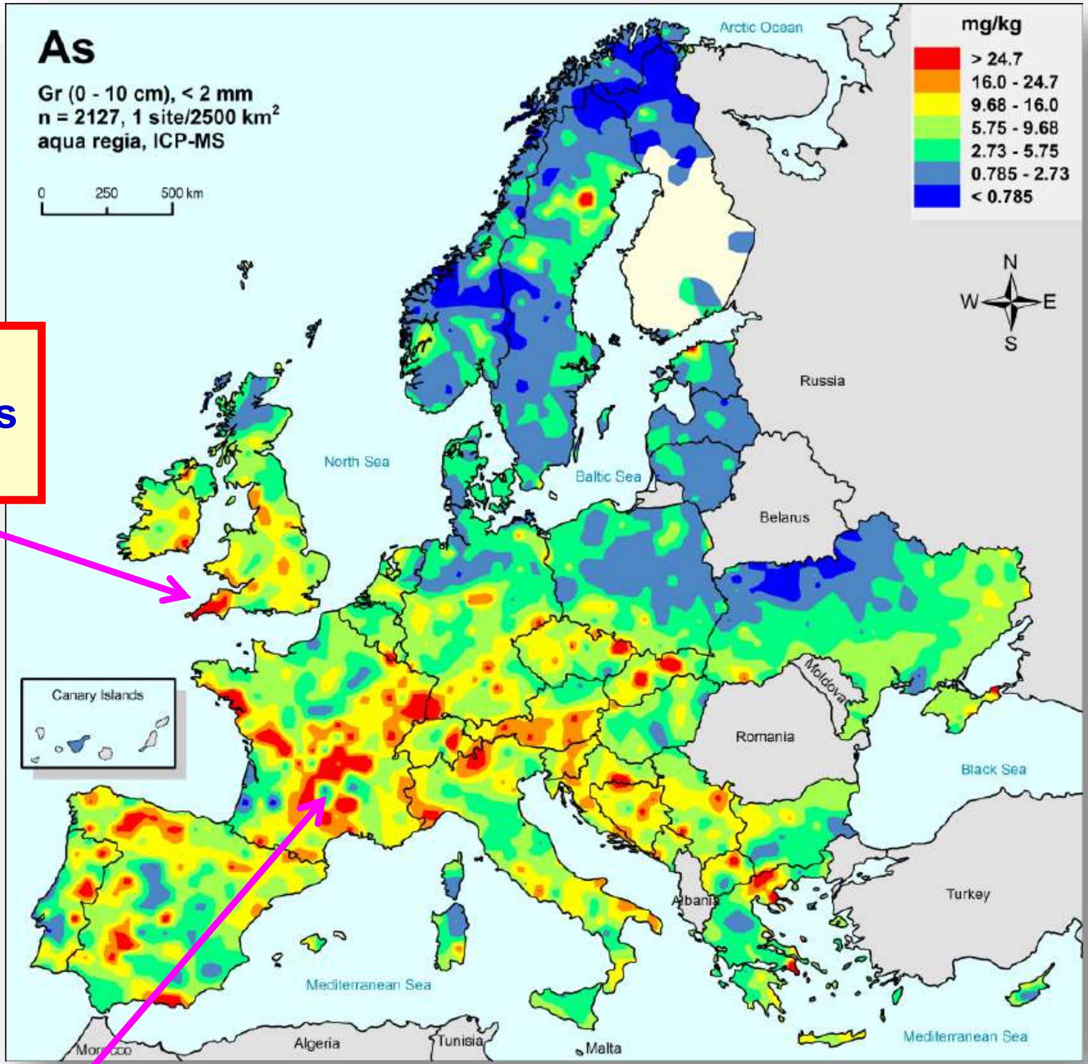
GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe

Agricultural soil, 0-20 cm



Source: Reimann *et al*., 2014c, Fig. 11.9.5, p.155

Grazing land soil, 0-10 cm



Source: Reimann *et al*., 2014c, Fig. 11.9.5, p.155

Cornwall, up to 2% As in soil

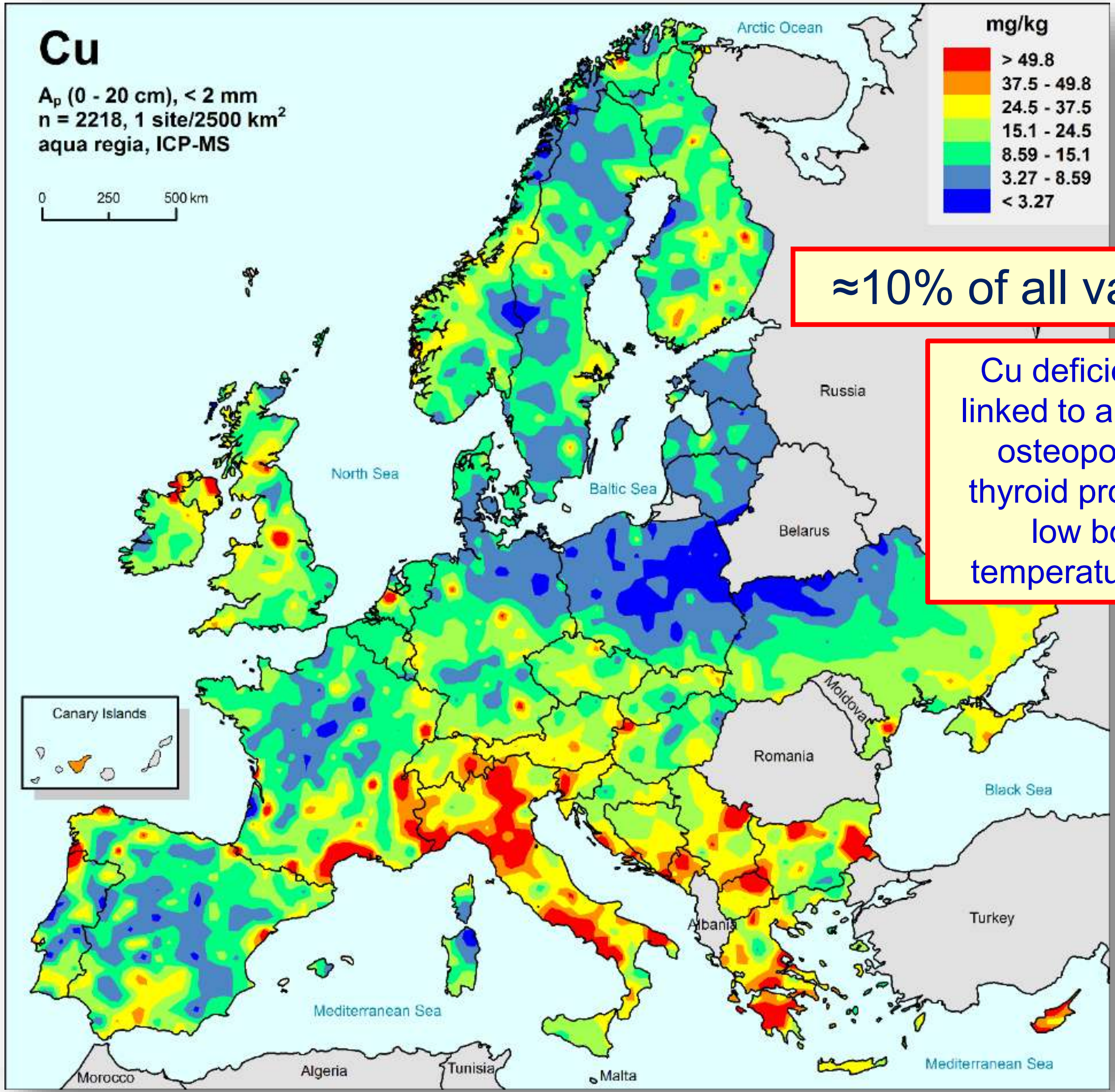
Lazio region, high As in groundwater (25-80 µg per l), used for crop irrigation

Massif Central, high As in soil (young volcanism, Au, Pb-Zn deposits)

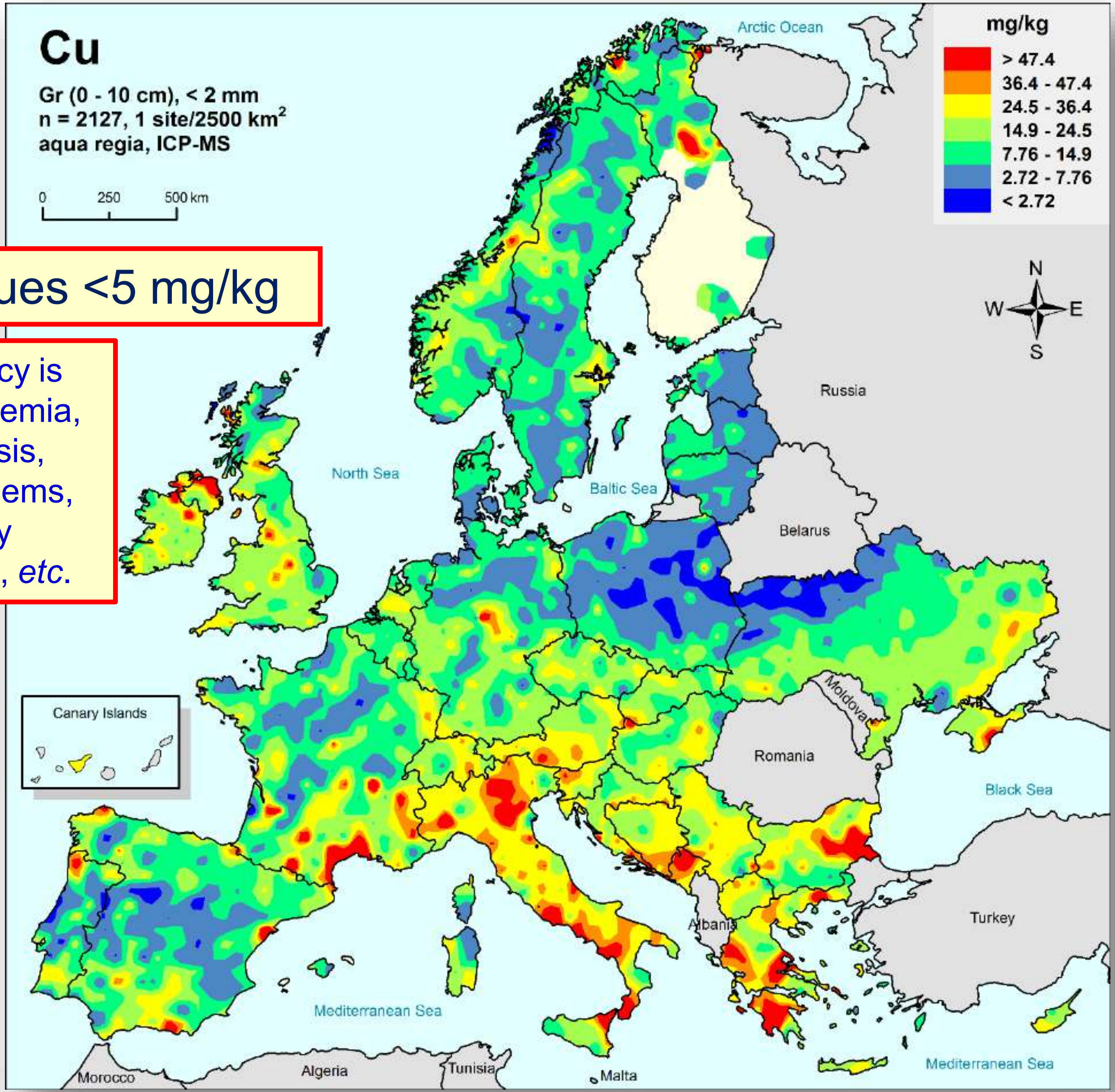
Health implications:

Element deficiency needs more attention

GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



Source: Reimann *et al.*, 2014c, Fig. 11.23.5, p.237

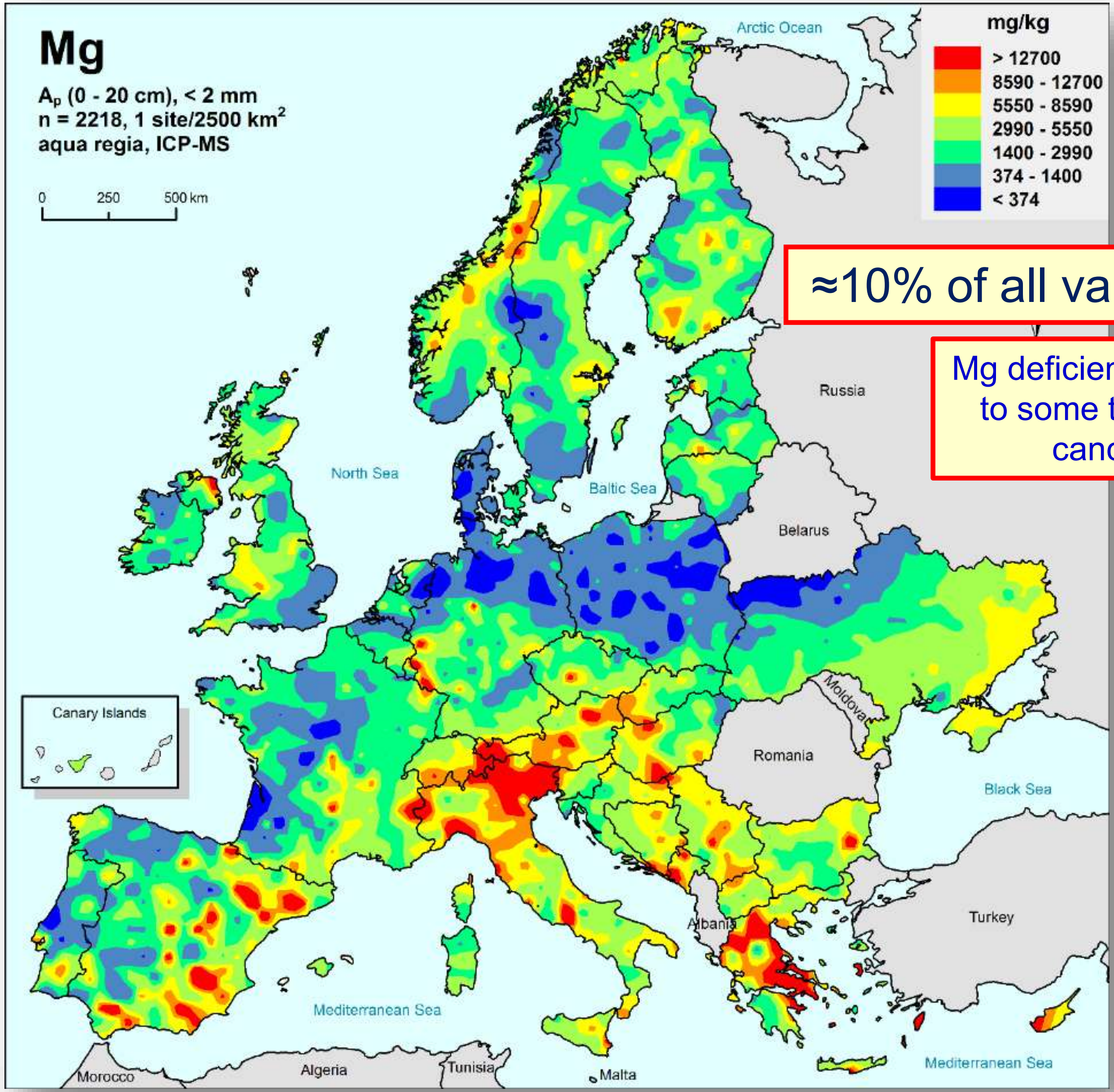


Source: Reimann *et al.*, 2014c, Fig. 11.23.5, p.237

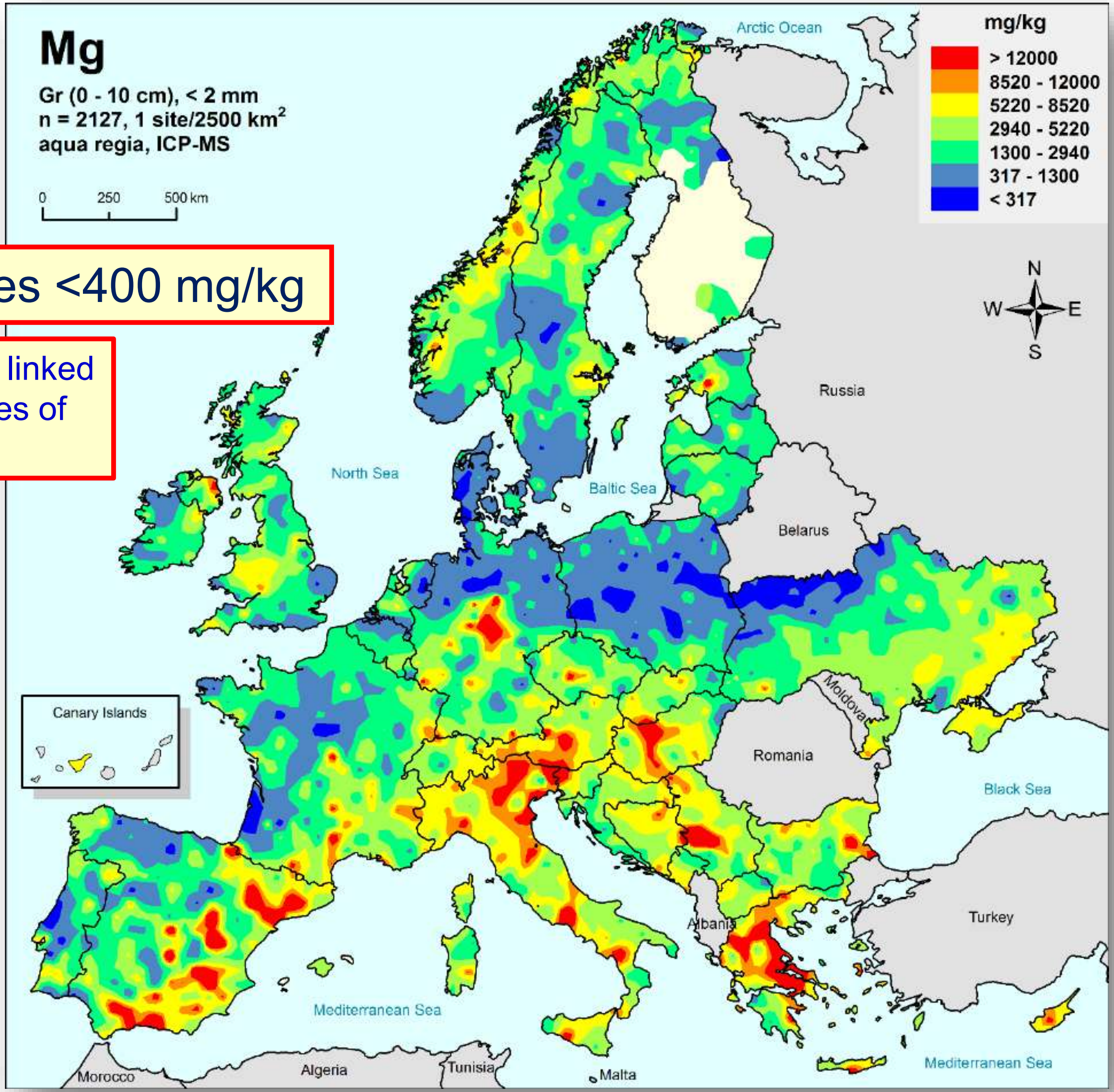
≈10% of all values <5 mg/kg

Cu deficiency is linked to anaemia, osteoporosis, thyroid problems, low body temperature, *etc.*

GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



Source: Reimann *et al.*, 2014c, Fig. 11.37.5, p.317

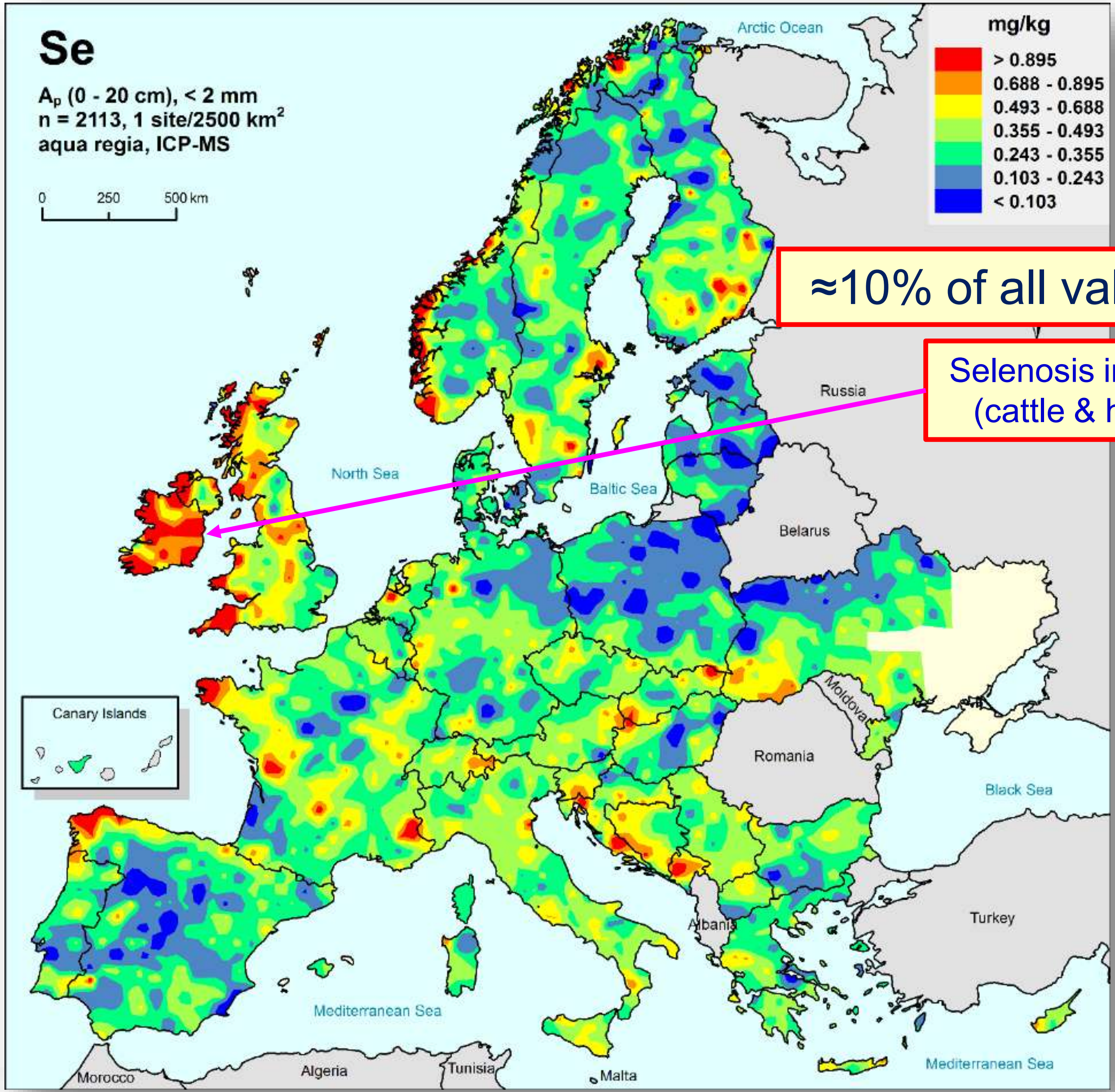


Source: Reimann *et al.*, 2014c, Fig. 11.37.5, p.317

≈10% of all values <400 mg/kg

Mg deficiency linked to some types of cancer

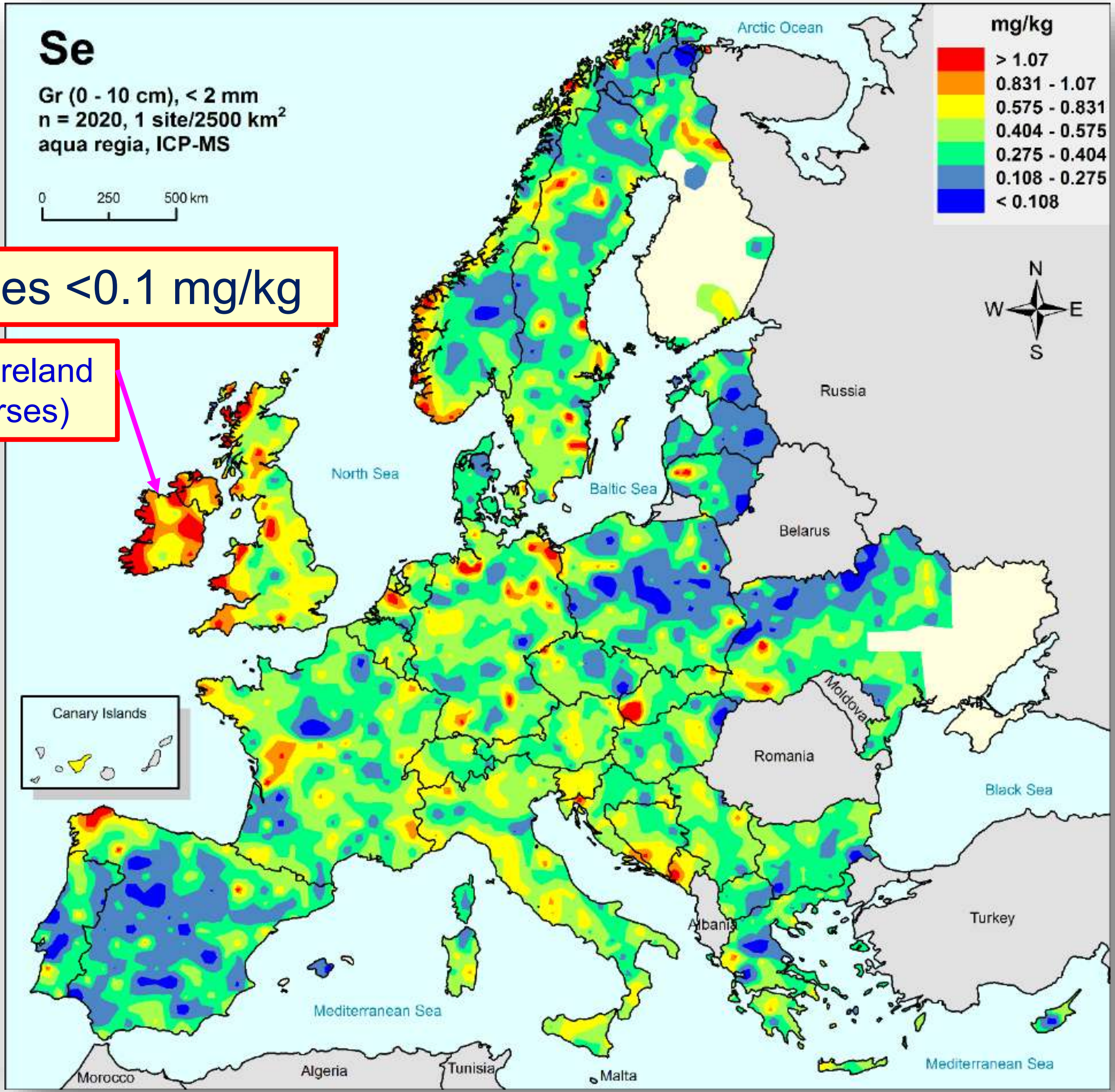
GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



Source: Reimann *et al.*, 2014c, Fig. 11.50.5, p.393

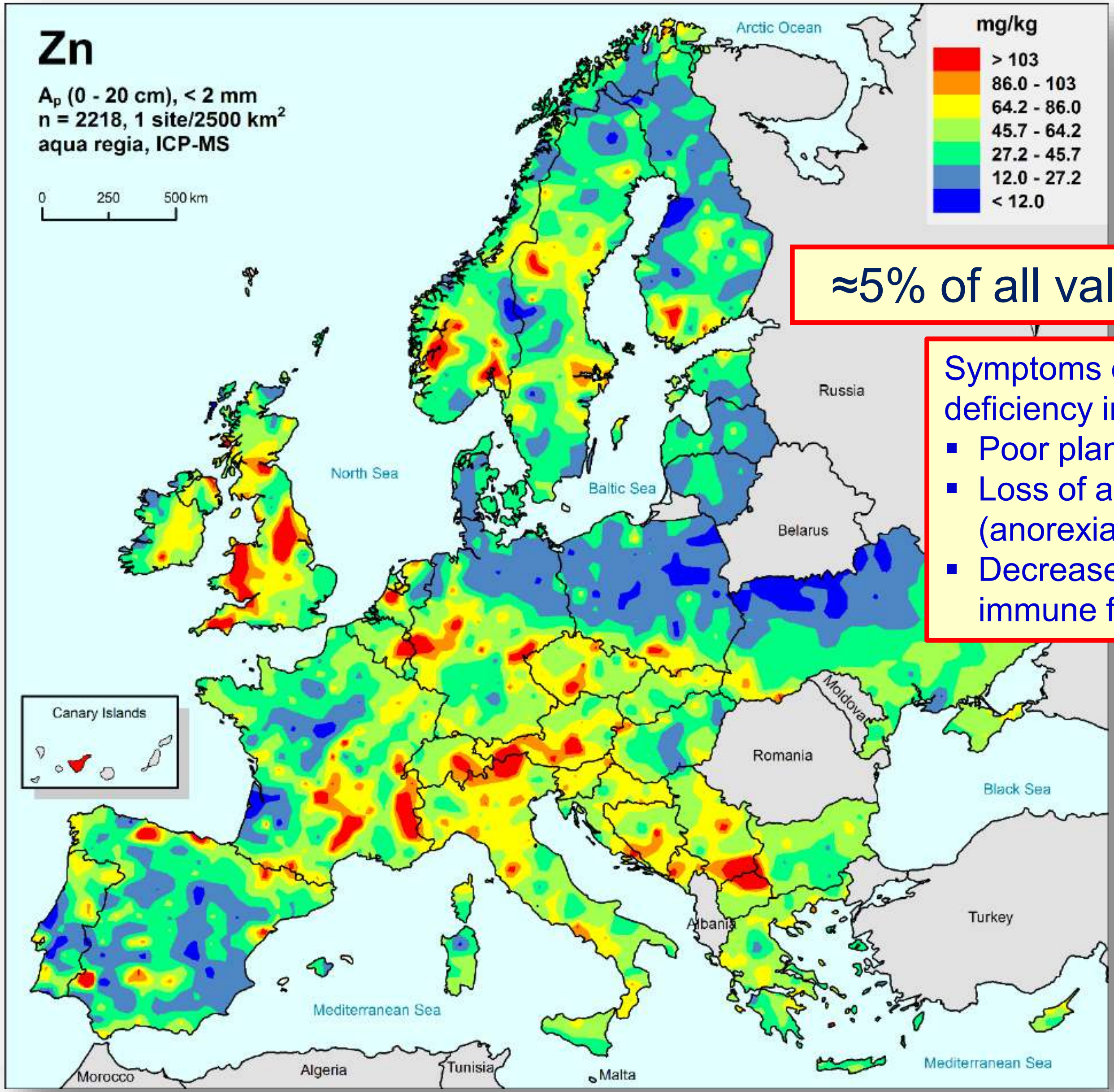
≈10% of all values <0.1 mg/kg

Selenosis in Ireland (cattle & horses)

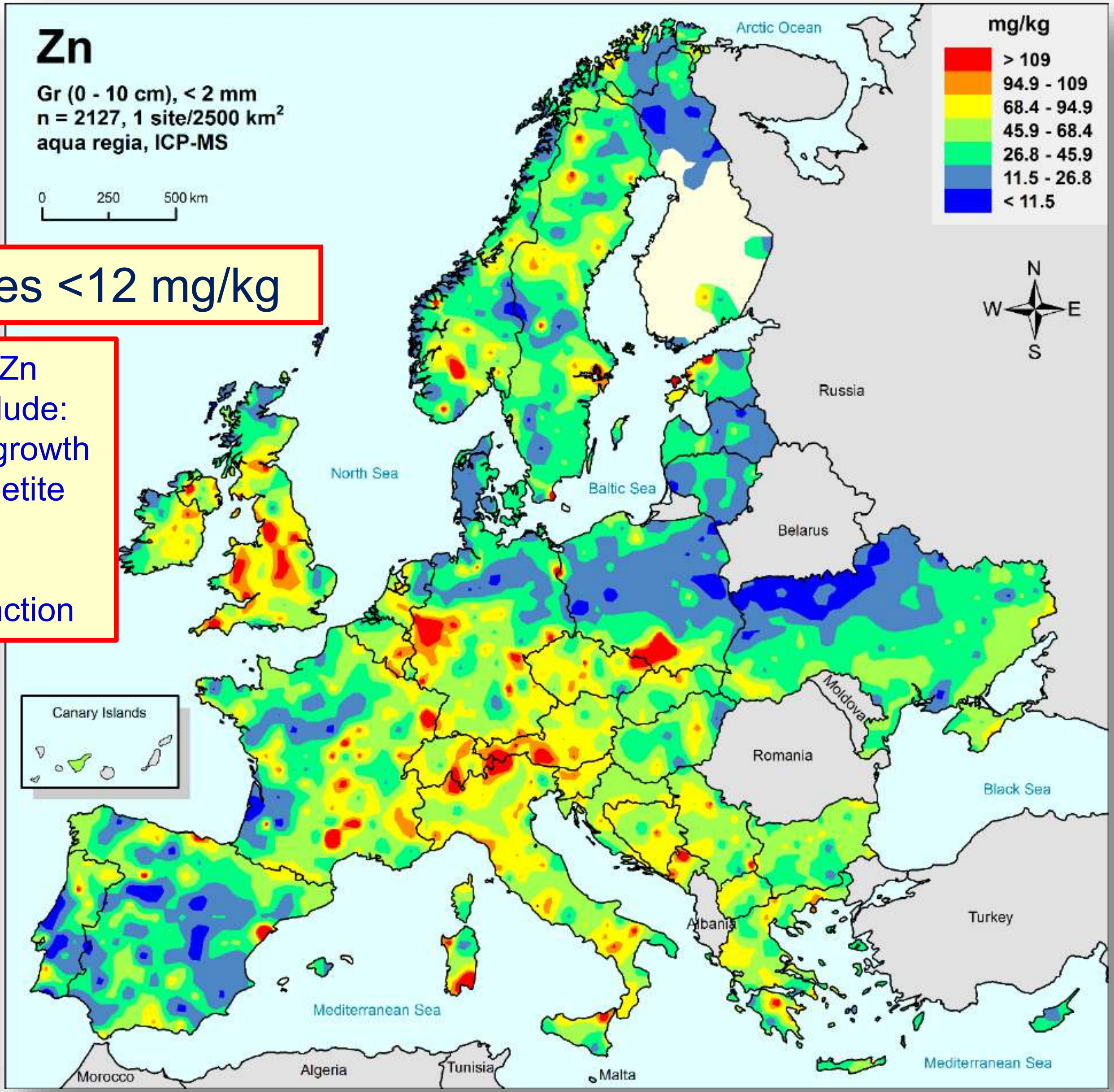


Source: Reimann *et al.*, 2014c, Fig. 11.50.5, p.393

GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



Source: Reimann *et al*., 2014c, Fig. 11.63.5, p.467



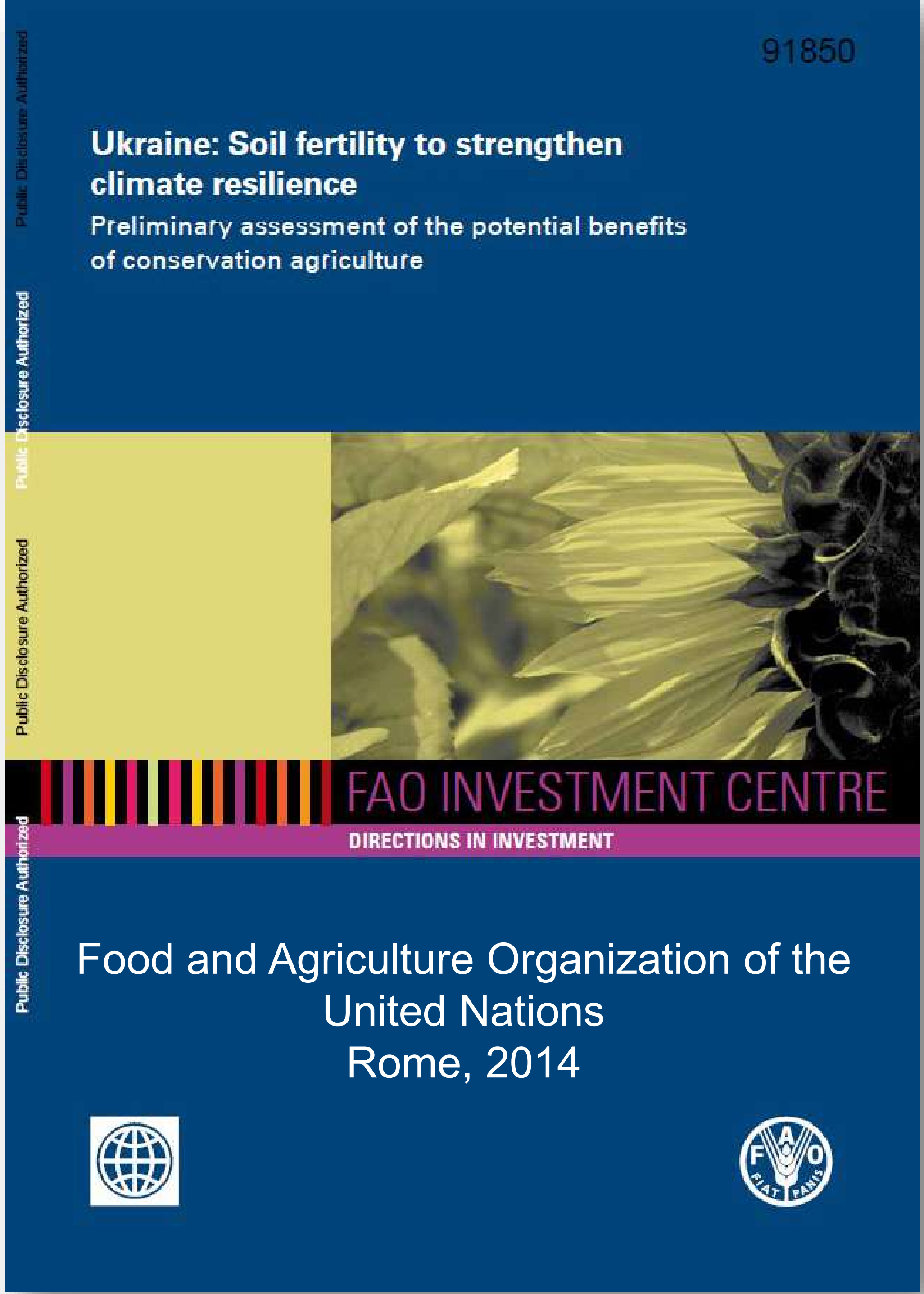
Source: Reimann *et al*., 2014c, Fig. 11.63.5, p.467

≈5% of all values <12 mg/kg

Symptoms of Zn deficiency include:

- Poor plant growth
- Loss of appetite (anorexia)
- Decreased immune function

European Black Soil Region with emphasis on Ukraine



Extract from the EXECUTIVE SUMMARY (p.ix)

(FAO, with World Bank support)

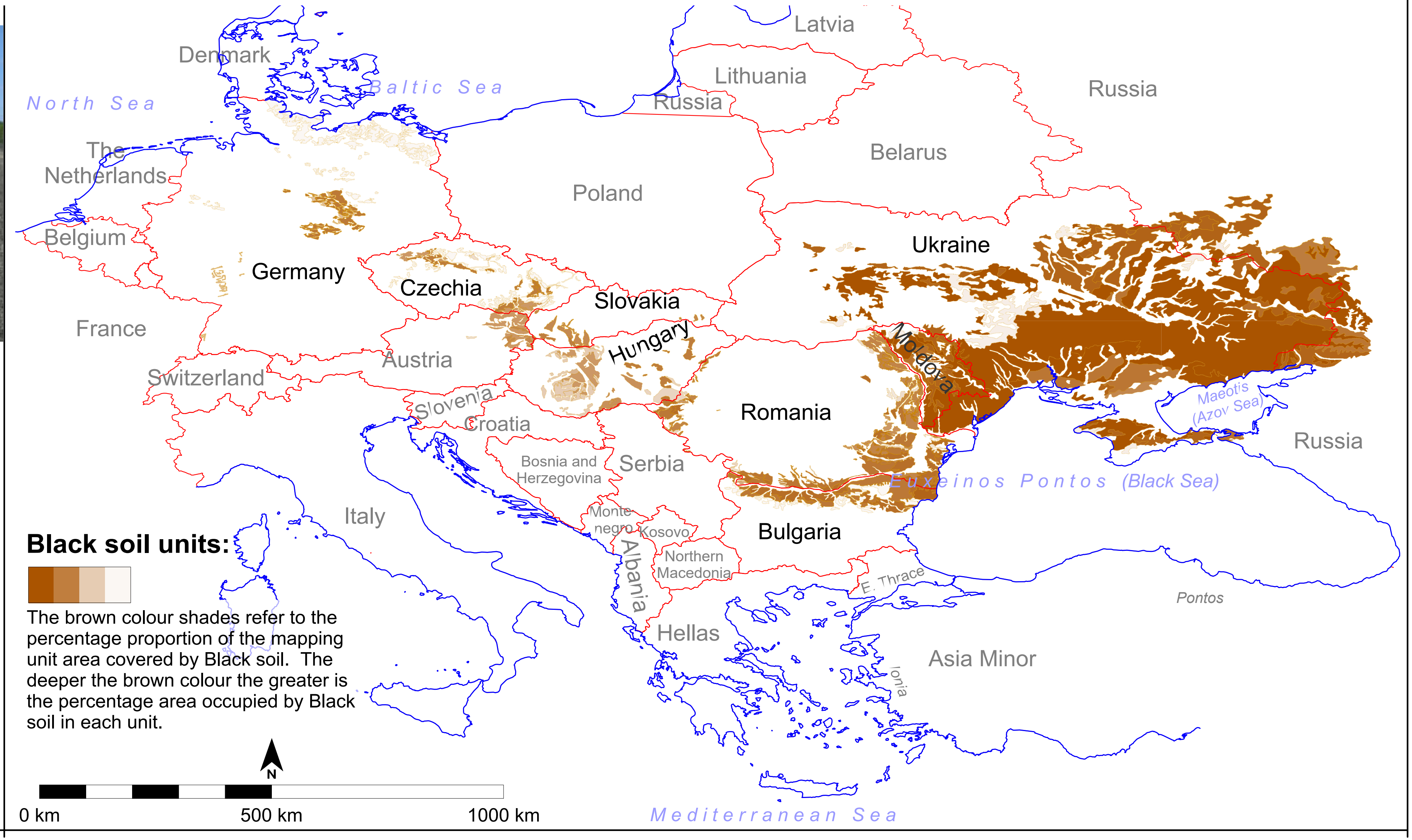
"Highly favourable agro-ecological conditions and an advantageous geographical location give Ukrainian agriculture its competitive edge

Ukraine is renowned as the breadbasket of Europe thanks to its black soils ("Chernozem" black because of the high organic matter content) which offer exceptional agronomic conditions. One-third of the worldwide stock of the fertile black soils, which cover more than half of Ukraine's arable land, a large variety of climatic zones, and favourable temperature and moisture regimes, offers attractive conditions for the production of a large range of crops including cereals and oilseeds."

https://documents1.worldbank.org/external/default/WDSContentServer/WDSP/IB/2014/10/27/000470435_20141027113422/Rendered/PDF/918500WP0UKRAI0E0Box385344B00OUO090.pdf

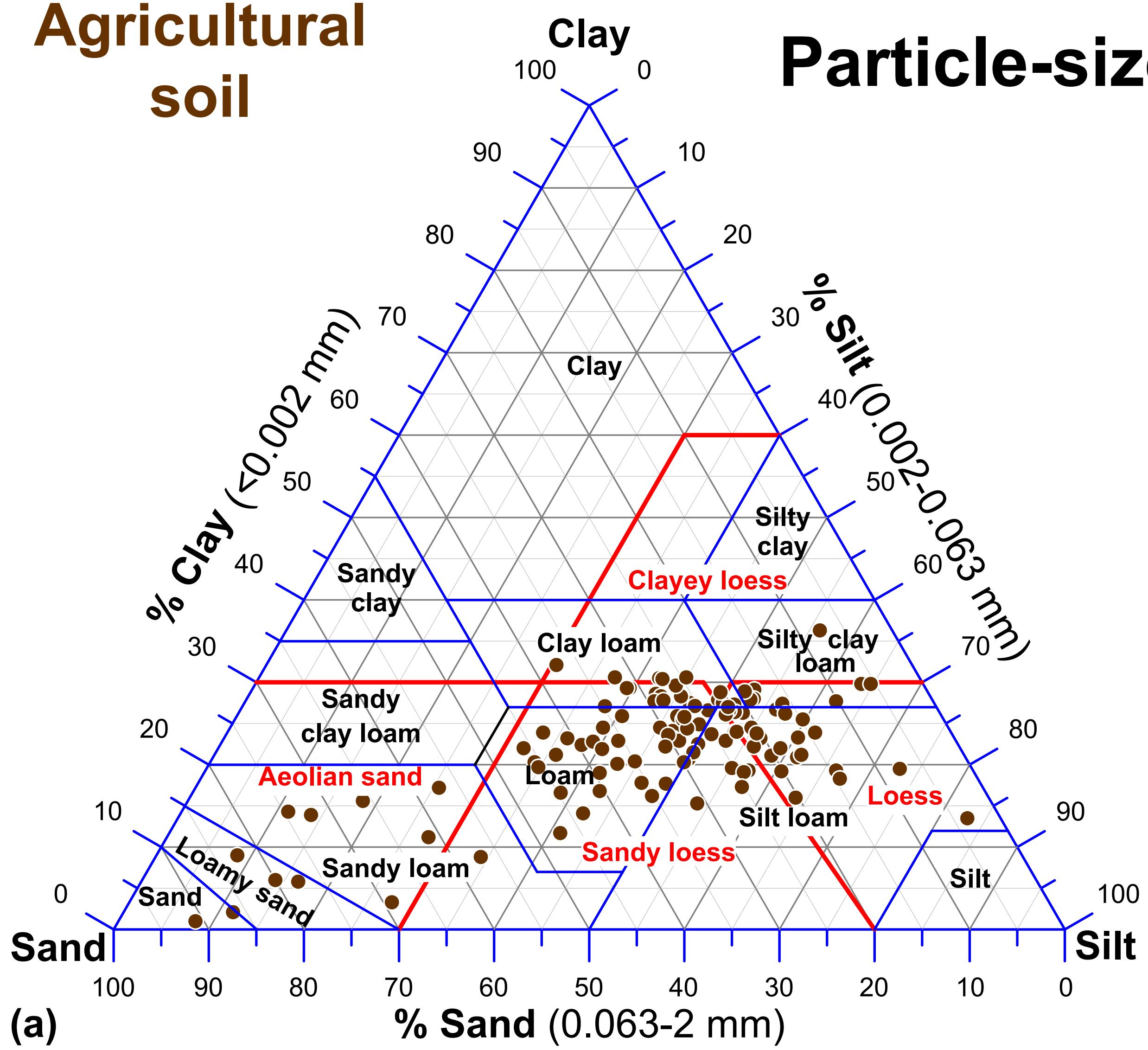
Distribution of black soil (chernozem) in Europe

Ukr190Ap

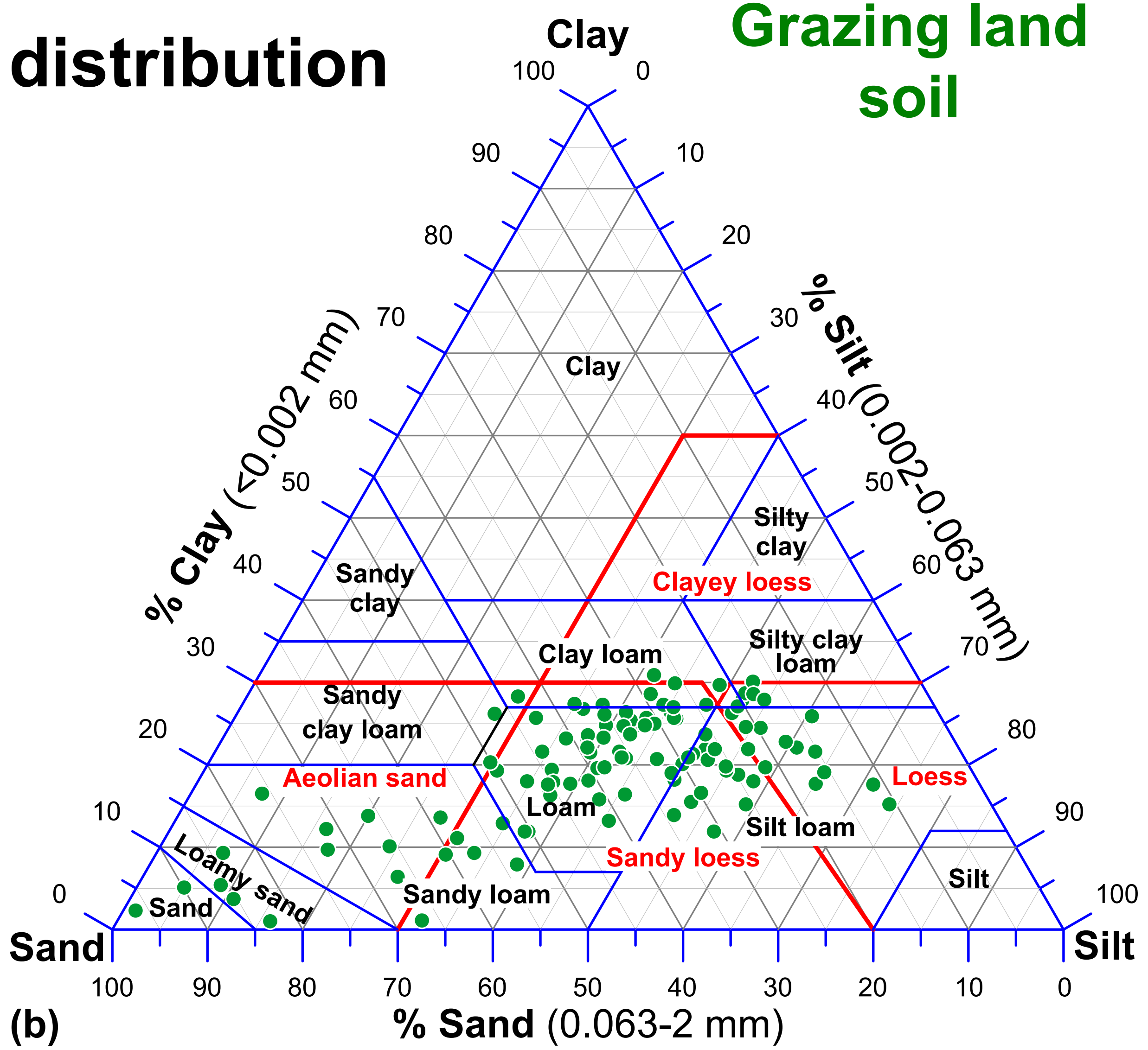


Particle-size distribution

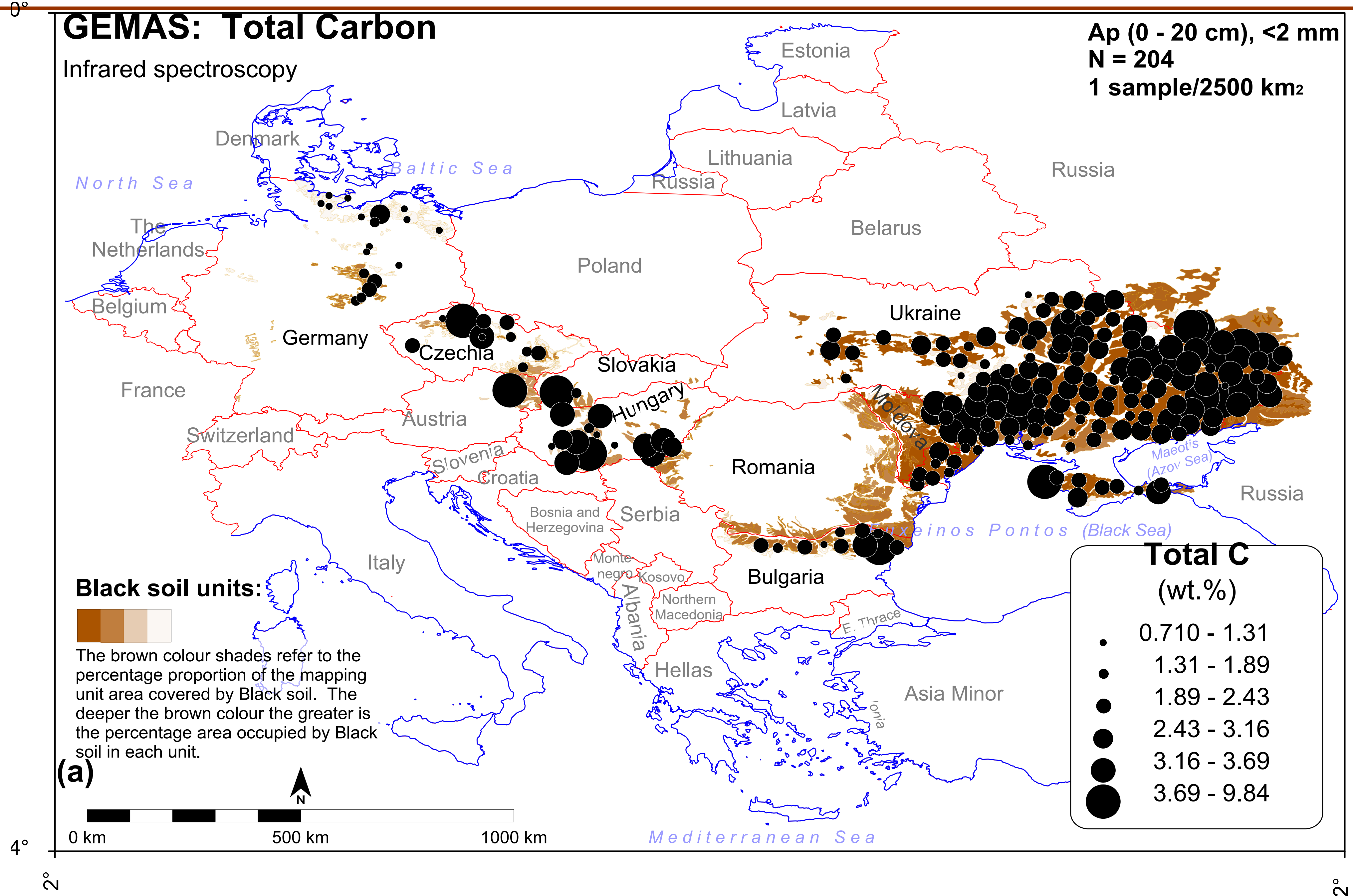
Agricultural soil



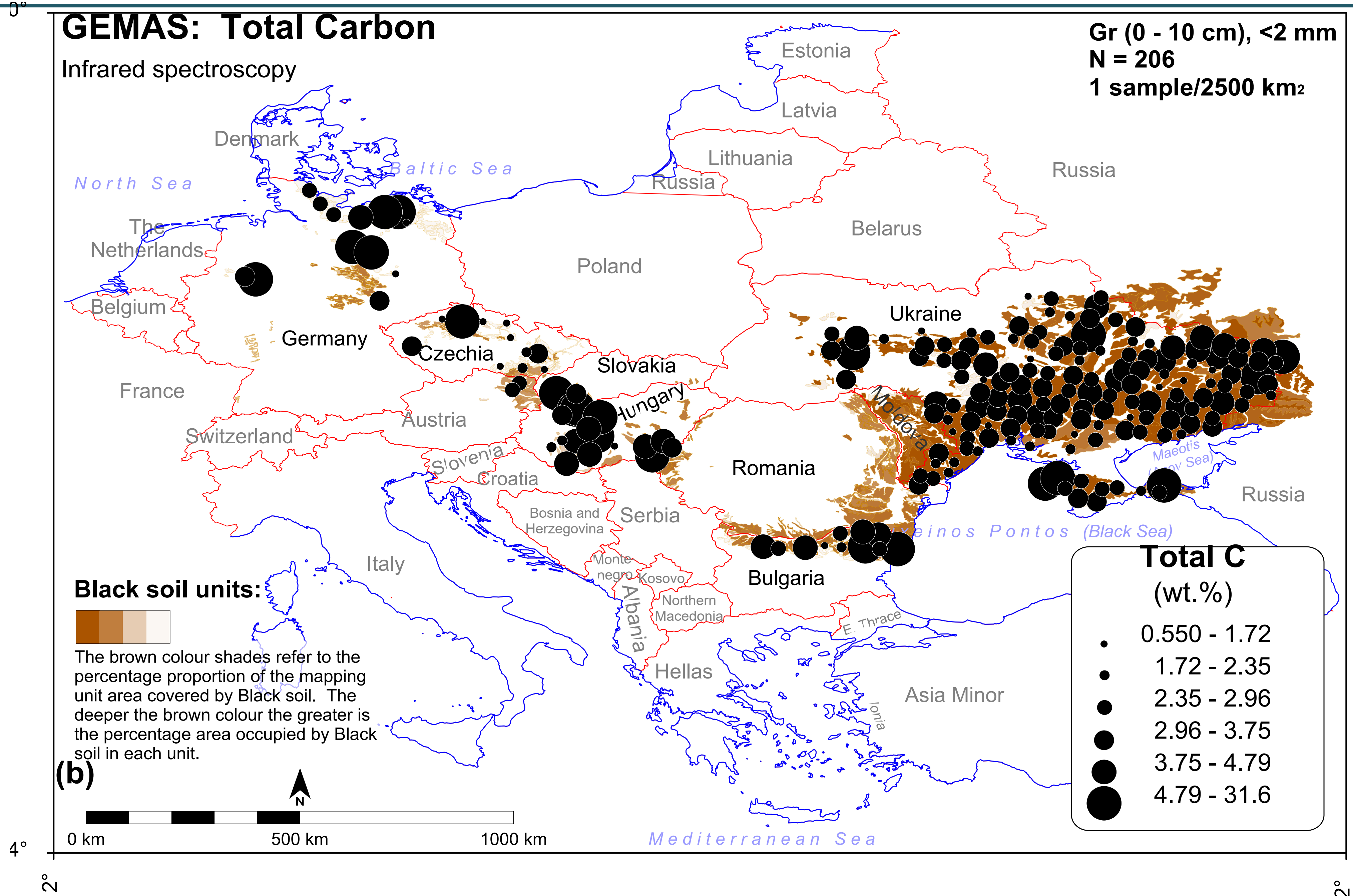
Grazing land soil



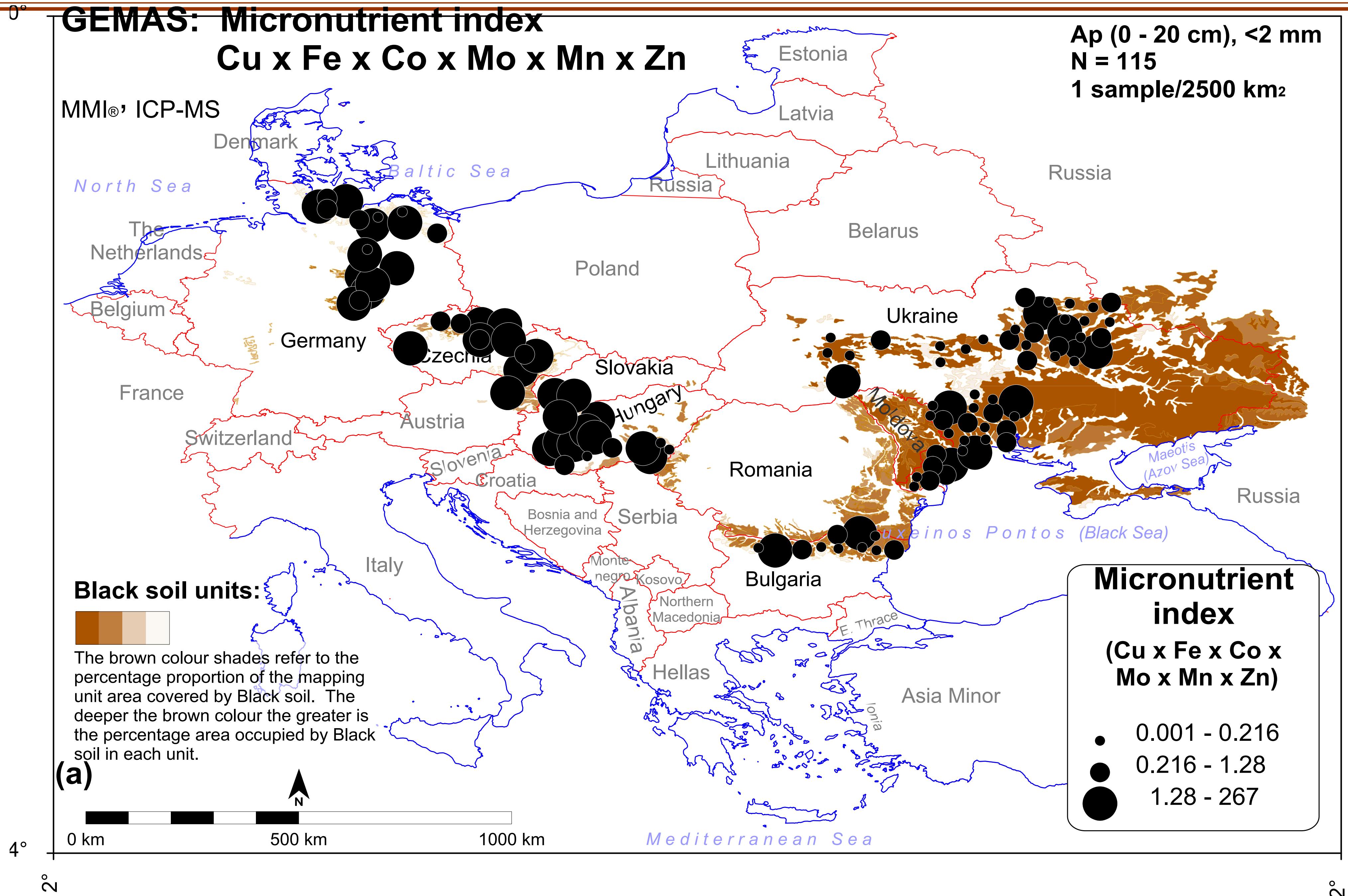
GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



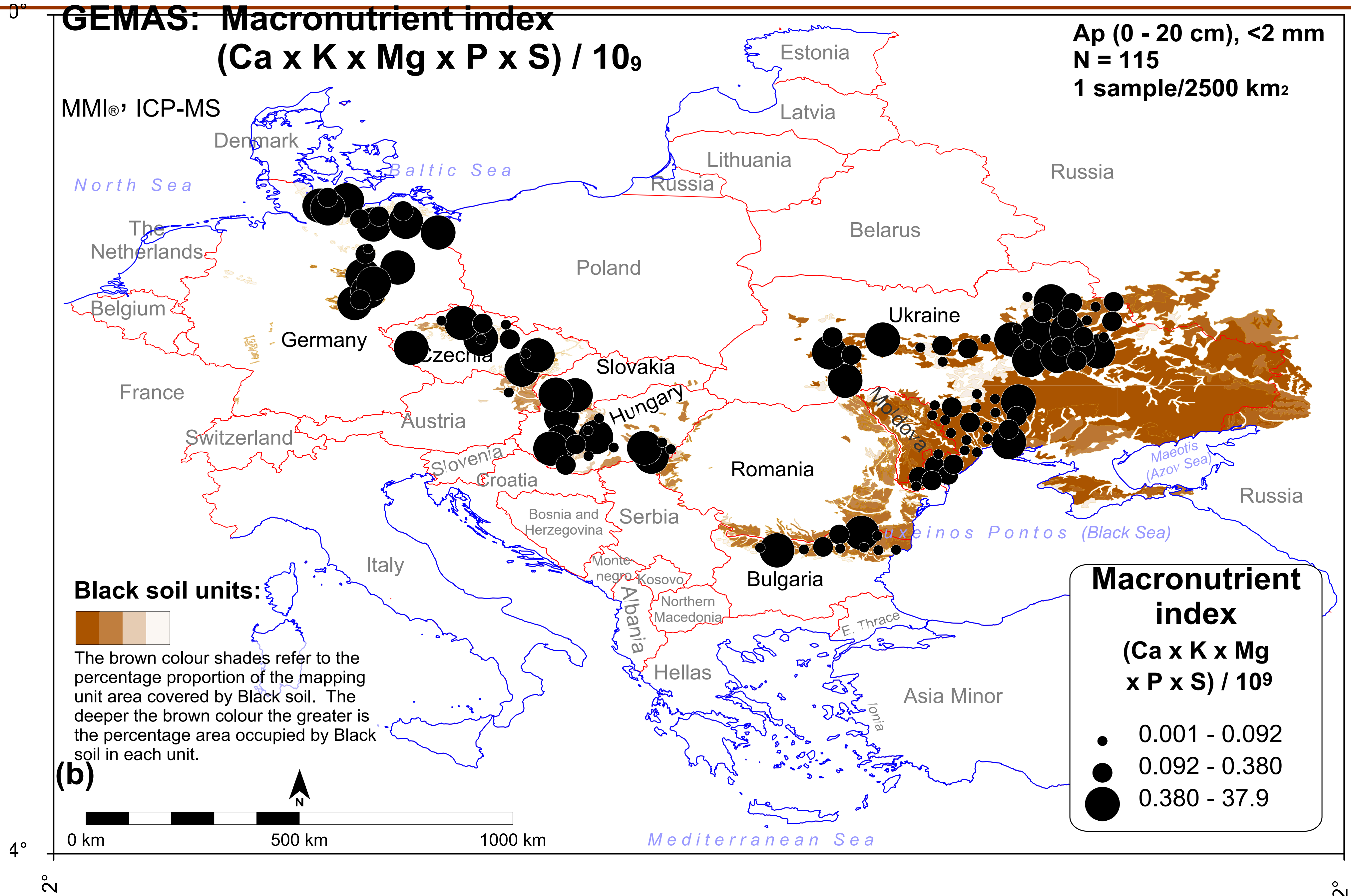
GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



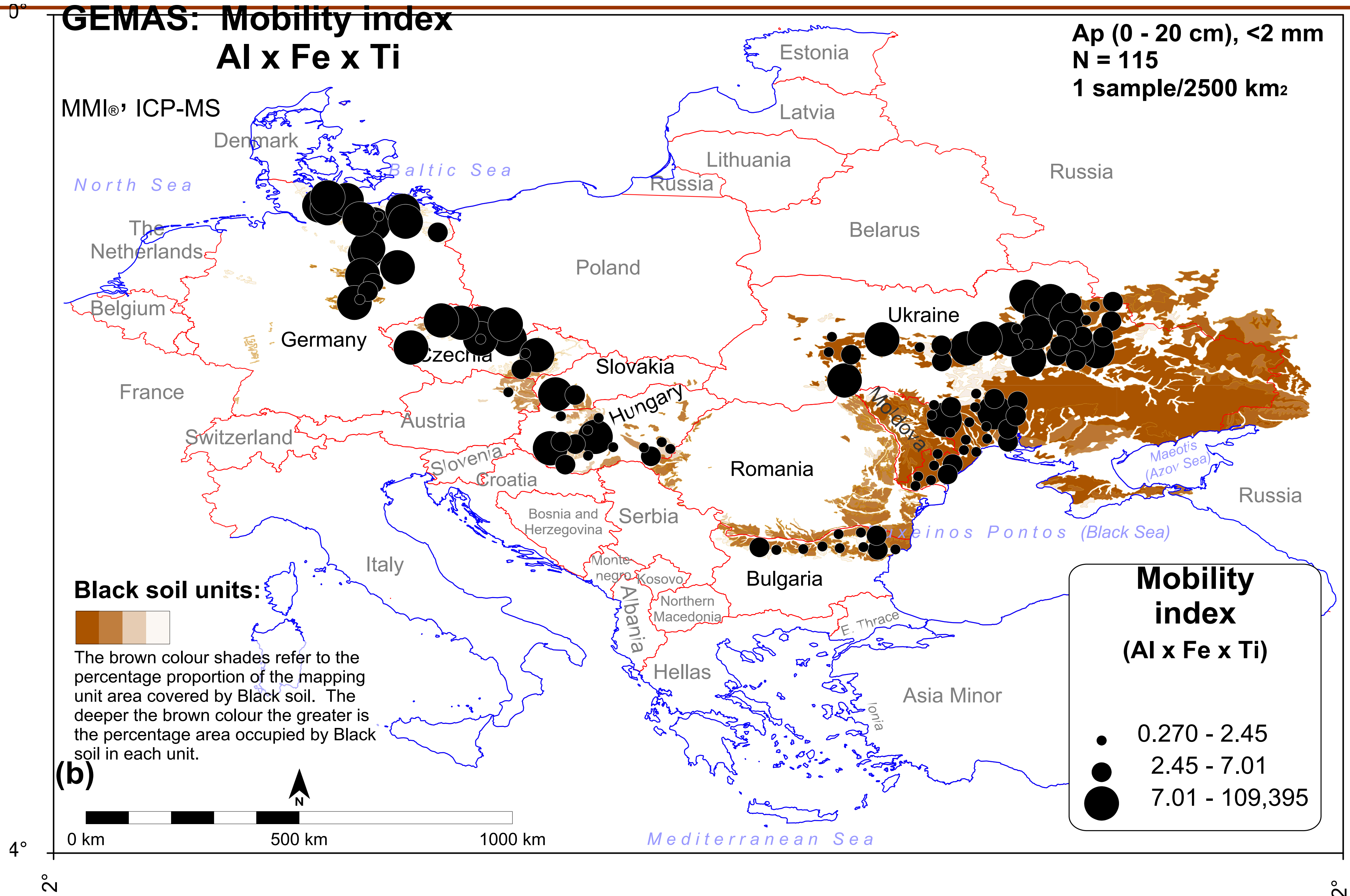
GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



Ukraine – Russia war and damage caused to black soil

A tail part of a missile sticks out of the ground in the village of Chornobaivka, near Kherson
Sergei Bobylev/TASS/ZUMA

https://worldcrunch.com/focus/ukraine-agriculture-war-pollution

Bomb-disposal experts from the State Emergency Service of Ukraine secure and remove a Russian rocket from a field in Borodyanka, outside Kyiv, on Tuesday. By some estimates, the clearing of unexploded ordinance could take five to seven years in the Kyiv region alone. (Christopher Furlong/Getty Images)
https://www.wsj.com/livecoverage/russia-ukraine-latest-news-2022-05-31/card/removing-a-russian-rocket-in-borodyanka-N1VNz2OqNQQupSdTUrdb

A field in Kharkiv Oblast (Eastern Ukraine), ravaged by craters left by shells and other projectiles.
Photo: MAXAR TECHNOLOGIES
https://www.pravda.com.ua/eng/articles/2023/08/13/7415256/

Together, these shells and projectiles upturned at least 90,000 tonnes of soil, adding tonnes of Hg, Pb, As, Fe, Cu, S, and other substances make soil incompatible with growing wheat.

Reuters: Two dozen experts who spoke with Reuters, including soil scientists, farmers, grain companies and analysts, said it would take decades to fix the damage to Europe's breadbasket - including contamination, mines and destroyed infrastructure - *and that global food supplies could suffer for years to come*.

https://www.reuters.com/world/europe/soils-war-toxic-legacy-ukraines-breadbasket-2023-03-01/

Question: What should the European leaders do to safeguard the Ukrainian Black Soil region?

The IUGS Commission on Global Geochemical Baselines was invited by the Shenyang Geological Survey in China to participate in the

IGCP Project 665 - Sustainable Use of Black Soil Critical Zone

Demetriades, A., Dai, H., Liu, K., Savin, I., Birke, M., Johnson, C.C., Argyraki, A. (Editors), 2020. *International Union of Geological Sciences Manual of Standard Geochemical Methods for the Global Black Soil Project*. International Union of Geological Sciences, Commission on Global Geochemical Baselines, Special Publication No. 1, Athens, Hellas, ISBN: 978-618-85049-0-5, 107 pages, 49 figures, 4 Tables, and 4 Appendices.

The manual can be downloaded directly from the following URL:

http://www.globalgeochemicalbaselines.eu/content/162/black-soil-project-manual-/

OR
https://doi.org/10.5281/zenodo.7267967

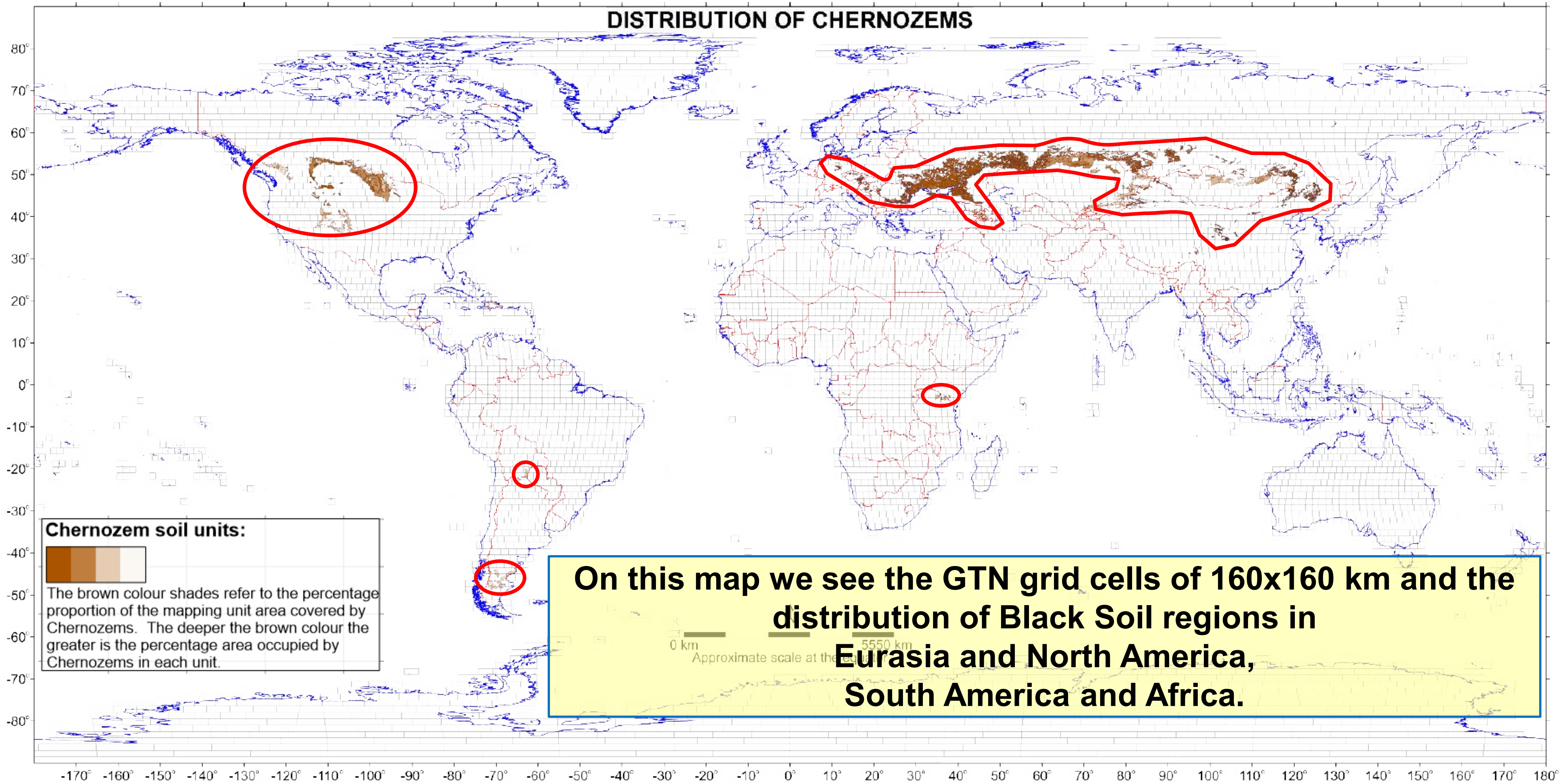
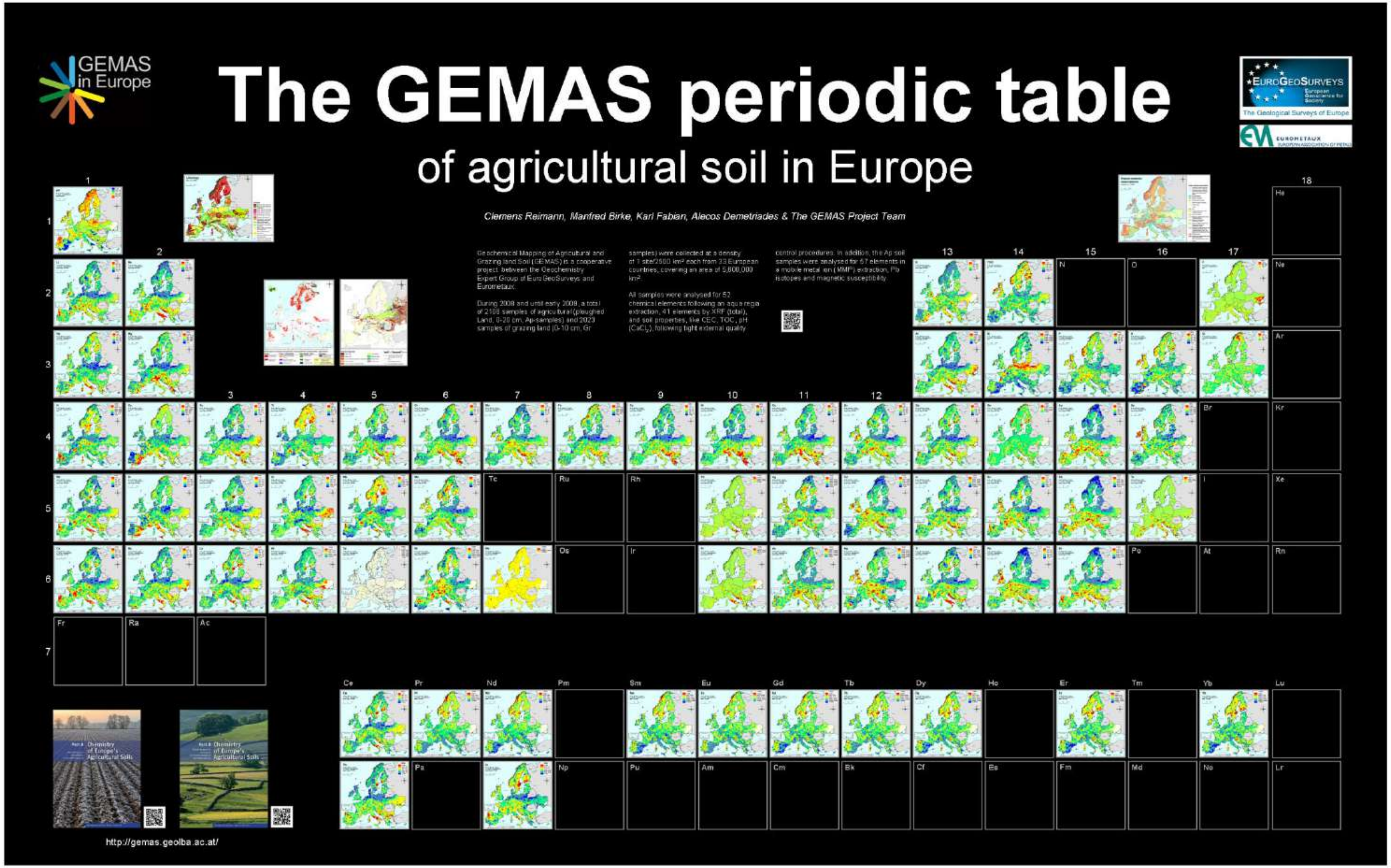


Figure A3.2.1.15 on page 156. Map showing the global distribution of Chernozems. *They occur in the mid-latitudes of both hemispheres, but are more extensive in the northern hemisphere*. ***The intensity of the brown colour shades within each polygon corresponds to the share of the soil type with respect to the total area: the higher the share the darker is the brown colour,*** *while the lower the share, the higher is the transparency of the polygon (lighter brown shades)*. The Global Terrestrial Network grid cells of 160x160 km are displayed in grey colour parallelograms. The map scale distortion is caused by the orthographic projection in degrees. Plotted by Alecos Demetriades (IGME/IUGS-CGGB) with Golden Software's Surfer v24 using the kml file (HWSD_CLASS_CL-Calcisols.kml), which can be downloaded from the Publications web page of the IUGS Commission on Global Geochemical Baselines (http://www.globalgeochemicalbaselines.eu/).

The GEMAS Periodic Tables

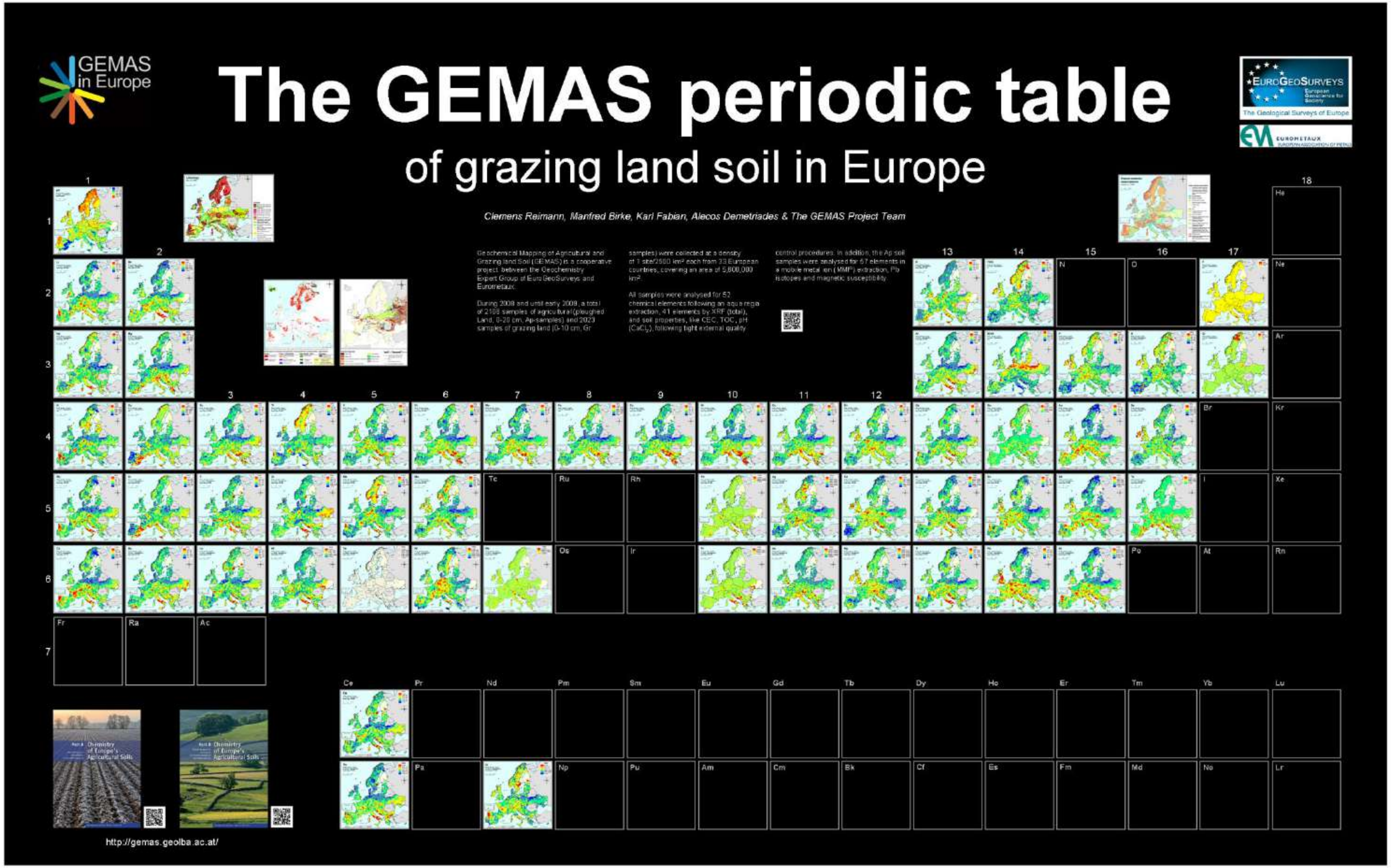
Note: If you would like to print The GEMAS Periodic Tables for teaching purposes the optimum size is Height 120 cm and Width 190 cm

GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



https://gemas.eurogeosurveys.org/Download/GEMAS_Periodic_Table_of_Elements_High_resolution.pdf

GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



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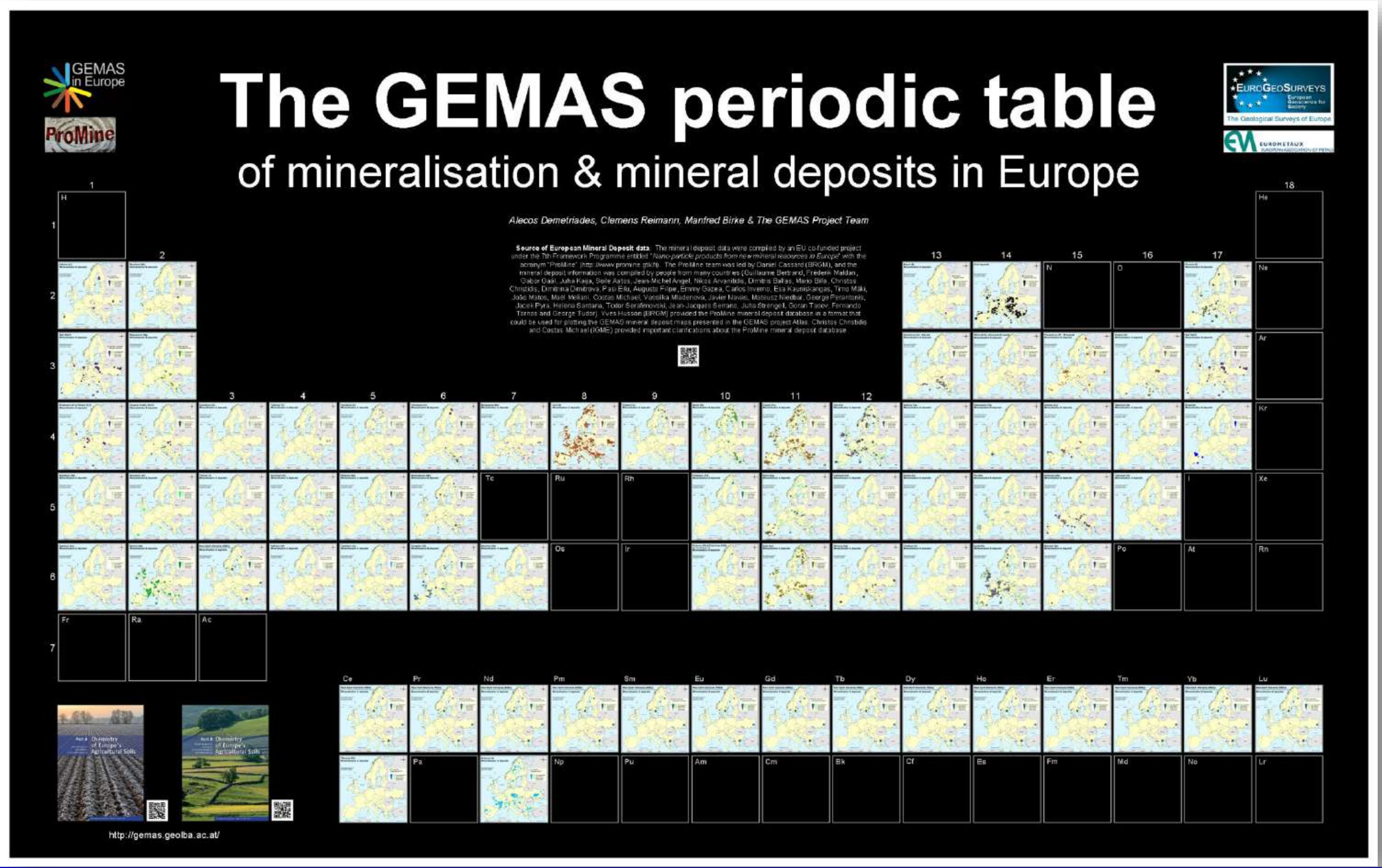
GEMAS atlas – GEochemical Mapping of Agricultural and grazing land Soil of Europe



https://gemas.eurogeosurveys.org/Download/GEMAS_Mineralisation_Periodic_Table_Poster_high.pdf

Data Gaps:

- ❖ **Platinoid elements (Pt, Pd, Rh, Ru, Ir, Os)**
- ❖ **Mineralogy** and
- ❖ **Organic compounds**

The GEMAS atlas results can be used for effective land use planning:

- Agriculture
- Grazing land
- Mineral exploration
- Land use policy
- Health-related research
- Environmental policy
- Construction of new towns, *etc.*

TEAMWORK - Final advice for early-career researchers

The most important components of collaboration for the effective and successful implementation of such multi-national continental-scale applied geochemical surveys are:

- Transparent cooperation
- Communication
- Assertiveness
- Autonomy (and at the same time responsibility and accountability)
- Dedication
- Mutual trust and respect and, last but not least,
- Coordination, prudent and ethical leadership.

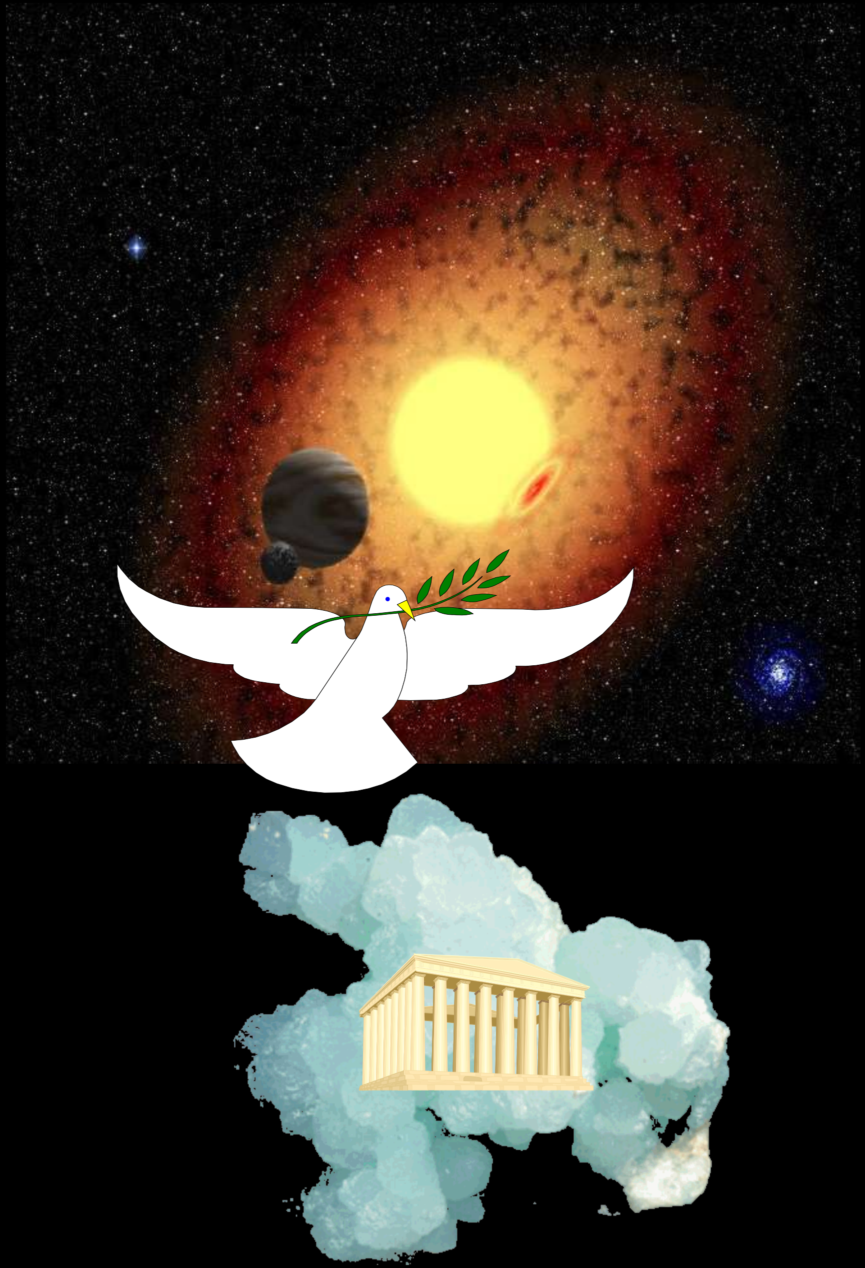
As Norsen *et al*. (1995) have stated "*Without trust and respect cooperation cannot exist, assertiveness becomes threatening, responsibility is avoided, communication is hampered, autonomy is suppressed, and cooperation is haphazard*".

Final advice for early-career researchers

The main job of the Applied Geochemist is to ensure that the field and laboratory procedures (sample preparation and chemical analysis) are applied correctly, and the produced data are of high quality and integrity.

Interpretation of the results is completely another matter and depends on the training and experience of the Applied Geochemist.

Geological Surveys consider it their obligation to provide to the present and future generations of humankind high quality geochemical databases for environmental and resource management, and for improving the living conditions on our home planet Earth



Thank you for your attention

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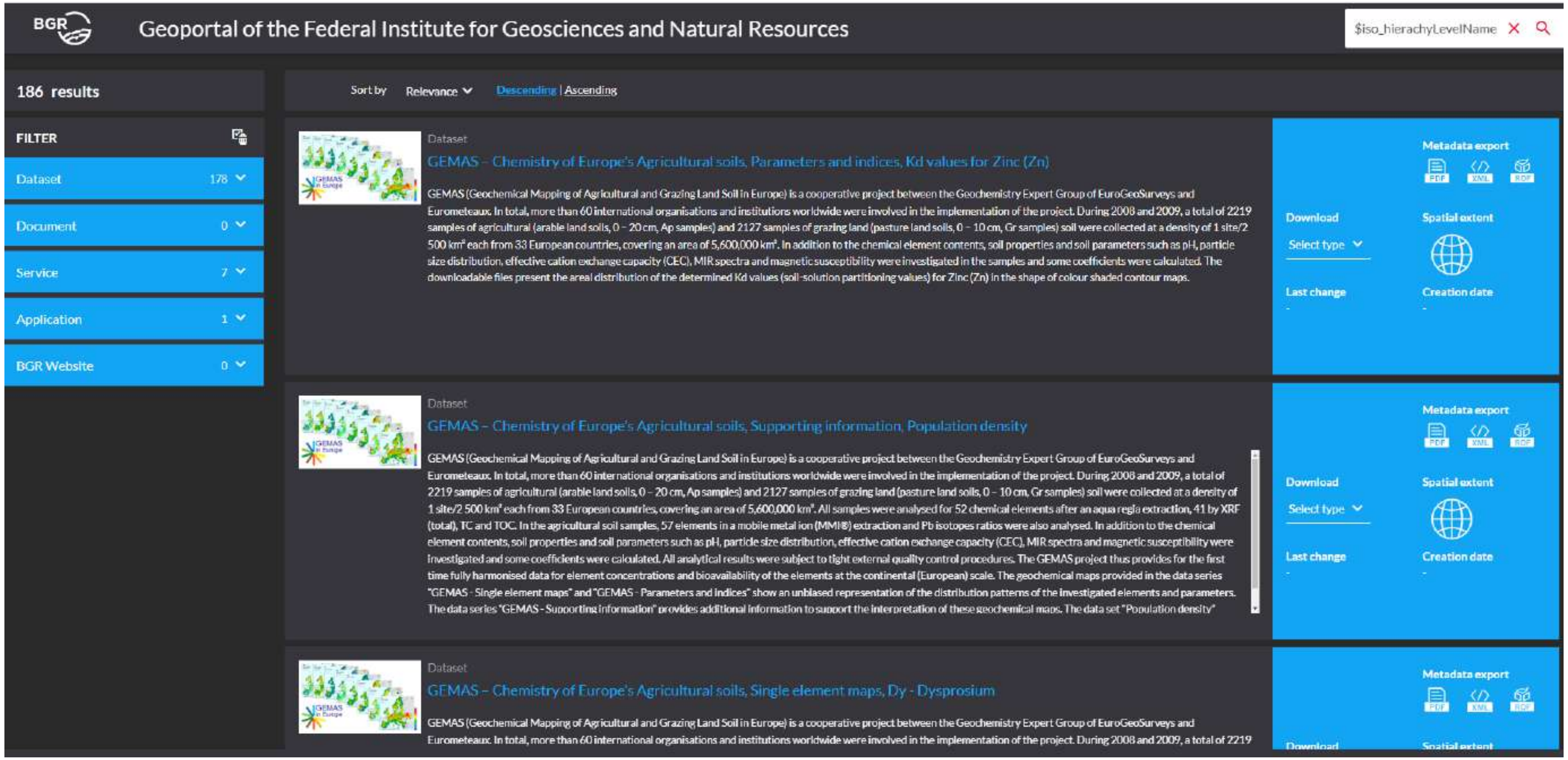
GEMAS project publications can be downloaded for personal use only from the following pCloud hyperlink: https://u.pcloud.link/publink/show?code=kZ4JfDZURdEoTF0F0fzFyqWGxGDRbApshv7.

GEMAS project website: https://gemas.eurogeosurveys.org/

BGR GEMAS portal: https://geoportal.bgr.de/mapapps/resources/apps/geoportal/index.html?lang=en#/



GEMAS: Geochemistry of Agricultural and Grazing land soil for healthy food production in Europe

Alecos Demetriades

With an ever-growing world population efficient food production is becoming a major challenge. Europe should develop an effective and long-term plan for how its farmers can produce enough healthy food to feed its present and future population. Efficient agriculture and animal rearing depend on healthy soil. Plant and animal production requires sufficient amounts of major and minor nutrients and low concentrations (or availability) of toxic elements in the soil.

REACH (Registration, Evaluation and Authorisation of Chemicals), the European Chemicals Regulation adopted in December 2006, requires from industry a sound knowledge of the natural geochemical background variation. In agricultural sciences, the focus is on the major nutrients in the soil, while trace elements, and especially contaminants (e.g., potentially toxic elements), are widely neglected. In environmental sciences today, much of the political attention is focused on 'too high' toxic element concentrations in soil. For some elements, maximum admissible concentrations have been defined for agricultural soil or sewage sludge used as fertiliser. It is not realised, however, that even 'too low', deficient element concentrations, may commonly have a more severe influence on productivity, and plant, animal and human health. Sound documentation of element concentrations, and their variation in agricultural and grazing land soil at the continental-scale, is needed before political actions are taken. Such data are also urgently needed at the continental-scale in forensic chemistry. For example, regional differences can be used to trace the origin of food.

The EuroGeoSurveys Geochemistry Expert Group has carried out the project of the GEochemical Mapping of Agricultural and grazing land Soil (GEMAS) according to the specifications of the European Chemical Agency's REACH regulation.

The GEMAS project documents, for the first time, the concentration of almost 60 chemical elements, and the parameters determining their availability and binding in agricultural and grazing land soils at the scale of a continent, i.e., covering 33 European countries and about 5.6 million km2 sampled. Key findings of the GEMAS project include:

- A major difference in agricultural and grazing land soil composition is observed between the young northern and the much older southern European soil for many elements.
- On average there is a sixfold (and up to a factor of more than 100) difference in the median concentration of elements between the 33 participating countries.
- The spatial element distribution depends mainly on geology and climate – the anthropogenic impact is hardly detectable at the European scale. High trace element values in soil are often related to mineral deposits and metallogenic provinces.
- Some cities (e.g., London, Paris) cause anthropogenic trace element anomalies (e.g., Au, Pb, Hg) in their near surroundings and element concentrations decrease rapidly with distance from the source.
- Risk assessment for metals like Cu shows that few samples have such high concentrations that they pose a toxic risk for soil organisms; most of these samples were taken in vineyards.
- Several important trace elements (minor nutrients, e.g., Cu, Zn) show such low levels over sizeable tracts of land in Europe that trace element deficiency is clearly of concern.

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