Soil Geochemical Atlas of Ireland

*The particular contribution that each author has made in the compilation of this atlas is acknowledged as follows: D. McGrath was the original project coordinator of the *National Soil Database*. On his retirement, D. Fay assumed overall responsibility for coordination and completion of the project, as well as final report writing. C. Zhang contributed the statistical analysis of the data and the generation of the maps as well as the relevant section of the main report. E. Grennan was brought in as a geological consultant and contributed significantly to the interpretation of the results. G. Kramers collated and edited the final text into the Atlas format.

Printed by Colourbooks Ltd., Dublin

Soil Geochemical Atlas of Ireland

Authors*:

Deirdre Fay[1], Gaelene Kramers[1], Chaosheng Zhang[2], David McGrath[1] and Eamonn Grennan[3]

Editor:

Gaelene Kramers[1]

[1]Teagasc, Environmental Research Centre, Johnstown Castle, Co. Wexford

[2]Department of Geography, National University of Ireland, Galway

[3]Institute of Technology, Sligo

*see opposite page

Published by Teagasc and the Environmental Protection Agency in 2007

ISBN: 1 84170 489 1

Price: € 10

Foreword

Soils provide us with food, fibre and timber. They filter our water, breakdown and transform organic wastes, store carbon, support wildlife and the built environment and preserve records of our ecological and cultural past. The biological diversity below ground far exceeds that above it, and this diversity is vital to enable soil to perform its multiple functions. Soil develops where there is dynamic interaction between air, water, living organisms and geology. It is these dynamic interactions that contribute to the multiple functions that soils perform. Soil also has an importance and value in its own right and needs to be protected.

Our soil is an immensely valuable national resource, which forms and evolves over very long periods of time and therefore is essentially a non-renewable resource. Once soil is severely damaged or destroyed it is effectively lost forever. The protection of soil poses some unique difficulties for a number of reasons, such as its enormous spatial variability, incomplete understanding of its exact functioning and reaction to pressures, limited information on soil biodiversity and the fact that soil is generally held in private ownership. However, soil protection needs to be placed on an equal footing with that of water and air.

At a national level our information on soil and soil quality is limited. We are pleased to see that this information deficit is being addressed with the publication of this, the first Soil Geochemical Atlas of Ireland. This Atlas shows the basic geochemical properties of soils in Ireland, as revealed by a detailed large-scale survey across the country and analysis of the findings. It provides Ireland with a sound, well-structured baseline of soil geochemical properties relevant to sustainable land use and soil management, and to environmental, agronomic and health-related pressures.

This Atlas is the result of a great deal of hard work by our relevant organisations and academic institutions from across the country and individual experts. They have produced a comprehensive picture of the basic chemistry underpinning life on land, which has resulted from the complex interactions of air, water, soil and human activities. This will aid all of those with an interest in the sustainable use of one of Ireland's principal natural resources to make well-informed decisions as to its management and conservation. It will also assist Ireland in meeting any future requirements under the proposed Soil Framework Directive. We believe that this Soil Geochemical Atlas is the beginning of a process to ensure that we develop good quality and scientifically robust information on the state of soil in Ireland. By developing our knowledge and understanding of soil we can ensure that soil and its multiple functions are protected for present and future generations.

Mary Kelly

Dr Mary Kelly
Director General
Environmental Protection Agency

G. E. Boyle

Professor Gerry Boyle
Director
Teagasc

Acknowledgements

The authors acknowledge the invaluable contribution of the hard-working and dedicated *National Soils Database* project steering committee for their time, critical comments and encouragement. The members included: Prof. P. Loveland, Dr. E.P. Farrell, Dr. C.D. Campbell, and J. Brogan (Chair).

The producers of this atlas wish to thank Dr. O. Schmidt (UCD), the SoilC project (Hydromet, UCC), in particular N. McGoff and J. Eaton, and G. Kramers (Teagasc) as well as D. Bankert, S.Kooman and J.D. Kramers for the contribution of the photographs in this atlas.

The authors gratefully acknowledge the comments and assistance received from Teagasc research and technical staff including Dr N. Culleton, Dr. O. T. Carton, Dr. B. Coulter, and Dr R. Schulte. Some former Teagasc research staff are also thanked for their expert opinion and discussion, particularly Mr S. Diamond and Dr. G. Fleming.

The support of the EPA Officers, H. Walsh, A. Wemaere and B. Donlon are also fully appreciated and acknowledged.

The following organisations are thanked for their contribution of data for the maps:

Geological Survey of Ireland (GSI) for the geological data
Ordnance Survey Ireland for the national and county border data provided under

SRTM of NASA for the digital elevation data

Table of Contents

A cautionary note on the use of the maps in this Atlas

Even though the maps in this study were created using the best available techniques, like all maps, they should be used with caution. There are sources of uncertainties that are beyond control, e.g. spatial variation and modelling uncertainty.

While the maps in this atlas will give a good and statistically significant indication of the distribution of the concentrations of an element, soil type, land use or geology, they will not provide local information for specific sites. The geochemical spatial distribution maps, although a very good tool to indicate the relationship between large scale trends related to geology, soil type, land use and climatic effect, are less likely to capture local anomalies. On a local scale, the data point maps may over-exaggerate anomalies when sampling occurred on a specific site which had an exceptionally high or low concentration of an element.

The use of the term level rather than concentration in this report to describe the concentrations of a given element in a general area avoids the misunderstanding that there can be any reference to a specific concentration at a given location on any of the maps printed.

Summary

The information contained in this Soil Geochemical Atlas of Ireland is summarised from data collected between 1995 and 2006 during a countrywide geochemical survey conducted as part of the '*National Soil Database'* project. The full report of that project is available from the EPA (Fay *et al.* 2007a) and it covers the sampling and analysis methods, as well as all the results and interpretation, in detail. A synthesis report is also available, which covers the objectives and outcomes of the project in summarised form (Fay *et al.* 2007b). A summary of the *National Soil Database* project including the project background, main findings, materials and methods and statistical analysis, is provided in this atlas. The main focus of this atlas is to present the geochemical maps and to interpret the information presented in them.

The sections in this Atlas preceding the geochemical maps are intended as background information to aid the interpretation of the maps. In the map section, each element measured is shown separately. A short description of the element and an interpretation of its distribution in Ireland accompany the spatial distribution and data point maps for each element. The description of the element provides background information such as occurrence of the element in the environment and its applications and uses, any known biological roles, deficiencies or toxicities for plant and animal health and potential environmental risks.

National Soil Database: The Acquisition of Baseline Soil Geochemical Data

Project background

In 1995 and 1996 a geochemical survey of the South East of Ireland was carried out by Teagasc (McGrath and McCormack, 1999). In 2002, funding was provided by the EPA to complete this survey to create a national database of geochemical data. Between 2003 and 2005, soil samples were collected in areas of the country not covered by the original study. All of the data have now been collated to produce point and interpolated spatial distribution maps of the measured chemical elements and to interpret these with respect to underlying parent material, glacial geology, anthropogenic and climatic effects. This *National Soil Database* has produced, for the first time, a national baseline database of soil geochemistry and is reported fully in Fay *et al*. (2007a) and summarised in Fay *et al*. (2007b). The project has also generated a National Soil Archive, comprising both dried soil samples and a nucleic acids archive.

Main findings of the *National Soil Database*

The soil sampling strategy used in the *National Soil Database* study has allowed an informed interpretation of the relationships between the geographical distribution of the measured geochemical data, soil types and the underlying geology.

Overall, the most obvious feature evident in the data was the geographical coherence of the geochemical results and their strong relationship with the soil type and underlying geology. Anthropogenic effects were also taken into account during the interpretation of the results but were found to have less influence than the effects of soil type and geology. In some isolated cases, local concentrations of elements could be related to urban, mining or agricultural activities. Climatic influences, such as oceanic deposition were observed for some elements.

Against a background of increasing soil protection policies, the *National Soil Database* and the archive provide Ireland with a sound, well structured baseline of soil geochemical properties relevant to environmental, agronomic and public health related pressures. Further benefits of the *National Soil Database* will arise from disseminating the findings to a wider audience including policy makers and stakeholders.

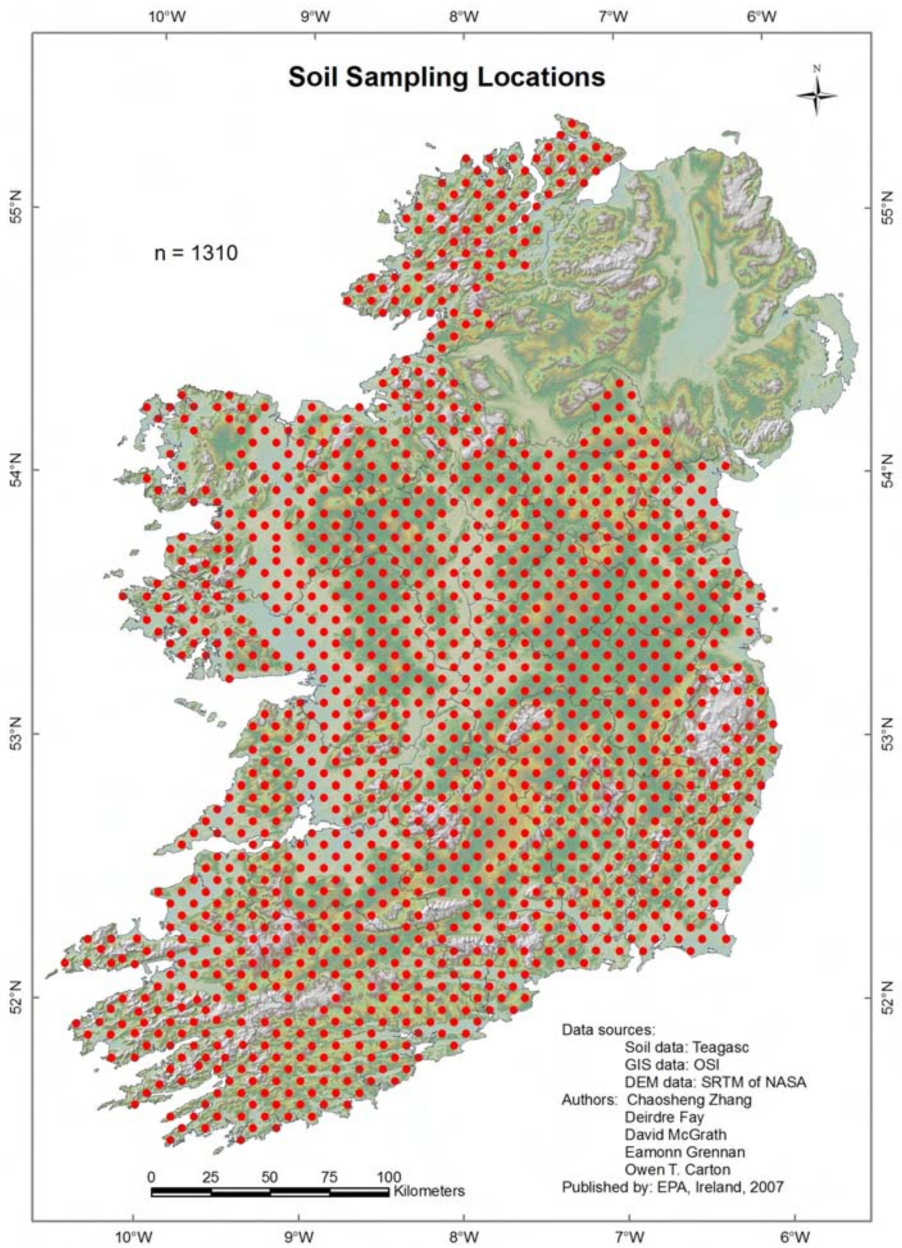
Material and Methods

The soil samples for the *National Soil Database* were taken at fixed locations on a predetermined National Grid made up of 10 x 10 km squares. Two samples were taken from each square, one on the intersection and one at the centre of the square. The sampling locations can be seen on the sample location map on the next page. Sites were located using 1:50,000 maps and assisted by GPS. In the event of it not being possible to take a sample at the projected sampling position, a default procedure similar to that used in the Geochemical Survey of England and Wales (McGrath and Loveland, 1992) was used. At the sites, a 20 x 20 m grid was created with the sampling position at the centre. Soil cores were then taken on the grid at 5 m intervals with a Dutch auger (Eijkelkamp, The Netherlands). The 25 cores were taken to a depth of 10 cm and bulked to form field moist, composite samples weighing approximately 2 – 4 kg. A total of 1310 samples were collected and analysed.

The samples were dried at ambient air temperature, then sieved (2 mm) and thoroughly mixed. The soil pH was measured on the soil solution from 10 ml of soil mixed with 20 ml of deionised water. Available K, Mg and P were measured using Morgan's extracting solution to extract the soil in a 1:5 soil:liquid volume ratio (Peech and English, 1944). The Soil Organic Carbon (SOC) was measured for the samples from the original study in 1995-1996 using the Walkley Black method (Walkley and Black, 1934) and for the later samples using a Leco CN-2000 dry combustion analyser. A correction factor of 1.16 (Brogan, 1966) was applied to the SOC data from the first study to account for the different methodology employed. For the remaining elemental analyses, 200 mg of finely ground subsample was digested (10 ml HF, 5 ml $HClO_4$, 2.5 ml HCl and 2.5 ml HNO_3) to dryness on a hot-plate. The resulting salts were dissolved in 20% aqua regia and made up to 10 ml. The solutions were analysed by ICP-OES or ICP-MS, depending on the element. Se and Hg were measured using atomic fluorescence spectrometry. A full account of the methods used can be found in Fay *et al*. (2007a).

Statistical Analysis

Statistical analyses including summary statistics, probability analyses, outlier detection, data transformation, multivariate analyses of correlation analysis, cluster analysis, and comparisons between sample groups were applied in this study. Based on the results of the statistical analyses, advanced geostatistical analyses and GIS mapping were carried out. A full description and explanation of the statistical methods used can be found in Fay *et al*. (2007a).



For the purpose of statistical analysis it was necessary to separate mineral soils from organic-rich soils, as organic matter is a distinct component of

Ireland's Peat soils. A Peat soil is defined by Gardiner and Radford (1980) as soil with a high organic matter content (>30%, ≈17% SOC) down to a depth of at least 30 cm. However, as the soil samples in this study were only collected to a depth of 10 cm, the term 'peat' cannot strictly be used. Based on the frequency distribution of the SOC data, the term 'organic soils' was used for all soil samples with a SOC content >15% (≈28% SOM). Any reference to Peat soils is a reference to the soils classified as such either by Gardiner and Radford (1980) or in the Peatlands map of Ireland (Hammond, 1978).

Since the raw data of the chemical elements and soil properties exhibited a wide range of variation, the median values were selected as the representative values of the soils. In this study, the majority of variables showed a positively skewed distribution. In order to achieve normality, or near normality, the optimal method of Box-Cox transformation was applied. Multivariate analyses were applied to mineral soils and organic-rich soils, using the Pearson's correlation coefficient (r). These multivariate analyses gave a good indication of the relationships and correlation between the variables, with $r = 0$ showing no relationship and $r = 1$ indicating a very strong relationship.

Geostatistics were used to carry out a spatial interpolation of the data for the sampling points. This is the best method to gain insight into the spatial distribution of the parameter data for the whole country. Trans-Gaussian kriging (Cressie, 1993) was used to create the spatial distribution maps in this study. The geostatistical analysis of data as it was performed here is purely a mathematical approach to the data, and does not take controlling factors such as geology and soil type into consideration. Any spatial interpolation requires the assumption that the data is spatially correlated, meaning that data from points that are closer together are more likely to be similar than data from points that are further apart. When this correlation is poor, the theoretic basis for spatial interpolation does not hold. Poor correlation is mathematically translated into a high nugget effect. Relatively high nugget effects were observed for all the variables under investigation, implying that strong local variations exist.

Description of soil from the EC

Soil is essentially a non-renewable resource. It is a very dynamic system which performs many functions and delivers services vital to human activities and to the survival of ecosystems

(EC, 2006)

Description of soil from the EPA

Soil is a biologically active complex mixture of weathered parent material, organic matter, organisms, air and water which provides the foundation for life in terrestrial ecosystems. Soil however, is not merely the sum of weathered parent material, organic matter, air and water but a product of their interactions

(EPA, 2002)

Definition of soil from the Soil Science Society of America

'(i) The unconsolidated mineral or organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. (ii) The unconsolidated mineral or organic matter on the surface of the earth that has been subjected to and shows effects of genetic and environmental factors of: climate (including water and temperature effects), and macro- and micro-organisms, conditioned by relief, acting on parent material over a period of time. A product-soil differs from the material from which it is derived in many physical, chemical, biological, and morphological properties and characteristics'

Glossary of Soil Science Terms (SSSAJ)

What is Soil?

Essentially, soil is the top layer of the earth's surface on which we depend for many vital functions. It is made up of a mixture of organic and mineral material, organisms, air and water. Soil forms the basis for agriculture and the food chain begins and ends with soil. It is only by combining soil with the organic matter produced by the consumption and decomposition of plant and animal material that nutrients can be made available for the next generation of plants and animals. Soil also plays an important role in the filtering of rainwater as it infiltrates into underground reservoirs, lakes and rivers from which we extract our drinking water. The landscape which surrounds us is defined by soil as certain soil types lend themselves better to different land uses.

Soils are complex systems in which the chemical, physical and biological properties vary over time and space. Variations will occur over short and long time periods and on a local and regional spatial scale. Soils are made up of soil parent material, which is derived from one or a combination of three things:

- solid rock which has weathered (discussed in the Bedrock Geology of Ireland section, pg 8)
- superficial deposits such as glacial drifts or alluvium which has been transported (discussed in the Recent Geology of Ireland section, pg 11)
- organic matter (discussed in the Recent Geology of Ireland section, pg 11)

Soil parent material is usually strongly related to local geology. The combination of parent material and soil forming processes defines a soil type (discussed in the Soils in Ireland section, pg 12). Short term changes in soil geochemistry will depend on anthropogenic activity, climate, soil physical properties and biological activity (discussed in the Continuing influences on Irish soils section, pg 15).

Bedrock Geology of Ireland

A simplified rock type map was generated for interpretative purposes in this atlas. Simplified rock types were classified based on a rock unit map from the Geological Survey of Ireland (GSI) (McConnell and Gately, 2006). It includes nine types of rock from the three main categories, igneous, sedimentary and metamorphic rocks.

Igneous rock types

- basalt
- granite
- rhyolite[x]

Sedimentary rock types

- impure limestone
- pure limestone
- sandstone (Old Red Sandstone)*
- sandstone and shale[+]
- shale

Metamorphic rock types

- schist

[x]For the purpose of simplification, the less commonly occurring andesites have been included with rhyolites in this map.
*On this simplified rock type map, the Old Red Sandstones of Devonian age are shown as a separate entity from the other sandstones.
[+]The category sandstone and shale incorporates all the other major sandstone and shale sequences, i.e. Cambrian quartzites, Lower and Upper Carboniferous sandstones, siltstones and shales. It also incorporates sedimentary rocks of varying particle sizes, i.e. grits, greywackes, mudstones, siltstones and muddy sandstones.

A short summary of Irish bedrock geology follows, starting in the North East of Ireland and working clockwise around the country, ending in the centre. A reference map of Ireland showing the location of the counties is provided at the end of the introduction section of the atlas (page 18). A simplified table of geological time is shown in the figure at the end of the text.

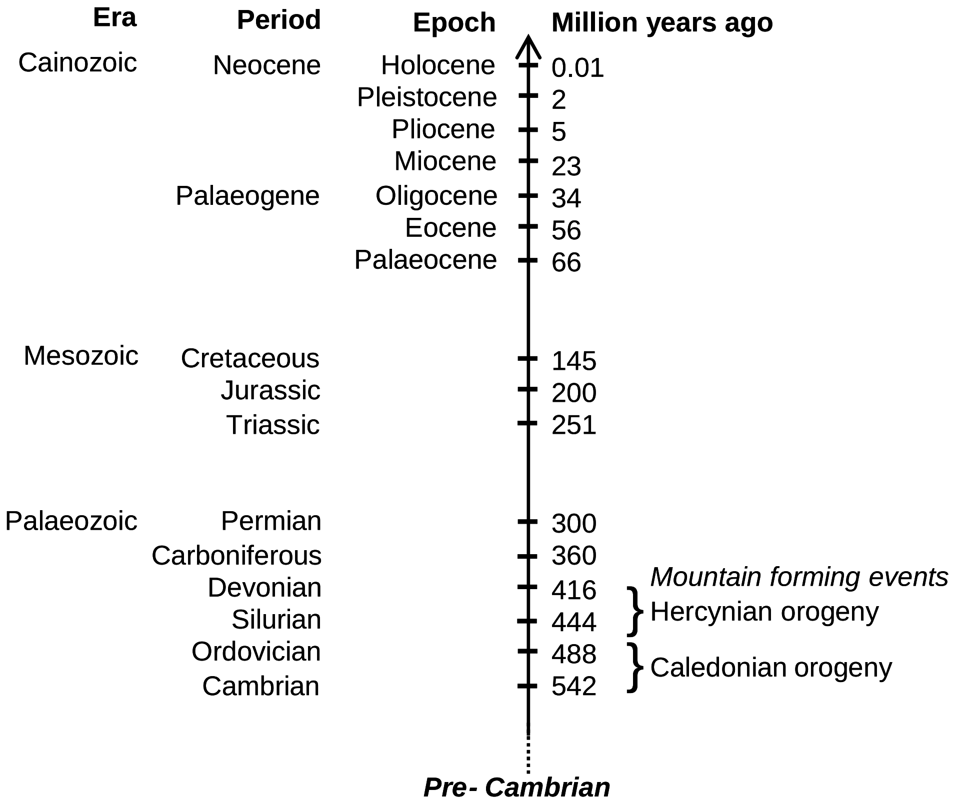
The counties Cavan and Monaghan are mainly underlain by Lower Palaeozoic shales, grits and greywackes, whilst counties Louth and Meath are mainly underlain by limestones or marginally younger shales and siltstones.

The South East of Ireland consists predominantly of Lower Palaeozoic sedimentary (mudstones, siltstones and greywackes) and igneous rocks (rhyolites, andesites and basalts). These have been intruded and metamorphosed during the Caledonian Orogeny by the Leinster Granite, which dominates the area’s topographic elevation (Wicklow Mountains).

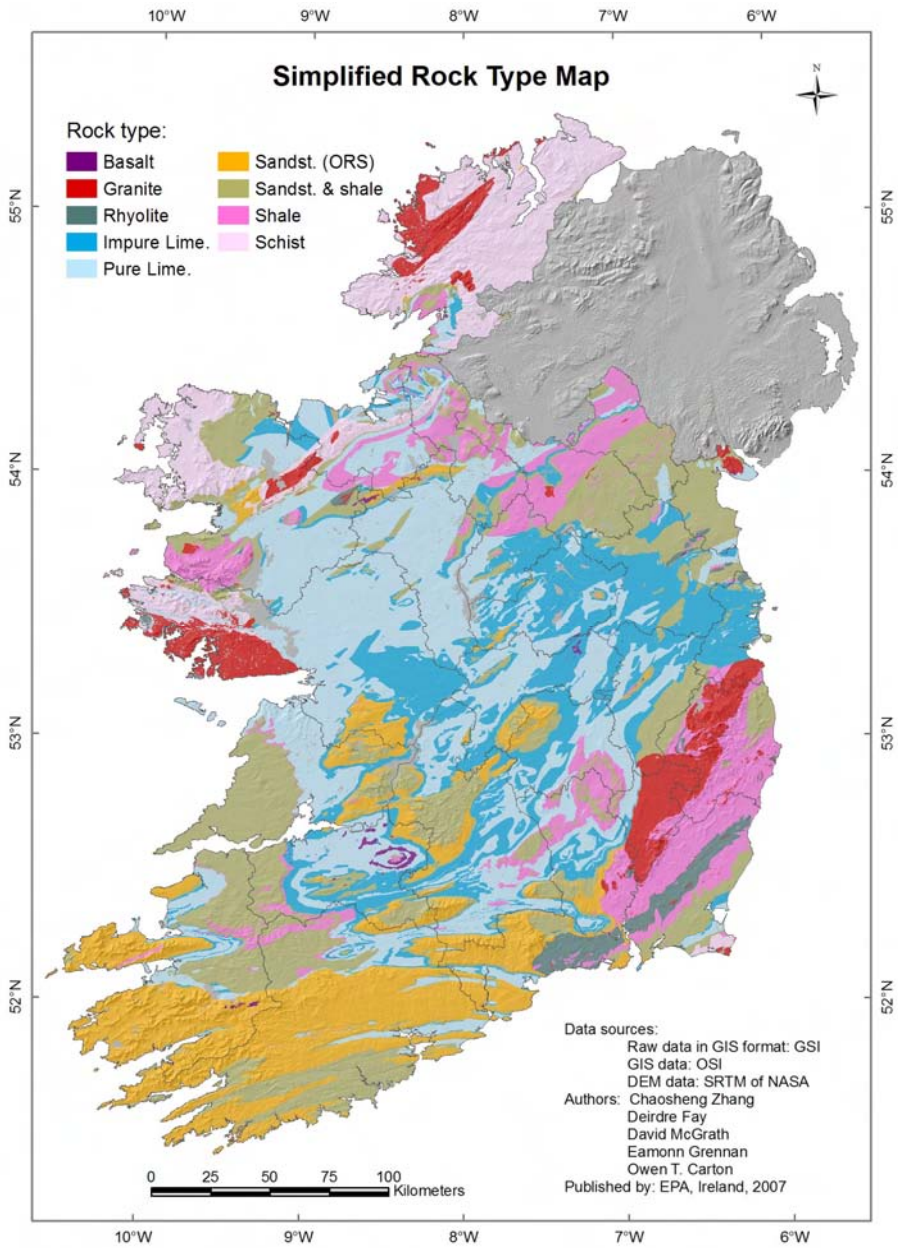
The South and South West are dominated by Old Red Sandstone and some shales in the west, whilst the easternmost part is more variable with sandstones, shales and limestones occurring in a series of gentle synclines and anticlines formed during the Hercynian Orogeny. North of these, in northern Kerry, western Limerick and western Clare there are a series of Upper Carboniferous sediments, mainly shales and grits, sitting on top of comparatively pure limestones.

West Galway and West Mayo are characterized by granite in the South (Caledonian Orogeny) and a combination of Lower Palaeozoic and late Pre-Cambrian metamorphic rocks north of this. In the North, most of county Donegal is underlain by a complex series of rocks comprising schists (metamorphosed from mudstones and muddy sandstones), and quartzites (from sandstones). These have been intruded by a series of granites during the Caledonian Orogeny.

The centre of Ireland is dominantly underlain by carboniferous limestones, which vary from very pure to impure shaley varieties. Within this large area there are two types of rock giving rise to pronounced topographic relief. The first and more frequent consist of Lower Palaeozoic shales and sandstones and Old Red Sandstones. The second consist of younger Carboniferous rocks, predominantly shales, siltstones and sandstones.



Simplified figure of the major geological eras, periods and epochs in their time frames



Granite outcrops in the Wicklow Mountains

Sandstone in southern Co. Mayo

Limestone pavement on a beach in Co. Clare

Recent Geology of Ireland

During the Pleistocene, Ireland experienced at least two major glacial episodes which are important from a soil formation point of view. The older of the two is known as the Munster General Glaciation (200,000 to 130,000 years ago) and enveloped the whole country. The later glacial period, known as the Midlandian General Glaciation (75,000 to 10,000 years ago), intruded into Ireland from the North down to an 'east-west' line running from the Shannon Estuary to Arklow and also into the south eastern coastal area. Most evidence of the earlier glacial period north of this line was removed or covered by that of the second.

The southern quarter of the country is covered with boulder clay deposited during the older Munsterian period. It consists of a rich soil layer covering a rolling landscape. In some areas, this layer can be very thin in which case the underlying rocks can have a strong local impact on the composition of the soil.

The deposits and topography associated with the Midlandian period are far more varied. Besides the widespread moraine deposits of boulder clay, there are extensive drumlin deposits in south Ulster and north Leinster and the areas around Donegal town, Ennis and Westport. There are also the eskers of counties Kildare, Offaly, Galway and Roscommon and very widespread thick (> 70m) deposits of glacial sands in the Curragh. Some local variations have also had an important influence on soils. The Irish Sea Ice Sheet, which intruded a collection of marine sediments consisting of sands, clays and marls and marine fauna, penetrated far into county Meath and the east coast of Wexford.

In most cases, the bulk of glacial material in the soil will have been transported at most 5 km and much of it less than 2 km from its origin. Any distances greater than this would be rare.

The last major ice sheet disappeared around 10,000 years ago and the country began to warm up. This led to the development of fen peat in the water-logged hollows surrounded by melting ice and glacial deposits. The fen peats were gradually transformed into raised bogs. By geological standards, this was a fairly rapid development. The development of blanket peat in Ireland was much slower.

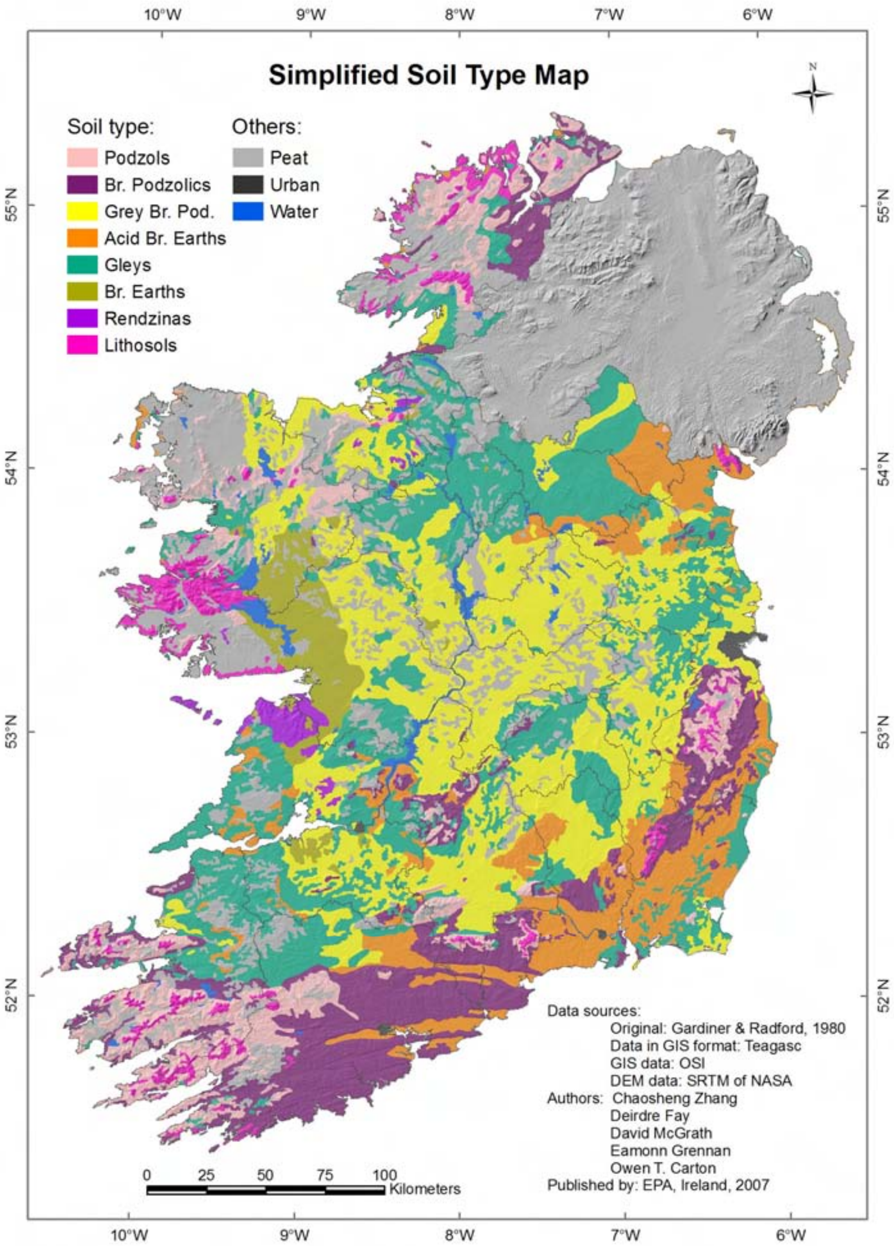
The Clew Bay islands in County Mayo are drumlins, glacial deposits from the end of the last glaciation

Soils in Ireland

The General Soil Map of Ireland and its associated explanatory bulletin were used to discriminate nine major soil types in Ireland for this atlas. While it is a gross simplification to only discuss nine soil types countrywide, the simplified soil map has been used to give an indication of the distribution of soil types in Ireland as a background for the soil geochemical interpretation. The simplified soil types were classified and described based on the 2nd edition of the General Soil Map of Ireland (Gardiner and Radford, 1980).

- Podzols
- Brown Podzolics
- Grey Brown Podzolics
- Acid Brown Earths
- Gleys
- Brown Earths
- Rendzinas
- Lithosols
- Peat

Podzols are formed by the leaching of nutrients from surface horizons, usually accompanied by the translocation of finer particles to subsurface layers. This process is called podzolisation. In essence it is the loss of the buffering base cations, for example Ca and Mg, which leads to soil acidification and subsequently to the leaching of Fe from the surface horizons. Even the insoluble Al is removed by the washing out of finest clay particles in which it is concentrated. The accumulation of Fe in subsurface layers is sometimes concentrated into a thin layer which is commonly referred to as an iron pan such as the one visible in the figure on the opposite page. Podzols are typically poorly drained soils that are formed in mountain and hill areas in Ireland.



A podzolic soil in the Wicklow mountains on the left with a close-up of the iron pan on the right

Brown Podzolics are similar to podzols, and have been formed under the podzolisation process. They are less depleted than podzols, and the surface horizon consists of a mixture of mineral and organic matter. The subsurface horizon is typically rich in Fe and Al, although the iron pan commonly associated with podzols is absent. They are mostly found in the South and South East of Ireland associated with sandstones and shales.

Grey Brown Podzolics are usually formed from a calcareous parent material, which is dissolved relatively easily, yielding alkalinity that counteracts the effects of leaching. As a result of this, the podzolisation process is restricted and the principal material translocated from the surface horizon to the subsurface horizon is made up of clay particles. The texture of the subsurface horizon is consequently 'heavier' than the surface horizon. Grey Brown Podzolics in Ireland are mostly found in the centre of the country and are underlain by pure and impure limestones.

Acid Brown Earths are brown earths which occur on lime deficient parent materials, and are therefore acid in nature. These soils possess medium texture, good friability, and favourable physical characteristics for agriculture. They are found in the South, South East and the North East of the country and are associated with sandstones and shales.

Gleys are soils with poor drainage, mostly due to high clay content. They have developed under the influence of permanent or intermittent water-logging. Most Gleys have poor physical conditions which make them unsuitable for cultivation or for intensive grassland production. Gleys occur in many parts of Ireland, often associated with shale or sandstone, but not exclusively. Typically, they are found in wet and often low-lying areas.

Brown Earths are relatively mature, well - drained mineral soils possessing a rather uniform profile, with little differentiation into horizons. It follows that little leaching has occurred. However, in some cases, translocation of soluble constituents such as Ca and Mg can occur. Brown earths are not very common in Ireland, occurring mostly in county Galway and some areas in county Limerick on limestone bedrock.

Rendzinas are shallow soils, usually not more than 50 cm deep, and are derived from parent material containing over 40% carbonates. The surface horizon often directly overlies the calcareous parent material. Rendzinas are found on limestone bedrock but are not very common in Ireland, found mostly in County Clare and small areas of Roscommon and Sligo.

Lithosols are thin stony soils usually overlying solid or shattered bedrock. They are typically associated with bare rock outcrops and steep slopes.

Their land use potential is limited to rough grazing. They are usually found in coastal, mountain or hill areas in Ireland, often in association with podzols.

A deep basin peat profile

Peats are characterised by a high organic matter content (defined as >30% down to at least 30 cm depth by Gardiner and Radford (1980) and >18-30%, depending on clay content, by the WRB). Two different types of peat, blanket and basin, occur in Ireland. Blanket peat is accumulated under conditions of high rainfall and humidity; conditions which prevail over much of the west of the country and in the upper parts of the mountain ranges where these soils can be found. Two types of basin peat are recognised, fen peats and raised bog peats. Fen peat was formed in basins under the influence of base-rich groundwater and is composed mainly of the remains of reeds, sedges and other semi-aquatic or woody plants. Raised bog peat may accumulate on top of fen peat under suitable climatic conditions. Basin peat occurs mostly in the centre of Ireland, in poorly drained areas and often in association with Gleys and Grey Brown Podzolics. Note that the occurrence of Peat as a major soil type in the soil map of Ireland is a separate issue from the definition "organic soils" in the statistical treatment of the soil geochemical data as mentioned above.

Eroded blanket peat in the Wicklow Mountains

Continuing Influences on Irish Soils

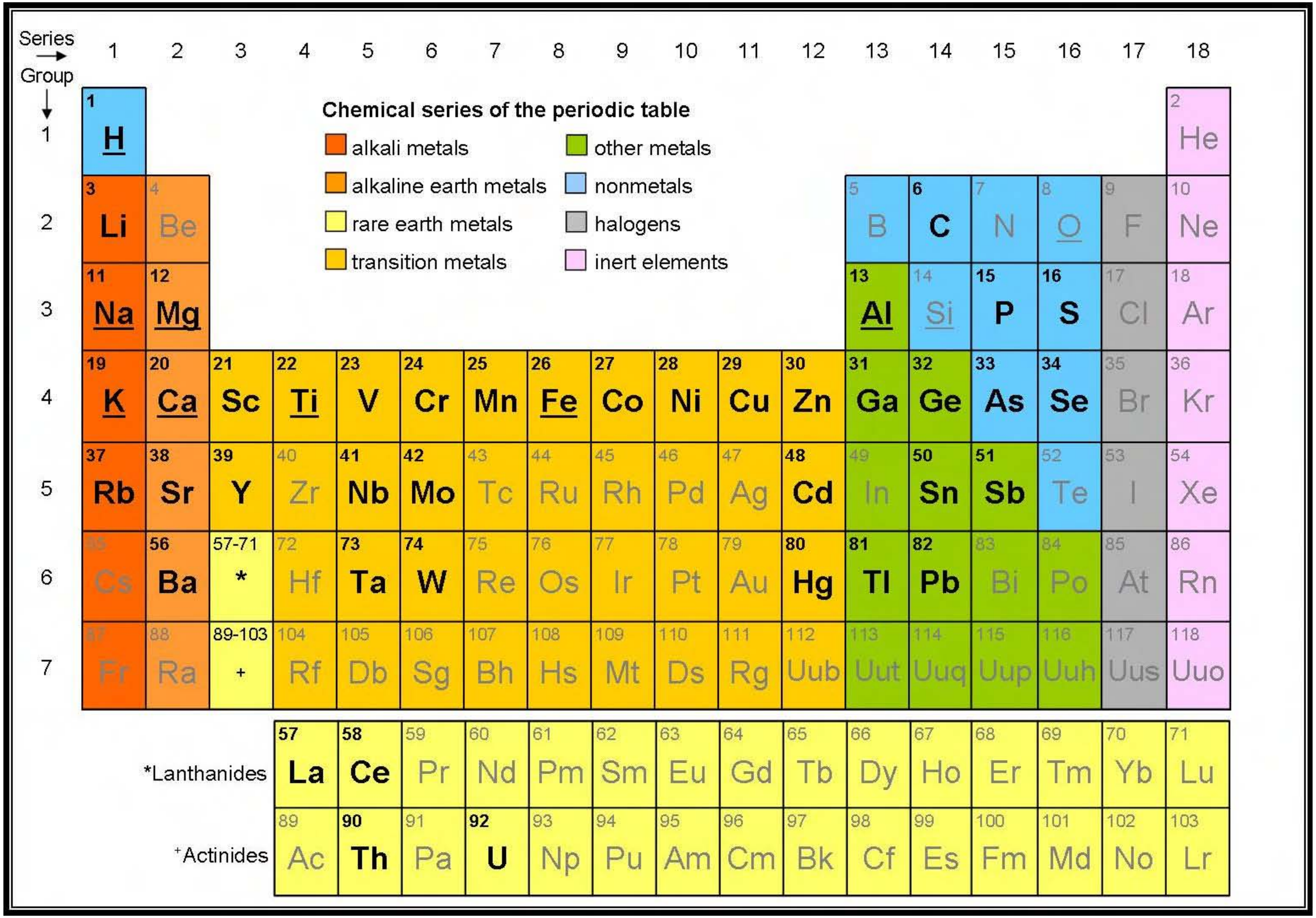
Soils are by no means static and there are many factors which continue to influence soil characteristics, both long- and short-term. Elements can be added to soil due to atmospheric deposition, fertilizer addition (inorganic or organic) or pollution sources. They can be removed through agricultural activity, erosion, leaching and soil removal or remediation. Elements are also circulated within the soil by plant growth and insect, worm and microbial activity.

The mild, wet climate in Ireland is responsible for the growth of the vegetation which forms the basis for peat soils. Warmer, drier weather and peat excavation influence both the character and distribution of these soils. The wet climate has and continues to contribute to the leaching of elements down through (podzolisation) and sometimes out of the soil on local and regional scales. Climatic deposition, be it acid rain or oceanic deposition of salts, is an ongoing process which will influence soil chemistry.

Soils are an important habitat for a wide range of living organisms. Given the abundance of these organisms in soil, biological activity is bound to influence both the physical and the chemical properties of soils. The most obvious example for this would be earthworm activity which is an important factor for the aeration of soils.

Anthropogenic activities in Ireland (e.g. farm management and mining activity) mostly have a local impact on soil. Soil geochemistry, to a certain point, defines the land use potential of a soil, while anthropogenic activities such as mining, industry, urbanization and agriculture can increase or decrease that potential. Two land use maps have been generated to serve as a background reference for the interpretation of the geochemical maps. Simplified land cover types were classified based on CORINE data from the EPA for the first map. The land cover types include pasture, arable land, forest and peat (and marshes). The principal mining sites in the country are also presented on this map and include metal, industrial, slate and coal deposits. A second land use map was generated based on the description of land use recorded by the soil samplers at each sampling point. The classifications used were bog, forest, grass, rough grazing and tillage. The category bog refers to wet soils, usually peats, whilst the category rough grazing covers land which can be used for grazing but is marginal, usually due to its location in exposed areas such as mountain or coastal regions and often on thin, depleted or wet soils.

Some examples of land use in Ireland, clockwise from top left: rough grazing, grass, tillage and forest



Periodic Table of Elements

Chemical Elements Measured

The periodic table of elements is shown opposite, with the elements measured highlighted in bold print. Ten of the major elements which constitute more than 99% of the elemental content of the Earth's crust (Lide, 2005) have been underlined in the table. The concentrations of these elements are expressed in weight percentage in this Atlas (%). The remaining elements occur in much smaller amounts in the crust and are referred to as trace elements. The concentrations of the trace elements, with the exception of P and S (in %), are expressed in weight ratios (mg/kg) also known as ppm (parts per million).

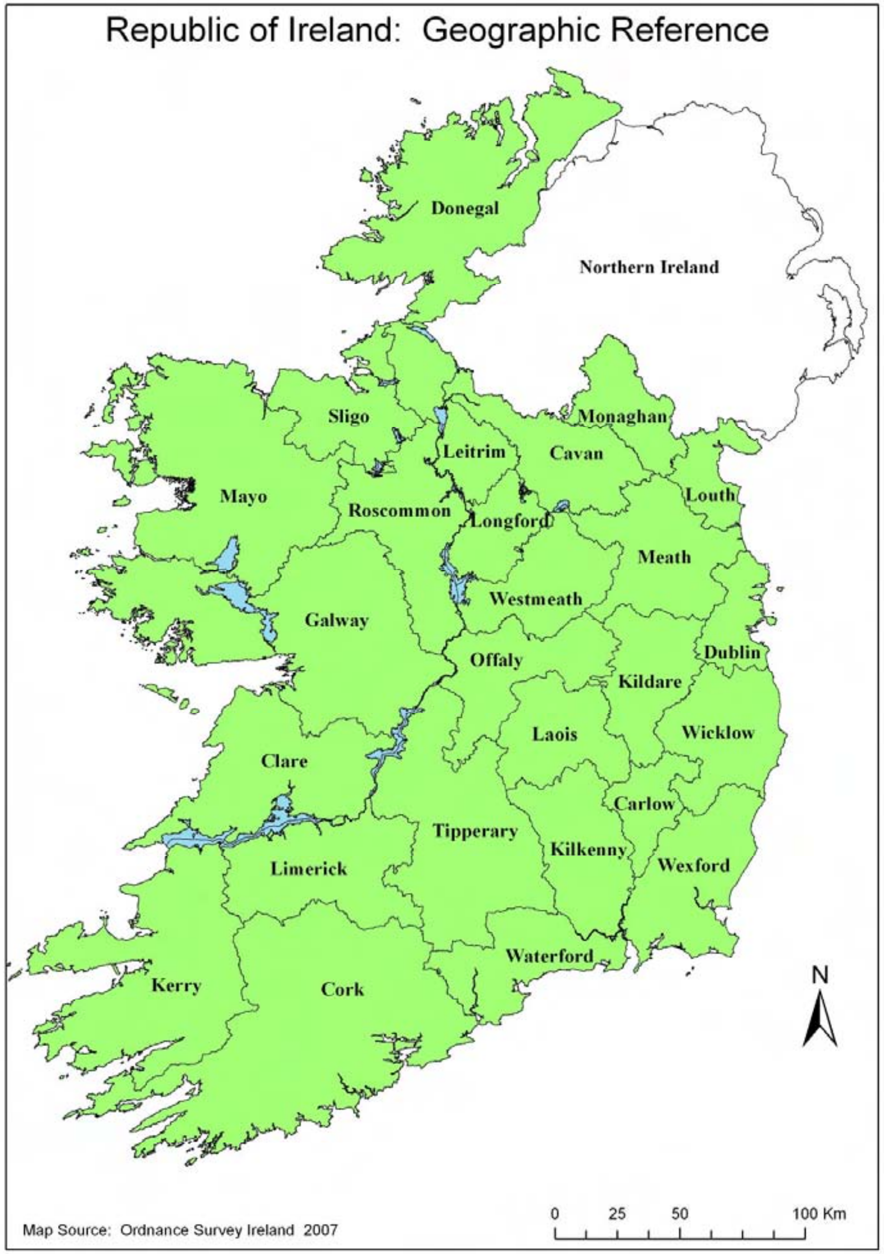
Of the trace elements measured in the soil samples, seven (Co, Cr, Cu, Mn, Mo, Se and Zn) are essential to most organisms, although they can be toxic where uptake is excessive. Five of the elements measured (As, Cd, Hg, Ni and Pb) are of particular interest as they are toxic to organisms at much lower concentrations than the essential trace elements. Six of the elements measured (Cd, Cu, Hg, Ni, Pb and Zn) are listed in the EU Sewage Sludge Directive which regulates the use of sewage sludge in agriculture (86/278/EEC).

The available concentrations of elements (K, Mg and P, expressed in mg/l), the pH (expressed in pH unit) and the SOC (expressed in %) are the soil characteristics most likely to change in the short term as a result of land use and management. Total concentrations of elements in soil are more likely to change due to more long-term and irreversible processes such as erosion, leaching, atmospheric deposition, pollution and soil removal or remediation.

The distribution of the elements in Irish soils has been interpreted as far as possible using expert opinion, literature and background information. Relative levels of the elements in the soils were considered in an Irish context for the interpretation. Typical background concentrations of the elements in unpolluted soils have been given as a reference where possible. It should be remembered that background concentrations are dependent on the soil parent material, organic matter content and sand, silt and clay content of soils, and hence may vary greatly without any anthropogenic influences. The specific level considered for the purpose of any discussion is always defined in brackets. Summary statistics are also shown for each element to give an overview of the occurrence of the element in Irish soils.

An alphabetic list of chemical symbols of the elements measured and their English names is shown in the table below. SOC and pH are considered basic soil characteristics and, as such, have been discussed separately preceding the other elements. All the elements have been interpreted separately and are ordered alphabetically according to their chemical symbols. K, Mg and P differ slightly from the other measured elements in their interpretation in that both the available and the total concentrations were measured for these elements, whereas only total concentrations were measured for all other elements.

Al	aluminium	**La**	lanthanum	**Se**	selenium
As	arsenic	**Li**	lithium	**Sn**	tin
Ba	barium	**Mg**	magnesium	**Sr**	strontium
Ca	calcium	**Mn**	manganese	**Ta**	tantalum
Cd	cadmium	**Mo**	molybdenum	**Th**	thorium
Ce	cerium	**Na**	sodium	**Ti**	titanium
Co	cobalt	**Nb**	niobium	**Tl**	thallium
Cr	chromium	**Ni**	nickel	**U**	uranium
Cu	copper	**pH**	phosphorous	**V**	vanadium
Fe	iron	**Pb**	lead	**W**	tungsten
Ga	gallium	**Rb**	rubidium	**Y**	yttrium
Ge	germanium	**S**	sulphur	**Zn**	zinc
Hg	mercury	**Sb**	antimony		
K	potassium	**Sc**	scandium		


Republic of Ireland: Geographic Reference
Donegal
Northern Ireland
Sligo
Monaghan
Leitrim
Cavan
Mayo
Roscommon
Louth
Longford
Meath
Westmeath
Galway
Offaly
Dublin
Kildare
Laois
Wicklow
Clare
Carlow
Tipperary
Kilkenny
Wexford
Limerick
Waterford
Kerry
Cork
N
0
25
50
100 Km
Map Source: Ordnance Survey Ireland 2007

Maps

A deep Basin Peat profile under heather scrub in Ireland.

SOC Soil Organic Carbon

Carbon is a non-metallic element which has the unique characteristic that it forms stable compounds with a wide variety of elements at ambient earth temperatures. Apart from carbon monoxide, carbon dioxide and carbonates, almost all C compounds also contain H. These compounds form the basis for all organic chemistry. C occurs as a pure element in different allotropic forms. Diamonds, the hardest known mineral, are used in jewellery and for industrial purposes, whilst graphite, one of the softest known minerals, is used in pencils, pigments and as a lubricant. Although the element is not toxic, poisonous compounds of the element exist, such as carbon monoxide, cyanide and many hydrocarbons such as e.g. benzol and formalin.

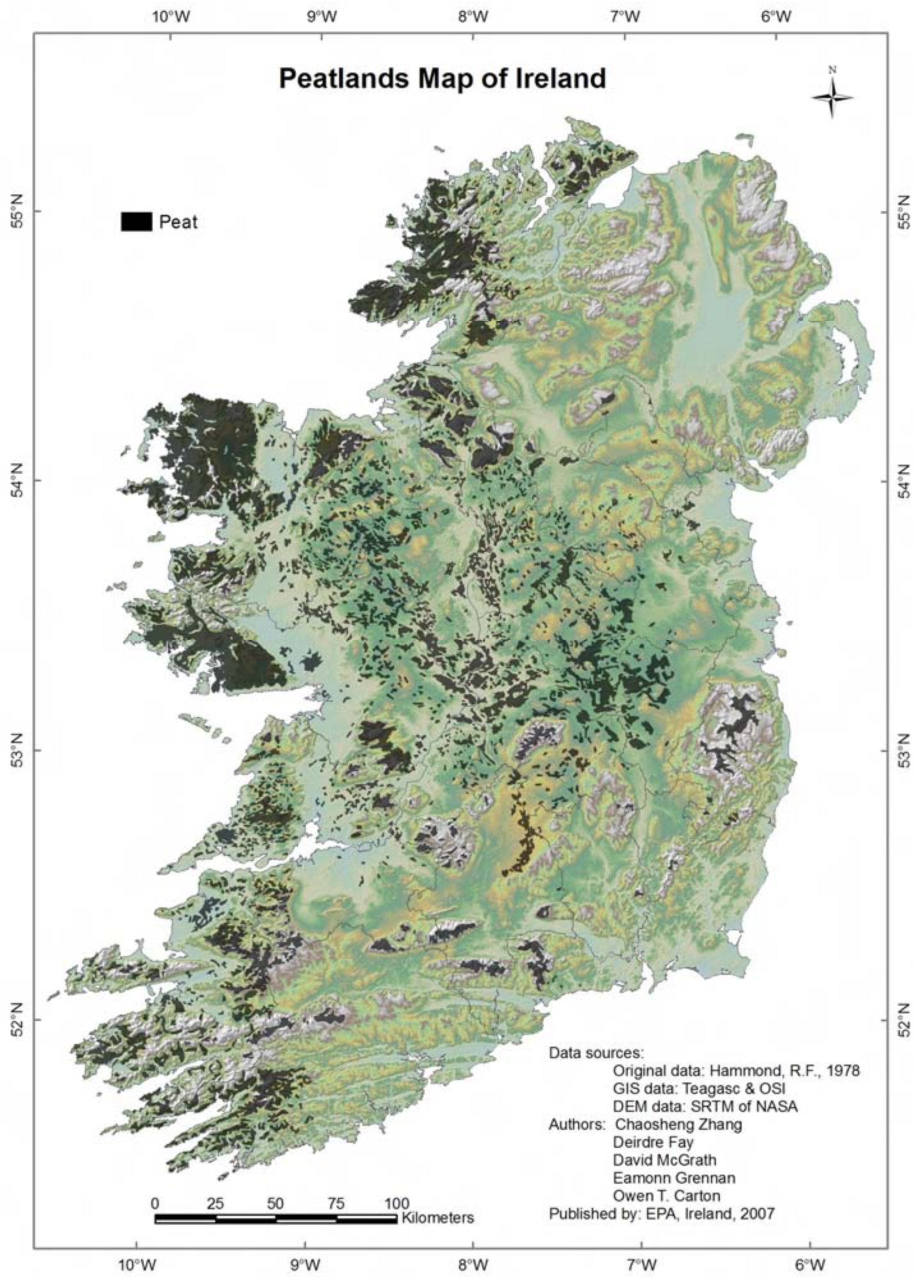
For all practical purposes, the absolute amount of C on earth is constant, but will vary over space and time depending on the stage in the C cycle. An important part of the C cycle is the release of CO_2 (e.g. decay, burning, respiration) and the consumption of this by plants. C is present in both its organic and inorganic forms in soils, the organic forms being the most prevalent and important. Organic C is both consumed and deposited by the living organisms present in soil systems. C cycles in soils are dependent on land use and management.

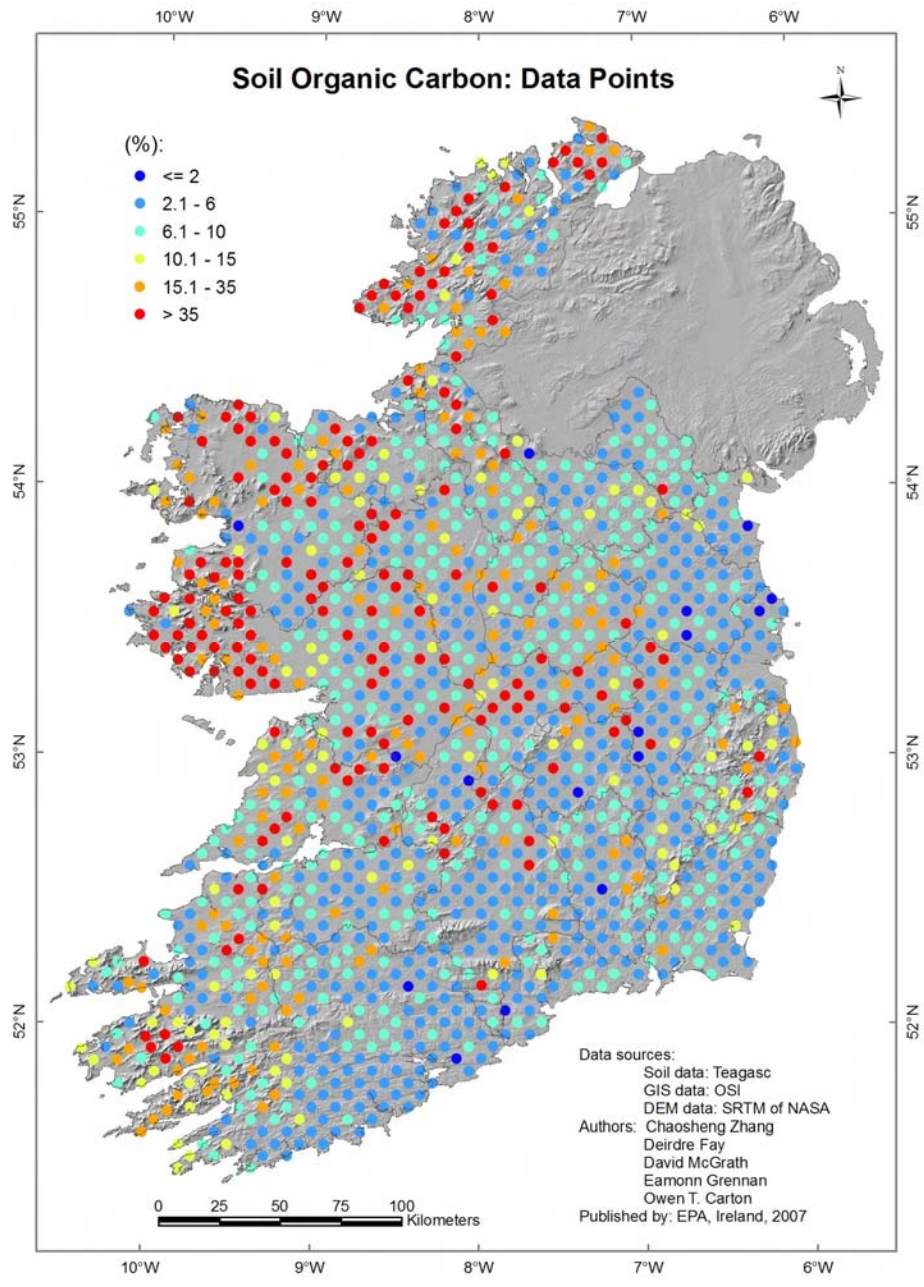
Soil organic carbon (SOC) is the main component of soil organic matter (SOM). The conversion factor from SOC to SOM is approximately 1.72 (i.e. SOM=1.72*SOC), depending on the soil. A depleted SOC content (<2%) can result in low soil fertility and poor soil physical quality, whilst soils with a high soil carbon content (>30%) tend to have a lower soil density and are often wet, peaty and acid, which can restrict their use from an agricultural point of view. SOC was measured for each sampling point in this study. For statistical analysis purposes, all soils were separated into mineral (<15% SOC) and organic (>15%) soils. This is slightly lower than the 30% SOM (±17% SOC), used to classify peat by Gardiner and Radford (1980).

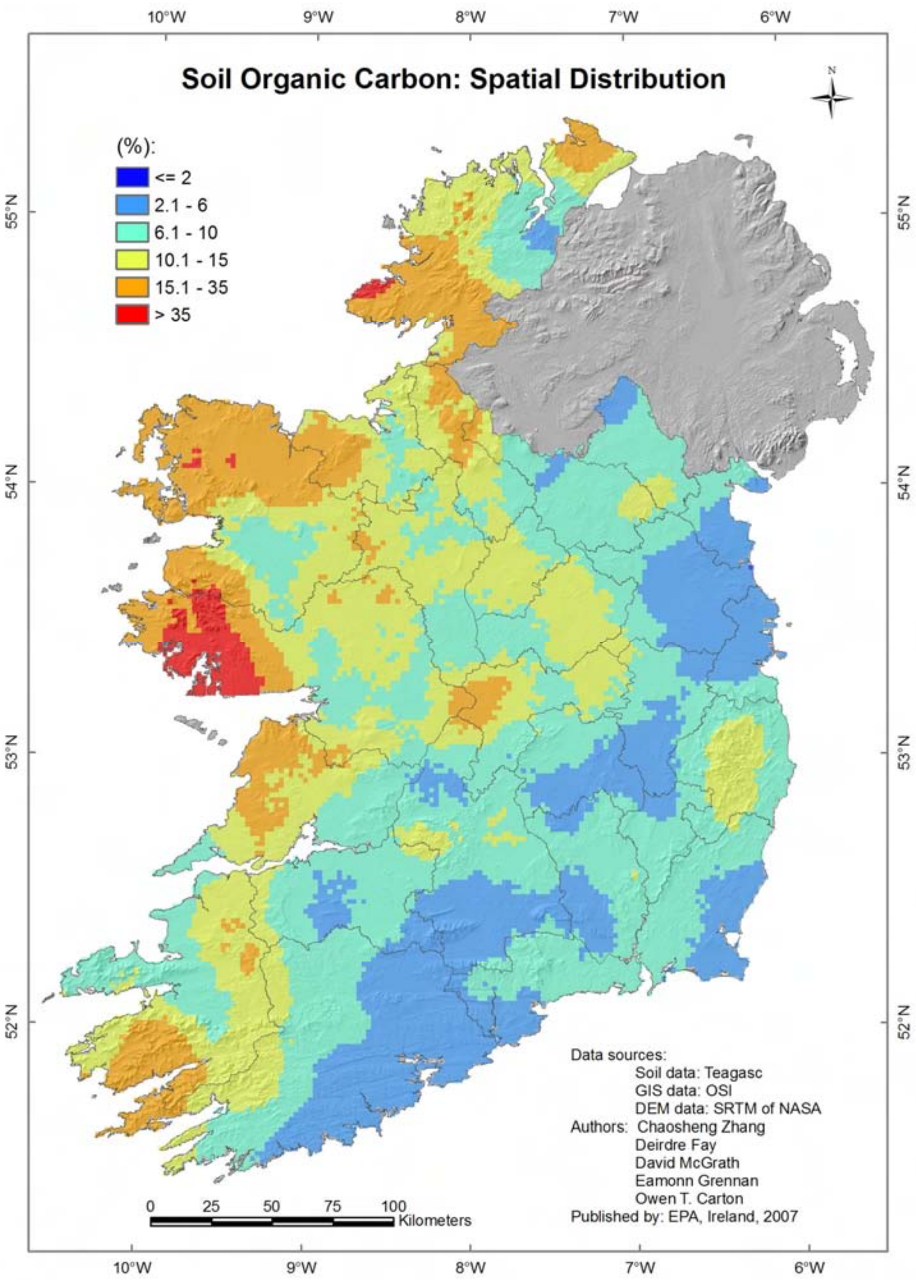
Table showing the minimum and maximum and some of the most important percentiles for the SOC content in %

	min	5%	25%	50%	75%	95%	max
all soils	1.40	2.86	4.92	7.00	14.26	48.01	55.80
mineral	1.40	2.69	4.47	5.93	7.66	12.03	14.83
organic	15.07	15.97	23.53	36.02	47.33	52.15	55.80

The soils classified as organic soils in this study (>15% SOC) coincide quite well with the peat soils on the western seaboard, in the midlands and in mountainous areas of the country. Hammond's (1978) Peatlands Map is shown here as it illustrates the relationship between these organic soils and the peat soils of Ireland. SOC contents below 6% in Ireland occur mostly in areas where more intensive agriculture is practised, such as the South East, Cork and the North East. This is coincident with a national survey of mineral soils reported by Brogan (1966), which delineated an area in the southern agriculturally-intensive region with a relatively low mean SOC value of 4.5%.




Soil Organic Carbon: Data Points
(%):
<= 2
2.1 - 6
6.1 - 10
10.1 - 15
15.1 - 35
> 35
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Soil Organic Carbon: Spatial Distribution
(%):
<= 2
2.1 - 6
6.1 - 10
10.1 - 15
15.1 - 35
> 35
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

pH Soil pH

The pH of a soil gives a measure of the concentration of [H+] ions in its soil solution. pH is an important soil property which will influence the fertility and potential land use of a given soil.

Table showing the median pH values for each land use type as classified for the sites

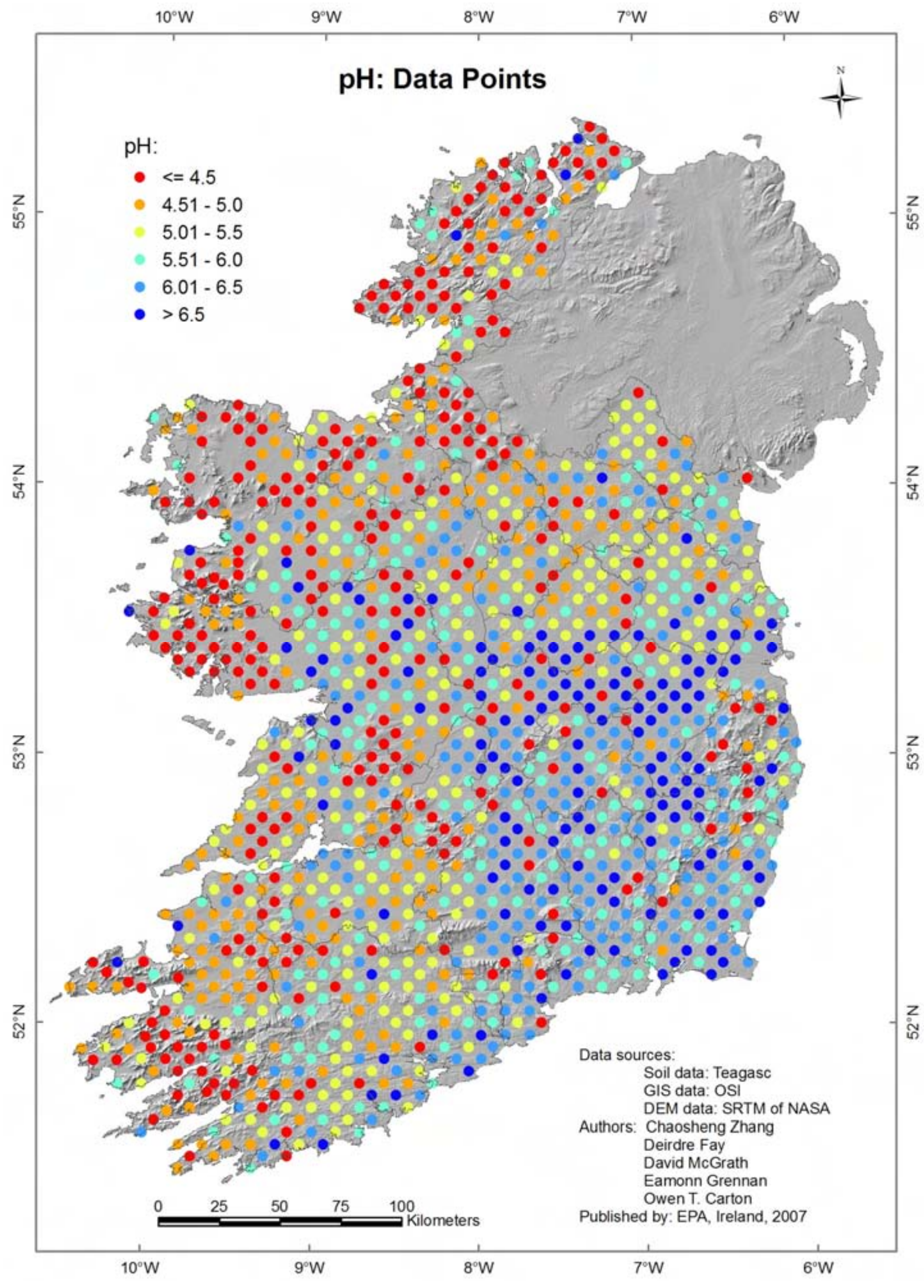
Bog	Forest	Grass	Rough grazing	Tillage
3.9	4	5.5	4.8	6.4

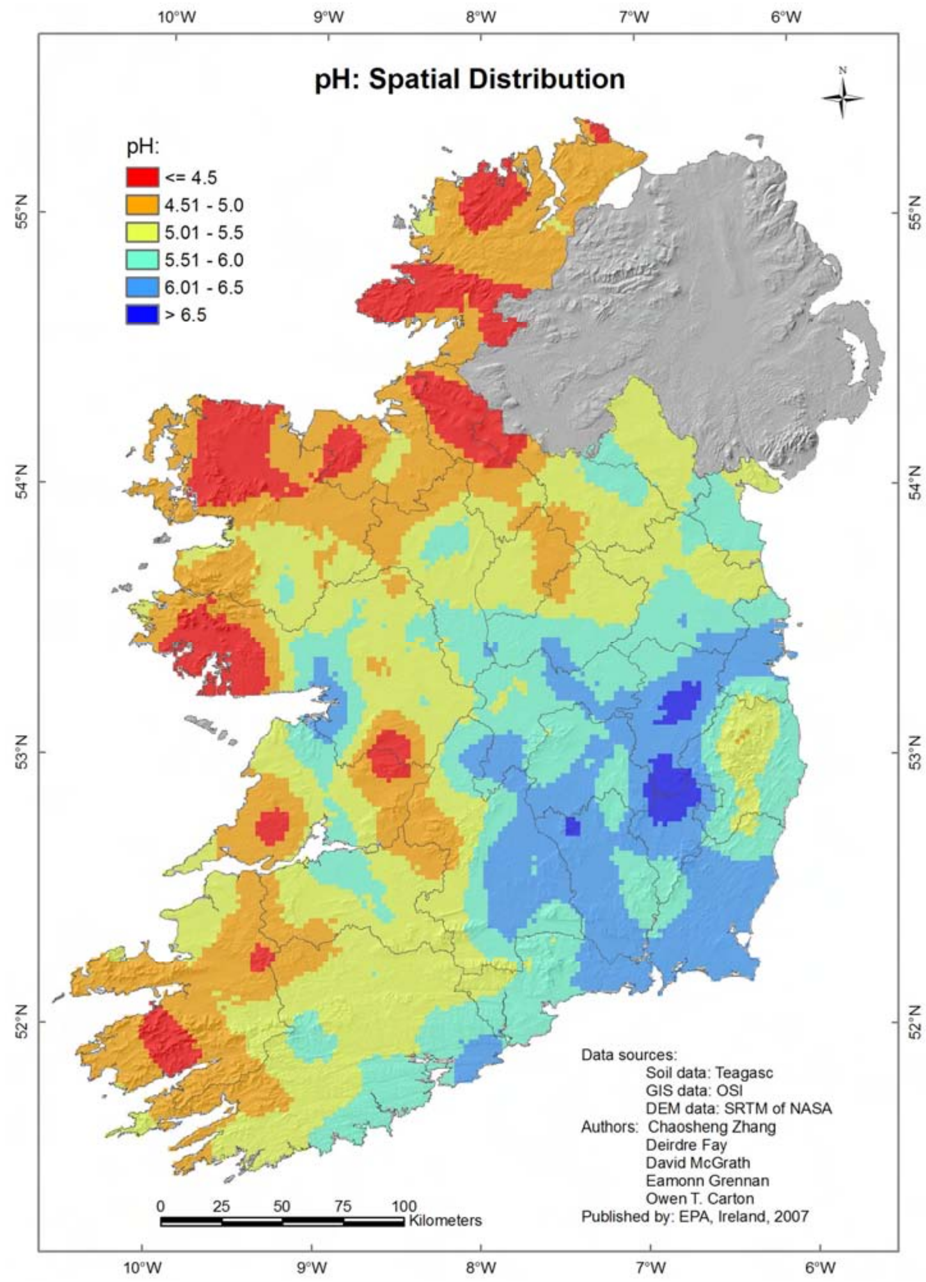
The majority of the soils in this study with a pH>6 occur in the South East of the country, where tillage is the predominant agricultural activity. pH values higher than 6 are also partially associated with the limestone distribution on the simplified rock type map, particularly in the Galway region. The Pearson's correlation coefficient (r_{min}) for Ca and pH was 0.7, showing a significant relationship between the two. pH values lower than 5 in this study corresponded well with the blanket peat and podzol areas of the western seaboard, parts of the midlands and the Wicklow Mountains.

The median pH values for each land use shown below indicate the relationship between pH and land use. Peat soils tend to be more acidic, whilst soils on which intensive agriculture is practised will often have a high pH: soils with an inherent basic character are more productive and are thus preferentially used for tillage. Lime treatments ensure a continuous high pH.

Table showing the minimum and maximum and some of the most important percentiles for pH in pH unit

	min	5%	25%	50%	75%	95%	max
all soils	3.20	3.70	4.60	5.30	6.10	7.00	7.70
mineral	3.40	4.40	5.00	5.50	6.20	7.10	7.70
organic	3.20	3.50	3.80	4.20	4.80	6.20	7.20


pH: Data Points
pH:
<= 4.5
4.51 - 5.0
5.01 - 5.5
5.51 - 6.0
6.01 - 6.5
> 6.5
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers


pH: Spatial Distribution
pH:
<= 4.5
4.51 - 5.0
5.01 - 5.5
5.51 - 6.0
6.01 - 6.5
> 6.5
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers

Al Aluminium

Aluminium is the most abundant metal and the third most abundant element in the earth's crust of which it makes up more than 8% (Lide, 2005). The main ore from which Al is commercially extracted is bauxite. Al occurs naturally in igneous rocks and shale, the parent material of most clay soils. It has many uses in both metal and compound form from aeroplane construction to deodorant, paint, packaging, wiring and cooking ware. Al is present in most food, but has not been found to be an essential element for any biological processes. Al compounds are toxic to most plants and slightly toxic to animals. Al can stunt plant growth on acid soils.

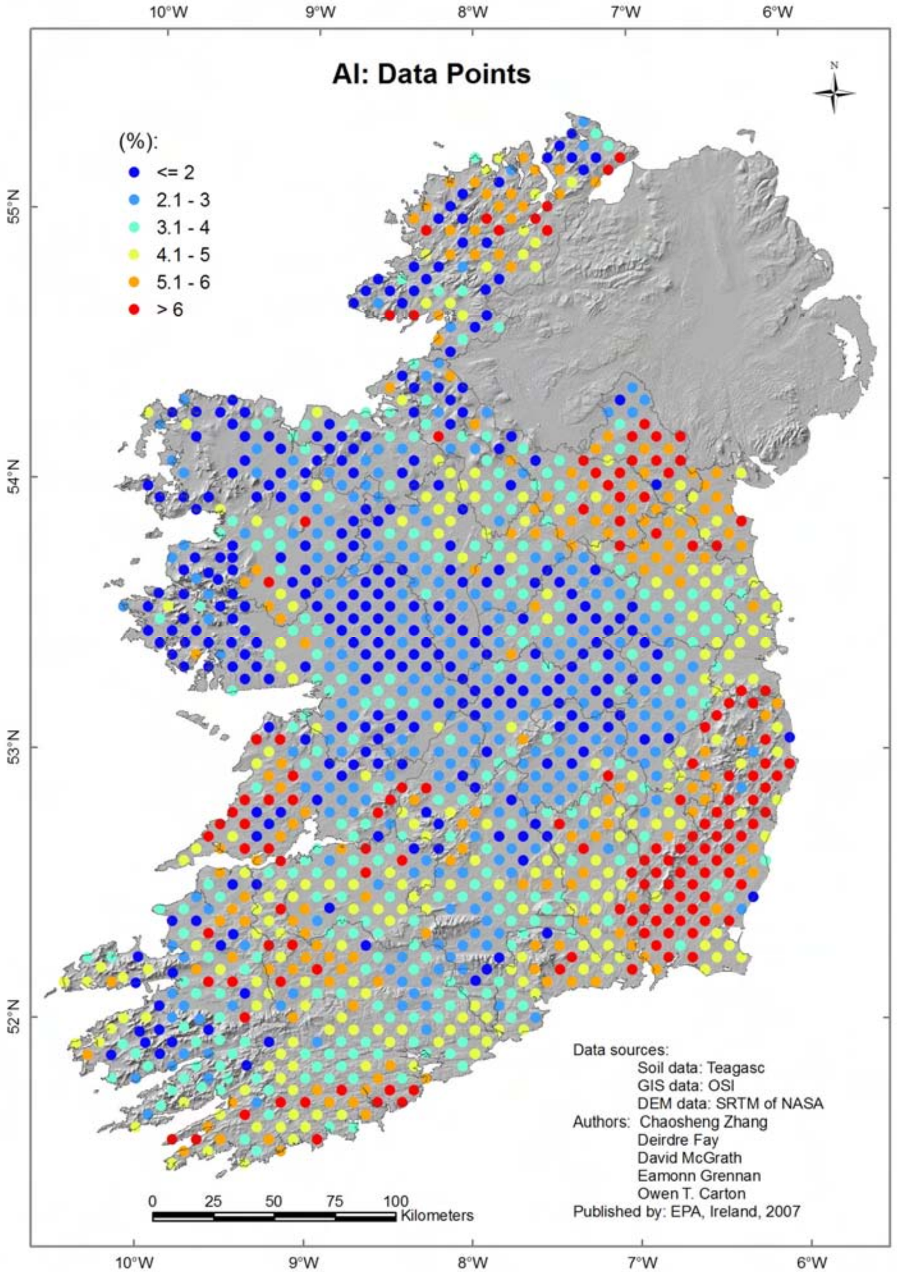
Aluminium levels above 4% in Irish soils are associated with the finer sandstones and shales in the North East (greywackes) and in western Cork, Limerick, Kerry and Clare. Igneous rocks and sandstones and shales in the South East are also associated with Al levels above 4%. In the North, schists have a high Al content related to the feldspar present in these rocks. Al levels in Irish soils below 3% are predominantly found on limestone. The Al levels in the Podzols, Lithosols and Peats along the whole of the western seaboard are also below 3%. Low levels of Al are to be expected in the upper layers of Podzols as Al and Fe are leached into the lower layers of these soils. The distribution of Al in Irish soils follows a pattern which recurs in similar forms for many of the measured elements. This is illustrated in the table with Pearson's correlation coefficients (r), which shows all the elements which had a strong correlation with Al in their distribution patterns ($r_{min} \geq 0.7$ for mineral and $r_{org} \geq 0.85$ for organic soils, see Statisitical Analysis, pg 4).

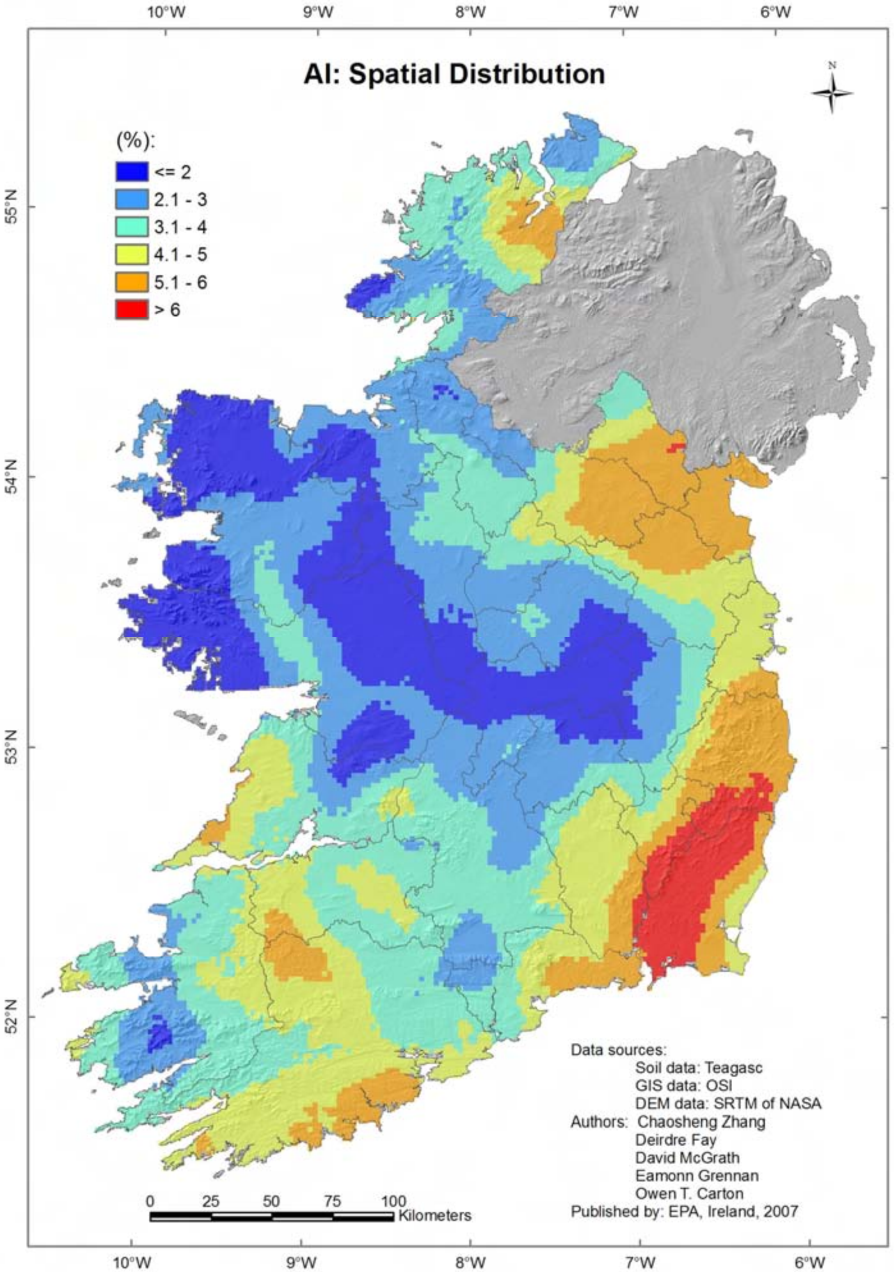
Table showing the Pearson's correlation coefficients for Al with other elements for soils where r_{min} >0.75 and/or r_{org} >0.85

Element	r_{min}	r_{org}
Ba	0.75	0.86
Ce	0.82	0.97
Cr	0.74	0.92
Fe	0.74	0.74
Ga	0.96	0.94
Ge	0.77	0.89
K	0.81	0.96
La	0.75	0.96
Li	0.71	0.88
Na	0.59	0.85
Nb	0.70	0.98
Rb	0.87	0.98
Sc	0.88	0.96
Sn	0.73	0.71
Ta	0.77	0.95
Th	0.87	0.98
Ti	0.78	0.97
V	0.80	0.93
W	0.77	0.89
Y	0.13	0.86

Table showing the minimum and maximum and some of the most important percentiles for total Al concentrations in %

	min	5%	25%	50%	75%	95%	max
all soils	0.06	0.20	2.21	3.48	4.89	6.65	9.74
mineral	0.34	1.93	2.96	4.01	5.24	6.93	9.74
organic	0.06	0.11	0.23	0.85	2.34	5.00	7.00


Al: Data Points
(%):
<= 2
2.1 - 3
3.1 - 4
4.1 - 5
5.1 - 6
> 6
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers


Al: Spatial Distribution
(%):
<= 2
2.1 - 3
3.1 - 4
4.1 - 5
5.1 - 6
> 6
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers

As Arsenic

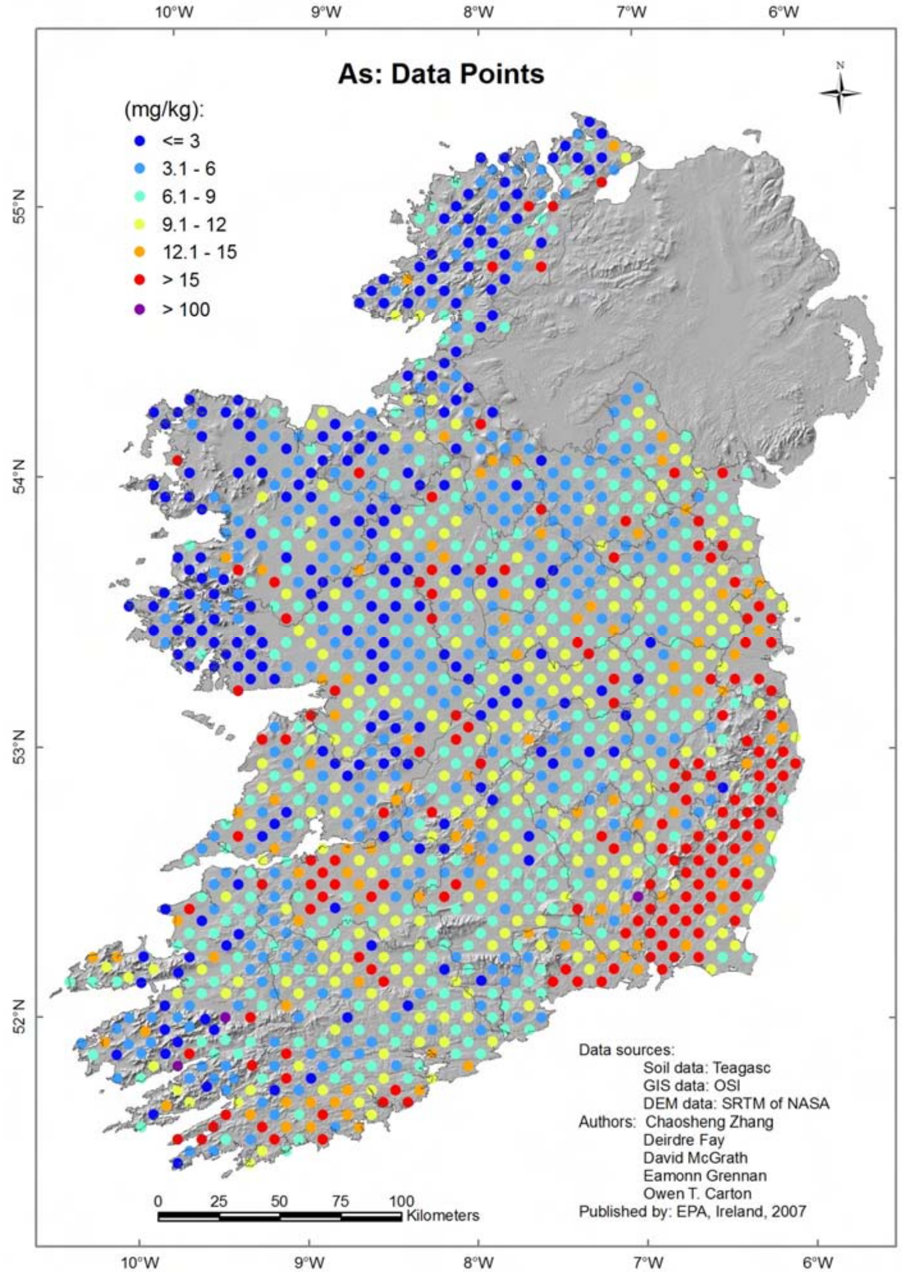
Arsenic occurs naturally in minerals and soil in small amounts and is often found in ores with Cu and Pb. As has very similar elemental properties to P and occurs in many different forms, both organic and inorganic. Sources of As in the environment are Pb and Cu mining, volcanic eruptions and the burning of fossil fuels. As and its compounds are used in pesticides, herbicides, insecticides, batteries, semi-conductors and LED's. As is an essential element for humans and animals, but only at very low levels. It is toxic and a well known poison. Both the metal and its compounds are toxic, although the organic compounds are less so.

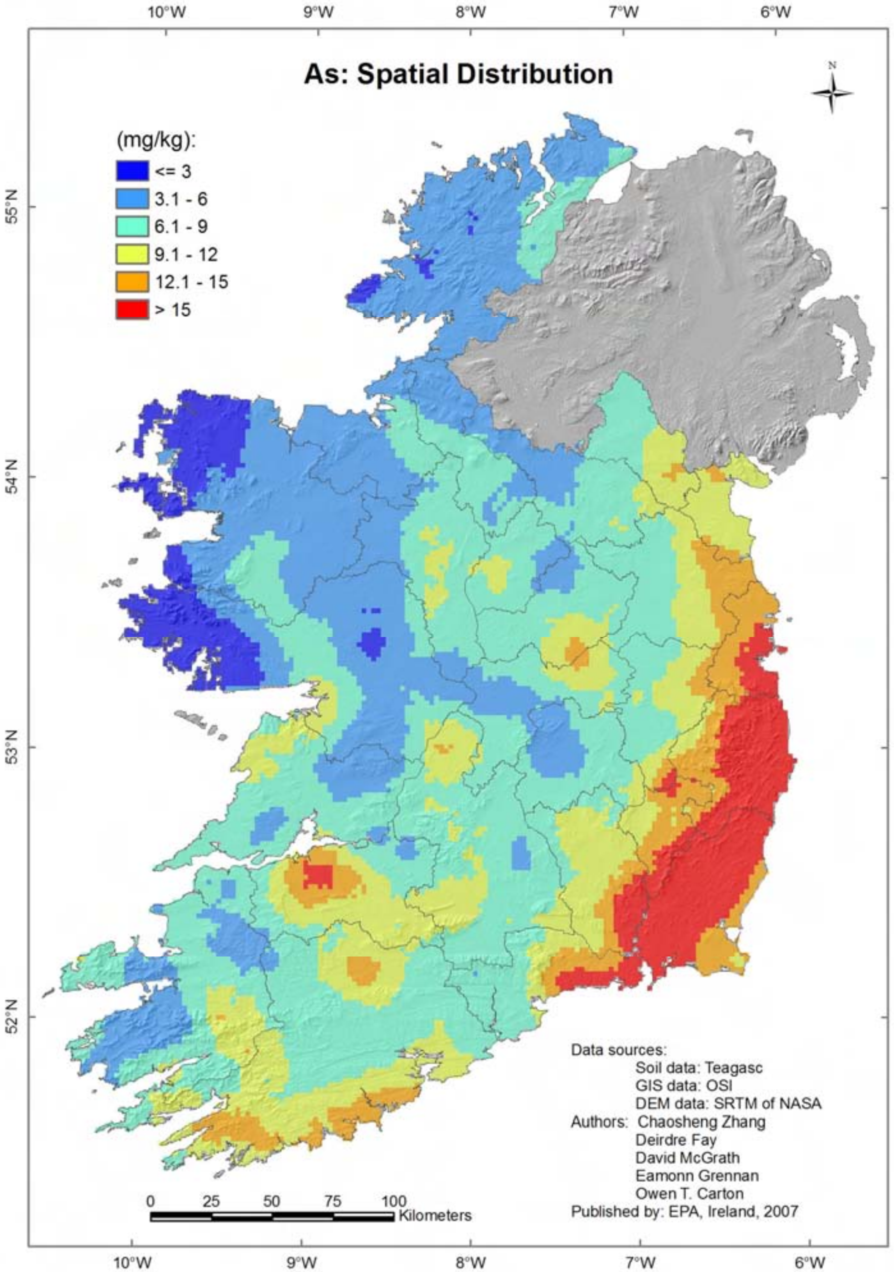
The mean background As concentration reported for soils worldwide is 11.3 mg/kg (Bowen, 1982). Levels above 12mg/kg in the soils in the area stretching from Dublin to eastern Waterford are probably largely due to the association of As with sesquioxides from Cu mining. There is an association between high levels of As and Cu on the south coast of Cork, and this is probably related to the incidence of historic Cu mining activities. The regional elevation of As in Limerick is associated with Carboniferous volcanic activity. Areas of known gold deposits tend to have high values of Sb and As. This is the case in County Monaghan along the Armagh border (>12mg/kg). Naturally occurring relatively high Pb values (>50mg/kg) are also present in this area. Levels of As below 6mg/kg are coincident with peat areas in Kerry, Galway, Mayo and Donegal. Three As values in excess of 100mg/kg were detected. However, even the highest concentration measured, 173mg/kg, was considered to be below the level at which it would be likely to impact on the health of animals and humans.

Table showing the minimum and maximum and some of the most important percentiles for total As concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<0.2**	1.43	4.41	7.25	10.66	21.90	122.70
mineral	0.53	3.07	5.74	8.00	11.16	22.47	111.21
organic	<0.2**	0.78	1.67	2.87	6.47	19.06	122.70

**One sample analysed was below the detection limit of 0.2 mg/kg for As


As: Data Points
(mg/kg):
<= 3
3.1 - 6
6.1 - 9
9.1 - 12
12.1 - 15
> 15
> 100
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


As: Spatial Distribution
(mg/kg):
<= 3
3.1 - 6
6.1 - 9
9.1 - 12
12.1 - 15
> 15
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

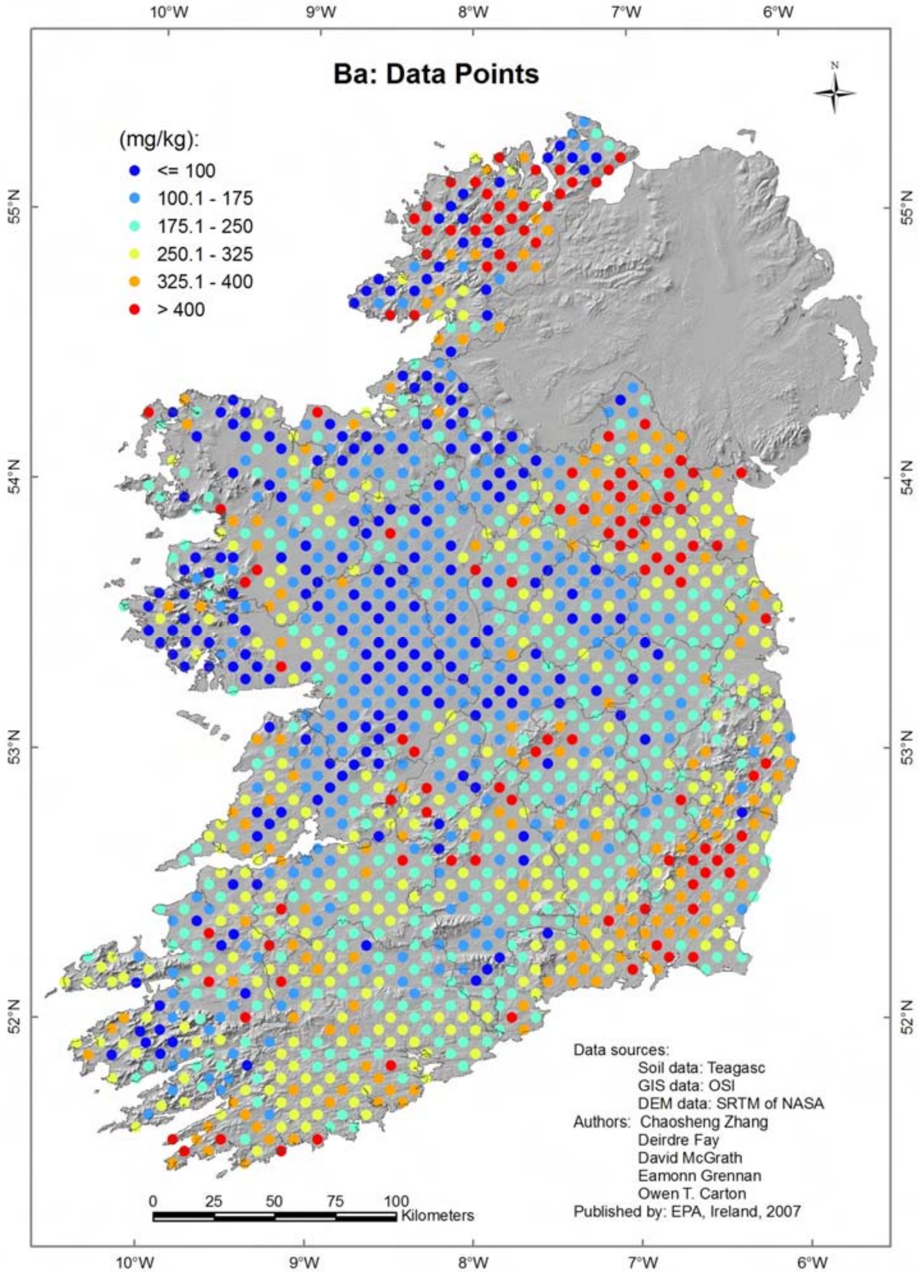
Ba Barium

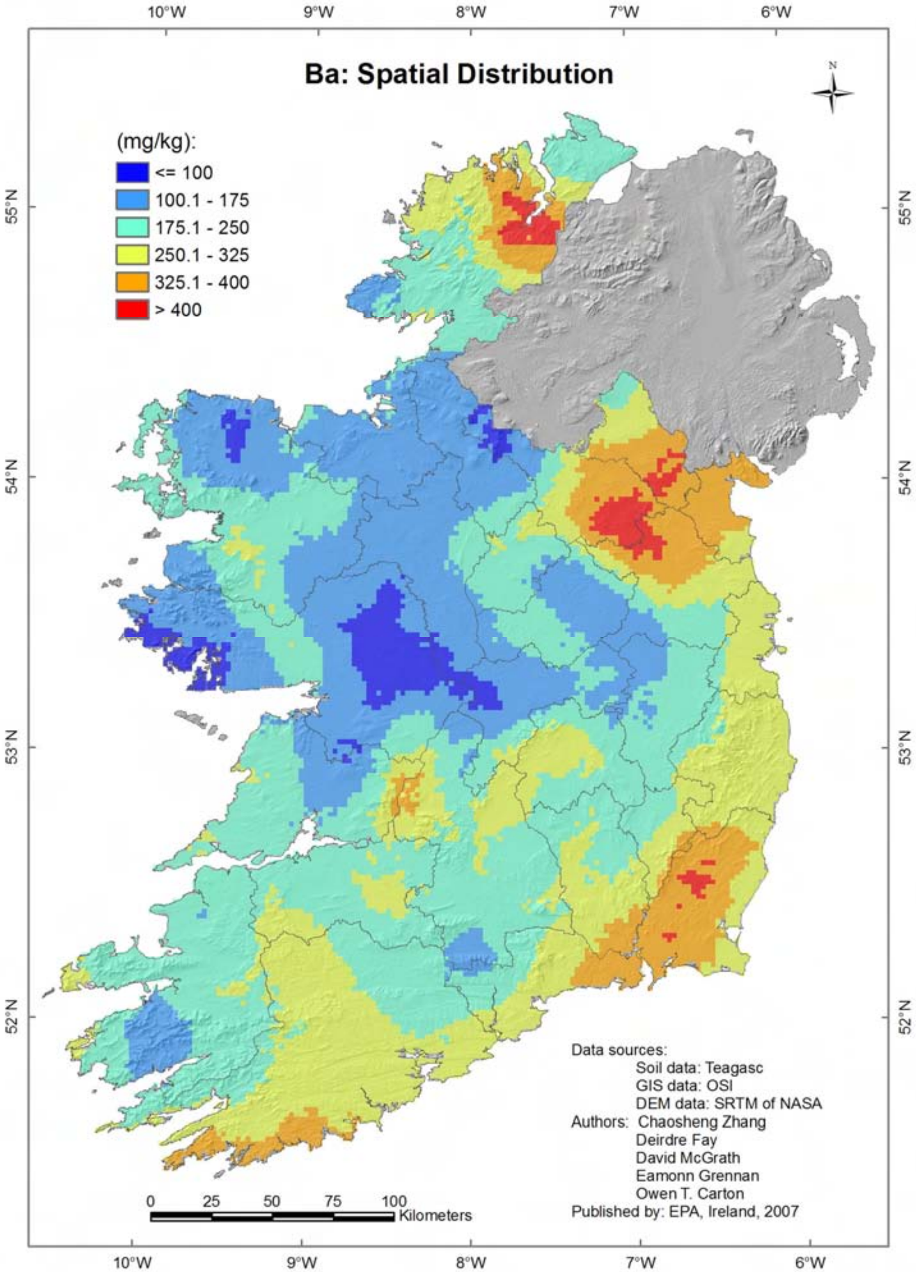
Barium is quite a common trace element that is found naturally in soil. It can be introduced into the environment through refining and mining processes, industries where Ba compounds are used and the burning of fossil fuels. Ba and its compounds have many applications including the production of paints, rubber, tiles, spark plugs, fluorescent lights, fireworks, bricks, as a lubricant for drills in the oil industry and in X-ray diagnostic work. Ba has no known biological role. Forms of Ba which are soluble in water and acid can be harmful.

Typical background concentrations of Ba in soil were determined as 100mg/kg by Ure (1991). Levels of Ba above 250mg/kg in Irish soils coincide with the greywackes in the North East and greywackes and igneous rocks in the South East. Similar levels are also coincident with marbles in Donegal. Relatively high levels are known to occur in the midlands along the base of the Lower Paleozoic inliers (shales and sandstones), where the acidic waters draining the elevated areas come into contact with the alkaline-neutral soils overlying the limestones forming the valley floors. The change from neutral/alkaline conditions causes precipitation of the dissolved metal content principally Ba, Pb and Zn. Co-precipitates commonly include Co, Ni and As. Ba may also be somewhat elevated in soils derived from limestone, especially when the latter are close to a mineralisation.

Table showing the minimum and maximum and some of the most important percentiles for total Ba concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	6.6	21.3	141.7	230.2	305.6	454.5	1296.9
mineral	54.0	110.7	188.4	253.1	329.0	473.9	1178.9
organic	6.6	11.4	25.9	85.1	192.1	329.1	1296.9

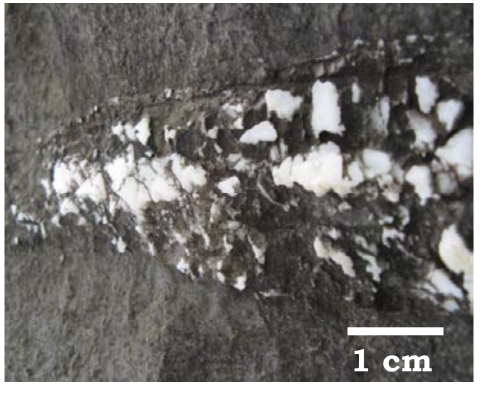

Ba: Data Points
(mg/kg):
<= 100
100.1 - 175
175.1 - 250
250.1 - 325
325.1 - 400
> 400
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers


Ba: Spatial Distribution
(mg/kg):
<= 100
100.1 - 175
175.1 - 250
250.1 - 325
325.1 - 400
> 400
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers

Ca Calcium

Calcium is the fifth most abundant element in the Earth's crust (Lide, 2005). It is common in sedimentary rocks, in the minerals calcite, dolomite and gypsum and is also present in many silicate minerals of igneous and metamorphic rocks. It occurs naturally in most soils, and can be lost through leaching, crop uptake and removal or by erosion. It is added to soils in the form of lime to increase their pH, to improve drainage and to provide plants with a source of Ca. Ca and its compounds can be found in a wide range of products including cement, alloys, crayons, insecticides, plastics and fertilizer. Ca is essential for living organisms and is the most common metal in many animals where it is mostly stored in bones and teeth.

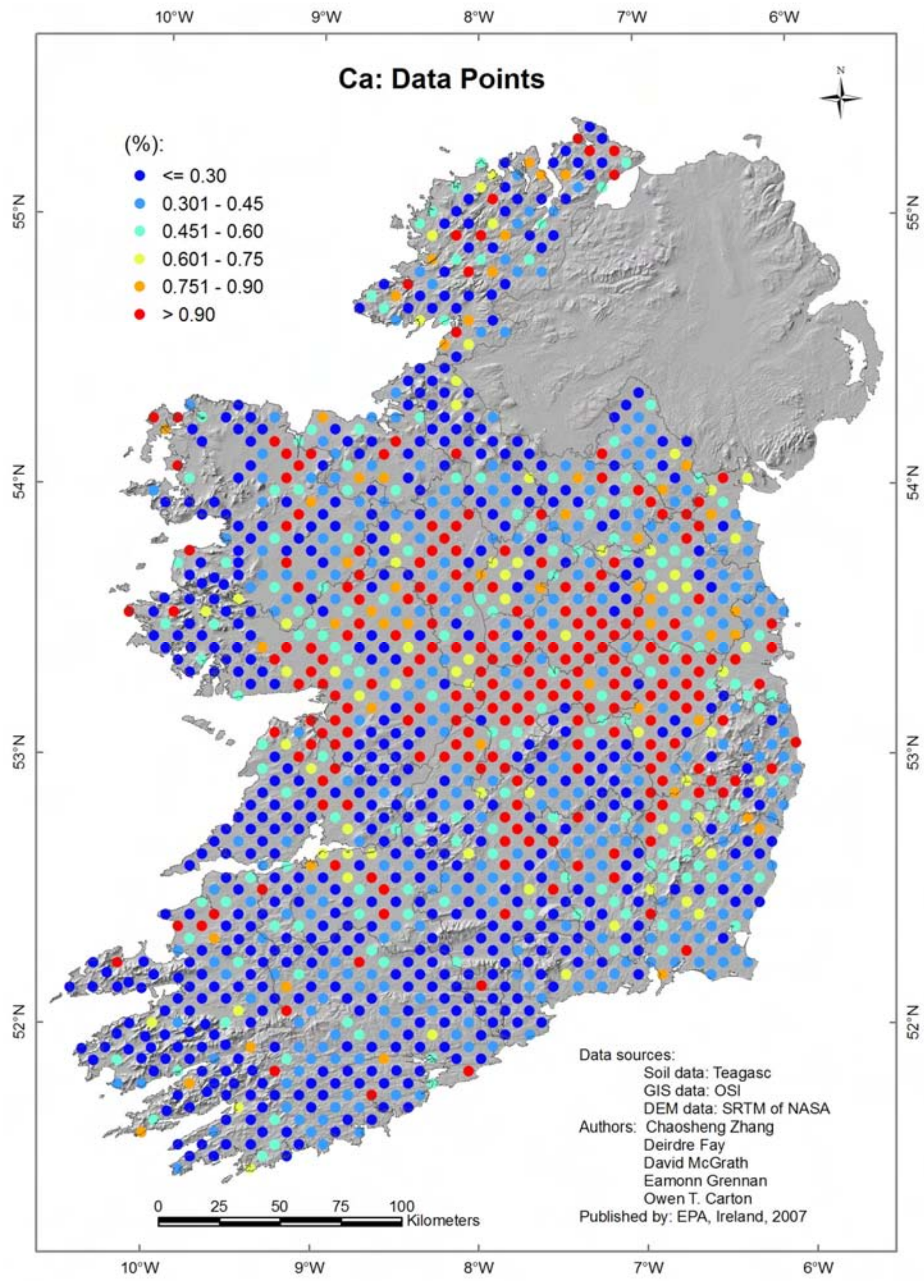
Ca levels above 0.45% in Irish soils are associated with limestone areas, as might be expected. The Ca concentrations were quite strongly correlated with the soil pH (r_{min} = 0.7) in the samples taken. As the Ca content decreases in soils, H^+ ions replace the Ca cations and the soil becomes more acid. Levels of Ca below 0.3% coincide most prevalently with the Old Red Sandstones in the South West and the Peat soils in Galway, Mayo and Roscommon.

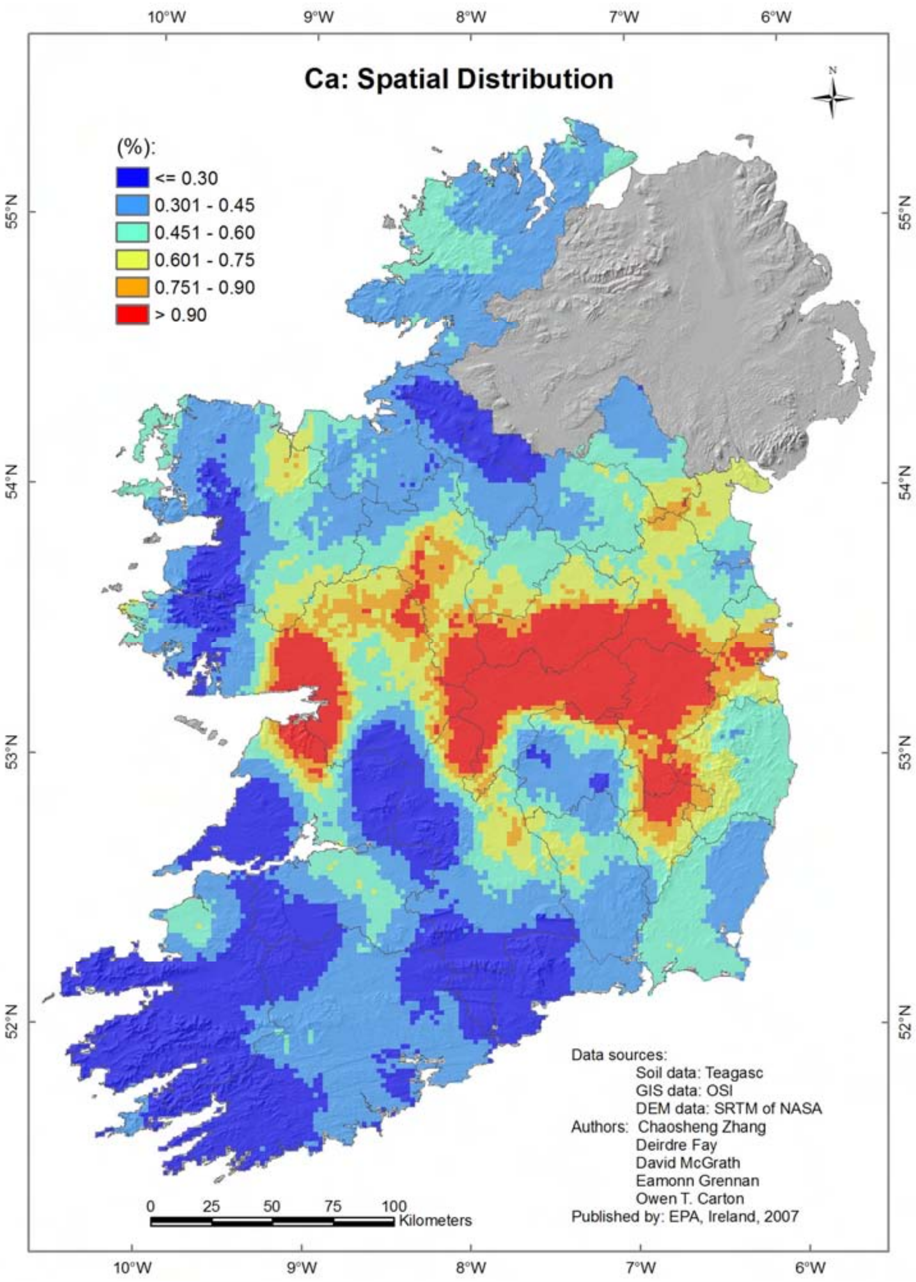


Calcite ($CaCO_3$) vein in a limestone rock in Co. Clare

Table showing the minimum and maximum and some of the most important percentiles for total Ca concentrations in %

	min	5%	25%	50%	75%	95%	max
all soils	0.03	0.10	0.23	0.36	0.61	2.59	26.63
mineral	0.03	0.12	0.24	0.37	0.58	2.19	26.63
organic	0.04	0.09	0.19	0.31	0.91	2.85	16.19


Ca: Data Points
(%):
<= 0.30
0.301 - 0.45
0.451 - 0.60
0.601 - 0.75
0.751 - 0.90
> 0.90
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers
10°W 9°W 8°W 7°W 6°W
55°N 54°N 53°N 52°N


Ca: Spatial Distribution
(%):
<= 0.30
0.301 - 0.45
0.451 - 0.60
0.601 - 0.75
0.751 - 0.90
> 0.90
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers
10°W 9°W 8°W 7°W 6°W
55°N 54°N 53°N 52°N

Cd Cadmium

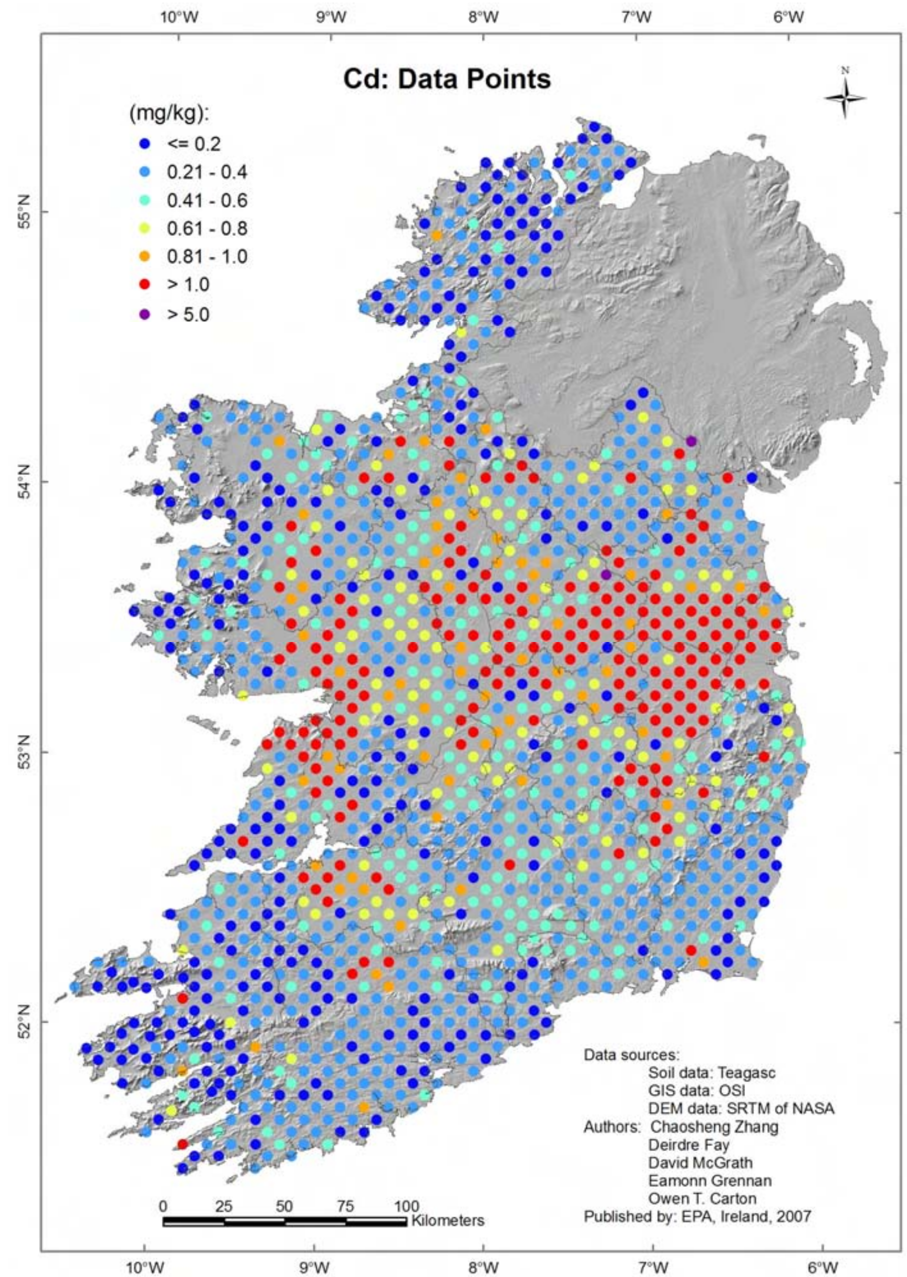
In the environment, Cadmium often occurs in association with Zn. Natural sources of Cd are rock weathering, volcanoes and forest fires. Industrial release of Cd occurs as a by-product from mining, smelting and the production of phosphate fertilizers. Cd and its compounds are used in Ni-Cd batteries, for pigments, plating and coating. Cd has no known biological role, but Cd and its compounds are toxic even at low concentrations, and can bio-accumulate in organisms and ecosystems. Uptake of the metal differs between plants. Soils with values in excess of 1 mg/kg Cd are prohibited from having sewage sludge spread on them by the provisions of the EU Sewage Sludge Directive (86/278/EEC).

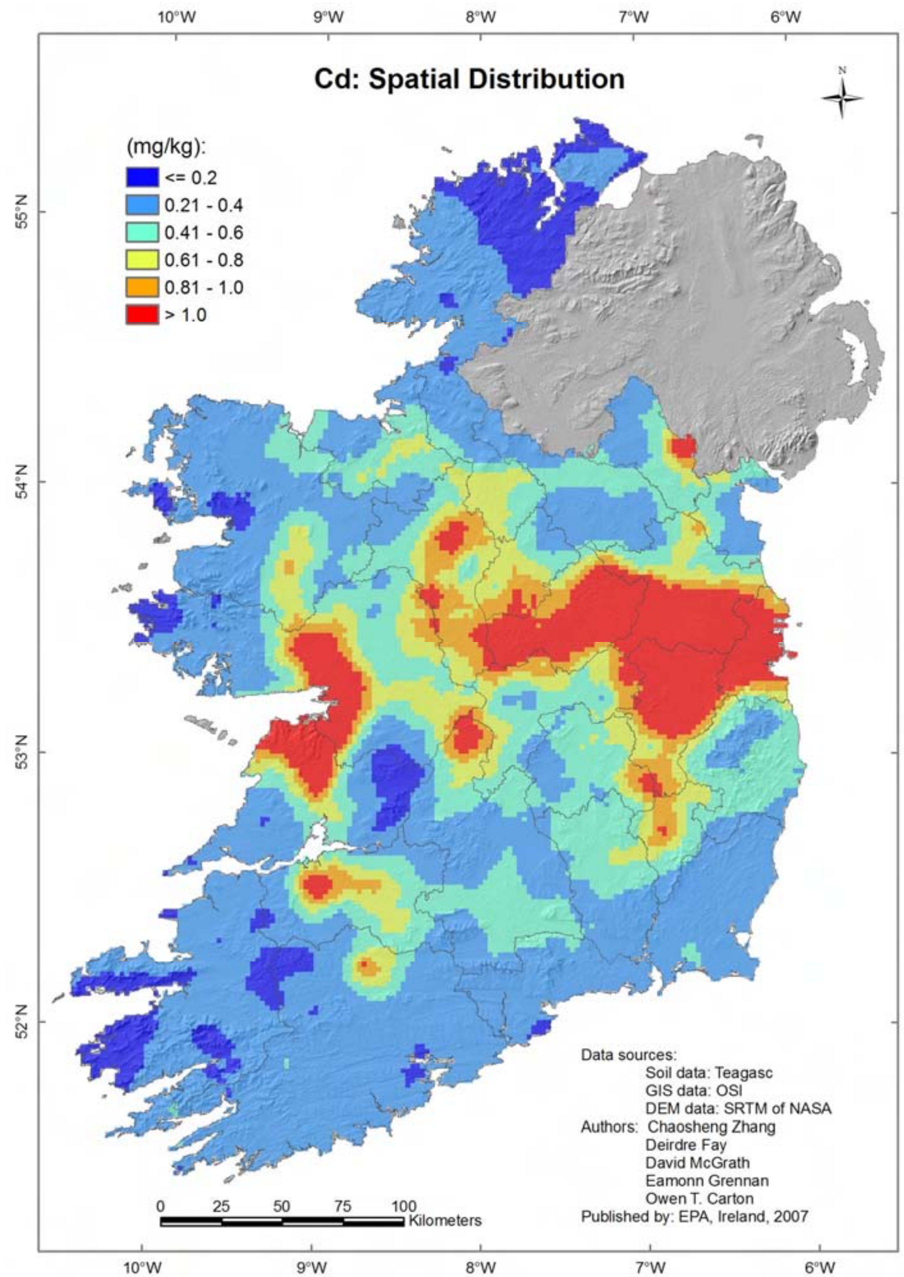
Background concentrations of 0.8 mg/kg were reported for Cd by Crommentuijn (1997) for unpolluted soils in the Netherlands. Soil Cd concentrations greater than 1mg/kg in Ireland frequently occur in soils derived from a belt of limestone shale stretching from North Clare to South West Limerick (McGrath, 1996). In North Clare, elevated Cd may be related to phosphate material of the Clare Shales. The levels of Cd above 1mg/kg in Dublin, Kildare, Meath, Westmeath, north Tipperary and Roscommon are attributed to underlying impure limestone geology in these areas. Similar high levels in counties Monaghan and Limerick are due to volcanic material in the soil. 15% of Irish soils exceed the EU threshold limit for Cd in soil of 1 mg/kg. It is believed that this is mostly due to naturally high background levels and only on rare occasions to human activities. The median values for Cd in Ireland are similar to the 0.33 mg/kg reported for Northern Ireland (Jordan *et al*. 2002).

Table showing the minimum and maximum and some of the most important percentiles for total Cd concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<0.02**	0.11	0.21	0.33	0.64	1.65	15.15
mineral	<0.02**	0.11	0.22	0.36	0.72	1.65	15.15
organic	0.05	0.10	0.19	0.29	0.53	1.59	6.92

**One sample analysed was below the detection limit of 0.02 mg/kg for Cd


Cd: Data Points
(mg/kg):
<= 0.2
0.21 - 0.4
0.41 - 0.6
0.61 - 0.8
0.81 - 1.0
> 1.0
> 5.0
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Cd: Spatial Distribution
(mg/kg):
<= 0.2
0.21 - 0.4
0.41 - 0.6
0.61 - 0.8
0.81 - 1.0
> 1.0
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

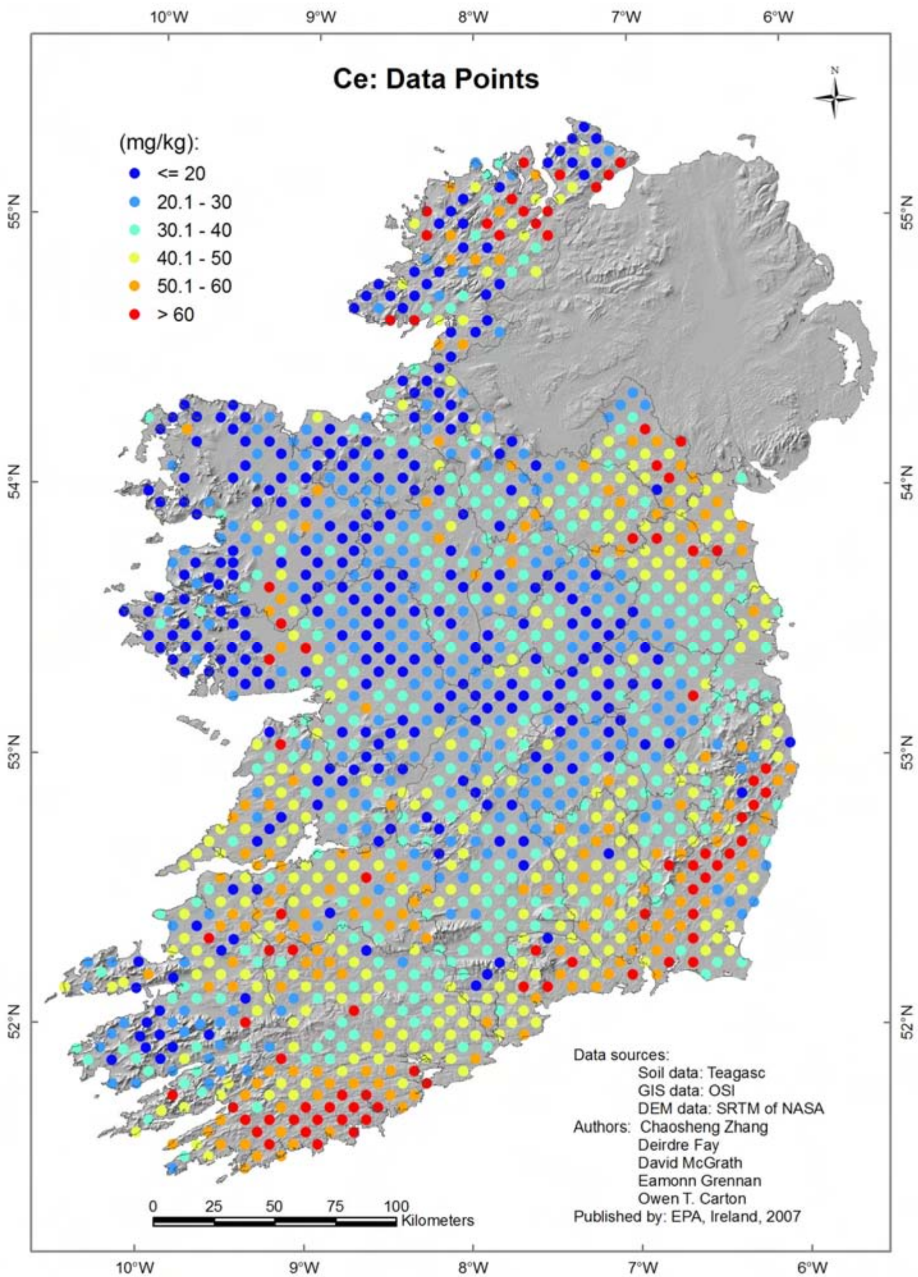
Ce Cerium

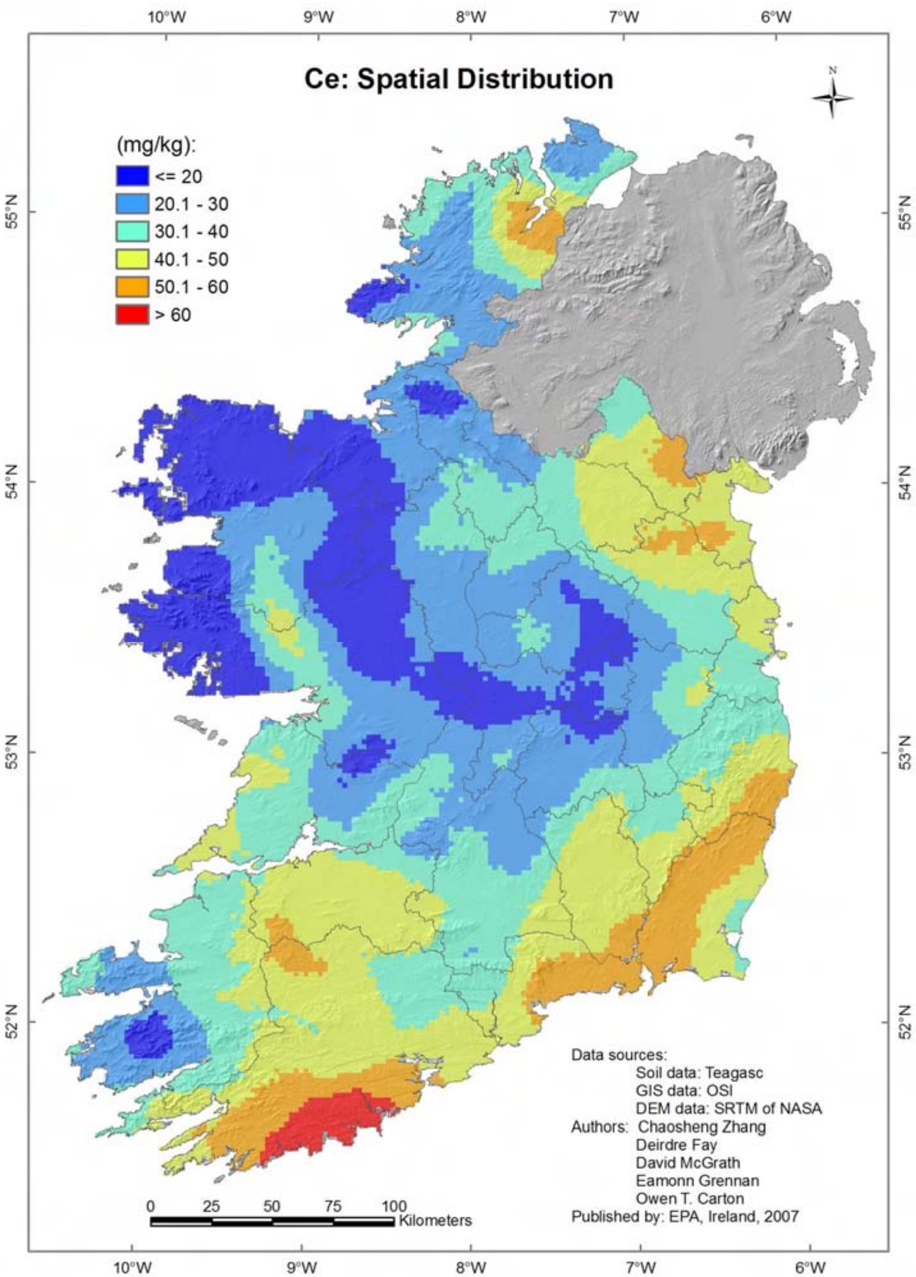
Cerium is the most abundant element of the rare metal group. Some of its uses are in metal alloys to make them heat resistant, glass and ceramic manufacture and as an additive to diesel fuel. It has no known biological role.

The distribution of Ce in Irish soils is very similar to La (r_{min} = 0.96), its neighbouring element on the periodic table of elements and an element with similar properties. They have a similar distribution to Al, with relatively high levels above 40mg/kg coincident with the greywackes in the North East and greywackes and rhyolites in the South East and with sandstone and shale in the South West. Similar levels in Donegal are coincident with Ca rich schists and coincide here with relatively high levels of Ba, Th and Sr. Lower levels of Ce, below 30mg/kg, are associated with Peat soils and soils underlain by limestone, the former most prevalently in Galway and Mayo.

Table showing the minimum and maximum and some of the most important percentiles for total Ce concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	0.60	1.90	22.30	348.00	46.60	62.30	136.40
mineral	3.70	20.10	30.40	39.50	49.10	64.10	124.60
organic	0.60	1.00	2.20	8.70	23.10	48.00	110.40


Ce: Data Points
(mg/kg):
<= 20
20.1 - 30
30.1 - 40
40.1 - 50
50.1 - 60
> 60
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Ce: Spatial Distribution
(mg/kg):
<= 20
20.1 - 30
30.1 - 40
40.1 - 50
50.1 - 60
> 60
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

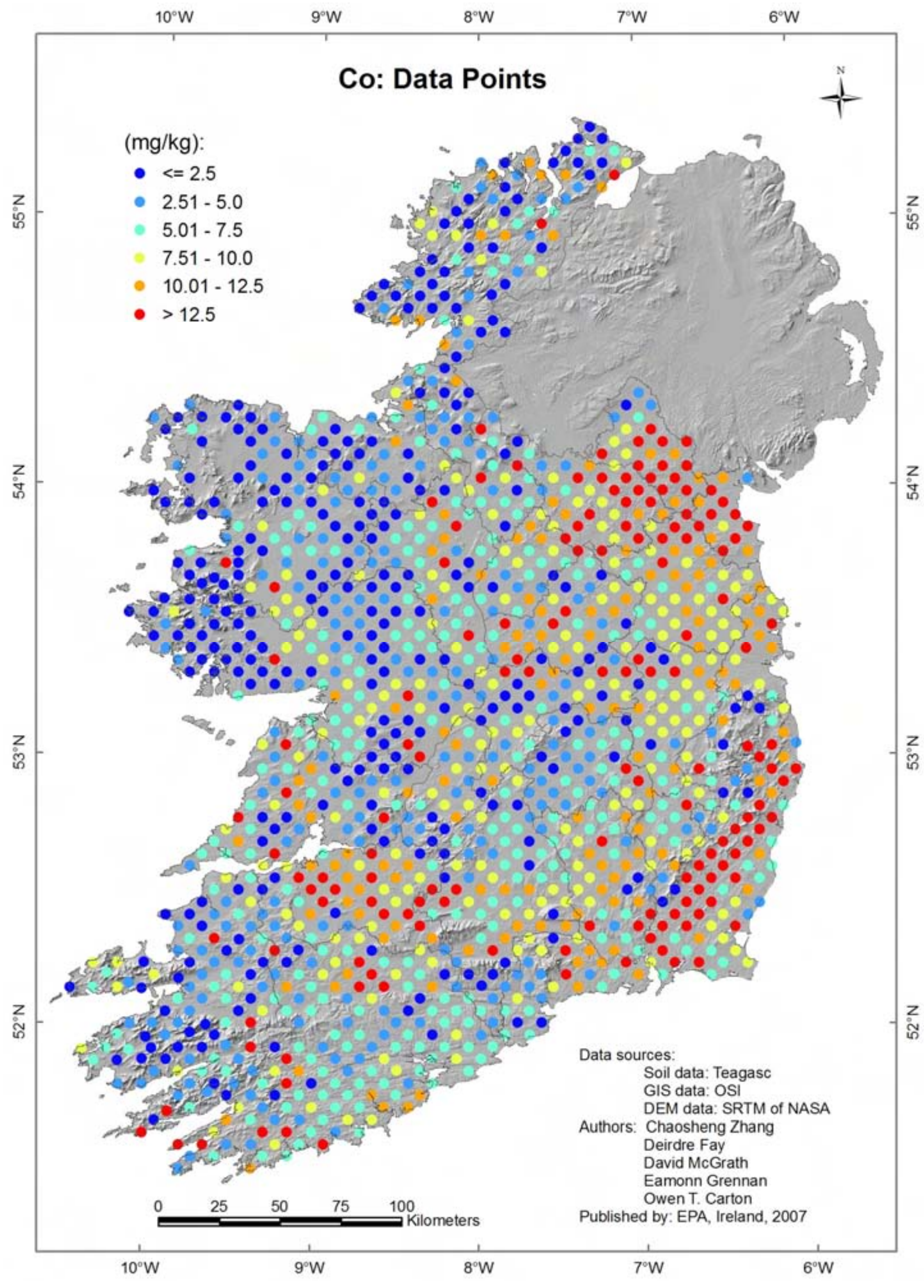
Co Cobalt

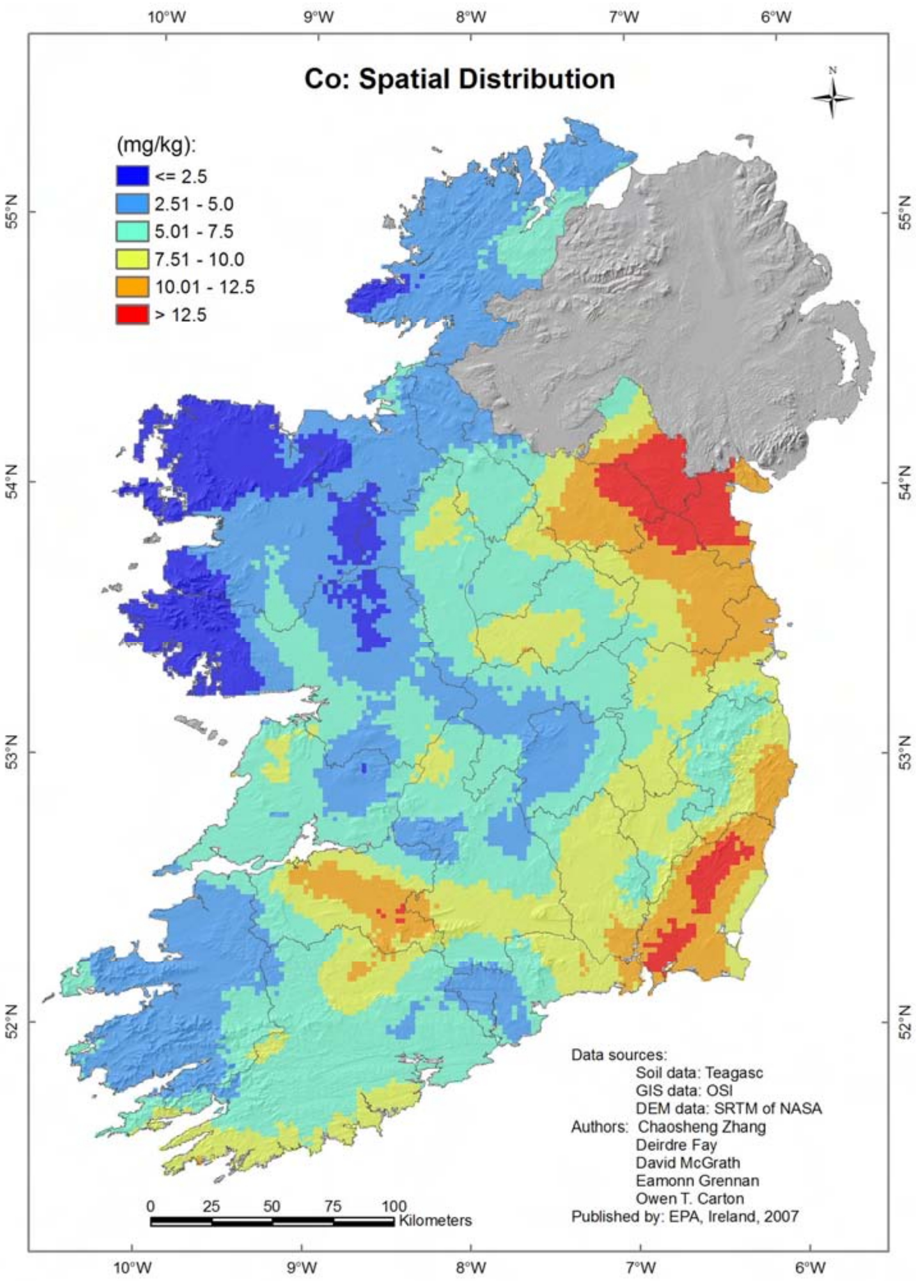
Cobalt is introduced into the environment through fossil fuel burning, seawater, volcanic eruptions and forest fires. Any industrial activity which uses Co or its derivatives will also be a potential source. The main industrial uses for Co are in paint driers, alloys, ground coats for enamels and coloured pigments. Radioactive isotopes of Co are also used in nuclear medicine and research. Co is a central component of vitamin B_{12} which is an essential part of all human and animal diets. Ruminant animals such as cows, sheep, goats and deer produce vitamin B_{12} from Co extracted from the plant matter in their diets. Soils low in Co can lead to vitamin B_{12} deficiency and higher disease risk in grazing animals.

Co concentrations are reported to vary between 0.5 and 3 mg/kg for sandy soils and 20-30 mg/kg for clay soils (Beeson *et al.*, 1965) and background concentrations of 9 mg/kg were reported for Co by Crommentuijn (1997) for unpolluted soils in the Netherlands. Levels of Co in Irish soils in the North East and South East above 10mg/kg are attributed to volcanic material in the greywackes, while volcanic material in East Limerick explains similar levels there. Co is often associated or co-precipitated with Ba, Pb, Zn, Fe and Mn. Many hill land soils with inherently low Co contents such as those found in Donegal, Mayo, Galway and Kerry, are further depleted in Co by podzolisation. During the podzolisation process Co is leached from the top soil and deposited deeper in the soil. These soils are often overlain by Peat soils used for rough grazing, where Co deficiency in livestock, particularly sheep, can be a problem. Levels of Co in limestone soils are very variable depending on the purity of the parent rock. Contents in shale soils range from low to quite high, depending on whether the shales are sandy or clayey.

Table showing the minimum and maximum and some of the most important percentiles for total Co concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	0.20	0.50	3.00	6.20	9.70	15.10	58.70
mineral	0.50	2.00	4.90	7.50	10.60	15.50	58.70
organic	0.20	0.30	0.50	1.30	3.40	11.90	33.20


Co: Data Points
(mg/kg):
<= 2.5
2.51 - 5.0
5.01 - 7.5
7.51 - 10.0
10.01 - 12.5
> 12.5
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Co: Spatial Distribution
(mg/kg):
<= 2.5
2.51 - 5.0
5.01 - 7.5
7.51 - 10.0
10.01 - 12.5
> 12.5
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

Cr Chromium

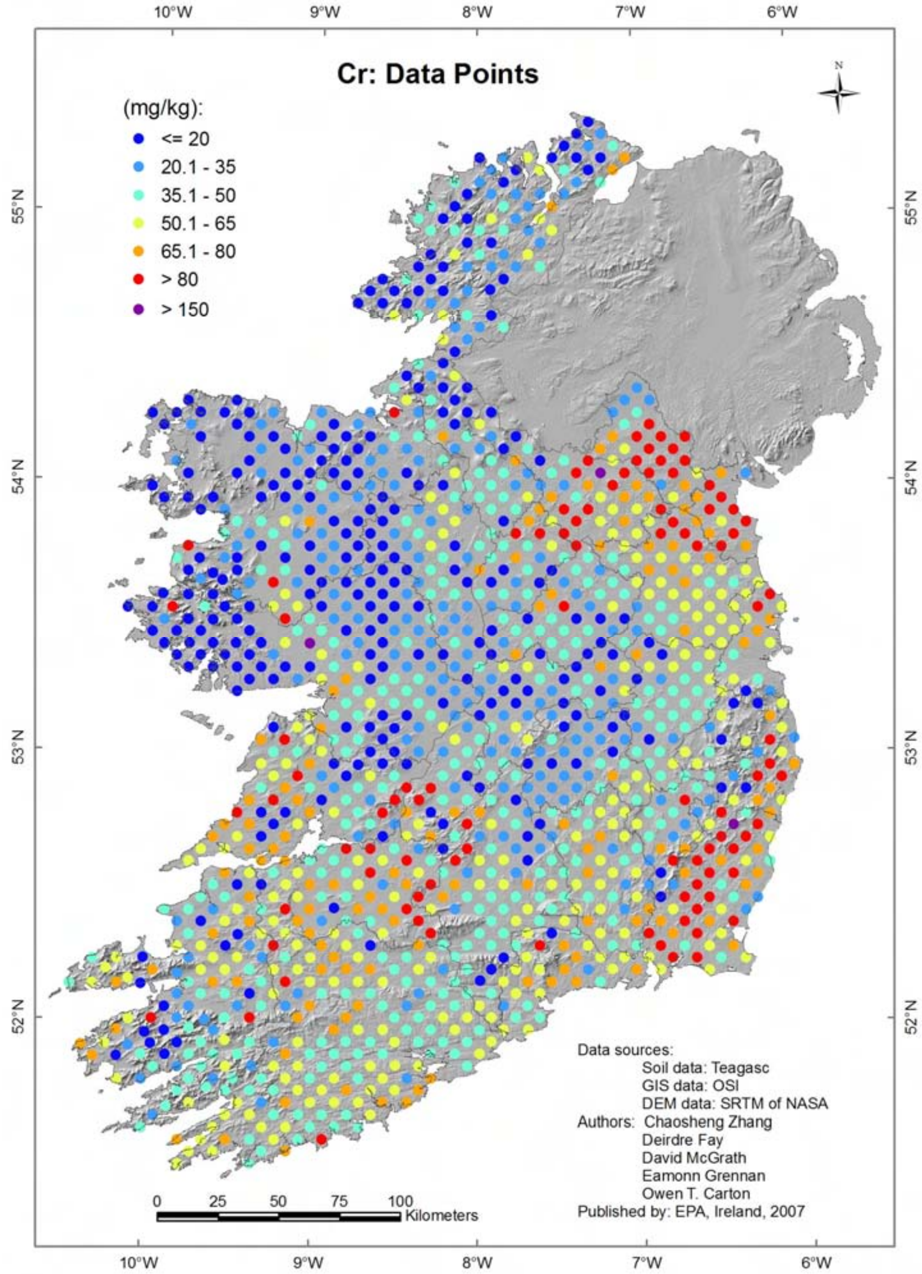
Chromium exists in different forms, of which Cr (III) and hexavelent Cr (VI) are the most common. Most naturally occurring Cr is Cr (III) and is found in rocks, soil, volcanic dust and living organisms. Cr (VI) is usually only present as a result of industrial activity. Cr is used to make alloys more corrosion resistant, as a colorant in dyes and paints, for chrome plating and in magnetic tape. The different forms of Cr have different effects on the environment and human health. Chromium metal and Cr (III) compounds are not usually considered health hazards and Cr (III) is an essential nutrient required by humans in very small amounts. Cr (VI) compounds are carcinogenic and can be toxic if orally ingested or inhaled.

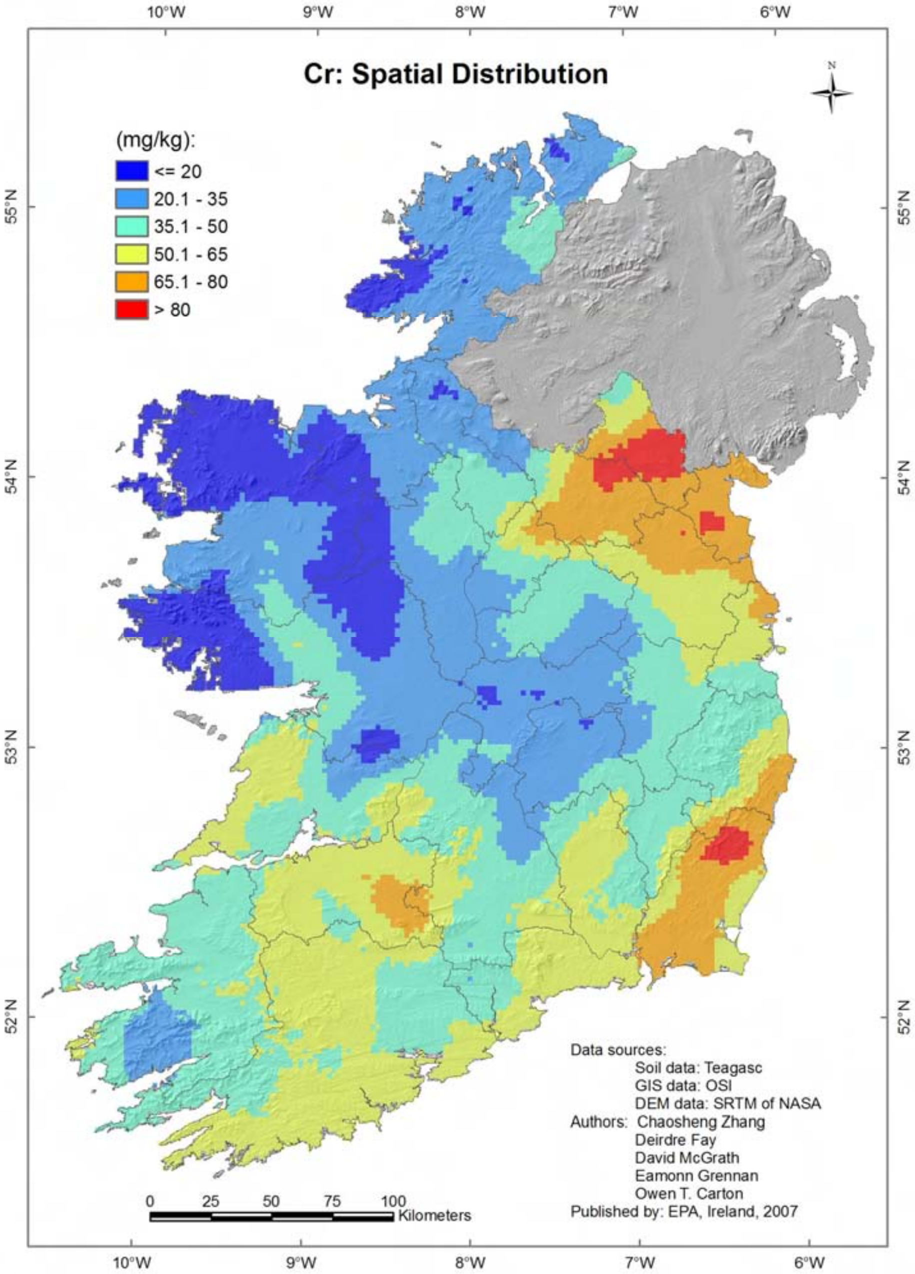
Background concentrations of 100 mg/kg were reported for Cr by Crommentuijn (1997) for unpolluted soils in the Netherlands. Levels of Cr higher than 50mg/kg in the North East of Ireland can be attributed to volcanic material in the greywackes, and in the South East to the presence of igneous rocks. Similar levels in eastern Limerick are due to the presence of the underlying basalts of Carboniferous age. Cr levels below 35mg/kg in Irish soils are mostly associated with areas with underlying limestone geology. Generally, the Cr concentrations measured in the Irish samples are considered to be innocuous, and the median value for Cr reported in this study for mineral soils is similar to those of Northern Ireland (46.5mg/kg, Jordan *et al.*, 2002), Scotland (41.4mg/kg, Paterson *et al.*, 2002) and England and Wales (39.3mg/kg, McGrath and Loveland, 1992).

Table showing the minimum and maximum and some of the most important percentiles for total Cr concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<2*	2.60	25.20	42.60	58.60	86.80	221.70
mineral	6.70	20.80	36.30	48.90	63.70	90.30	221.70
organic	<2*	<2*	3.00	9.80	26.10	53.50	114.30

**44 samples analysed were below the detection limit of 2 mg/kg for Cr


Cr: Data Points
(mg/kg):
<= 20
20.1 - 35
35.1 - 50
50.1 - 65
65.1 - 80
> 80
> 150
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Cr: Spatial Distribution
(mg/kg):
<= 20
20.1 - 35
35.1 - 50
50.1 - 65
65.1 - 80
> 80
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

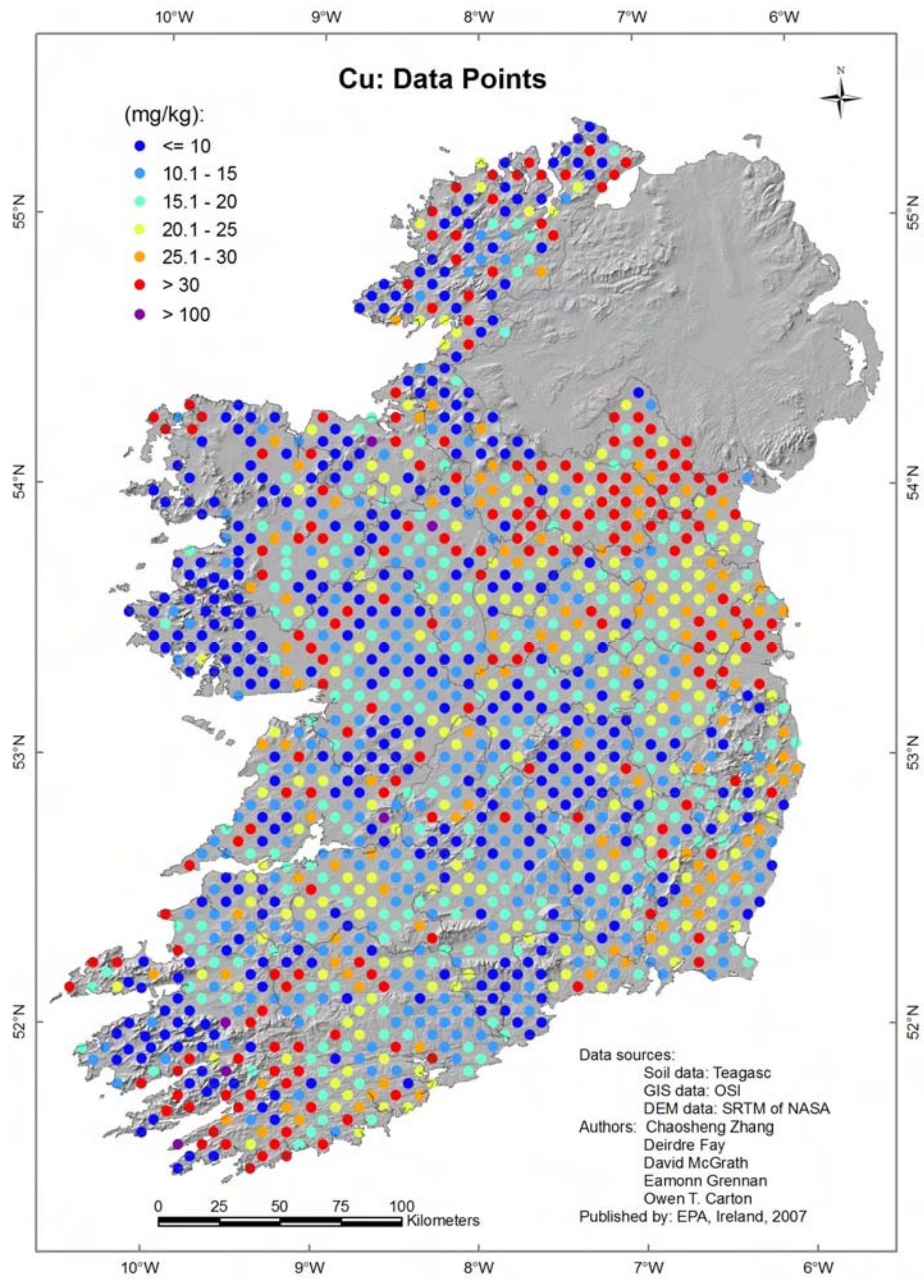
Cu Copper

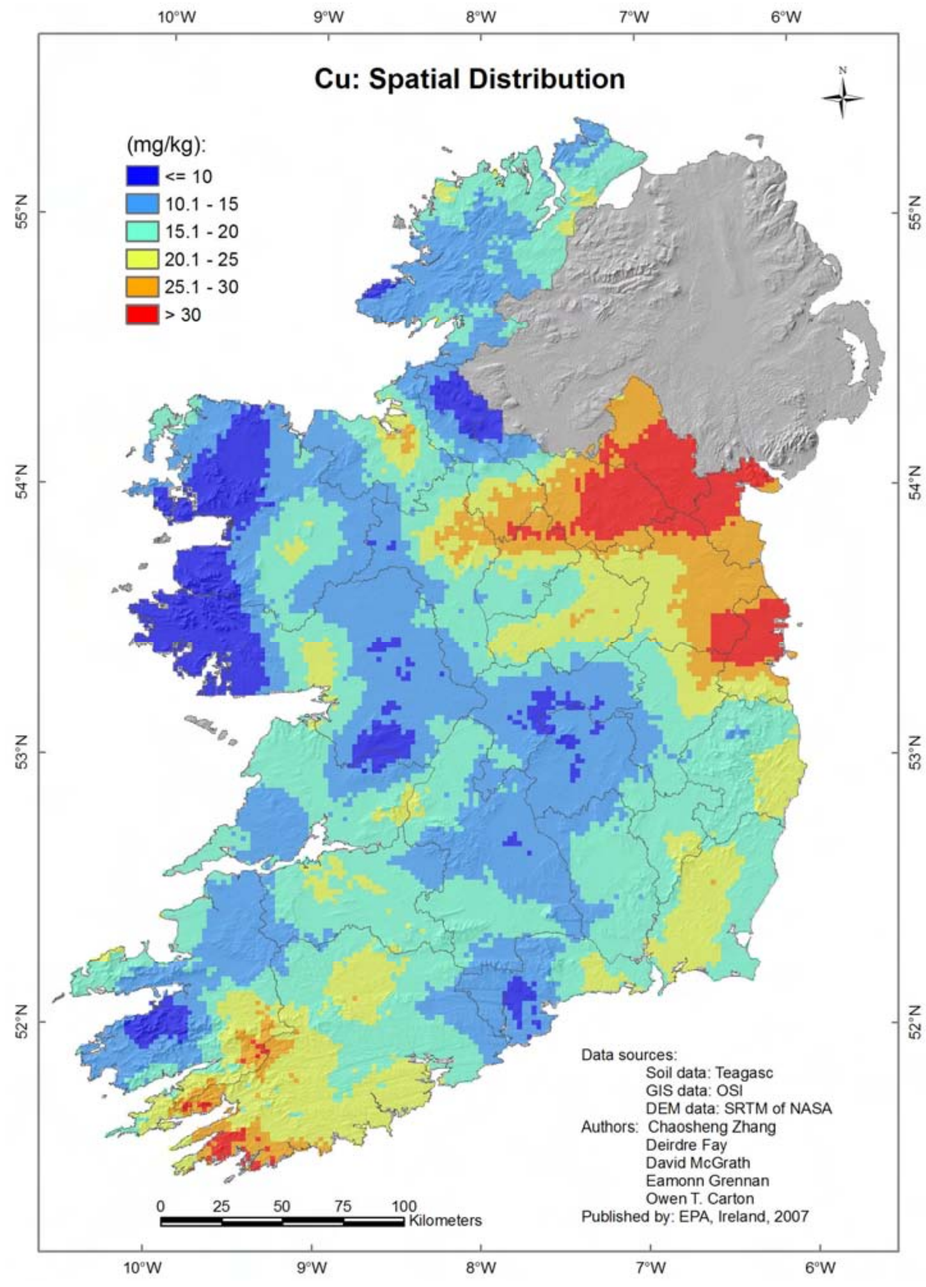
Copper occurs and spreads naturally in the environment, for example through the decay of vegetation, forest fires or sea spray. Activities such as mining, metal production, fossil fuel burning, phosphate fertilizer production and the spreading of sewage sludge and pig slurry introduce Cu into the environment. Cu and its compounds are used for electrical equipment, construction, alloys, coins, biostatic surfaces in hospitals, fungicides and fire extinguishers. Cu is an essential element for all plants and animals and is widely used in feed additives for farm animals. At high concentrations, Cu and all its compounds can be toxic, particularly for sheep and young calves. The sewage sludge Directive and national regulations set a limit value of 50 mg/kg DM of soil for Cu on soils receiving sewage sludge amendments (EEC, 1986).

Uncontaminated soils will usually contain between 6 and 60 mg/kg Cu (Kabata-Pendias and Pendias, 1985). Levels above 30mg/kg in soils in the North East of Ireland and Dublin are attributed to volcanic material in the greywackes. Cu has been mined in Ireland for over 4,500 years. Cu deposits in Ireland were always of the (localised) vein-type, but the areas surrounding the deposits and the soils in the general area may well have elevated Cu contents. Very slightly elevated Cu values are present over broad areas in east Wicklow and along the Waterford coastline. Localized high Cu concentrations exceeding 100mg/kg are coincident with historic mining areas in west Cork. Leaching and podzolisation leads to Cu depletion in soils. Organic-rich soils generally have a very low Cu status and benefit from the addition of Cu as fertiliser. Cu levels below 10mg/kg are clearly evident in areas with Peat soils in Ireland. The median value for Cu reported in this study for mineral soils, is similar to that reported in the geochemical soil survey of England and Wales (18.1 mg/kg, McGrath and Loveland, 1992).

Table showing the minimum and maximum and some of the most important percentiles for total Cu concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	1.10	3.50	9.50	16.20	24.70	45.90	272.40
mineral	1.80	6.40	12.50	18.60	26.20	46.10	272.40
organic	1.10	2.30	3.90	6.70	13.00	41.10	147.30


Cu: Data Points
(mg/kg):
<= 10
10.1 - 15
15.1 - 20
20.1 - 25
25.1 - 30
> 30
> 100
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100
Kilometers


Cu: Spatial Distribution
(mg/kg):
<= 10
10.1 - 15
15.1 - 20
20.1 - 25
25.1 - 30
> 30
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100
Kilometers

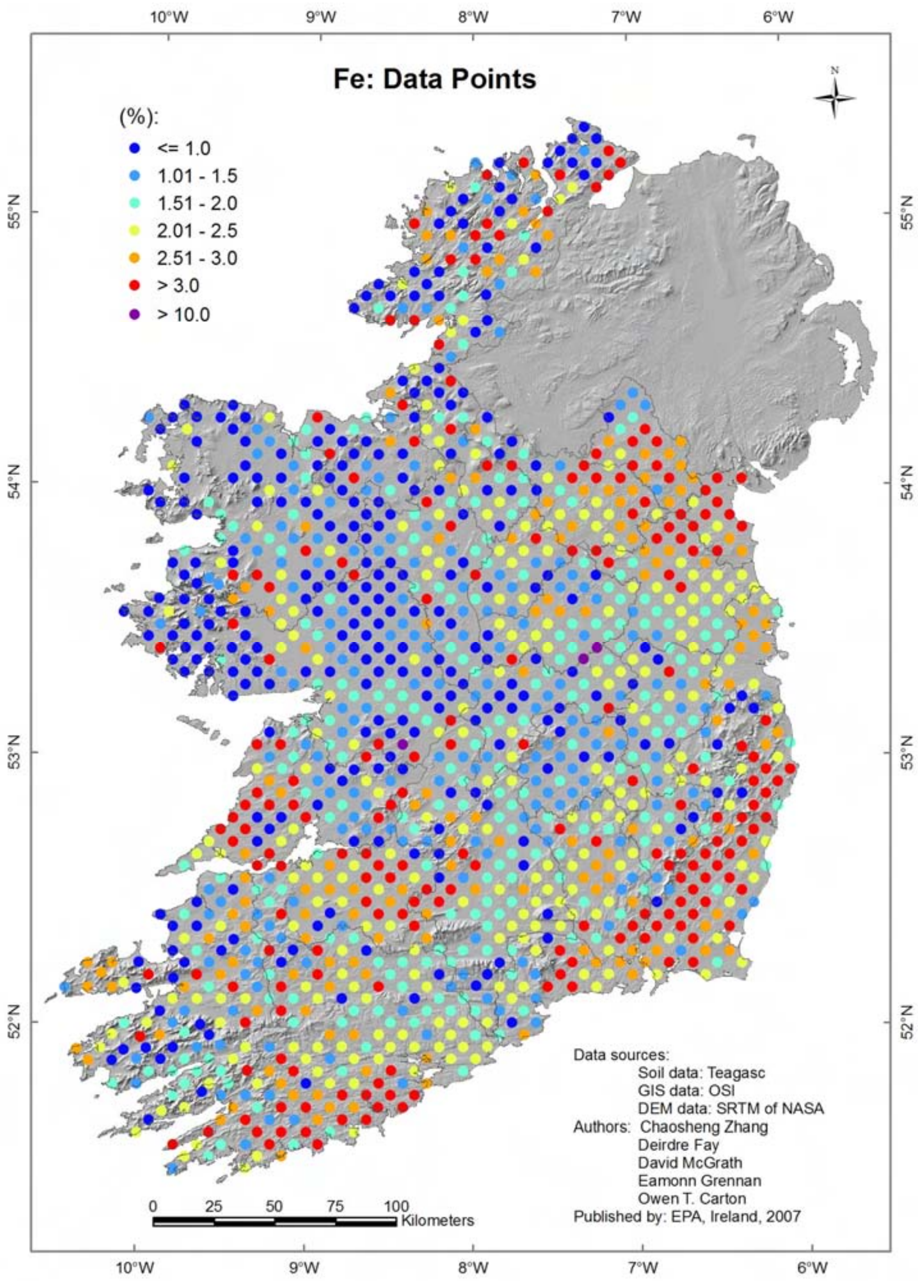
Fe Iron

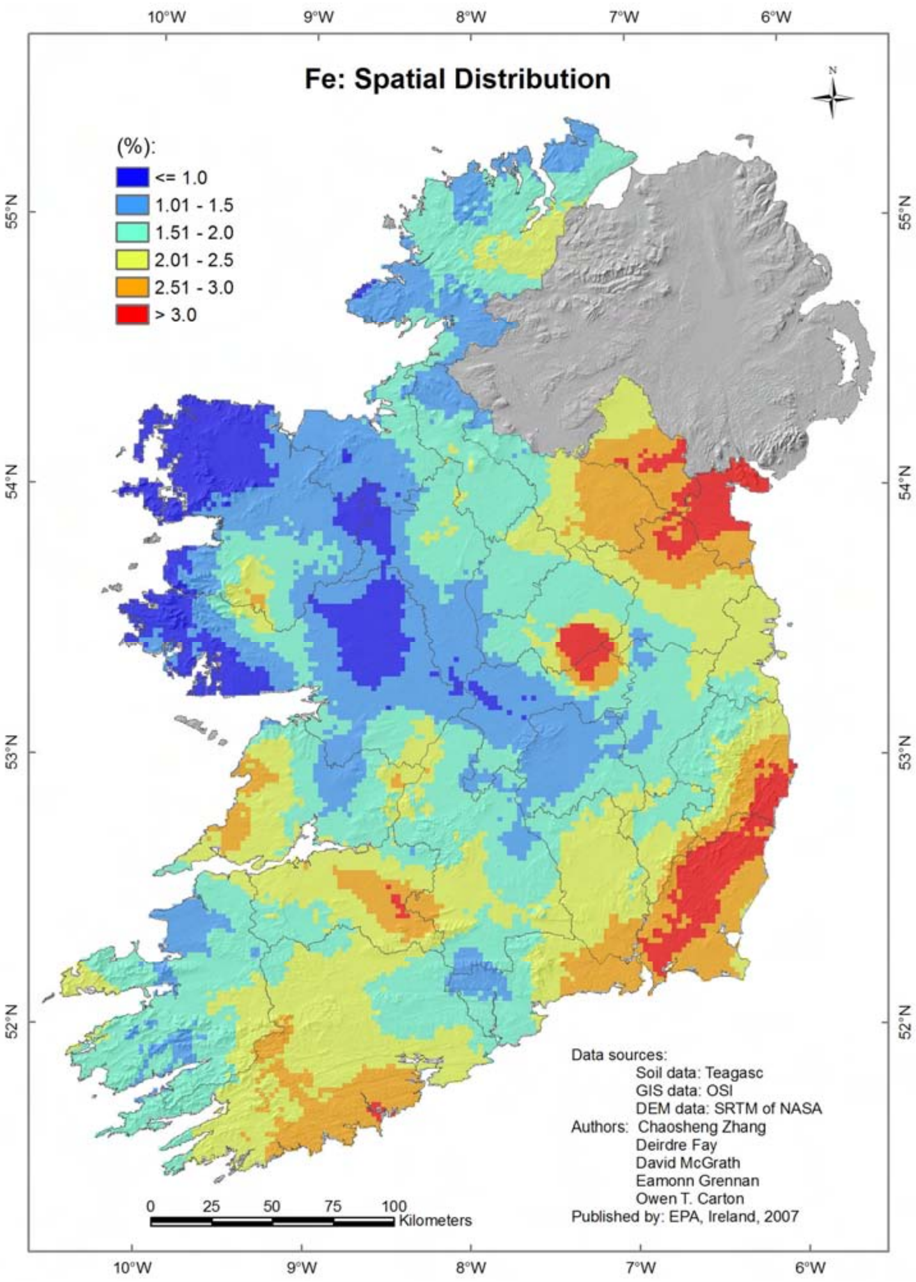
Iron is the second most abundant metal and fourth most abundant element in the earth's crust of which it makes up more than 5% (Lide, 2005). Fe is the most commonly used metal. Its production constitutes 95% of all metal production. It is most commonly used in its alloys, for example: cast iron, wrought iron and steel. It is a durable and at the same time relatively inexpensive metal. It is an essential element for all known organisms. Although excessive Fe is toxic to humans, Fe-deficiency is much more common and results in anaemia. Excess Fe intake can lower Cu and Zn absorption by animals.

The median Fe concentration reported for soils by Murad and Fischer (1988) is 3%. In Ireland, levels of Fe above 3% are mostly found in soils overlying the greywackes in the North East and the South East. Igneous rocks in the South East and the fine sandstones and shales in western Cork and Kerry explain Fe levels above 2.5%. Similar levels in County Limerick are the result of chemical deposition. Waters draining sandstone dominated areas precipitate dissolved Fe in a similar way to Mn when they encounter the more alkaline soils on the flanks and floors of the valleys. Since Fe (and Mn) hydroxides and hydrated oxides often act as scavengers for other metal oxides and hydroxides, Co, Ni and Zn are commonly co-precipitated. Although the correlation coefficients for these elements with Fe are not all high, high levels of Co (>7.5mg/kg), Ni (>30mg/kg) and Zn (>80mg/kg) can be observed in this same area in the west of county Limerick. The Brown Earths which occur in Galway and Mayo are quite Fe-rich with levels above 2%. Two areas of localized, as yet unexplained relatively high Fe concentrations exceeding 10% are visible on the Offaly/Westmeath border on the data point map. Levels of Fe below 1.5% are found in Roscommon and parts of Mayo, Galway and Clare which are underlain by pure limestone.

Table showing the minimum and maximum and some of the most important percentiles for total Fe concentrations in %

	min	5%	25%	50%	75%	95%	max
all soils	0.05	0.20	1.14	1.87	2.59	3.80	19.43
mineral	0.23	0.79	1.51	2.07	2.73	3.80	5.54
organic	0.05	0.10	0.23	0.77	1.63	3.56	19.43


Fe: Data Points
(%):
<= 1.0
1.01 - 1.5
1.51 - 2.0
2.01 - 2.5
2.51 - 3.0
> 3.0
> 10.0
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Fe: Spatial Distribution
(%):
<= 1.0
1.01 - 1.5
1.51 - 2.0
2.01 - 2.5
2.51 - 3.0
> 3.0
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

Ga Gallium

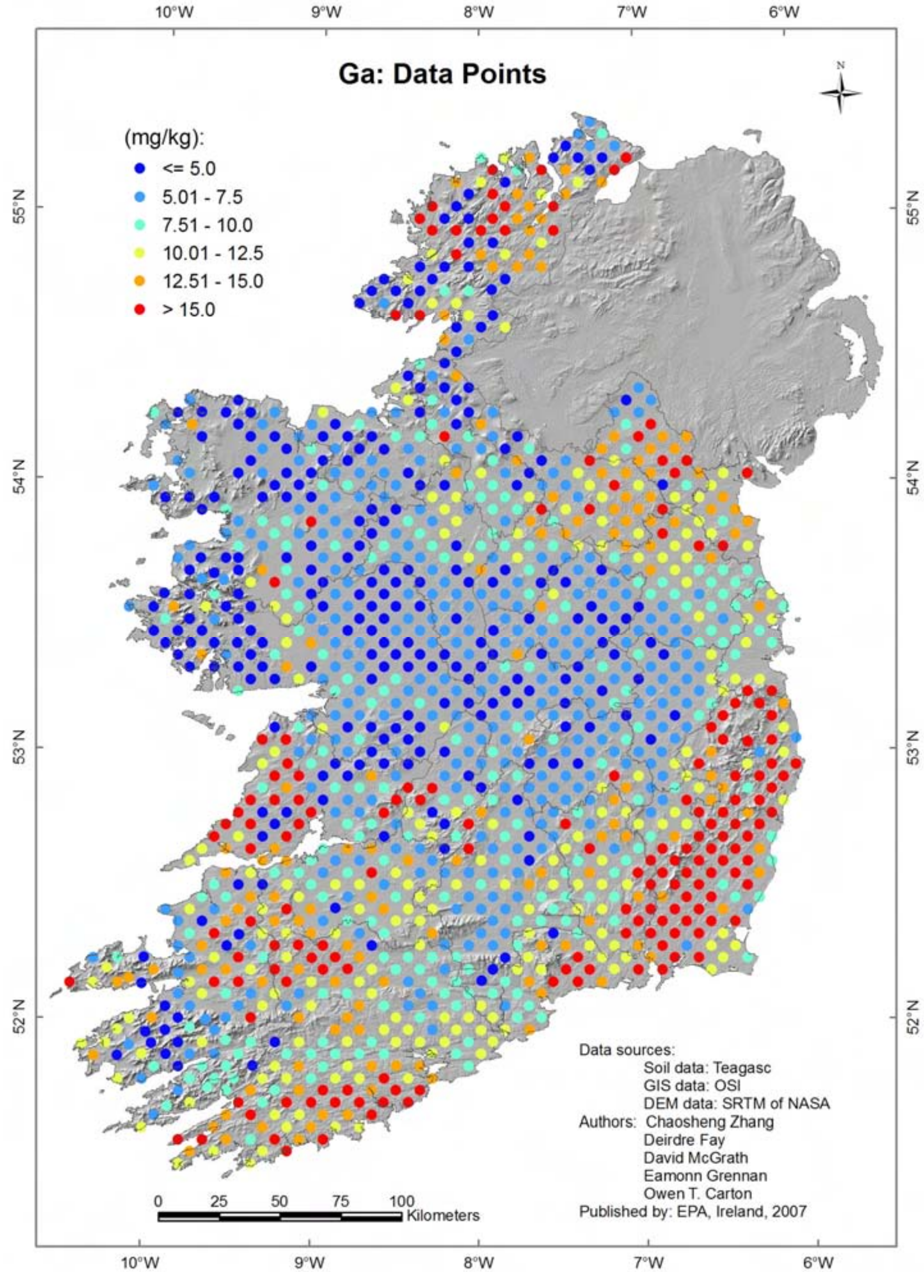
Gallium occurs in trace amounts in bauxite, coal and Zn ores and also in most soils. It is used in low melting alloys, plutonium pits in nuclear weapons, analogue integrated circuits, diodes and brilliant mirrors. Ga is present in small amounts in the human body but has no known biological role. Though Ga is not considered toxic, little is known about it.

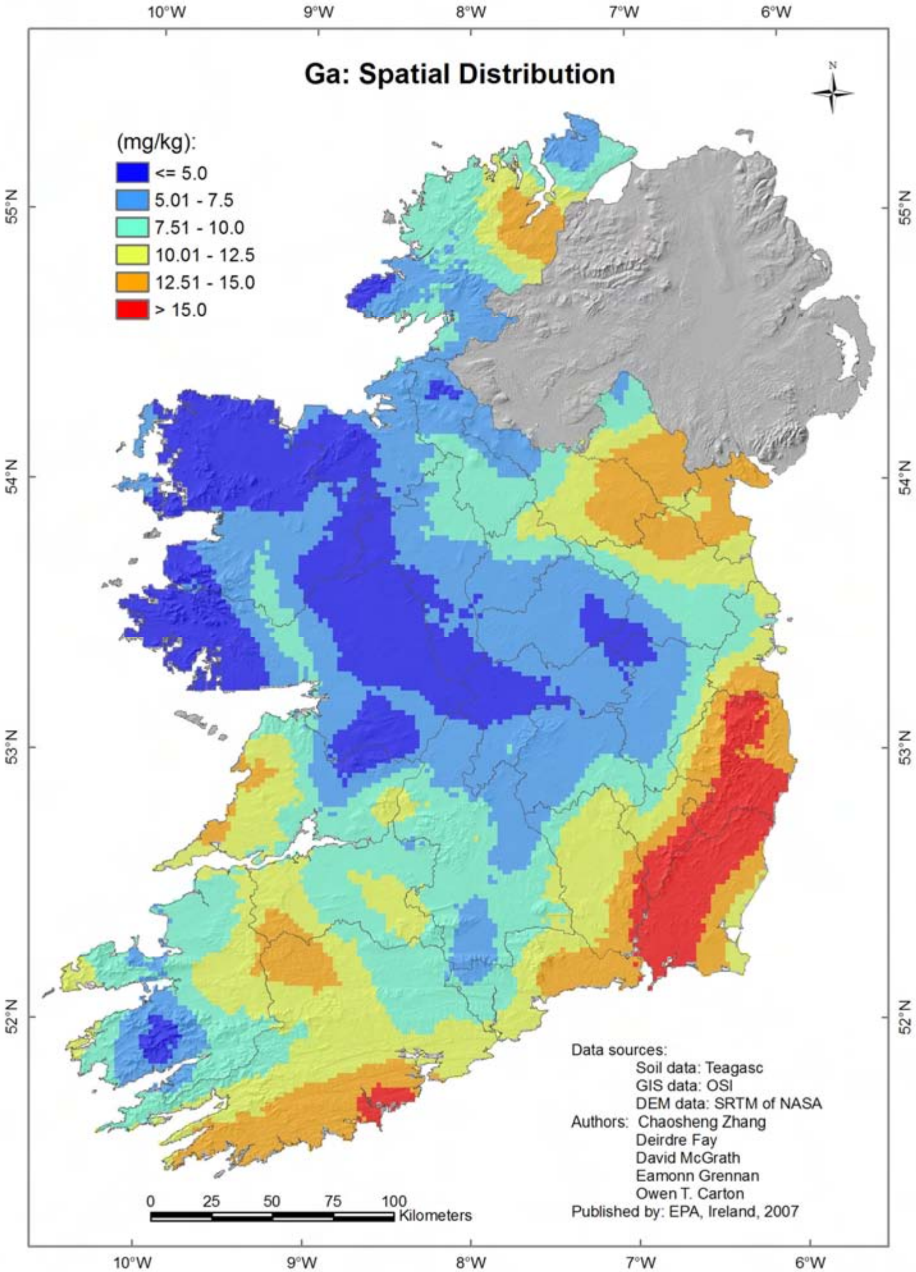
The Ga values measured correlate strongly with those measured for Al (r_{min} = 0.96) and the distribution pattern for the two elements is very similar. Levels of Ga above 10 mg/kg are coincident with the greywackes in the North East and greywackes and rhyolites in the South East as well as with sandstones and shales in Cork, Kerry, Limerick and Clare and Ca-rich schists in Donegal. Levels below 7.5 mg/kg are associated with Peats, Lithosols and Podzols in mountain and hill areas and Grey Brown Podzolics and Peats on limestone bedrock.

Table showing the minimum and maximum and some of the most important percentiles for total Ga concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<0.1*	0.60	5.66	8.46	12.47	17.76	25.16
mineral	0.98	5.15	7.03	9.89	13.24	18.18	25.16
organic	<0.1*	0.17	0.72	2.52	5.85	12.99	21.51

**10 samples analysed were below the detection limit of 0.1 mg/kg for Ga


Ga: Data Points
(mg/kg):
<= 5.0
5.01 - 7.5
7.51 - 10.0
10.01 - 12.5
12.51 - 15.0
> 15.0
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers


Ga: Spatial Distribution
(mg/kg):
<= 5.0
5.01 - 7.5
7.51 - 10.0
10.01 - 12.5
12.51 - 15.0
> 15.0
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers

Ge Germanium

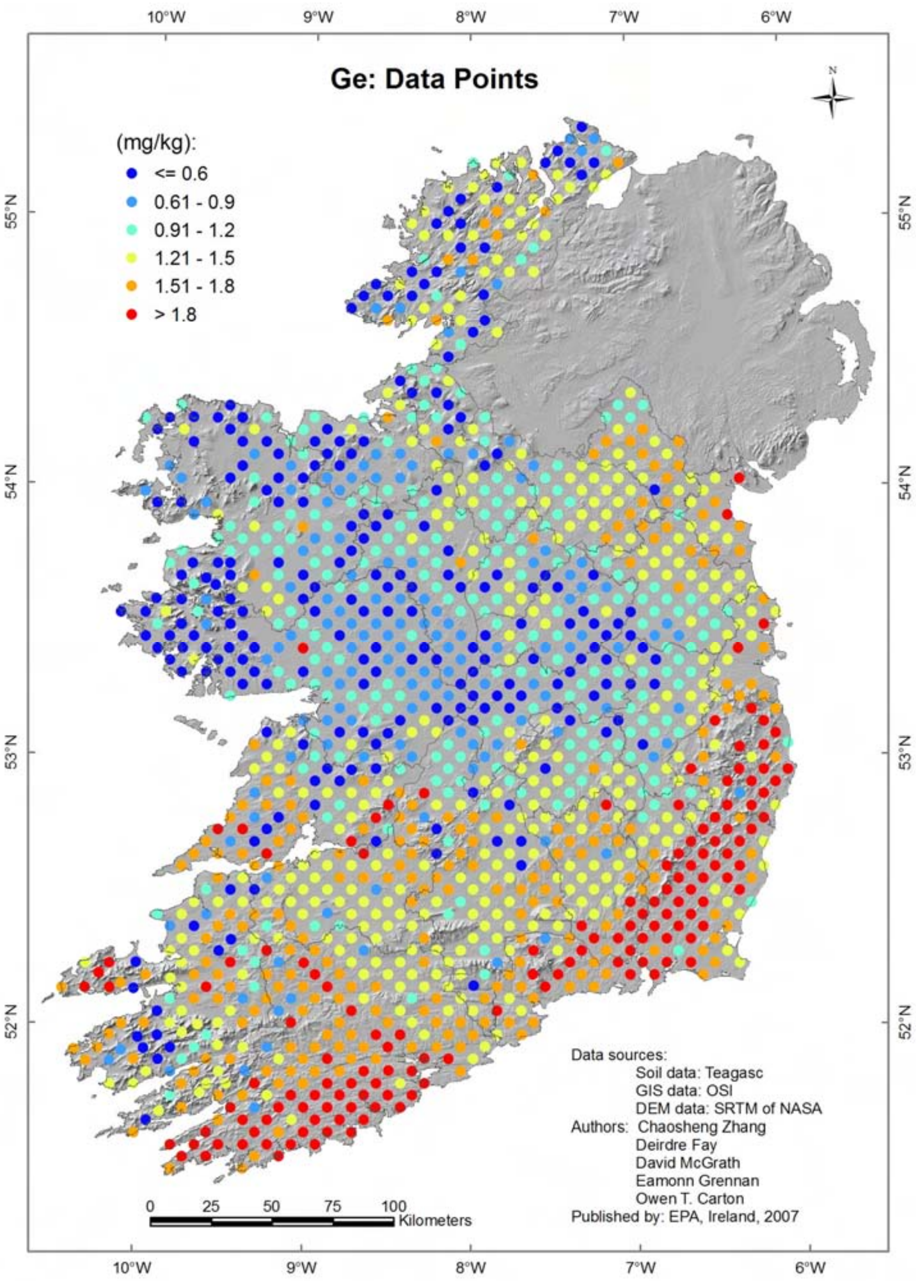
Germanium, similar to Ga, is usually widely dispersed in minerals and thus difficult to isolate. It is found in coal and in Zn ores and in trace amounts in most soils. It is used in wide-angle and microscope objective lenses, infra-red optical material and some alloys. Ge has been thought to have health benefits, but these have never been proven. Inhalation of Ge gases can be detrimental to health. Ge is a heavy metal and is thought to have a negative impact on certain bacteria and on aquatic ecosystems.

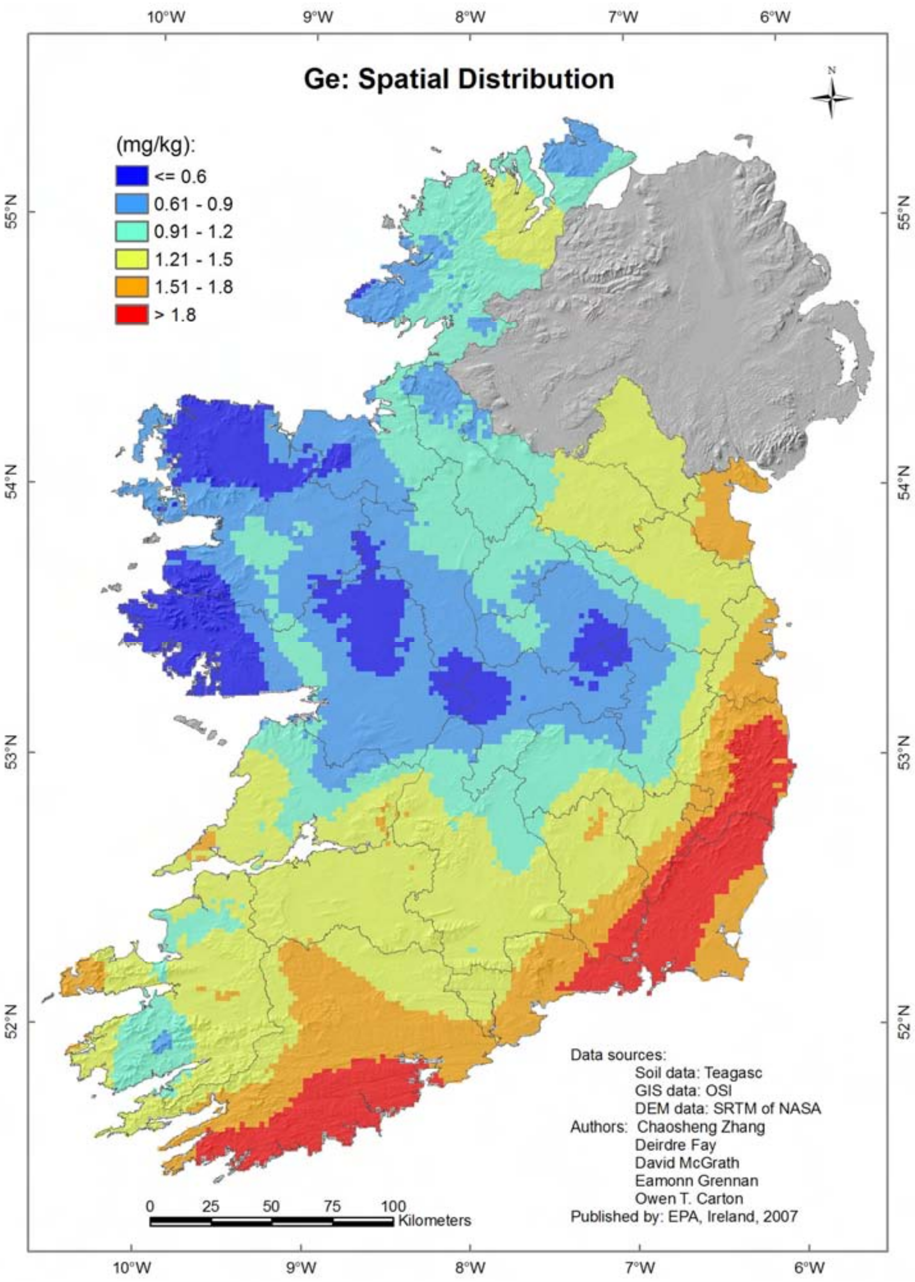
The distribution of Ge in Irish soils follows a similar pattern to a large group of elements including Al, with levels above 1.5mg/kg coincident with sandstones and shales, although with relatively higher concentrations in the South West (>1.8mg/kg) and lower in the North East (<1.8mg/kg). Levels of Ge below 0.9 mg/kg are coincident with Grey Brown Podzolics in Offaly, Roscommon and Galway, and with Peats, Podzols and Lithosols in hill, mountain and coastal areas in the West of Ireland.

Table showing the minimum and maximum and some of the most important percentiles for total Ge concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<0.1**	<0.1**	0.86	1.26	1.55	2.00	2.58
mineral	<0.1**	0.80	1.14	1.39	1.63	2.06	2.58
organic	<0.1**	0.05	0.12	0.33	0.77	1.42	2.09

**72 samples analysed were below the detection limit of 0.2 mg/kg for Ge


Ge: Data Points
(mg/kg):
<= 0.6
0.61 - 0.9
0.91 - 1.2
1.21 - 1.5
1.51 - 1.8
> 1.8
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Ge: Spatial Distribution
(mg/kg):
<= 0.6
0.61 - 0.9
0.91 - 1.2
1.21 - 1.5
1.51 - 1.8
> 1.8
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

Hg Mercury

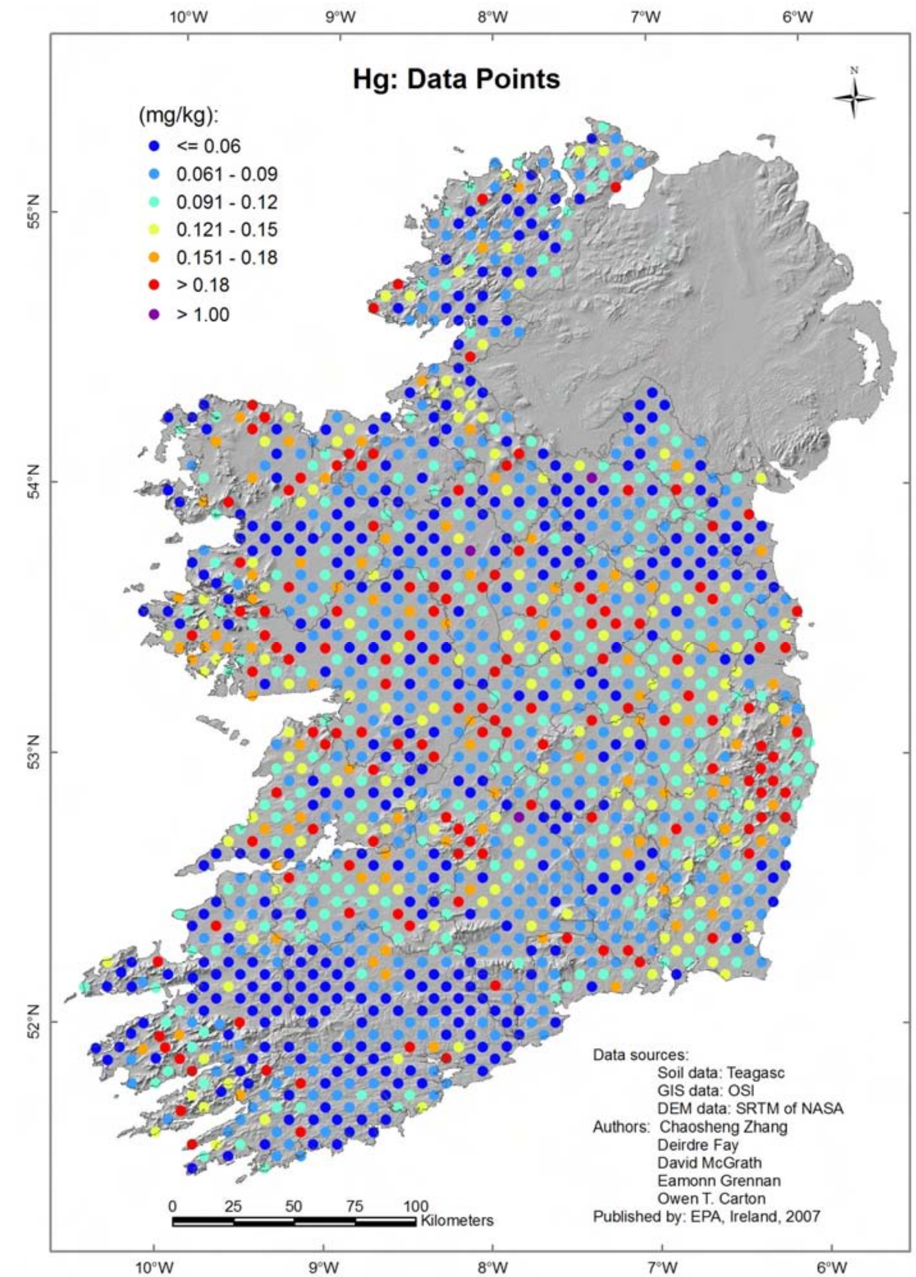
Mercury occurs naturally in the environment as Hg salts, metal or organic compounds. Although it does enter the environment naturally through weathering processes, most Hg is introduced through the burning of fossil fuels, mining and smelting and through the disposal of waste containing Hg. It has been and sometimes still is used in thermometers, dental fillings, disinfectants, barometers, diffusion pumps and fluorescent lamps. Hg has no known biological role but is widespread in most food chains. Hg and most of its compounds are highly toxic. It accumulates in fish tissue as methyl mercury. The upper limit for the concentration of Hg in soil under the EU Sewage Sludge Directive is 1 mg/kg DM in a representative sample (EEC, 1986).

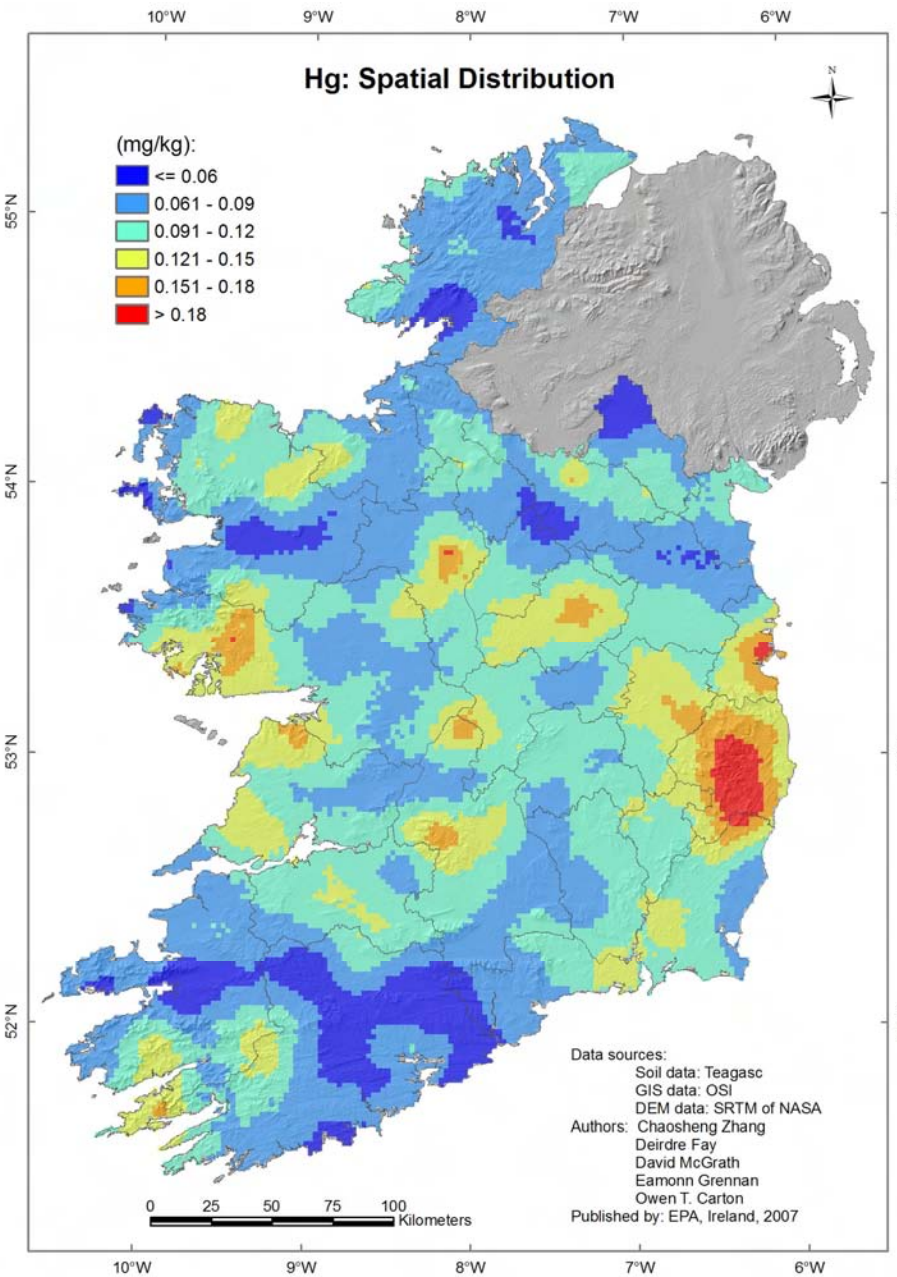
Background concentrations of 0.3 mg/kg were reported for Hg by Crommentuijn (1997) for unpolluted soils in the Netherlands. According to expert opinion, Hg concentrations in Irish soils below 0.2 mg/kg can be considered background concentration and above 0.4 mg/kg should be considered significantly elevated. Levels above 0.15mg/kg in soils in Dublin and Wicklow are attributed to an anthropogenic effect (urban and historic mining). Hg has been shown to be associated with some of the Zn-Pb deposits present throughout the midlands and with the sulphide deposits in Wicklow. Slightly elevated levels of Hg (>0.12mg/kg) were observed associated with Peat soils. The majority of soils (90%) analysed in this study had Hg concentrations lower than 0.2mg/kg. Three extreme values greater than 1mg/kg, visible on the point map, were observed in this study.

Table showing the minimum and maximum and some of the most important percentiles for total Hg concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<0.02**	0.02	0.06	0.09	0.13	0.24	3.45
mineral	<0.02**	0.02	0.05	0.08	0.10	0.19	3.45
organic	<0.02**	0.03	0.10	0.14	0.19	0.30	2.55

**11 samples analysed were below the detection limit of 0.02 mg/kg for Hg


Hg: Data Points
(mg/kg):
<= 0.06
0.061 - 0.09
0.091 - 0.12
0.121 - 0.15
0.151 - 0.18
> 0.18
> 1.00
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers


Hg: Spatial Distribution
(mg/kg):
<= 0.06
0.061 - 0.09
0.091 - 0.12
0.121 - 0.15
0.151 - 0.18
> 0.18
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers

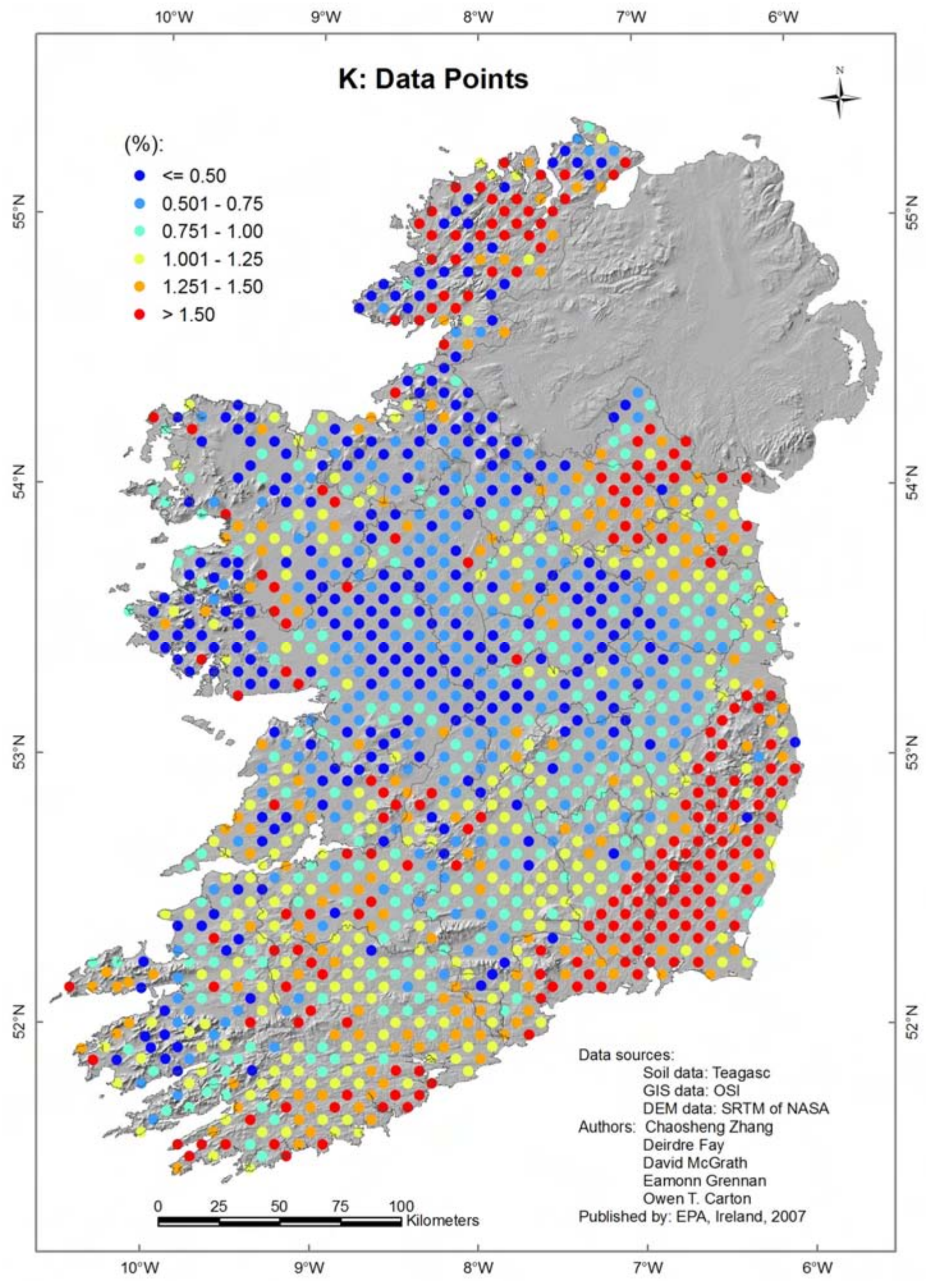
K *Total* Potassium

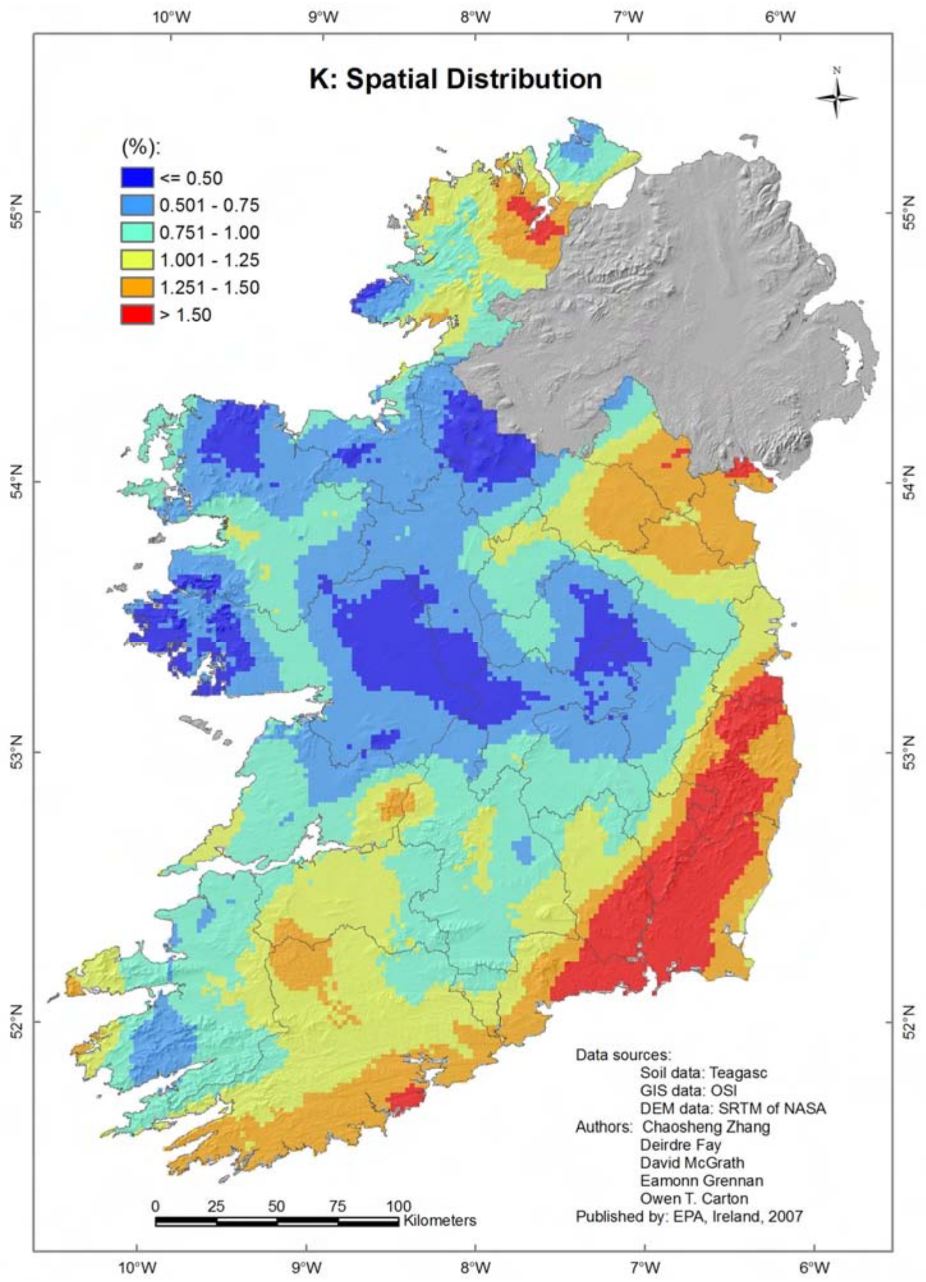
Potassium is a major element and the eighth most abundant in the earth's crust (Lide, 2005). It occurs in many minerals and salts and due to its solubility is readily available in sea water. The main source of K is potash. K and its compounds have many uses including fertilizer, gunpowder, glass manufacture, detergents, dyes, photographic film, fireworks and baking powder. K is an essential macronutrient for both animals and plants. It regulates fluid and electrolyte balances and assists muscle contractions in animals. K-deficiency in plants leads to stunted growth and reduced yield while excessive water soluble K in soil will damage germinating seeds and reduce crop quality.

The *total* K content of mineral soils usually ranges from 0.04% to 3% (Helmke and Sparks, 1996). The *total* K concentrations measured in this study seemed higher than expected, but this is due to the use of hydrofluoric acid (HF) in the digestion procedure for the samples, which dissolved silicate minerals including the K-rich feldspar and mica. These are among the principal constituents of granites, schists, greywackes, sandstones, and the clay minerals. Levels above 1% in Donegal are attributed to the feldspars in the local schist and granite. Similar levels in the North and South East are associated with fine feldspars in the greywackes, shales and granites and in southern Cork. They are probably due to the micas in the underlying shales and siltstones. Levels of K below 0.5% are coincident with soils on limestone bedrock.

Table showing the minimum and maximum and some of the most important percentiles for *total* K concentrations in %

	min	5%	25%	50%	75%	95%	max
all soils	0.02	0.08	0.59	0.98	1.33	1.85	2.64
mineral	0.10	0.50	0.81	1.11	1.42	1.90	2.64
organic	0.02	0.05	0.09	0.26	0.67	1.33	2.39


K: Data Points
(%):
<= 0.50
0.501 - 0.75
0.751 - 1.00
1.001 - 1.25
1.251 - 1.50
> 1.50
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


K: Spatial Distribution
(%):
<= 0.50
0.501 - 0.75
0.751 - 1.00
1.001 - 1.25
1.251 - 1.50
> 1.50
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

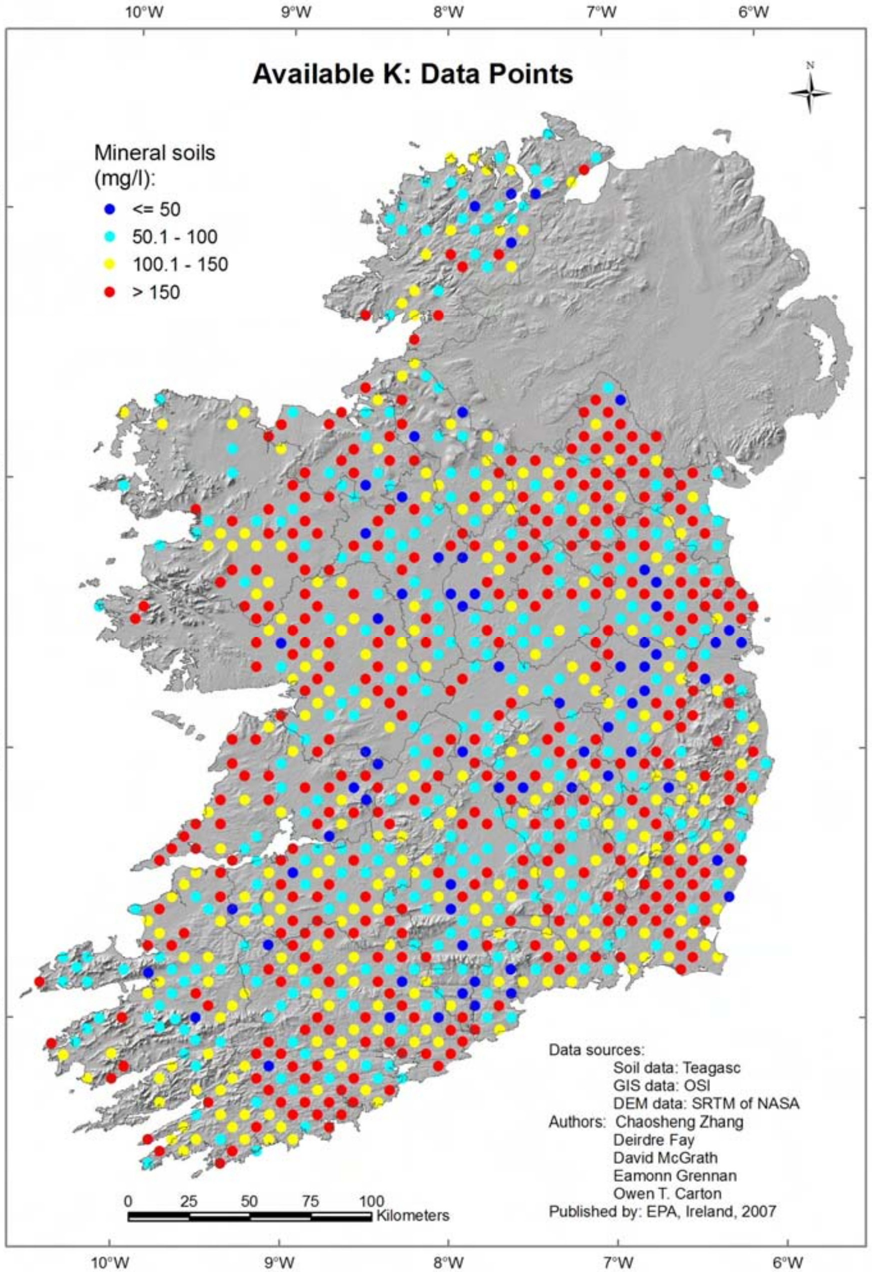
K *Available* Potassium

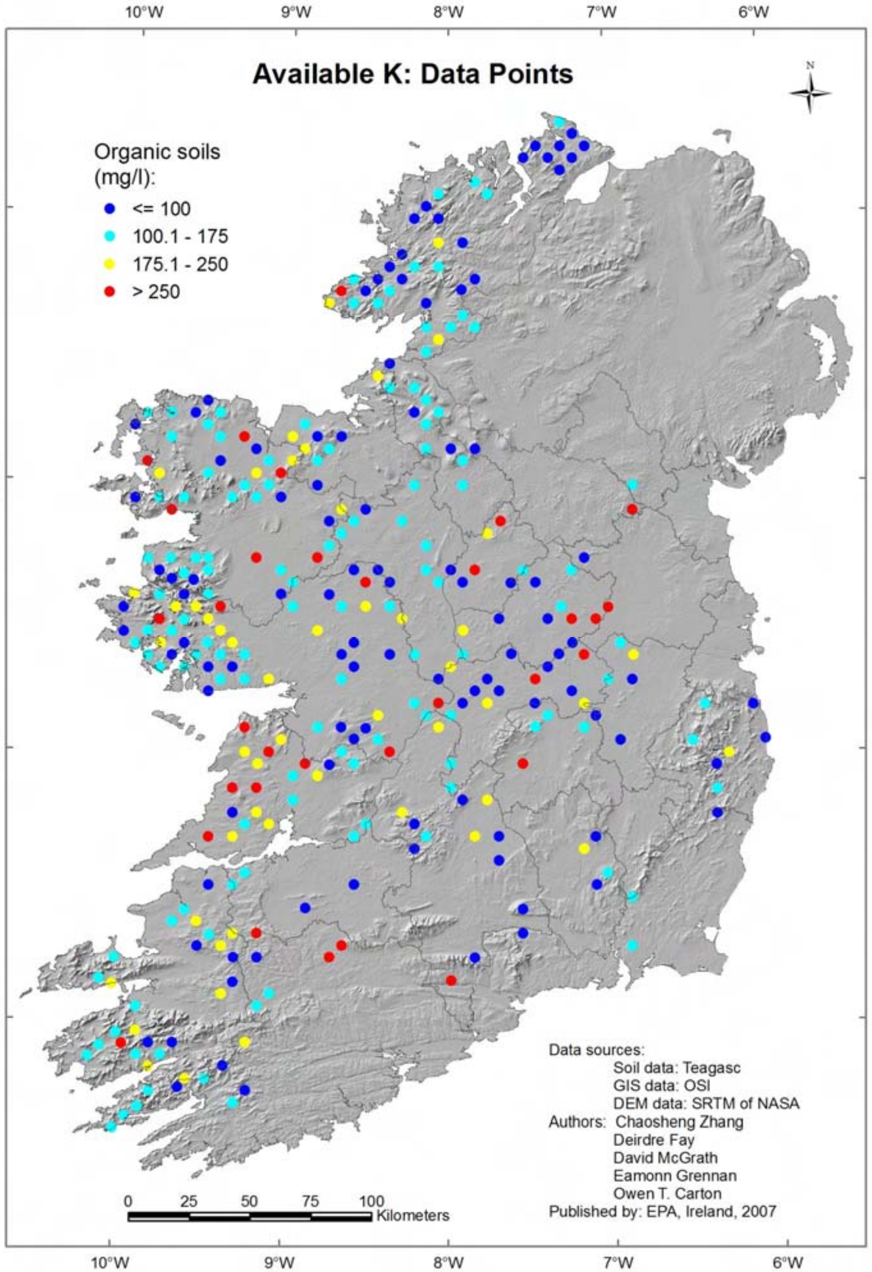
See text for *total* Potassium on pg 52

The spatial coherence for the *available* K, similar to that of *available* P, was insufficient for a spatial distribution map to be generated, therefore only data point maps are presented here. The maps for *available* K are shown separately for the mineral and the organic soils. Local soil management practices, including fertilizer application, influence the availability of K strongly, which explains this lack of coherence.

Table showing the minimum and maximum and some of the most important percentiles for *available* K concentrations in mg/l

	min	5%	25%	50%	75%	95%	max
all soils	4.66	45.52	82.51	124.01	181.95	312.77	949.23
mineral	20.62	45.12	81.21	125.44	183.57	311.76	949.23
organic	4.66	49.27	87.33	119.84	177.14	317.19	535.93


Available K: Data Points
Mineral soils
(mg/l):
<= 50
50.1 - 100
100.1 - 150
> 150
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100
Kilometers


Available K: Data Points
Organic soils
(mg/l):
<= 100
100.1 - 175
175.1 - 250
> 250
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100
Kilometers

La Lanthanum

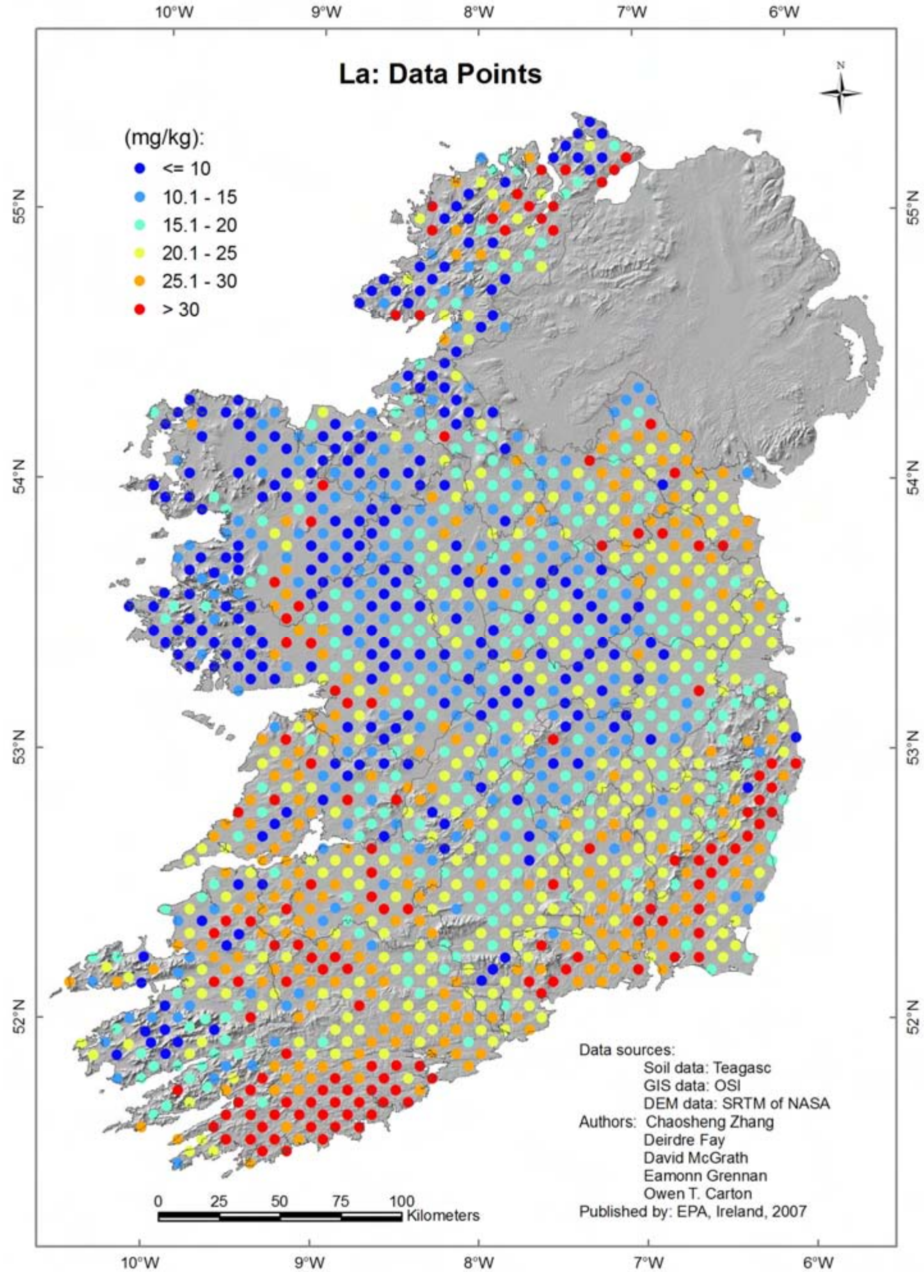
Lanthanum is a very reactive metal, and one of the more abundant rare earth metals. It occurs in many of the same minerals as Ce. They are neighbouring elements on the periodic table of elements and chemically similar. La is used in carbon lighting for projection in the film industry, glass manufacture and petrol catalysts. It has no known biological role but its compounds are used in medication to absorb excess phosphate and anticoagulants. It has a low to moderate toxicity level.

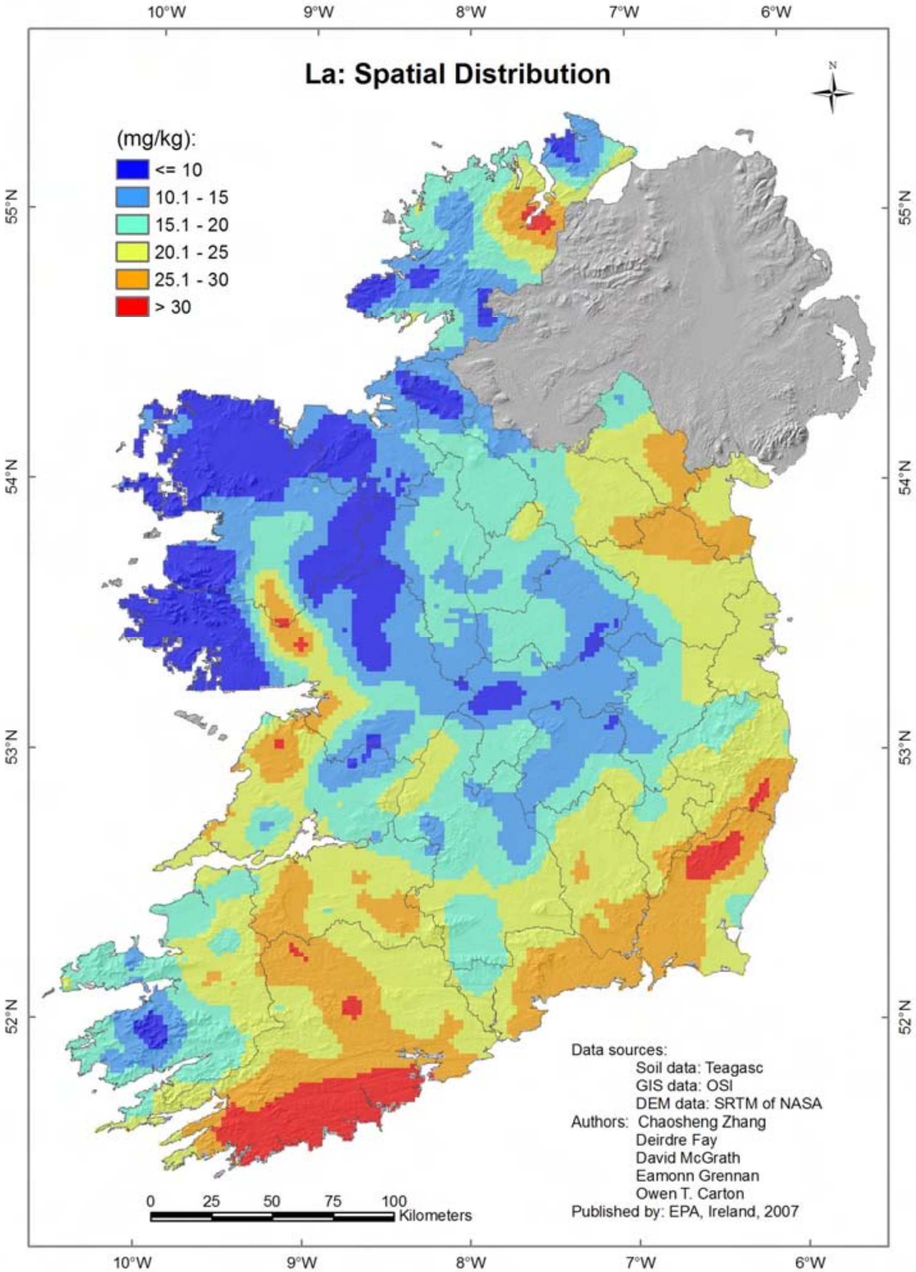
The distribution of La is very similar to Ce (r_{min} = 0.96). They have a similar distribution to Al, with relatively high levels above 25mg/kg coincident with the greywackes in the North East, greywackes, shales and rhyolites in the South East and with sandstones and shales in Cork, Limerick and Clare. Similar levels in Donegal are coincident with Ca-rich schists and coincide with relatively high levels of Ba, Th and Sr. Levels of La below 15mg/kg are associated with Grey Brown Podzolic soils on limestone and with Lithosols, Podzols and Peat soils, most prevalently in Galway and Mayo.

Table showing the minimum and maximum and some of the most important percentiles for total La concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<0.5**	1.10	12.70	20.00	25.40	33.10	75.20
mineral	3.00	11.40	17.30	22.10	26.90	34.00	75.20
organic	<0.5**	0.60	1.30	5.30	12.90	25.90	36.50

**12 samples analysed were below the detection limit of 0.5 mg/kg for La


La: Data Points
(mg/kg):
<= 10
10.1 - 15
15.1 - 20
20.1 - 25
25.1 - 30
> 30
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers
10°W 9°W 8°W 7°W 6°W
55°N 54°N 53°N 52°N


La: Spatial Distribution
(mg/kg):
<= 10
10.1 - 15
15.1 - 20
20.1 - 25
25.1 - 30
> 30
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers
10°W 9°W 8°W 7°W 6°W
55°N 54°N 53°N 52°N

Li Lithium

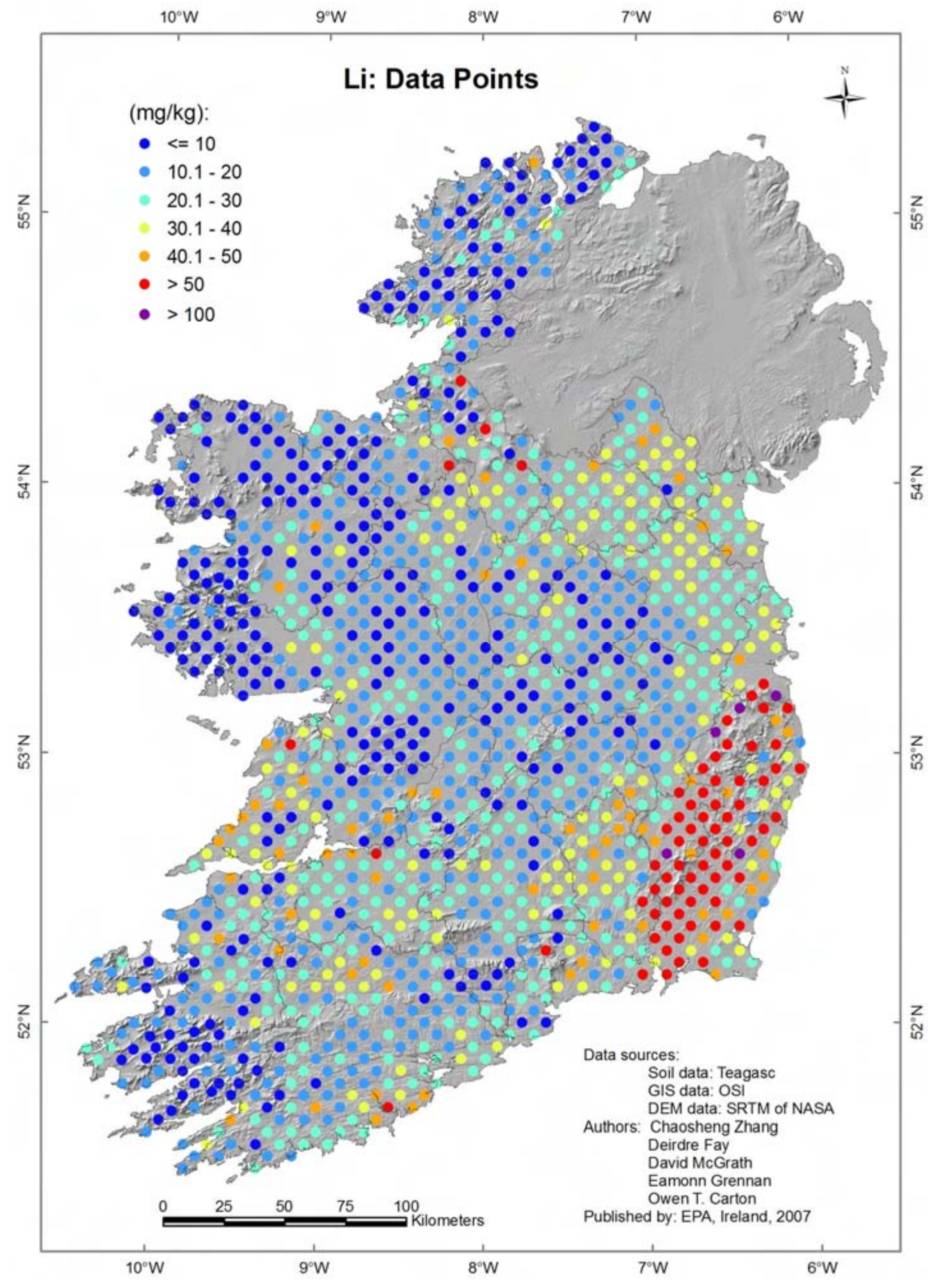
Lithium is an alkali metal and hence highly reactive, particularly with water. It occurs in small amounts in most igneous rocks. Li is used in rechargeable batteries, alloys, lubricants, as a desiccator and in mood-stabilizing drugs. Li has been found to be an essential trace element for goats, and possibly rats. Like the other alkali metals, Li in its pure form is highly flammable and corrosive to the skin, causing burns.

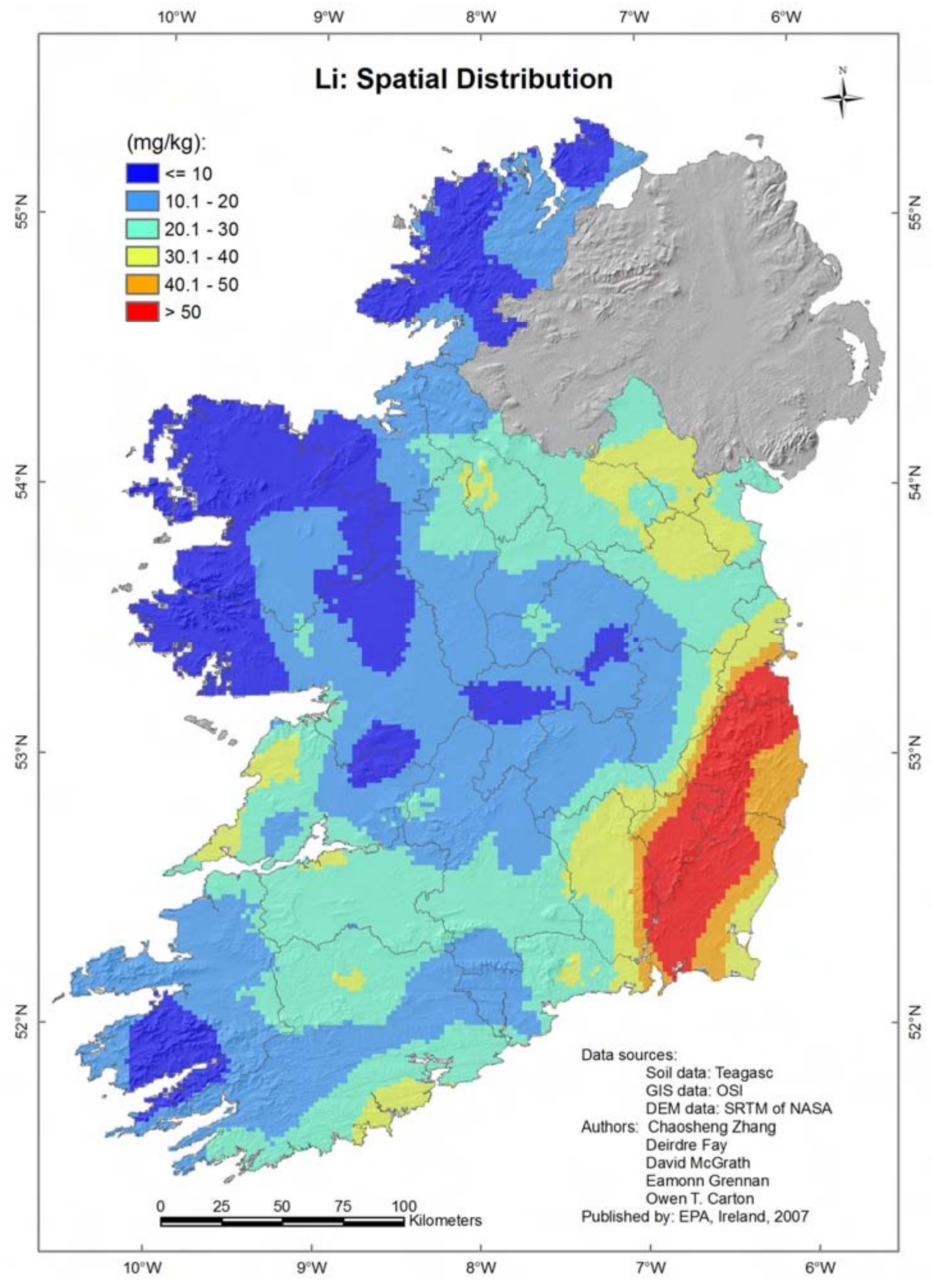
Concentrations of Li in soils would normally be between 20 and 30 mg/kg (Helmke and Sparks, 1996). Levels above 40mg/kg in Irish soils can especially be observed in the South East and coincide with the Leinster Granite and adjacent areas. This region was prospected for spodumene, a mineral which is a commercial source of Li. Levels above 20mg/kg are evident in the soils overlying the greywackes in the North East and the shales in the South West. Levels of Li below 20mg/kg are associated with Peats, Lithosols and Podzols in mountain and hill areas and Grey Brown Podzolics and Peats on limestone bedrock.

Table showing the minimum and maximum and some of the most important percentiles for total Li concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<2**	<2**	10.70	19.70	29.10	54.20	155.40
mineral	<2**	9.20	16.70	22.80	32.10	59.60	155.40
organic	<2**	<2**	<2**	2.80	8.90	26.80	142.20

**137 samples analysed were below the detection limit of 2 mg/kg for Li


Li: Data Points
(mg/kg):
<= 10
10.1 - 20
20.1 - 30
30.1 - 40
40.1 - 50
> 50
> 100
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers


Li: Spatial Distribution
(mg/kg):
<= 10
10.1 - 20
20.1 - 30
30.1 - 40
40.1 - 50
> 50
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers

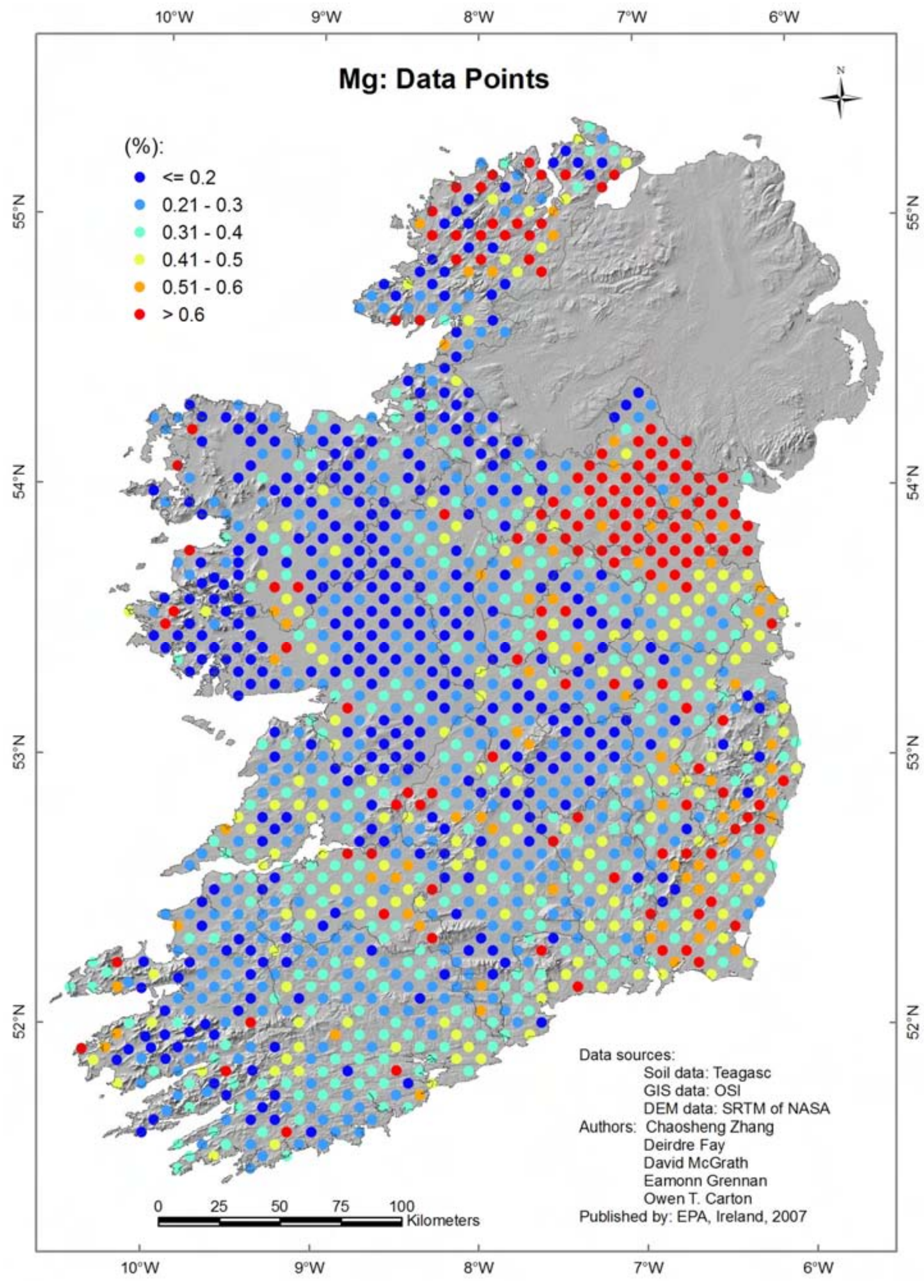
Mg *Total* Magnesium

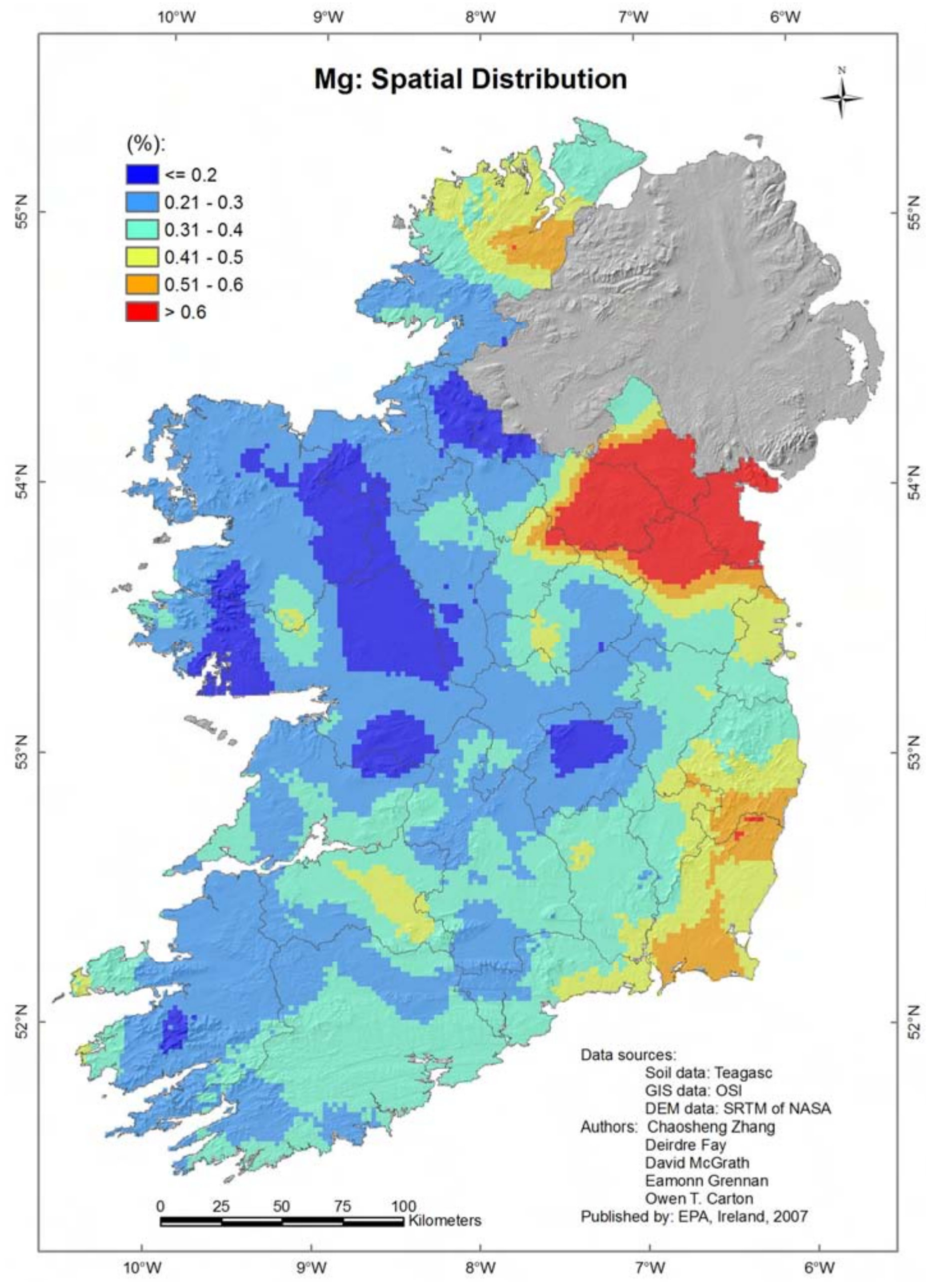
Magnesium is the seventh most common element in the earth's crust (Lide, 2005). It is also the third most plentiful element dissolved in sea water. Mg in metal form is used for many applications, most importantly in alloys, particularly for airplane and missile construction. Mg compounds are found in desiccants, fireworks, disinfectants and medicines. Mg is essential to all cells of all known living organisms. It is also an essential constituent and an activator of more enzymes than any other element. Hypomagnesaemia, attributed to deficiency of Mg in grazing animals, is aggravated by an excess of K.

Levels of *total* Mg above 0.6% in the North East are attributed to the presence of basic volcanic material within the greywackes, and glacial till of Irish Sea origin. Levels in the South East greater than 0.4% are indicative of the marine derived glacial mud. Similar values in Donegal are probably due to the presence of marbles and other Mg bearing minerals within the schists. Levels of *total* Mg below 0.3% are found in the West of the country.

Table showing the minimum and maximum and some of the most important percentiles for *total* Mg concentrations in %

	min	5%	25%	50%	75%	95%	max
all soils	0.04	0.11	0.20	0.30	0.43	0.82	2.10
mineral	0.05	0.15	0.25	0.35	0.47	0.87	2.10
organic	0.04	0.08	0.13	0.17	0.22	0.44	1.08


Mg: Data Points
(%):
<= 0.2
0.21 - 0.3
0.31 - 0.4
0.41 - 0.5
0.51 - 0.6
> 0.6
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Mg: Spatial Distribution
(%):
<= 0.2
0.21 - 0.3
0.31 - 0.4
0.41 - 0.5
0.51 - 0.6
> 0.6
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

Mg *Available* Magnesium

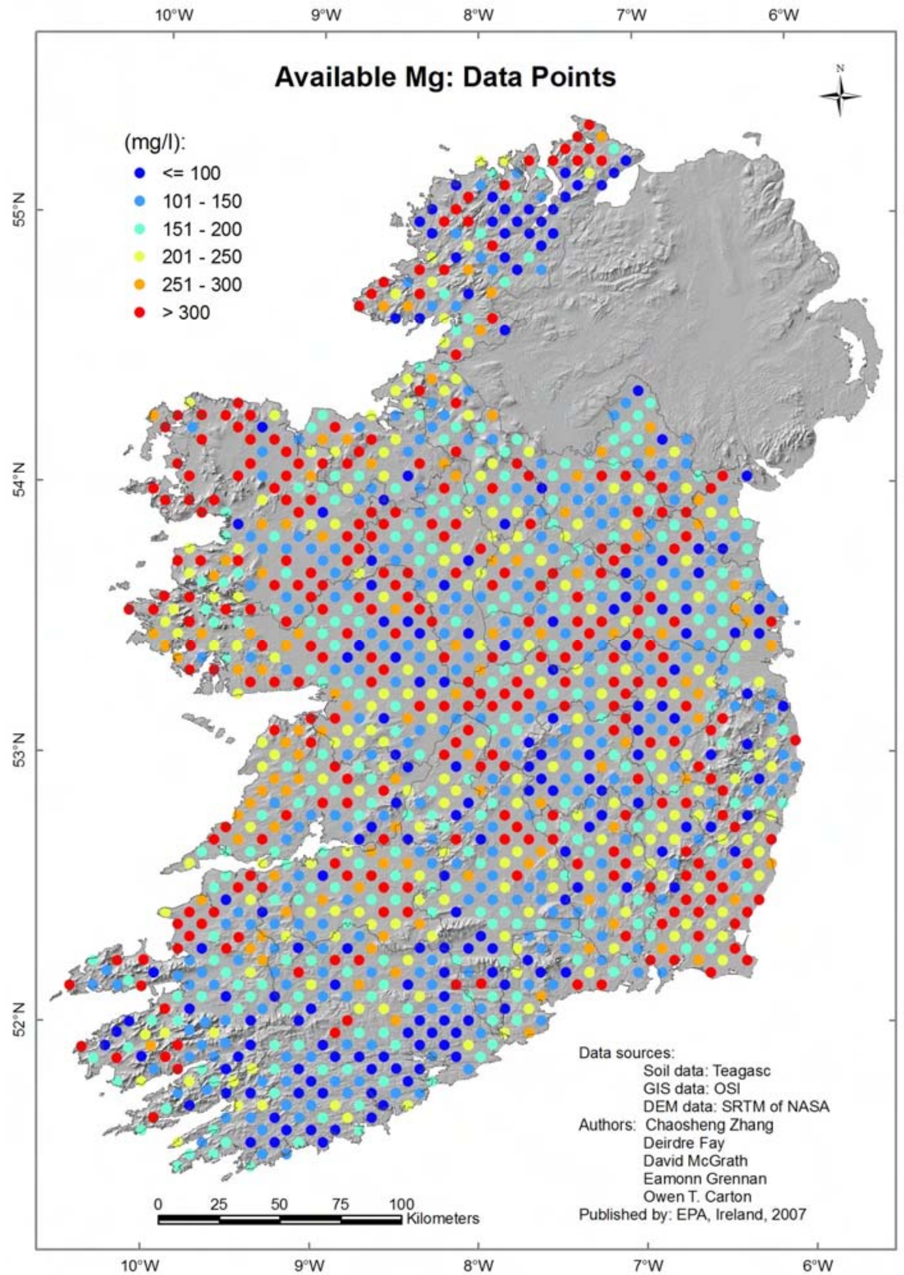
See text for *total* Magnesium on pg. 62

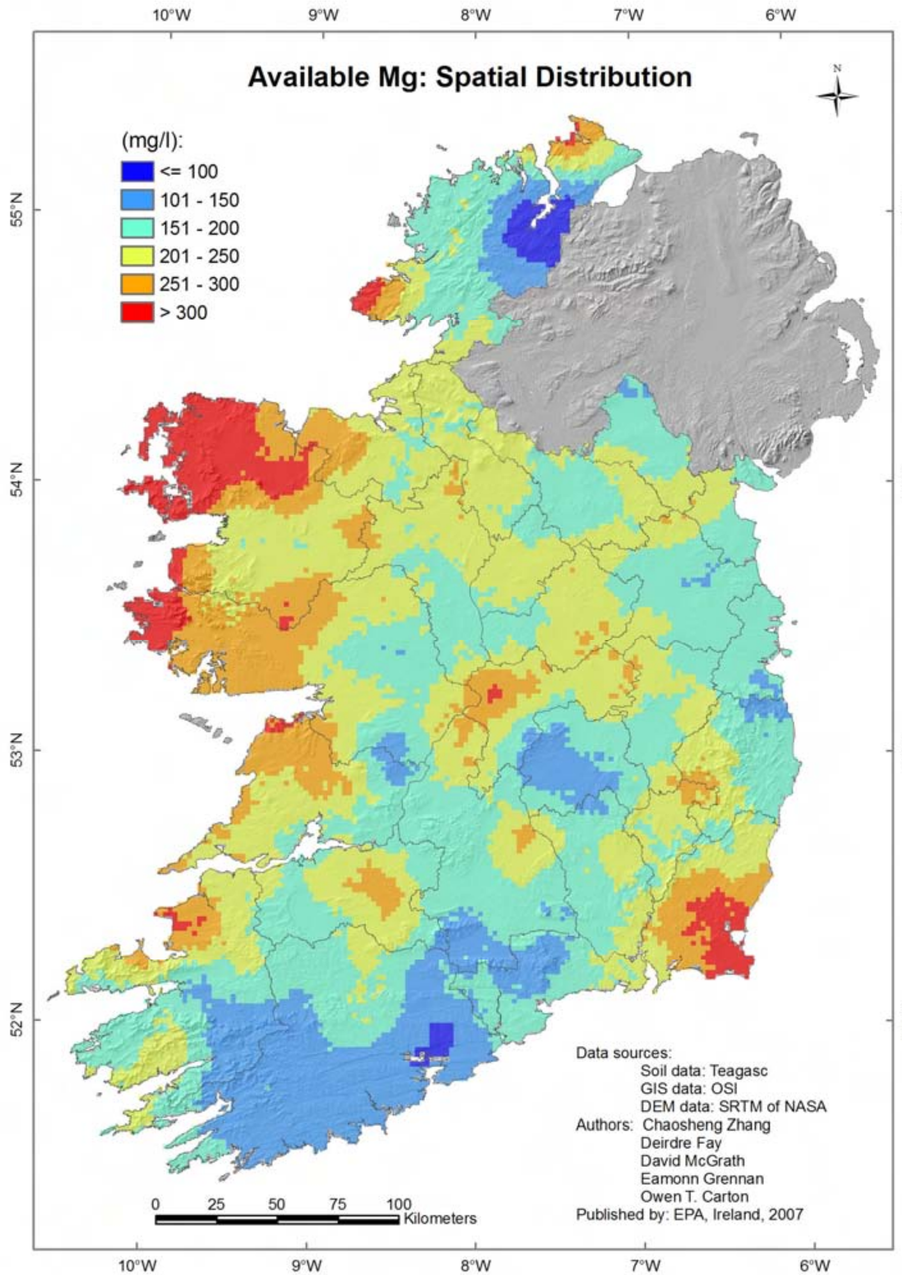
The spatial distribution map of *available* Mg shows that it is particularly enriched, with values above 200mg/l along the western seaboard and in Wexford. The former is due to the prevailing westerly winds blowing the Mg-enriched seawater spray overland, either as rain or in the wind, where it precipitates along the coast and in mountainous areas. The 'high' in Wexford is due to the presence of the marine derived till and the low-lying coastal area of south Wexford. There also appears to be an elevation of *available* Mg in areas with underlying limestone geology.

Unlike *available* P and K, where the availability is mostly influenced by fertilizer application, the availability of Mg appears strongly influenced by oceanic and atmospheric deposition, whilst *total* Mg was more associated with soil type and geology. The spatial distribution of *total* and *available* Mg illustrates clearly that the presence of high concentrations of an element does not in any way necessarily mirror high availability of that element.

Table showing the minimum and maximum and some of the most important percentiles for *available* Mg concentrations in mg/l

	min	5%	25%	50%	75%	95%	max
all soils	13.49	71.11	127.51	186.13	276.28	485.92	1001.97
mineral	13.49	66.69	113.97	162.37	225.49	388.79	1001.97
organic	45.22	124.30	205.03	301.58	416.58	564.29	931.38


Available Mg: Data Points
(mg/l):
<= 100
101 - 150
151 - 200
201 - 250
251 - 300
> 300
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Available Mg: Spatial Distribution
(mg/l):
<= 100
101 - 150
151 - 200
201 - 250
251 - 300
> 300
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

Mn Manganese

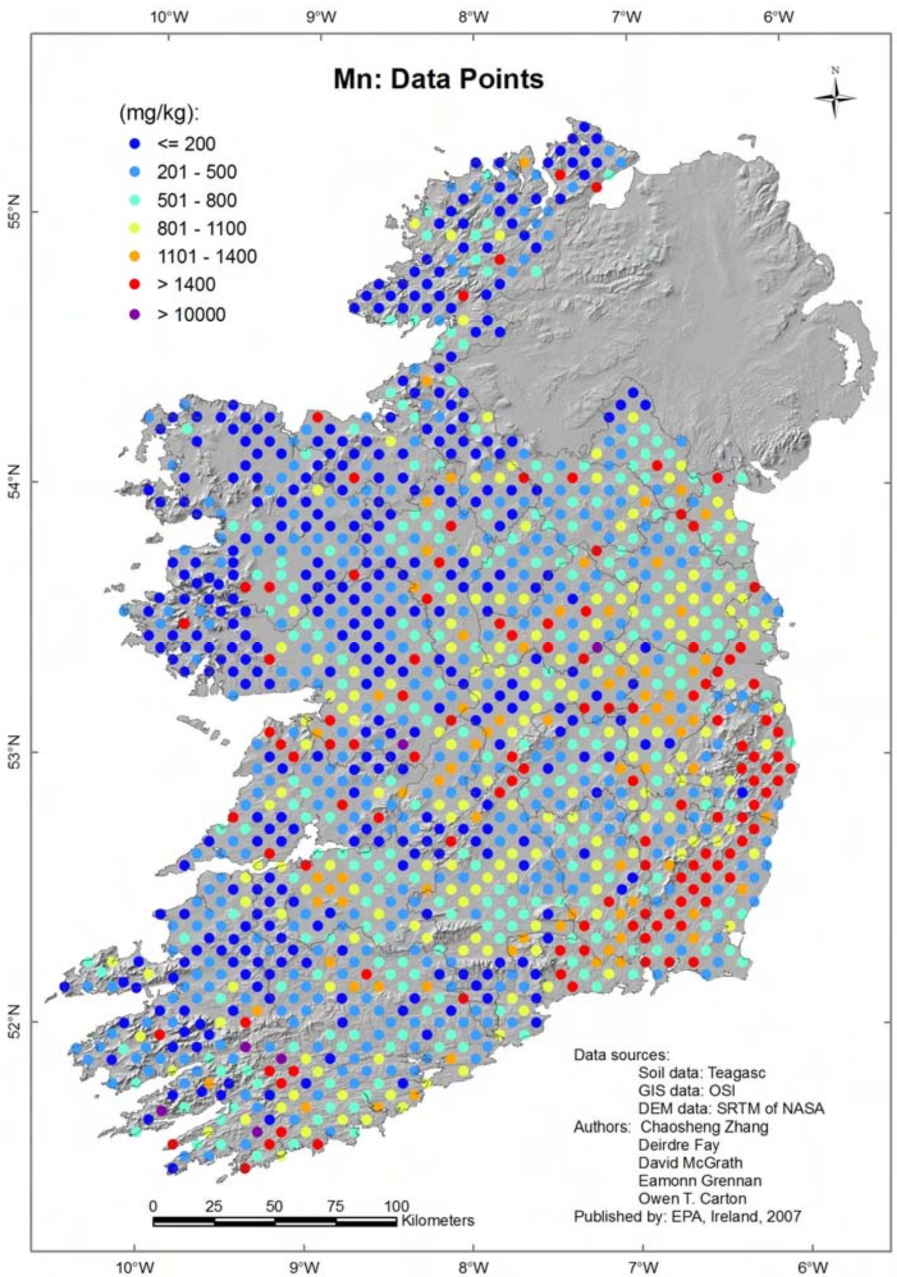
Manganese is relatively abundant in the earth's crust and in soils. It occurs in many minerals, but is mainly mined from oxide and hydroxide deposits in sediments. The metal is used for Fe and Al alloys, while its compounds can be found in pigments, alkaline batteries and as an additive in petrol. Potassium permanganate is used as a disinfectant. Mn (mostly mixed with Fe) - oxide and hydroxide coatings on soil minerals enhance the fertility of soils, as they adsorb soluble nutrient elements even at neutral pH, and thus help prevent their loss by leaching. Alkaline soils with low Mn contents often result in Mn-deficiency in farm ruminants. Typically, this is the case on acidic soils that have been ameliorated by the addition of lime. Mn is an essential element for all living organisms. Excessive uptake of Mn, although not as detrimental to health as other common metals such as Cu, Ni and Fe, is toxic. Mn deficiency in crops is influenced both by the Mn concentrations and the pH.

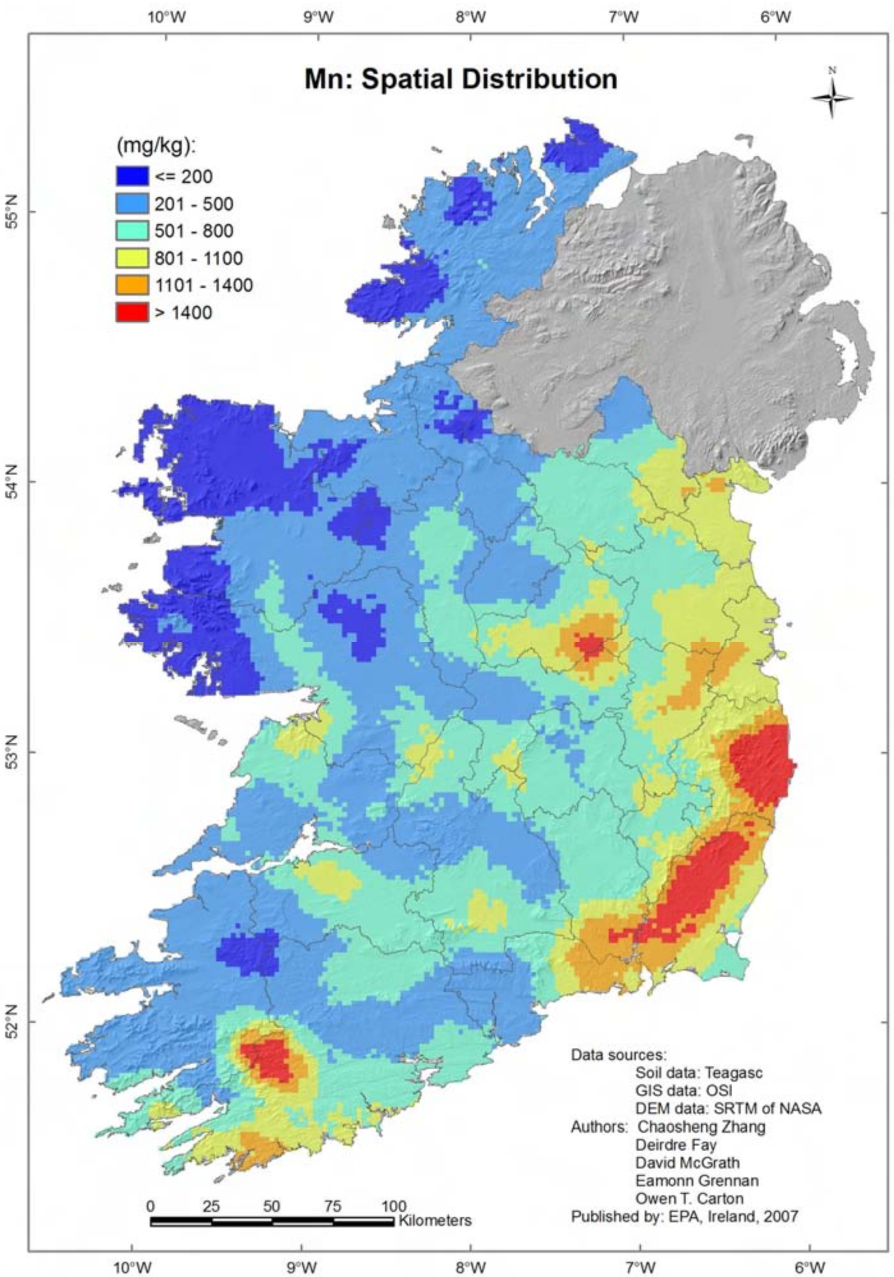
Typical total concentrations for Mn in soil would be around 600 mg/kg (Fuller and Warrick, 1985). Mn levels in the South East and County Louth above 1100mg/kg are coincident with Acid Brown Earths underlain by shales. Regionally enhanced levels of Mn, above 800mg/kg, are evident in Dublin and surrounding counties, with no apparent explanation. The two spot high concentrations exceeding 1400 mg/kg in western Meath and in the South West coincide with small outcrops of basalt. Mn levels below 500mg/kg coincide largely with areas underlain by limestone and the Peats in the West.

The mobility of Mn in soil is strongly influenced by pH. Waters draining the sandstone dominated areas of Cork and Kerry precipitate dissolved Mn in a similar process to that for Fe when they encounter the more alkaline soils on the flanks of or in the valleys. This could explain the local high levels (>800mg/kg) in the middle of the country. Since Mn (and Fe) hydroxides and hydrated oxides often act as scavengers for other metal oxides and hydroxides, Co, Ni and Zn are commonly co-precipitated. These elements show similar distribution patterns in this area.

Table showing the minimum and maximum and some of the most important percentiles for total Mn concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	7	25	190	462	844	1903	21077
mineral	13	108	303	580	926	1988	14197
organic	7	13	35	90	307	1465	21077


Mn: Data Points
(mg/kg):
<= 200
201 - 500
501 - 800
801 - 1100
1101 - 1400
> 1400
> 10000
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers


Mn: Spatial Distribution
(mg/kg):
<= 200
201 - 500
501 - 800
801 - 1100
1101 - 1400
> 1400
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers

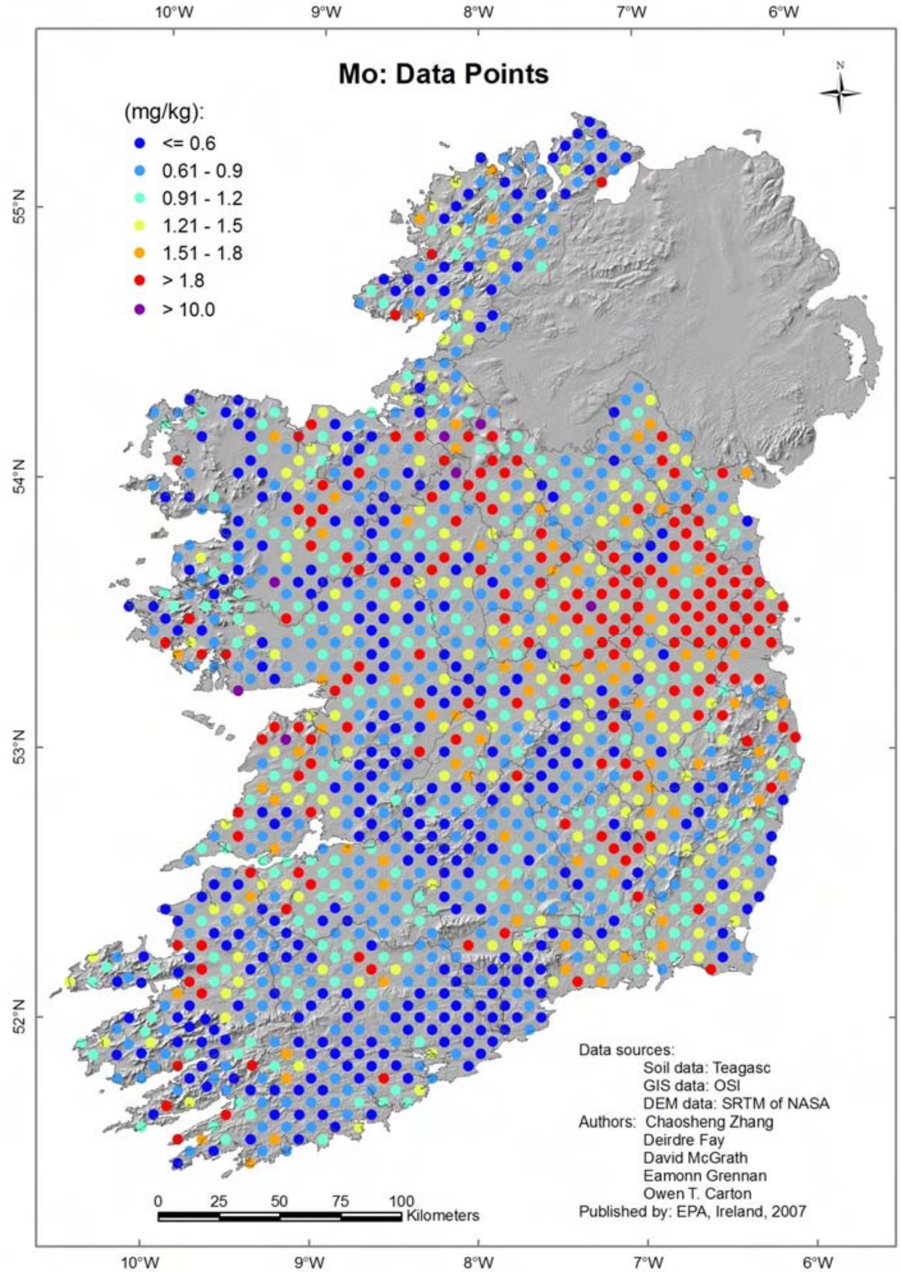
Mo Molybdenum

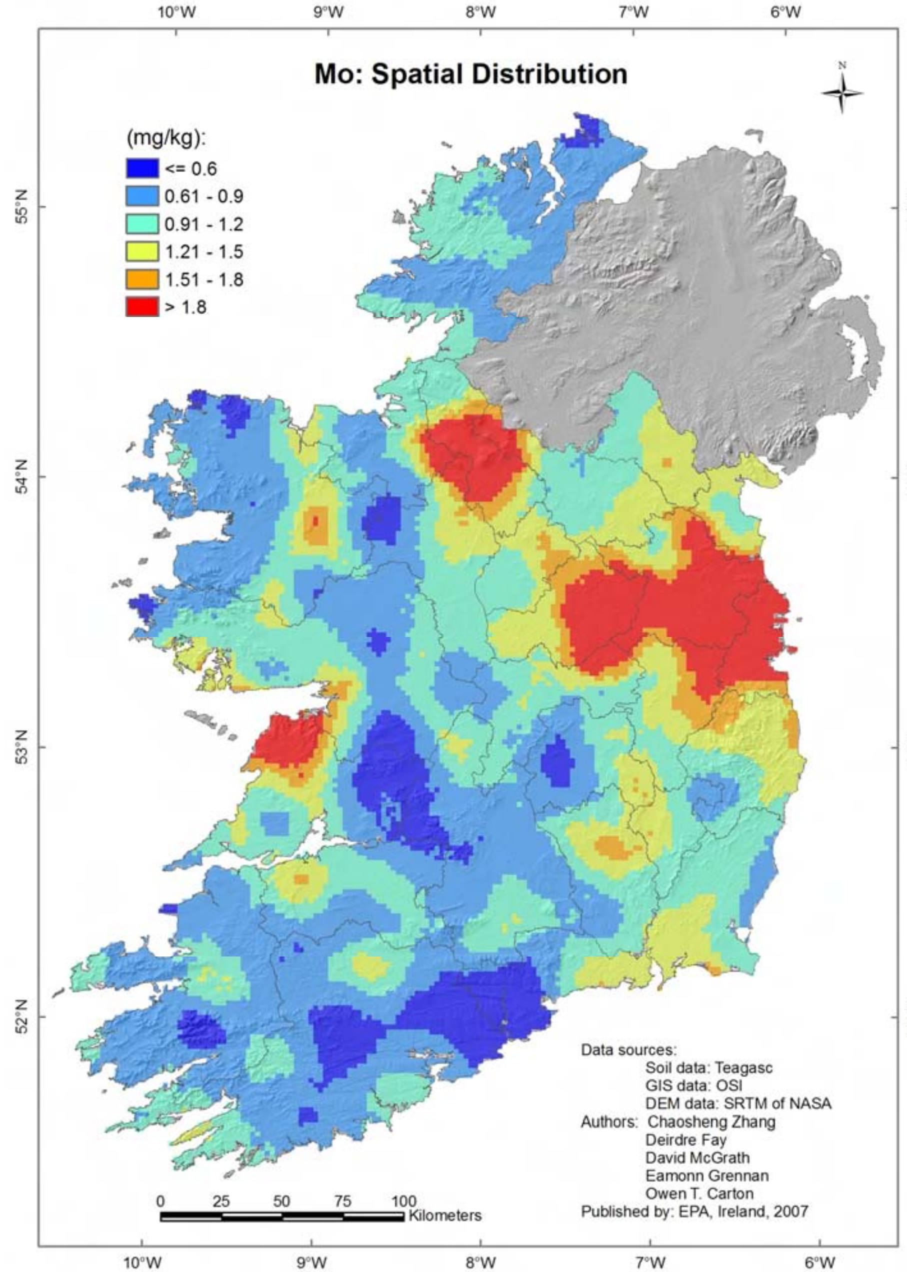
Molybdenum is often associated with certain granites. Organic matter seems to act as a concentrating agent since Mo is enriched in organic sediments. Mo is soluble under a wide range of conditions, and is probably the most mobile of all the transition metals. Mo is used in alloys, electrodes and catalysts. Mo in grassland is important from both deficiency and toxicity perspectives. It is an essential element to all living species but is toxic in high doses. High uptake of Mo through vegetation can contribute to Cu-deficiency in ruminants. Mo is necessary for N fixating bacterial colonies (*Rhizobium*) living in symbiosis with some plants (e.g. clover and *Lucerne*), and deficiency can affect the establishment of these plants in "green manuring".

Typical Mo concentrations in soils range from 1-2 mg/kg (Sims, 1996). The associations with soil type and geology are not as clear for Mo levels in Irish soils as for some other elements. Levels of Mo in Irish soils above 1.8mg/kg are associated with the presence of Namurian shale in the parent materials. These concentrations are not confined to any single great soil group but occur in Grey Brown Podzolics, Acid Brown Earths and Gleys (Finch and Rogers, 1978). Mo levels above 1.8mg/kg are also present in areas where the soil parent material is influenced by the shaley Carboniferous limestone in Dublin and surrounding counties and in the Rendzinas in Galway. Overall, Mo concentrations in Irish soils are relatively high and Mo deficiency is less likely to create a challenge than high concentrations.

Table showing the minimum and maximum and some of the most important percentiles for total Mo concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	0.07	0.32	0.61	0.91	1.37	3.29	21.14
mineral	0.07	0.35	0.66	0.94	1.40	3.26	21.14
organic	0.13	0.28	0.50	0.76	1.26	3.38	10.63


Mo: Data Points
(mg/kg):
<= 0.6
0.61 - 0.9
0.91 - 1.2
1.21 - 1.5
1.51 - 1.8
> 1.8
> 10.0
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers


Mo: Spatial Distribution
(mg/kg):
<= 0.6
0.61 - 0.9
0.91 - 1.2
1.21 - 1.5
1.51 - 1.8
> 1.8
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers

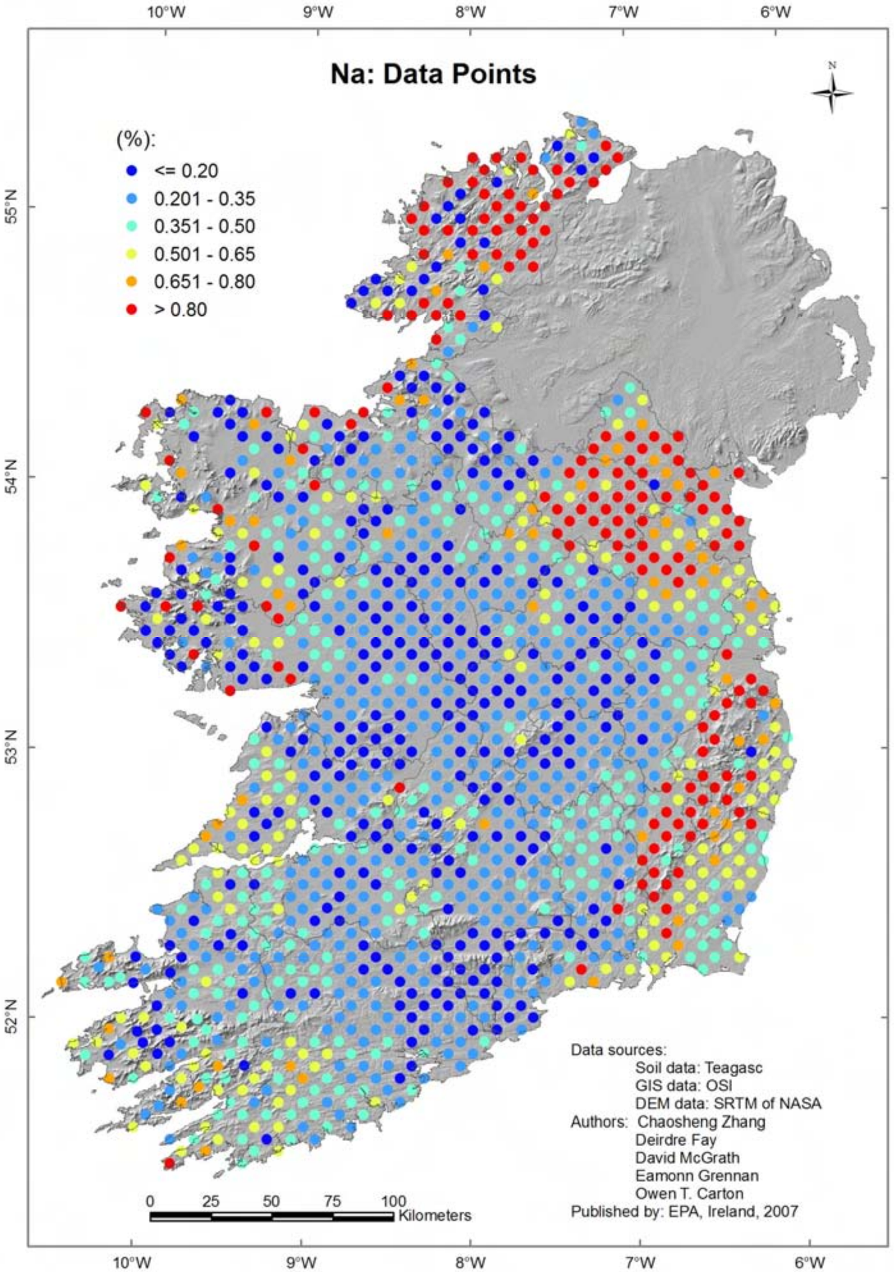
Na Sodium

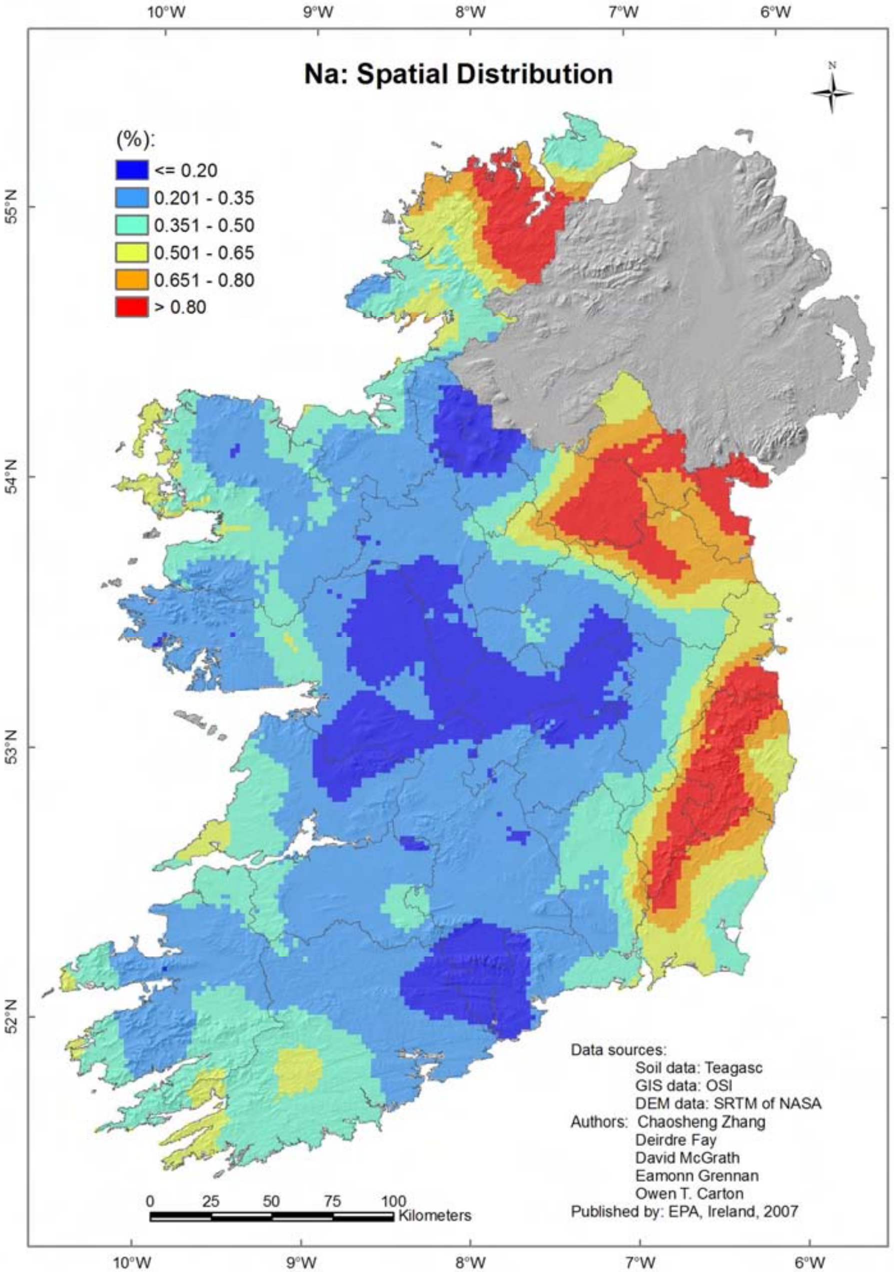
Sodium is the sixth most abundant element and the most abundant alkali metal in the earth's crust (Lide, 2005). It is used in alloys, in soaps and in sodium vapour lamps often used for street lighting. Its most common compound in the environment, NaCl, is the salt of the sea and has been an important commodity in food seasoning and preservation for millennia. Na ions play a role in diverse physiological processes. Na is required by animals, which maintain high concentrations in their blood and extracellular fluids. Few plants require Na, and plant-based diets are therefore low in Na. This requires some herbivores to obtain their Na from salt licks and other mineral sources.

Levels of Na higher than 0.65% in Irish soils are coincident with the Leinster and Donegal granites, the greywackes in the North East and South East and Precambrian schists in Donegal. Relatively high Na values in these areas closely parallel similarly high total K values. As with the analysis for K, the strong acid (HF) used to digest the samples for analysis has resulted in very high values, as the Na-bearing feldspars were fully dissolved. Thus, high Na content in Irish soils strongly reflects the presence of fine grained feldspars in greywackes, schists and granites in the areas underlain by these rocks. There appears to be some oceanic deposition of Na in the West, although this is not evident in the Peat soils in Galway and Mayo, which have relatively low levels. The Grey Brown Podzolics and Peats of central Ireland have relatively low Na levels below 0.35%.

Table showing the minimum and maximum and some of the most important percentiles for total Na concentrations in %

	min	5%	25%	50%	75%	95%	max
all soils	0.02	0.05	0.21	0.34	0.55	1.09	2.25
mineral	0.05	0.15	0.26	0.39	0.60	1.13	2.25
organic	0.02	0.03	0.06	0.12	0.31	0.73	1.93


Na: Data Points
(%):
<= 0.20
0.201 - 0.35
0.351 - 0.50
0.501 - 0.65
0.651 - 0.80
> 0.80
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100
Kilometers


Na: Spatial Distribution
(%):
<= 0.20
0.201 - 0.35
0.351 - 0.50
0.501 - 0.65
0.651 - 0.80
> 0.80
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100
Kilometers

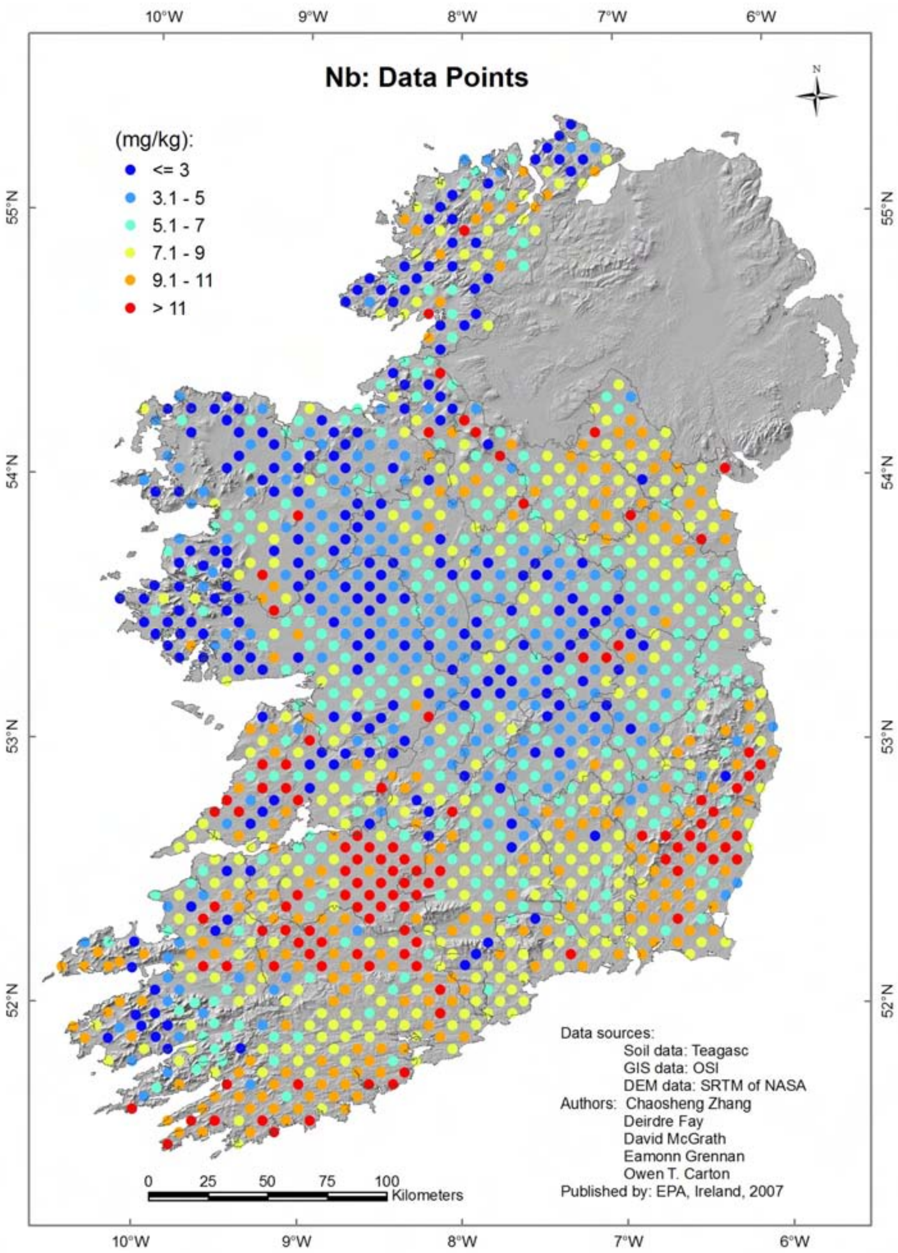
Nb Niobium

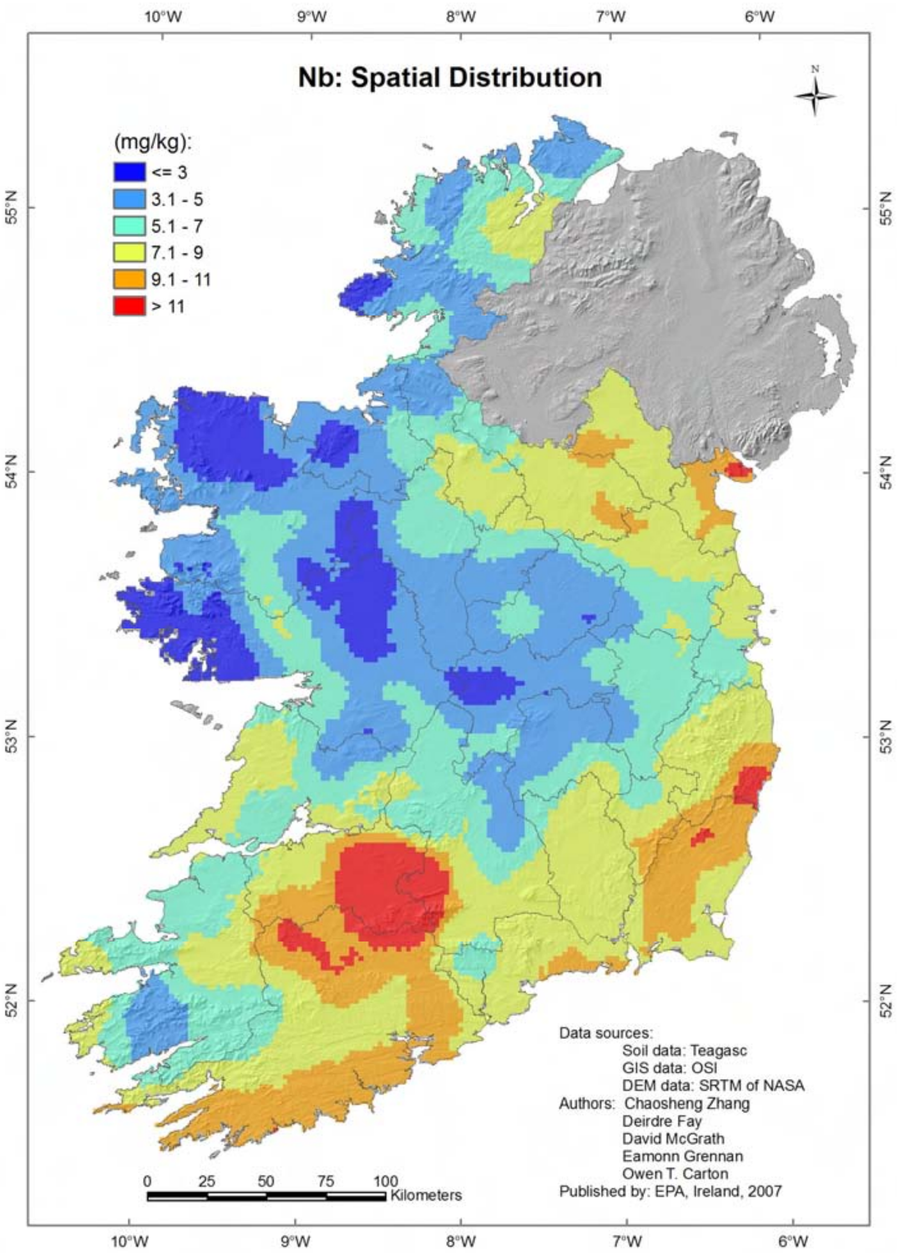
Niobium has similar physical and chemical properties to Ta and is often found in minerals that also contain Ta. It reacts readily with O, C, S and N. It is used for temperature resistant alloys and in Ti and Sn alloys used for superconducting magnets. It is also used to make surgical implants and in jewellery as it does not react with human tissue. There are no known biological functions in which Nb plays a role. Nb compounds can be toxic, although they are rarely encountered. Nb dust can cause skin irritation.

The distribution of Nb in Ireland is very similar to that of Ta (r_{min} = 0.96) and Ti (r_{min} = 0.92). The highest Nb values (>11mg/kg) measured in Irish soils are centred on the Carboniferous basalt in East Limerick. Levels of Nb above 7 mg/kg were associated with the greywackes in the North East, the Tertiary granite intrusions in Carlingford and the greywackes and igneous rocks in the South East. Levels of Nb above 5 mg/kg are coincident with Brown Earths in Galway. Levels of Nb below 5 mg/kg are associated with Peats, Lithosols and Podzols in mountain and hill areas and Grey Brown Podzolics and Peats on limestone bedrock with the exception of the higher values in Limerick.

Table showing the minimum and maximum and some of the most important percentiles for total Nb concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	0.06	0.34	4.42	6.83	8.95	12.01	38.88
mineral	0.58	3.98	5.87	7.66	9.52	12.62	38.88
organic	0.06	0.17	0.40	1.57	4.09	8.59	17.37


Nb: Data Points
(mg/kg):
<= 3
3.1 - 5
5.1 - 7
7.1 - 9
9.1 - 11
> 11
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers


Nb: Spatial Distribution
(mg/kg):
<= 3
3.1 - 5
5.1 - 7
7.1 - 9
9.1 - 11
> 11
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers

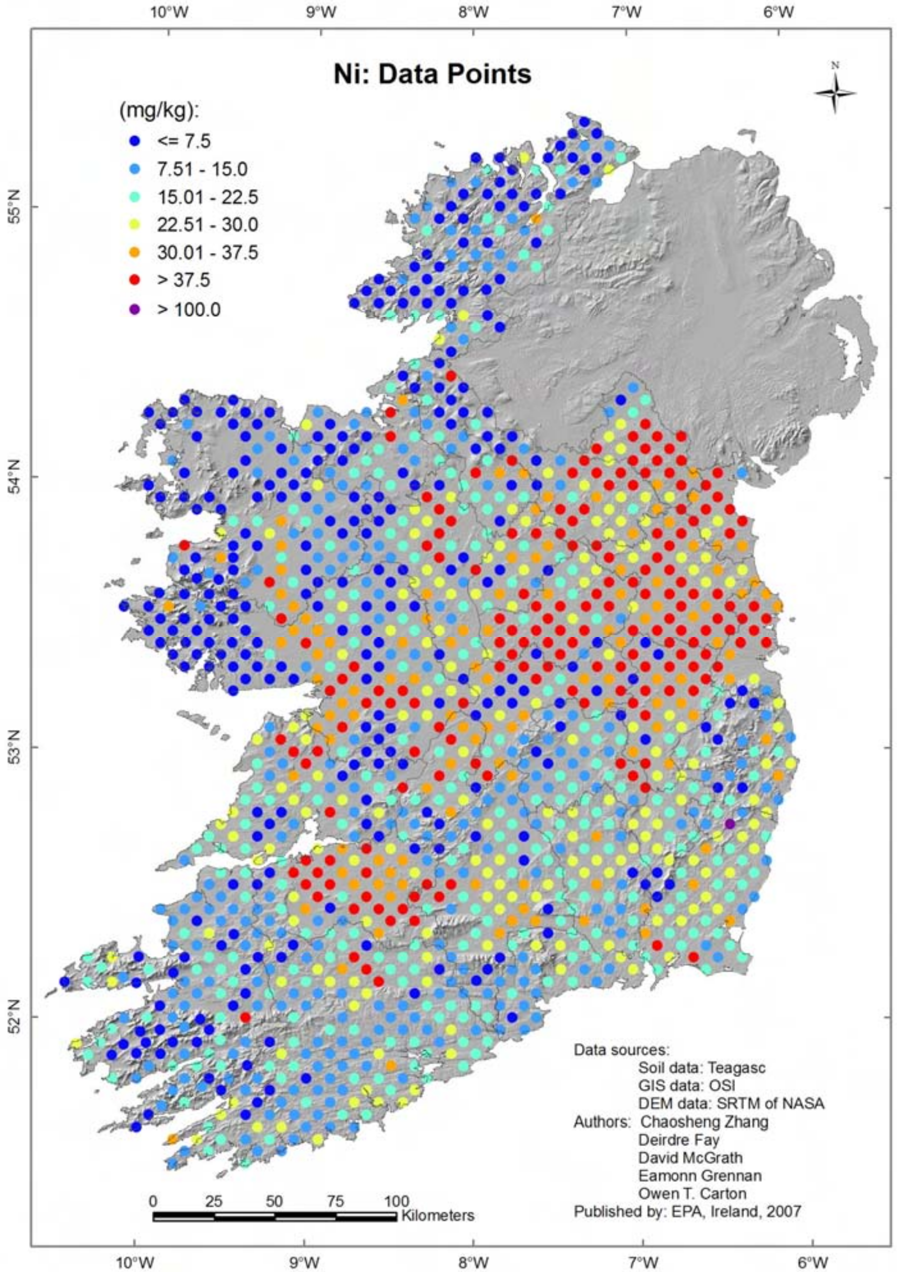
Ni Nickel

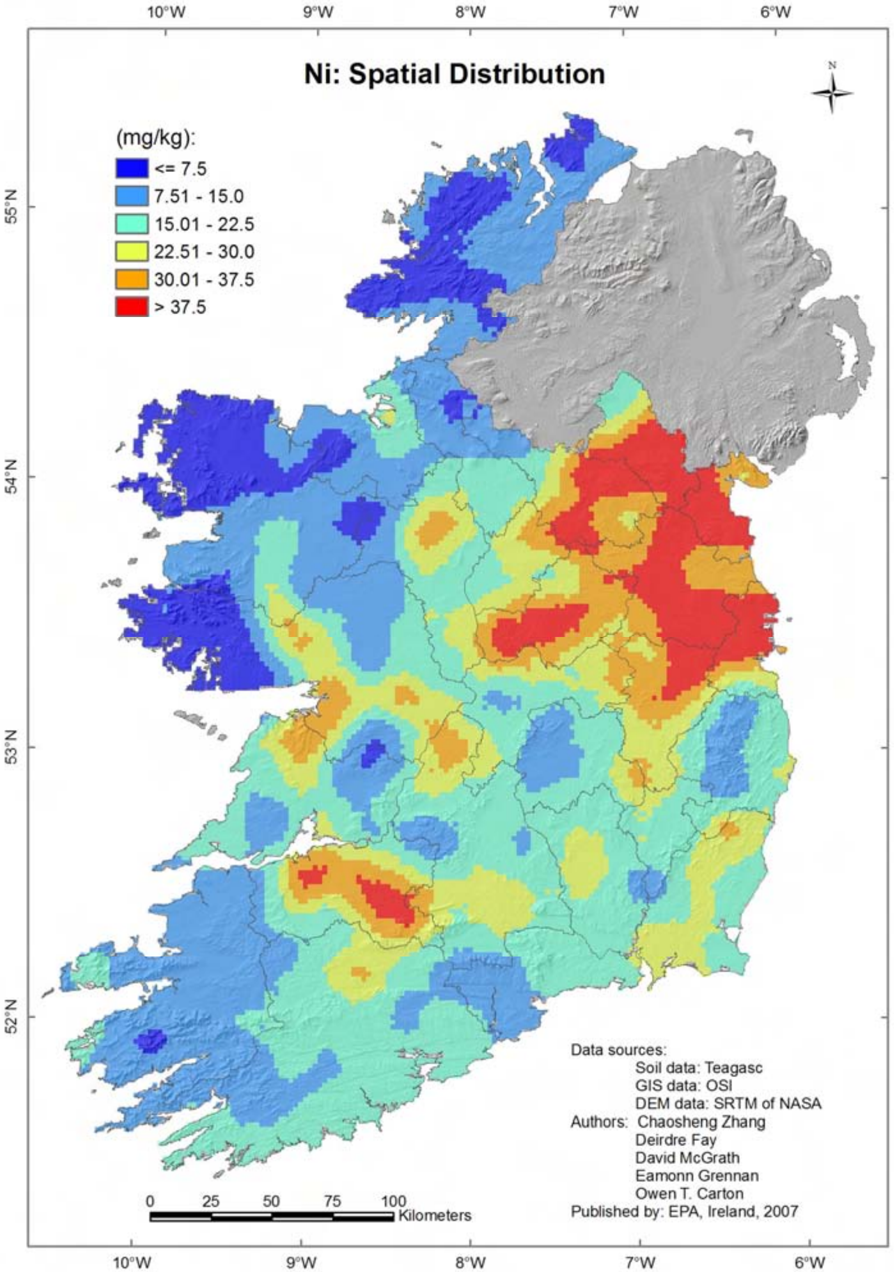
Nickel is relatively abundantly present in most soil, water and food. The occurrence of Ni in the environment is a result of the natural weathering of rocks, volcanic emissions, combustion of fossil fuels, waste incineration, application of sewage sludge and emissions from industrial activities using or producing Ni. The main industrial uses for Ni are in alloys, rechargeable batteries, jewellery, paints and ceramics and magnets. Small amounts of Ni are essential for our health, but adverse health effects can be encountered from Ni when large amounts are ingested or inhaled and exposure to the skin can cause skin allergies. The limit value for Ni in soils receiving sewage sludge under the EU Sewage Sludge Directive is 30 mg/kg.

Background concentrations of 35 mg/kg were reported for Ni by Crommentuijn (1997) for soils in the Netherlands. Levels of Ni in the North East above 30mg/kg are attributed to volcanic material in the greywackes. Ni is associated with other elements in this area such as Co, Cu, Cr and Pb. Similar levels in Limerick are strongly associated with the Carboniferous basalt as well as the precipitation effect described for Fe. Ni is commonly co-precipitated with Ba, Zn, Fe and Mn. Ni levels above 22 mg/kg are evident in areas with underlying impure limestone geology such as Dublin, Meath, Westmeath and Kildare, and there also appears to be an association with Carboniferous shales. Levels below 15mg/kg are evident in the western part of the country. 23% of Irish soils exceed the limit set by the Sewage Sludge Directive and the Waste Management (Use of Sewage Sludge in Agriculture) Regulations 1998 to 2001. Similar to Cd, this is mostly due to naturally high background levels and only on rare occasions to human activities. The median value for Ni measured, is similar to those reported for England and Wales (22.6 mg/kg, McGrath and Loveland, 1992) and Northern Ireland (29.2 mg/kg, Jordan *et al*. 2002).

Table showing the minimum and maximum and some of the most important percentiles for total Ni concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	0.80	1.90	9.20	17.50	28.60	50.00	176.00
mineral	1.70	5.90	14.10	20.60	31.40	51.90	176.00
organic	0.80	1.20	2.10	4.10	10.90	35.40	70.20


Ni: Data Points
(mg/kg):
<= 7.5
7.51 - 15.0
15.01 - 22.5
22.51 - 30.0
30.01 - 37.5
> 37.5
> 100.0
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Ni: Spatial Distribution
(mg/kg):
<= 7.5
7.51 - 15.0
15.01 - 22.5
22.51 - 30.0
30.01 - 37.5
> 37.5
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

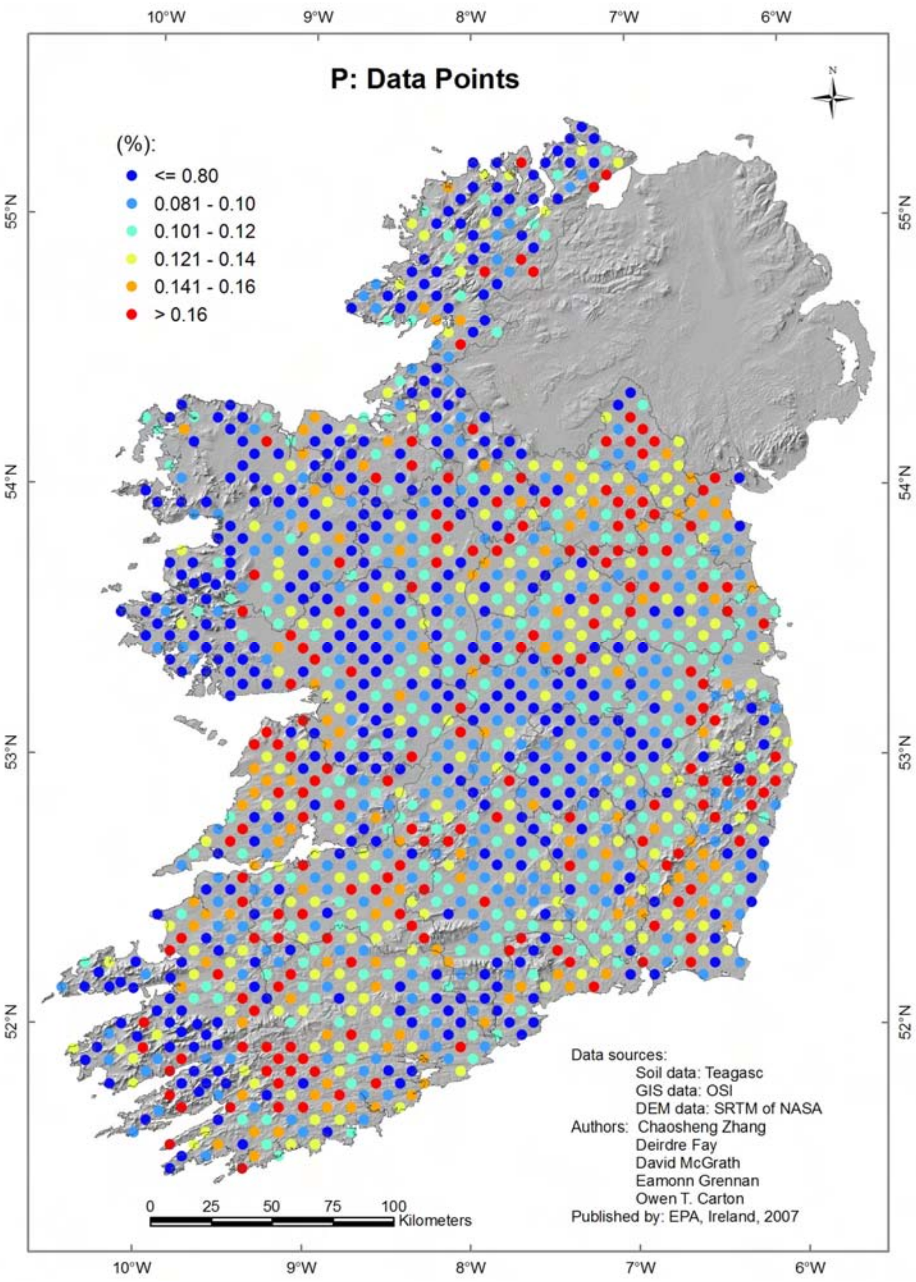
P *Total* Phosphorous

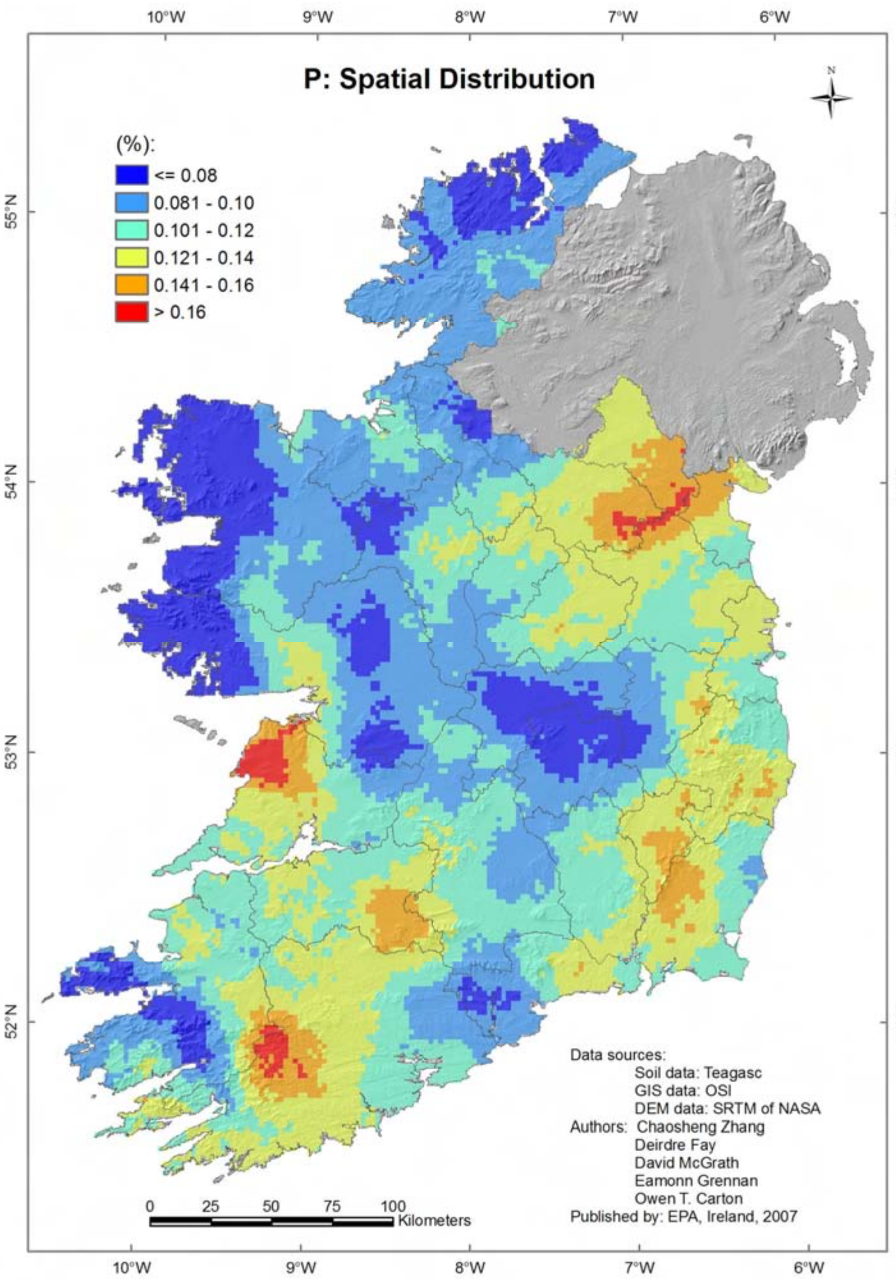
Phosphorous is a highly reactive element, most commonly found in nature as phosphate salts. P moves faster through the organic cycle (plants and animals) than through the inorganic one (rocks and sediments). P and its compounds are used in fertilizers, explosives, fireworks, pesticides and detergents. P is a key element in all known forms of life. It plays a major role in biological molecules such as DNA and RNA, and calcium phosphate is the substance of bones and teeth. P is often a limiting nutrient for growth, and needs to be added to the soil as fertilizer to maximise production. P is the main nutrient responsible for the eutrophication of aquatic ecosystems.

Generally, *total* P concentrations in soils are between 0.02 and 0.5% (Lindsay, 1979). *Total* P levels above 0.12% in Irish soils are associated with the greywackes in the North East, igneous rocks in the South East, and the Rendzinas which are underlain by phosphate rich rocks in North Clare. *Total* P is generally lower (<0.08%) in the organic-rich soils in the midlands and along the western seaboard.

Table showing the minimum and maximum and some of the most important percentiles for *total* P concentrations in %

	min	5%	25%	50%	75%	95%	max
all soils	0.01	0.04	0.08	0.11	0.14	0.20	0.49
mineral	0.01	0.05	0.09	0.11	0.14	0.20	0.43
organic	0.02	0.03	0.05	0.08	0.12	0.19	0.49


P: Data Points
(%):
<= 0.80
0.081 - 0.10
0.101 - 0.12
0.121 - 0.14
0.141 - 0.16
> 0.16
N
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


P: Spatial Distribution
(%):
<= 0.08
0.081 - 0.10
0.101 - 0.12
0.121 - 0.14
0.141 - 0.16
> 0.16
N
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

P *Available* Phosphorous

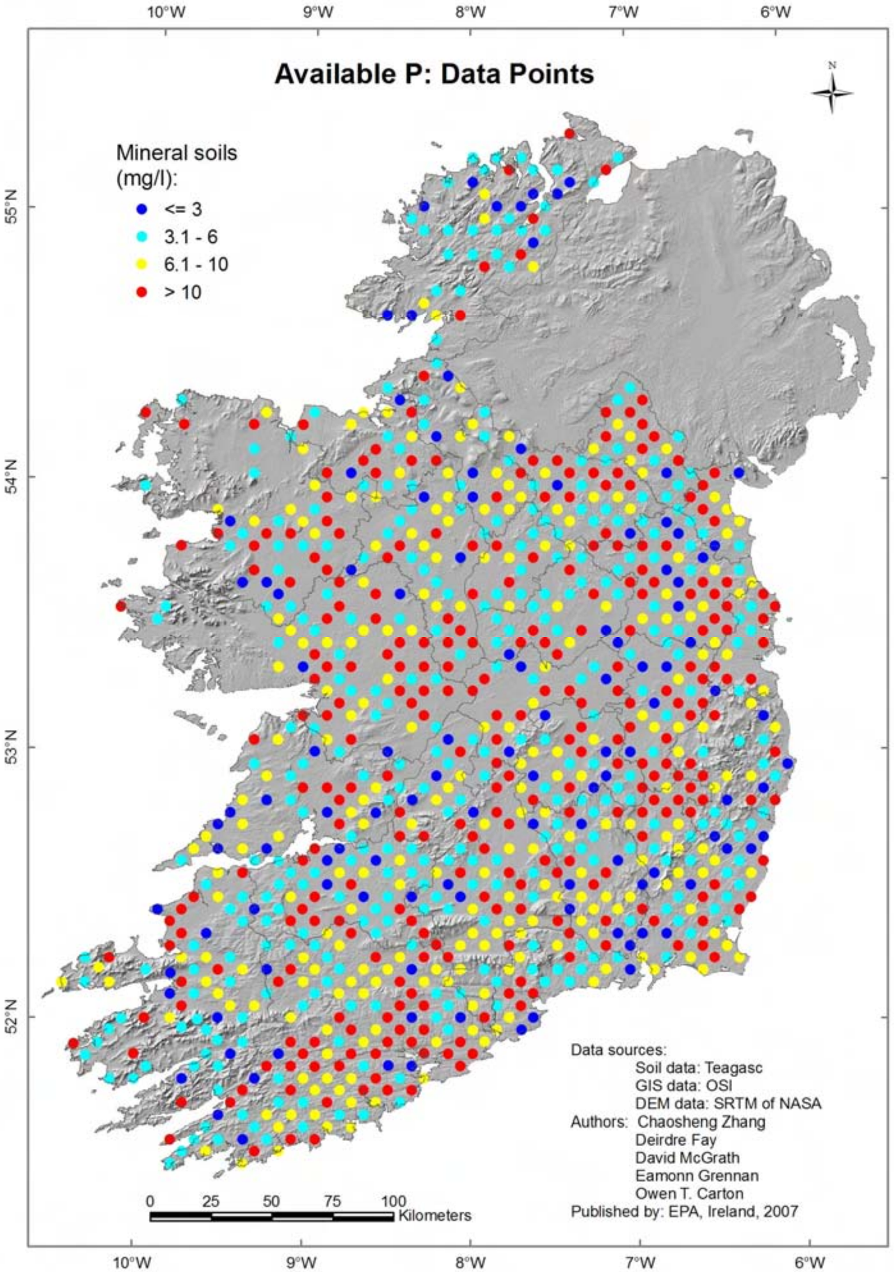
See text for *total* Phosphorous on pg. 74

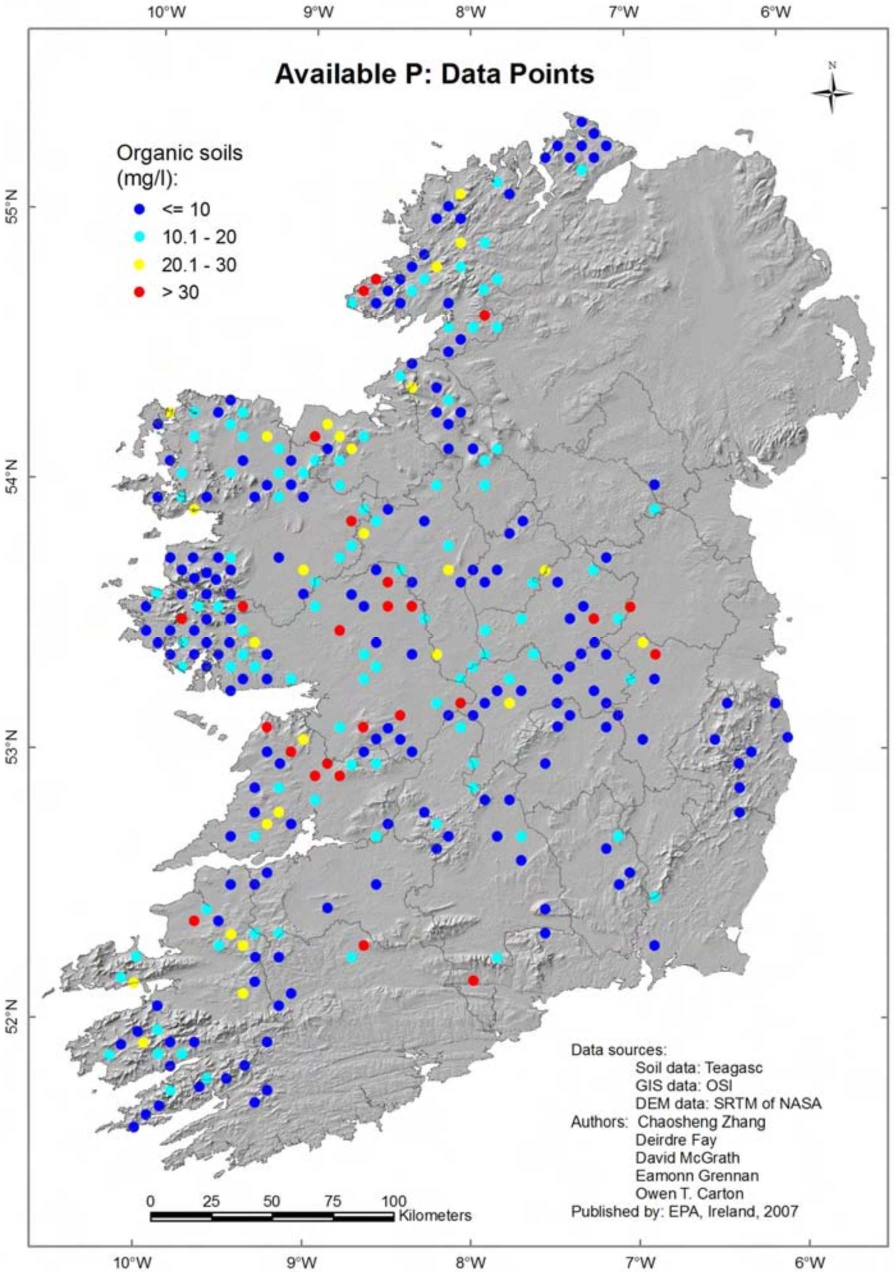
The spatial coherence of *available* P concentrations was not sufficient to create a spatial distribution map. As in the case of K, this is largely due to the influence of fertilizer application on this parameter. The maps for *available* P are shown separately for the mineral and the organic soils.

The *available* P levels and the difference between *available* and *total* P for Irish soils can mostly be explained by land use, rock and soil type. Generally, intensive farming practices (particularly poultry and pigs) will result in higher *available* P in soils due to the production of manure. Tillage agriculture is also often associated with higher *available* P due to higher fertilizer application rates. High *available* P levels are evident in areas in Ireland where intensive agriculture is practised and for tillage soils. P is more readily extracted from calcareous soils. This is visible in Irish soils where relatively low *total* P levels were measured (<0.12%) for calcareous soils on limestone rocks whilst the *available* P levels on these soils were not necessarily particularly low.

Table showing the minimum and maximum and some of the most important percentiles for *available* P concentrations in mg/l

	min	5%	25%	50%	75%	95%	max
all soils	0.56	2.32	4.32	7.05	12.47	30.52	316.41
mineral	0.71	2.28	4.10	6.44	11.33	27.50	316.41
organic	0.56	2.80	5.52	9.29	15.43	36.80	116.77


Available P: Data Points
Mineral soils
(mg/l):
<= 3
3.1 - 6
6.1 - 10
> 10
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Available P: Data Points
Organic soils
(mg/l):
<= 10
10.1 - 20
20.1 - 30
> 30
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

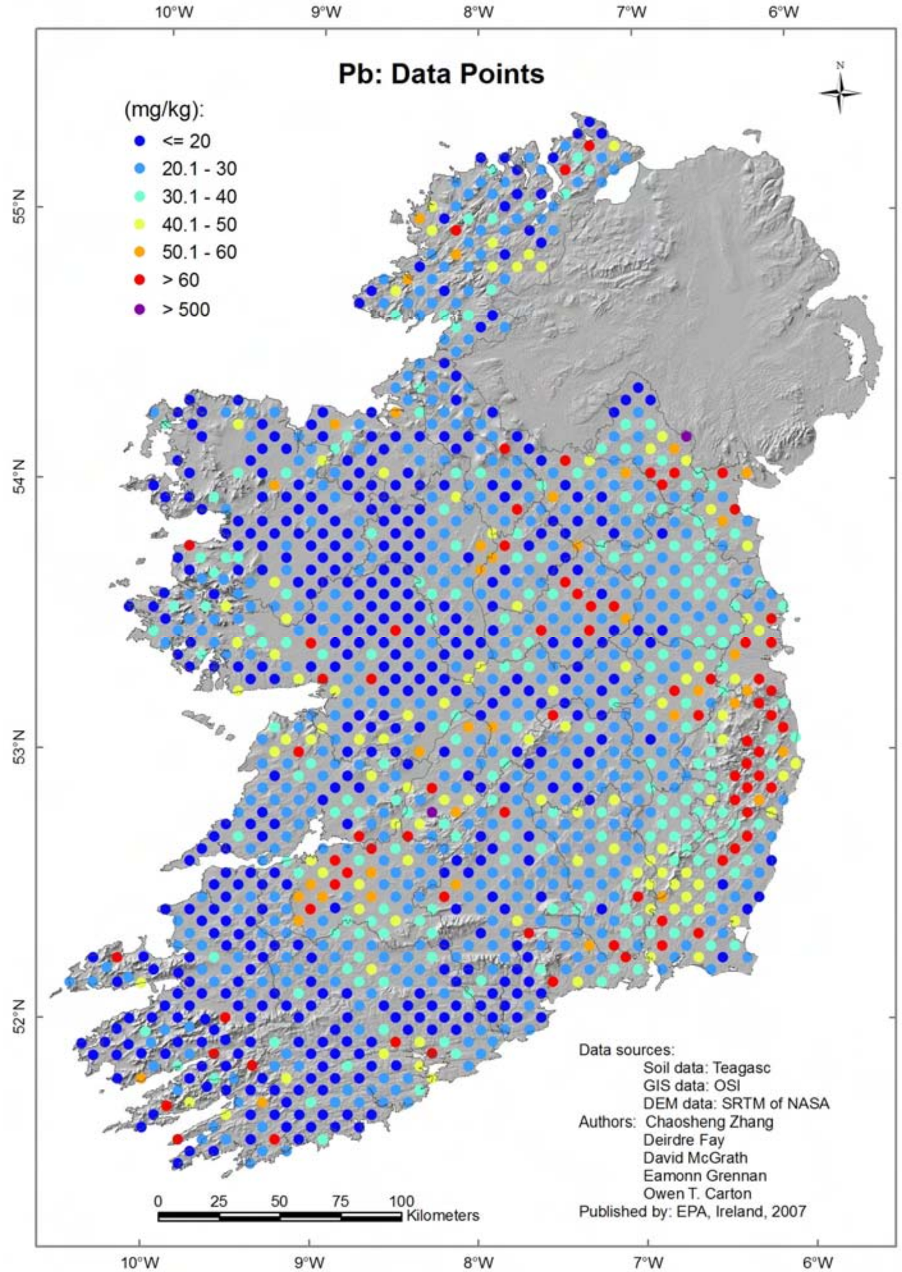
Pb Lead

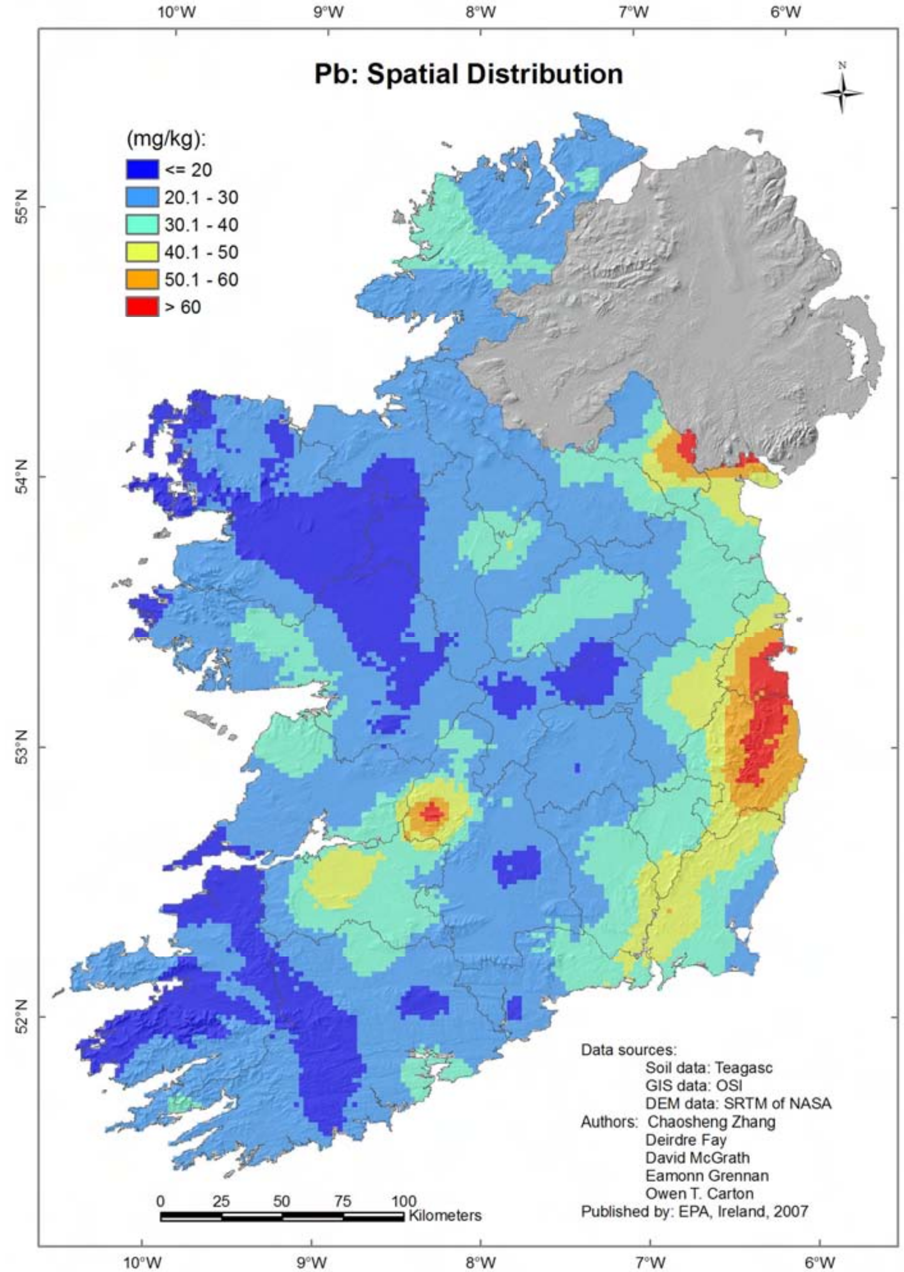
Lead is a heavy, soft metal, often found in ores with Zn and Cu. Although Pb does occur naturally in the environment, it is often introduced by anthropogenic activities. In built-up areas, elevated soil Pb contents are largely related to the past use of leaded petrol, usually confined to areas within short distances (metres) of roadways. High Pb values can also be encountered at target/shooting ranges. Pb is used in ammunition, batteries, glass, organ pipes, electrodes and in computer and television screens. Pb is not essential for humans, animals or plants. It is highly toxic and bio-accumulates in organisms and food chains over time. The limit value for Pb in soils receiving sewage sludge under the EU Sewage Sludge Directive is 50 mg/kg.

Levels of Pb in Dublin and Wicklow exceeding 50mg/kg are attributed to a combination of urbanisation and historical mining activity. Similar levels in the North East can be partly attributed to volcanic material in the greywackes. In Limerick, levels above 40mg/kg are attributed to a regional enhancement, confirming the close relationship between Pb and Zn in this area. Similar levels on the east coast may be attributable to long range transboundary pollution. It has previously been shown that Pb concentrations in Irish agricultural soils are considerably lower than those in urban areas (McGrath, 1995). The median value for Pb reported in this study for mineral soils is similar to those of Northern Ireland (17.9 mg/kg, Jordan *et al.*, 2002) and Scotland (23.2 mg/kg, Paterson *et al.*, 2002). Extreme Pb concentrations measured in Irish soils with values above 500 mg/kg are coincident with local pollution sources. They are found in Tipperary near Silvermines and near Keady Mine in Northern Ireland.

Table showing the minimum and maximum and some of the most important percentiles for total Pb concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	1.1	11.7	18.2	24.8	33.5	61.9	2634.7
mineral	4.8	12.4	18.8	24.8	33.3	61.0	550.9
organic	1.1	9.5	16.4	24.3	33.2	58.1	2634.7


Pb: Data Points
(mg/kg):
<= 20
20.1 - 30
30.1 - 40
40.1 - 50
50.1 - 60
> 60
> 500
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Pb: Spatial Distribution
(mg/kg):
<= 20
20.1 - 30
30.1 - 40
40.1 - 50
50.1 - 60
> 60
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

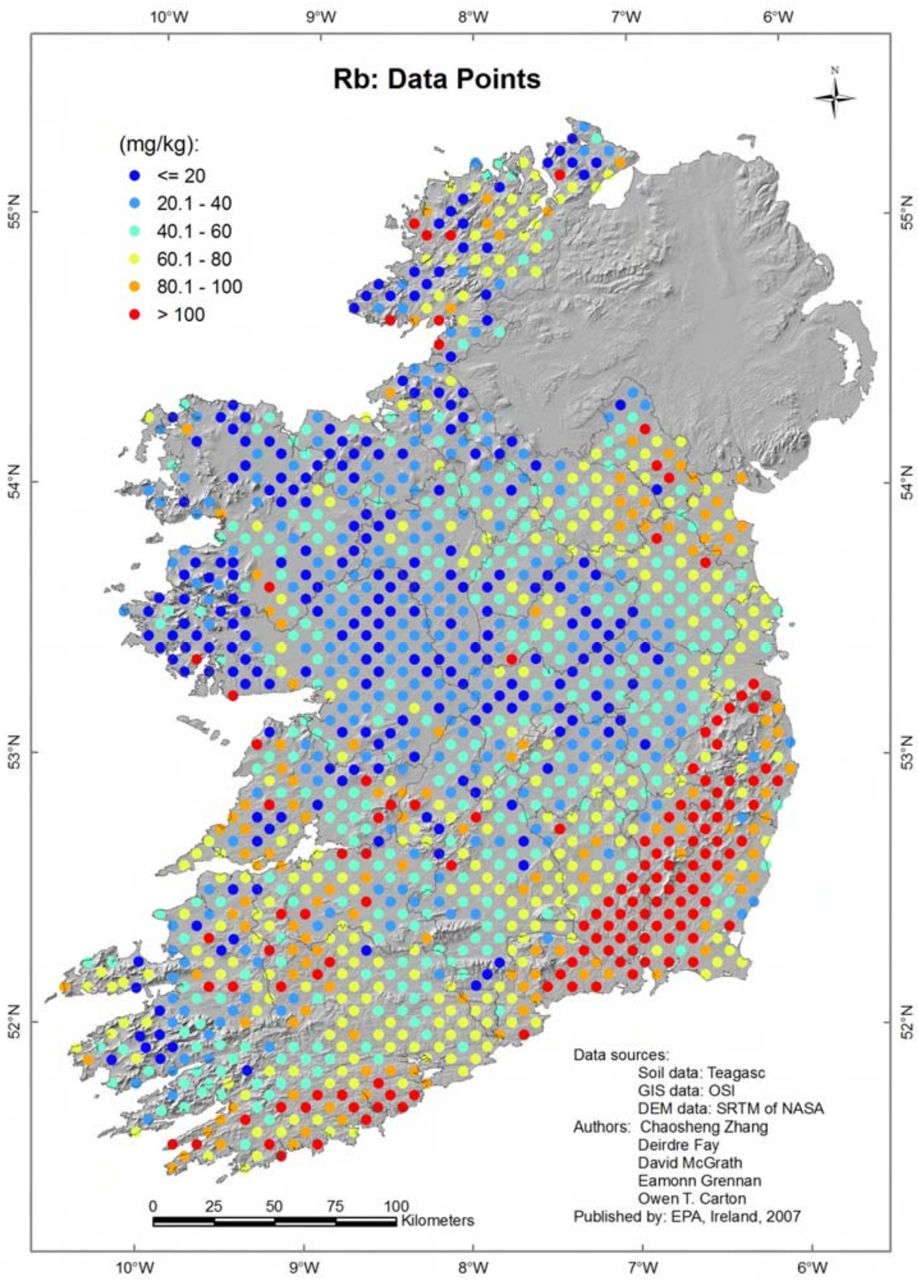
Rb Rubidium

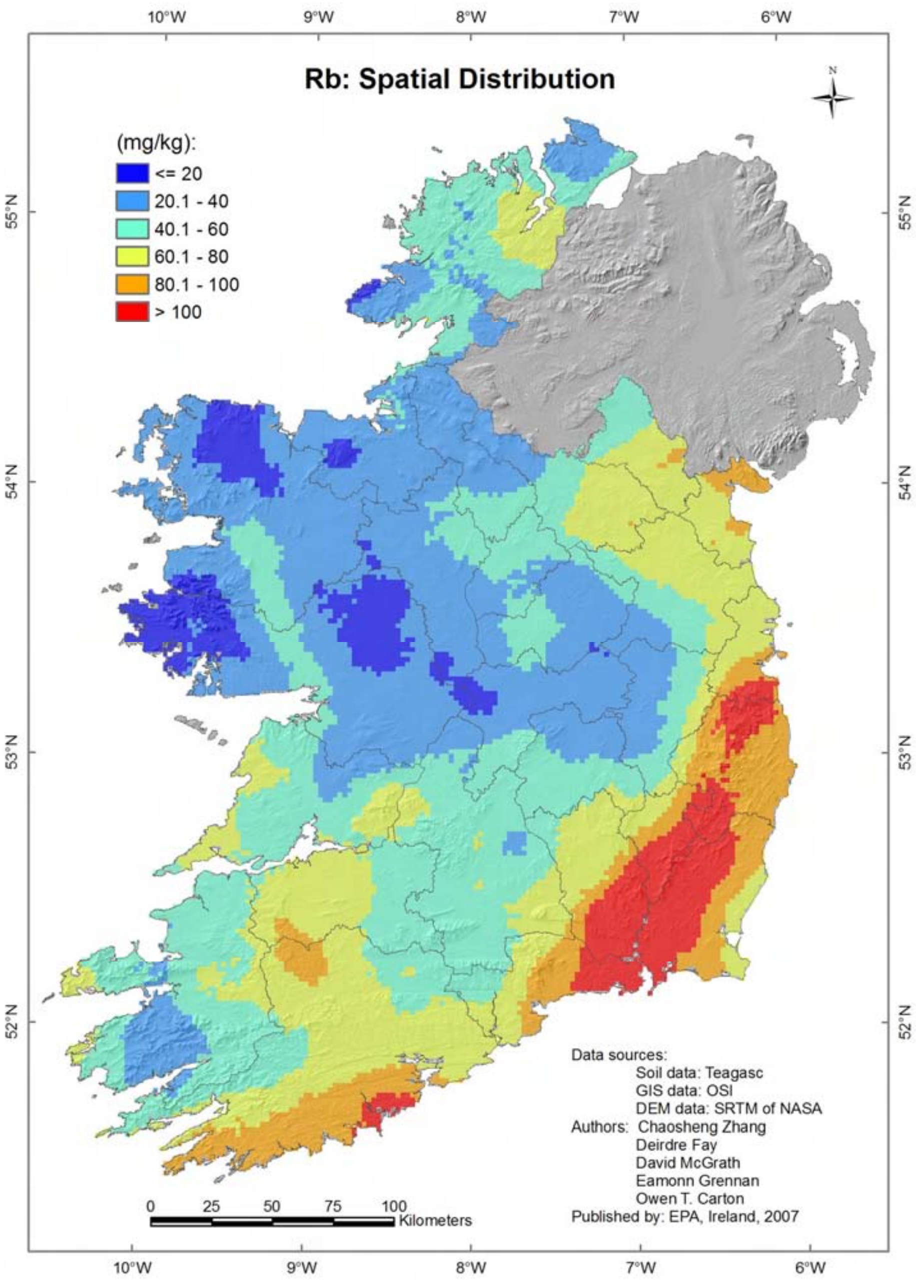
Rubidium is an alkali metal similar to K (below it in the periodic table) and the two elements generally correlate. It has few commercial uses, but is present in some glasses and ceramics and is sometimes used to give fireworks a purple colour. It is also used to remove residual gases from vacuum tubes. Rb is not known to play any major biological role. Plants suffering from K-deficiency may take up Rb instead. Rb is only toxic in high doses and is easily removed from the body through perspiration.

Normal concentrations of Rb in soils would be around 100 mg/kg (Helmke and Sparks, 1996). The distribution of Rb in Ireland closely mirrors that of K and the two elements correlate well (r_{min} = 0.90). Levels of Rb above 60 mg/kg in Irish soils are coincident with the greywackes in the North East and greywackes and igneous rocks in the South East as well as with sandstones and shales in Cork, Kerry, Limerick and Clare and Ca-rich schists in Donegal. Levels below 40 mg/kg are associated with Peats, Lithosols and Podzols in mountain and hill areas and Grey Brown Podzolics and Peats on limestone bedrock.

Table showing the minimum and maximum and some of the most important percentiles for total Rb concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	0.60	2.20	29.80	53.50	75.70	117.50	222.00
mineral	4.10	25.80	45.70	61.80	80.60	121.60	222.00
organic	0.60	1.20	2.60	10.60	28.80	75.00	163.30


Rb: Data Points
(mg/kg):
<= 20
20.1 - 40
40.1 - 60
60.1 - 80
80.1 - 100
> 100
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers


Rb: Spatial Distribution
(mg/kg):
<= 20
20.1 - 40
40.1 - 60
60.1 - 80
80.1 - 100
> 100
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers

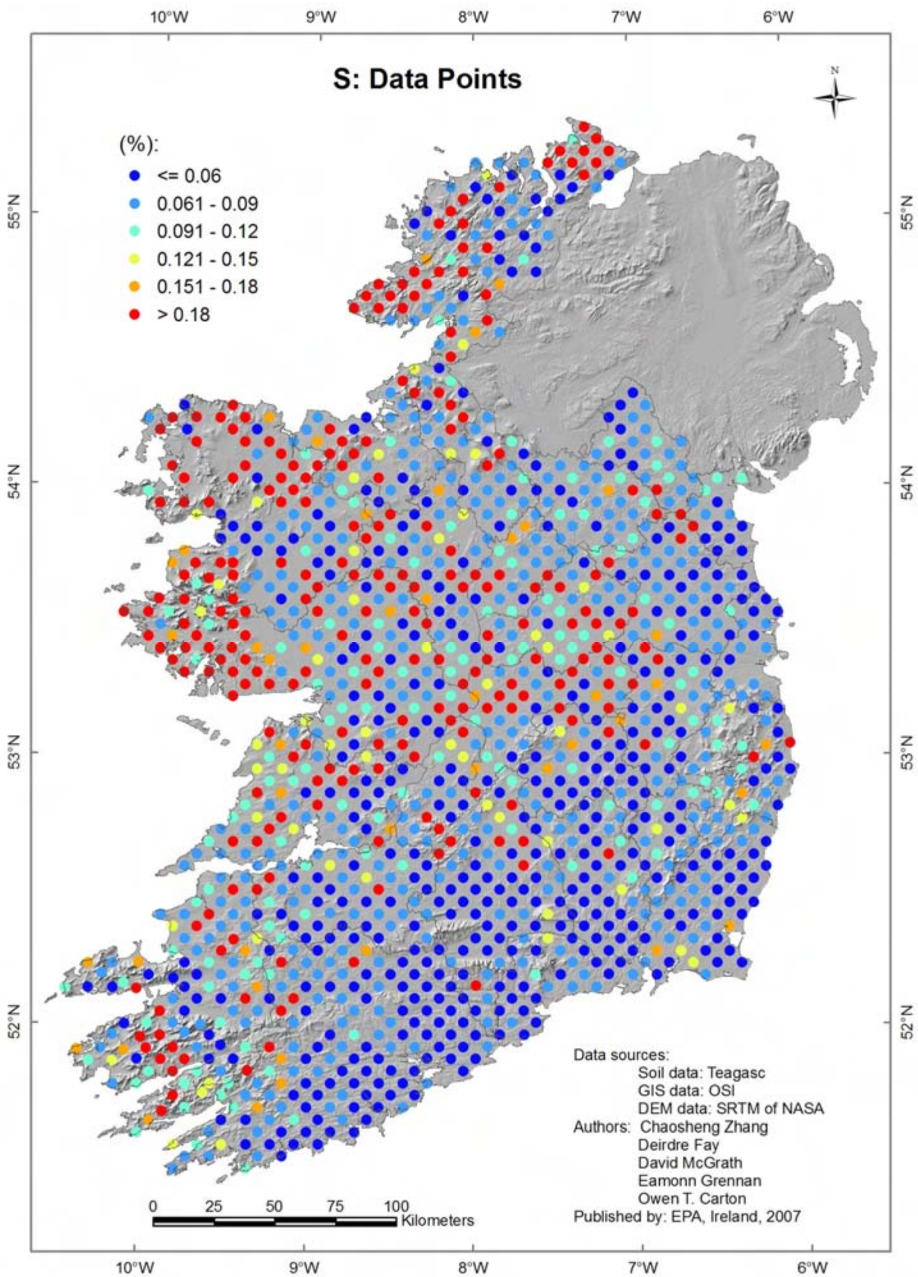
S Sulphur

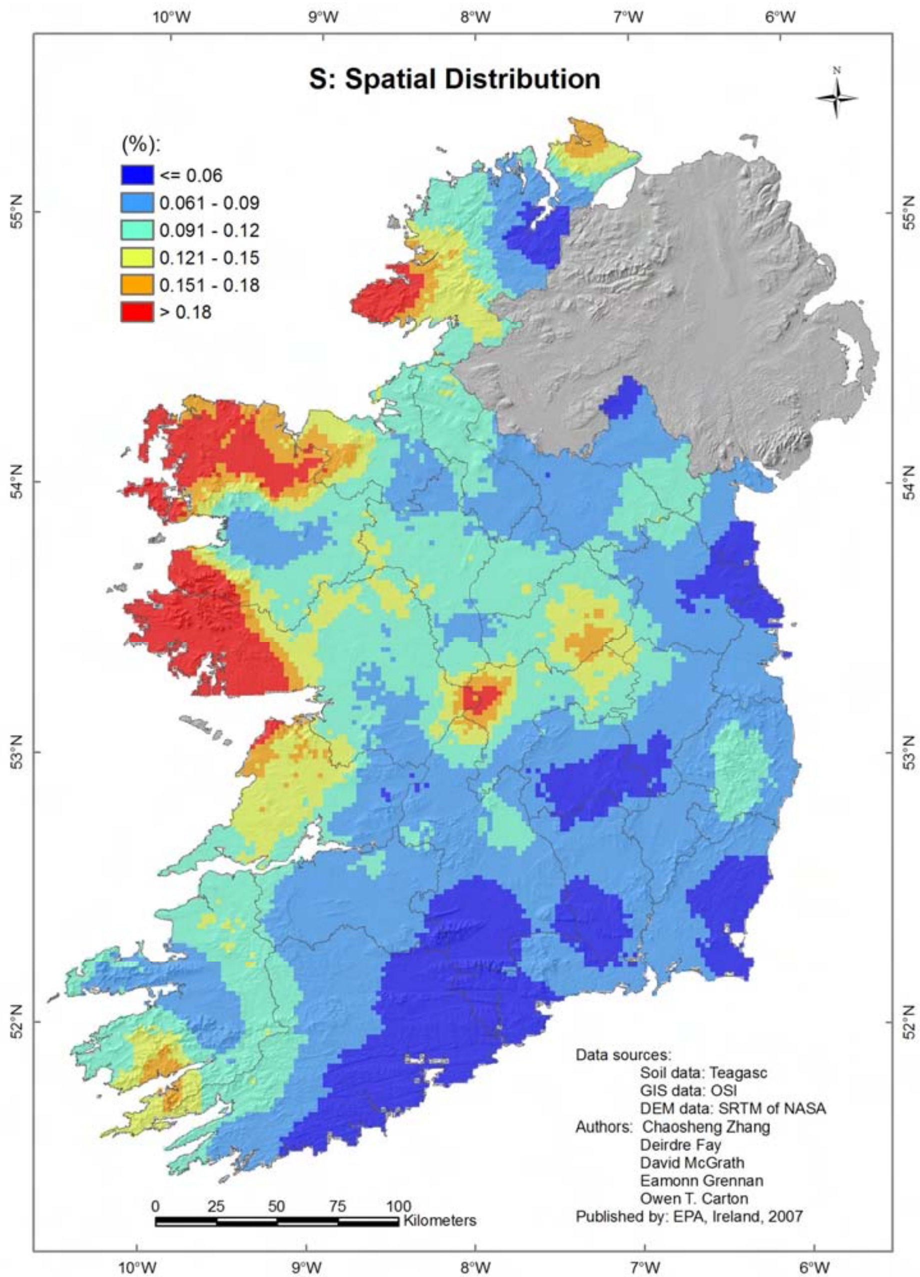
Sulphur is a non-metal which occurs as a pure element or in sulfate and sulfide minerals. Elemental S occurs naturally near volcanoes and hot springs. It is introduced into the environment as SO_2 on the burning of fossil fuels from which the S has not been extracted. SO_2 combines with water to form acid rain. S has many commercial uses including fertilizer production, oil refining processes, batteries, matches, insecticides and as a preservative in wine. S is a necessary component of all living cells. It is a component of the amino acids cysteine and methionine, contained in all polypeptides, proteins, and enzymes. Elemental S is not toxic, but some of its compounds are.

Most soils contain between 0.01% and 0.05% S (Tabatabai, 1996). The distribution of S in Irish soils is interesting in that its pattern is opposite to the commonly occurring pattern illustrated by Al. The Pearson's correlation coefficient for S and SOC reflects the strong relationship between organic soils and S concentrations (r_{min} = 0.82). Levels of S above 0.15% in Peat soils in the West, North West and midlands are mostly a result of the high organic matter content. There may also be some effect of oceanic deposition in the West and North West. Levels of S below 0.09% are coincident with arable land in the South East of Ireland and county Cork on the Grey Brown Podzolics and Acid Brown Earth soils underlain by sandstones and shales.

Table showing the minimum and maximum and some of the most important percentiles for total S concentrations in %

	min	5%	25%	50%	75%	95%	max
all soils	0.01	0.04	0.06	0.07	0.13	0.32	0.70
mineral	0.01	0.03	0.05	0.06	0.08	0.12	0.29
organic	0.03	0.11	0.17	0.23	0.31	0.43	0.70


S: Data Points
(%):
<= 0.06
0.061 - 0.09
0.091 - 0.12
0.121 - 0.15
0.151 - 0.18
> 0.18
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


S: Spatial Distribution
(%):
<= 0.06
0.061 - 0.09
0.091 - 0.12
0.121 - 0.15
0.151 - 0.18
> 0.18
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

Sb Antimony

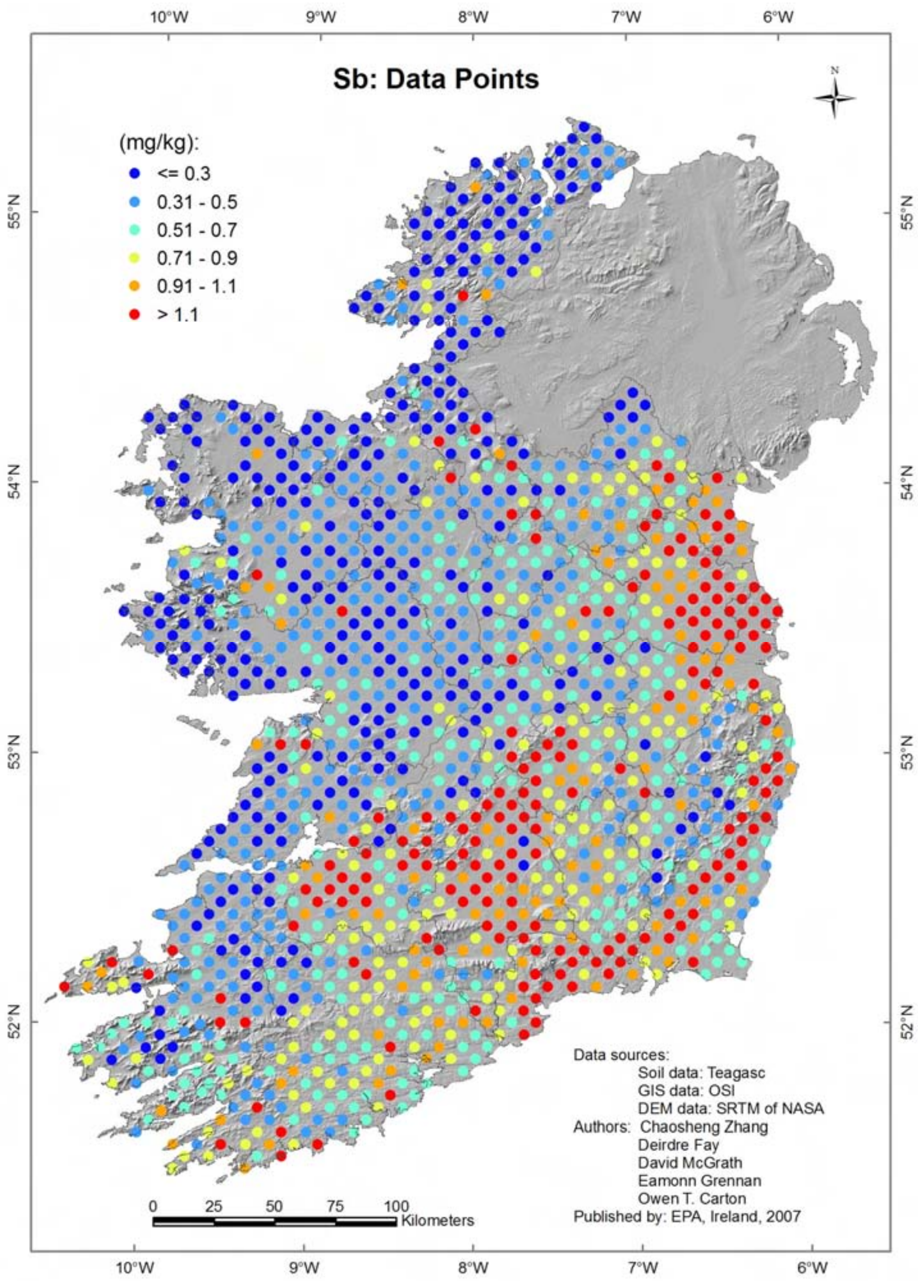
Antimony is a rare element, and is usually found in the sulfide stibnite. It is present in trace amounts in many different minerals. Some examples for uses of the metal and its compounds are: alloys, batteries, ammunition, plumbing, flame retardants, veterinary preparations and safety matches. It has no known biological role. Sb and many of its compounds are toxic with clinical effects similar to As in humans.

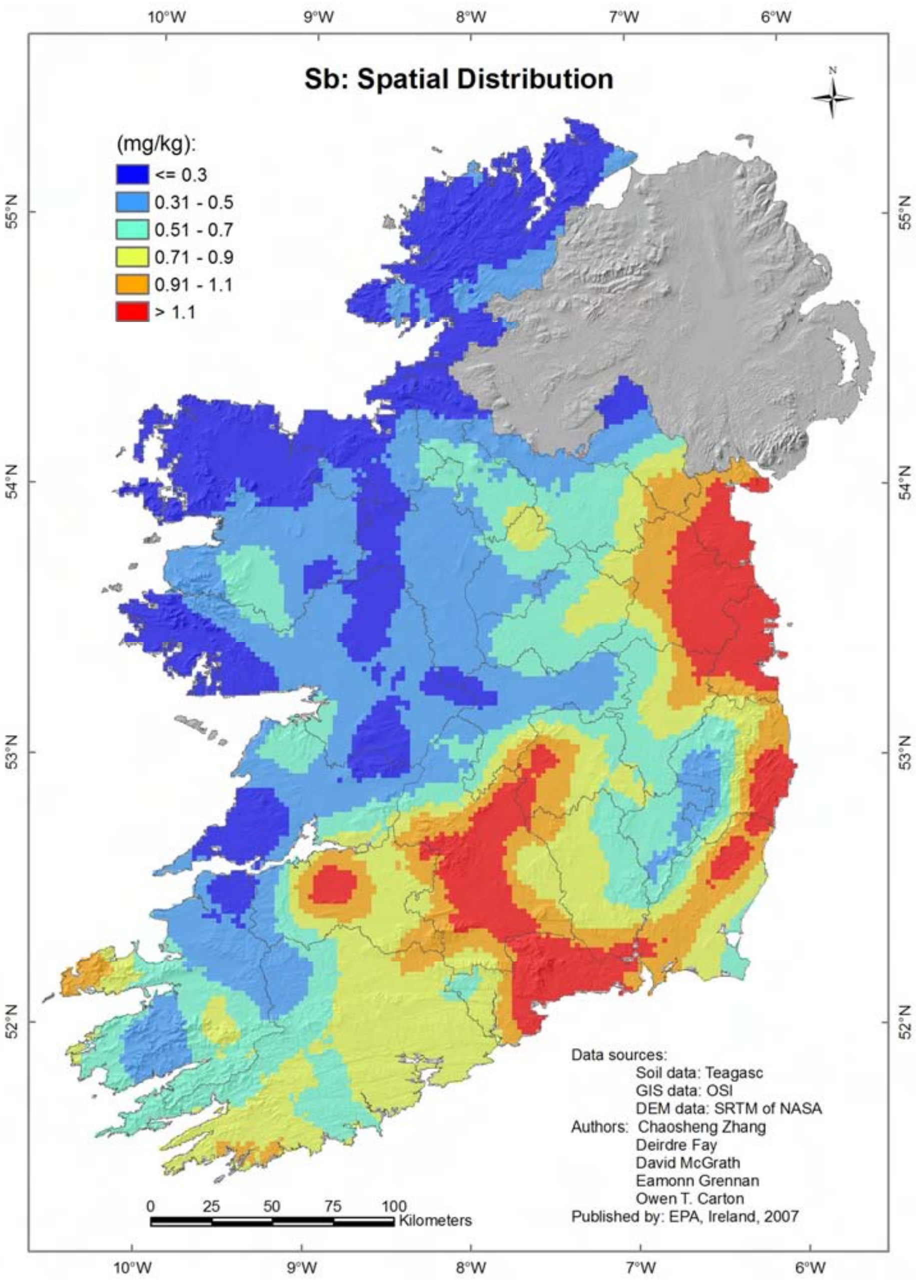
Background concentrations of 3 mg/kg were reported for Sb by Crommentuijn (1997) for unpolluted soils in the Netherlands. The levels of Sb measured in Irish soils were all low, with 95% of the samples having a concentration of less than 1.54 mg/kg and 2% of the samples below the detection limit of 0.05 mg/kg. Relatively high levels of Sb (>0.7mg/kg) were measured in the South East and the South, and in Waterford and Tipperary, whereas the lower levels (<0.3mg/kg) were measured in the North and North West. There is no apparent association with a specific rock or soil type in the distribution of Sb and it did not show a strong correlation in its distribution with any of the other measured elements.

Table showing the minimum and maximum and some of the most important percentiles for total Sb concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<0.05**	0.10	0.31	0.53	0.85	1.54	5.29
mineral	<0.05**	0.19	0.39	0.62	0.94	1.65	4.80
organic	<0.05**	0.03	0.17	0.29	0.47	0.97	5.29

**30 samples analysed were below the detection limit of 0.05 mg/kg for Sb


Sb: Data Points
(mg/kg):
<= 0.3
0.31 - 0.5
0.51 - 0.7
0.71 - 0.9
0.91 - 1.1
> 1.1
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Sb: Spatial Distribution
(mg/kg):
<= 0.3
0.31 - 0.5
0.51 - 0.7
0.71 - 0.9
0.91 - 1.1
> 1.1
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

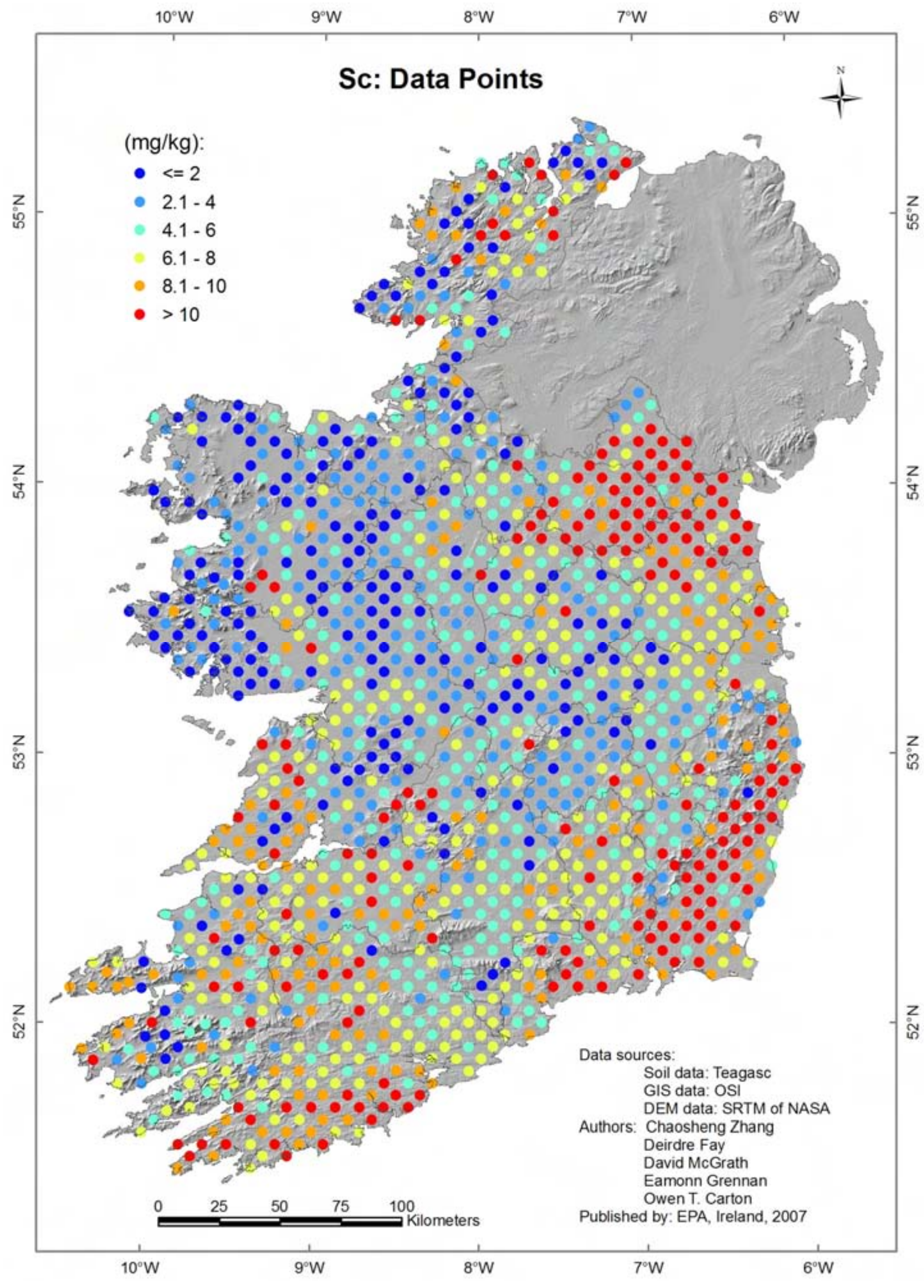
Sc Scandium

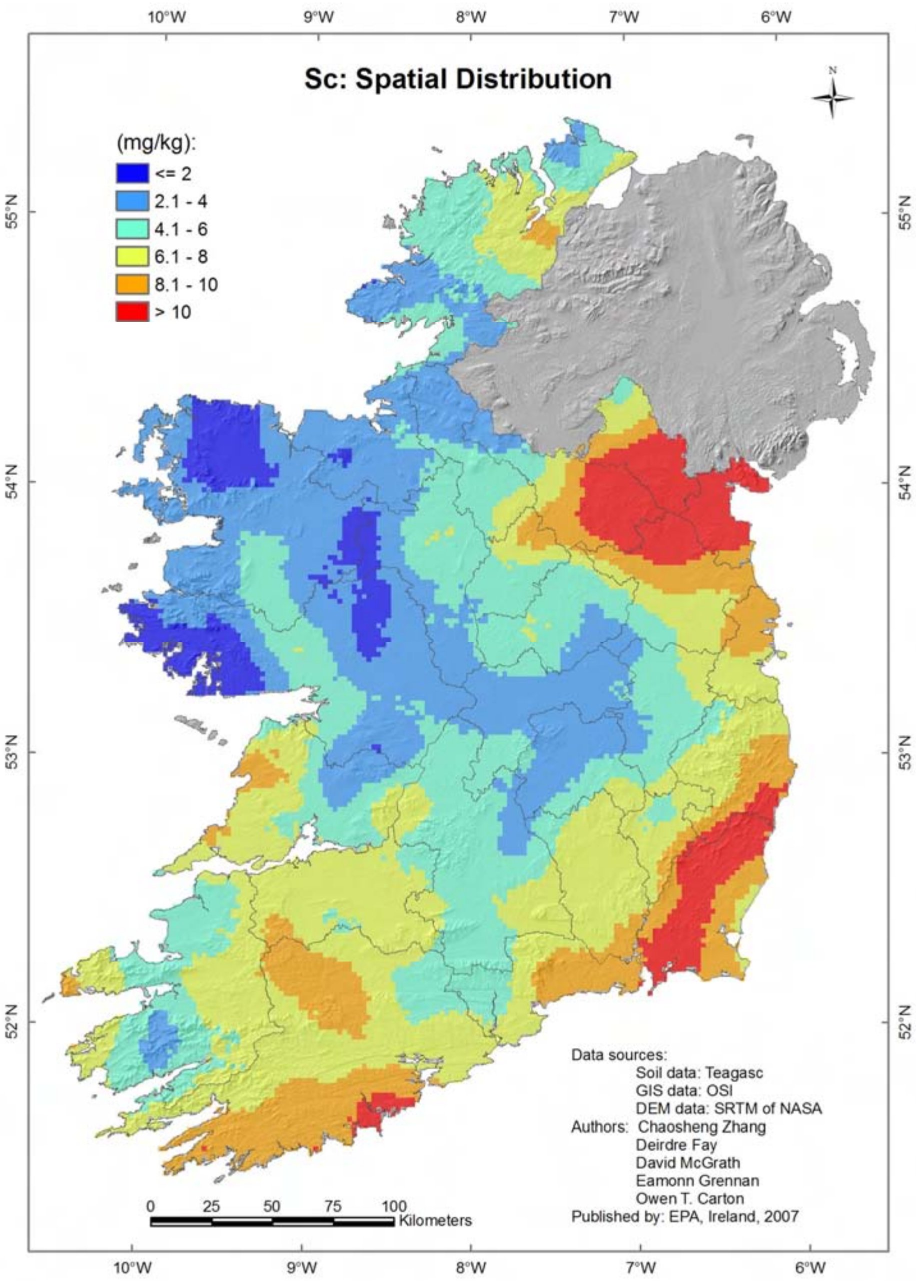
Scandium is a rare element which only occurs naturally in trace amounts in minerals. Similarly to Y it is used in household appliances such as colour televisions and fluorescent lamps. It is used in Al alloys for aero-space technology and sports equipment. Sc has not been found to play any biological role in organisms. It is not thought to be toxic, however it does form gases which, when inhaled, will have negative health effects.

Levels of Sc above 8mg/kg in Irish soils are coincident with the greywackes in the North East and greywackes and igneous rocks in the South East as well as with sandstones and shales in Cork, Kerry, Limerick and Clare and Ca-rich schists in Donegal. Levels below 4 mg/kg are associated with Peats, Lithosols and Podzols in mountain and hill areas and Grey Brown Podzolics and Peats on limestone bedrock.

Table showing the minimum and maximum and some of the most important percentiles for total Sc concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<0.1*	0.36	3.34	5.85	8.37	12.33	17.11
mineral	0.72	2.63	4.80	6.71	9.17	12.77	17.11
organic	<0.1*	0.20	0.40	1.33	3.72	8.34	13.80


Sc: Data Points
(mg/kg):
<= 2
2.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10
> 10
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Sc: Spatial Distribution
(mg/kg):
<= 2
2.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10
> 10
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

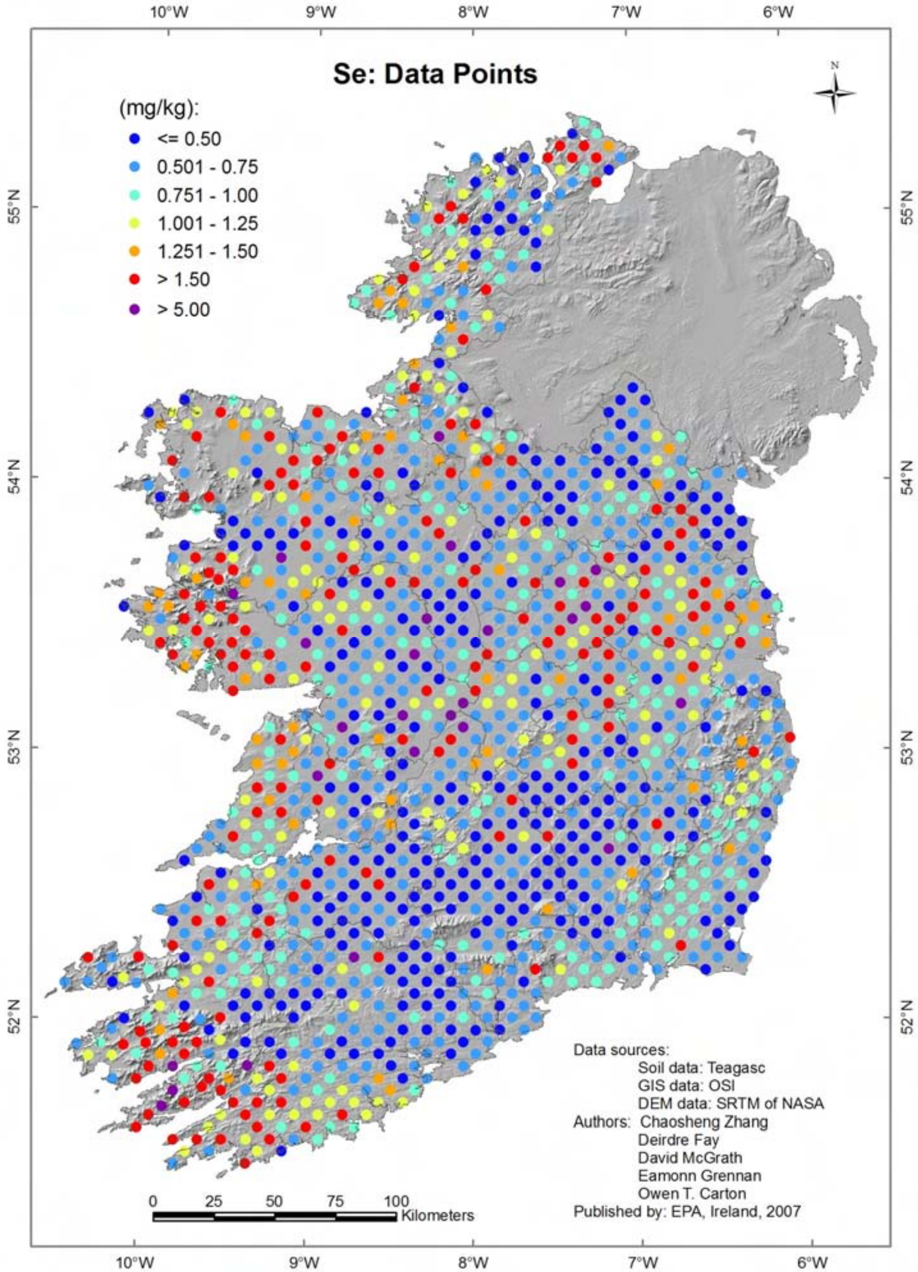
Se Selenium

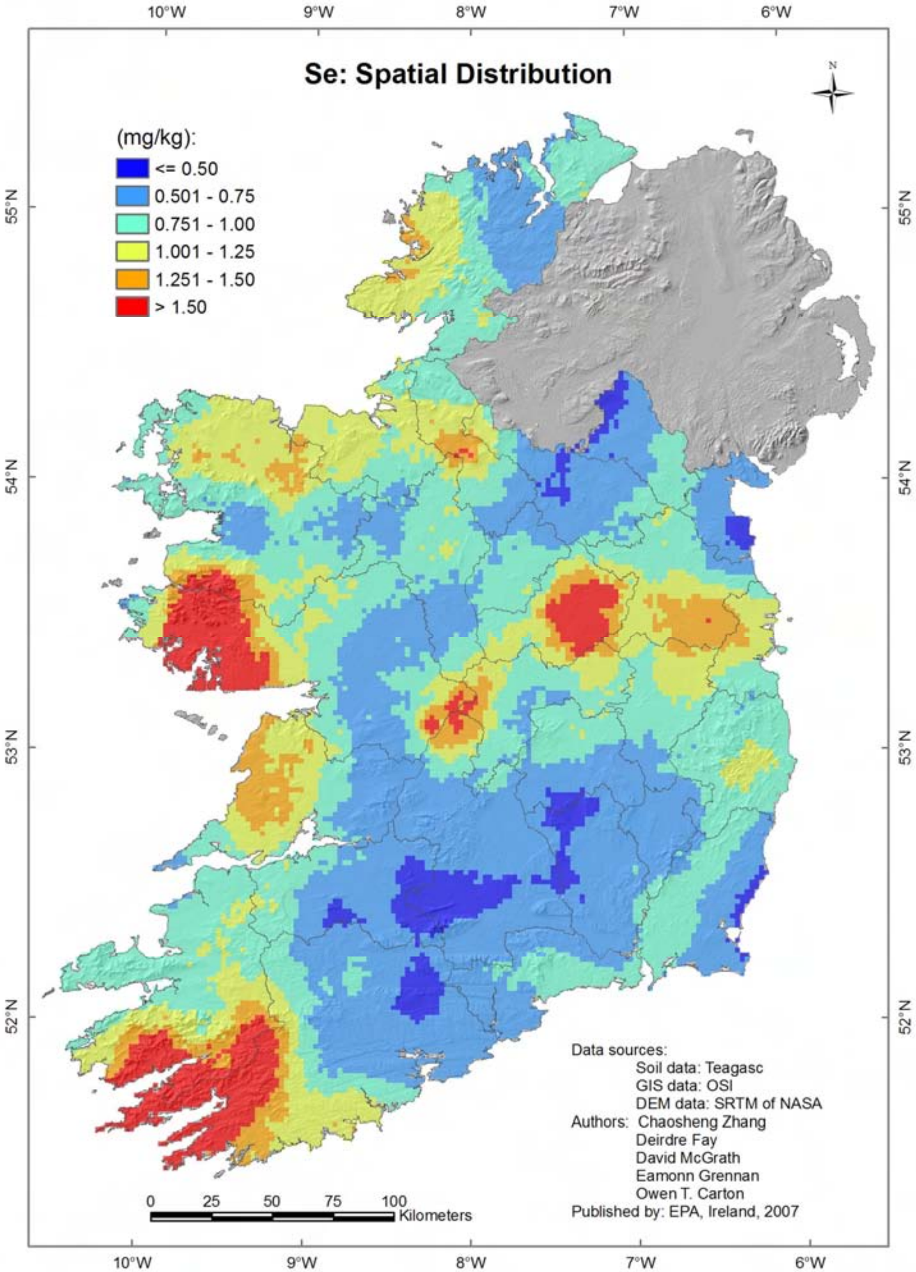
Selenium is a non-metal, similar in its chemical properties to S. Although not common, it occurs naturally in the environment but is also introduced through coal burning and the mining and smelting of sulfide ores. Se is used in the glass industry, in food supplements, vulcanized rubbers, photography, light cells and solar cells. It is naturally present in soils and is added with phosphate fertilizer, in which it is present. Se is an essential trace element for all animals and many plants although the required amounts are not known. However, high Se concentrations in soils can have a toxic effect on grazing animals. These effects include loss of hair and cracking of hooves, which can cause permanent damage and even death.

An average Se concentration of 0.4 mg/kg was reported for 1623 soils taken worldwide by Ure and Berrow (1982). Background concentrations of 0.7mg/kg were reported for Se by Crommentuijn (1997) for unpolluted soils in the Netherlands. Levels of Se above 1mg/kg in Irish soils are found in areas with underlying impure limestone geology, such as Dublin, Meath, Westmeath, west Offaly, east Galway and north Tipperary. The Se toxic areas of Meath were already known in the 19th century, though the identity of the toxic element was not known and early writings refer to 'the poisoned lands of Meath' (Fream, 1890). Geochemically, lower Se levels would be expected on soils formed from sandstone, granite, the purer limestones, and soils developed on glacial and fluvio-glacial sands and gravels. Levels of Se below 1mg/kg in Irish soils are found in the South and East of the country, in Louth and in coastal areas in Wexford, which encompasses marine derived glacial soils. Relatively low Se levels also occur in parts of east Galway and east Clare on light-textured soils. Fleming (1978) measured Se in about 50% of the 678 geo-referenced mineral soils collected by Brogan (1966). There was a good correspondence between those data and the data collected for this atlas.

Table showing the minimum and maximum and some of the most important percentiles for total Se concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	0.08	0.34	0.51	0.74	1.14	2.67	17.44
mineral	0.08	0.33	0.46	0.65	0.90	1.87	6.72
organic	0.23	0.64	0.96	1.31	2.06	6.08	17.44


Se: Data Points
(mg/kg):
<= 0.50
0.501 - 0.75
0.751 - 1.00
1.001 - 1.25
1.251 - 1.50
> 1.50
> 5.00
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100
Kilometers


Se: Spatial Distribution
(mg/kg):
<= 0.50
0.501 - 0.75
0.751 - 1.00
1.001 - 1.25
1.251 - 1.50
> 1.50
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100
Kilometers

Sn Tin

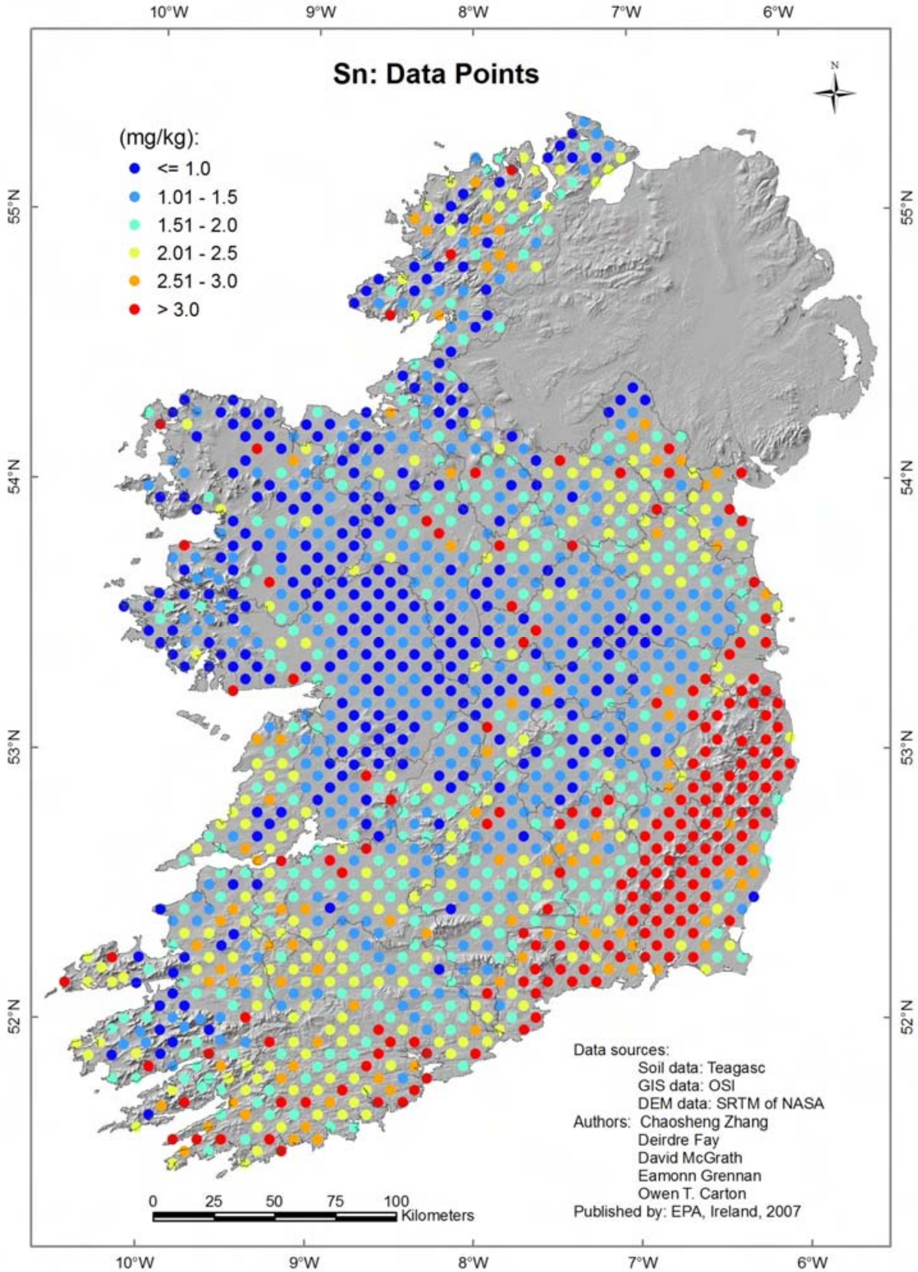
Tin is a metal which does not easily corrode. It is often used to coat other metals and thus reduce their corrodibility, as in tin cans. Sn is also used in super-conducting magnets, ceramics, in solders, in the paint and plastic industry and in bactericides and fungicides. Sn is an essential element for rats. Whilst the metal Sn is not toxic in normally occurring concentrations, most organic tin compounds are toxic and do not biodegrade well.

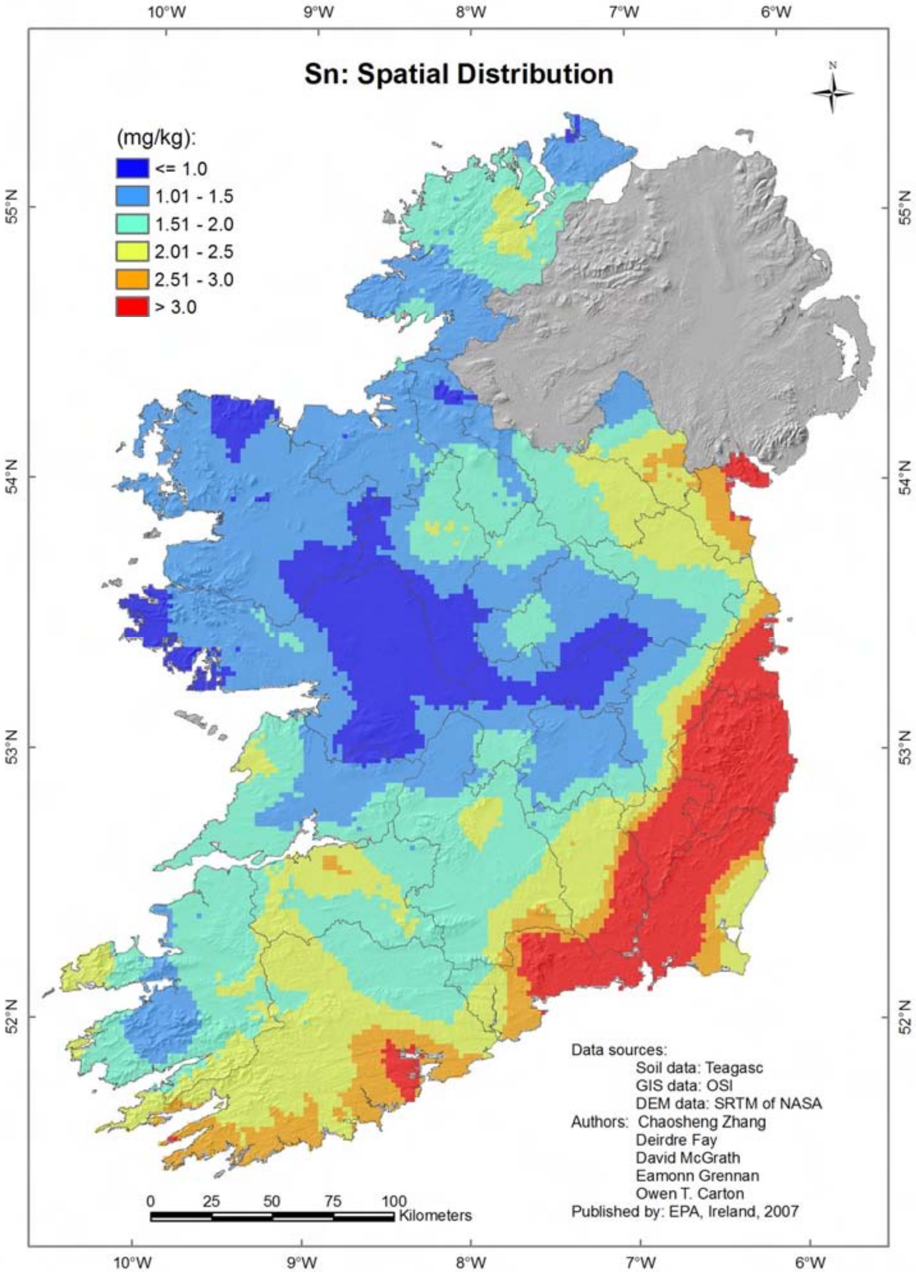
Levels of Sn above 2.5 mg/kg in Irish soils seem to be particularly associated with Brown Podzolics and Acid Brown Earths. They are also coincident with the greywackes in the North East and associated with the Leinster Granite. Possible anthropogenic derived enrichment can be seen in Dublin and Cork. Levels of Sn (<2 mg/kg) are especially evident in soils underlain by limestone and in Peat soils in Galway and Mayo.

Table showing the minimum and maximum and some of the most important percentiles for total Sn concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<0.2**	0.54	1.12	1.68	2.34	4.72	17.84
mineral	0.33	0.83	1.30	1.85	2.47	5.08	17.84
organic	<0.2**	0.26	0.63	1.00	1.59	3.14	13.07

**10 samples analysed were below the detection limit of 0.2 mg/kg for Sn


Sn: Data Points
(mg/kg):
<= 1.0
1.01 - 1.5
1.51 - 2.0
2.01 - 2.5
2.51 - 3.0
> 3.0
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers


Sn: Spatial Distribution
(mg/kg):
<= 1.0
1.01 - 1.5
1.51 - 2.0
2.01 - 2.5
2.51 - 3.0
> 3.0
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers

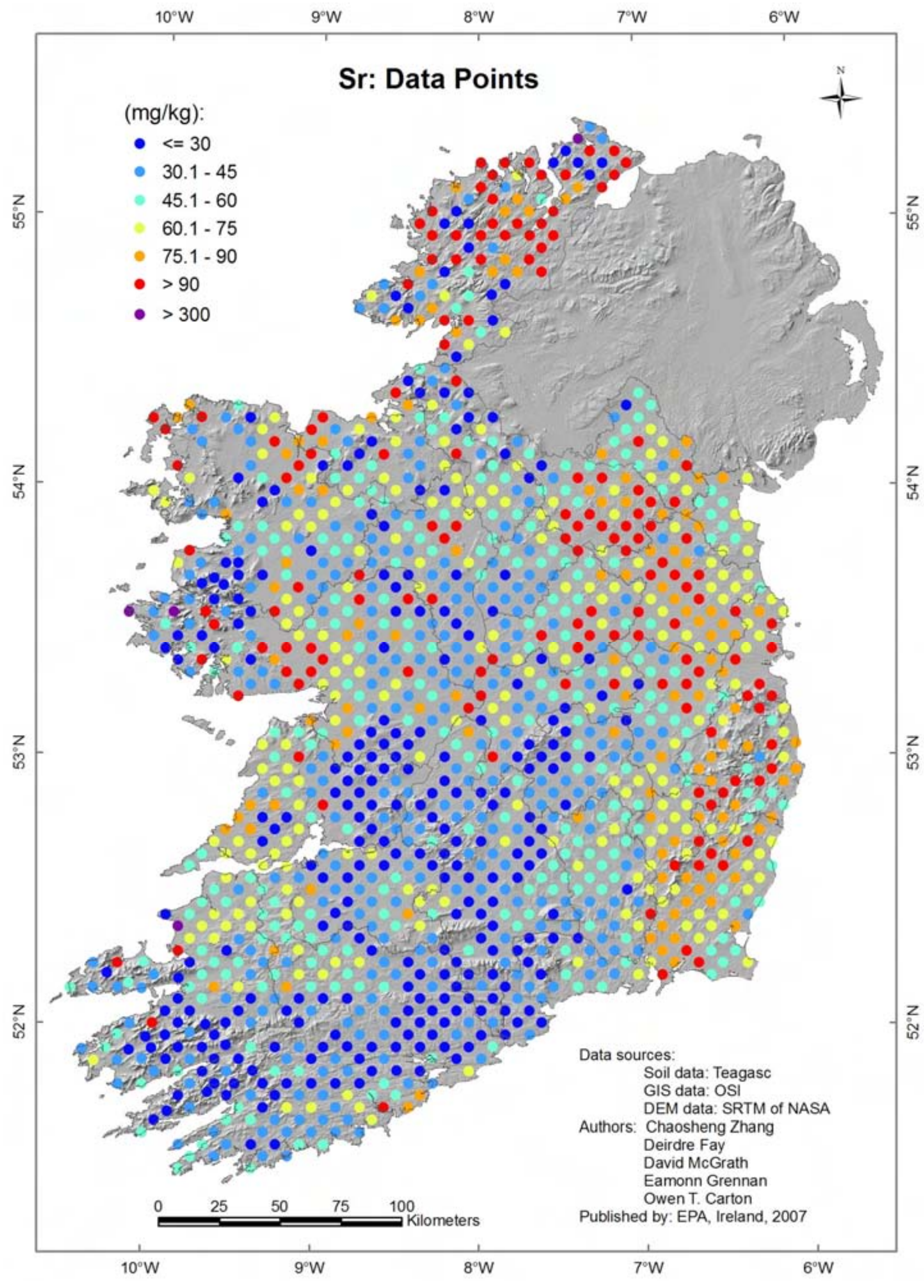
Sr Strontium

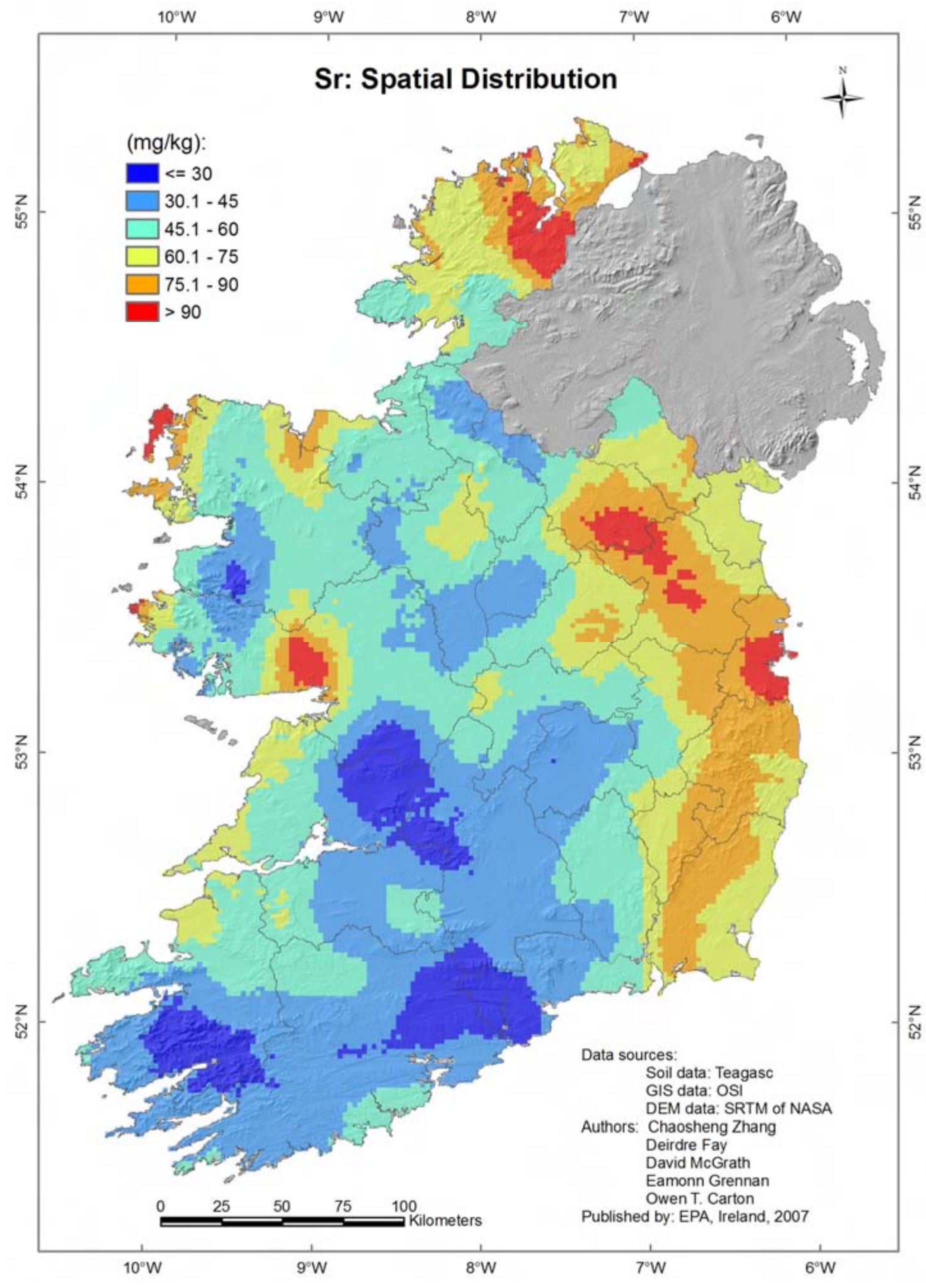
Strontium is chemically and physically very similar to its neighbouring elements on the periodic table, Ca and Ba. It occurs naturally in many igneous rocks, and as dust in the atmosphere. Sr is introduced into the atmosphere by fossil fuel burning. It is used in Al alloys, colour television tubes, toothpaste and pyrotechnics. Medical applications include cancer radiotherapy and treatments for osteoporosis. Sr has no known biological role. It is absorbed by the body in the same way as Ca. Therefore the radioactive isotope Sr-90, a component in nuclear reactor (or bomb) waste which does not occur naturally, is highly harmful, but common Sr is harmless.

Background concentrations of Sr in soils are reported to be around 300 mg/kg (Ure, 1991). Sr does not appear to have a clearly similar distribution to any other element, although it follows the typical pattern for Al locally on the east coast and in Donegal. Levels above 75 mg/kg in Irish soils are attributed to the greywackes in the North East, greywackes and igneous rocks in the South East, and Ca-rich schists in Donegal. There appears to be a possible oceanic influence in the west, although the Peat soils in Galway and Mayo have low levels of Sr. Levels below 60 mg/kg seem to be associated with Peats, Podzols and Brown Podzolics except in the South East and in Donegal.

Table showing the minimum and maximum and some of the most important percentiles for total Sr concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	9.2	20.7	32.5	49.7	70.1	115.0	1252.5
mineral	11.1	23.4	36.7	53.2	72.6	113.9	1252.5
organic	9.2	17.1	25.7	35.8	60.5	117.3	195.6


Sr: Data Points
(mg/kg):
<= 30
30.1 - 45
45.1 - 60
60.1 - 75
75.1 - 90
> 90
> 300
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Sr: Spatial Distribution
(mg/kg):
<= 30
30.1 - 45
45.1 - 60
60.1 - 75
75.1 - 90
> 90
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

Ta Tantalum

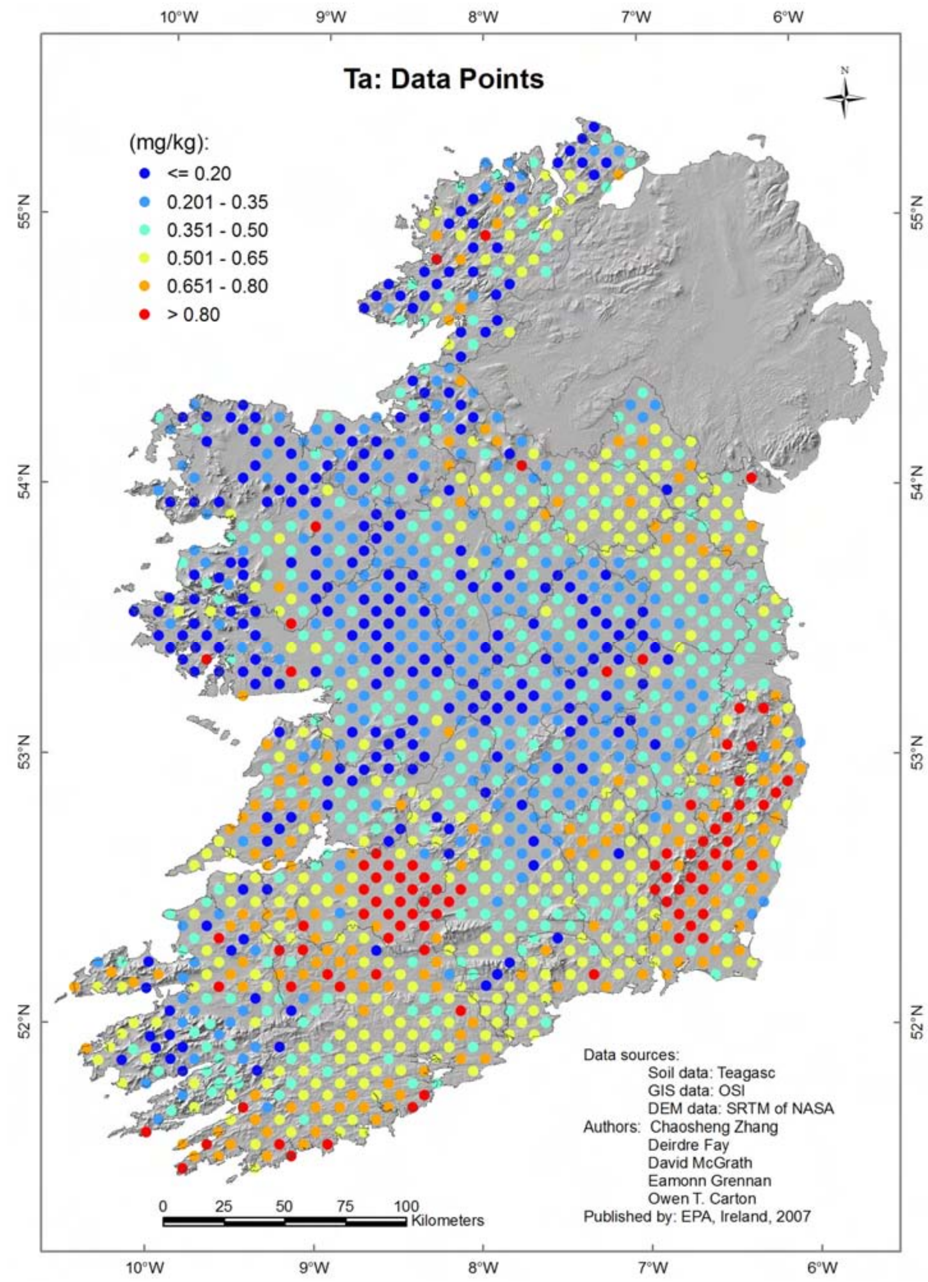
Tantalum is a neighbour element to Nb on the periodic table, is similar to it and mainly occurs naturally in the mineral tantalite. Similarly to Nb, Ta is used for making implants and surgical implements as it does not react with human tissue. It is also used in super alloys for aircraft engines and electrical appliances and in eye-glasses. Ta has no known biological role. Pure Ta can be harmful on inhalation, ingestion or skin contact but is rarely encountered.

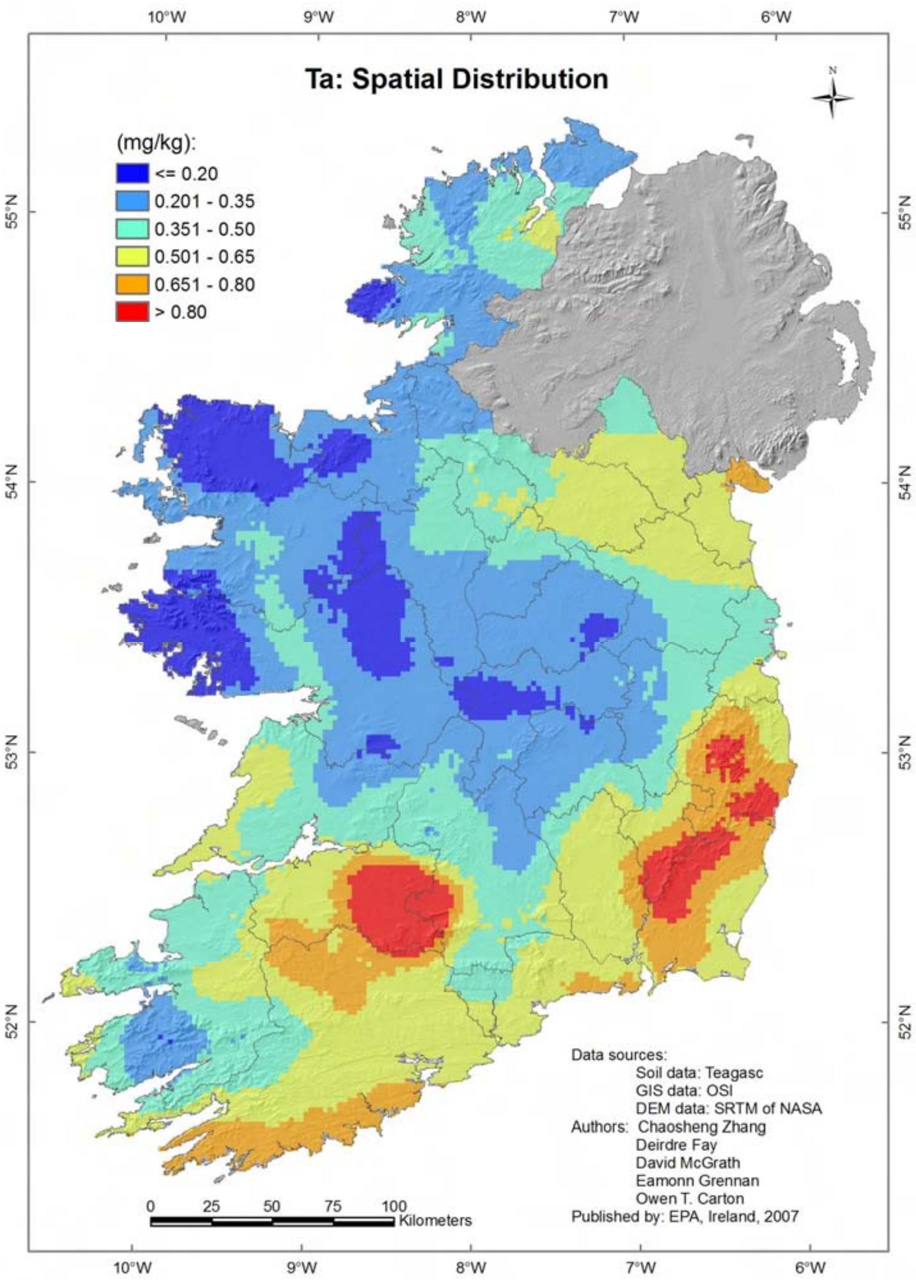
The distribution of Ta in Ireland is very similar to that of Ti (r_{min} = 0.89) and Nb (r_{min} = 0.96). It is a rare metal, which is reflected in Irish soils as 10% of the samples were below the detection limit of 0.05mg/kg. Levels of Ta above 0.65 mg/kg in Irish soils are attributed to the Limerick basalts, greywackes in the North East and greywackes and igneous rocks in the South East. The Brown Earths in Galway also show slightly elevated levels (>0.35 mg/kg) of Ta. Localised elevated Ta concentrations are known to be present along the flanks of the Wicklow mountains. Levels below 0.35mg/kg are coincident with low levels of Nb associated with Peats, Lithosols and Podzols in mountain and hill areas and Grey Brown Podzolics and Peats on limestone bedrock with the exception of the higher values in Limerick.

Table showing the minimum and maximum and some of the most important percentiles for total Ta concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<0.05**	<0.05**	0.27	0.45	0.61	0.85	2.71
mineral	<0.05**	0.24	0.38	0.51	0.64	0.88	2.47
organic	<0.05**	<0.05**	<0.05**	0.09	0.25	0.60	2.71

**129 samples analysed were below the detection limit of 0.05 mg/kg for Ta


Ta: Data Points
(mg/kg):
<= 0.20
0.201 - 0.35
0.351 - 0.50
0.501 - 0.65
0.651 - 0.80
> 0.80
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100
Kilometers


Ta: Spatial Distribution
(mg/kg):
<= 0.20
0.201 - 0.35
0.351 - 0.50
0.501 - 0.65
0.651 - 0.80
> 0.80
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100
Kilometers

Th Thorium

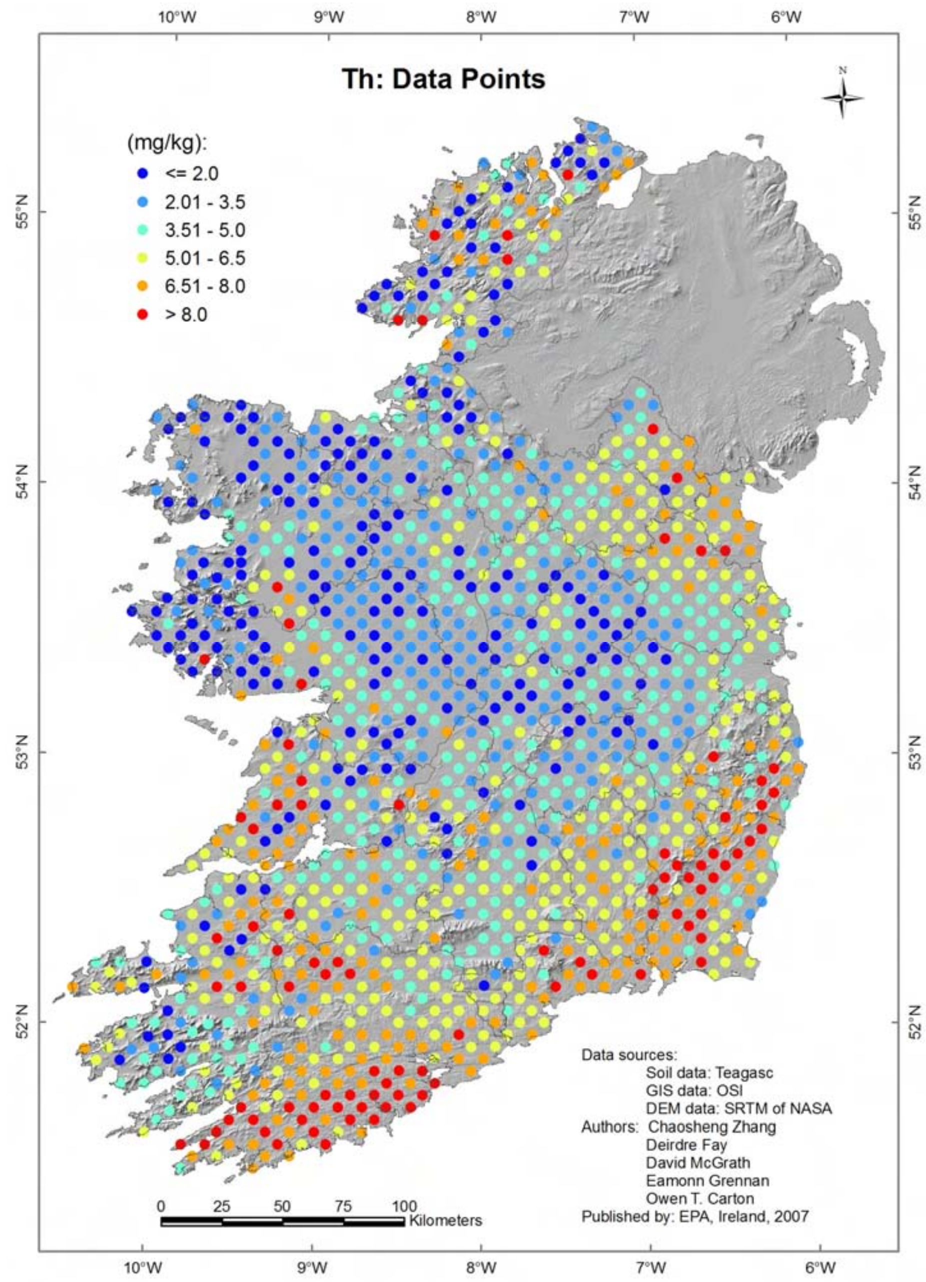
Th is a slightly radioactive metal which occurs naturally in the environment. It is found in most soils and rocks, and is more abundant than U. Th is used in Mg alloys and as a coating for W wire in electrical appliances and Th oxide is used in high temperature laboratory crucibles. It is potentially a good fuel for nuclear reactors. Th has no known biological role. Natural Th decays slowly, and the alpha radiation which it emits does not penetrate human skin, although it will penetrate organ walls if ingested. Inhalation of aerosolized Th is more dangerous than ingestion and is carcinogenic. Th has no known biological role.

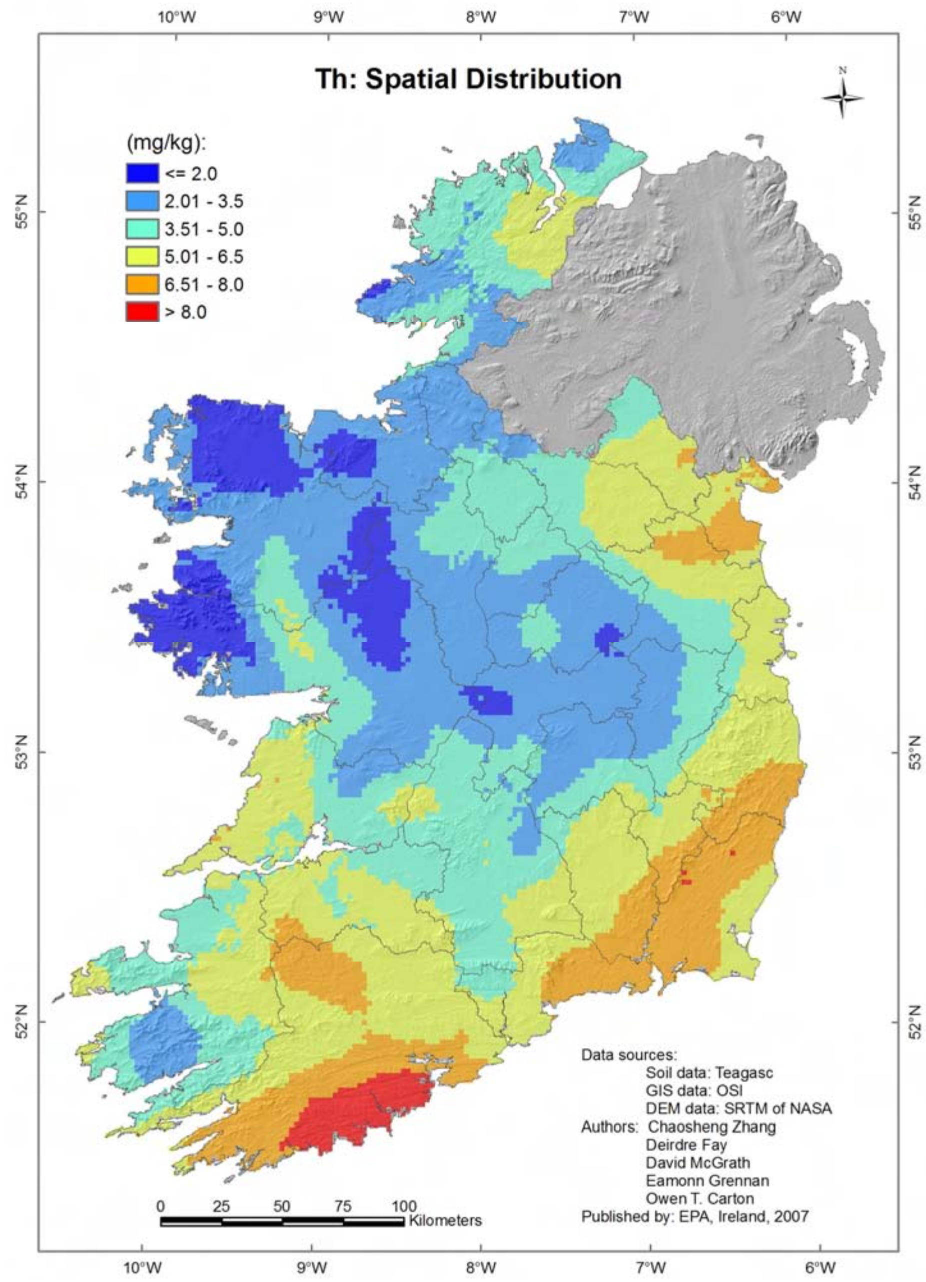
Levels of Th in Irish soils closely follow the Ce (r_{min} = 0.91) and La (r_{min} = 0.88) levels. The three elements are all present in the mineral monazite. Their distribution in Irish soils is similar to that of Al. Levels above 5mg/kg are coincident with the greywackes in the North East and greywackes and igneous rocks in the South East and with sandstone and shale in Cork, Limerick and Clare. Relatively high levels in Donegal are coincident with Ca rich schists and high levels here coincide with high levels of Ba and Sr. Levels below 3.5 mg/kg are associated with Peats, Lithosols and Podzols in mountain and hill areas and Grey Brown Podzolics and Peats on limestone bedrock.

Table showing the minimum and maximum and some of the most important percentiles for total Th concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<0.1**	0.25	2.91	4.65	6.28	8.50	11.15
mineral	0.57	2.53	3.96	5.37	6.65	8.66	11.15
organic	<0.1**	0.13	0.31	1.10	2.98	6.26	9.73

**6 samples analysed were below the detection limit of 0.1 mg/kg for Th


Th: Data Points
(mg/kg):
<= 2.0
2.01 - 3.5
3.51 - 5.0
5.01 - 6.5
6.51 - 8.0
> 8.0
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Th: Spatial Distribution
(mg/kg):
<= 2.0
2.01 - 3.5
3.51 - 5.0
5.01 - 6.5
6.51 - 8.0
> 8.0
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

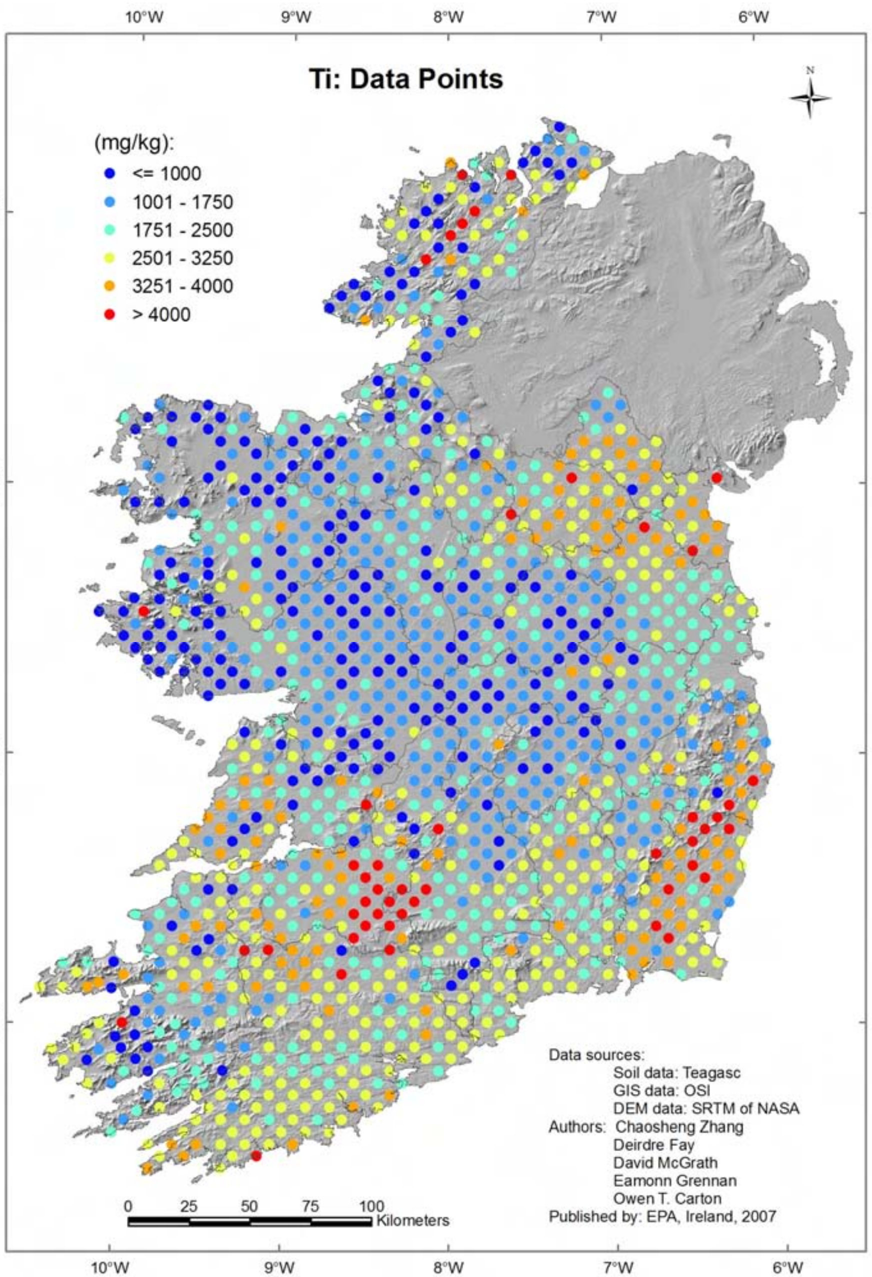
Ti Titanium

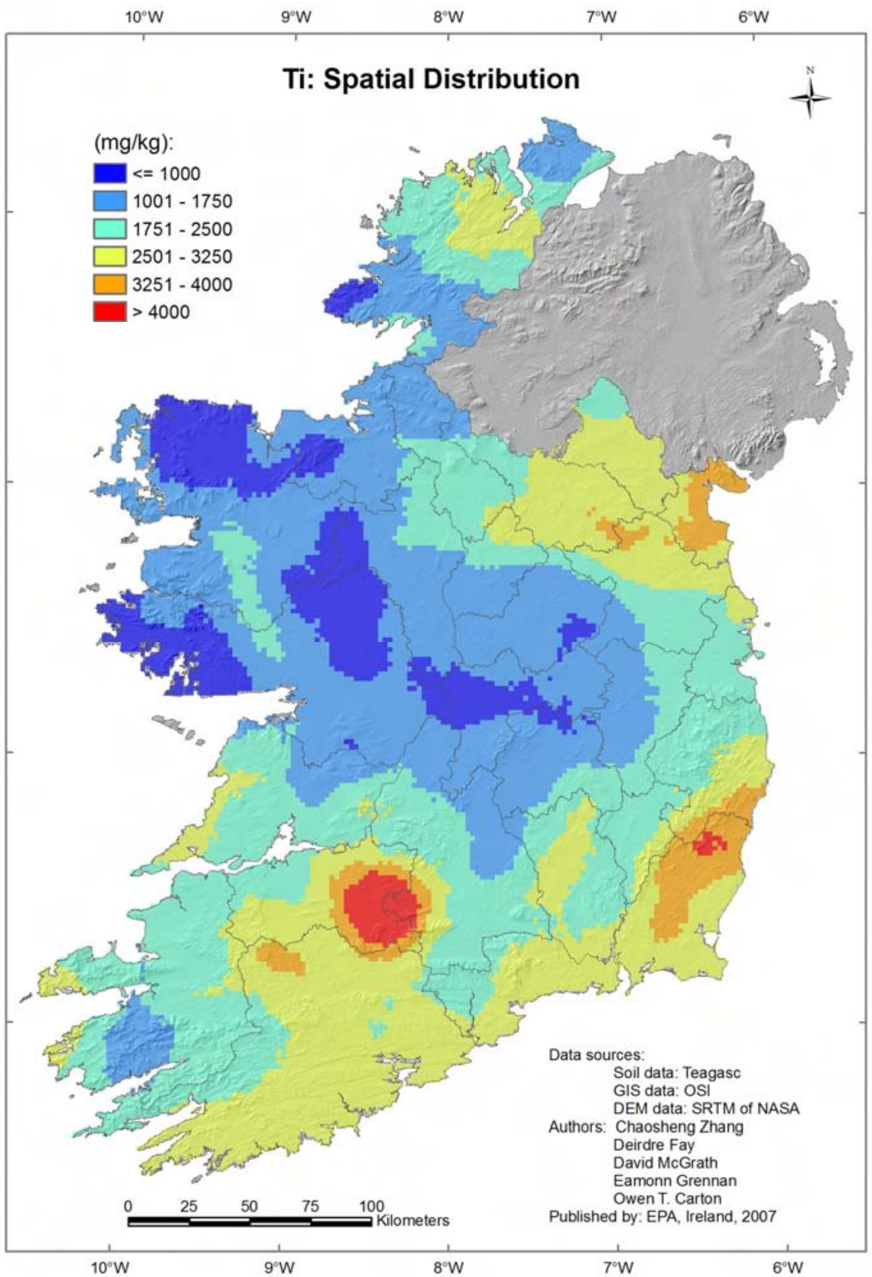
Ti is the ninth most abundant element in the Earth's crust (Lide, 2005) and is present in most igneous rocks and their sediments. It is always found bound to other elements. Ti is only mobile under strongly acidic conditions. It is a corrosion resistant metal and is as strong as steel but is much lighter. Ti is used in alloys for the manufacture of aircraft, missiles and navy ships but also for a wide range of other applications from surgical implants to jewellery and lipstick. It is considered to be harmless, and is not believed to be a bio-essential element.

Ti shows very similar distribution patterns to Nb (r_{min} = 0.92) and Ta (r_{min} = 0.89). Ti levels above 4000mg/kg in East Limerick are associated with the basalts in this area while levels elevated above 2500mg/kg in the North East and South East of the country are related to volcanic material in the greywackes in these areas. Slightly elevated levels are visible for the Brown Earths in Galway and Mayo. Levels of Ti lower than 1750mg/kg are associated with Peats, Lithosols and Podzols in mountain and hill areas and Grey Brown Podzolics and Peats on limestone bedrock. Typically, limestones, older granites and gneisses are low in Ti and this is evident for the granites in Wicklow and Carlow. It is worth noting that Ti prospecting was carried out in Wicklow and parts of Carlow.

Table showing the minimum and maximum and some of the most important percentiles for total Ti concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	39	125	1355	2133	2851	3773	8704
mineral	165	1247	1774	2469	3020	3960	8704
organic	39	73	147	517	1197	2705	4016


Ti: Data Points
(mg/kg):
<= 1000
1001 - 1750
1751 - 2500
2501 - 3250
3251 - 4000
> 4000
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Ti: Spatial Distribution
(mg/kg):
<= 1000
1001 - 1750
1751 - 2500
2501 - 3250
3251 - 4000
> 4000
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

Tl Thallium

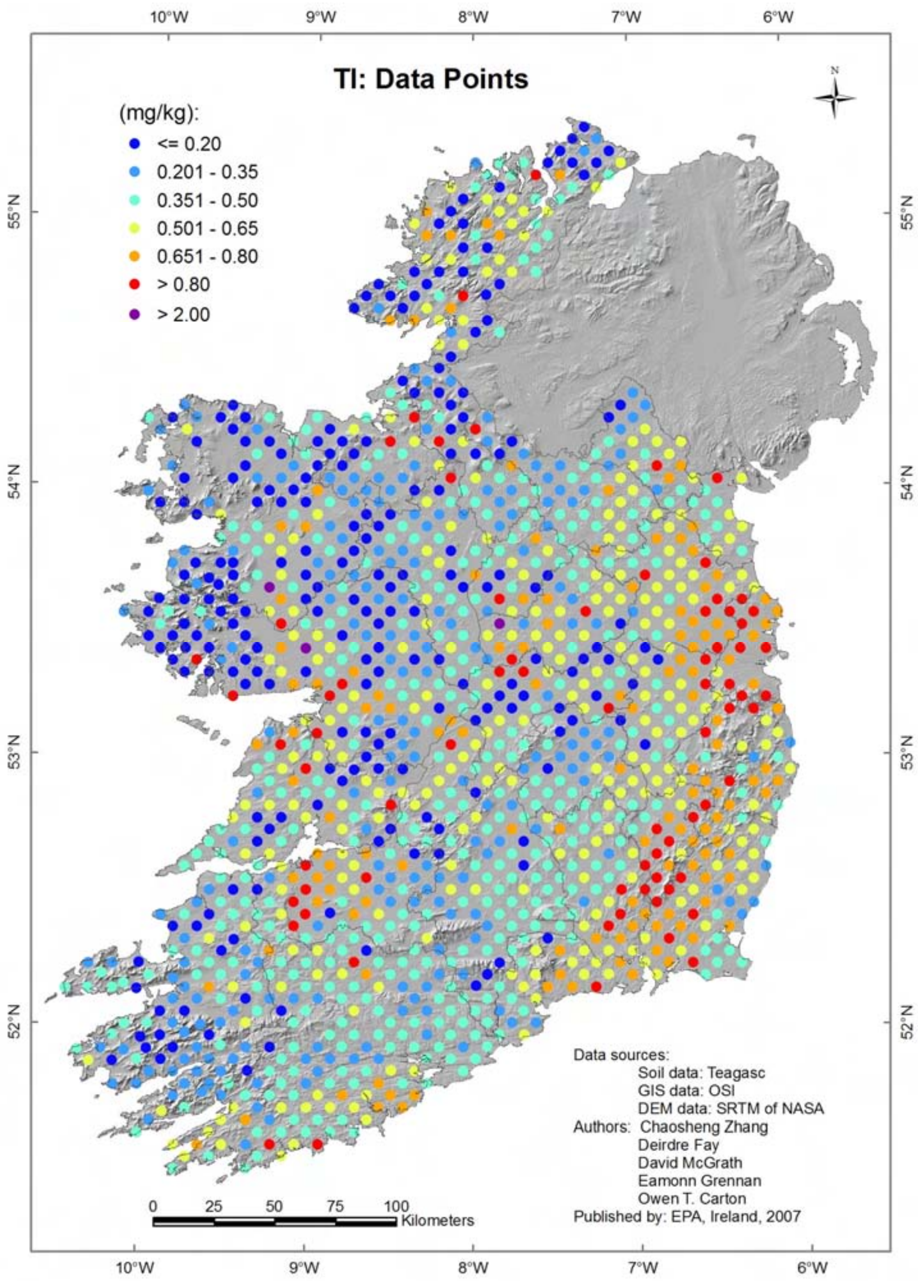
Thallium occurs mostly in association with K minerals, although the main commercial source is trace extraction from Cu, Pb and Zn ores. Tl is less likely to be introduced into the environment by industry than its neighbours in the periodic table, Pb and Hg, but suspected anthropogenic sources include (soft) coal combustion and cement manufacturing plants. It is used in rat poison, in photocells, low temperature thermometers and nuclear medicine. Tl can be strongly fixed by MnO_2 in soils. Tl has no known biological role. Tl and its compounds are highly toxic. It is also a suspected human carcinogen.

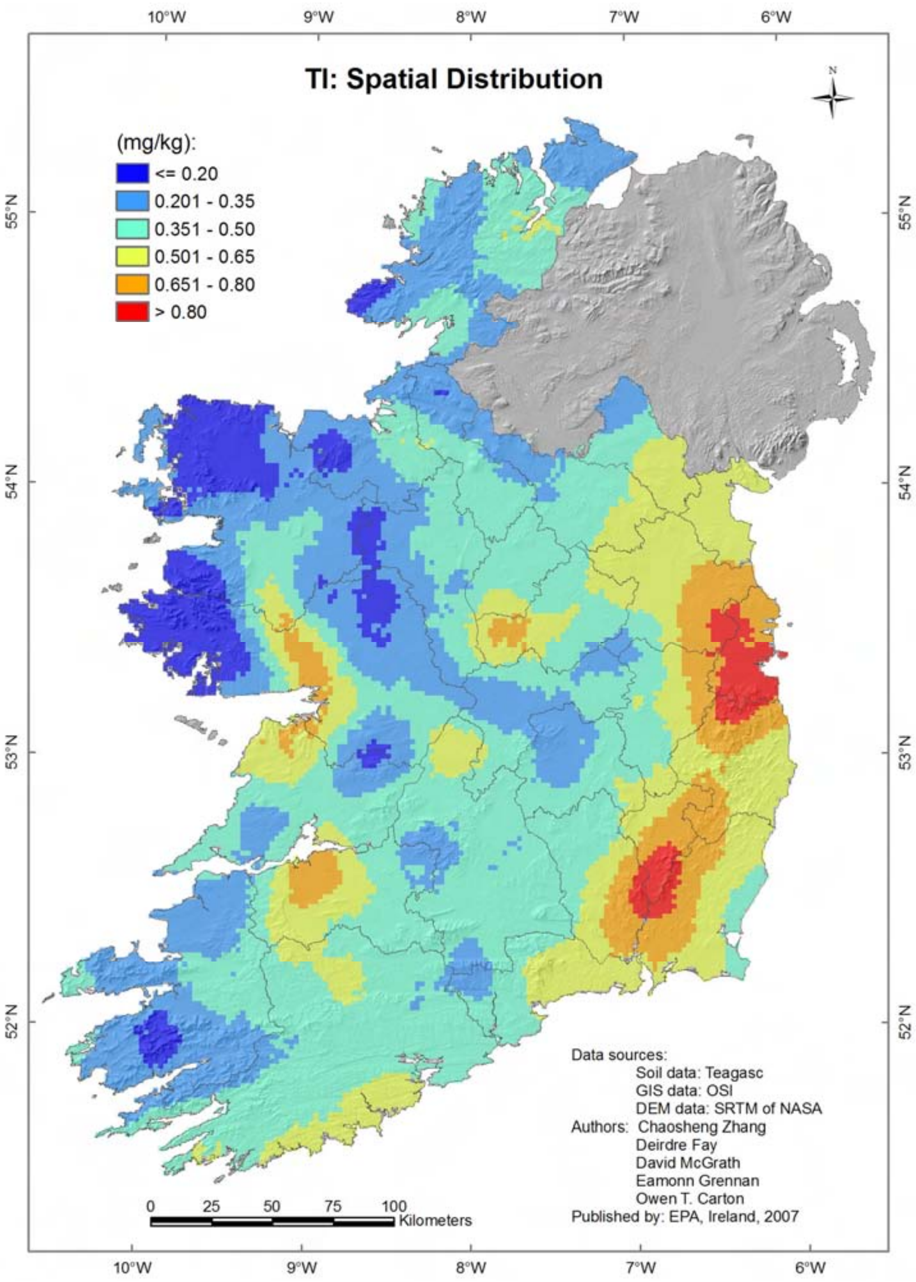
The background Tl concentration for unpolluted soils suggested in the Netherlands by Crommentuijn (1997) is 1mg/kg. There appears to be some evidence of an anthropogenic effect in Dublin, where Tl levels in soils are relatively high (>0.8mg/kg). Levels of Tl above 0.65 mg/kg in the South East are coincident with the Leinster Granite. Levels exceeding 0.5mg/kg Tl in soils on the south coast of Cork, west central Limerick, and northern Clare are coincident with black shales and with Brown Earths and Rendzinas. A local high concentration of Ti (>2mg/kg) in western Westmeath and relatively high levels in northern Tipperary have no apparent explanation. Levels below 0.2mg/kg are evident along much of the west coast, particularly in counties Galway and Mayo.

Table showing the minimum and maximum and some of the most important percentiles for total Tl concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<0.02**	<0.02**	0.29	0.43	0.57	0.82	2.66
mineral	0.10	0.26	0.38	0.48	0.60	0.86	2.66
organic	<0.02**	<0.02**	0.02	0.13	0.30	0.64	1.46

**72 samples analysed were below the detection limit of 0.02 mg/kg for Tl


Tl: Data Points
(mg/kg):
<= 0.20
0.201 - 0.35
0.351 - 0.50
0.501 - 0.65
0.651 - 0.80
> 0.80
> 2.00
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100
Kilometers


Tl: Spatial Distribution
(mg/kg):
<= 0.20
0.201 - 0.35
0.351 - 0.50
0.501 - 0.65
0.651 - 0.80
> 0.80
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100
Kilometers

U Uranium

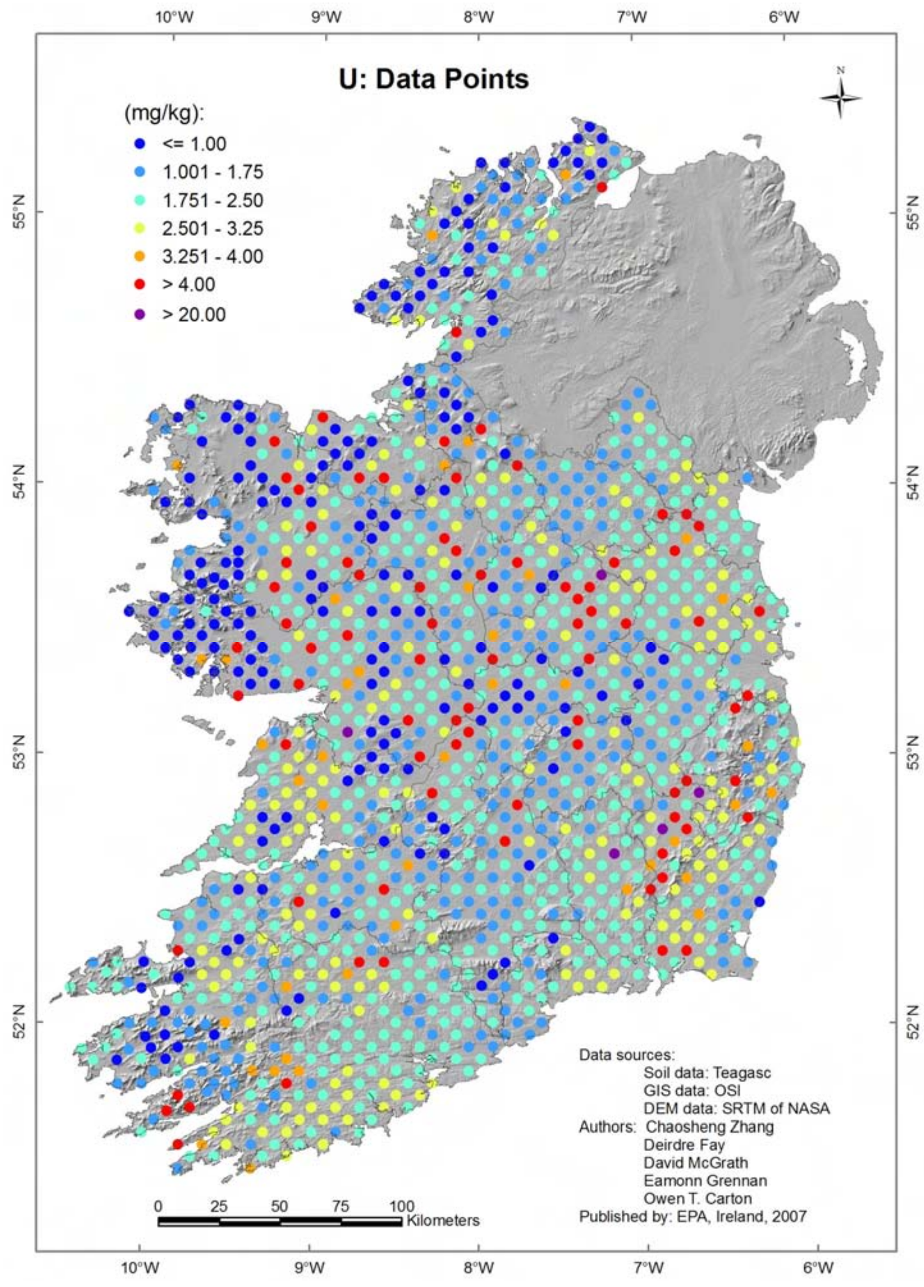
U is naturally present in small amounts in rocks, soil, and water. It is geochemically similar to Th, except that it is highly water soluble under oxidizing conditions, so that it is leached from soils and its concentration in groundwater can be relatively high (up to several mg/l). Mining processes also introduce U into the environment. U is a radioactive element and its most important industrial use (as U-235) is as fuel for nuclear energy. It is also used in warfare as a shielding material and in ammunition. For scientific purposes, it is used to date rocks, and has provided most of the time markers in the history of the earth and the solar system. U has no known biological role. When ingested, it is toxic and can bioaccumulate in the bone tissue as it has an affinity for phosphates. Exposure to U itself is not associated with cancer, but exposure to its decay products, particularly radon, can pose a health threat.

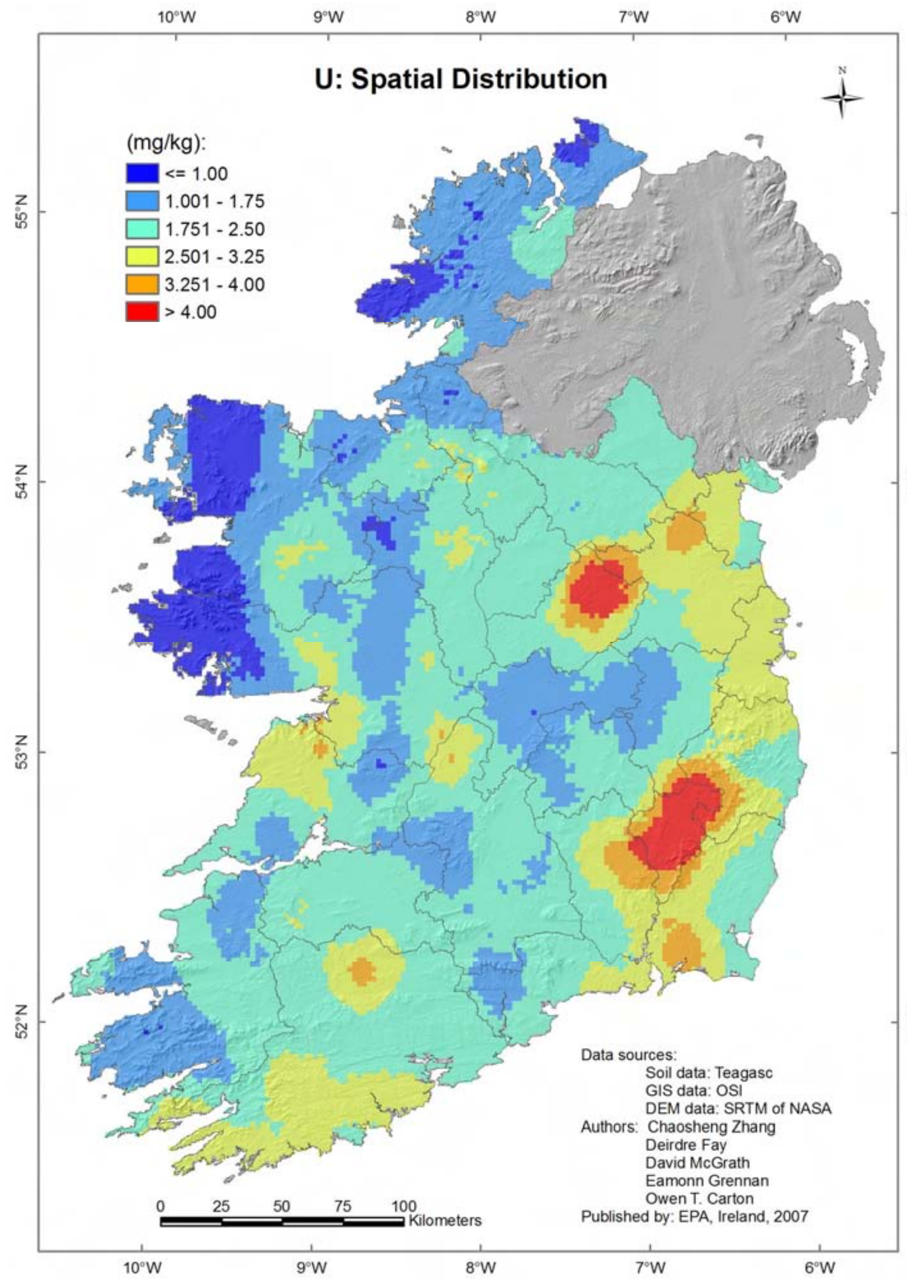
Soils typically contain U concentrations of 1 – 4 mg/kg (Vinogradov, 1959). Elevated values of radioactive elements, especially U, are to be expected in Wicklow, Carlow and Clare as a result of the underlying geology. Levels in Carlow of above 4mg/kg are related to underlying granite and its occurrence has been extensively studied. Relatively high U levels (>2.5 mg/kg) in northern Clare and south central Cork are coincident with underlying black shales. A number of small localised U deposits have been discovered in central Donegal, and they have been recognised as being distinct from the broad uraniferous nature of the Leinster granite. Levels of U exceeding 4mg/kg in Westmeath are attributed to the organic-rich soils in this area. An association between elevated U concentrations and high organic matter content has been investigated (Vinogradov, 1959) and is thought to be caused by the sorption of U from ground waters by organic substances. The U content of a surface peaty sample in west Limerick was found to be as high as 550 mg/kg (Williams and Brown, 1971).

Table showing the minimum and maximum and some of the most important percentiles for total U concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<0.1**	0.20	1.48	1.96	2.48	4.74	64.19
mineral	0.35	1.29	1.71	2.07	2.51	3.86	36.25
organic	<0.1**	<0.1**	0.22	0.79	2.17	6.69	64.19

**20 samples analysed were below the detection limit of 0.1 mg/kg for U


U: Data Points
(mg/kg):
<= 1.00
1.001 - 1.75
1.751 - 2.50
2.501 - 3.25
3.251 - 4.00
> 4.00
> 20.00
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


U: Spatial Distribution
(mg/kg):
<= 1.00
1.001 - 1.75
1.751 - 2.50
2.501 - 3.25
3.251 - 4.00
> 4.00
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

V Vanadium

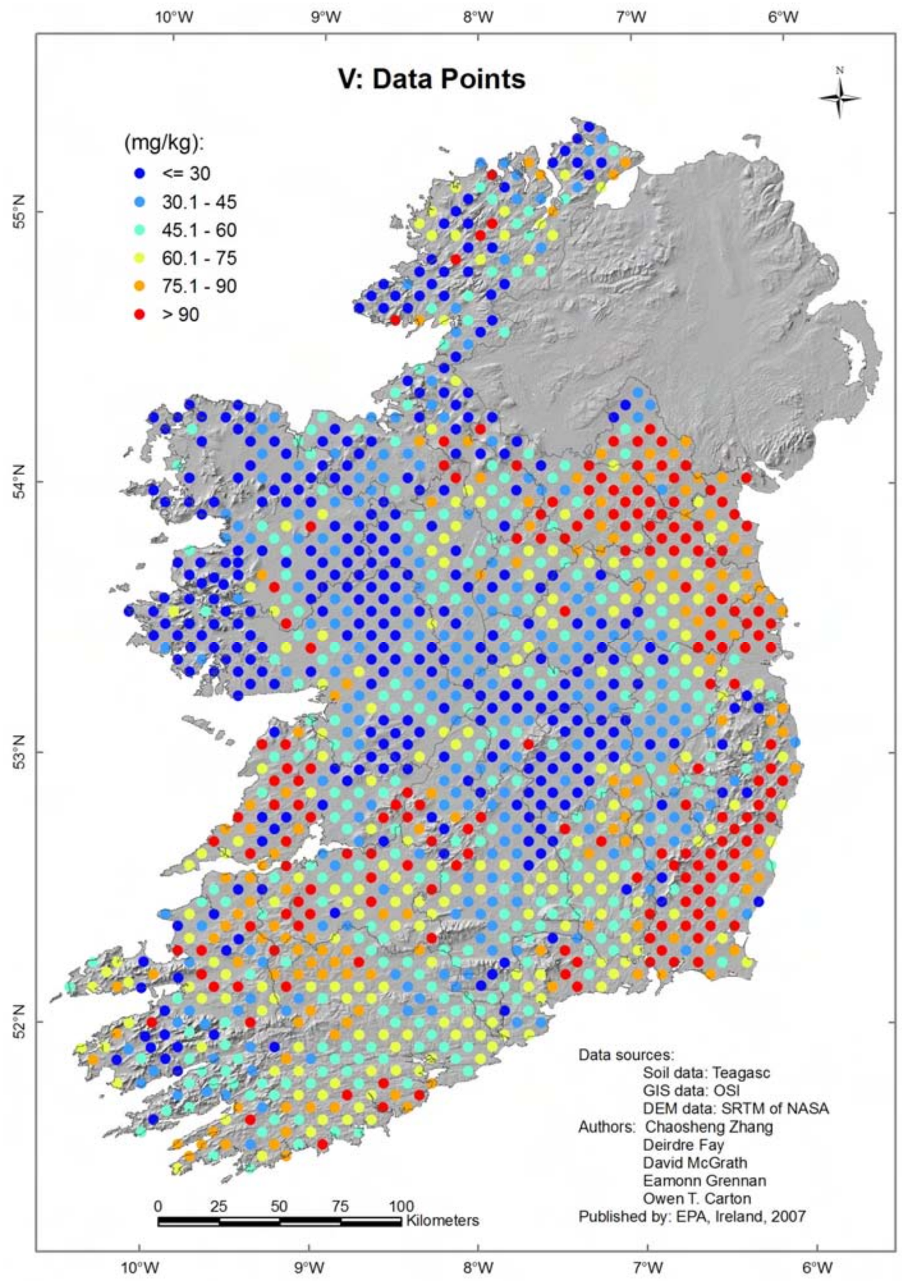
V occurs in bauxite and in C containing deposits. It is relatively abundant in soils and living organisms. The metal V is mainly used in steel and other alloys. V is an essential component of some enzymes and is a necessary component in the diet of rats and young chickens. Excess intake of V can have negative health effects.

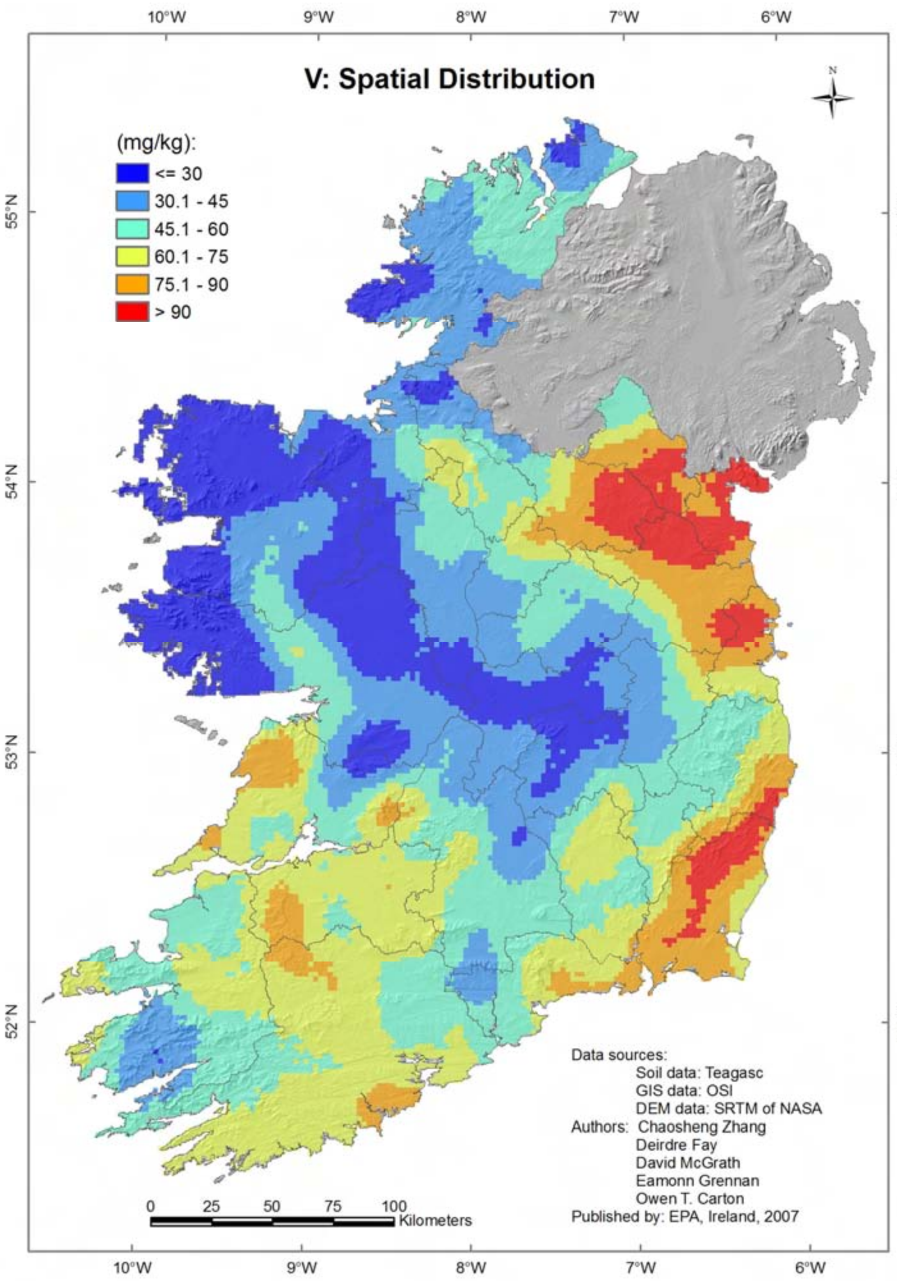
Background concentrations of 42 mg/kg were reported for V by Crommentuijn (1997) for unpolluted soils in the Netherlands. Levels of V exceeding 75 mg/kg in Irish soils are associated with the greywackes in the North East and greywackes and igneous rocks in the South East. Similar levels are also associated with phosphatic rocks in Clare. With the exception of parts of the southern counties, levels of V below 30 mg/kg are coincident with limestone rocks and Grey Brown Podzolic, Lithosol, Podzol and Peat soils.

Table showing the minimum and maximum and some of the most important percentiles for total V concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<2**	3.90	30.80	52.20	74.20	104.80	240.30
mineral	10.00	25.40	43.70	60.00	80.70	108.50	240.30
organic	<2**	2.20	4.60	14.90	32.70	74.90	100.90

**14 samples analysed were below the detection limit of 2 mg/kg for V


V: Data Points
(mg/kg):
<= 30
30.1 - 45
45.1 - 60
60.1 - 75
75.1 - 90
> 90
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers
10°W 9°W 8°W 7°W 6°W
55°N 54°N 53°N 52°N


V: Spatial Distribution
(mg/kg):
<= 30
30.1 - 45
45.1 - 60
60.1 - 75
75.1 - 90
> 90
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers
10°W 9°W 8°W 7°W 6°W
55°N 54°N 53°N 52°N

W Tungsten

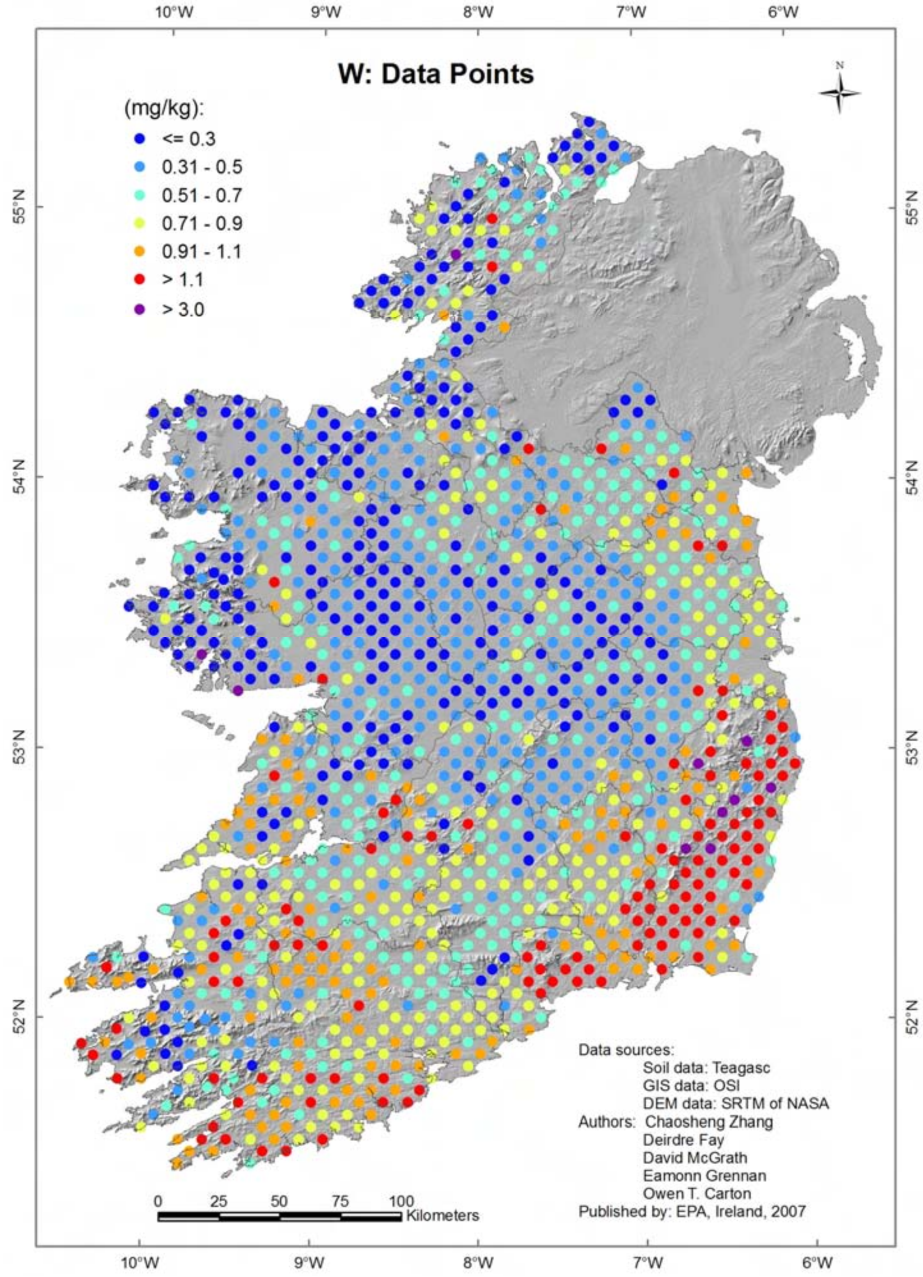
W is one of the less common trace elements. It occurs mostly in the minerals scheelite and wolframite. Due to the costs of W extraction, 30% of the W demand is covered by recycling of the element. The metal has the highest melting point of all metals (3422°C) and is used in light bulb filaments and X-ray tubes. It also has a high corrosion resistance and is often used in steel alloys. W has a very limited biological role, known only to be used by some enzymes. There are no proven health benefits or threats related to W except for very high concentrations (e.g. refineries), where it can be toxic.

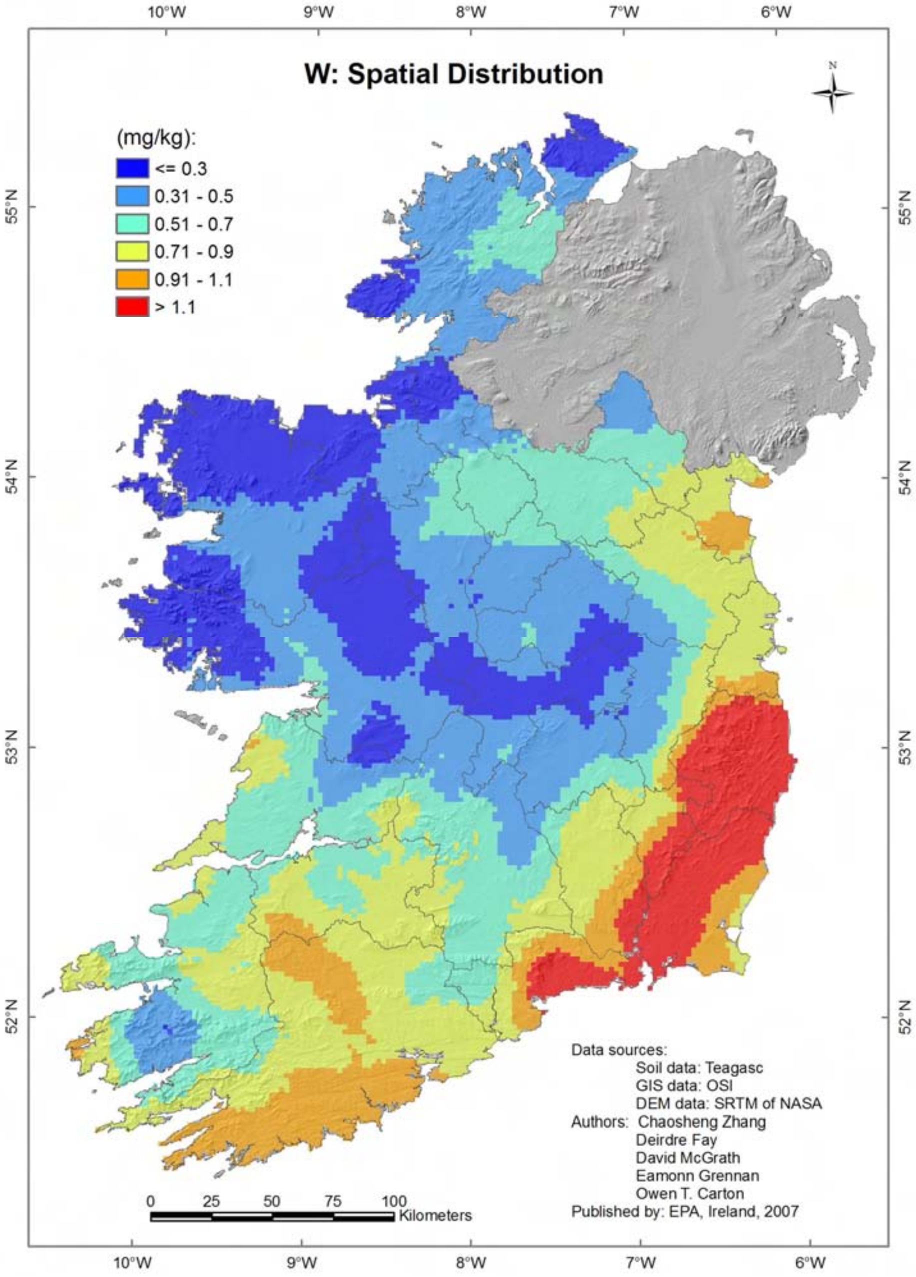
Very few soils have a high W content and Irish soils reflected this with 10% of the samples being under the detection limit of 0.1mg/kg. Relatively high levels of W observed in Ireland above 0.9 mg/kg are associated with known mineral showings, especially along the flanks of the Wicklow mountains. These levels are found in soils on igneous rocks extending from Wicklow to Waterford; and to a lesser extent on greywackes in the North East; and on black shales and fine sandstones in Cork. Levels of W below 0.5mg/kg are mostly associated with Peats, Lithosols and Podzols in mountain and hill areas and Grey Brown Podzolics and Peats on limestone bedrock.

Table showing the minimum and maximum and some of the most important percentiles for total W concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	<0.1**	<0.1**	0.36	0.59	0.85	1.31	7.72
mineral	<0.1**	0.31	0.48	0.69	0.91	1.38	7.72
organic	<0.1**	<0.1**	<0.1**	0.15	0.37	0.90	4.29

**132 samples analysed were below the detection limit of 0.1 mg/kg for W


W: Data Points
(mg/kg):
<= 0.3
0.31 - 0.5
0.51 - 0.7
0.71 - 0.9
0.91 - 1.1
> 1.1
> 3.0
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers


W: Spatial Distribution
(mg/kg):
<= 0.3
0.31 - 0.5
0.51 - 0.7
0.71 - 0.9
0.91 - 1.1
> 1.1
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007
0 25 50 75 100 Kilometers

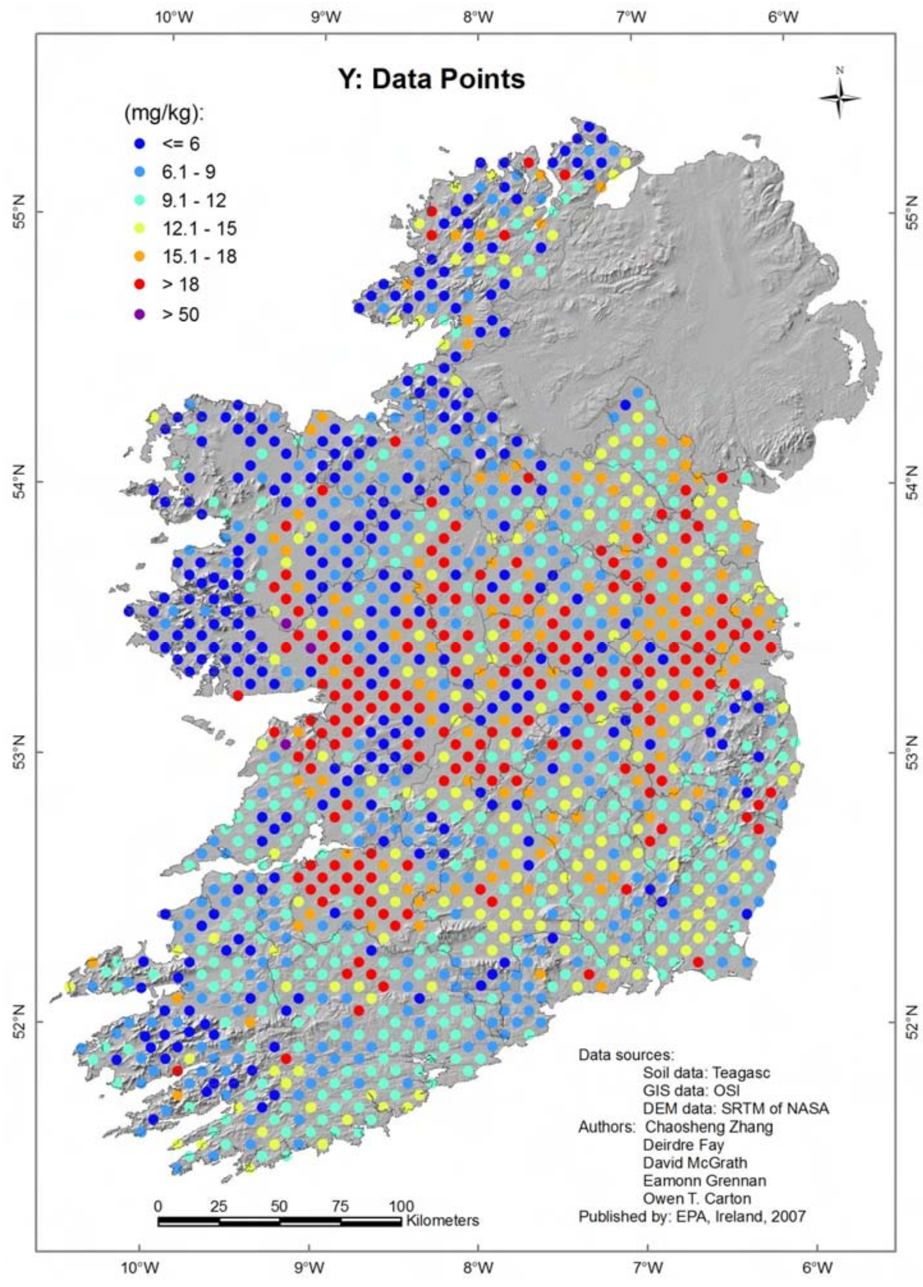
Y Yttrium

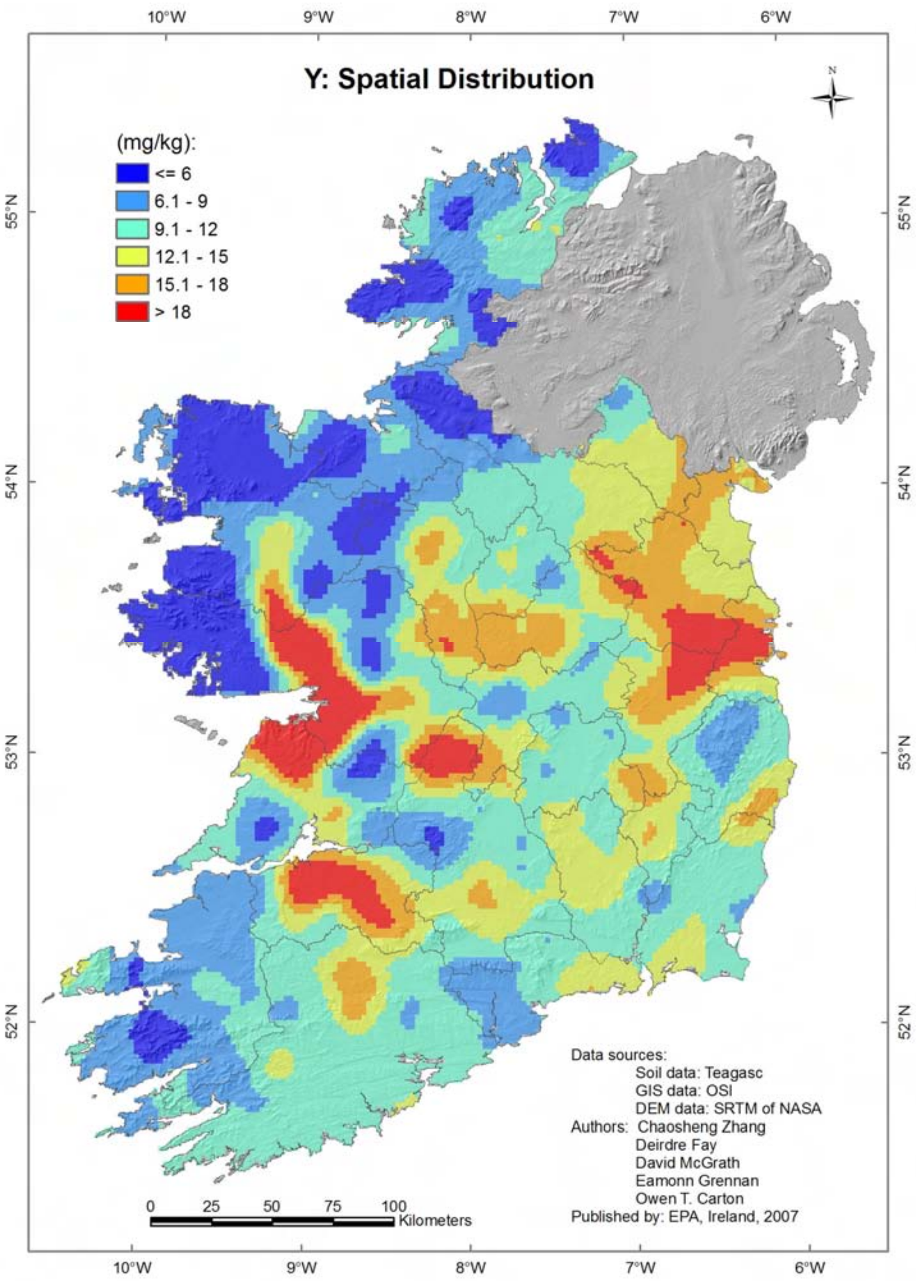
Y occurs in nature only in very small amounts and is rarely found and never as a free element. It occurs in most rare-earth minerals. It is used in some alloys, in spark plugs and in colour tubes such as those in televisions. Y is not known to be an essential element for any organisms and can be toxic or carcinogenic in high concentrations, although these rarely occur.

The distribution of Y in Irish soils is similar to the Cd (r_{min} = 0.69) and Ni (r_{min} = 0.77) distribution, particularly in the western half of Ireland. Levels of Y above 18 mg/kg appear to be associated with the Brown Earths and Rendzinas in Galway and to a small extent in Limerick. Levels below 9 mg/kg coincide with the occurrence of Peats, Podzols, Lithosols and Gleys around the country. An explanation for the sporadically distributed relatively elevated levels of Y above 12 mg/kg in the centre of the country and in the North East of the country is difficult to explain without further investigation.

Table showing the minimum and maximum and some of the most important percentiles for total Y concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	0.22	0.73	6.94	10.33	14.46	24.04	111.78
mineral	2.18	5.88	8.85	11.28	15.68	24.81	111.78
organic	0.22	0.40	0.87	3.07	7.20	18.31	49.50


Y: Data Points
(mg/kg):
<= 6
6.1 - 9
9.1 - 12
12.1 - 15
15.1 - 18
> 18
> 50
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Y: Spatial Distribution
(mg/kg):
<= 6
6.1 - 9
9.1 - 12
12.1 - 15
15.1 - 18
> 18
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

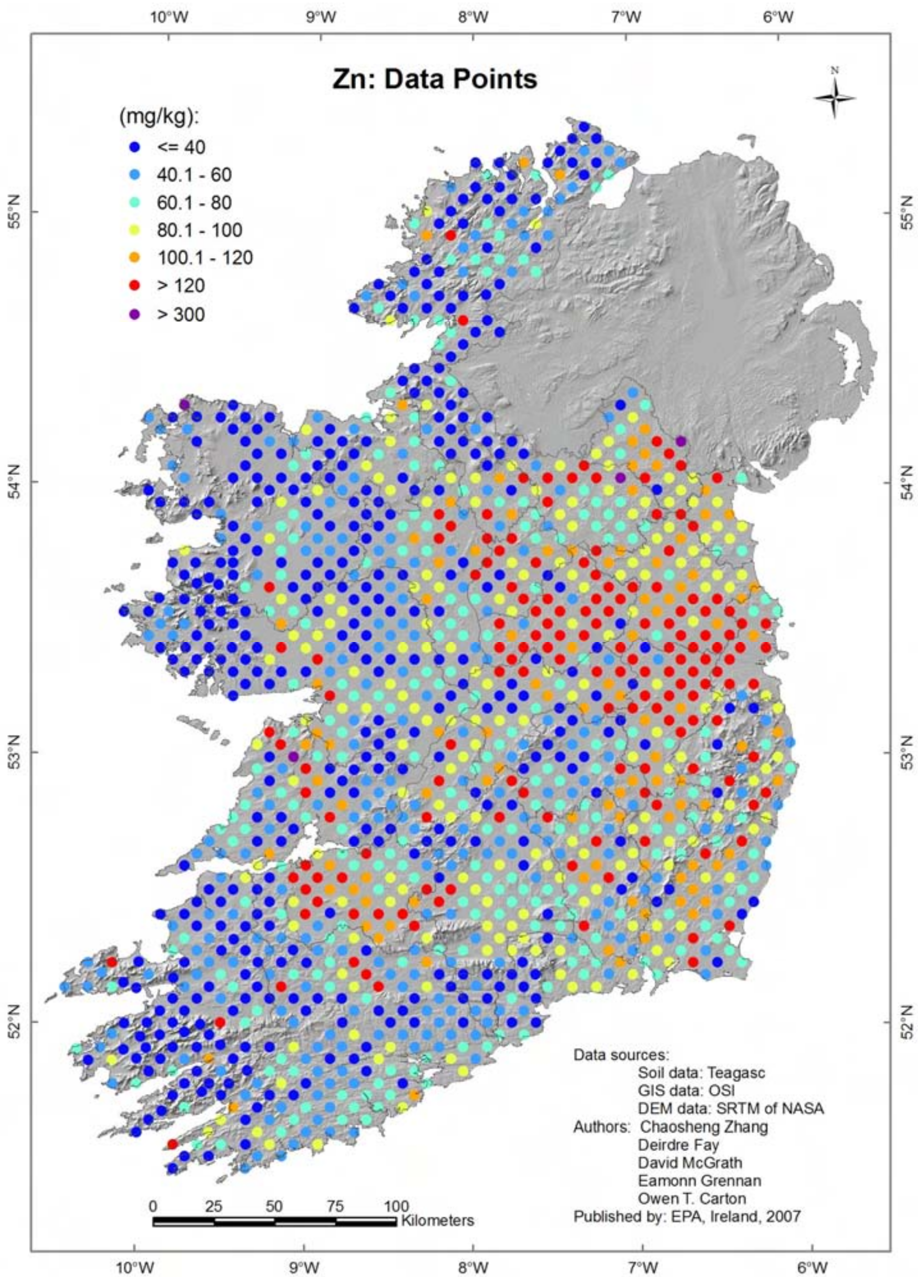
Zn Zinc

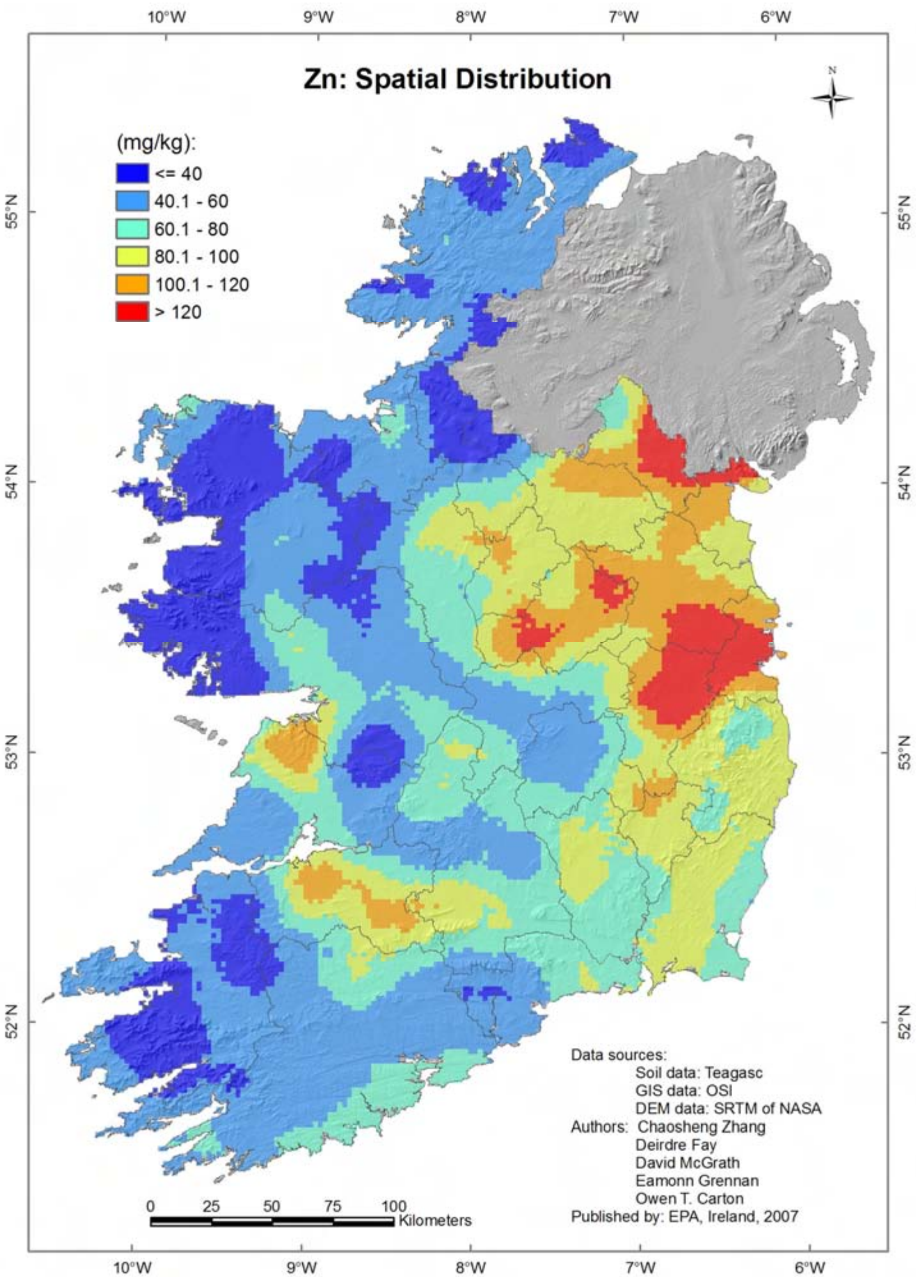
Zn is the most commonly used metal after Fe, Al and Cu. Contamination of soils with Zn occurs from mine wastes, fertilisers and sewage sludge and aerial deposition. Zn and its compounds are used in galvanized steel, various alloys and batteries. Zn is an essential trace element for plants and animals and is a standard ingredient in vitamin and mineral supplements. Excessive ingestion of Zn is toxic, but levels of toxicity depend on the organism and developmental stage. Both high and low Zn concentrations in soils can be a cause for concern. Zn in soil systems can reduce the speed of organic matter breakdown and negatively influence the activity of soil organisms. The Sewage Sludge Directive sets limit values for Zn of 150 to 300 mg/kg in soil receiving sewage sludge applications.

Typically, uncontaminated soils will have Zn concentrations of 17 to 160 mg/kg (Iyengar *et al.*, 1981). Levels of Zn exceeding 100mg/kg in Irish soils are mirroring underlying impure limestones in Dublin and the surrounding counties. There may also be a soil type effect in these soils, as high (basic) pH values associated with Grey Brown Podzolics could be minimising the leaching of Zn in these soils. Zn values above 100 mg/kg in Limerick are known to occur along the base of the Lower Paleozoic inliers where precipitation of the dissolved metal occurs under alkaline conditions in the same way as Fe and Mn. Ireland ranks in the world's top 10 for Zn concentrate production. At present there are three mines in production and two other major mines closed during the past 25 years. The local very high concentrations exceeding 300mg/kg at the border in Monaghan and in north Clare are related to mining activity. Zn levels of 40 mg/kg were evident in Peat and Podzol soils. The median value for Zn reported in this study for mineral soils is similar to those of Northern Ireland (65,4 mg/kg, Jordan *et al.*, 2002), Scotland (48 mg/kg, Paterson *et al.*, 2002), and England and Wales (82 mg/kg, McGrath and Loveland, 1992).

Table showing the minimum and maximum and some of the most important percentiles for total Zn concentrations in mg/kg

	min	5%	25%	50%	75%	95%	max
all soils	3.6	15.9	35.6	62.6	90.8	144.7	1384.4
mineral	8.6	24.9	49.2	72.7	98.2	150.4	1384.4
organic	3.6	10.4	19.6	28.1	44.3	99.6	304.2


Zn: Data Points
(mg/kg):
<= 40
40.1 - 60
60.1 - 80
80.1 - 100
100.1 - 120
> 120
> 300
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007


Zn: Spatial Distribution
(mg/kg):
<= 40
40.1 - 60
60.1 - 80
80.1 - 100
100.1 - 120
> 120
10°W
9°W
8°W
7°W
6°W
55°N
54°N
53°N
52°N
0 25 50 75 100 Kilometers
Data sources:
Soil data: Teagasc
GIS data: OSI
DEM data: SRTM of NASA
Authors: Chaosheng Zhang
Deirdre Fay
David McGrath
Eamonn Grennan
Owen T. Carton
Published by: EPA, Ireland, 2007

References

Beeson, K.C., Kubota, J. And Lazar, V.A. 1965. Cobalt. Pg 1064-1076. In C.A. Black *et al* (ed.) Methods of Soil Analysis. Part 2. Agron. Monogr. 9. ASA, Madison, WI.

Bowen, J.M. 1982 The Elemental Constituents of Soils. Environmental Chemistry, Vol. 2, The Royal Society of Chemistry, London, 204pp.

Brogan, J. C. 1966.Organic carbon in Irish soils. Irish J. Agric.Res. 169-176.

Cressie, N., 1993. Statistics for spatial data, revised ed. John Wiley and Sons, New York.

Crommentuijn, T., Polder, M.D., van de Plasche, E.J., 1997. Maximum permissible concentrations and negligible concentrations of metals, taking background concentrations into account. RIVM Report No. 601 501 001, National Institute of Public Health and the Environment, Bilthoven, The Netherlands

EEC, 1986. On the Protection of the Environment, and in particular of the Soil when Sewage Sludge is used in Agriculture, 86/278/EEC.

Environmental Protection Agency. 2002. Towards setting environmental quality objectives for soil – Developing a soil protection strategy for Ireland – A discussion Document. EPA, Johnstown Castle Estate, Wexford.

European Commission. 2006. Proposal for a Directive of the European Parliament and of the Council establishing a framework for the protection of soil. Commission of the European Communities.

Fay, D., McGrath, D., Zhang, C., Carrigg, C., O'Flaherty, V., Carton, O.T., Grennan, E. 2007. EPA report: Towards a National Soil Database (2001-CD/S2 M2).

Fay, D., McGrath, D., Zhang, C., Carrigg, C., O'Flaherty, V., Kramers, G., Carton, O.T., Grennan, E. 2007. Towards a National Soil Database: Synthesis Report. (2001-CD/S2 M2) ERTDI Report Series No. 69

Finch, T. and Rogers, P.A.M. 1978. Distribution of cobalt and molybdenum in soils in the eastern midlands of Ireland. Irish Journal of Agricultural Research 17, 107 – 113.

Fleming, G.A. 1978. Trace Elements in Irish Soils with Special Reference to Cobalt and Selenium. PhD Thesis, NUI.

Fream, W. 1890 The herbage of pastures. J. Royal Agric. Soc. 1 (Ser. 3), 384-392.

Fuller, W.H. and Warrick, A.W. 1985. Soils in waste treatment and utilization. Volume I. Land-treatment. CRC Press Inc., Boca Raton, FL.

Gardiner, M.J., and Radford, T., 1980. Soil Associations of Ireland and Their Land Use Potential – Explanatory Bulletin to Soil Map of Ireland. The Agricultural Institute, Dublin.

Hammond, R.F. 1978 The Peatland Map of Ireland. An Foras Taluntais, Dublin.

Helmke, P.A. and Sparks, D.L. 1996. Lithium, Sodium, Potassium, Rubidium and Cesium. In Bartels, J.M. and Bigham, J.M. (eds) Methods of Soil Analysis: Part 3, Chemical Methods. Soil Science Society of America, Madison, Wisconsin.

Iyengar, S.S., Martens, D.C. and Miller, W.P. 1981. Distribution and plant availability of soil zinc fractions. Soil Sci. Soc. Am. J. 45:735-739.

Jordan, C., Higgins, A. and Hamill, A. and Cruickshank, J.G. 2002. The Soil Geochemical Atlas of Northern Ireland. Department of Agriculture and Rural Development, Belfast.

Kabata-Pendias, A. and Pendias, H. 1991. Trace elements in soil and plants. 2nd ed. CRC press, Inc., Boca Raton, FL.

Lide, D. R. (ed.) 2005. CRC Handbook of Chemistry and Physics, 85th Edition. CRC Press. Boca Raton, Florida.

Lindsay, W.L. 1979. Chemical equilibria in soils. John Wiley & Sons, New York.

McConnell, B and Gately, S. 2006 Bedrock Geological Map of Ireland, Geological Survey of Ireland, Dublin.

McGrath, D. 1995. Organic micropollutant and trace element pollution of Irish soils. Sci. Tot. Environ. 164, 125-133.

McGrath, D. 1996. Application of single and sequential procedures to polluted and unpolluted soils. Sci. Tot. Environ. 178, 37-44.

McGrath, D. and McCormack, R.J. 1999. The significance of heavy metal and organic micropollutants in soils. Teagasc End of Project Report, Dublin.

McGrath, S.P. and Loveland, P.J. 1992. The Soil Geochemical Atlas of England and Wales. Blackie Academic and Professional, Glasgow.

Murad, E. and Fischer, W.R. 1988. The geobiochemical cycle of Iron. Pg 1-18. In J.W. Stucki *et al.* (ed.) Iron in Soils and clay minerals. Reidel, Dordrecht, the Netherlands.

Paterson, E., Towers, W., Bacon, J.R. and Jones, M. 2002. Background levels of contaminants in Scottish soils. Scottish Environment Protection Agency.

Peech, M. and English, L. 1944. Rapid microchemical soil tests. Soil Science 57, 16.

Sims, J.L. 1996. Molybdenum and Cobalt. In Bartels, J.M. and Bigham, J.M. (eds) Methods of Soil Analysis: Part 3, Chemical Methods. Soil Science Society of America, Madison, Wisconsin.

SSSAJ, Soil Science Society of America Glossary of Soil Science Terms: www.soils.org/gloss

Tabatabai, M.A. 1996. Sulfur. In Bartels, J.M. and Bigham, J.M. (eds) Methods of Soil Analysis: Part 3, Chemical Methods. Soil Science Society of America, Madison, Wisconsin.

Ure, A.M. 1991.Atomic absorption and flame emission spectrometry. P. 1-62. In K. Smith (ed.) Soil analysis-modern instrumental techniques. 2nd ed. Marcel Dekker, New York.

Ure, A.M. and Berrow, M.L. 1982. The elemental composition of soils. In H.J.M. Bowen (ed.) Environmental Chemistry. Vol 2. Royal Soc. Chem. London.

Vinogradov, A.P. 1959 The geochemistry of rare and dispersed chemical elements in soils. 2nd Ed., Consultants Bureau, New York, 209 pp.

Walsh,T., Fleming, G.A., Kavanagh, T.J. and Ryan, P. 1952. The cobalt status of Irish soils and pasture in relation to pining in sheep and cattle.J. Dept. Agric.(Ireland) 52:1-62.

Walkley, A. and Black, I.A. 1934 An examination of the Degtjareff method for determining soil organic matter, and proposed modification of the chromic acid titration method. Soil Science 37, 29 – 38.

Williams, C. and Brown, G. 1971.Uranium content of peaty soils rich in molybdenum and selenium from Co. Limerick. Eire. Geoderma 6:223-225.

Useful Websites:

http://www.soils.org/gloss
http://www.eeb.org/activities/Soil/background.htm
http://www.epa.ie/EnvironmentalResearch/ReportsOutputs/
http://soilweb.tripod.com/soilsite.htm
http://www.soil-net.com/
http://www.wossac.com/
http://www.fao.org/ag/agl/agll/wrb/
http://environmentalchemistry.com/yogi/periodic/
http://www.lenntech.com/periodic-chart.htm
http://www.ene.gov.on.ca/en/land/index.php
http://pubs.acs.org/cen/80th/elements.html
http://www.webelements.com/index.html
http://education.jlab.org/itselemental/

Acronyms

EPA	Environmental Protection Agency (Ireland)
EC	European Commision
EEC	European Economic Community
EU	European Union
ICP-OES	Inductively Coupled Plasma-Optical Emission Spectroscopy
ICP-MS	Inductively Coupled Plasma Mass Spectroscopy
ORS	Old Red Sandstone
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SSSA	Soil Science Society of America
WRB	World Reference Base