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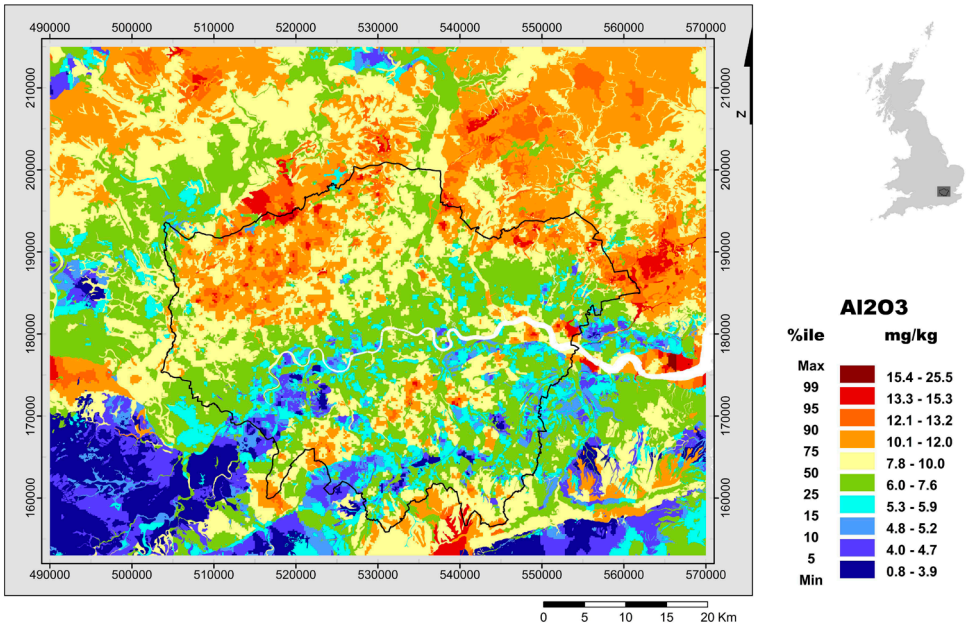
London Region Atlas of Topsoil Geochemistry



A, Ferreira, C C Johnson, J D Appleton, D M A Flight, T R Lister, K V Knights, L Ander, C Scheib, A Scheib, M Cave, J Wragg, F Fordyce, F and R Lawley.

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BRITISH GEOLOGICAL SURVEY

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London Region Atlas of Topsoil Geochemistry

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Maps and diagrams in this book use topography based on Ordnance Survey mapping.

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London Atlas: Overview

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The London Region Atlas of Topsoil Geochemistry (LRA) is a further step towards understanding the chemical quality of soils in London, following a previous project called London Earth carried out by the British Geological Survey (BGS) (Johnson et al., 2010[1]). The main advantage of the LRA is that it includes soil geochemical data from the counties surrounding London; placing the city within the context of its rural hinterland, allowing assessments of the impact of urbanisation on soil quality.

The London Region Atlas of Topsoil Geochemistry is a product derived from the BGS Geochemical Baseline Survey of the Environment (G-BASE[2]) project. The London Region Geochemical Dataset (**LRD**, *n*=8400), on which the atlas is based, includes TOPSOIL data from two complementary surveys: i) the urban London Earth (LOND) and ii) the rural South East England (SEEN). The LRA covers the Greater London Authority (GLA) and its outskirts in a rectangular area of 80x62 km. This extends from British National Grid coordinates Easting 490000–570000, and Northing 153000–215000. The urban **LOND** and the rural **SEEN** surveys contribute with 6801 and 1599 samples respectively to the **LRD**.

The concentrations of 44 inorganic chemical elements (Al_2O_3, CaO, Fe_2O_3, K_2O, MgO, MnO, Na_2O, P_2O_5, SiO_2, TiO_2, Ag, As, Ba, Bi, Br, Cd, Ce, Co, Cr, Cs, Cu, Ga, Ge, Hf, I, La, Mo, Nb, Nd, Ni, Pb, Rb, Sb, Sc, Se, Sn, Sr, Th, U, V, W, Y, Zn and Zr), loss on ignition (LOI) and pH in topsoil are included in the LRA. For each element, a map showing the distribution in topsoil across the atlas area and a one-page sketch of descriptive statistics and graphs are presented. Statistics and graphs for whole dataset (**LRD**), London urban subset (**LOND**) and London surroundings rural subset (**SEEN**), as well as graphs of topsoil element concentrations over each simplified geology unit are shown.

The LRD has been used already in a study aiming to detect geogenic (geological) signatures and controls on soil chemistry in the London region (Appleton et al., 2013[3]). It includes maps showing the distribution of Al, Si, La and I (and Th, Ca, Mn, As, Pb and Zr in supplementary material) and it is concluded that the spatial distribution of a range of elements is primarily controlled by the rocks from where soil derives, and that these geogenic patterns are still recognisable inside the urban centre. Other studies have been done that are based on data in the **LRD**, namely using the **LOND** subset or part of it. The main focus of these studies was the mercury content (Scheib et al., 2010[4]), the influence of land use on geochemistry (Knights and Scheib, 2011[5]; Lark and Scheib, 2013[6]); the bioaccessibility of pollutants such as As and Pb (Appleton et al., 2012[7]; Appleton et al., 2012[8]; Cave, 2012[9]; Appleton et al., 2013[10]; Cave et al., 2013[11]) and the lability of lead in soils (Mao et al., 2014[12]); the determination of normal background concentrations of contaminants in English soil (Ander et al., 2013[13]) and the contribution of geochemical and other environmental data to the future of the cities (Ludden et al., 2015[14]).

The London Region Atlas of Topsoil Geochemistry formally presents detailed information for all chemical elements in the **LRD**. This information can be easily visualised and elements compared as its production and layout is standardised. Differences in topsoil element concentrations between the centre of the city and its outskirts can be assessed by observing the map and comparing statistics and graphs reported for the **LOND** and **SEEN** subsets respectively. This urban/rural contrast is particularly evident for elements such as Pb, Sb, Sn, Cu and Zn, for which mean concentrations in the urban environment are two to three times higher than those observed in the rural environment. This is a typical indicator suite of urban soil pollution reported in several other cities in the UK also (Fordyce et al., 2005[15]).

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London Atlas: Introduction

Ferreira, A, Johnson, C C, Appleton, J D, Flight, D M A, Lister, T R, Knights, K V, Ander, L, Scheib, C, Scheib, A, Cave, M, Wragg, J, Fordyce, F and Lawley, R. 2016. London Region Atlas of Topsoil Geochemistry. *British Geological Survey*.

The British Geological Survey's Geochemical Baseline Survey of the Environment (G-BASE[1]) project systematically maps the distribution of inorganic chemical elements in the surface environment of Great Britain (Johnson et al., 2005[2]) to help characterise land quality. This systematic and high-resolution geochemical baseline mapping, completed in 2015, was initially based on drainage samples collected from low order streams (Plant, 1971[3]) but has since been expanded to include soils. The work started in the late 1960s in northern Britain and was primarily concerned with mineral exploration. Since commencement, the geochemical mapping has progressed southwards. It is now principally focused on underpinning research projects, supporting stakeholders, and work on maintaining sustainable and healthy environments, particularly since the project's remit was expanded to include the mapping of urban areas in the 1990s (Fordyce et al., 2005[4]; Johnson and Ander, 2008[5]; Flight and Scheib, 2011[6]). The systematically collected rural and urban G-BASE[1] soil database available for England is summarised in **Figure 1** and the area covered by this atlas is indicated on this figure. Separate to the G-BASE[1] survey, the National Soil Inventory (NSI[7]) samples were collected by the Soil Survey of England and Wales. These were re-analysed by X-ray fluorescence spectrometry (XRFS) in the BGS laboratories to be compatible with the G-BASE[1] dataset and reported by Rawlins et al. (2012)[8]. The NSI[7] samples were collected at a low density (1 site every 25 km^2) and not from urban areas. With the high density G-BASE[1] samples available for the London region there was no need to include the low density NSI[7] samples in this atlas. For the last G-BASE rural survey (SSEEN) carried out in 2014/2015 (**Figure 1**, sample sites in blue), a lower sampling density was used. These samples were not used for this atlas, as the dataset here was compiled before the SSEEN results were available.

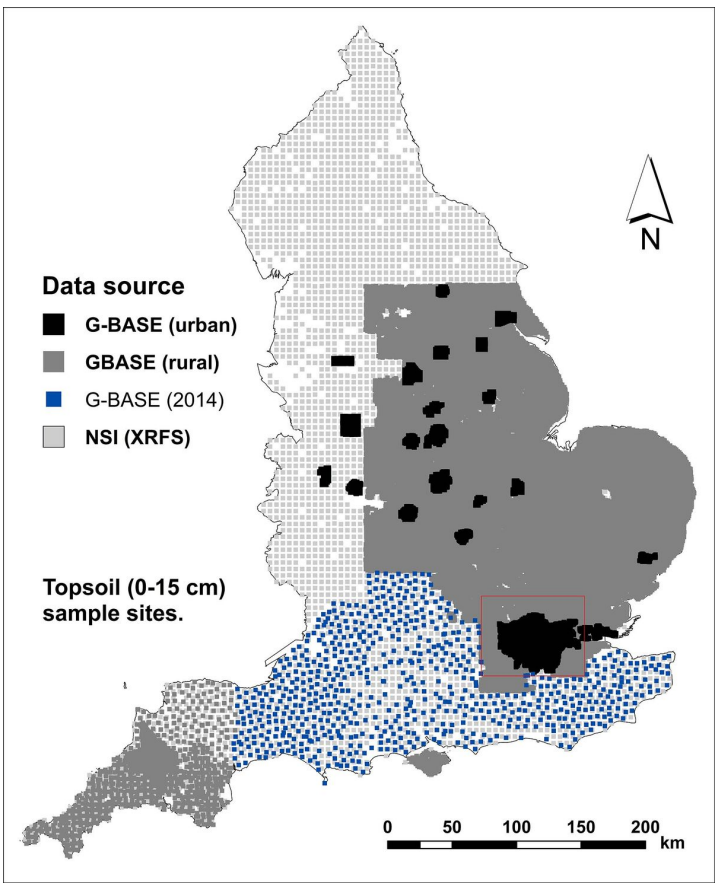

Figure 1 Map showing the distribution of systematically collected topsoil samples from England (until 2015) with the area covered by this atlas shown by the red rectangle around London. NSI (XRFS) covers the whole of England at a sample density of 1:25 km^2. G-BASE sampling densities for rural and urban are 1:2 km^2 and 4:1 km^2, respectively, except for the 2014 survey (in blue). Only G-BASE samples collected previous to 2014 are used in this atlas. (P929857).

By 2005 the geochemical survey had reached the outskirts of northern London and sampling in urban areas of London commenced with priority given to the area proposed for the main Olympic site at Stratford. After sampling in some south Essex urban centres (Scheib and Brown, 2005[9]; Scheib et al., 2006[10]), a project sampling soils of the Greater London Autority area (GLA), known as the London Earth[11] project, commenced in 2008 and was completed in 2009 (Johnson et al., 2010[12]). Soils were collected from over 6000 sites across London at a density of four sites for every British National Grid (BNG) kilometre square (Knights and Scheib, 2010[13] and **Table 1**). The GLA has an area of 1579 km^2 (607 sq mi) and in 2011, was reported to contain a population of 8.2 million (ONS, 2012[14]). The London Earth[11] project represents the world's largest systematic geochemical survey of an urban area.

Table 1 Details of the number of soil samples collected from each London local government district and urban centres in south Essex, 2005–2009 (after Knights and Scheib, 2010[15])

London local government districts	Sample sites	Date of sampling	London local government districts	Sample sites	Date of sampling
Barking and Dagenham	140	2005, 2006 & 2008	Lambeth	113	2009
Barnet	354	2008	Lewisham	143	2009
Bexley	269	2009	Merton	155	2009
Brent	176	2008	Newham	164	2006 & 2008
Bromley	610	2009	Redbridge	233	2008
Camden	92	2008	Richmond upon Thames	247	2009
City of London	16	2008	Royal Borough of Kensington and Chelsea	57	2008
City of Westminster	87	2008	Royal Borough of Kingston upon Thames	149	2009
Croydon	353	2009	Southwark	126	2009
Ealing	227	2008	Sutton	181	2009
Enfield	325	2008	Tower Hamlets	87	2006 & 2008
Greenwich	191	2009	Waltham Forest	153	2006 & 2008
Hackney	75	2006 & 2008	Wandsworth	146	2009
Hammersmith and Fulham	69	2008			
Haringey	118	2008	**South Essex urban centres**		
Harrow	206	2008	Basildon	115	2005
Havering	453	2005, 2006 & 2008	Brentwood	66	2005, 2006 & 2008
Hillingdon	423	2008 & 2009	Grays and Tilbury	180	2005 & 2006
Hounslow	234	2008 & 2009	Southend-on-Sea	271	2006
Islington	63	2008	Stanford-le-Hope and Shell Haven	51	2006

A selection of geochemical maps showing element concentrations in topsoil for the GLA area were published online in 2011 as part of the London Earth[11] project and the database of soil results made publicly available (Johnson et al., 2011[16]). In addition to sampling urban areas, the G-BASE[1] project has continued to collect soils from rural areas at a density of 1 site every 2 km^2 using the same sampling and analytical methods as used in the urban area. The region around the GLA has, therefore, been sampled also (**Figure 2**). As a result, in this atlas it is possible to study the London soils in the context of surrounding rural areas, so that the impact of urbanisation on the geochemical baseline can be determined. The atlas provides details of the sampling and analytical methodology along with initial data exploration to accompany a set of extrapolated grid geochemical maps for each soil element created using the parent-material polygon-mapping method described by Appleton and Adlam (2012)[17]. The data exploration is reported here and is seen as a resource and catalyst for further research on the surface chemical environment of London.

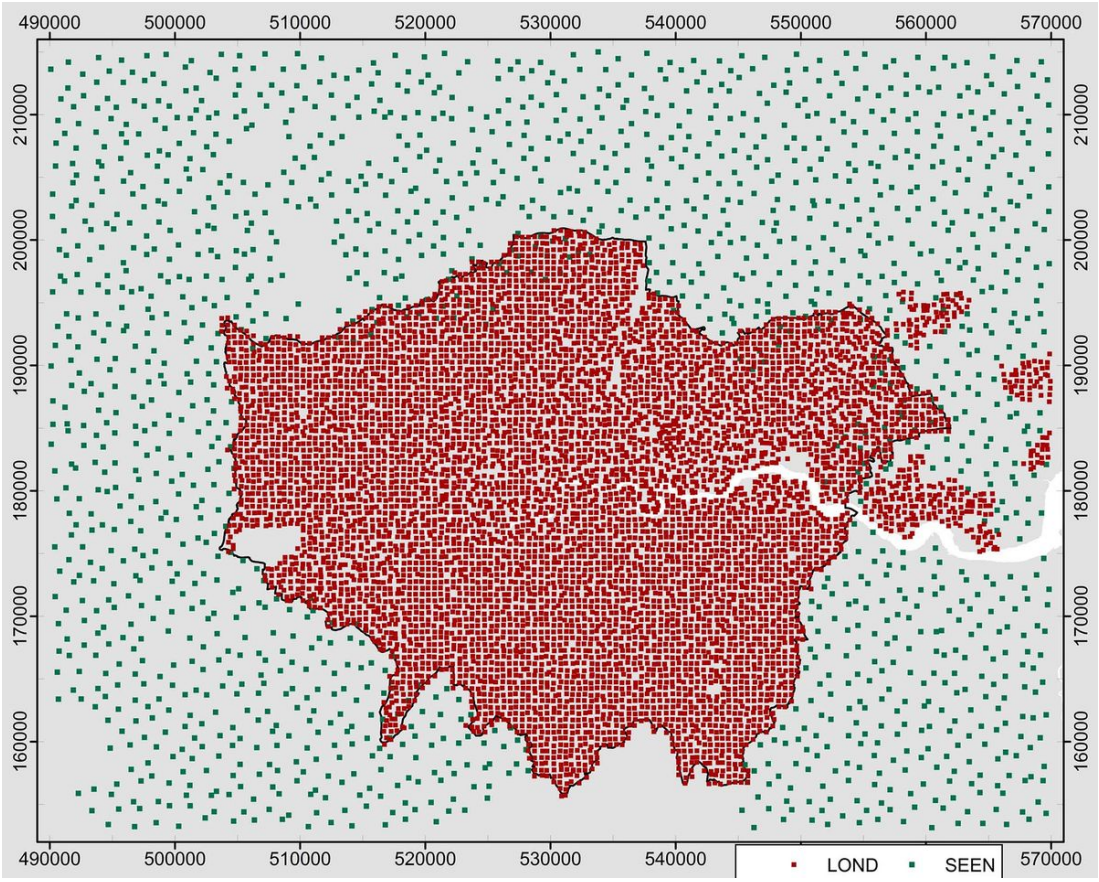

Figure 2 Map showing the topsoil sample locations in the London Region. (P929858).

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London Atlas: Geology

Ferreira, A, Johnson, C C, Appleton, J D, Flight, D M A, Lister, T R, Knights, K V, Ander, L, Scheib, C, Scheib, A, Cave, M, Wragg, J, Fordyce, F and Lawley, R. 2016. London Region Atlas of Topsoil Geochemistry. *British Geological Survey*.

The simplified geological map used in this atlas (**Figure 3**), and in particular for creating the soil parent material (PM) classes, is based on the classification used for radon mapping in England and Wales (Miles and Appleton, 2005[1]). The area is underlain by Cretaceous and Palaeogene bedrock, which is covered in some areas by Quaternary superficial deposits (**Figure 4**). Artificial ground is not used as a soil PM class, because spatial information on the distribution of artificial ground in urban areas in the UK is incomplete. Parent material classes are summarised in **Table 2** with an indication of the number of topsoil results associated with each class.

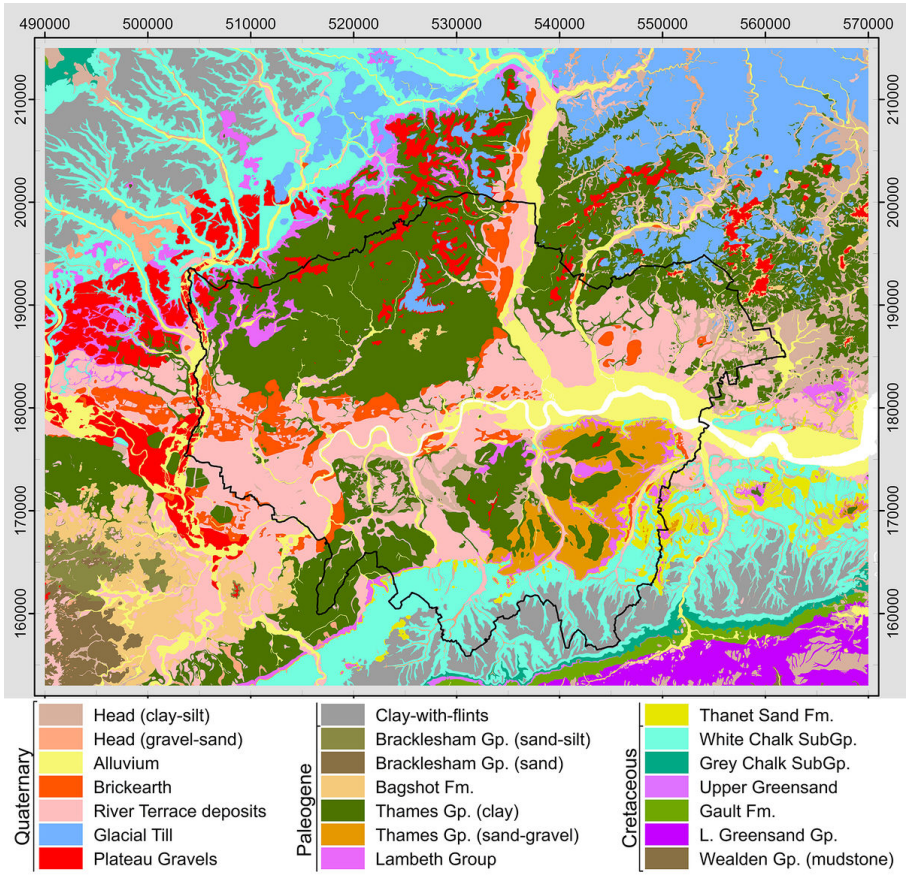

Figure 3 Simplified geological map of the London Region with the parent material classes used. (P929859).

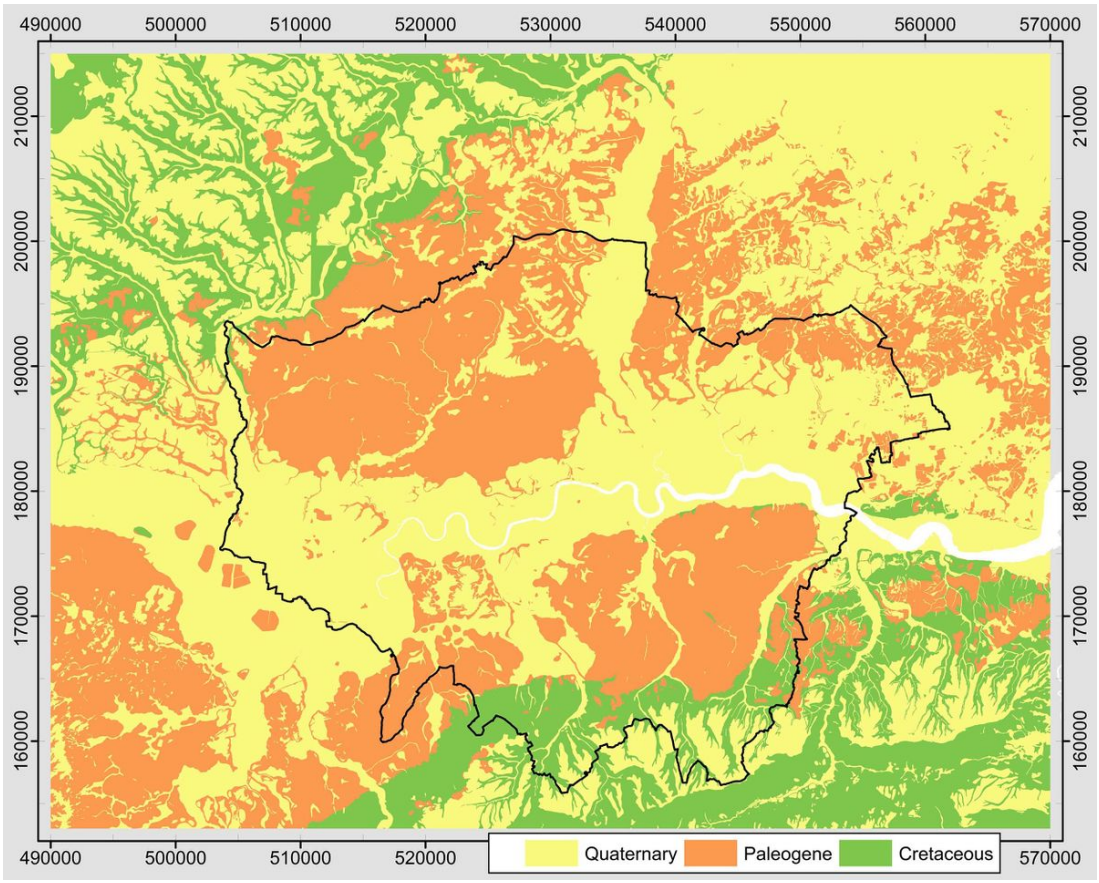

Figure 4 Simplified geological map of the London Region grouped by geological period. (P929860).

Table 2 Parent material classes (or simplified geology) showing the number of topsoil samples from each class.

Age	Parent material (PM) class	Number of soil samples
Quaternary	Head (clay-silt)	426
	Head (gravel-sand)	23
	Alluvium	690
	Brickearth	390
	River terrace deposits	1824
	Glacial till	292
	Plateau gravels	261
	Clay-with-flints	312
Palaeogene	Bracklesham Group (sand-silt)	20
	Bracklesham Group (sand)	12
	Bagshot Formation	88
	Thames Group (clay)	2602
	Thames Group (sand-gravel)	307
	Lambeth Group	213
	Thanet Sand Formation	159

Cretaceous	White Chalk Sub-group	707
	Grey Chalk Sub-group	15
	Gault Formation	13
	Upper Greensand	0
	Lower Greensand Group	46
	Wealden Group (mudstone)	0

The following account of the geology was prepared for Appleton et al. (2013)[2] and contains information derived from Ellison et al. (2004)[3], Royse et al. (2012)[4] and the London Earth[5] project.

Cretaceous

The **Wealden Group** mudstone is the oldest bedrock exposed at the surface (**Figure 3**, at the southern margin of the area BNG Eastings = 560 000 to 570 000) and these are succeeded by the **Lower Greensand Group**, which comprises calcareous greenish grey sands and sandstones and the thin Hythe Formation mudstone overlain by glauconitic sand and coarse-rained sands of the Sandgate and Folkestone formations. These in turn are overlain by the grey mudstones with small calcareous phosphate nodules of the **Gault Formation** succeeded by the fine-grained, glauconitic, shelly, sometimes silty sand and sandstone of the **Upper Greensand Formation**.

The Cretaceous Chalk is mostly covered by younger Palaeogene deposits but crops out extensively in the north-west and along the southern sector of the London region. The **Grey Chalk Subgroup** at the base is characterised by marl beds and relatively rare flints whilst the overlying **White Chalk Subgroup** (Newhaven, Seaford and Lewes Nodular Chalk formations) comprises white chalk with numerous seams of flint nodules. The lower parts of the White Chalk (New Pit and Holywell Nodular Chalk Formations) in the south-east contain little flint. Chalk is typically a very fine-grained white limestone consisting predominantly of the disaggregated skeletal remains of tiny planktonic algae, composed of almost pure calcium carbonate in the form of low-magnesium calcite. Iron-stained, glauconised and phosphatised, highly indurated nodular chalk, referred to as hardgrounds, occur at the top of the Grey Chalk and intermittently throughout the White Chalk, especially in the Lewes Chalk.

Palaeogene

The **Thanet Sand Formation** is the oldest Palaeogene deposit within the region and crops out only in the south and south-east. The bulk of the Thanet Formation is a coarsening-upwards sequence dominated by silty, fine-grained sand with a more clayey and silty basal section. The heavy minerals present (epidote, hornblende, garnet, zircon, rutile and tourmaline) indicate that the sands are derived from the metamorphic rocks of the Scottish Highlands (Ellison et al., 2004).

The overlying **Lambeth Group**, crops out in the central, south-east and north-west of the region, and has a more extensive distribution than the Thanet Sand Formation. At the base, the Upnor Formation is typically composed of fine- to medium-grained sands with varying proportions of glauconite, flint pebble beds, and clay. The clays are smectite with subordinate illite and heavy minerals include zircon, rutile and tourmaline. The lithology of the Lambeth Group is highly variable both laterally and vertically and consists of three formations in the London region. The lower part of the Reading Formation is succeeded by the Woolwich Formation, consisting of the brackish–marine Lower Shelly Clays (grey laminated clay, with occasional silts and sands and abundant layers of shells) and the Laminated Beds (thinly laminated clay-silt and silt-sand, with frequent organic remains and occasional shell beds). These sediments thin rapidly westwards across London and are succeeded by the Upper Reading Formation (mottled clays, silts and sands with the rare deep sand channel deposits). In the far west of the London Basin, the Lower Reading Formation is succeeded directly by the Upper Reading Formation; both Lower

and Upper Reading Formations thin eastwards across the London area (Ellison et al., 2004). Heavy minerals in the Reading and Woolwich beds are predominantly zircon, rutile and tourmaline with minor epidote, apatite and garnet.

The marine **Thames Group** consists of the thin sandy and gravelly **Harwich Formation** (glauconitic sandy clays and very fine-grained glauconitic sands; glauconitic fine-grained sand and pebble beds of black flint, calcareous and ferruginous cement) which overlies the Lambeth Group and is succeeded by the thick **London Clay Formation** which is the most widespread of the Palaeogene deposits in the London region. The London Clay is typically composed of fairly homogenous silty clay but has some sandy or pebbly layers, and it is generally sandier towards the top of the formation. The sandy facies of the Claygate Member lies beneath the **Bracklesham Group**, which comprises interbedded laminated silts and silty clays, sands and silty sands, which are locally shelly. At the base of the Bracklesham Group is the **Bagshot Formation** dominated by white, yellow, orange-brown, and ochreous-brown, fine-grained quartz sand containing zircon and tourmaline, with subsidiary silt-clay and local beds of flint-pebble gravel. The overlying **Windlesham Formation and Camberley Sand Formation** are mainly sands whereas the dominantly clayey parts of the Bracklesham Group are found in the **Windlesham Formation**. The clays crop out mainly in the south-west of the London region whilst the sand units of the Bracklesham Group crop out both in the south-west and also at Hampstead Heath, Highgate, northern Camden areas to the north of the River Thames.

Quaternary

The pre-Anglian **clay-with-flints** crops out extensively in the south-east and north-east of the region, resting on the Chalk. Clay-with-flints is a heterogeneous, unbedded residual deposit formed by weathering and solifluction of the original Palaeogene cover and earlier Quaternary deposits, and by dissolution of the underlying chalk. The thickness of the clay-with-flints is very variable, ranging from 5 to 10 m. Lithologies include reddish brown clay with large unworn flint cobbles, yellow fine- to medium-grained sand, reddish brown clayey silt, and sandy clay with beds of well-rounded flint pebbles. At the base there is frequently a 100 mm thick dark brown to black waxy clay with flints stained by manganese precipitated from groundwater and with a green glauconitic cortex. The clay-with-flints has been subjected to weathering during periods of warm climate and several periglacial periods.

Pre-diversionary (pre-Anglian) river sand and gravel terrace deposits of the ancestral Thames river system were deposited mainly in the west of the region where they are commonly mapped as **plateau gravels**, especially where they overlie the Chalk. The gravels mainly form hill-top caps and are characterised by quartz and quartzite pebbles from the English Midlands and more locally derived flint pebbles from the Chalk. The deposits, which include the Stanmore Gravel, invariably cap hill tops and primarily comprise well-rounded flint pebbles in a clay matrix.

Glacial till, formerly known as 'chalky boulder clay' and now known as the Lowestoft Till, crops out mainly in the north-east of the region with one outlier around Finchley. It was laid down at the southern margin of the Anglian ice sheet and is part of an once-continuous till sheet that extends north and north-east into Hertfordshire, Essex and Suffolk. The till is a heterogeneous deposit consisting mainly of stiff, pebbly to boulder-rich, variably silty and sandy clay. Clasts are typically of chalk and flint with subordinate Triassic sandstone, vein quartz and quartzite in a clay matrix containing a substantial proportion of chalk flour.

The River Thames was diverted into its present valley late in Anglian times (c. 500 000 years ago) initiating the deposition of extensive **river terrace gravels** throughout the Thames valley. Within the region these gravels form a central belt extending north into the Lee valley. The bulk of the gravels were deposited on a broad river braidplain (an estimated 5 km wide) during past colder periods, when greater volumes of sediment were available. Many of the older outcrops can be found on hilltops, for example at Wimbledon Common.

Deposits mapped as **brickearth** comprise very fine-grained sand, silt and clayey silt, brown to orange-brown in colour with re-precipitated, calcium carbonate nodules. They are considered to be loessic (windblown) in origin but basal gravels are probably solifluction deposits with some evidence of fluvial deposition. The deposits have been used for brickmaking since Roman times.

The most recent superficial deposit is **alluvium** which forms a nearly flat surface in valley floors and occurs mainly in the valleys of the rivers Thames, Lee, Wandle and Roding, where there is a distinctive floodplain developed. On average the alluvium is less than 3 m thick and consists largely of silty clay and clayey silt with locally developed beds of fine- to coarse-grained sands. In the east, interbedded peats also occur within the River Thames alluvial deposits.

Solifluction (**head**) deposits formed under periglacial conditions have compositions that reflect the underlying geological units (e.g. head derived from the London Clay is clayey whilst that derived from the Chalk is generally calcareous, but may be locally decalcified). In the simplified PM map (**Figure 3**), the head deposits are classified as *clay-silt* or *gravel-sand*. The latter occur over the Stanmore Gravel and overlying post-diversionary river terrace deposits.

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London Atlas: Materials and methods I: data acquisition

Ferreira, A, Johnson, C C, Appleton, J D, Flight, D M A, Lister, T R, Knights, K V, Ander, L, Scheib, C, Scheib, A, Cave, M, Wragg, J, Fordyce, F and Lawley, R. 2016. London Region Atlas of Topsoil Geochemistry. *British Geological Survey*.

The London Region Atlas of Topsoil Geochemistry (LRA) covers a rectangular area of 80 x 62 km (4960 km^2), from British National Grid coordinates X, Y: 490000, 153000 to 570000, 215000. The LRA was produced using the London Region Topsoil Dataset (**LRD**, N=8400), which was created from two BGS geochemical surveys (LOND and SEEN) carried out under the Geochemical Baseline Survey of the Environment (G-BASE[1]) project between 2005 and 2009. LOND is an **urban** soil survey based on 6801 sampling sites at a sampling density of 1 per 0.25 km^2; 6494 (95.5%) of the LOND samples are part of the London Earth[2] project as they are located within the GLA. SEEN is a south-east England **rural** soil survey carried out at a sampling density of 1 per 2 km^2; 1599 (out of the 4089) SEEN sample sites are included in the LRA rectangle area; however, 95% are outwith the GLA limit as these are rural samples (**Figure 2**).

Field procedures and laboratory methods were undertaken in a standardised way to ensure consistency and enable quality assessment of the analytical results (Johnson et al., 2005[3]). This allowed adequate levelling of geochemical datasets from contiguous areas, sampled and analysed at different times or under different projects. Methods are described in the following sections. Descriptions of the interpolation method (parent material mapping method, Appleton and Adlam, 2012[4]) used to generate maps of the soil geochemical properties and of the exploratory data analysis techniques deployed are outlined in the last section.

Throughout this atlas the **LRD** dataset, and **SEEN** and **LOND** subsets are generally represented by the colours **black/white**, **dark green** and **dark red** respectively, while Quaternary, Palaeogene and Cretaceous geological time periods are represented by soft yellow, orange and lime green colours respectively.

Sampling

Sampling strategies for geochemical mapping using soil samples in rural (regional) and urban areas are described by Johnson et al. (2005) and Fordyce et al. (2005)[5], respectively. The only major difference between the two is the sampling density. In rural areas soil samples are collected from alternate British National Grid (BNG) kilometre squares, corresponding to a sampling density of 1 sample/2 km^2 (or 0.5 samples/km^2); sites are ideally located at least 100 m from roads, buildings, railways, electricity pylons etc., on open unforested, and undisturbed ground whenever possible; the site should be generally representative of the land use within the selected kilometre square. In urban areas, the sample density is 1 sample/0.25 km^2 (or 4 samples/km^2); samples are collected from open ground (preferably gardens, parks, sports fields, road verges, allotments, open spaces, schoolyards, and waste ground) as close as possible to the centre of each 500 m cell (subdivisions of the BNG 1 km cell) (**Figure 5**). The greater density in urban areas allows the capture of more local-scale element concentration variability caused by human activity. The way of defining an urban area for sample collection purposes is described by Johnson and Ander (2008)[6].

Soil sampling was carried out according to the procedures detailed in the G-BASE[1] field procedures manual (Johnson, 2005[7]). All soil samples were collected and transported in 5”x10” Kraft™ paper bags. Each sample consisted of approximately 250 g of unsieved material and was a composite of five subsamples from auger holes distributed within an area of approximately 20 x 20 m whenever possible. Auger holes were located at the corners and centre of a square (**Figure 6**). A 1 m stainless steel Dutch auger with a 15 cm auger flight was used to collect soil samples from a fixed depth.

Topsoil samples (sample type code ‘A’) were collected to a depth of 20 cm, after removal of surface vegetation, surface litter and root zone. The bottom depth of the sample was recorded on the field card and the depth of any rootlet zone and surface litter was also noted. The deep soil sample (sample type code ‘S’) was targeted to collect to a depth of 35-50 cm (in rural areas this had the objective of sampling below any ploughed horizon), the actual sampling depth was recorded on the field card. Over terrains where only thin soils were developed e.g. over chalk, then a topsoil sample was collected from the normal surface depth, i.e. 5 to 20 cm and the S sample from as deep as possible down to bedrock. In such instances there may be little difference in the sampling depths between the A and S samples.

An extra surface sample (0–2 cm) was collected in the London Earth[2] GLA area, designated as sample type code ‘X’. The X samples often demanded material from additional auger holes within the 20 m square in order to reach the required sample weight of ca. 250 g. If a root layer was present this was collected as part of the surface sample (Knights and Scheib, 2010[8]).

Field duplicate samples were collected at a rate of 1 duplicate per 100 sampling sites in rural surveys. This rate was doubled (2 per 100 sampling sites) in urban surveys following the higher sampling density implemented in these areas. For quality control purposes, the field duplicates were collected with exactly the same procedure as a regular sample, but in an adjacent auger square (**Figure 6**).

At each sampling site, information about date of sampling, local details (location, geology, visible contamination, land use, etc.) and observations of the sample, such as soil colour, depth, clast lithology and apparent abundance, and textural classification, were recorded on a field card.

The geochemical results for the topsoil samples type ‘A’ (5-20 cm depth) only are presented in this atlas.

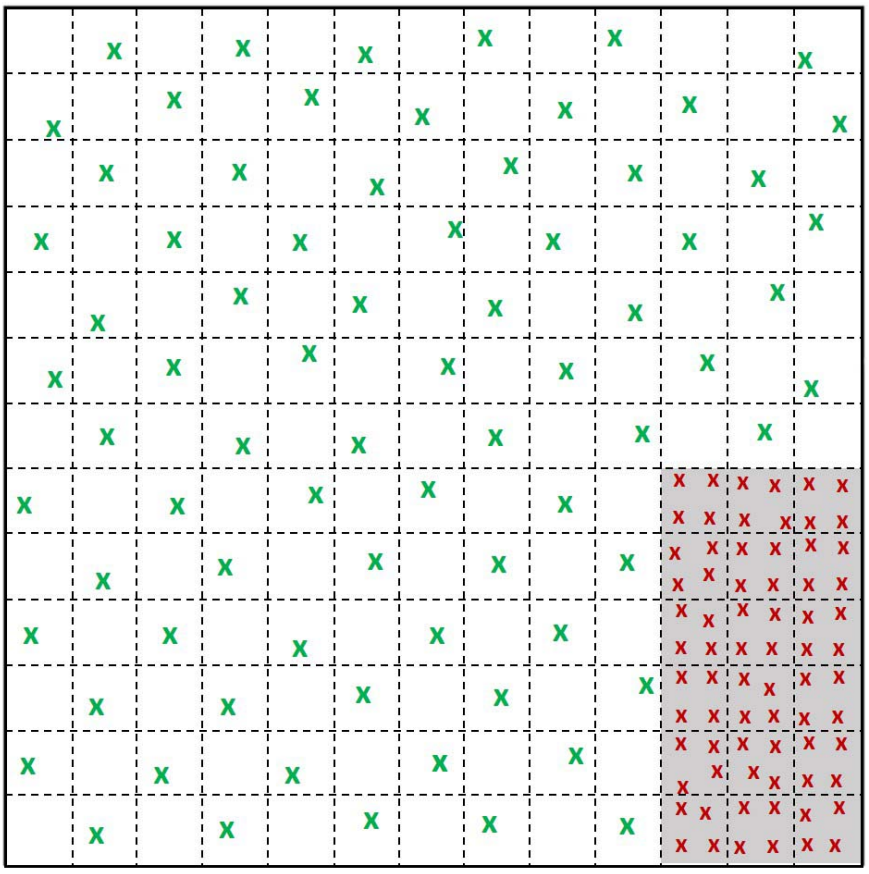

Figure 5 The G-BASE strategy for urban (red X) and rural (green X) soil sampling sites. The grid represents 1 km squares and the urban region is shaded (adapted from Johnson, 2005). (P929861).

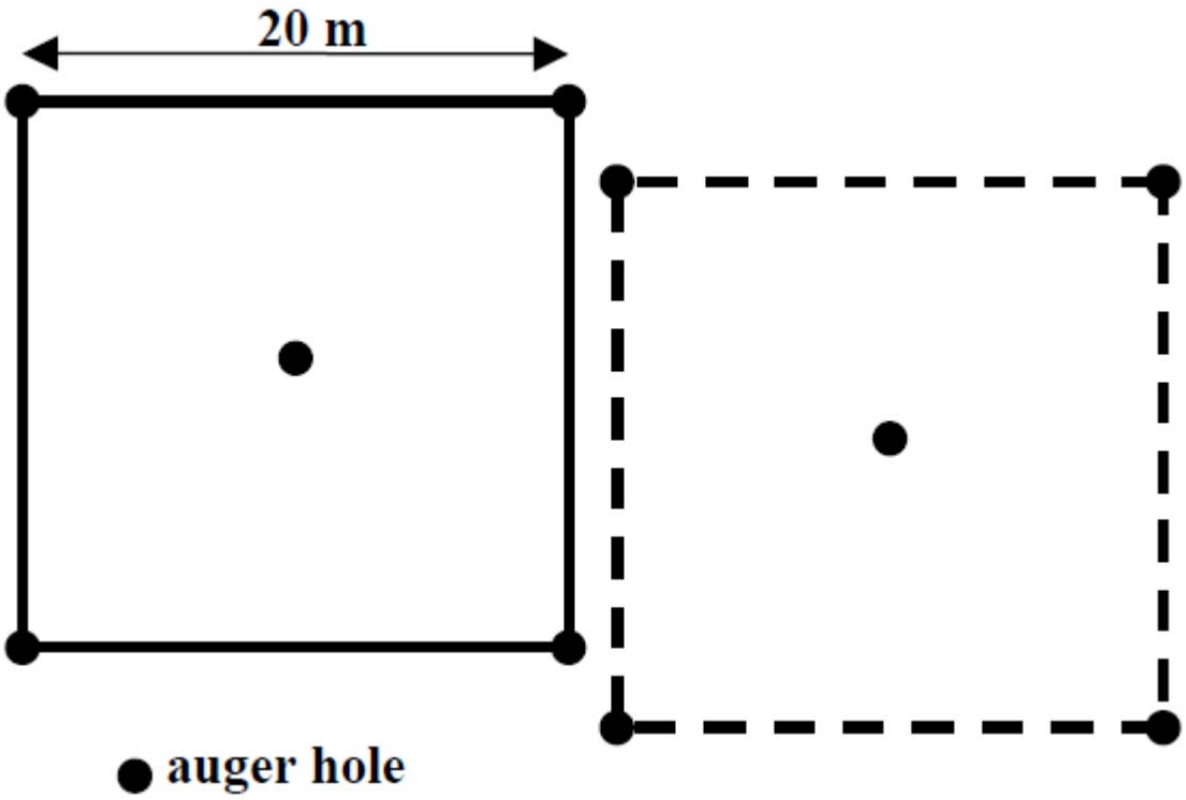

Figure 6 Plan of composite auger holes for collecting a soil sample (dashed square represents adjacent duplicate sample) (from Johnson, 2005). (P929862).

Sample preparation and analysis

Soil samples were prepared and analysed at the BGS laboratories in Keyworth. All samples were dried and sieved but only the topsoils were routinely analysed by XRFS. After air-drying at <35°C (to prevent volatilisation of Se and Hg), each sample was sieved through a nylon sieve to give the <2 mm fraction. The sample was then homogenised, coned and quartered before a 50 g subsample was pulverised in an agate planetary ball mill to create a homogeneous sample (95% under 53 mm), from which a portion (12 g) was taken to prepare a pressed powder pellet for XRFS analysis.

Samples were analysed for total element concentration by XRFS in the BGS laboratories[9] in Keyworth. Analysis is accredited to ISO 17025 and to the Environment Agency's Monitoring Certification Scheme (*M*CERTS) standard for soils. Several different XRFS instruments were used, namely a PANalytical Axios advanced and a Philips MagiX PRO wavelength dispersive XRF spectrometer (WD-XRFS); and a PANalytical Epsilon-5 polarised energy dispersive XRF spectrometer (ED(P)XRFS), to determine 53 chemical elements. Forty-four of these elements are listed together with their lower limit of detection (LLD[10]) and the number of samples below LLD in **Table 3**. The remaining nine elements (**Table 4**) were excluded as six of them (Cl, In, S, Te, Hg and Ta) showed more than 90% of the results below the LLD in at least one of the **LRD** subsets (**SEEN**, **LOND**) and five of them (Sm, Tl, Yb, Hg and Ta) showed a very small between-site variability (less than 35%), due to high within-sample and/or within-site variability mostly as a results of data close to the LLD (**Table 5**). Of the 44 elements shown in the London Region Atlas of Topsoil Geochemistry, the 10 most abundant elements (Al_2O_3, CaO, Fe_2O_3, K_2O, MgO, MnO, Na_2O, P_2O_5, SiO_2, TiO_2) are expressed in terms of weight percent oxide (wt%) as concentration units, while the remaining 34 (Ag, As, Ba, Bi, Br, Cd, Ce, Co, Cr, Cs, Cu, Ga, Ge, Hf, I, La, Mo, Nb, Nd, Ni, Pb, Rb, Sb, Sc, Se, Sn, Sr, Th, U, V, W, Y, Zn and Zr) are shown in mg/kg (equivalent to the non-SI old notation ppm - parts per million).

Two extra parameters, loss on ignition (LOI) and pH were also determined on the topsoil samples from the **LOND** subset (except one for LOI) and about two thirds (1128 out of 1599) of the **SEEN** subset, resulting in a total of 7928 (for LOI) and 7929 (for pH) measurements. The loss on ignition, a proxy for the soil's organic matter content (but can be affected by the loss of structural water in clay soils (Rowell, 1994[11]), was determined on 2 g of <2 mm size material by weighing the sample before and after heating in a furnace at 450°C for 24 hrs. The soil pH was determined with a pH electrode after mixing 10 g of <2 mm size material in 25 ml of 0.01 M $CaCl_2.2H_2O$ and shaking until a slurry was formed.

Table 3 List of elements determined by XRFS reported in the London Region Atlas of Topsoil Geochemistry. The lower limit of detection (LLD), the number of samples below the LLD (n<LLD) and the n<LLD in percent (%<LLD) are shown for the London Region Dataset (LRD), and the two subsets (SEEN and LOND). Number of samples (N) is as follow: LRD = 8400, SEEN = 1599 and LOND = 6801.

Element Symbol Units	Data	LLD	n<LLD	%<LLD	Element Symbol Units	Data	LLD	n<LLD	%<LLD	Element Symbol Units	Data	LLD	n<LLD	%<LLD
Aluminium oxide Al_2O_3 %	LRD	0.2	0	0.0	Cadmium Cd mg/kg	LRD	0.5	2317	27.6	Lead Pb mg/kg	LRD	1.3	0	0.0
	SEEN	0.2	0	0.0		SEEN	0.5	787	49.2		SEEN	1.3	0	0.0
	LOND	0.2	0	0.0		LOND	0.5	1530	22.5		LOND	1.3	0	0.0
Calcium oxide CaO %	LRD	0.05	14	0.2	Cerium Ce mg/kg	LRD	1	0	0.0	Rubidium Rb mg/kg	LRD	1	0	0.0
	SEEN	0.05	14	0.9		SEEN	1	0	0.0		SEEN	1	0	0.0
	LOND	0.05	0	0.0		LOND	1	0	0.0		LOND	1	0	0.0
Iron (III) oxide Fe_2O_3 %	LRD	0.01	0	0.0	Cobalt Co mg/kg	LRD	1.5	27	0.3	Antimony Sb mg/kg	LRD	0.5	84	1.0
	SEEN	0.01	0	0.0		SEEN	1.5	19	1.2		SEEN	0.5	68	4.3
	LOND	0.01	0	0.0		LOND	1.5	8	0.1		LOND	0.5	16	0.2
Potassium oxide K_2O %	LRD	0.01	0	0.0	Chromium Cr mg/kg	LRD	3	0	0.0	Scandium Sc mg/kg	LRD	3	374	4.5
	SEEN	0.01	0	0.0		SEEN	3	0	0.0		SEEN	3	198	12.4
	LOND	0.01	0	0.0		LOND	3	0	0.0		LOND	3	176	2.6
Magnesium oxide MgO %	LRD	0.3	376	4.5	Caesium Cs mg/kg	LRD	1	0	0.0	Selenium Se mg/kg	LRD	0.2	140	1.7
	SEEN	0.3	83	5.2		SEEN	1	0	0.0		SEEN	0.2	51	3.2
	LOND	0.3	293	4.3		LOND	1	0	0.0		LOND	0.2	89	1.3

Element Symbol Units	Data	LLD	n<LLD	%<LLD	Element Symbol Units	Data	LLD	n<LLD	%<LLD	Element Symbol Units	Data	LLD	n<LLD	%<LLD
Manganese oxide MnO %	LRD	0.005	20	0.2	Copper Cu mg/kg	LRD	1.3	0	0.0	Tin Sn mg/kg	LRD	0.5	0	0.0
	SEEN	0.005	12	0.8		SEEN	1.3	0	0.0		SEEN	0.5	0	0.0
	LOND	0.005	8	0.1		LOND	1.3	0	0.0		LOND	0.5	0	0.0
Sodium oxide Na_2O %	LRD	0.3	447	5.3	Gallium Ga mg/kg	LRD	1	0	0.0	Strontium Sr mg/kg	LRD	1	0	0.0
	SEEN	0.3	167	10.4		SEEN	1	0	0.0		SEEN	1	0	0.0
	LOND	0.3	280	4.1		LOND	1	0	0.0		LOND	1	0	0.0
Phosphorous pentoxide P_2O_5 %	LRD	0.05	16	0.2	Germanium Ge mg/kg	LRD	0.5	384	4.6	Thorium Th mg/kg	LRD	0.7	3	0.0
	SEEN	0.05	15	0.9		SEEN	0.5	109	6.8		SEEN	0.7	1	0.1
	LOND	0.05	1	0.0		LOND	0.5	275	4.0		LOND	0.7	2	0.0
Silica SiO_2 %	LRD	0.1	0	0.0	Hafnium Hf mg/kg	LRD	1	0	0.0	Uranium U mg/kg	LRD	0.5	43	0.5
	SEEN	0.1	0	0.0		SEEN	1	0	0.0		SEEN	0.5	1	0.1
	LOND	0.1	0	0.0		LOND	1	0	0.0		LOND	0.5	42	0.6
Titanium dioxide TiO_2 %	LRD	0.01	0	0.0	Iodine I mg/kg	LRD	0.5	15	0.2	Vanadium V mg/kg	LRD	3	0	0.0
	SEEN	0.01	0	0.0		SEEN	0.5	3	0.2		SEEN	3	0	0.0
	LOND	0.01	0	0.0		LOND	0.5	12	0.2		LOND	3	0	0.0

Element Symbol Units	Data	LLD	n<LLD	%<LLD	Element Symbol Units	Data	LLD	n<LLD	%<LLD	Element Symbol Units	Data	LLD	n<LLD	%<LLD
Silver Ag mg/kg	LRD	0.5	1232	14.7	Lanthanum La mg/kg	LRD	1	0	0.0	Tungsten W mg/kg	LRD	0.6	219	2.6
	SEEN	0.5	175	10.9		SEEN	1	0	0.0		SEEN	0.6	81	5.1
	LOND	0.5	1057	15.5		LOND	1	0	0.0		LOND	0.6	138	2.0

Arsenic As mg/kg	**LRD**	2.4	9	0.1	**Molybdenum Mo mg/kg**	**LRD**	0.2	18	0.2	**Yttrium Y mg/kg**	**LRD**	1	0	0.0
	SEEN	2.4	5	0.3		**SEEN**	0.2	11	0.7		**SEEN**	1	0	0.0
	LOND	2.4	4	0.1		**LOND**	0.2	7	0.1		**LOND**	1	0	0.0
Barium Ba mg/kg	**LRD**	1	0	0.0	**Niobium Nb mg/kg**	**LRD**	1	0	0.0	**Zinc Zn mg/kg**	**LRD**	1.3	3	0.0
	SEEN	1	0	0.0		**SEEN**	1	0	0.0		**SEEN**	1.3	1	0.1
	LOND	1	0	0.0		**LOND**	1	0	0.0		**LOND**	1.3	2	0.0
Bismuth Bi mg/kg	**LRD**	0.3	4490	53.5	**Neodymium Nd mg/kg**	**LRD**	4	19	0.2	**Zirconium Zr mg/kg**	**LRD**	1	0	0.0
	SEEN	0.3	918	57.4		**SEEN**	4	14	0.9		**SEEN**	1	0	0.0
	LOND	0.3	3572	52.5		**LOND**	4	5	0.1		**LOND**	1	0	0.0
Bromine Br mg/kg	**LRD**	0.8	0	0.0	**Nickel Ni mg/kg**	**LRD**	1.3	3	0.0	.				
	SEEN	0.8	0	0.0		**SEEN**	1.3	3	0.2					
	LOND	0.8	0	0.0		**LOND**	1.3	0	0.0					

Table 4 List of elements determined by XRFS not reported in the London Region Atlas of Topsoil Geochemistry. The lower limit of detection (LLD), the number of samples below the LLD (n<LLD) and the n<LLD in percent (%<LLD) are shown for the London Region Dataset (LRD), and the two subsets (SEEN and LOND). Number of samples (N) is as follow: LRD = 8400, SEEN = 1599 and LOND = 6801.

Element Symbol Units	Data	LLD	n<LLD	%<LLD	Element Symbol Units	Data	LLD	n<LLD	%<LLD	Element Symbol Units	Data	LLD	n<LLD	%<LLD
Chlorine Cl mg/kg	**LRD**	200	8378	99.7	**Tellurium Te mg/kg**	**LRD**	0.5	8347	99.4	**Samarium Sm mg/kg**	**LRD**	3.0	3217	38.3
	SEEN	200	1596	99.8		**SEEN**	0.5	1583	99.0		**SEEN**	3.0	533	33.3
	LOND	200	6782	99.7		**LOND**	0.5	6764	99.5		**LOND**	3.0	2684	41.9
Indium In mg/kg	**LRD**	0.5	8348	99.4	**Mercury Hg mg/kg**	**LRD**	0.5	6921	82.4	**Thallium Tl mg/kg**	**LRD**	0.5	6054	72.1
	SEEN	0.5	1586	99.2		**SEEN**	0.5	1513	94.6		**SEEN**	0.5	1049	65.6
	LOND	0.5	6762	99.4		**LOND**	0.5	5408	79.5		**LOND**	0.5	5005	78.2
Sulphur S mg/kg	**LRD**	2000	8243	98.1	**Tantalum Ta mg/kg**	**LRD**	1.0	7741	92.9	**Ytterbium Yb mg/kg**	**LRD**	1.5	2520	30.0
	SEEN	2000	1586	99.2		**SEEN**	1.0	1368	85.6		**SEEN**	1.5	371	23.2
	LOND	2000	6657	97.9		**LOND**	1.0	6373	93.7		**LOND**	1.5	2149	33.6

Table 5 Nested ANOVA results for the London Region Data topsoil duplicate and replicate sets. The number of sites indicate the number of locations with duplicate and replicate samples. Results below the lower limit of detection are excluded from the ANOVA analysis (Johnson et al., 2010[12]). Elements are ordered according to their performance in the nested ANOVA test. Shaded elements were excluded from the atlas after this test.

Element	Between-site %	Within-site %	Within-sample %	Number of sites	Element	Between-site %	Within-site %	Within-sample %	Number of sites
Nb	94.5	4.2	1.3	171	MnO	84.2	13.1	2.7	171
K_2O	93.3	6.4	0.3	171	As	83.8	13.4	2.8	171
Rb	93.1	6.6	0.3	171	P_2O_5	82.5	16.6	0.9	171
La	92.0	6.0	2.0	171	Ba	82.3	15.3	2.4	171
TiO_2	91.6	7.1	1.3	171	Na_2O	82.3	10.2	7.5	124
Ce	91.0	7.4	1.6	171	Co	82.1	10.6	7.3	171
Ga	90.7	6.3	2.9	171	Cs	81.7	4.5	13.7	171
MgO	90.7	8.4	0.9	168	W	80.1	5.5	14.4	166
Y	90.6	7.0	2.4	171	Ni	79.9	16.2	3.9	171
Al_2O_3	90.5	8.7	0.7	171	Cu	79.6	17.8	2.6	171
V	90.5	8.3	1.2	171	Zn	77.0	20.9	2.0	171
Th	89.4	6.2	4.4	171	Sc	76.4	9.3	14.2	165
Zr	88.9	9.4	1.7	171	Sb	75.9	14.9	9.2	170
CaO	88.3	10.3	1.3	171	Sn	75.0	16.4	8.5	171
Fe_2O_3	88.1	8.8	3.1	171	U	72.1	5.5	22.3	165
Mo	88.1	8.9	3.0	151	Se	66.7	14.9	18.4	171
Sr	88.0	10.5	1.5	171	Cd	62.9	24.7	12.4	108
Nd	86.6	7.5	5.9	170	Ge	62.3	17.8	20.0	168
Br	86.4	11.4	2.2	171	Ag	58.9	30.9	10.2	26
Hf	86.0	7.1	6.9	171	Bi	52.2	28.1	19.7	55
Pb	85.3	10.7	4.0	171	Yb	34.8	5.3	59.8	99
I	85.2	8.8	6.0	171	Hg	29.7	55.2	15.1	39
SiO_2	85.0	12.5	2.5	171	Sm	25.7	4.5	69.8	166
Cr	85.0	13.9	1.2	171	Tl	16.6	-8.6	91.9	65
					Ta	15.3	3.0	81.7	54

Quality control

G-BASE[1] analytical results are subjected to rigorous quality control procedures described in detail elsewhere (Lister and Johnson, 2005[13]; Johnson, 2011[14]). The entire process, from field procedures to sample preparation and analysis in the laboratory is designed to minimise errors. Systematic errors are able to be checked because a randomised number is assigned to samples on collection.

Accuracy, precision and long-term analytical drift is assessed by including BGS XRF laboratory primary and secondary certified reference materials (CRMs) along with every batch of 500 samples in the analytical runs. Secondary CRMs allow any between batch bias to be identified and corrected. Primary CRMs ensure that bias from the 'true' result is minimized. Primary and secondary reference materials have been used routinely to assess the quality of regional geochemical data since the UK national mapping programme commenced in the 1960s (Lister and Johnson, 2005[15]; Johnson et al., 2008[16]). This ensures a 'seamless' continuation of geochemical data across large regions for samples collected over many field campaigns and analysed by different analytical instruments. All data in this London Region Geochemical Dataset are levelled using four accredited reference materials (GSD-7, GSS-1, LKSD-1, LKSD-4). Certified values (in red) together with the values reported by the BGS XRF laboratory are shown in **Table 6**.

A previously unrecognised analytical interference between high topsoil Pb concentration and U measurement in the London Earth[2] results, where high Pb was suppressing the U results, has been corrected in this London Region dataset.

The G-BASE[1] project also inserts field *duplicate* and laboratory *replicate* samples in every batch of fifty (urban) or one hundred (rural) samples. The laboratory *replicate* is a sub-sample of the *same sample* taken before analysis, whilst a field *duplicate* is a *second sample* collected in the field at the same location as a regular sample. These two control samples allow assessment of the analytical and sampling variability respectively and comparison to the total variability. This provides a check that the local (within-site) 'noise' is low enough so that the regional patterns (between sites) are distinguishable and reliable. This was achieved by performing a nested unbalanced analysis of variance (ANOVA) using these duplicate and replicate samples (Johnson, 2002[17]). The validity of the nested ANOVA depends on the representativeness of the duplicates and replicates, and it may not be valid if a large number of samples have element concentrations that are near or below the LLD. Nevertheless, results give an indication of the elements for which the natural geochemical variability is significantly higher than the variability related to the sampling and analytical procedures. The higher the percentage of total variability attributed between sites, the higher the confidence in the results (**Table 5**). For elements with a value above 80% the sampling and analytical methodology is considered suitable, as it does not introduce too much 'background noise'. As between-site variability decreases from 80% down to about 50%, increasing caution must be taken during statistical analysis and/or interpretation. Elements showing a between-site variability below 50% (Yb, Hg, Sm, Tl and Ta) are not considered further in the LRA, as already explained under the Sample preparation and analysis section of this atlas.

Table 6 Summary of primary reference material results for soil samples XRFS analyses in the London Region Atlas of Topsoil Geochemistry. Units for elements shown as oxides are wt% and mg/kg otherwise.

	Elements by XRF-ED																					
CRM ID	Ag	Cert Ag	Cd	Cert Cd	In	Cert In	Sn	Cert Sn	Sb	Cert Sb	I	Cert I	Cs	Cert Cs	Ba	Cert Ba	La	Cert La	Ce	Cert Ce
GSD-7	1.4	1.1	0.9	1.1	not detected	no data	4.8	5.4	2.8	2.6	0.9	no data	5	6	740	720	45	45	82	78.0
GSS-1	0.4	0.4	4.4	4.3	not detected	no data	5.9	6.1	1.0	0.9	1.9	1.9	9	9	587	590	34	34	68	70.0

LKSD-1	0.5	0.6	1.1	1.2	0.5	no data	15.2	16.0	0.9	1.2	1.7	no data	1	2	396	430	14	16	25	27.0
LKSD-4	0.1	0.2	1.9	1.9	not detected	no data	4.6	5.0	1.3	1.7	9.5	no data	2	2	262	330	21	26	38	48.0

Elements by XRF-WDT

CRM ID	K_2O	Cert K_2O	CaO	Cert CaO	TiO_2	Cert TiO_2	MnO	Cert MnO	Fe_2O_3	Cert Fe_2O_3	S	Cert S	Cl	Cert Cl	Sc	Cert Sc
GSD-7	3.64	3.54	1.65	1.67	0.707	0.747	0.093	0.089	6.50	6.51	646	190	83	no data	13.7	14.6
GSS-1	2.53	2.59	1.75	1.72	0.766	0.805	0.238	0.227	5.18	5.19	847	310	114	78	10.4	11.2
LKSD-1	1.06	1.10	12.14	10.80	0.448	0.500	0.093	0.100	4.03	4.10	9306	1570	430	no data	6.5	9.0
LKSD-4	0.76	0.80	1.85	1.80	0.299	0.400	0.068	0.100	4.20	4.10	5952	999	215	no data	7.1	7.0

CRM ID	V	Cert V	Cr	Cert Cr	Co	Cert Co	Ni	Cert Ni	Cu	Cert Cu	Zn	Cert Zn	Ga	Cert Ga	Ge	Cert Ge
GSD-7	93.4	96.0	119.3	122.0	20.6	21.0	55.6	53.0	36.1	38.0	246.2	238.0	16.7	17.7	0.9	1.4
GSS-1	80.7	86.0	60.0	62.0	13.9	14.2	20.7	20.4	19.7	21.0	671.6	680.0	17.6	19.3	0.6	1.3
LKSD-1	47.8	50.0	27.0	31.0	11.0	11.0	16.0	16.0	40.6	44.0	322.4	331.0	9.0	no data	0.1	no data
LKSD-4	45.5	49.0	30.1	33.0	11.7	11.0	34.1	31.0	30.1	31.0	194.3	194.0	7.9	no data	0.5	no data

CRM ID	As	Cert As	Se	Cert Se	Br	Cert Br	Rb	Cert Rb	Sr	Cert Sr	Y	Cert Y	Zr	Cert Zr	Nb	Cert Nb
GSD-7	83.7	84.0	0.2	0.3	0.6	no data	146.4	147.0	222.4	220.0	24.9	24.0	156.9	162.0	15.1	17.0
GSS-1	35.8	33.5	0.1	0.1	2.5	2.9	137.9	140.0	156.6	155.0	24.9	25.0	250.1	245.0	14.7	16.6
LKSD-1	34.9	40.0	1.0	no data	10.3	11.0	22.7	24.0	259.4	250.0	20.9	19.0	132.8	134.0	4.0	7.0
LKSD-4	16.6	16.0	2.3	no data	50.6	49.0	25.0	28.0	121.0	110.0	22.2	23.0	101.3	105.0	4.3	9.0

CRM ID	Mo	Cert Mo	Nd	Cert Nd	Sm	Cert Sm	Yb	Cert Yb	Hf	Cert Hf	Ta	Cert Ta	W	Cert W	Hg	Cert Hg
GSD-7	1.3	1.4	34.1	37.0	4.4	6.1	2.2	2.6	5.0	4.9	0.8	1.4	6.5	5.5	-0.3	0.1
GSS-1	1.1	1.4	26.3	28.0	3.9	5.2	2.1	2.7	7.7	6.8	0.5	1.4	4.6	3.1	-0.8	0.0
LKSD-1	9.4	10.0	19.4	16.0	2.9	4.0	1.7	2.0	4.1	3.6	-0.2	0.3	1.7	<4	-0.6	0.0
LKSD-4	1.3	<5	27.1	25.0	4.3	5.0	2.1	2.0	3.1	2.8	-0.1	0.4	1.8	<4	-0.5	no data

CRM ID	Tl	Cert Tl	Pb	Cert Pb	Bi	Cert Bi	Th	Cert Th	U	Cert U
GSD-7	0.7	0.9	361.1	350.0	0.6	0.7	12.6	12.6	3.4	3.5

GSS-1	0.7	1.0	98.2	98.0	0.7	1.2	11.4	11.6	3.7	3.3		
LKSD-1	0.1	no data	83.7	82.0	0.6	no data	2.1	2.2	9.7	9.7		
LKSD-4	0.8	no data	97.3	91.0	0.0	no data	5.1	5.1	31.4	31		

Elements by XRF-WDM												
CRM ID	**Na_2O**	**Cert Na_2O**	**MgO**	**Cert MgO**	**Al_2O_3**	**Cert Al_2O_3**	**SiO_2**	**Cert SiO_2**	**P_2O_5**	**Cert P_2O_5**	**SO_3**	**Cert SO_3**
GSD-7	1.2	1.2	4.3	3.1	14.6	13.4	67.3	64.7	0.21	0.19	not detected	no data
GSS-1	1.4	1.7	2.1	1.8	14.1	14.2	57.4	62.6	0.18	0.17	0.1	0.08
LKSD-1	1.6	2.0	1.8	1.7	5.6	7.8	31.5	40.1	0.16	0.20	2.6	no data
LKSD-4	0.5	0.7	1.0	0.9	5.2	5.9	45.2	41.6	0.36	0.30	2.1	no data

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London Atlas: Materials and methods II: data visualisation

Ferreira, A, Johnson, C C, Appleton, J D, Flight, D M A, Lister, T R, Knights, K V, Ander, L, Scheib, C, Scheib, A, Cave, M, Wragg, J, Fordyce, F and Lawley, R. 2016. London Region Atlas of Topsoil Geochemistry. *British Geological Survey*.

The dataset described here, the London Region Topsoil Dataset (**LRD**), was initially created to investigate how the geochemical baseline of the London region is influenced by the underlying parent material. The data are a combination of the G-BASE[1] urban data released as part of the London Earth[2] project in 2011 (Johnson, 2011[3]) plus other available rural or urban G-BASE[1] topsoil results falling within the rectangular area shown in **Figure 2**. This includes samples collected over several summer field campaigns from 2005 to 2009, which in practice can be grouped into two main subsets, **SEEN** and **LOND**, as previously described. The area selected was designed to give insight in to how geochemical signatures may change over the same parent materials passing from central London to more rural areas on the periphery. As such, the rectangular areas of the LRA include, whenever possible, a representative number of rural **SEEN** samples over the same parent material (PM, simplified geology) classes that underlie the urban **LOND**. The number of topsoil samples in **LOND** and in **SEEN** subsets collected on each PM are shown in **Table 7**. The simplified geological classes are ordered from the most to the least represented in **LOND**, and the font is coloured grey for the simplified geological class not represented (or poorly represented) in one of the subsets (**LOND** and **SEEN**) at least. The background colour of the first column is according to the geological time period.

Thirteen (out of the 21) PMs observed in the LRA are able to be compared as they are fairly well represented in both subset areas (**LOND** and **SEEN**). Only one of the PM classes represented in the urban **LOND**, Thames Group (sand-gravel), is poorly represented (one sample only) in the surrounding rural **SEEN**. Seven PM classes are represented in **SEEN** subset only, including two on which topsoil was casually not collected, due to small spatial extension relative to the sampling density (**Table 7**). The parent material (PM) mapping method described by Appleton and Adlam (2012)[4] was used to create geochemical images in ESRI® ArcGIS and their geogenic signatures are described in Appleton et al. (2013)[5]. Using PM polygons as soil chemistry mapping units, it is possible to estimate element concentrations based on local averages, without significant errors at PM boundaries (Appleton et al., 2008[6]; Appleton and Adlam, 2012[4]). In case of a large positive skewness distribution, the geometric mean (GM) should be used for mapping the spatial variation in element concentrations, in order to minimise the bias associated with that type of distribution. The PM methodology is generally appropriate in situations and for elements where PM explains a relatively high proportion of the variance, but less so for elements where the proportion of variance explained by PM is low, for example where point or non-point source anthropogenic contamination is a major factor, such as Pb. Previously published London Earth[2] geochemical images were based on standard inverse distance weighted squared (IDW^2) maps created in ArcGIS with an 80 m cell size and an isotropic search radius of 750 m. By contrast, the parent material mapping method uses parent material (simplified geology) polygons subdivided into separate 200 m square cells (subdivisions of the BNG). These store non-topological geometry and attribute information for the spatial features that form the basis for the production of the geochemical maps.

Parent material (PM) codes for each 200 m grid square were attached to the locations of all soil samples. Parent material geochemical mapping was executed using an ArcGIS tool written in Vb.Net (Appleton and Adlam, 2012) to calculate the geometric mean (GM) element concentration for each 200 m-PM polygon. The optimum number of samples for calculating the GMs was between four and seven for topsoil data (Appleton et al. 2008[7]). For the maps generated here, GMs were calculated using data for the nearest four samples on the same PM apart from (a) four very minor PM units (calcrete, peat, the Upper Greensand and the Wealden Group), which comprise about 0.2% of

the study area and which have no soil samples located on them and (b) polygons for which the average distance to the four samples required to calculate the GM was greater than 7000 m, which comprise about 4% of the study area. This largely affects sinuous polygon features, such as narrow alluvium areas along the upper reaches of tributaries to the River Thames. This approach was adopted to prevent excessive extrapolation of high element concentrations related to anthropogenic contamination, such as Pb. For both these sets of polygons (a and b), the GM was calculated from soil chemistry data for the nearest four samples, irrespective of PM.

The colour coding of the geochemical maps of the London Region follow the standard G-BASE[1] geochemical map classification applied in past geochemical atlases (e.g., BGS, 2000[8]). The percentiles 5, 10, 15, 25, 50, 75, 90, 95 and 99 of the data distribution are used as class boundaries for a ramp of colours (**Table 8**).

Table 7 The number of topsoil samples (out of 8400) observed in LOND and in SEEN subsets over each simplified geology class.

Geological time period	Simplified geology class	LOND	SEEN	LRD
Palaeogene	Thames Gp. (clay)	2328	274	2602
Quaternary	River terrace deposits	1677	147	1824
Quaternary	Alluvium	618	72	690
Cretaceous	White Chalk SubGp.	449	258	707
Quaternary	Brickearth	370	20	390
Quaternary	Head (clay-silt)	326	100	426
Palaeogene	Thames Gp. (sand-gravel)	306	1	307
Palaeogene	Lambeth Group	178	35	213
Quaternary	Clay-with-flints	159	153	312
Quaternary	Plateau gravels	152	109	261
Palaeogene	Thanet Sand Fm.	136	26	159
Quaternary	Glacial till	68	224	292
Palaeogene	Bagshot Fm.	25	63	88
Quaternary	Head (gravel-sand)	9	14	23
Cretaceous	Lower Greensand Gp.	0	46	46
Palaeogene	Bracklesham Gp. (sand-silt)	0	20	20
Cretaceous	Grey Chalk SubGp.	0	15	15
Cretaceous	Gault Fm.	0	13	13
Palaeogene	Bracklesham Gp. (sand)	0	12	12
Cretaceous	Upper Greensand	0	0	0
Cretaceous	Wealden Gp. (mudstone)	0	0	0

Table 8 Percentiles of topsoil element concentrations (N = 8400) plus LOI (N = 7928) and pH (N = 7929). Concentrations are in wt% for the 10 most abundant elements (shown as oxides) and for LOI; the remaining 34 elements are in mg/kg and pH is in log[H+] mol/L.

Colour	Percentile	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	SiO_2	TiO_2	Ag	As	Ba	Bi	Br	Cd	Ce	Co	Cr	Cs	Cu	Ga	Ge
	Min	0.8	<0.05	0.13	0.12	<0.3	<0.005	<0.3	<0.05	4.6	0.17	<0.5	<2.4	139	<0.3	1.1	<0.5	16	<1.5	9	1	3	1.0	<0.5
	5	**3.9**	**0.37**	**2.09**	**0.74**	**0.4**	**0.022**	**<0.3**	**0.15**	**48.0**	**0.37**	**<0.5**	**8.6**	**257**	**<0.3**	**6.4**	**<0.5**	**33**	**5.3**	**46**	**2**	**13**	**7.2**	**0.5**
	10	**4.7**	**0.50**	**2.48**	**0.88**	**0.4**	**0.030**	**0.3**	**0.18**	**54.2**	**0.41**	**<0.5**	**10.0**	**283**	**<0.3**	**7.4**	**<0.5**	**37**	**6.7**	**52**	**2**	**17**	**7.9**	**0.7**
	15	**5.2**	**0.59**	**2.71**	**0.97**	**0.5**	**0.035**	**0.3**	**0.19**	**56.8**	**0.44**	**0.5**	**10.9**	**300**	**<0.3**	**8.1**	**<0.5**	**39**	**7.7**	**56**	**2**	**20**	**8.4**	**0.8**
	20	5.6	0.67	2.93	1.03	0.5	0.039	0.3	0.218	58.7	0.46	0.5	11.6	313	<0.3	8.7	<0.5	41	8.4	59	2	22	8.7	0.9
	25	**5.9**	**0.74**	**3.10**	**1.08**	**0.6**	**0.043**	**0.3**	**0.22**	**60.2**	**0.47**	**0.5**	**12.2**	**324**	**<0.3**	**9.2**	**<0.5**	**43**	**9.0**	**61**	**2**	**24**	**9.1**	**1.0**
	30	6.2	0.81	3.24	1.13	0.6	0.046	0.3	0.24	61.6	0.49	0.5	12.8	334	<0.3	9.7	0.5	44	9.6	63	2	26	9.4	1.1
	35	6.5	0.89	3.38	1.18	0.7	0.048	0.4	0.25	62.9	0.51	0.5	13.3	344	<0.3	10.1	0.5	45	10.0	65	2	29	9.7	1.2
	40	6.9	0.96	3.52	1.23	0.7	0.051	0.4	0.27	64.1	0.53	0.5	13.8	353	<0.3	10.5	0.5	47	10.5	67	3	32	9.9	1.2
	45	7.2	1.06	3.67	1.27	0.7	0.054	0.4	0.28	65.4	0.55	0.5	14.3	362	<0.3	11.0	0.5	49	11.0	70	3	35	10.3	1.3
	50	**7.6**	**1.18**	**3.80**	**1.32**	**0.8**	**0.056**	**0.4**	**0.31**	**66.6**	**0.57**	**0.5**	**14.8**	**371**	**<0.3**	**11.4**	**0.6**	**50**	**11.4**	**73**	**3**	**38**	**10.6**	**1.4**
	55	8.0	1.32	3.96	1.38	0.8	0.060	0.4	0.31	68.0	0.59	0.5	15.4	379	0.3	11.9	0.6	52	11.9	75	3	43	11.0	1.5
	60	8.4	1.48	4.13	1.45	0.9	0.062	0.4	0.33	69.3	0.61	0.5	16.0	387	0.3	12.4	0.7	54	12.5	78	3	47	11.3	1.6
	65	8.8	1.68	4.31	1.52	0.9	0.066	0.5	0.35	70.5	0.64	0.5	16.6	396	0.4	13.0	0.7	56	13.0	81	3	52	11.8	1.7
	70	9.4	1.92	4.49	1.61	1.0	0.070	0.5	0.37	72.0	0.67	0.5	17.3	405	0.5	13.7	0.7	57	13.7	84	4	59	12.3	1.9
	75	**10.0**	**2.23**	**4.70**	**1.71**	**1.2**	**0.075**	**0.5**	**0.40**	**73.3**	**0.70**	**0.5**	**18.2**	**417**	**0.6**	**14.5**	**0.8**	**59**	**14.4**	**88**	**4**	**67**	**12.9**	**2.1**
	80	10.6	2.65	4.92	1.82	1.1	0.081	0.5	0.43	75.0	0.74	0.5	19.2	432	0.7	15.4	0.9	61	15.2	93	4	77	13.6	2.3
	85	11.3	3.28	5.20	1.94	1.2	0.092	0.6	0.47	76.9	0.78	0.6	20.5	455	0.9	16.6	1.0	64	16.4	98	5	91	14.3	2.6
	90	**12.0**	**4.31**	**5.52**	**2.07**	**1.4**	**0.108**	**0.6**	**0.54**	**79.2**	**0.82**	**1.0**	**22.9**	**490**	**1.2**	**18.5**	**1.3**	**68**	**18.0**	**104**	**5**	**114**	**15.1**	**3.1**
	95	**13.2**	**6.95**	**6.09**	**2.28**	**1.6**	**0.147**	**0.7**	**0.66**	**82.7**	**0.88**	**2.2**	**27.5**	**577**	**2.2**	**22.1**	**1.9**	**74**	**20.8**	**116**	**6**	**167**	**16.3**	**4.1**
	99	**15.3**	**23.26**	**7.14**	**2.58**	**2.2**	**0.264**	**0.9**	**1.09**	**89.1**	**0.97**	**11.5**	**46.5**	**885**	**7.5**	**33.6**	**6.8**	**101**	**31.6**	**172**	**7**	**433**	**18.9**	**7.6**
	Max	25.5	48.97	15.59	3.47	4.6	0.697	10.0	4.49	100.0	1.10	268.8	160.9	3475	70.5	241.1	165.2	238	85.2	2094	11	5326	44.1	38.7

Colour	Percentile	Hf	I	La	Mo	Nb	Nd	Ni	Pb	Rb	Sb	Sc	Se	Sn	Sr	Th	U	V	W	Y	Zn	Zr	LOI	pH
	Min	1.1	<0.5	3	<0.2	4.7	<4	<1.3	10	6.5	<0.5	<3	<0.2	0.9	11	<0.7	<0.5	9	<0.6	3	<1.3	35	0.7	2.8
	5	**4.5**	**1.5**	**14**	**0.6**	**9.3**	**10.4**	**11.3**	**38**	**33.1**	**0.7**	**3.0**	**0.2**	**3.1**	**38**	**3.8**	**1.4**	**44**	**0.8**	**12**	**44**	**182**	**3.9**	**4.0**
	10	**5.2**	**1.8**	**16**	**0.7**	**9.9**	**12.9**	**13.9**	**46**	**38.4**	**0.9**	**4.0**	**0.3**	**3.7**	**45**	**4.4**	**1.6**	**50**	**1.1**	**14**	**58**	**204**	**4.5**	**4.6**
	15	**5.5**	**2.1**	**18**	**0.8**	**10.3**	**14.6**	**15.9**	**54**	**41.3**	**1.0**	**4.8**	**0.3**	**4.3**	**50**	**4.8**	**1.7**	**54**	**1.3**	**15**	**66**	**218**	**5.0**	**5.0**
	20	5.9	2.2	19	0.9	10.7	15.9	17.3	62	43.7	1.2	5.4	0.4	4.9	54	5.1	1.8	58	1.4	16	74	230	5.3	5.2
	25	**6.2**	**2.4**	**20**	**1.0**	**11.0**	**17.0**	**18.7**	**70**	**45.9**	**1.3**	**5.8**	**0.4**	**5.6**	**57**	**5.4**	**1.9**	**61**	**1.6**	**17**	**81**	**240**	**5.7**	**5.5**
	30	6.4	2.5	21	1.1	11.3	18.0	19.8	80	48.0	1.5	6.2	0.4	6.5	61	5.7	1.9	63	1.7	18	88	250	6.0	5.8
	35	6.6	2.7	22	1.1	11.6	19.0	21.0	92	50.1	1.7	6.6	0.5	7.4	64	6.0	2.0	66	1.8	19	97	259	6.3	6.0
	40	6.9	2.8	23	1.2	11.9	19.9	22.2	105	52.2	1.9	7.0	0.5	8.4	67	6.2	2.1	69	1.9	19	107	269	6.6	6.2
	45	7.2	3.0	24	1.3	12.3	20.8	23.4	121	54.3	2.1	7.4	0.5	9.6	70	6.5	2.2	72	2.0	20	118	278	6.9	6.4
	50	**7.4**	**3.1**	**25**	**1.4**	**12.6**	**21.8**	**24.6**	**138**	**56.5**	**2.4**	**7.8**	**0.5**	**10.9**	**73**	**6.8**	**2.2**	**75**	**2.1**	**21**	**130**	**288**	**7.1**	**6.5**
	55	7.7	3.3	26	1.5	13.0	22.7	25.9	159	59.1	2.7	8.2	0.6	12.6	77	7.1	2.3	79	2.2	21	144	299	7.4	6.7

	60	8.0	3.5	27	1.6	13.4	23.6	27.2	182	62.0	3.0	8.6	0.6	14.5	80	7.4	2.4	83	2.3	22	159	309	7.8	6.8
	65	8.4	3.7	28	1.7	13.9	24.5	28.6	209	65.1	3.4	9.1	0.6	16.7	83	7.7	2.4	87	2.4	23	178	322	8.1	6.9
	70	8.7	3.9	29	1.8	14.5	25.6	30.2	243	68.6	3.9	9.6	0.7	19.4	87	8.1	2.5	92	2.5	24	199	334	8.5	6.9
	75	**9.1**	**4.2**	**30**	**2.0**	**15.1**	**26.9**	**32.2**	**284**	**72.5**	**4.5**	**10.2**	**0.7**	**22.6**	**93**	**8.4**	**2.6**	**98**	**2.6**	**25**	**225**	**350**	**8.9**	**7.0**
	80	9.6	4.6	32	2.1	15.7	28.3	34.5	340	77.1	5.3	10.9	0.8	26.4	100	8.7	2.7	105	2.8	26	256	368	9.4	7.1
	85	10.3	5.4	33	2.4	16.2	30.1	37.3	415	82.9	6.4	11.7	0.9	32.8	111	9.1	2.8	113	3.0	27	301	391	10.0	7.2
	90	**11.3**	**6.6**	**36**	**2.8**	**16.9**	**32.5**	**41.3**	**531**	**89.5**	**8.2**	**12.6**	**1.0**	**44.2**	**125**	**9.5**	**2.9**	**122**	**3.3**	**29**	**371**	**424**	**10.9**	**7.3**
	95	**12.8**	**8.8**	**40**	**3.6**	**17.8**	**36.7**	**49.6**	**775**	**98.0**	**12.7**	**14.0**	**1.2**	**67.2**	**153**	**10.1**	**3.1**	**135**	**3.9**	**32**	**521**	**478**	**12.5**	**7.4**
	99	**15.8**	**16.7**	**59**	**7.5**	**19.0**	**54.8**	**78.3**	**1668**	**113.5**	**33.1**	**16.9**	**2.3**	**169.1**	**272**	**11.0**	**3.6**	**163**	**8.4**	**50**	**1120**	**580**	**18.3**	**7.6**
	Max	40.7	79.9	134	561.2	146.7	172.7	505.6	25206	157.2	612.3	35.6	19.6	1041.5	601	456.5	11.5	531	316.8	158	10095	1488	72.1	8.4

References

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London Atlas: Materials and methods III: data analysis

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The subsets SEEN and LOND

The London Region Topsoil Dataset (**LRD**) is composed of the **LOND** and **SEEN** data subsets, which were collected using two different sampling densities (**LOND** 1 per 0.25 km^2, **SEEN** 1 per 2 km^2), and broadly correspond to two regions, which are very different in terms of population density and historical record of human occupancy. About 95% of **LOND** and **SEEN** samples are located respectively inside and outside of the GLA. **LOND** samples collected outside GLA (307 out of 6801) are grouped into four urban clusters located to the east of the GLA, while **SEEN** samples collected inside GLA (80 out of 1599) are mainly located in the northern and north-eastern London outskirts, always close to the GLA border (**Figure 2**). Given the different sampling densities between **LOND** and **SEEN** subsets, **LRD** statistics are necessarily biased towards the values observed inside the GLA, thus not adequately representing the ***area*** of the London Region Atlas of Topsoil Geochemistry. The effect of this bias is particularly important for elements for which concentrations are expected to be much higher (or much lower) inside the GLA, such as those commonly classified as anthropogenic.

Accordingly, it was decided to include statistics and graphs of **LOND** and **SEEN** subsets separately in addition to the statistics and graphs of the London Region Topsoil Dataset as a whole (**LRD**). By showing the summary statistics and distribution of the two subsets (**SEEN** and **LOND**), and taking into account that they mainly represent the area outside and inside the GLA respectively, an unbiased view of topsoil geochemistry within the built up area of London relative to the outskirts is obtained. This enables a better understanding of soil quality in the LRA area, the distinctive anthropogenic geochemical signal observed within and outside the GLA becoming particularly clear.

The term *urban domain* in Appleton et al. (2013)[1], one of the key references of the present atlas, is used as in Ander et al. (2011)[2] and Ander et al. (2013)[3], while *rural domain* includes both *rural* and *semi-urban* areas defined in the same document. This *urban domain* definition is based on a urbanisation index after the Generalised Land Use Database (GLUD) Statistics for England, 2005 (Department for Communities and Local Government, 2007[4]), a document from the Office of National Statistics (ONS). This definition is such that its complementary *rural* includes large open-space areas within central London, such as Richmond Park and Wimbledon Common in south-west London. For the present atlas, *urban* and *rural* are rather used to define the sampling survey type (**LOND** and **SEEN**, respectively) or when referring to the 'GLA area' or 'central London' (urban) relative to 'outwith GLA area' or 'London outskirts' (rural).

Univariate statistics and graphics

A preliminary outline of the 46 variables (44 elements, LOI, pH) in the **LRD** dataset and in the two subsets (**SEEN** and **LOND**) is given in **Table 9**. This was built in *Microsoft Excel*®, and includes some of the most commonly used distribution measures reporting univariate descriptive statistics, namely percentiles and some non-parametric statistics in attempting to obtain robust statistics, less dependent on outliers (Reimann et al., 2008)[5]. It includes the lower limit of detection (**LLD**), 9 **percentiles** (or quantiles, **Q02, Q05, Q10, Q25, Q75, Q90, Q95, Q98, Q99**), the minimum (**Min**) and the maximum (**Max**); measures of central tendency, namely, the median (**Mdn**), the geometric mean (**GM**) and the arithmetic mean (**AM**); some measures of dispersion, namely, the interquartile range (**IQR**), the median absolute deviation (**MAD**), the standard deviation (**SD**) and the geometric standard deviation (**GSD**); two

other measures of dispersion, the coefficient of variation (**CV%**) and the robust coefficient of variation (**CVR%**), expressed in percent, are also shown, as they have the advantage of being independent of the magnitude of the data (Reimann et al., 2008). The CV% is defined as the SD divided by the AM, while the CVR% is defined as the MAD divided by the Mdn. The MAD is a robust equivalent of the SD measuring the average deviation from a central value, in this case the median. **Powers**, also a measure of dispersion, are defined as the decimal logarithm of the ratio between the Max and the Min, thus showing the orders of magnitude of the variation. Finally, the skewness is also shown, both for normal (**Skew**) and log-transformed (**SkewLOG**) data. Skewness is a measure of asymmetry of the distribution, indicating if the tails on both sides of the AM (or the GM) balance out or not. This statistic, however, must always be evaluated together with other information, such as a histogram or other graphical representation of the distribution, as has been done for the present work. These measures of asymmetry can be helpful in deciding whether to use a linear or a logarithmic scale in the graphical representation of element concentrations, and, together with the descriptive graphics, can be used to decide the most appropriate parametric statistics, in case these are required.

Table 9 Summary table providing a selection of statistical parameters to describe analytes determined on topsoils from the London region. Number of samples is LRD = 8400 (7928 for LOI and 7929 for pH), SEEN = 1599 (1128 for LOI and pH) and LOND = 6801 (6800 for LOI). For further explanation go to Univariate statistics and graphics

Analytes units	Dataset	LLD	Min	Q02	Q05	Q10	Q25	Mdn	Q75	Q90	Q95	Q98	Q99	Max	IQR	MAD	CVR%	AM	SD	CV%	GM	GSD	Powers	Skew	Skew LOG
Al_2O_3 %	LRD	0.2	0.8	3.0	3.9	4.7	5.9	**7.6**	10.0	12.0	13.2	14.4	15.3	25.5	4.1	2.8	37.1	8.0	2.9	35.9	7.5	1.47	1.50	**0.52**	-0.71
	SEEN	0.2	0.8	2.3	3.0	3.8	5.7	**8.2**	10.7	12.2	13.4	14.6	15.6	19.9	4.9	3.7	45.2	8.2	3.3	39.7	7.4	1.62	1.40	**0.09**	-1.11
	LOND	0.2	0.8	3.4	4.3	4.9	5.9	**7.5**	9.7	11.9	13.2	14.4	15.2	25.5	3.8	2.7"	35.6"	8.0	2.8	34.9	7.5	1.43	1.50	0.66	**-0.44**
CaO %	LRD	0.05	<0.05	0.27	0.37	0.50	0.74	**1.18**	2.23	4.31	6.95	15.45	23.26	48.97	1.49	0.84	71.3	2.30	3.97	172.7	1.34	2.51	3.09	5.58	**0.62**
	SEEN	0.05	<0.05	0.11	0.18	0.29	0.55	**0.80**	1.44	5.75	13.14	28.04	32.48	47.47	0.89	0.49	61.4	2.64	5.97	226.0	0.99	3.33	3.07	4.20	**0.84**
	LOND	0.05	0.22	0.34	0.43	0.56	0.81	**1.31**	2.31	4.20	6.15	12.84	18.54	48.97	1.49	0.91	69.1	2.22	3.33	149.9	1.44	2.29	2.35	5.86	**0.76**
Fe_2O_3 %	LRD	0.01	0.13	1.56	2.09	2.48	3.10	**3.80**	4.70	5.52	6.09	6.66	7.14	15.59	1.60	1.17	30.7	3.93	1.27	32.4	3.71	1.43	2.08	**0.87**	-1.42
	SEEN	0.01	0.13	0.91	1.51	2.00	2.80	**3.65**	4.53	5.25	5.90	6.62	7.31	15.59	1.73	1.29	35.3	3.70	1.42	38.3	3.39	1.59	2.08	**1.06**	-1.83
	LOND	0.01	0.15	1.81	2.24	2.56	3.15	**3.82**	4.76	5.57	6.11	6.66	7.12	15.37	1.61	1.14"	29.7"	3.98	1.23	30.9	3.79	1.39	2.00	**0.85**	-0.89
K_2O %	LRD	0.01	0.12	0.57	0.74	0.88	1.08	**1.32**	1.71	2.07	2.28	2.48	2.58	3.47	0.63	0.43"	32.6"	1.41	0.47	33.2	1.33	1.42	1.46	**0.52**	-0.72
	SEEN	0.01	0.15	0.48	0.63	0.79	1.05	**1.36**	1.83	2.15	2.32	2.51	2.65	3.47	0.78	0.55"	40.3"	1.43	0.52	36.6	1.32	1.52	1.36	**0.26**	-1.01
	LOND	0.01	0.12	0.63	0.78	0.90	1.09	**1.32**	1.68	2.06	2.27	2.46	2.57	3.33	0.59	0.42"	31.4"	1.40	0.45	32.2	1.33	1.40	1.44	0.59	**-0.57**
MgO %	LRD	0.3	<0.3	0.3	0.4	0.4	0.6	**0.8**	1.1	1.4	1.6	2.0	2.2	4.6	0.5	0.3"	37.1"	0.9	0.4	48.5	0.8	1.59	1.36	1.65	**-0.16**
	SEEN	0.3	<0.3	<0.3	0.3	0.5	0.7	**0.8**	1.0	1.2	1.4	1.8	2.0	4.2	0.3	0.3"	37.1"	0.9	0.3	40.6	0.8	1.53	1.32	1.78	**-0.82**
	LOND	0.3	<0.3	0.3	0.4	0.4	0.6	**0.8**	1.1	1.4	1.7	2.0	2.3	4.6	0.5	0.3"	37.1"	0.9	0.4	50.2	0.8	1.61	1.36	1.62	**-0.05**
Analytes units	**Dataset**	**LLD**	**Min**	**Q02**	**Q05**	**Q10**	**Q25**	**Mdn**	**Q75**	**Q90**	**Q95**	**Q98**	**Q99**	**Max**	**IQR**	**MAD**	**CVR%**	**AM**	**SD**	**CV%**	**GM**	**GSD**	**Powers**	**Skew**	**Skew LOG**
MnO %	LRD	0.005	<0.005	0.013	0.022	0.030	0.043	**0.056**	0.075	0.108	0.147	0.204	0.264	0.697	0.032	0.022	39.6	0.066	0.047	70.7	0.056	1.79	2.24	4.01	**-0.35**

	SEEN	0.005	<0.005	0.008	0.016	0.025	0.043	**0.071**	0.108	0.162	0.205	0.261	0.290	0.573	0.065	0.047	66.9	0.085	0.062	73.6	0.065	2.21	2.16	1.98	**-0.74**
	LOND	0.005	<0.005	0.016	0.024	0.031	0.043	**0.055**	0.070	0.093	0.120	0.170	0.226	0.697	0.027	0.019	35.2	0.062	0.041	66.6	0.054	1.67	2.24	5.23	**-0.27**
Na_2O %	LRD	0.3	<0.3	<0.3	<0.3	0.3	0.3	**0.4**	0.5	0.6	0.7	0.8	0.9	10.0	0.2	0.1	34.2	0.4	0.2	47.5	0.4	1.39	1.70	21.43	**0.24**
	SEEN	0.3	<0.3	<0.3	<0.3	<0.3	0.3	**0.4**	0.6	0.7	0.7	0.8	0.9	1.1	0.3	0.1	37.1	0.4	0.2	37.8	0.4	1.47	0.74	0.65	**-0.12**
	LOND	0.3	<0.3	<0.3	0.3	0.3	0.3	**0.4**	0.5	0.6	0.7	0.8	0.9	10.0	0.2	0.1	34.2	0.4	0.2	49.5	0.4	1.38	1.70	23.28	**0.40**
P_2O_5 %	LRD	0.05	<0.05	0.12	0.15	0.18	0.22	**0.30**	0.40	0.54	0.66	0.88	1.09	4.49	0.18	0.12	39.5	0.34	0.22	64.3	0.30	1.60	2.05	5.82	**0.34**
	SEEN	0.05	<0.05	0.09	0.12	0.14	0.18	**0.24**	0.30	0.39	0.47	0.59	0.77	3.26	0.12	0.09	37.0	0.26	0.17	64.3	0.24	1.57	1.91	8.38	**0.00**
	LOND	0.05	<0.05	0.13	0.16	0.19	0.24	**0.31**	0.42	0.56	0.69	0.91	1.13	4.49	0.18	0.13	43.1	0.36	0.23	62.7	0.32	1.58	2.05	5.67	**0.50**
SiO_2 %	LRD	0.1	4.6	34.9	48.0	54.2	60.2	**66.6**	73.3	79.2	82.7	86.4	89.1	100.0	13.1	9.8	14.7	66.1	11.4	17.3	64.8	1.25	1.34	**-1.04**	-3.48
	SEEN	0.1	5.9	20.6	39.0	52.0	61.6	**69.7**	76.8	83.4	86.9	90.4	93.5	100.0	15.2	11.3	16.2	67.7	14.7	21.6	65.3	1.37	1.23	**-1.37**	-3.34
	LOND	0.1	4.6	39.3	49.1	54.5	59.9	**66.0**	72.6	78.1	81.4	84.6	87.1	100.0	12.7	9.3	14.2	65.7	10.5	16.0	64.7	1.22	1.34	**-0.90**	-3.17
TiO_2 %	LRD	0.01	0.17	0.33	0.37	0.41	0.47	**0.57**	0.70	0.82	0.88	0.93	0.97	1.18	0.23	0.16	28.3	0.59	0.16	26.5	0.57	1.31	0.83	0.44	**-0.21**
	SEEN	0.01	0.18	0.29	0.34	0.38	0.49	**0.63**	0.75	0.86	0.90	0.95	0.98	1.06	0.26	0.19	30.6	0.62	0.17	28.1	0.59	1.36	0.78	**-0.05**	-0.73
	LOND	0.01	0.17	0.34	0.38	0.42	0.47	**0.56**	0.68	0.81	0.87	0.93	0.96	1.18	0.21	0.15	26.2	0.59	0.15	25.9	0.57	1.29	0.83	0.57	**-0.04**

Analytes units	**Dataset**	**LLD**	**Min**	**Q02**	**Q05**	**Q10**	**Q25**	**Mdn**	**Q75**	**Q90**	**Q95**	**Q98**	**Q99**	**Max**	**IQR**	**MAD**	**CVR%**	**AM**	**SD**	**CV%**	**GM**	**GSD**	**Powers**	**Skew**	**Skew LOG**
Ag mg/kg	**LRD**	0.5	<0.5	<0.5	<0.5	<0.5	0.5	**0.5**	0.5	1.0	2.2	6.2	11.5	268.8	0.0	0.0	0.0	1.1	5.8	552.0	0.6	1.95	2.95	30.49	**3.35**
	SEEN	0.5	<0.5	<0.5	<0.5	<0.5	0.5	**0.5**	0.5	0.5	1.4	4.2	7.3	237.2	0.0	0.0	0.0	0.9	6.2	681.6	0.5	1.74	2.90	34.46	**4.35**
	LOND	0.5	<0.5	<0.5	<0.5	<0.5	0.5	**0.5**	0.5	1.1	2.5	6.6	12.4	268.8	0.0	0.0	0.0	1.1	5.7	525.9	0.6	1.99	2.95	29.22	**3.19**
As mg/kg	**LRD**	2.4	<2.4	6.8	8.6	10.0	12.2	**14.8**	18.2	22.9	27.5	36.9	46.5	160.9	6.0	4.3	29.1	16.3	8.2	50.7	15.0	1.46	1.91	5.42	**0.31**
	SEEN	2.4	<2.4	4.5	6.0	7.6	10.2	**12.7**	15.2	17.8	20.4	25.4	29.3	111.8	5.0	3.7	29.2	13.1	5.6	43.1	12.1	1.48	1.75	5.36	**-0.65**
	LOND	2.4	<2.4	8.1	9.5	10.7	12.8	**15.4**	18.8	24.0	28.5	38.8	48.8	160.9	6.0	4.3	27.9	17.0	8.6	50.4	15.8	1.43	1.91	5.46	**0.76**
Ba mg/kg	**LRD**	1	139	229	257	283	324	**371**	417	490	577	738	885	3475	93	70	18.8	389	140	36.0	374	1.30	1.40	6.48	**1.26**
	SEEN	1	139	198	228	248	298	**340**	376	405	422	443	518	1850	78	58	17.0	339	91	26.7	330	1.24	1.12	6.88	**0.40**
	LOND	1	143	242	271	293	331	**380**	429	512	602	763	920	3475	98	73	19.1	401	147	36.6	386	1.30	1.39	6.43	**1.41**
Bi mg/kg	**LRD**	0.3	<0.3	<0.3	<0.3	<0.3	<0.3	**<0.3**	0.6	1.2	2.2	4.2	7.5	70.5	0.4	0.0	0.0	0.8	2.5	338.5	0.4	2.42	2.55	14.43	**1.72**
	SEEN	0.3	<0.3	<0.3	<0.3	<0.3	<0.3	**<0.3**	0.4	0.7	1.0	1.9	3.2	59.3	0.2	0.0	0.0	0.5	1.9	381.4	0.3	1.94	2.47	23.74	**2.17**
	LOND	0.3	<0.3	<0.3	<0.3	<0.3	<0.3	**<0.3**	0.6	1.4	2.4	4.7	8.1	70.5	0.4	0.0	0.0	0.8	2.7	328.9	0.4	2.51	2.55	13.41	**1.61**
Br mg/kg	**LRD**	0.8	1.1	5.3	6.4	7.4	9.2	**11.4**	14.5	18.5	22.1	27.4	33.6	241.1	5.3	3.9	33.8	12.7	6.9	54.5	11.6	1.48	2.34	8.76	**0.34**
	SEEN	0.8	1.1	4.2	5.5	6.4	7.9	**9.5**	11.6	14.6	17.7	23.3	28.2	94.8	3.7	2.7	28.1	10.4	5.6	53.5	9.6	1.47	1.94	6.35	**0.28**
	LOND	0.8	1.5	5.7	6.8	7.8	9.7	**12.0**	15.0	19.0	22.5	28.5	34.1	241.1	5.3	3.9	32.1	13.2	7.1	53.7	12.1	1.47	2.21	9.22	**0.42**

Analytes units	**Dataset**	**LLD**	**Min**	**Q02**	**Q05**	**Q10**	**Q25**	**Mdn**	**Q75**	**Q90**	**Q95**	**Q98**	**Q99**	**Max**	**IQR**	**MAD**	**CVR%**	**AM**	**SD**	**CV%**	**GM**	**GSD**	**Powers**	**Skew**	**Skew LOG**

Cd mg/kg	**LRD**	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	**0.6**	0.8	1.3	1.9	3.8	6.8	165.2	0.5	0.3	49.4	0.9	3.5	375.2	0.6	1.95	2.74	30.07	**1.81**
	SEEN	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	**0.5**	0.6	0.9	1.3	2.1	3.4	135.8	0.3	0.3	59.3	0.8	4.7	605.7	0.5	1.81	2.66	25.08	**2.81**
	LOND	0.5	<0.5	<0.5	<0.5	<0.5	0.5	**0.6**	0.8	1.4	2.1	4.2	7.3	165.2	0.3	0.3	49.4	1.0	3.1	325.4	0.6	1.95	2.74	31.43	**1.72**
Ce mg/kg	**LRD**	1	16	29	33	37	43	**50**	59	68	74	85	101	238	16	11.9	23.7	51.8	14.2	27.5	50.1	1.29	1.17	1.93	**0.11**
	SEEN	1	16	24	29	33	44	**55**	65	75	86	106	117	165	21	14.8	27.0	55.7	18.3	32.8	52.8	1.39	1.01	1.04	**-0.38**
	LOND	1	18	31	34	38	43	**50**	57	65	70	79	91	238	14	10.4	20.8	50.9	12.9	25.4	49.5	1.26	1.12	2.27	**0.27**
Co mg/kg	**LRD**	1.5	<1.5	3.6	5.3	6.7	9.0	**11.4**	14.4	18.0	20.8	26.0	31.6	85.2	5.4	3.9	33.8	12.2	5.5	45.5	11.1	1.57	1.93	2.63	**-0.90**
	SEEN	1.5	<1.5	2.1	3.4	4.9	8.1	**11.4**	14.6	19.3	23.7	29.1	36.4	69.9	6.5	4.9	42.9	12.1	6.6	55.0	10.4	1.82	1.84	1.95	**-1.04**
	LOND	1.5	<1.5	4.3	5.8	7.1	9.2	**11.4**	14.3	17.7	20.2	24.7	30.6	85.2	5.1	3.7	32.5	12.2	5.2	43.0	11.3	1.50	1.93	2.91	**-0.59**
Cr mg/kg	**LRD**	3	9	38	46	52	61	**73**	88	104	116	140	172	2094	27	19	26.4	78	45	58.3	73	1.38	2.37	20.75	**0.79**
	SEEN	3	9	32	39	47	61	**74**	88	104	118	133	155	718	27	19	26.0	77	35	45.3	72	1.42	1.90	8.39	**-0.22**
	LOND	3	15	41	47	52	61	**72**	89	104	115	142	177	2094	28	19	26.8	78	48	60.8	74	1.37	2.14	21.51	**1.15**
Cs mg/kg	**LRD**	1	1.0	1.0	1.5	2.0	2.0	**3.0**	4.0	5.0	6.0	6.9	7.0	11.2	2.0	1.5	49.4	3.2	1.4	44.5	2.9	1.55	1.05	1.12	**-0.14**
	SEEN	1	1.0	1.0	2.0	2.0	2.0	**3.0**	4.7	5.8	6.9	7.0	8.0	11.2	2.7	1.5	49.4	3.5	1.6	45.0	3.2	1.58	1.05	0.92	**-0.18**
	LOND	1	1.0	1.0	1.0	2.0	2.0	**3.0**	4.0	5.0	6.0	6.0	7.0	11.0	2.0	1.5	49.4	3.1	1.3	43.6	2.8	1.54	1.04	1.14	**-0.15**

Analytes units	**Dataset**	**LLD**	**Min**	**Q02**	**Q05**	**Q10**	**Q25**	**Mdn**	**Q75**	**Q90**	**Q95**	**Q98**	**Q99**	**Max**	**IQR**	**MAD**	**CVR%**	**AM**	**SD**	**CV%**	**GM**	**GSD**	**Powers**	**Skew**	**Skew LOG**
Cu mg/kg	**LRD**	1.3	3	10	13	17	24	**38**	67	114	167	285	433	5326	43	25.7	67.7	63.5	132	207.8	41.7	2.23	3.25	19.83	**0.71**
	SEEN	1.3	3	7	9	11	17	**22**	29	41	55	96	180	1055	13	8.3	38.4	29.2	54	186.2	22.1	1.83	2.55	12.97	**1.16**
	LOND	1.3	3	13	16	20	28	**45**	75	126	184	315	461	5326	47	29.7	65.9	71.6	143	199.9	48.4	2.15	3.25	18.91	**0.76**
Ga mg/kg	**LRD**	1.0	1.0	6.5	7.2	7.9	9.1	**10.6**	12.9	15.1	16.3	18.0	18.9	44.1	3.8	2.7	25.2	11.1	2.9	25.9	10.8	1.29	1.64	0.92	**-0.04**
	SEEN	1.0	3.1	5.8	6.3	7.2	9.0	**11.1**	13.5	14.9	16.2	17.7	18.9	34.7	4.5	3.4	30.7	11.2	3.1	27.7	10.8	1.34	1.05	0.48	**-0.43**
	LOND	1.0	1.0	6.9	7.5	8.0	9.1	**10.6**	12.7	15.1	16.4	18.1	18.9	44.1	3.6	2.5	23.8	11.1	2.8	25.5	10.8	1.28	1.64	1.04	**0.11**
Ge mg/kg	**LRD**	0.5	<0.5	<0.5	0.5	0.7	1.0	**1.4**	2.1	3.1	4.1	5.9	7.6	38.7	1.1	0.7	53.0	1.8	1.6	91.4	1.4	1.92	2.11	7.17	**0.06**
	SEEN	0.5	<0.5	<0.5	<0.5	0.5	0.8	**1.1**	1.4	1.7	1.9	2.4	2.9	38.7	0.6	0.4	40.4	1.2	1.2	99.9	1.0	1.65	2.11	23.26	**-0.26**
	LOND	0.5	<0.5	<0.5	0.5	0.7	1.1	**1.5**	2.3	3.4	4.3	6.3	8.1	32.7	1.2	0.7	49.4	1.9	1.7	87.6	1.5	1.93	2.04	6.06	**-0.03**
Hf mg/kg	**LRD**	1.0	1.1	3.8	4.5	5.2	6.2	**7.4**	9.1	11.3	12.8	14.3	15.8	40.7	2.9	2.1	28.0	7.9	2.7	34.5	7.5	1.38	1.57	2.02	**-0.03**
	SEEN	1.0	1.2	3.7	4.7	5.9	7.6	**9.5**	11.7	13.5	14.5	16.5	18.7	31.2	4.1	3.1	32.8	9.7	3.2	33.5	9.1	1.43	1.41	0.94	**-0.86**
	LOND	1.0	1.1	3.8	4.5	5.1	6.0	**7.2**	8.6	10.1	11.5	13.4	14.6	40.7	2.6	1.9	26.8	7.5	2.4	32.1	7.2	1.34	1.57	2.58	**0.03**
I mg/kg	**LRD**	0.5	<0.5	1.2	1.5	1.8	2.4	**3.1**	4.2	6.6	8.8	12.3	16.7	79.9	1.8	1.2	38.3	3.9	3.4	86.5	3.3	1.72	2.30	7.12	**0.65**
	SEEN	0.5	<0.5	1.1	1.4	1.8	2.7	**3.9**	5.7	8.2	10.0	12.6	15.5	32.9	3.0	2.1	53.2	4.6	3.1	68.1	3.9	1.82	1.92	3.03	**-0.12**
	LOND	0.5	<0.5	1.2	1.5	1.8	2.4	**3.0**	3.9	5.8	8.2	12.2	16.8	79.9	1.5	1.0	34.6	3.7	3.4	91.2	3.2	1.68	2.30	8.02	**0.87**

Analytes units	Dataset	LLD	Min	Q02	Q05	Q10	Q25	Mdn	Q75	Q90	Q95	Q98	Q99	Max	IQR	MAD	CVR%	AM	SD	CV%	GM	GSD	Powers	Skew	Skew LOG
La mg/kg	**LRD**	1	3	12	14	16	20	**25**	30	36	40	49	59	134	10	7.4	29.7	25.9	10	37.0	24.4	1.41	1.65	2.41	**-0.19**
	SEEN	1	3	9	12	16	22	**28**	34	41	47	59	73	134	12	8.9	31.8	29.0	12	41.5	26.7	1.53	1.65	1.94	**-0.80**
	LOND	1	3	12	14	16	20	**24**	29	34	38	45	55	130	9	7.4	30.9	25.1	9	34.7	23.9	1.37	1.64	2.49	**0.00**
Mo mg/kg	**LRD**	0.2	<0.2	0.4	0.6	0.7	1.0	**1.4**	2.0	2.8	3.6	5.5	7.5	561.2	1.0	0.7	53.0	1.9	8.1	432.6	1.4	1.83	3.75	52.74	**0.56**
	SEEN	0.2	<0.2	0.3	0.4	0.5	0.7	**0.9**	1.2	1.5	1.8	2.6	3.8	192.2	0.5	0.3	32.9	1.1	4.8	424.7	0.9	1.70	3.28	38.41	**0.48**
	LOND	0.2	<0.2	0.5	0.7	0.8	1.1	**1.5**	2.1	3.0	3.8	5.9	7.8	561.2	1.0	0.7	49.4	2.0	8.7	424.7	1.6	1.77	3.75	51.32	**0.79**
Nb mg/kg	**LRD**	1.0	4.7	8.3	9.3	9.9	11.0	**12.6**	15.1	16.9	17.8	18.5	19.0	146.7	4.1	2.8	22.4	13.1	3.1	23.5	12.8	1.23	1.49	10.08	**0.01**
	SEEN	1.0	4.7	7.2	8.2	9.2	11.3	**14.2**	16.4	17.7	18.3	18.8	19.1	23.4	5.1	3.7	26.1	13.8	3.2	23.3	13.3	1.29	0.70	**-0.35**	-0.86
	LOND	1.0	5.3	8.8	9.4	10.0	11.0	**12.5**	14.6	16.6	17.5	18.4	18.8	146.7	3.6	2.5	20.2	12.9	3.0	23.4	12.6	1.22	1.44	13.26	**0.36**
Nd mg/kg	**LRD**	4.0	<4.0	8.0	10.4	12.9	17.0	**21.8**	26.9	32.5	36.7	45.5	54.8	172.7	9.9	7.3	33.3	22.7	9.7	42.5	21.0	1.49	1.69	3.05	**-0.47**
	SEEN	4.0	<4.0	5.8	8.4	11.4	17.8	**24.2**	30.7	36.7	41.7	55.1	71.2	172.7	12.9	9.6	39.8	25.1	12.6	50.3	22.3	1.66	1.69	3.08	**-0.83**
	LOND	4.0	<4.0	8.6	11.0	13.2	16.9	**21.3**	26.1	31.1	34.7	42.0	51.4	122.8	9.2	6.7	31.3	22.2	8.7	39.4	20.7	1.45	1.55	2.70	**-0.34**
Ni mg/kg	**LRD**	1.3	<1.3	8.0	11.3	13.9	18.7	**24.6**	32.2	41.3	49.6	62.3	78.3	505.6	13.5	9.8	39.8	27.2	16.8	61.8	24.2	1.62	2.62	8.77	**-0.40**
	SEEN	1.3	<1.3	3.7	6.6	9.6	15.2	**21.1**	30.0	38.7	45.6	56.8	74.6	469.4	14.8	10.4	49.2	24.1	20.0	82.7	20.1	1.86	2.59	10.41	**-0.73**
	LOND	1.3	2.3	10.0	12.7	15.1	19.5	**25.4**	32.6	41.8	50.2	63.7	79.0	505.6	13.1	9.3	36.8	27.9	15.9	57.0	25.3	1.54	2.34	8.05	**0.16**

Analytes units	Dataset	LLD	Min	Q02	Q05	Q10	Q25	Mdn	Q75	Q90	Q95	Q98	Q99	Max	IQR	MAD	CVR%	AM	SD	CV%	GM	GSD	Powers	Skew	Skew LOG
Pb mg/kg	**LRD**	1.3	10	32	38	46	70	**138**	284	531	775	1222	1668	25206	214	122	88.	251	477	190.3	149	2.59	3.40	22.98	**0.46**
	SEEN	1.3	10	25	30	34	40	**55**	81	126	184	325	484	1914	41	25	45.8	79	105	133.4	61	1.82	2.28	8.95	**1.39**
	LOND	1.3	11	39	49	60	94	**175**	332	593	845	1323	1864	25206	238	145	83.0	291	520	178.4	184	2.45	3.36	21.74	**0.42**
Rb mg/kg	**LRD**	1.0	6.5	25.5	33.1	38.4	45.9	**56.5**	72.5	89.5	98.0	107.4	113.5	157.2	26.6	18.7	33.1	60.3	20.1	33.4	57.0	1.41	1.38	0.64	**-0.50**
	SEEN	1.0	6.5	21.1	27.3	35.4	47.2	**62.8**	80.0	95.7	103.0	111.0	114.1	157.2	32.8	24.2	38.5	63.8	23.0	36.1	59.1	1.52	1.38	**0.21**	-1.05
	LOND	1.0	8.9	28.4	34.4	38.9	45.8	**55.8**	70.8	87.7	96.4	106.5	112.9	148.6	25.0	17.3	31.1	59.5	19.3	32.4	56.5	1.39	1.22	0.77	**-0.26**
Sb mg/kg	**LRD**	0.5	<0.5	0.5	0.7	0.9	1.3	**2.4**	4.5	8.2	12.7	22.0	33.1	612.3	3.2	1.9	80.3	4.5	13.2	294.8	2.6	2.48	3.18	26.04	**0.67**
	SEEN	0.5	<0.5	<0.5	0.5	0.6	0.8	**1.0**	1.4	2.2	3.1	5.7	9.9	47.1	0.6	0.4	44.5	1.4	2.1	148.4	1.1	1.81	2.07	11.40	**1.42**
	LOND	0.5	<0.5	0.7	1.0	1.2	1.7	**2.9**	5.2	9.3	14.2	24.9	38.2	612.3	3.5	2.1	71.6	5.2	14.6	279.9	3.2	2.34	3.18	23.91	**0.76**
Sc mg/kg	**LRD**	3.0	<3.0	<3.0	3.0	4.0	5.8	**7.8**	10.2	12.6	14.0	15.7	16.9	35.6	4.4	3.3	41.8	8.1	3.4	41.5	7.4	1.60	1.25	**0.61**	-0.83
	SEEN	3.0	<3.0	<3.0	<3.0	<3.0	4.6	**7.3**	10.0	12.3	13.7	15.6	17.3	35.6	5.4	4.0	54.8	7.5	3.8	50.6	6.4	1.81	1.25	**0.65**	**-0.65**
	LOND	3.0	<3.0	<3.0	3.5	4.5	6.0	**7.9**	10.3	12.6	14.1	15.7	16.8	33.3	4.3	3.1	39.4	8.3	3.2	39.2	7.6	1.54	1.22	**0.66**	-0.73
Se mg/kg	**LRD**	0.2	<0.2	0.2	0.2	0.3	0.4	**0.5**	0.7	1.0	1.2	1.7	2.3	19.6	0.3	0.3	59.3	0.6	0.6	92.6	0.5	1.72	2.29	14.13	**0.09**

	SEEN	0.2	<0.2	<0.2	0.2	0.2	0.3	**0.4**	0.6	0.7	0.9	1.3	1.7	15.4	0.3	0.1	37.1	0.5	0.5	101.4	0.4	1.69	2.19	18.10	**0.14**
	LOND	0.2	<0.2	0.2	0.2	0.3	0.4	**0.6**	0.8	1.0	1.3	1.8	2.3	19.6	0.4	0.3	49.4	0.7	0.6	90.1	0.6	1.71	2.29	13.75	**0.09**
Analytes units	**Dataset**	**LLD**	**Min**	**Q02**	**Q05**	**Q10**	**Q25**	**Mdn**	**Q75**	**Q90**	**Q95**	**Q98**	**Q99**	**Max**	**IQR**	**MAD**	**CVR%**	**AM**	**SD**	**CV%**	**GM**	**GSD**	**Powers**	**Skew**	**Skew LOG**
Sn mg/kg	**LRD**	0.5	0.9	2.6	3.1	3.7	5.6	**10.9**	22.6	44.2	67.2	124.4	169.1	1041.5	17.0	9.6	88.4	21.5	40.0	186.2	12.1	2.64	3.06	9.24	**0.62**
	SEEN	0.5	1.2	2.2	2.5	2.7	3.4	**4.5**	7.3	11.9	18.9	38.1	71.8	466.5	3.9	2.2	49.4	8.1	19.7	243.5	5.3	2.00	2.59	13.61	**1.80**
	LOND	0.5	0.9	3.2	4.0	4.7	7.3	**13.6**	25.7	50.0	75.9	133.5	181.1	1041.5	18.4	11.4	83.9	24.6	42.8	173.9	14.6	2.52	3.06	8.83	**0.59**
Sr mg/kg	**LRD**	1	11	29	38	45	57	**73**	93	125	153	217	272	601	36	25.2	34.5	82.2	44.4	54.0	74.2	1.55	1.74	3.24	**0.34**
	SEEN	1	11	24	29	35	48	**63**	80	115	171	277	330	576	32	22.2	35.3	75.1	54.9	73	64.3	1.68	1.72	3.53	**0.71**
	LOND	1	12	33	41	48	60	**76**	96	126	152	198	254	601	36	25.2	33.2	83.9	41.4	49.3	76.8	1.50	1.70	3.09	**0.34**
Th mg/kg	**LRD**	0.7	<0.7	3.1	3.8	4.4	5.4	**6.8**	8.4	9.5	10.1	10.6	11.0	456.5	3.0	2.2	32.7	7.0	5.3	76.1	6.6	1.38	2.88	73.02	**-0.69**
	SEEN	0.7	<0.7	2.2	3.1	3.9	5.7	**7.7**	9.1	10.0	10.4	10.8	11.0	15.7	3.4	2.4	30.8	7.3	2.3	31.6	6.8	1.49	1.42	**-0.49**	-1.49
	LOND	0.7	<0.7	3.3	4.0	4.5	5.4	**6.6**	8.2	9.4	9.9	10.6	11.0	456.5	2.8	2.1	31.4	6.9	5.8	83.9	6.5	1.35	2.88	69.56	**-0.29**
U mg/kg	**LRD**	0.5	<0.5	1.1	1.4	1.6	1.9	**2.2**	2.6	2.9	3.1	3.4	3.6	11.5	0.7	0.5	24.7	2.2	0.6	26.1	2.2	1.34	1.46	**0.88**	-1.55
	SEEN	0.5	<0.5	1.1	1.3	1.5	1.9	**2.3**	2.6	2.9	3.1	3.2	3.4	7.3	0.7	0.5	23.6	2.2	0.6	24.9	2.2	1.31	1.26	**0.43**	-1.00
	LOND	0.5	<0.5	1.1	1.4	1.6	1.9	**2.2**	2.6	2.9	3.2	3.4	3.6	11.5	0.7	0.5	24.2	2.2	0.6	26.4	2.1	1.34	1.46	**0.96**	-1.65
V mg/kg	**LRD**	3	9	36	44	50	61	**75**	98	122	135	151	163	531	37	25.2	33.6	81.4	29.7	36.4	76.5	1.43	1.77	1.41	**-0.24**
	SEEN	3	9	25	33	41	54	**71**	91	113	128	146	161	352	37	26.7	37.6	74.5	30.1	40.4	68.6	1.52	1.59	1.24	**-0.59**
	LOND	3	16	40	47	53	62	**76**	100	124	137	151	163	531	38	25.2	33.2	83.1	29.3	35.3	78.4	1.40	1.52	1.50	**0.04**
Analytes units	**Dataset**	**LLD**	**Min**	**Q02**	**Q05**	**Q10**	**Q25**	**Mdn**	**Q75**	**Q90**	**Q95**	**Q98**	**Q99**	**Max**	**IQR**	**MAD**	**CVR%**	**AM**	**SD**	**CV%**	**GM**	**GSD**	**Powers**	**Skew**	**Skew LOG**
W mg/kg	**LRD**	0.6	<0.6	<0.6	0.8	1.1	1.6	**2.1**	2.6	3.3	3.9	5.6	8.4	316.8	1.0	0.7	35.3	2.4	5.8	241.8	2.0	1.70	2.90	37.19	**0.21**
	SEEN	0.6	<0.6	<0.6	<0.6	0.8	1.6	**2.4**	3.0	3.5	4.0	4.8	5.5	184.6	1.4	1.0	43.2	2.5	4.8	193.1	2.0	1.83	2.66	35.32	**-0.70**
	LOND	0.6	<0.6	<0.6	0.9	1.1	1.6	**2.0**	2.5	3.2	3.9	6.2	8.7	316.8	0.9	0.7	37.1	2.4	6.1	252.4	2.0	1.67	2.90	36.98	**0.55**
Y mg/kg	**LRD**	1	3	9	12	14	17	**21**	25	29	32	42	50	158	8.0	5.9	28.2	21.6	8.5	39.3	20.3	1.40	1.72	4.16	**0.01**
	SEEN	1	3	7	9	12	18	**23**	28	32	39	51	69	158	10.5	7.4	32.2	23.5	11.3	48.1	21.4	1.55	1.72	3.47	**-0.41**
	LOND	1	5	10	12	14	17	**20**	24	28	30	37	48	133	7.0	5.9	29.7	21.1	7.6	35.9	20.1	1.35	1.42	4.24	**0.18**
Zn mg/kg	**LRD**	1.3	<1.3	27	44	58	81	**130**	225	371	521	801	1120	10095	144	89	68.4	195	269	138.0	137	2.21	4.00	13.90	**0.14**
	SEEN	1.3	<1.3	18	28	42	60	**77**	98	136	176	254	446	2505	38	27	34.7	94	120	127.8	76	1.84	3.40	11.83	**-0.42**
	LOND	1.3	<1.3	35	51	65	95	**152**	252	412	563	842	1214	10095	157	102	67.3	219	288	131.7	158	2.15	4.00	13.57	**0.15**
Zr mg/kg	**LRD**	1	35	153	182	204	240	**288**	350	424	478	536	580	1488	110	79	27.3	304	99	32.4	290	1.36	1.63	2.02	**-0.14**
	SEEN	1	48	137	182	219	286	**351**	434	504	537	596	646	1062	148	107	30.4	360	115	32.1	340	1.43	1.34	**0.60**	-1.14
	LOND	1	35	156	182	202	235	**277**	330	391	437	496	552	1488	95	70	25.2	291	89	30.7	279	1.32	1.63	2.71	**0.05**

LOI %	**LRD**	0.01	0.7	3.2	3.9	4.5	5.7	**7.1**	8.9	10.9	12.5	15.5	18.3	72.1	3.2	2.4	33.4	7.6	3.3	43.8	7.1	1.45	2.01	4.27	**0.10**
	SEEN	0.01	1.2	2.8	3.3	3.8	4.8	**6.0**	8.0	10.6	12.8	15.9	18.7	72.1	3.2	2.1	34.6	6.9	4.3	61.7	6.2	1.53	1.78	6.31	**0.72**
	LOND	0.01	0.7	3.3	4.0	4.7	5.8	**7.3**	9.1	11.0	12.5	15.5	18.3	58.7	3.3	2.4	32.5	7.8	3.2	40.6	7.3	1.43	1.92	3.46	**0.02**
pH log[H+] mol/L	**LRD**	0.01	2.8	3.4	4.0	4.6	5.5	**6.5**	7.0	7.3	7.4	7.5	7.6	8.4	1.5	0.9	14.1	6.2	1.1	17.3	6.1	1.22	0.48	**-0.96**	-1.38
	SEEN	0.01	2.9	3.2	3.6	4.3	5.0	**6.2**	7.1	7.4	7.5	7.5	7.6	7.8	2.1	1.5	24.5	5.9	1.2	20.6	5.8	1.26	0.44	**-0.53**	-0.95
	LOND	0.01	2.8	3.5	4.1	4.7	5.6	**6.6**	7.0	7.3	7.4	7.5	7.6	8.4	1.4	0.8	12.9	6.2	1.0	16.6	6.1	1.21	0.48	**-1.03**	-1.45

Following **Table 9**, a set of box-plots of the 44 elements are shown in **Figure 7**, **Figure 8**, and **Figure 9** for **LRD**, **SEEN** and **LOND** respectively. These were generated running R (Rx64 3.1.0) in RStudio (Version 0.98.977) with an R script derived mainly from functions and scripts in StatDA R package (Reimann et al., 2008). The elements are ordered by abundance in the **SEEN** subset. Each figure is composed of two graphics, one (on the left) showing the 10 most abundant elements (expressed as oxides in wt%) and another (on the right) showing the less abundant elements (in mg/kg); Mn is included in both graphics allowing a visual calibration of the concentration scale (Y axis). The concentration scales of these three figures are log-decimal, thus allowing visualisation of elements with orders of magnitude difference in content on the same graphic. This also has advantage when showing elements with a highly positive skewed distribution.

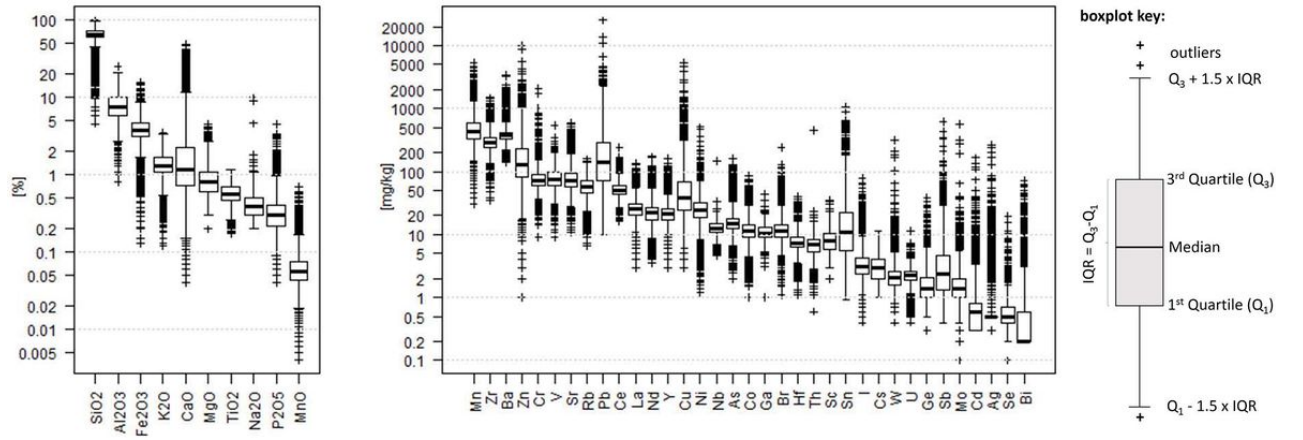

Figure 7 Box-plot of element concentrations in topsoil in the **LRD** dataset (8400 samples), shown by order of abundance in the **SEEN** subset. The 10 most abundant elements (expressed as oxides in wt%) on the left and the less abundant (in mg/kg) on the right. Manganese is shown as MnO and as Mn for reference between both graphs. (P929864).

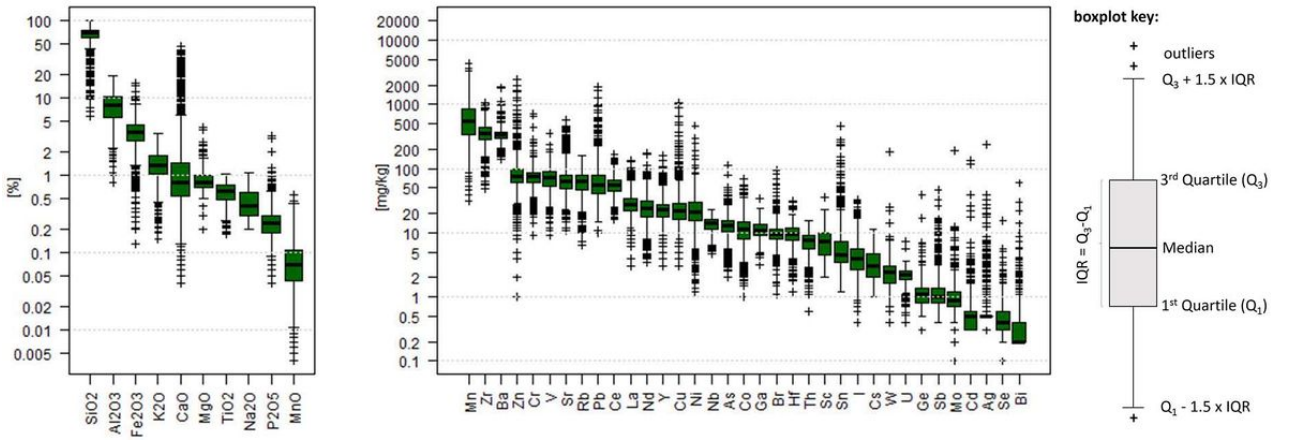

Figure 8 Box-plot of element concentrations in topsoil in the **SEEN** subset (1599 samples), shown by order of abundance in the **SEEN** subset. The 10 most abundant elements (expressed as oxides in wt%) on the left and the less abundant (in mg/kg) on the right. Manganese is shown as MnO and as Mn for reference between both graphs. (P929865).

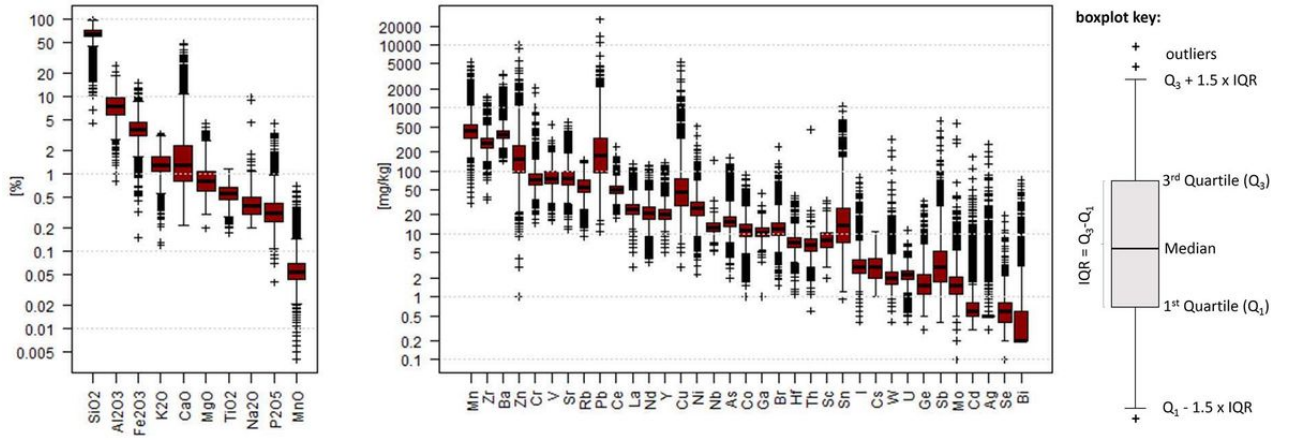

Figure 9 Box-plot of element concentrations in topsoil in the **LOND** subset (6801 samples), shown by order of abundance in the **SEEN** subset. The 10 most abundant elements (expressed as oxides in wt%) on the left and the less abundant (in mg/kg) on the right. Manganese is shown as MnO and as Mn for reference between both graphs. (P929866).

Adjacent to each element map, a univariate table of statistics (e.g.: **Figure 10**) and a set of statistical graphics are shown. These were also generated running R (Rx64 3.1.0) in RStudio (Version 0.98.977) using an R script derived from functions and scripts from StatDA[6] R package (Reimann et al., 2008).

Where appropriate the **LRD** dataset, and **SEEN** and **LOND** subsets are represented in **black/white**, **dark green** and **dark red** respectively. **Quaternary**, **Palaeogene** and **Cretaceous** geological time periods are represented by **soft yellow**, **orange** and **lime green** colours respectively.

Graphics shown are (i) a histogram of **LRD** data distribution with the density lines of the **SEEN** and **LOND** subsets; (ii) a Tukey boxplot of the **LRD**, **SEEN** and **LOND** dataset distributions and (iii) a cumulative probability plot of the **LRD**, **SEEN** and **LOND** datasets (e.g.: **Figure 11**); (iv) the **LOND** and **SEEN** topsoil parameter concentrations over each geological unit (e.g.: **Figure 12**); (v) the **LRD** topsoil parameter concentrations over each geological unit (e.g.: **Figure 13** and **Figure 14**).

The **histogram**, is used to show the **LRD** topsoil parameter distribution. The **SEEN** and **LOND** subsets are shown as **density traces**, as these allow overlap of the three data distributions (**LRD**, **SEEN**, **LOND**), thus directly comparing their shapes, independently of the number of soil samples. The **Tukey boxplots** (Tukey, 1977[7]) are built around the median (line dividing the box in two parts); the box representing the interquartile range (Q_3-Q_1=IQR), that is, 50%

of the data, from the lower (Q_1) to the upper (Q_3) quartiles; the lowest end of the whiskers is 1.5 times the length of the box (IQR) starting from the lower quartile, while the highest one is 1.5 times the IQR starting from the upper quartile; in this graphical representation, data below and above the whiskers (plotted with the symbol **+**) are considered as outliers. The boxplots shown also include a notch around the median. This gives an approximate indication as to whether the medians are different or not. If notches of different boxplots do not overlap, there is some evidence of a statistical difference between the medians. The **cumulative probability (CP) plots** (Sinclair, 1976[8]) are built with a non-linear probability scale on the Y axis (from >0 to <100%). The quartiles are close together near the median (probability = 50%) and stretch out symmetrically moving away from the median. If the variable follows a normal (or lognormal) distribution, then its values (or log transformed values) fall in a straight line from the bottom left to the top right of the graph; inflexion points on the curve suggest that the distribution is made up of multiple data populations. CP plots are a good complement to the previous graphs in understanding and comparing the distribution of several datasets.

The Tukey style of boxplots used to display the **LRD**, **SEEN** and **LOND** datasets were used to show element concentrations over each geological parent material unit also. In the **LOND** and **SEEN** comparison, two boxplots (**LOND** above **SEEN**) are shown, together with the number of soil samples collected over each geological unit (n, on the right of the graphic) (**Figure 12**). For some parent material classes (e.g.: **LOND** over Gault Fm.), the boxplot is not shown as there are no soil samples over this rock type (**Table 7**). The **LRD** geological parent material comparison is presented in two formats. The upper set of boxplots show topsoil element concentrations over each geological unit (**Figure 13**), whereas the lower set of boxplots show topsoil element concentrations classified by parent material geological period (**Figure 14**). The number of soil samples in each geological time zone is shown in brackets and the boxplots are coloured according to the geological time period. The last boxplot refers to **LRD** and is shown for reference.

Al2O3 [%]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.2)	0	0	0
minimum	0.8	0.8	0.8
Q25	5.9	5.8	5.9
median	**7.6**	**8.2**	**7.5**
Q75	10	10.7	9.7
Q95	13.2	13.4	13.2
Q99	15.3	15.6	15.2
maximum	25.5	19.9	25.5
MAD	**2.8**	**3.7**	**2.7**
CVR%	37.1	45.2	35.6
mean	8	8.2	8
SD	2.9	3.3	2.8
CV%	35.9	39.7	34.9
GM	7.5	7.4	7.5
GSD	1.47	1.62	1.43
powers	1.5	1.4	1.5
skewness	0.52	0.09	0.66

Figure 10 Example of a univariate table of statistics for **LRD**, **SEEN** and **LOND** shown next to the respective map. The case for Al_2O_3. These and other statistical parameters are shown in **Table 9** for other elements also. For further explanation go to Univariate statistics and graphics (P929875).

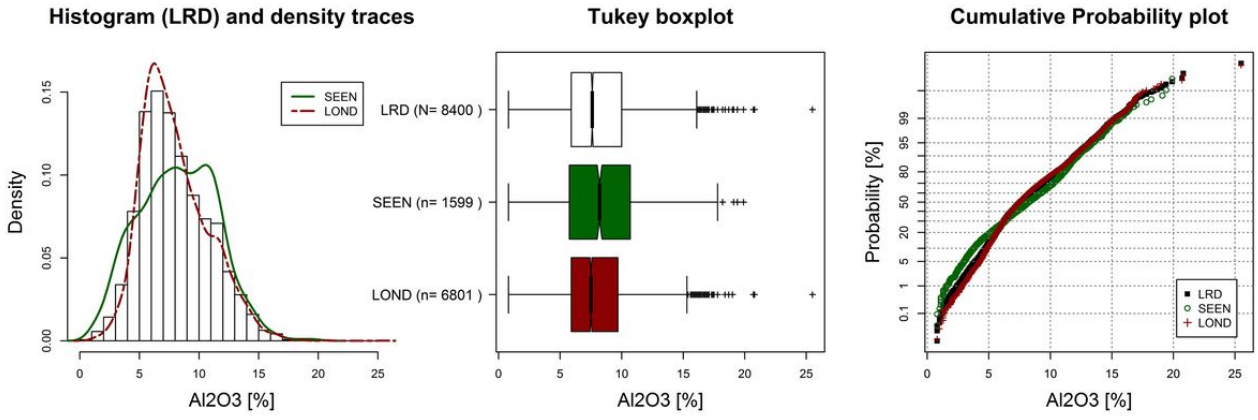

Figure 11 Example of a histogram, a Tukey boxplot and a cumulative probability plot shown for **LRD**, **SEEN** and **LOND** next to the respective map. The case for Al_2O_3. For further explanation go to Here (P929874).

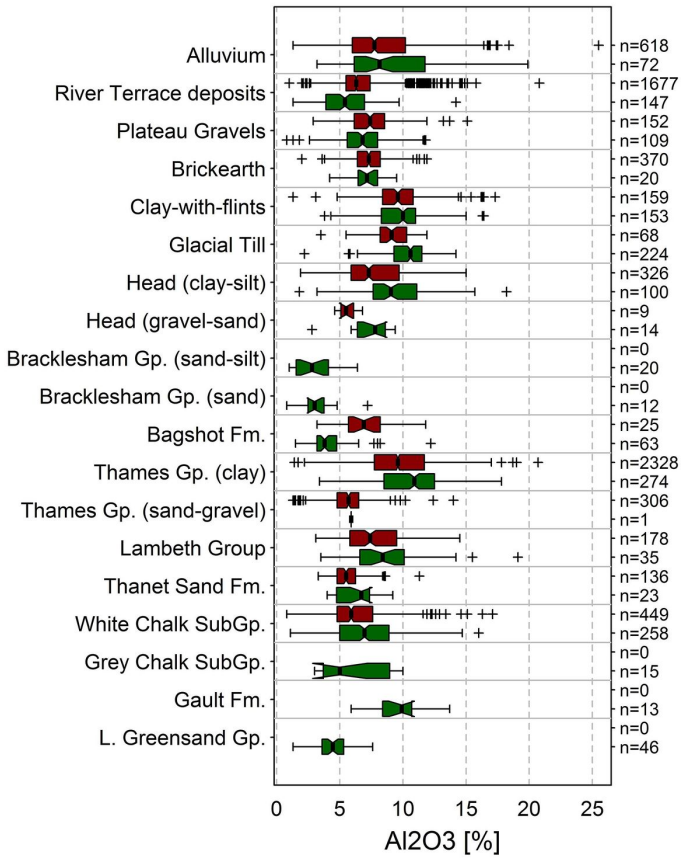

Figure 12 Example of a **LOND** and **SEEN** topsoil parameter concentrations over each geological unit shown next to the respective map. The case for Al_2O_3. For further explanation go to Here (P929876).

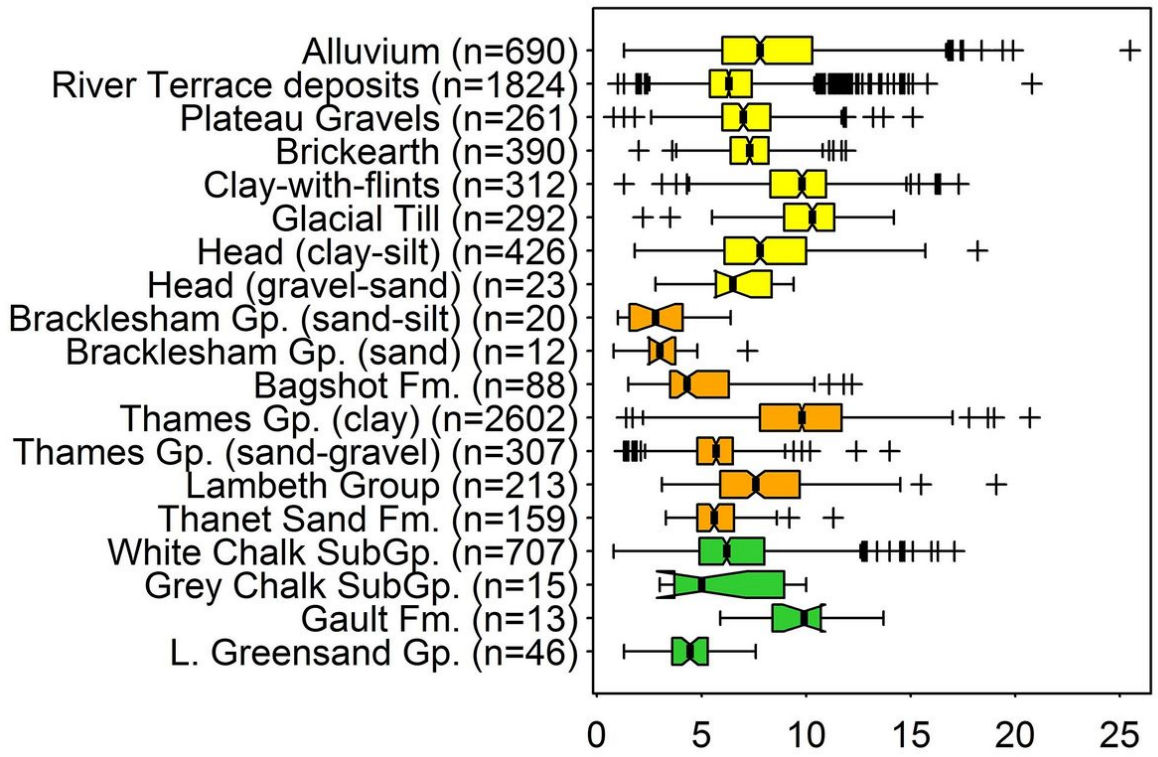

Figure 13 Example of the **LRD** topsoil parameter concentrations over each geological unit (parent material) shown next to the respective map. The case for Al_2O_3. For further explanation go to Here (P929877).

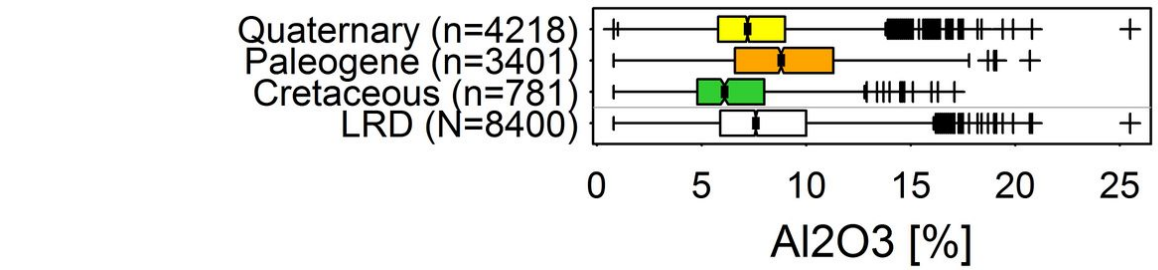

Figure 14 Example of the **LRD** topsoil parameter concentrations over each geological time period shown next to the respective map. The case for Al_2O_3. For further explanation go to Here (P929878).

Compositional data analysis (CoDA)

Geochemical data have an intrinsic compositional nature (Aitchison, 1986[9]), as the sum of all parts in a sample necessarily sum up to a constant (frequently 1, 100% or 1 000 000 mg/kg). These datasets are called *compositional data* or *closed data*. For closed data the concentration obtained for one part (element) does not vary independently from the others, thus the information is not absolute but only relative. As pointed out by Pearson (1897)[10], applying classical methods of statistical data analysis to this type of dataset may lead to wrong results, as for example, in the form of spurious correlations when performing a bivariate analysis. This problem was first tackled by Aitchison (1986), who found that compositional data is better encompassed, not in the usual Euclidean space (on which classical statistical methods have been developed), but in the Aitchison geometry on the simplex. As the statistical evaluation and interpretation of a certain element concentration should take into account the remaining parts, the statistical methods and techniques developed in this context are mainly based on three different logratio

transformations. The *alr* - additive logratio and the *clr* – centred logratio transformation, both proposed by Aitchison (1986), and the *ilr* – isometric logratio transformation (Egozcue et al., 2003[11]). The idea of these transformations is that the data should be transformed into the correct geometry first, after which classical methods can be fully applied.

However these transformations lead to dimensionless values, which constitute a serious drawback when the main task is to document and to study the spatial distribution of element concentrations (Reimann et al., 2012[12]). This is particularly evident in the production of geochemical atlases where the primary aim is to present single element distribution maps and associated statistics (Reimann et al., 2014[13]).

As this work is a geochemical atlas, the uni-element maps and associated statistics are shown as prevoiusly explained, as the absolute values are of interest. However, readers, especially earth science practitioners, are advised to take into account that the geochemical dataset presented here is clearly a case of compositional data. Thus a conflict with the CoDA approach may exist, particularly for the statistics typically used to compare variables such as the measures of dispersion, despite of some extenuatory reasoning as referred by Filzmoser et al. (2009)[14] and Reimann et al. (2014).

As pointed out above, uni-element and bivariate statistics are not among the best practices when statistically analysing compositions, because these datasets are multivariate in nature. Still, the *center* or *compositional mean* (equation 4.1 in van den Boogaart and Tolosana-Delgado, 2013[15]) is meaningful in the CoDA context, namely with respect to translation and scaling operations, referred as perturbation and powering in CoDA (van den Boogaart and Tolosana-Delgado, 2013[15]). This central tendency CoDA statistic is computed for the **LRD** dataset and **SEEN** and **LOND** subsets after the line command *mean(x)*, with *x* being a composition, in *compositions*[16] R package (**Table 10**); the composition is based on all the 44 chemical elements and in all the topsoil samples of this atlas (8400 for **LRD**, 1599 for **SEEN** and 6801 for **LOND**). The *compositional mean* was computed after converting the trace elements to percent (%, i.e.: concentration in mg/kg / 10000); the obtained values were then back transformed to the original units (% for the 10 major and mg/kg for the 34 less abundant elements).

By computing the *compositional mean* in **LOND** and in **SEEN**, a preliminary overview of the geochemical signatures in urban versus rural areas can be obtained. The comparison of **LOND** and **SEEN** is better achieved after the (Log(**LOND**/**SEEN**) in **Table 10**, which gives an indication of element enrichment (positive) / depletion (negative) in the urban environment relative to the rural environment, and the degree (distance to zero) of this enrichment / depletion; the elements are ordered from the highest to the lowest Log(**LOND**/**SEEN**) value in order to facilitate comparison of the elements. Pb (closely followed by Sb, Sn, Cu, Zn) is the element showing the highest relative enrichment in **LOND**, contrary to Hf (closely followed by I, Zr, MnO) which shows the highest relative depletion in **LOND**; in this sense the major Al_2O_3 and K_2O are the elements showing the lowest enrichment or depletion in **LOND** relative to **SEEN** as their Log(**LOND**/**SEEN**) values are the closest to zero among all elements. This sort of approach, i.e., the use of ratios to estimate enrichment / depletion (enrichment factors, EFs), has been used previously to examine urban data relative to rural data (e.g.: Fordyce et al., 2005[17]; Flight and Scheib, 2011[18], among many others). This and other indexes, such as the I_{geo}-index (Müller, G, 1979[19]), have been widely used in searching for anthropogenic impact on the surface environment since their introduction in the 1970s (e.g.: Chester and Stoner, 1973[20]; Zoller et al., 1974[21]).

Table 10 Compositional mean based on the concentration of 44 chemical elements in 8400, 1599 and 6801 topsoil samples respectively for LRD, SEEN and LOND. Log(LOND/SEEN) corresponds to the logarithm of column 6 (ratio between the LOND and the SEEN compositional mean values). Elements are ordered from the highest to lowest log(LOND/SEEN) value.

Chemical element	Units	LRD	SEEN	LOND	LOND/SEEN	Log(LOND/SEEN)
Pb	mg/kg	183.9	75.4	226.7	3.01	0.478
Sb	mg/kg	3.20	1.37	3.90	2.86	0.456
Sn	mg/kg	14.92	6.59	18.08	2.74	0.438
Cu	mg/kg	51.50	27.35	59.74	2.18	0.339
Zn	mg/kg	169.6	93.8	194.8	2.08	0.318
Mo	mg/kg	1.73	1.10	1.93	1.75	0.243
Ge	mg/kg	1.75	1.25	1.89	1.51	0.179
CaO	%	1.66	1.23	1.78	1.44	0.160
Cd	mg/kg	0.75	0.57	0.80	1.39	0.143
P_2O_5	%	0.37	0.29	0.40	1.35	0.131
Se	mg/kg	0.67	0.53	0.70	1.33	0.125
As	mg/kg	18.62	15.11	19.55	1.29	0.112
Br	mg/kg	14.35	11.91	14.99	1.26	0.100
Bi	mg/kg	0.46	0.38	0.48	1.25	0.098
Ni	mg/kg	29.97	25.00	31.26	1.25	0.097
Sr	mg/kg	91.70	79.72	94.73	1.19	0.075
Sc	mg/kg	9.10	7.95	9.39	1.18	0.072
Ba	mg/kg	462.6	409.2	476.0	1.16	0.066
V	mg/kg	94.47	85.04	96.80	1.14	0.056
Fe_2O_3	%	4.59	4.20	4.68	1.11	0.047
Co	mg/kg	13.71	12.86	13.91	1.08	0.034
Ag	mg/kg	0.70	0.67	0.71	1.06	0.027
Cr	mg/kg	90.53	89.00	90.86	1.02	0.009
Na_2O	%	0.51	0.50	0.51	1.02	0.006
Al_2O_3	%	9.26	9.23	9.26	1.00	0.002
K_2O	%	1.642	1.640	1.642	1.00	0.001
U	mg/kg	2.66	2.67	2.65	1.00	-0.002
Ga	mg/kg	13.31	13.37	13.29	0.99	-0.002
SiO_2	%	80.1	80.9	79.8	0.99	-0.006
W	mg/kg	2.45	2.51	2.43	0.97	-0.014
MgO	%	0.96	0.98	0.95	0.97	-0.015
Th	mg/kg	8.14	8.45	8.07	0.95	-0.020
Rb	mg/kg	70.48	73.30	69.81	0.95	-0.021

TiO_2	%	0.71	0.74	0.70	0.95	-0.023
Nb	mg/kg	15.77	16.53	15.59	0.94	-0.026
Y	mg/kg	25.14	26.50	24.83	0.94	-0.028
Ce	mg/kg	61.91	65.50	61.07	0.93	-0.030
Nd	mg/kg	26.06	27.78	25.67	0.92	-0.034
La	mg/kg	30.15	33.11	29.48	0.89	-0.050
Cs	mg/kg	3.55	3.98	3.45	0.87	-0.062
MnO	%	0.069	0.081	0.067	0.83	-0.080
Zr	mg/kg	358.1	421.2	344.5	0.82	-0.087
I	mg/kg	4.06	4.79	3.90	0.81	-0.089
Hf	mg/kg	9.34	11.39	8.91	0.78	-0.107

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London Atlas: Preliminary conclusion

Ferreira, A, Johnson, C C, Appleton, J D, Flight, D M A, Lister, T R, Knights, K V, Ander, L, Scheib, C, Scheib, A, Cave, M, Wragg, J, Fordyce, F and Lawley, R. 2016. London Region Atlas of Topsoil Geochemistry. *British Geological Survey*.

The geochemistry of soil is dependent on several factors, principally the bedrock geology and/or superficial deposits from which they are derived. Other spatially and temporally varying factors, such as climate, land use and topography, are crucial in the development and shaping of the soil itself. Soil is a complex and evolving entity consisting of a mixture of minerals, organic matter, living organisms, water and air, with the depth extension and composition varying from place to place. The mineral component is frequently composed of weathered rock and mineral fragments, and different clay minerals, Fe, Mn and Al oxides and hydroxides, secondary carbonates and sulphates, all derived from the materials under weathering. Organic matter originates from living organism, namely plants and soil biota, decay. Water and air are mainly obtained from the atmosphere, but also from chemical, physical and microbial reactions permanently taking place. Soil also contains pollutants derived from anthropogenic activity such as urbanisation, energy generation, transportation, waste disposal, agriculture, mining and industry. This and further information about soil structure and composition can be found in FitzPatrick, 1986[1], White, 2006[2], Kabata-Pendias, 2011[3].

A previously published BGS G-BASE[4] project, London Earth[5], was carried out to provide insight into the environmental impacts of urbanisation and industrialisation on land quality as well as to characterise the soil geochemical baseline of the Greater London Authority area. Detailed descriptions of the controls on soil chemistry for selected elements within the London Earth area have been described previously (London Earth[5], Knights and Scheib, 2011[6]; Scheib et al., 2011[7] and Appleton et al., 2013[8]). Scheib et al. (2011)[9], when referring to evidence of anthropogenic modification to soil baseline concentrations, point to the higher concentrations of, for example, Pb, Sb, CaO, Zn, Cu, Sn and As in the oldest, most intensely urbanised parts of the city; as well as to several Se, Cd, Ni, Cu and Zn 'hot spots' in the vicinity of an industrial area on the banks of the River Lee in north London and to the high concentrations of Cr and Cd around Heathrow airport in the west. Patterns of other elements, are referred as being strongly related to the geology, namely the high contents of CaO, Ce, I, La, MnO, Nd, P_2O_5, Sr and Y over Cretaceous chalk bedrock, the high contents of Al_2O_3, Fe_2O_3, MgO, K_2O, Cr, La, TiO_2, Ga, Rb and Ni over Palaeogene clays, or elevated contents of Hf and Zr over Eocene marine and Quaternary wind-blown deposits. Another interesting feature also pointed out by Knights and Scheib, 2011[6], is the consistently low concentrations of As, CaO, Cr, Cu, Fe_2O_3, Ni, Pb and Zn associated with four park areas in south-west London, which contrast with surrounding areas. The relation between Pb concentration and land use classes is further studied by Lark and Scheib (2013)[10] inside the Greater London Authority area; the authors observe that the land use is an important source of variation in lead content of topsoil, with the largest mean lead content observed on the industrial sites followed by domestic gardens, contrary to, for example, parks and recreational areas; these authors suggest that the high Pb content in domestic gardens is most likely related with two historical factors: burning of domestic waste and spreading of ash (no longer a practice) and the use of lead-based paints (banned since 1992). Mao et al. (2014)[11], after analysing Pb isotopic ratios (206Pb/207Pb and 208Pb/207Pb) in soil samples from three land use types, namely, land adjacent to a major rural road, from a sewage processing farm and from London, concluded that the total Pb in soil, including that from London, falls on a mixing line between those of petrol and UK coal or Pb ore; these autors further concluded that soil pH is the main determinant of the isotopically exchangeable Pb fraction in soil, with exchangeable Pb decreasing with increasing pH. Appleton et al. (2013)[12], after an analysis of variance (ANOVA), suggest that the geochemical patterns of Cd, As, Ba, Cr, Cu, Mo, P_2O_5, Pb, Sb, Se, Sn and Zn in topsoils

of the London area are poorly dependent on the underlying geology, thus most likely influenced by anthropogenic factors; and that, for most of these same elements, the geochemical patterns are generally less dependent on the underlying geology in urban domain compared with the rural domain. On the contrary, the patterns of Al_2O_3, Ce, Cs, Ga, K_2O, La, MgO, MnO, Nb, Nd, Rb, TiO_2, V and Y closely associate to the underlying geology, and, for most of these elements, the geochemical patterns related to underlying geology are equally detectable in rural and urban domains. Patterns of CaO, Co, Fe_2O_3, I, Ni, Sc, Sr and Th show an intermediate behaviour relative to the previous groups of elements.

The link between soil geochemistry and the underlying geology, including in urban areas, led to the development of a geochemical mapping method using parent material classified data (Appleton and Adlam, 2012[13]). This same geochemical mapping method has been used for the production of this present atlas (see Data visualisation for further explanation).

The London Region Atlas of Topsoil Geochemistry presented here, was developed by joining the topsoil geochemical data from the London Earth project with other G-BASE topsoil geochemical data from rural locations in south-eastern England (SEEN). This provided a framework to investigate and compare the soil geochemical signature of the urbanised Greater London Authority area with that of the surrounding peri-urban / rural area, thus allowing for a better understanding of the environmental impacts of urbanisation and industrialisation of London on soil quality.

Comparisons of compositional mean values show that soils in central London contain more than double the amount of Pb, Sb, Sn, Cu and Zn than rural soils (**LOND/SEEN** ratio > 2, Log(**LOND/SEEN**) > 0.3, **Table 10**). This enrichment pattern applies to the 13 parent materials for which is possible to compare **LOND** and **SEEN** (**Table 7**), as can be observed in the respective graphics of **LOND** and **SEEN** topsoil concentrations over each geological unit. Similarly, the urban soils are enriched in Mo, Ge and CaO (**LOND/SEEN** ratio > 1.4, Log(**LOND/SEEN**) > 0.15, **Table 10**) and to a lesser extent Cd, P_2O_5, Se, As, Br, Bi and Ni (**LOND/SEEN** ratio > 1.2, Log(**LOND/SEEN**) > 0.08, **Table 10**) than rural soils. These parameters constitute a typical indicator suite of urban soil pollution reported in several other cities also (Fordyce et al., 2005[14]; Flight and Scheib, 2011[15]).

This reflects the strong anthropogenic fingerprint of London and its impact on land quality, as exemplified by the distribution of Pb in topsoil, which shows a bullseye pattern radiating out from higher values in the centre of London to background values in the surrounding rural environment over a distance of ca. 20 km. In the case of Pb, this probably reflects its former use in petrol and paint with dispersion into the soil environment greatest in areas of highest traffic and building density in the city centre. For the other elements, typical urban sources of pollution in soils include demolition and building rubble; burial of waste; presence of artificial ground; the historic dispersal of domestic and industrial coal ash into urban soils; fertiliser use; atmospheric deposition of pollutants; surface-water run-off; emissions and waste disposal from traffic, energy generation, waste disposal, industry and domestic sources (Johnson et al., 2011[16]).

The Br marginal enrichment observed in central London is perhaps the exception to the typical indicator suite of urban soil pollution referred above. The Br content of many soils is controlled by the deposition of marine aerosols, which are trapped in organic matter; hence its distribution is similar to that of LOI (an indicator of organic matter content) across London. The distribution of Br could also reflect the marine nature of the underlying parent materials of London soils. The salt-water influence on Br concentrations in soil in the Thames estuary is evident from the Br map also. The observation of the graphics of **LOND** and **SEEN** topsoil concentrations over each geological unit, however, strongly suggests that the Br (and LOI) marginal enrichment in central London is independent of the parent material, and, thus, it is not likely to be explained by the geology alone. This contrasts with other cities of the UK. In most of the cities, LOI values are higher in the surrounding rural soils, reflecting their more natural composition and higher organic matter content, relative to the urban environment.

The general anthropogenic pattern observed for central London is possibly emphasised by the geographical characteristics of this area: a topographic low related with the tidal section of the River Thames walled by the

north-west and south-east Chalk-related topographic highs, which may act as a trap where the surrounding geogenic and anthopogenic loadings converge.

By contrast to the enriched set of elements, parameters such as Hf, I, Zr, MnO, Cs and La are marginally lower on average (**LOND**/**SEEN** ratio < 0.9, Log(**LOND**/**SEEN**) < -0.05, **Table 10**) in urban than in rural soils demonstrating that the distributions of these elements are largely controlled by geological and soil-forming processes rather than anthropogenic pollution. Again, this is a typical indicator suite of geogenic signature elements found around other cities also (Fordyce et al., 2005[14]; Flight and Scheib, 2011[15]). The depression observed in the central London in the distribution of these elements (e.g.: Hf) do not necessarily mean that these elements have been *removed* from the central London soils. Instead, this is, most likely, a direct consequence of the *excess* loading of anthropogenic elements (e.g. Pb). Thus the depression is rather an effect of the compositional nature of the dataset. In fact, if a soil has 100 units of a geogenic pristine composition A, to which is *added* 100 units of an anthropogenic composition B, the measured values will be 50 of A and 50 of B. The geogenic component will look like depressed (A = 50%) relative to another pristine soil having 100 units of the same geogenic composition A only (A = 100%).

In summary, the process of urbanisation has had a significant impact on topsoil quality within the London region. Chemical elements that are typically found in very low concentration in most natural soil such as Pb, Sn, Sb, Cu, Zn are on average up to three times higher in urban than in rural soils as a result of pollution from anthropogenic activities.

This atlas provides comprehensive information on the chemical quality of soils across the London region, contributing to an understanding of the sources and pathways of pollutants in the environment to aid sustainable land use planning and urban management in the future.

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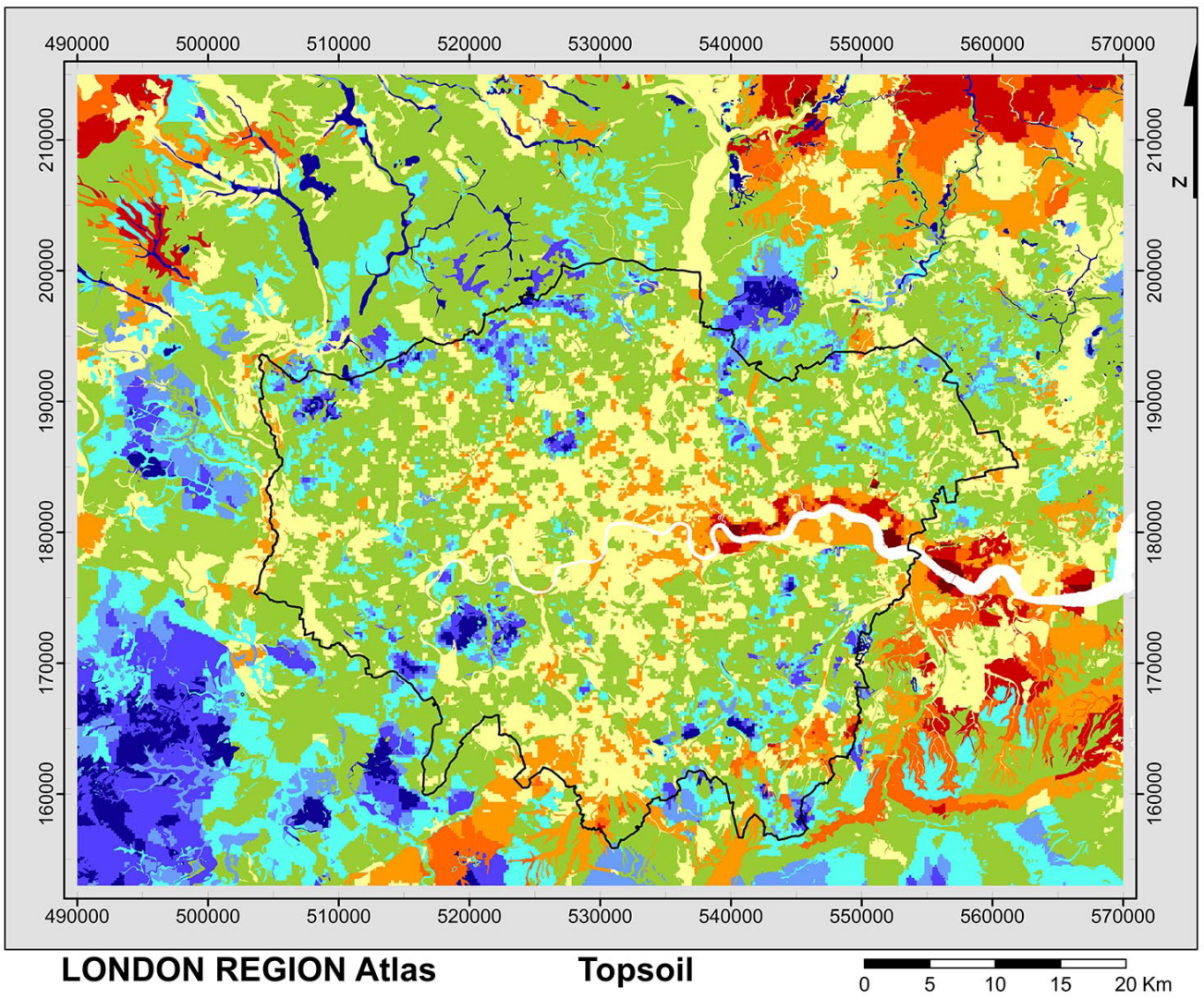
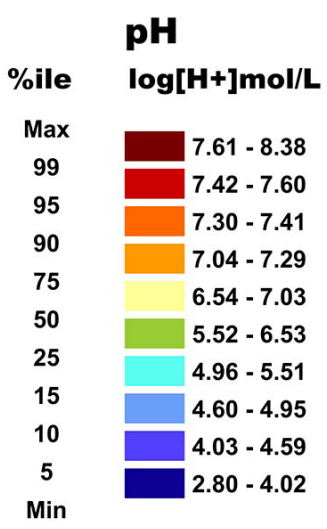
Acidity/Basicity: LRA

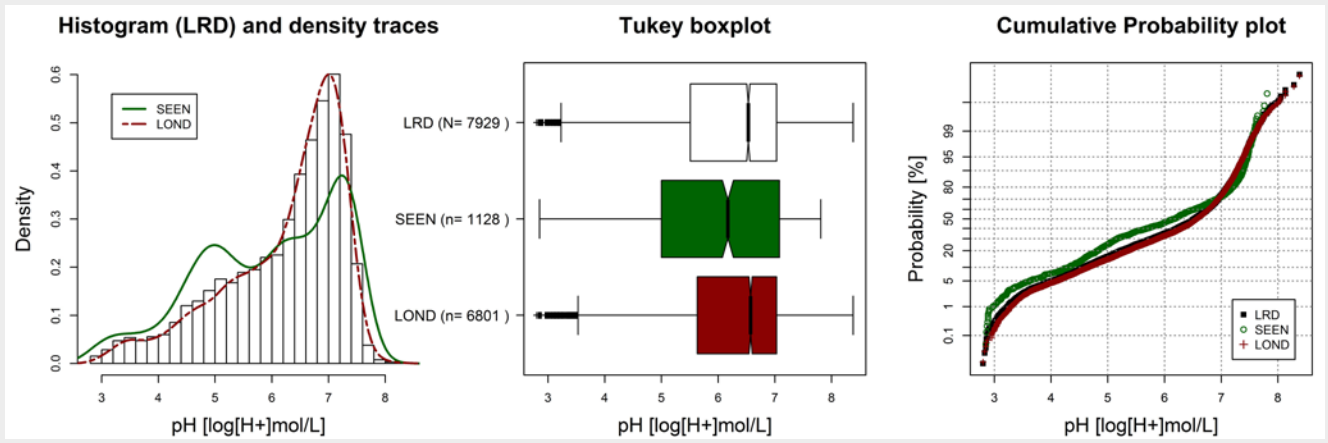




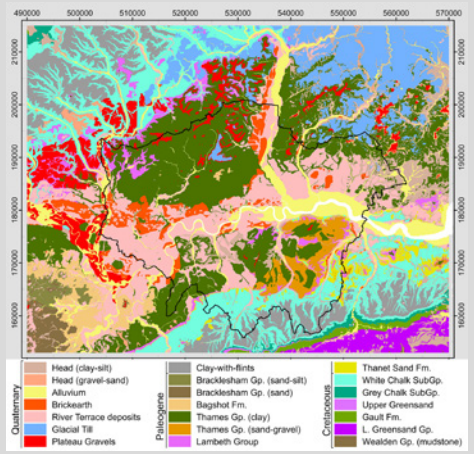
The black outline represents geographical limit of the Greater London Authority (GLA). Areas in white represent tidal waters of the River Thames.

The London Region Atlas (LRA) covers a rectangular area of 80 x 62 km, from British National Grid coordinates: Easting 490 000 to 570 000 and Northing 153 000 to 215 000. The LRA was produced using the London Region Dataset (LRD, n=8400), created from two geochemical surveys (LOND and SEEN) carried out by the Geochemical Baseline Survey of the Environment (G-BASE) project during 2008 and 2009 for LOND, and from 2005 to 2009 for SEEN. The LOND survey is an urban soil geochemical survey based on 6801 sampling sites, 93% of which are located within the GLA, at a sampling density of 1 per 0.25 km^2. SEEN is a south-east England rural soil survey done at a sampling density of 1 per 2 km^2. A total of 1599 of the SEEN samples are included in the LRA area. As these are rural samples, 95% of them are outwith the GLA limit.

Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



Simplified GEOLOGY (adapted from DiGMapGB-50)

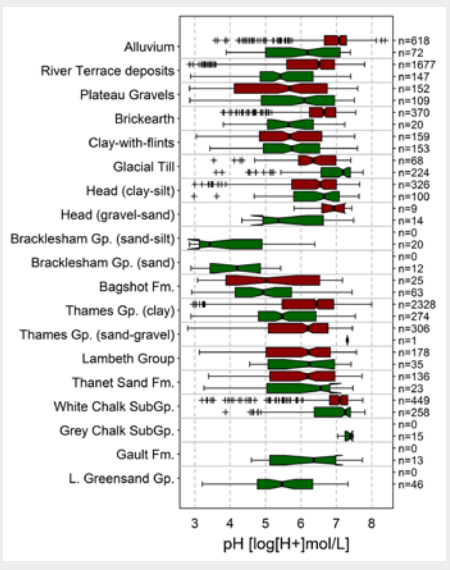


pH [log[H+]mol/L] statistical parameters

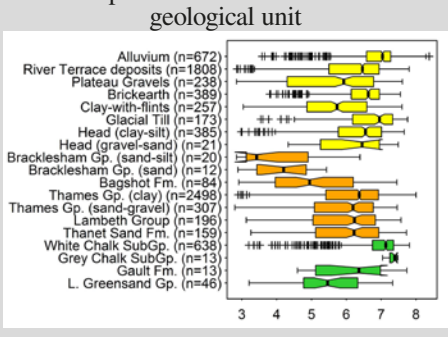
	LRD	SEEN	LOND
N	7929	1128	6801
%<LLD (0.01)	0	0	0
minimum	2.8	2.85	2.8
Q25	5.51	5	5.63
median	**6.53**	**6.17**	**6.57**
Q75	7.03	7.08	7.03
Q95	7.41	7.47	7.39
Q99	7.6	7.58	7.61
maximum	8.38	7.81	8.38
MAD	**0.92**	**1.51**	**0.85**
CVR%	14.1	24.5	12.9
mean	6.2	5.95	6.24
SD	1.07	1.22	1.04
CV%	17.3	20.6	16.6
GM	6.09	5.81	6.14
GSD	1.22	1.26	1.21
powers	0.48	0.44	0.48
skewness	-0.96	-0.53	-1.03

Sample locations

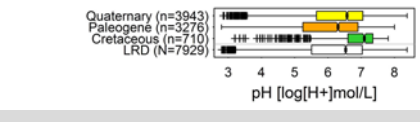
LOND and SEEN topsoil concentrations over each geological unit



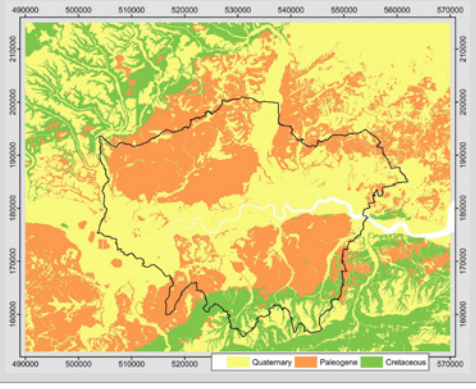
LRD topsoil concentrations over each geological unit



Geology time period:



At each site a composite topsoil (5–20 cm depth) sample comprising five subsamples was collected from the corners and centre of a 20 x 20 m square. After collection samples were air/oven dried and sieved to <2 mm before analysis to determine the total contents of more than 50 chemical elements by X-ray fluorescence spectrometry (XRFS).



Each geochemical map was prepared by interpolating the point data using the parent material mapping method (Appleton et al., 2013[1]). The LRA area was subdivided into 200 x 200 m squares and intercepted with the geology (parent material) polygons, thereby creating the basic 200 m-PM polygons. For each 200 m-PM polygon the average concentration based on the four nearest samples over the same PM was computed (see further explanation in Materials and methods and references therein). As the maps (produced in ArcGIS 10.1) show estimated concentrations, there is a degree of uncertainty due to variability in soil composition. The element concentration colour ramp is based on percentile classes of the LRD dataset distribution. The tables and graphs were generated running R (R x 64 3.1.0) in RStudio (Version 0.98.977). The LRD, LOND and SEEN surveys are represented by the colours black/white, dark green and dark red respectively. Quaternary, Palaeogene and Cretaceous geological time periods are represented by soft yellow, orange and lime green colours respectively. For further information go to Univariate statistics and graphics.

Reference

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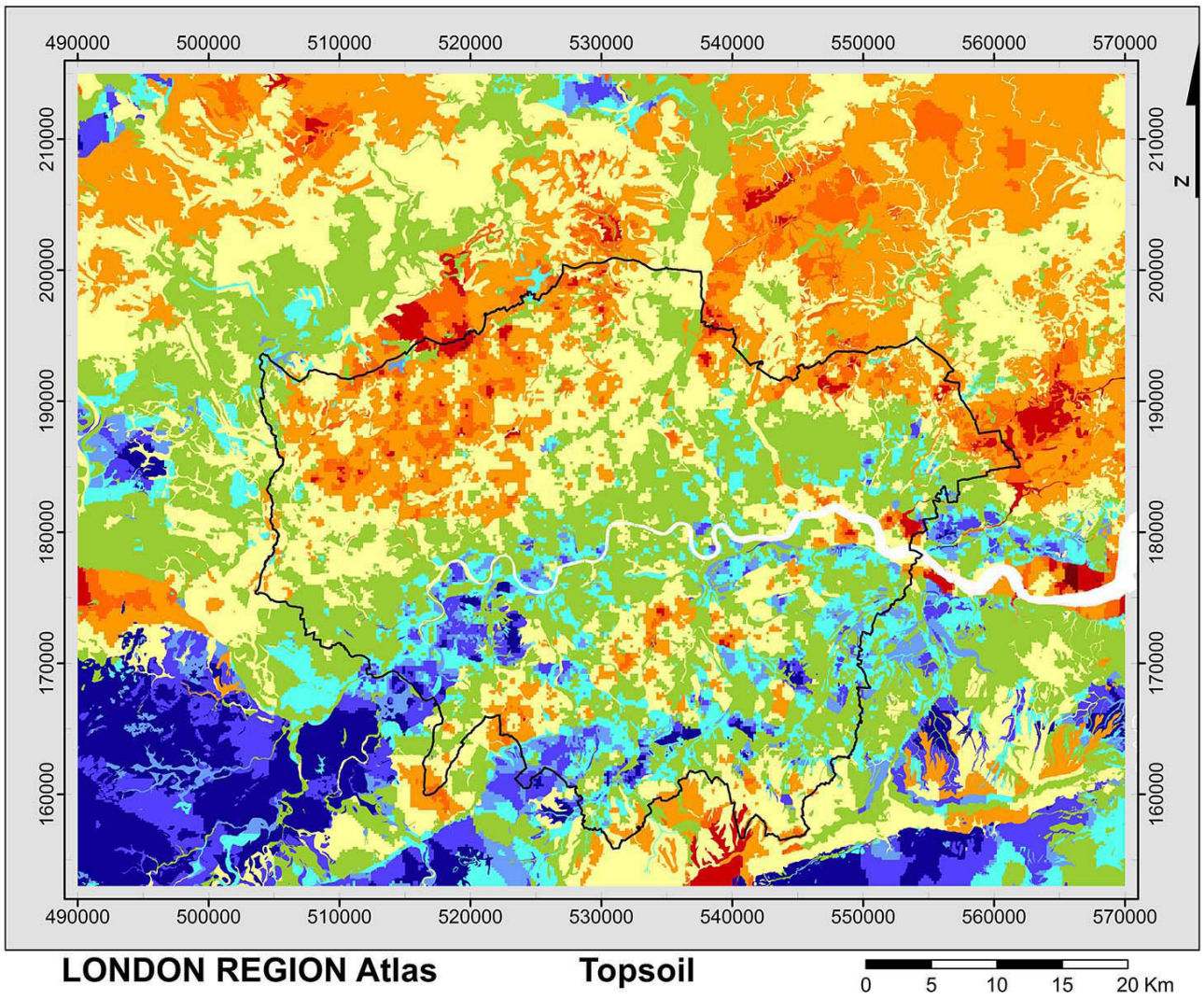
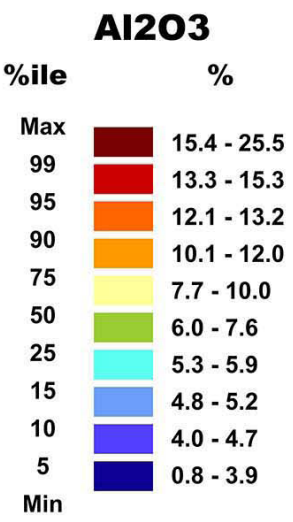
Aluminium: LRA





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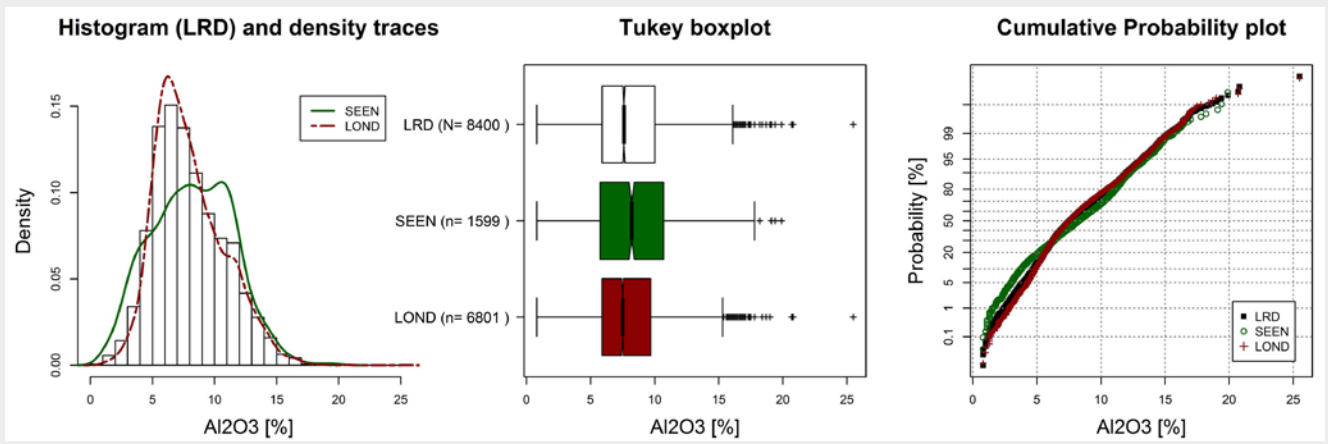
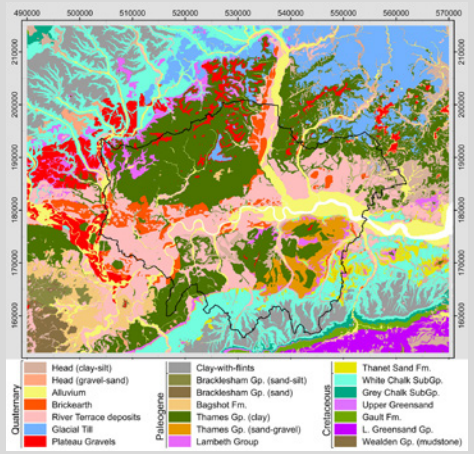
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets

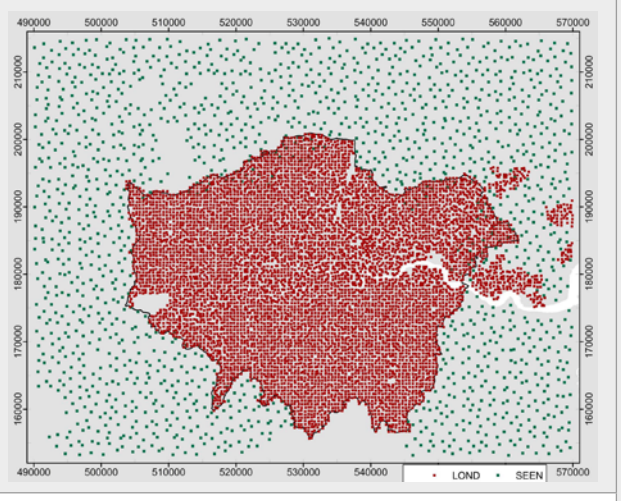


Simplified GEOLOGY (adapted from DiGMapGB-50)

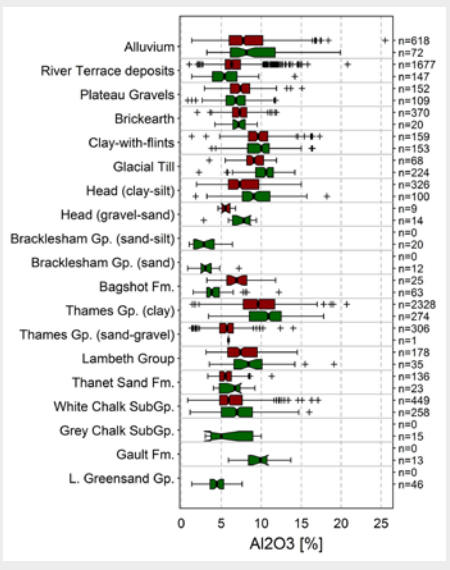


Al2O3 [%]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.2)	0	0	0
minimum	0.8	0.8	0.8
Q25	5.9	5.8	5.9
median	**7.6**	**8.2**	**7.5**
Q75	10	10.7	9.7
Q95	13.2	13.4	13.2
Q99	15.3	15.6	15.2
maximum	25.5	19.9	25.5
MAD	**2.8**	**3.7**	**2.7**
CVR%	37.1	45.2	35.6
mean	8	8.2	8
SD	2.9	3.3	2.8
CV%	35.9	39.7	34.9
GM	7.5	7.4	7.5
GSD	1.47	1.62	1.43
powers	1.5	1.4	1.5
skewness	0.52	0.09	0.66

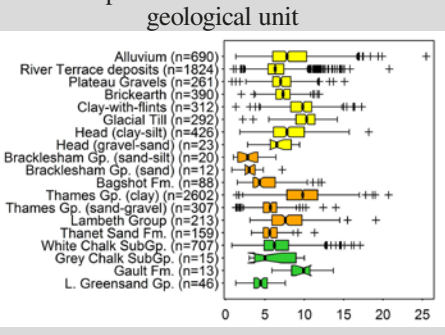
Sample locations



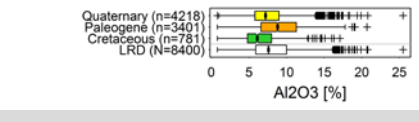
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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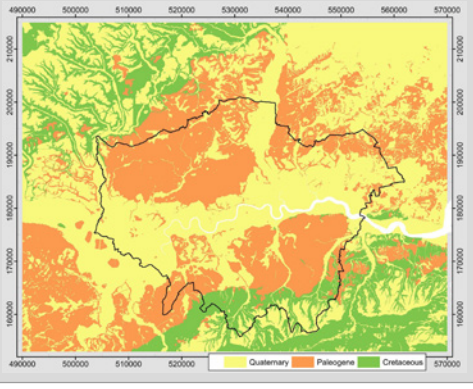

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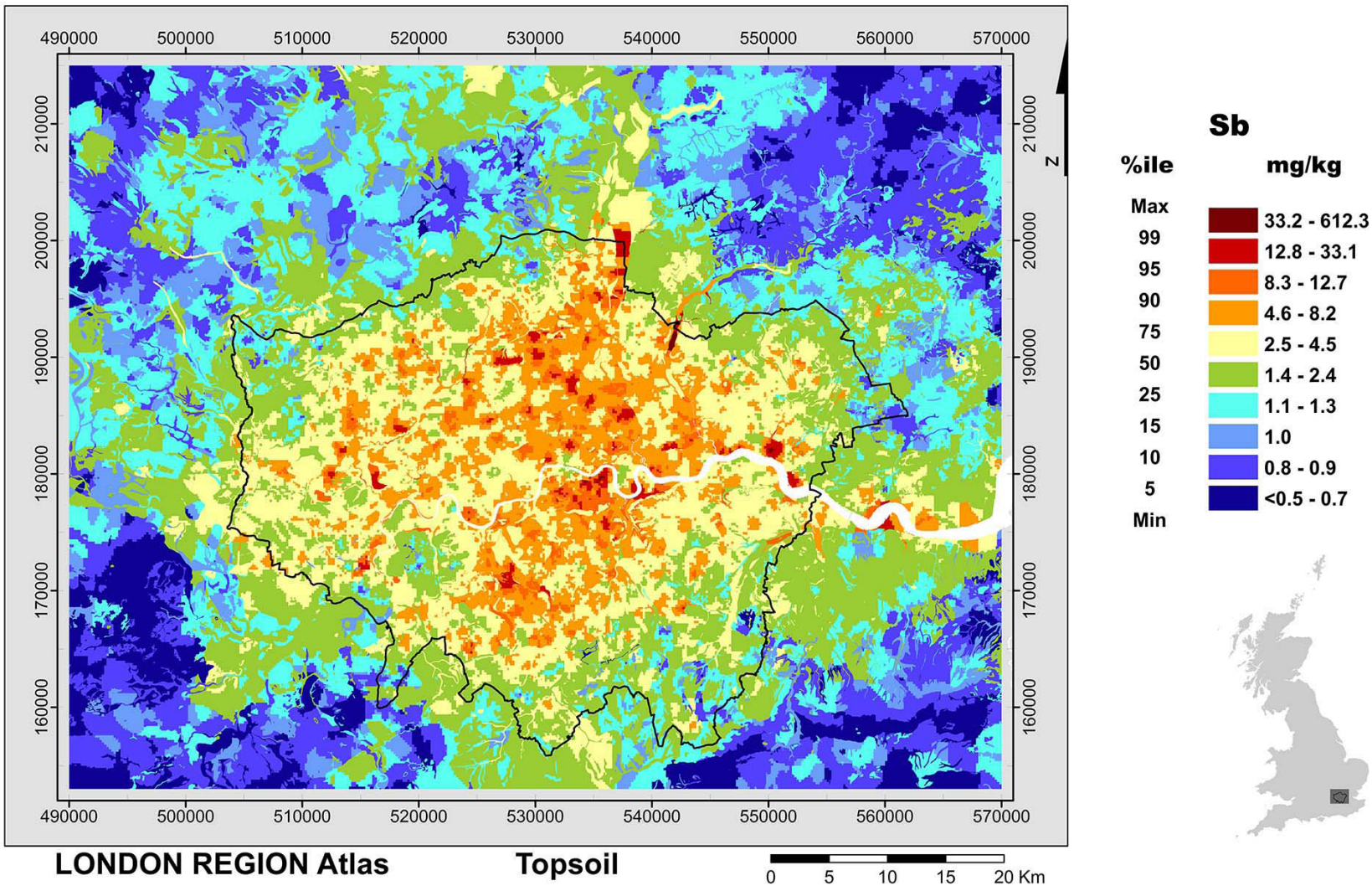
Antimony: LRA



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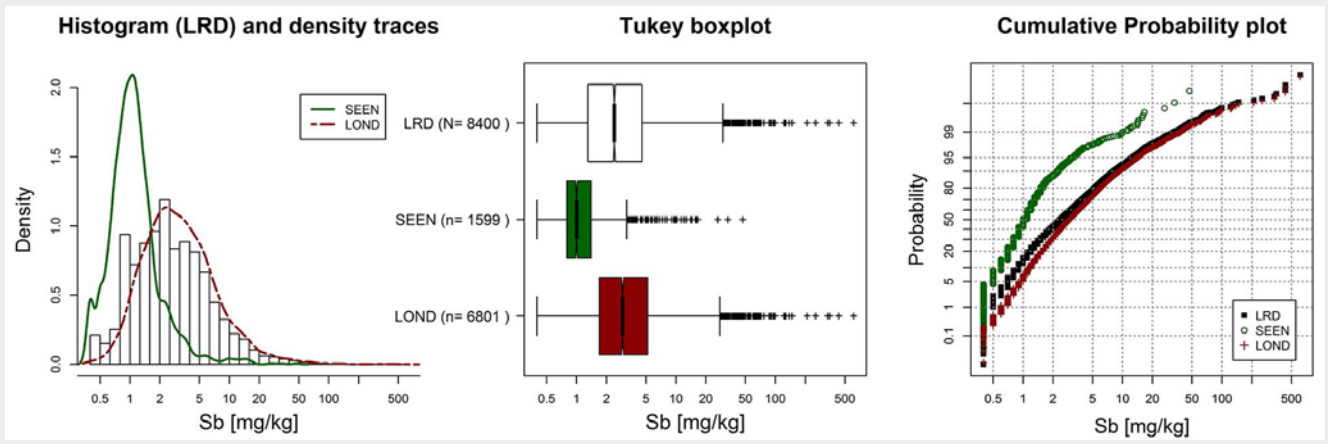
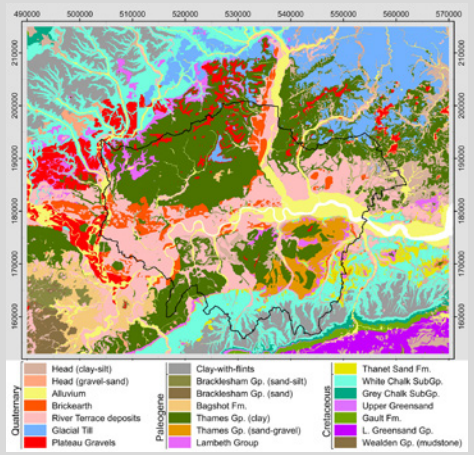
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



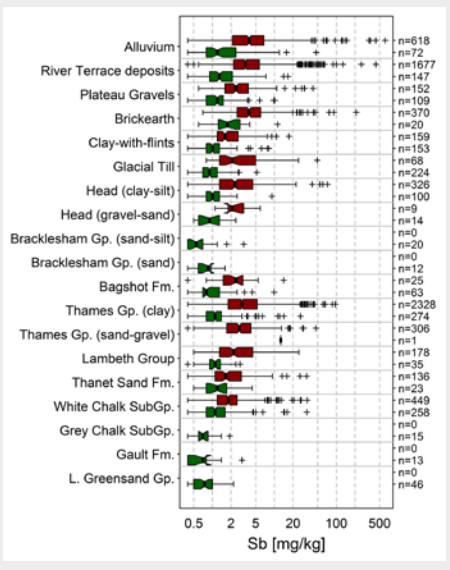
Simplified GEOLOGY (adapted from DiGMapGB-50)



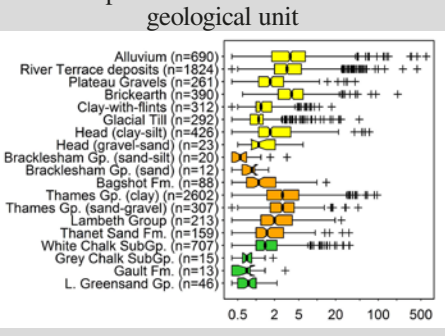
Sb [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.5)	1	4.25	0.24
minimum	<0.5	<0.5	<0.5
Q25	1.3	0.8	1.7
median	**2.4**	**1**	**2.9**
Q75	4.5	1.4	5.2
Q95	12.7	3.1	14.2
Q99	33.1	9.9	38.2
maximum	612.3	47.1	612.3
MAD	**1.9**	**0.4**	**2.1**
CVR%	80.3	44.5	71.6
mean	4.5	1.4	5.2
SD	13.2	2.1	14.6
CV%	294.8	148.4	279.9
GM	2.6	1.1	3.2
GSD	2.48	1.81	2.34
powers	3.18	2.07	3.18
skewness	26.03	11.38	23.9

Sample locations

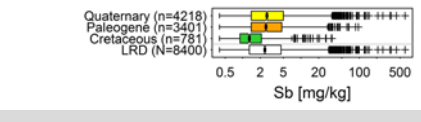
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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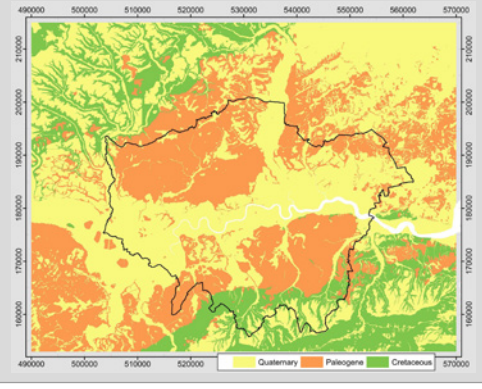

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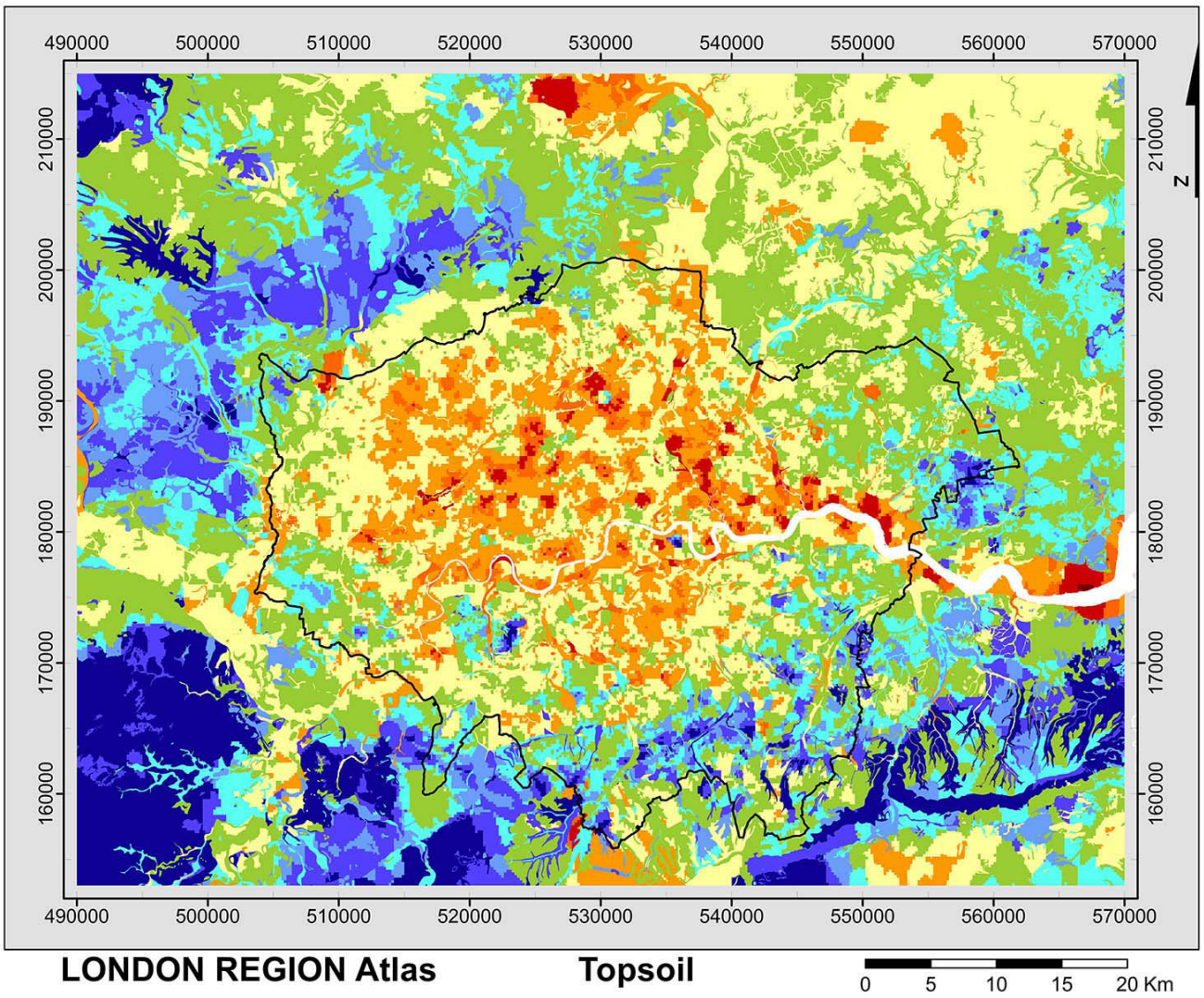
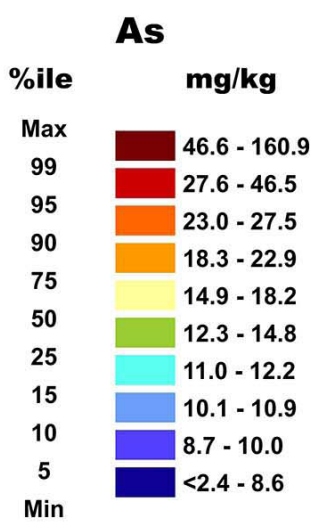
Arsenic: LRA





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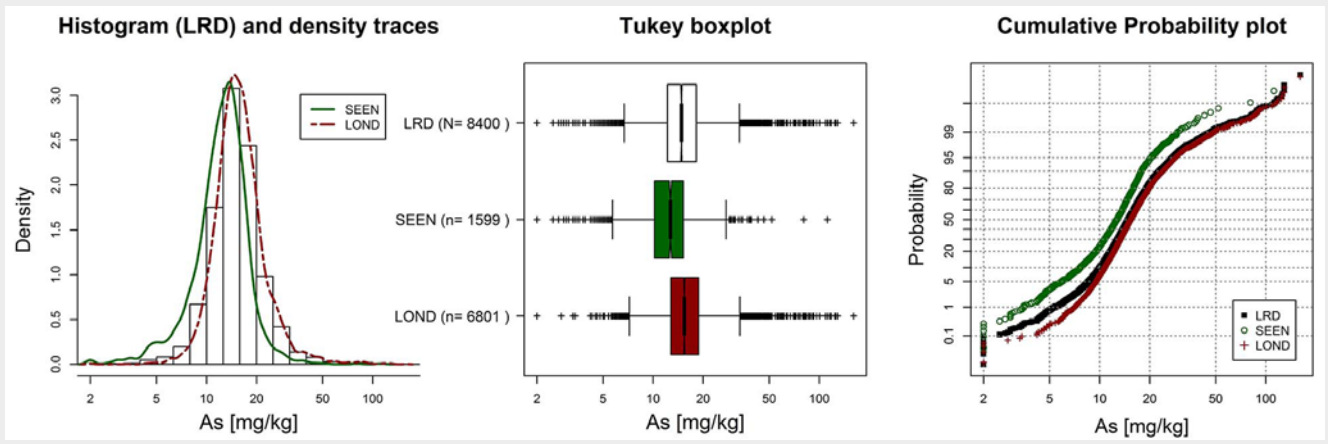
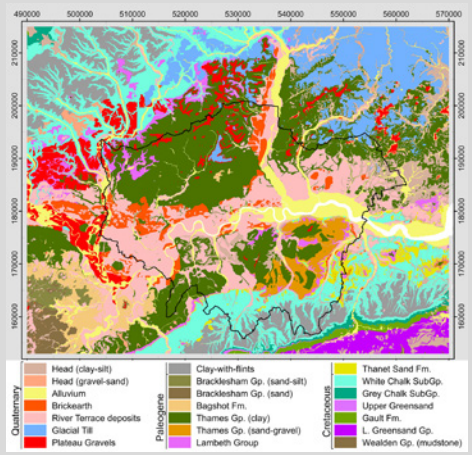
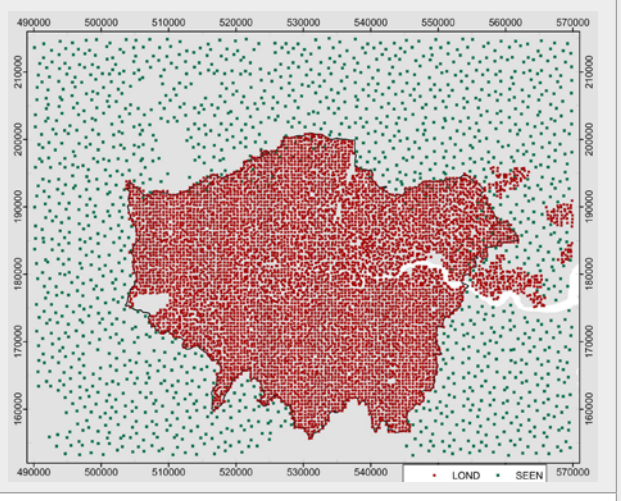


As [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (2.4)	0.11	0.31	0.06
minimum	<2.4	<2.4	<2.4
Q25	12.2	10.2	12.8
median	**14.8**	**12.7**	**15.4**
Q75	18.2	15.2	18.8
Q95	27.5	20.4	28.5
Q99	46.5	29.3	48.8
maximum	160.9	111.8	160.9
MAD	**4.3**	**3.7**	**4.3**
CVR%	29.1	29.2	27.9
mean	16.3	13.1	17
SD	8.2	5.6	8.6
CV%	50.7	43.1	50.4
GM	15	12.1	15.8
GSD	1.46	1.48	1.43
powers	1.91	1.75	1.91
skewness	5.42	5.35	5.46

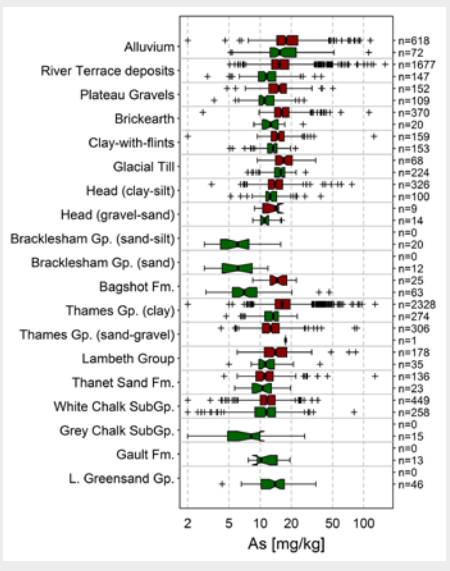
Simplified GEOLOGY (adapted from DiGMapGB-50)



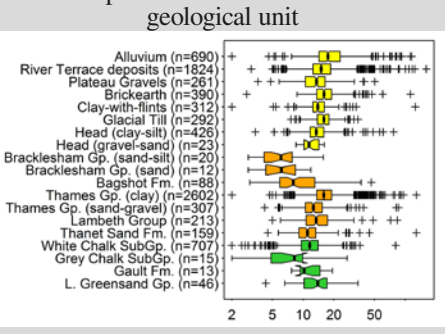
Sample locations



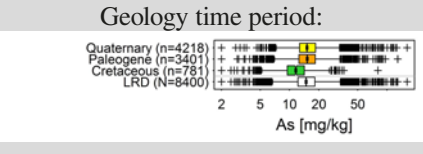
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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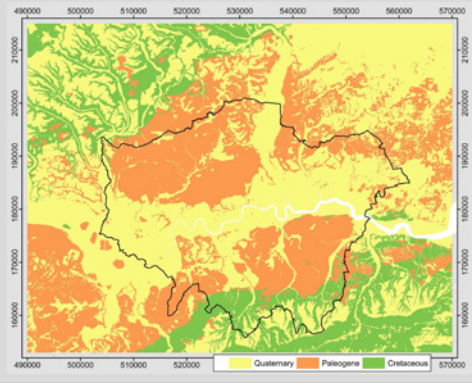

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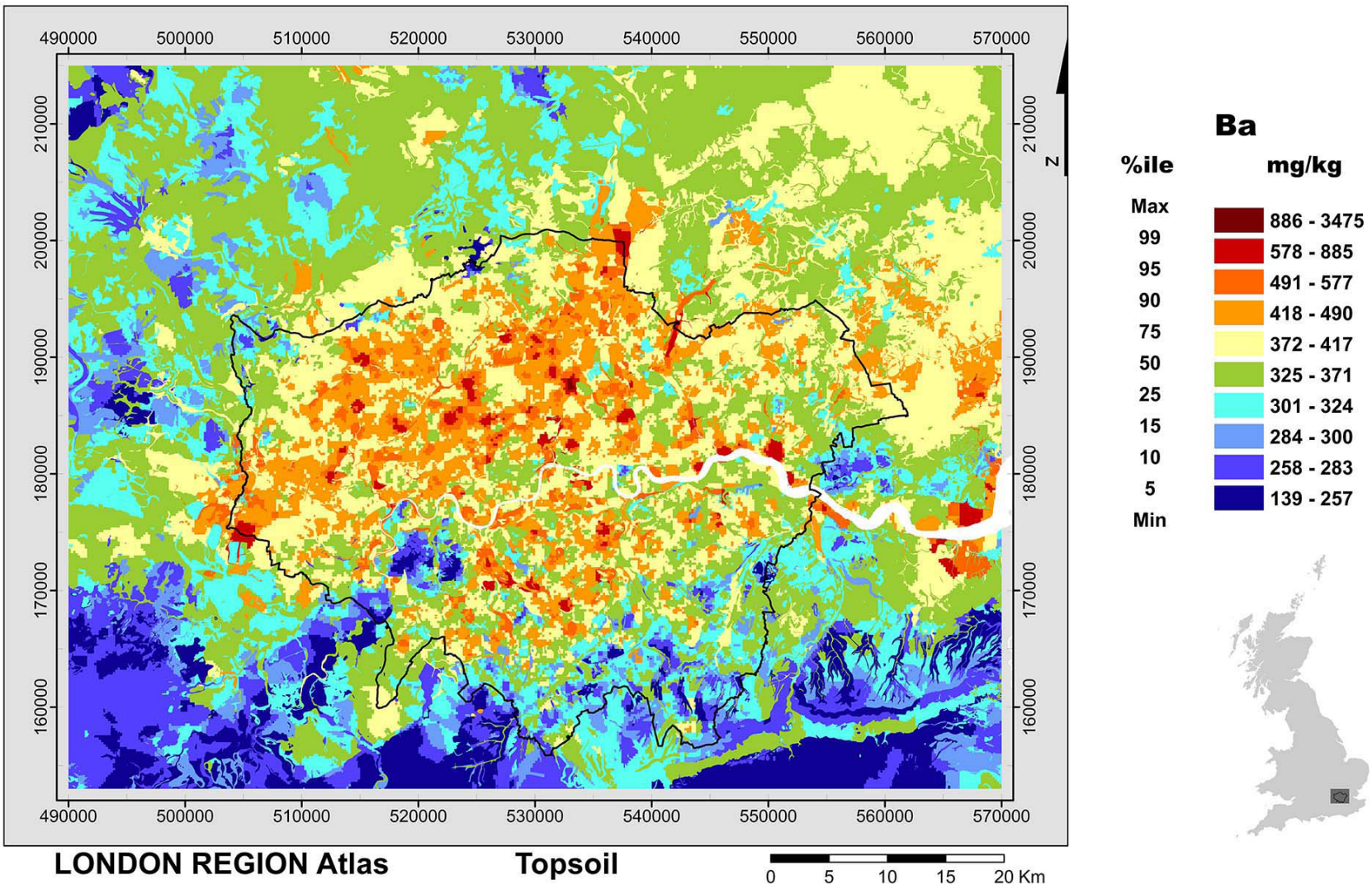
Barium: LRA



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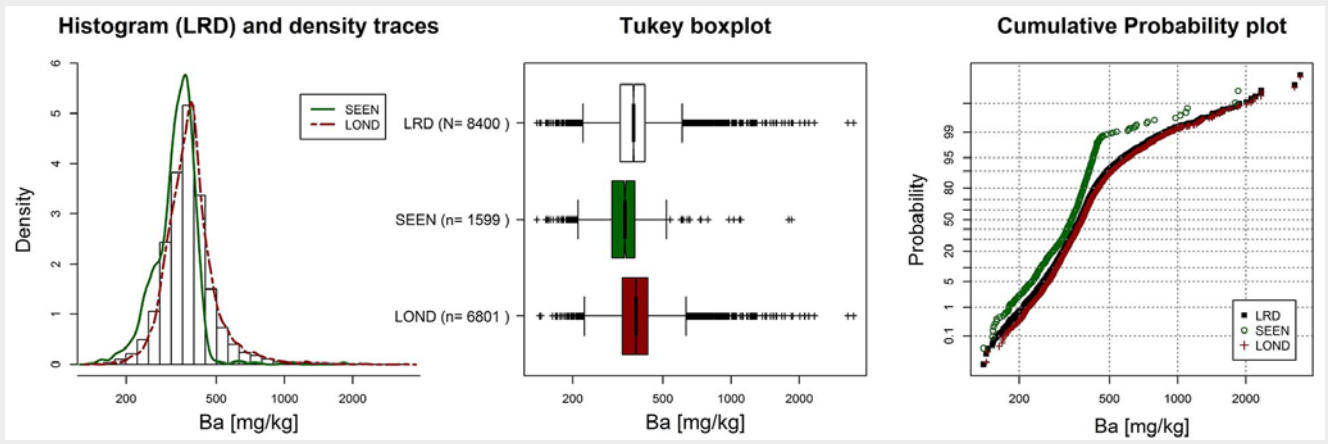
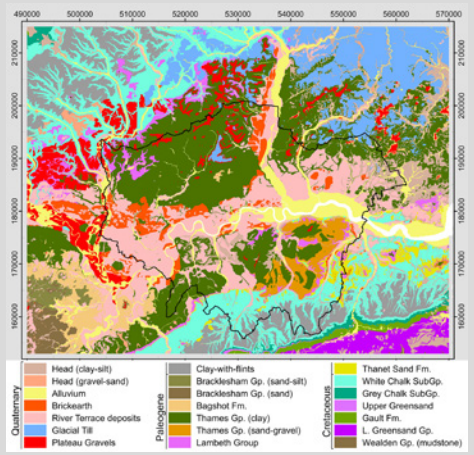
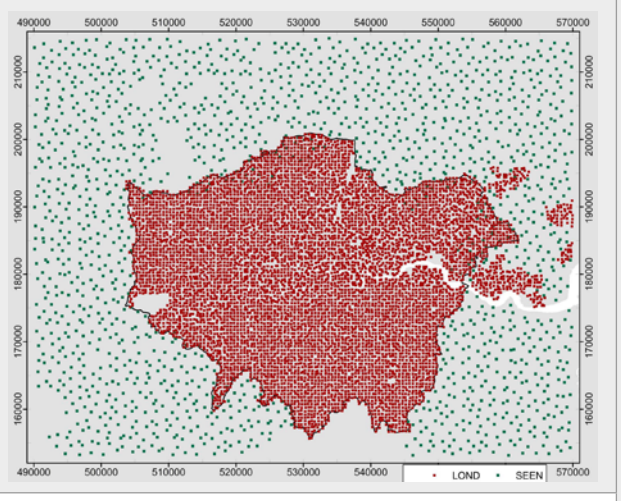


Ba [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1)	0	0	0
minimum	139	139	143
Q25	324	298	331
median	**371**	**340**	**380**
Q75	417	376	429
Q95	577	422	602
Q99	885	518	920
maximum	3475	1850	3475
MAD	**70**	**58**	**73**
CVR%	18.8	17	19.1
mean	389	339	401
SD	140	91	147
CV%	36	26.7	36.6
GM	374	330	386
GSD	1.3	1.24	1.3
powers	1.4	1.12	1.39
skewness	6.48	6.86	6.42

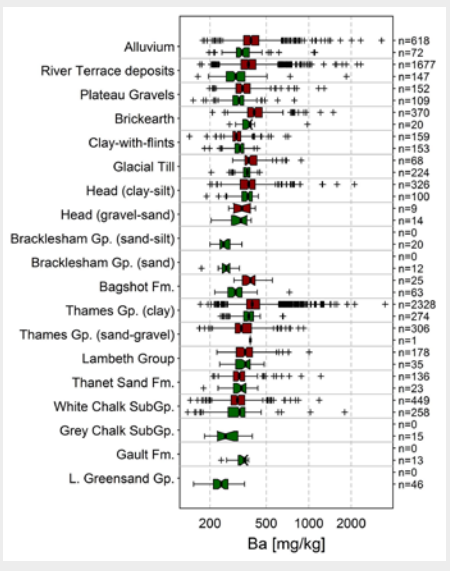
Simplified GEOLOGY (adapted from DiGMapGB-50)



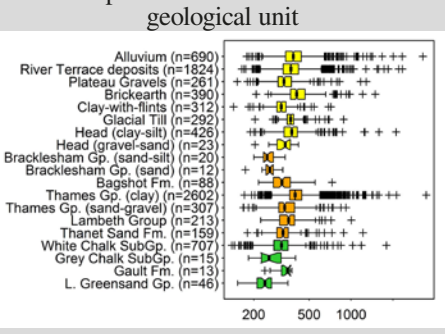
Sample locations



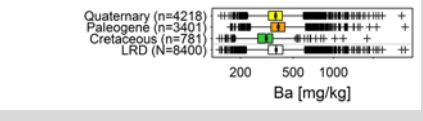
LOND and SEEN topsoil concentrations over each geological unit



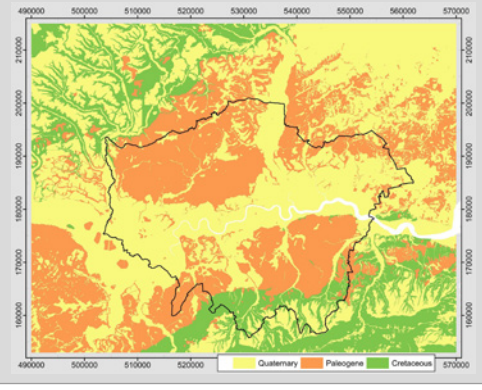
LRD topsoil concentrations over each geological unit



Geology time period:



At each site a composite topsoil (5–20 cm depth) sample comprising five subsamples was collected from the corners and centre of a 20 x 20 m square. After collection samples were air/oven dried and sieved to <2 mm before analysis to determine the total contents of more than 50 chemical elements by X-ray fluorescence spectrometry (XRFS).



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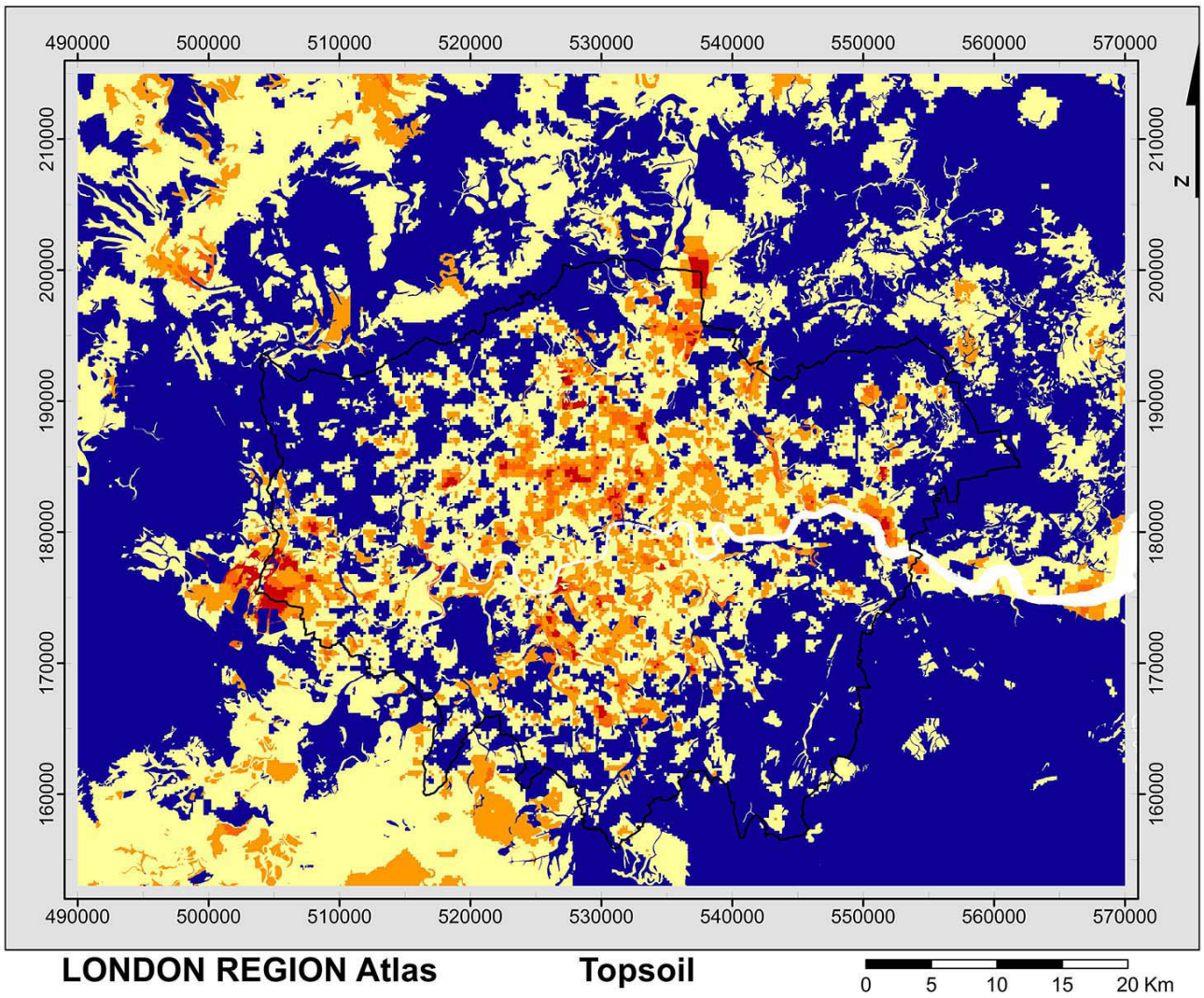
Bismuth: LRA



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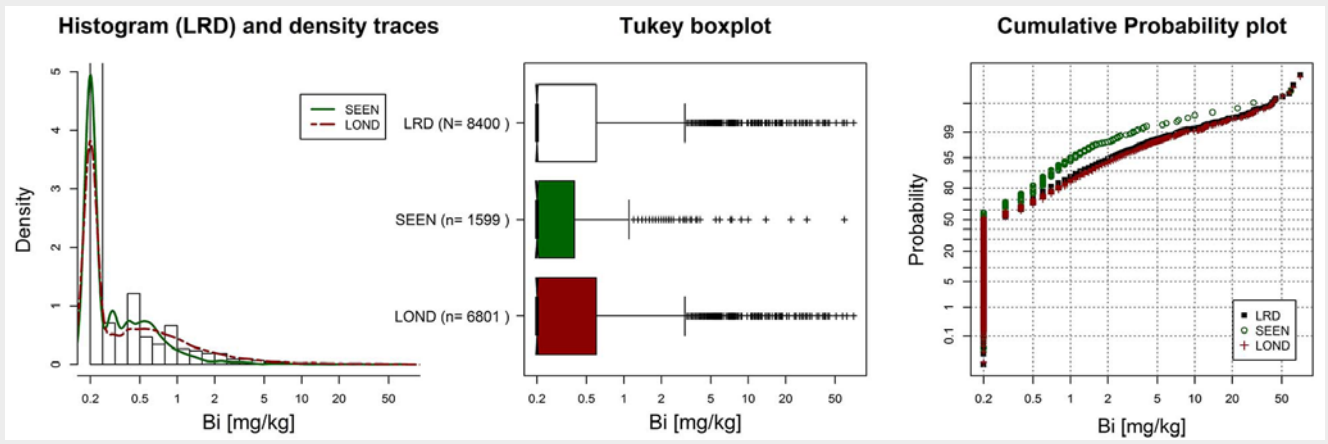
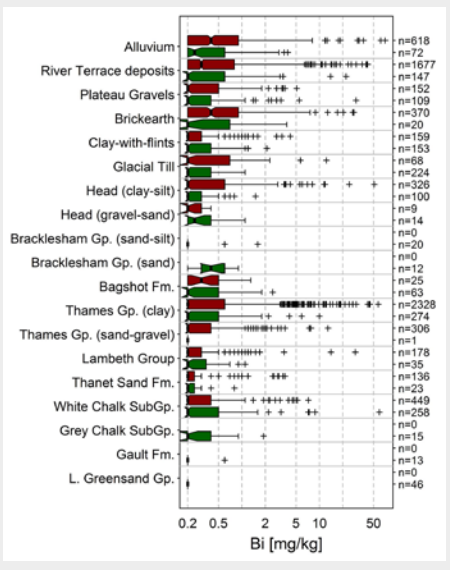
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



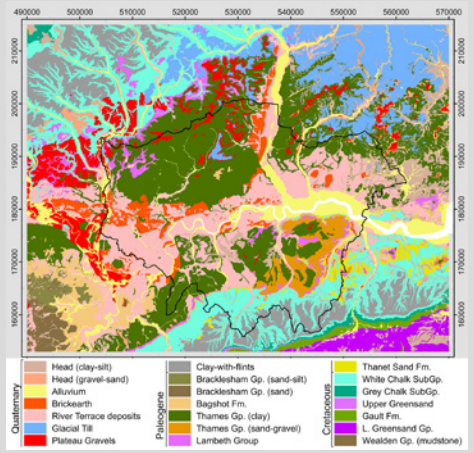
Bi [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.3)	53.45	57.41	52.52
minimum	<0.3	<0.3	<0.3
Q25	<0.3	<0.3	<0.3
median	**<0.3**	**<0.3**	**<0.3**
Q75	0.6	0.4	0.6
Q95	2.2	1	2.4
Q99	7.5	3.2	8.1
maximum	70.5	59.3	70.5
MAD	**0**	**0**	**0**
CVR%	0	0	0
mean	0.8	0.5	0.8
SD	2.5	1.9	2.7
CV%	338.5	381.4	328.9
GM	0.4	0.3	0.4
GSD	2.42	1.94	2.51
powers	2.55	2.47	2.55
skewness	14.42	23.7	13.4

Sample locations

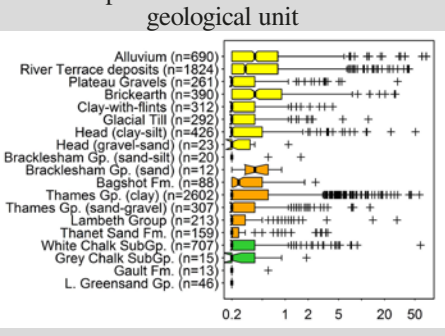
LOND and SEEN topsoil concentrations over each geological unit



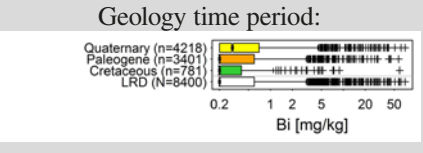
Simplified GEOLOGY (adapted from DiGMapGB-50)



LRD topsoil concentrations over each geological unit



Geology time period:



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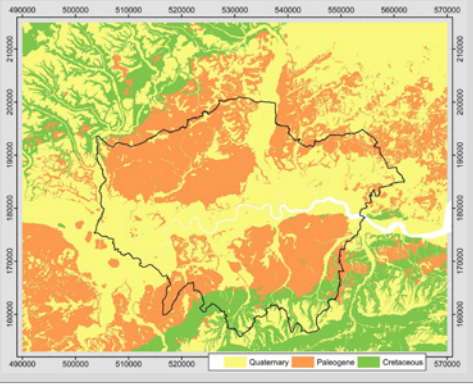

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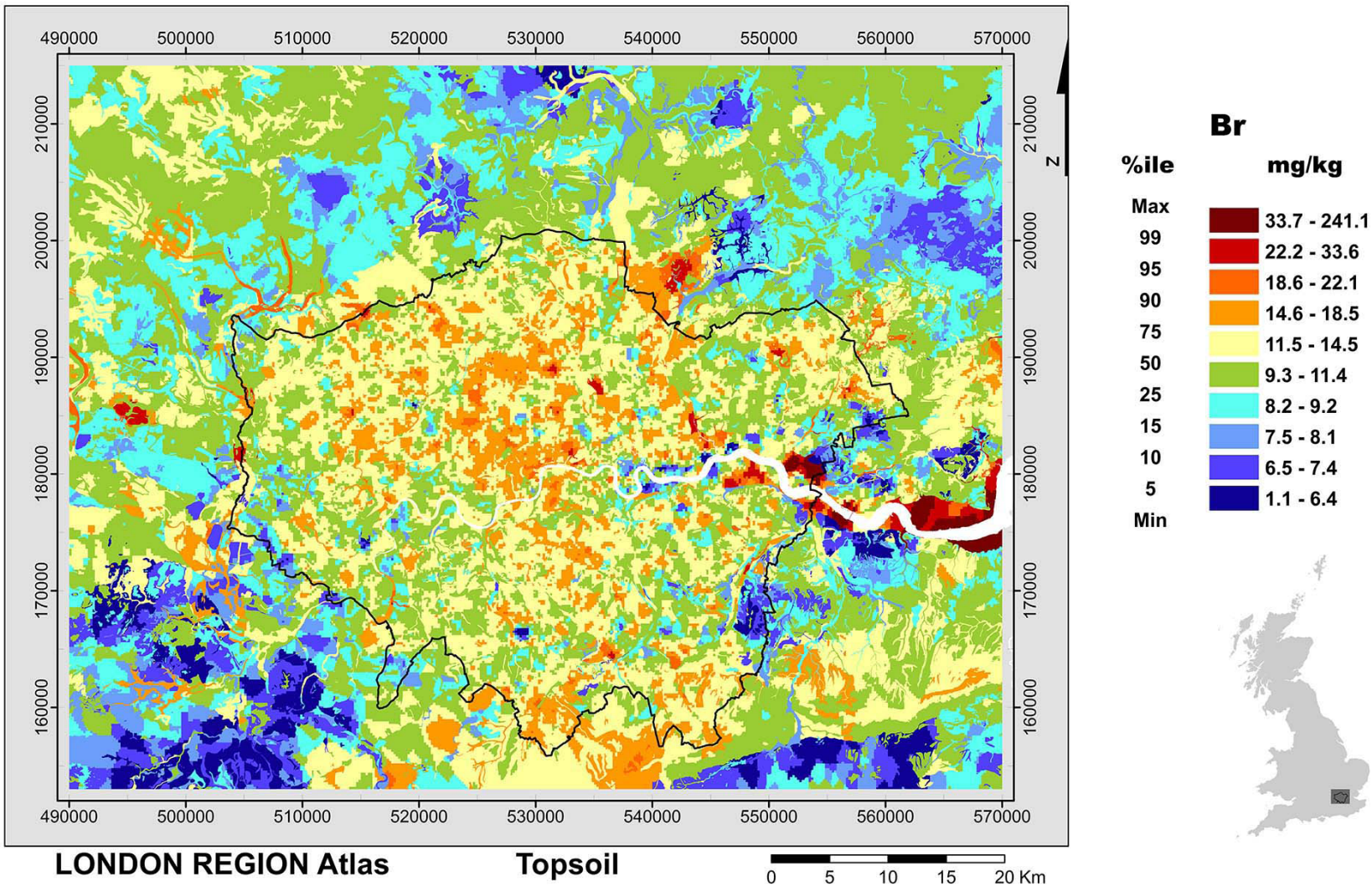
Bromine: LRA



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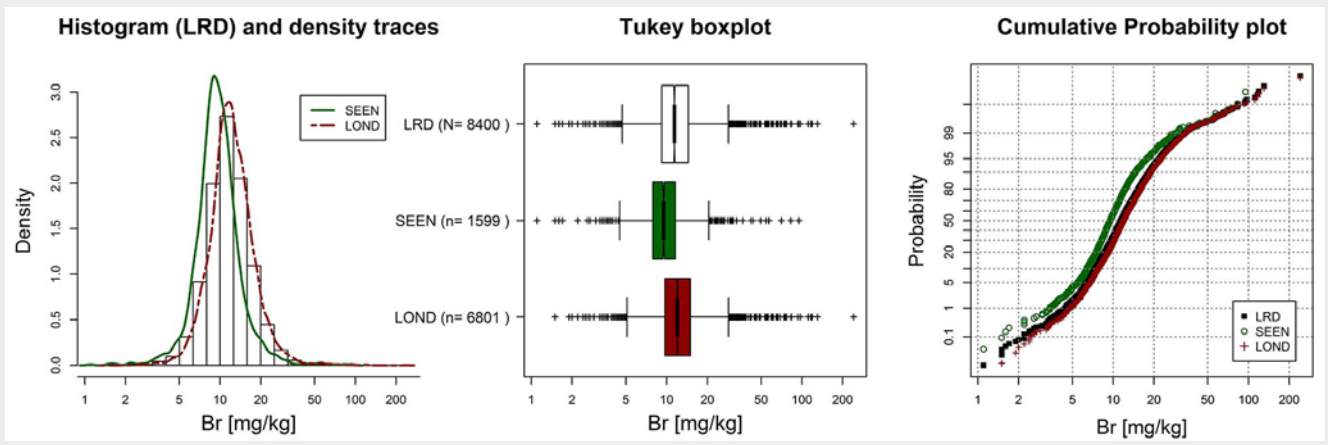
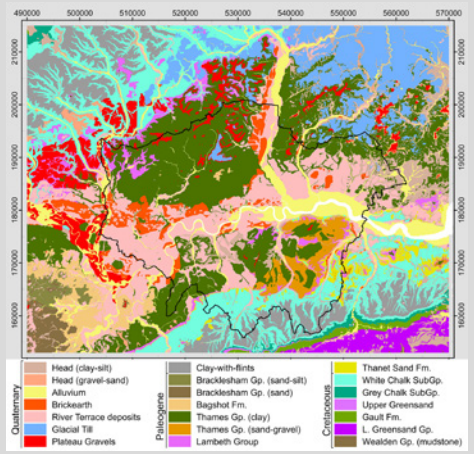
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets

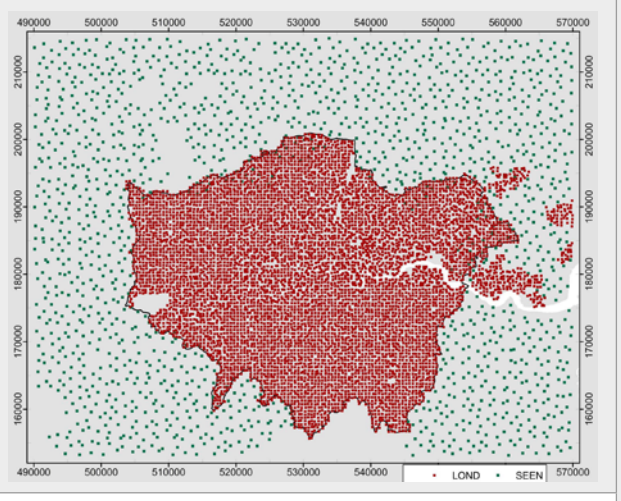


Br [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.8)	0	0	0
minimum	1.1	1.1	1.5
Q25	9.2	7.9	9.7
median	**11.4**	**9.5**	**12**
Q75	14.5	11.6	15
Q95	22.1	17.7	22.5
Q99	33.6	28.2	34.1
maximum	241.1	94.8	241.1
MAD	**3.9**	**2.7**	**3.9**
CVR%	33.8	28.1	32.1
mean	12.7	10.4	13.2
SD	6.9	5.6	7.1
CV%	54.5	53.5	53.7
GM	11.6	9.6	12.1
GSD	1.48	1.47	1.47
powers	2.34	1.94	2.21
skewness	8.75	6.34	9.22

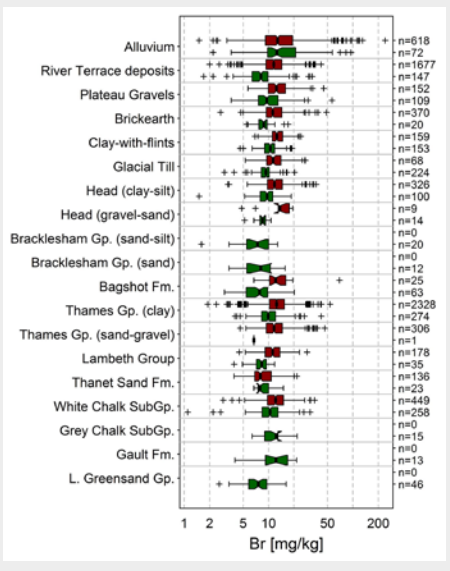
Simplified GEOLOGY (adapted from DiGMapGB-50)



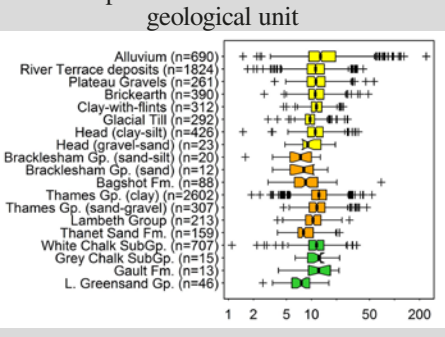
Sample locations



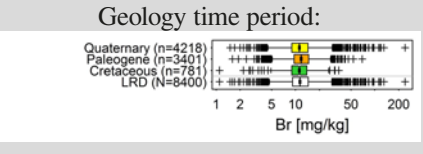
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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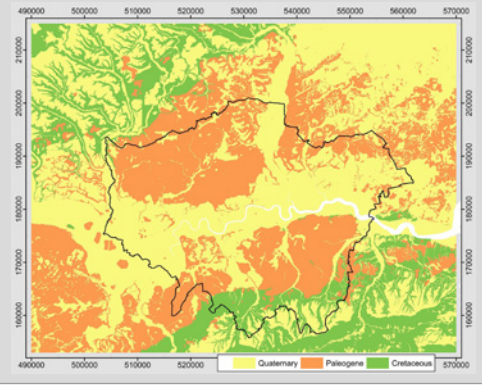

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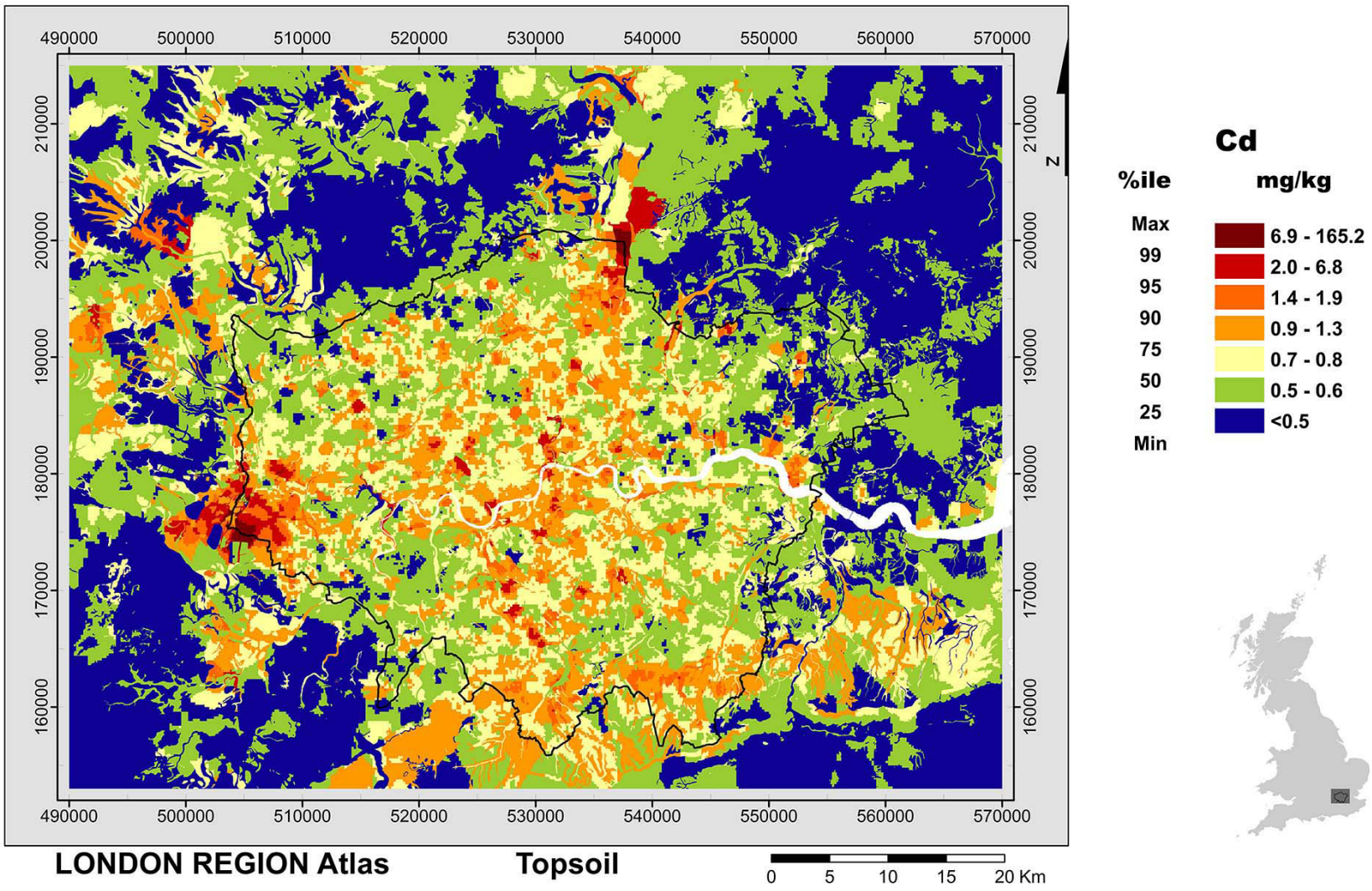
Cadmium: LRA



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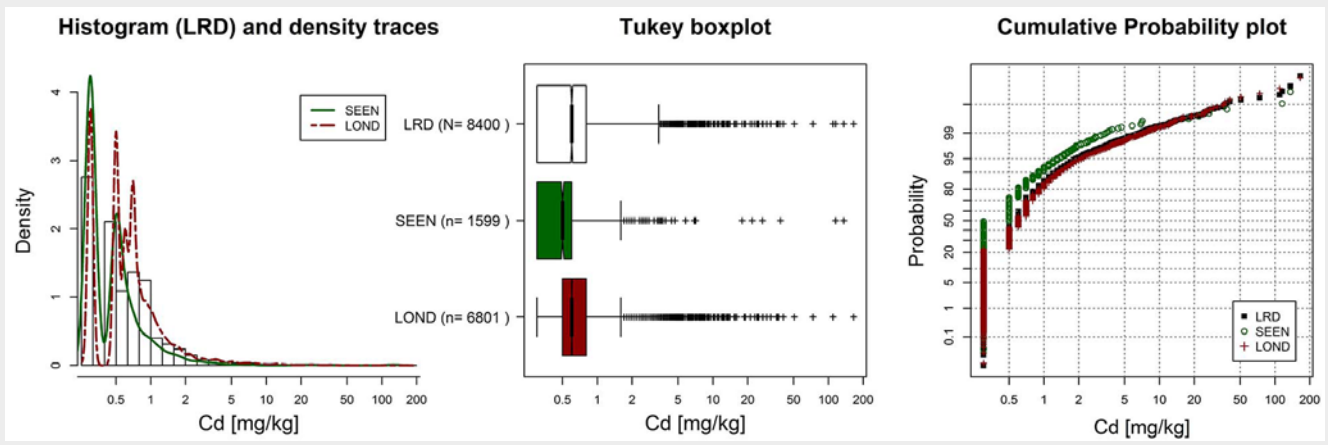
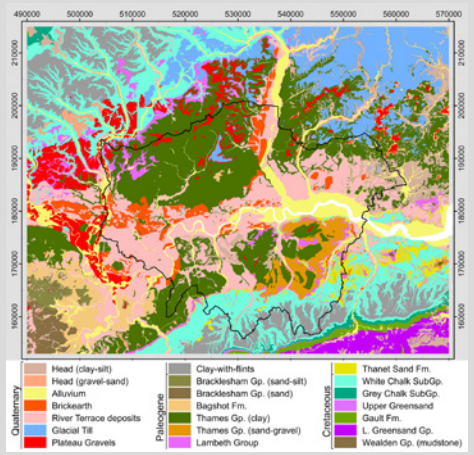
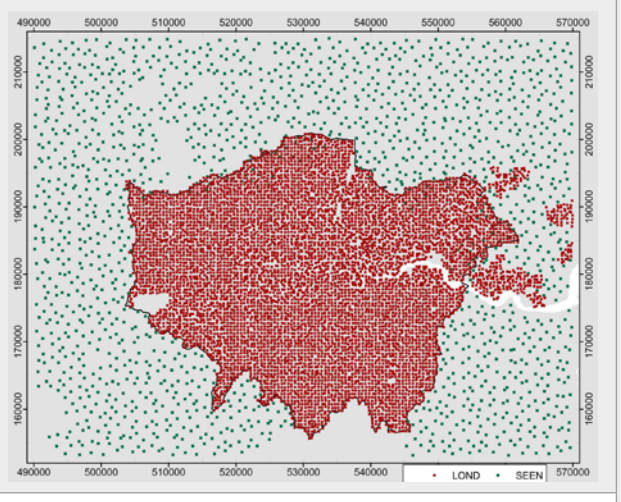


Cd [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.5)	27.58	49.22	22.5
minimum	<0.5	<0.5	<0.5
Q25	<0.5	<0.5	0.5
median	**0.6**	**0.5**	**0.6**
Q75	0.8	0.6	0.8
Q95	1.9	1.3	2.1
Q99	6.8	3.4	7.3
maximum	165.2	135.8	165.2
MAD	**0.3**	**0.3**	**0.3**
CVR%	49.4	59.3	49.4
mean	0.9	0.8	1
SD	3.5	4.7	3.1
CV%	375.2	605.7	325.4
GM	0.6	0.5	0.6
GSD	1.95	1.81	1.95
powers	2.74	2.66	2.74
skewness	30.06	25.03	31.42

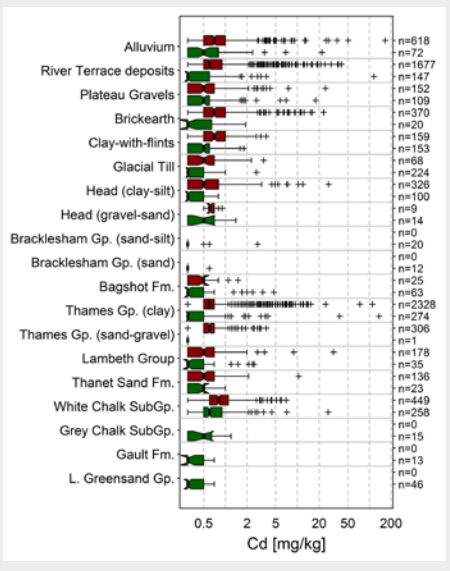
Simplified GEOLOGY (adapted from DiGMapGB-50)



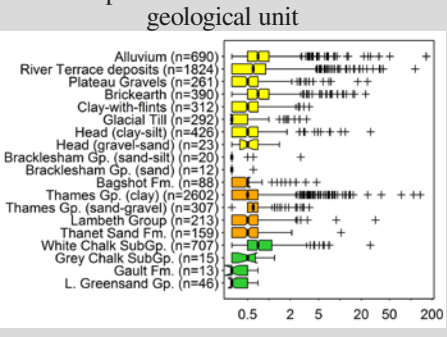
Sample locations



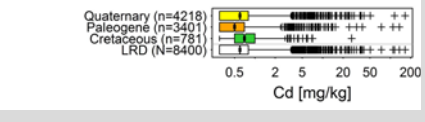
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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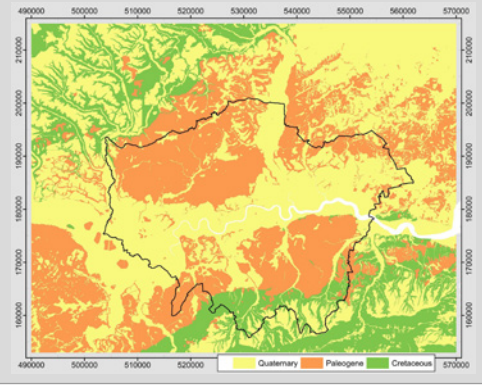

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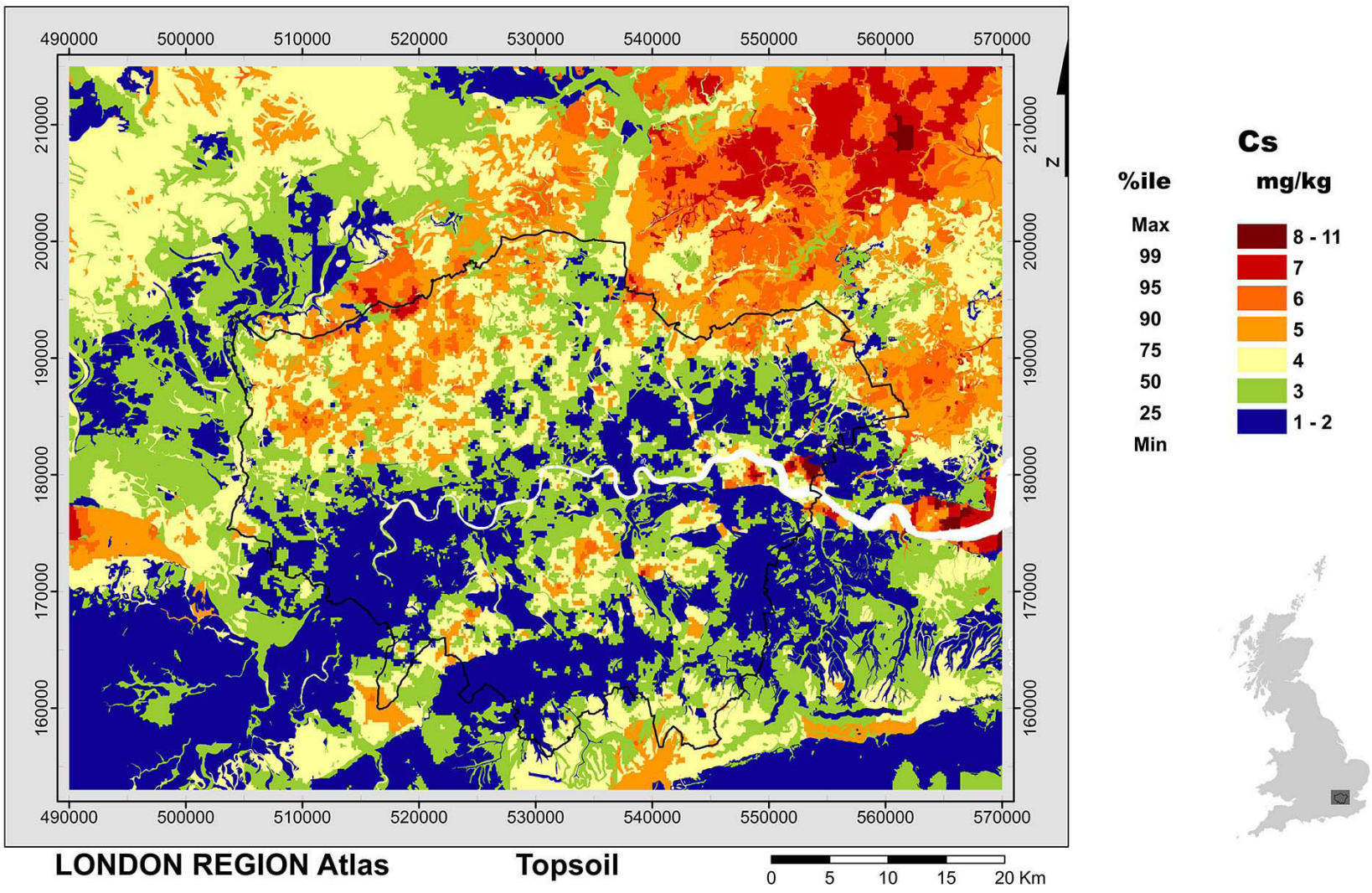
Caesium: LRA



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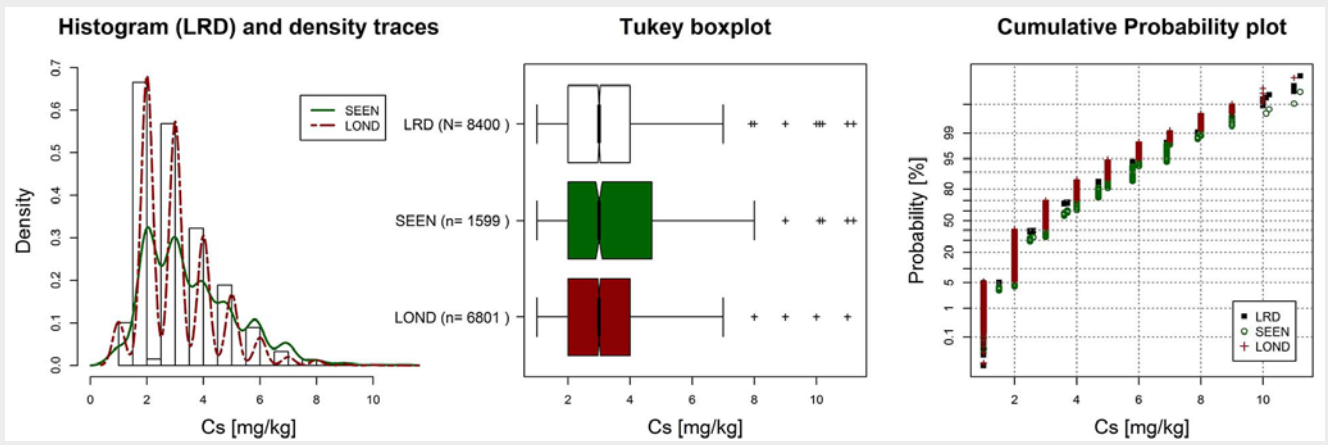
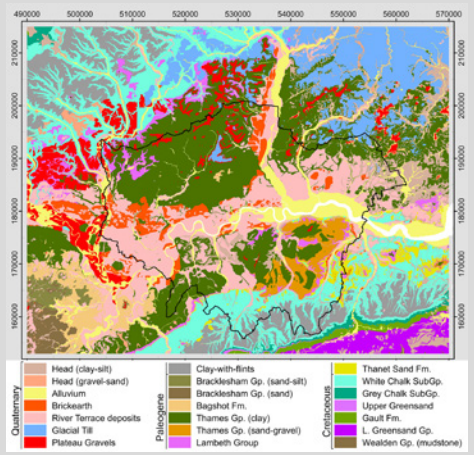


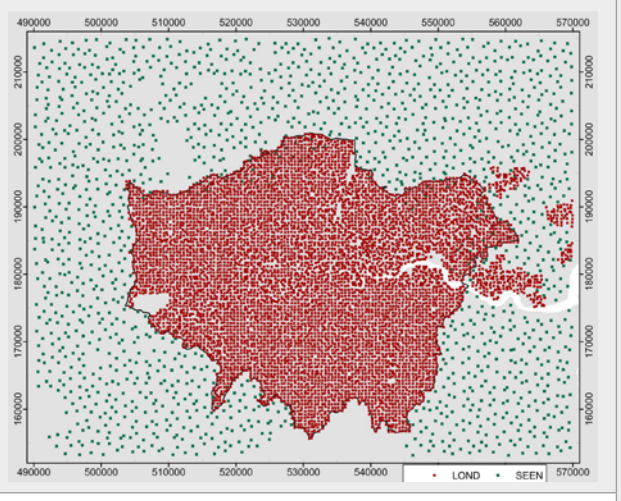
Cs [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1)	0	0	0
minimum	1	1	1
Q25	2	2	2
median	**3**	**3**	**3**
Q75	4	4.7	4
Q95	6	6.9	6
Q99	7	8	7
maximum	11.2	11.2	11
MAD	**1.5**	**1.5**	**1.5**
CVR%	49.4	49.4	49.4
mean	3.2	3.5	3.1
SD	1.4	1.6	1.3
CV%	44.5	45	43.6
GM	2.9	3.2	2.8
GSD	1.55	1.58	1.54
powers	1.05	1.05	1.04
skewness	1.12	0.92	1.13

At each site a composite topsoil (5–20 cm depth) sample comprising five subsamples was collected from the corners and centre of a 20 x 20 m square. After collection samples were air/oven dried and sieved to <2 mm before analysis to determine the total contents of more than 50 chemical elements by X-ray fluorescence spectrometry (XRFS).

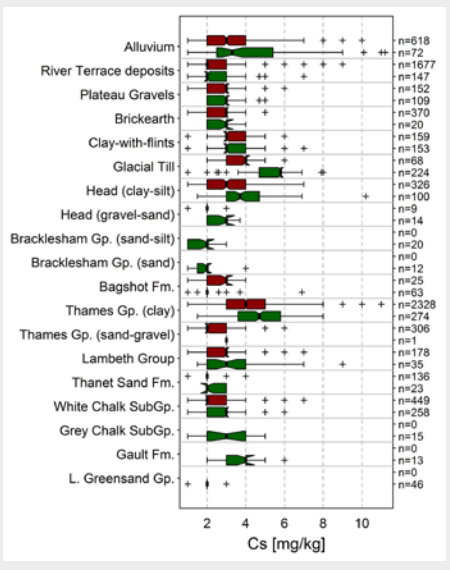
Simplified GEOLOGY (adapted from DiGMapGB-50)



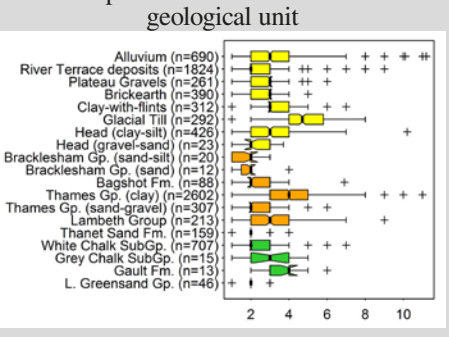
Sample locations



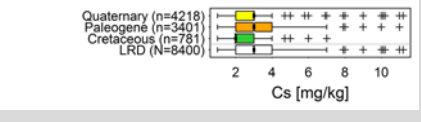
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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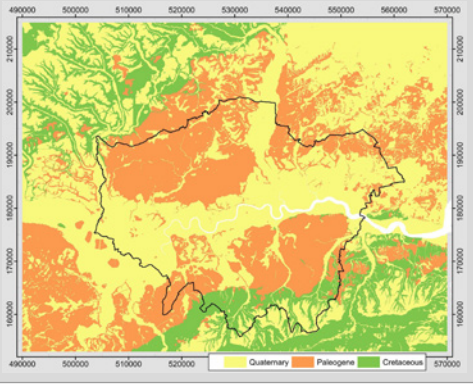

Reference

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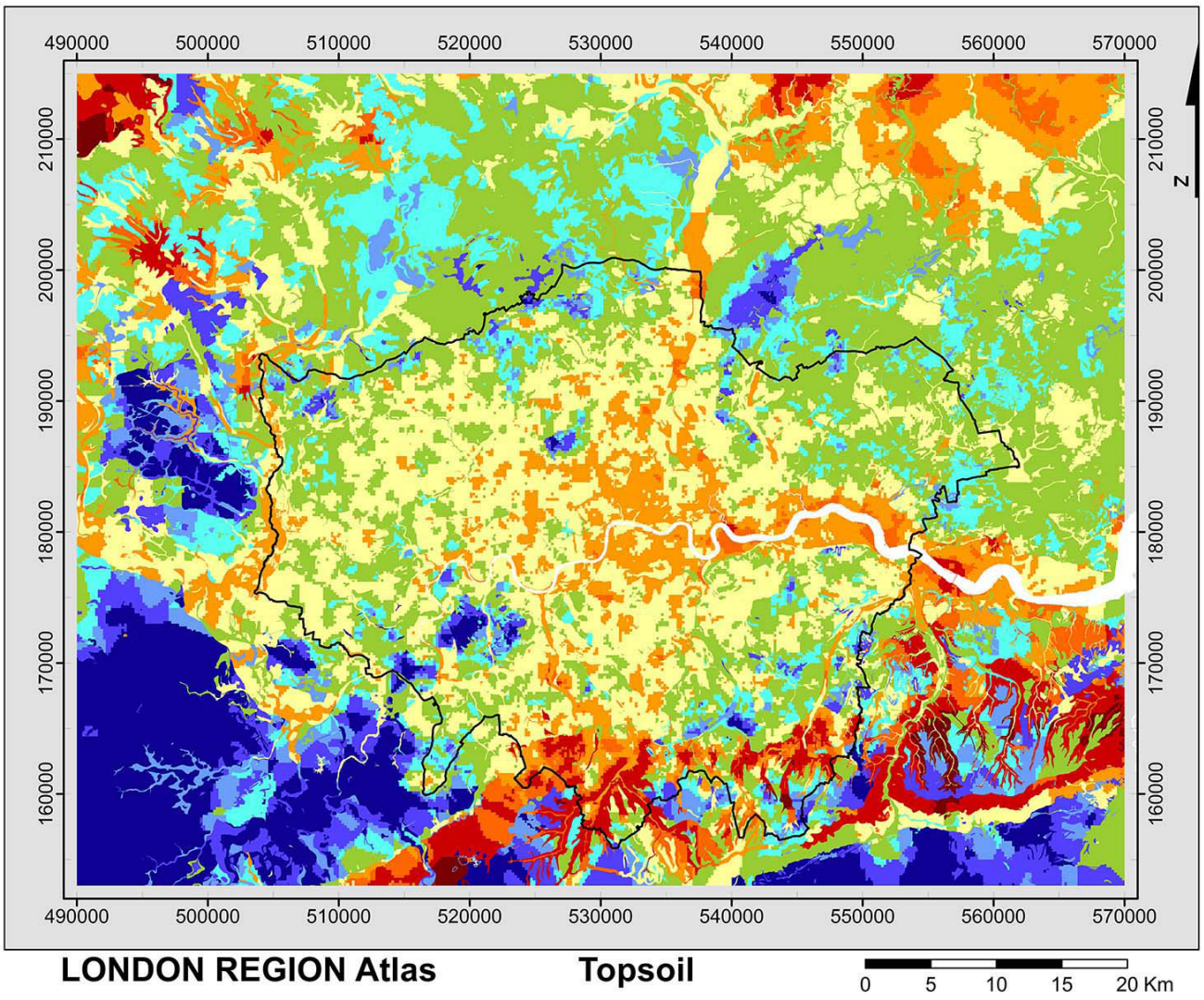
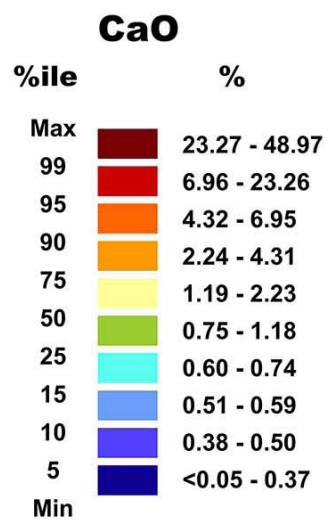
Calcium: LRA





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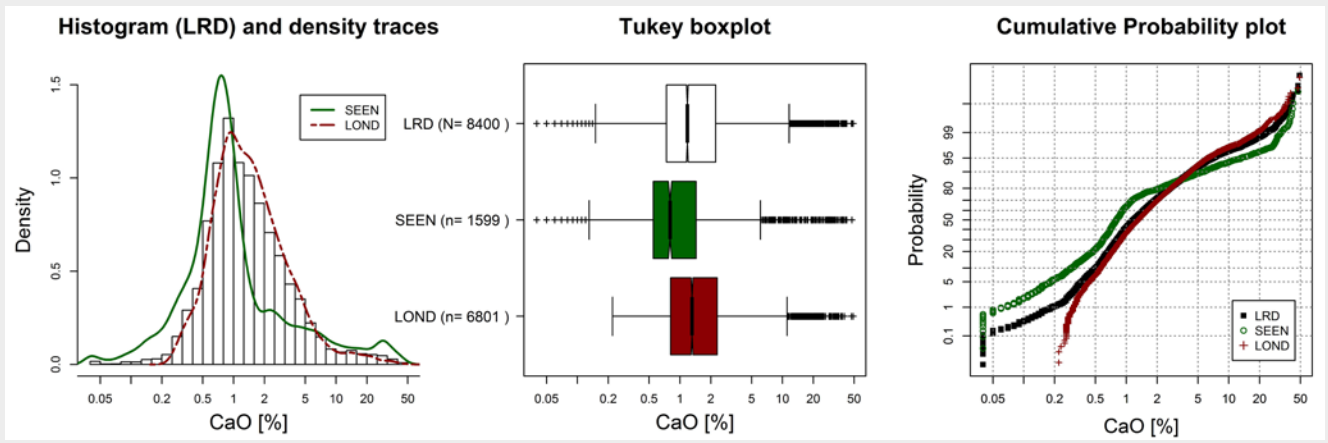
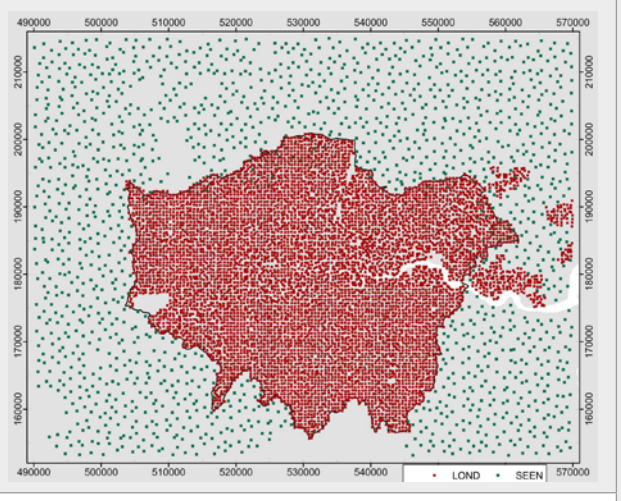
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



CaO [%]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.05)	0.12	0.63	0
minimum	<0.05	<0.05	0.22
Q25	0.74	0.55	0.81
median	**1.18**	**0.8**	**1.31**
Q75	2.23	1.44	2.31
Q95	6.95	13.14	6.15
Q99	23.26	32.49	18.54
maximum	48.97	47.47	48.97
MAD	**0.85**	**0.49**	**0.9**
CVR%	71.6	61.2	69
mean	2.3	2.64	2.22
SD	3.97	5.98	3.33
CV%	172.7	226	149.9
GM	1.34	0.99	1.44
GSD	2.51	3.33	2.29
powers	3.09	3.07	2.35
skewness	5.58	4.19	5.86

Sample locations



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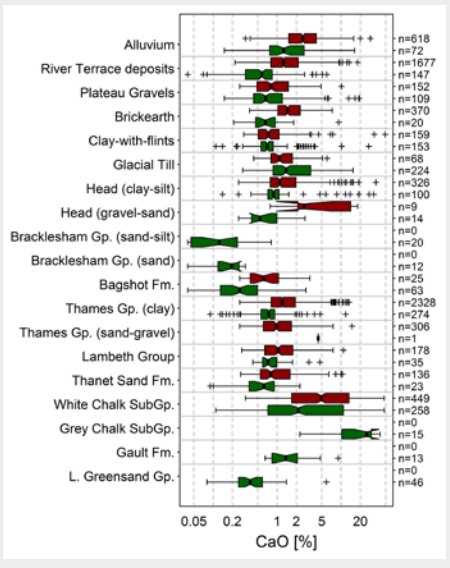
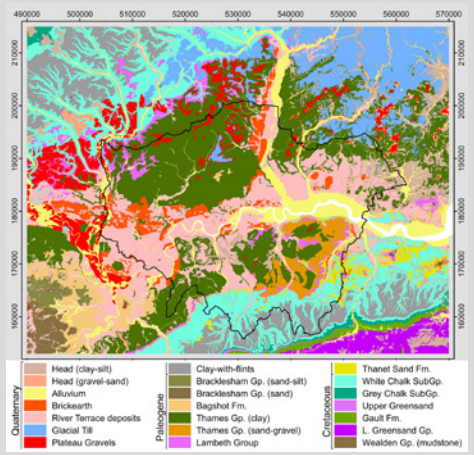
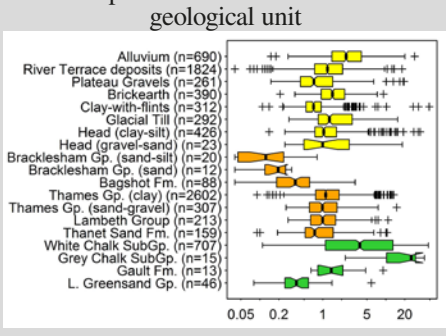
LOND and SEEN topsoil concentrations over each geological unit



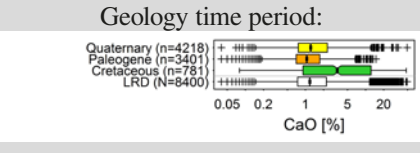
Simplified GEOLOGY (adapted from DiGMapGB-50)

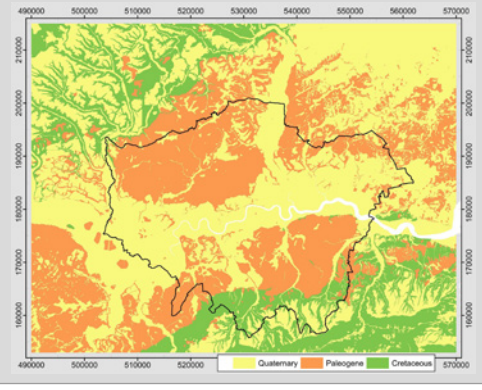


LRD topsoil concentrations over each geological unit



Geology time period:





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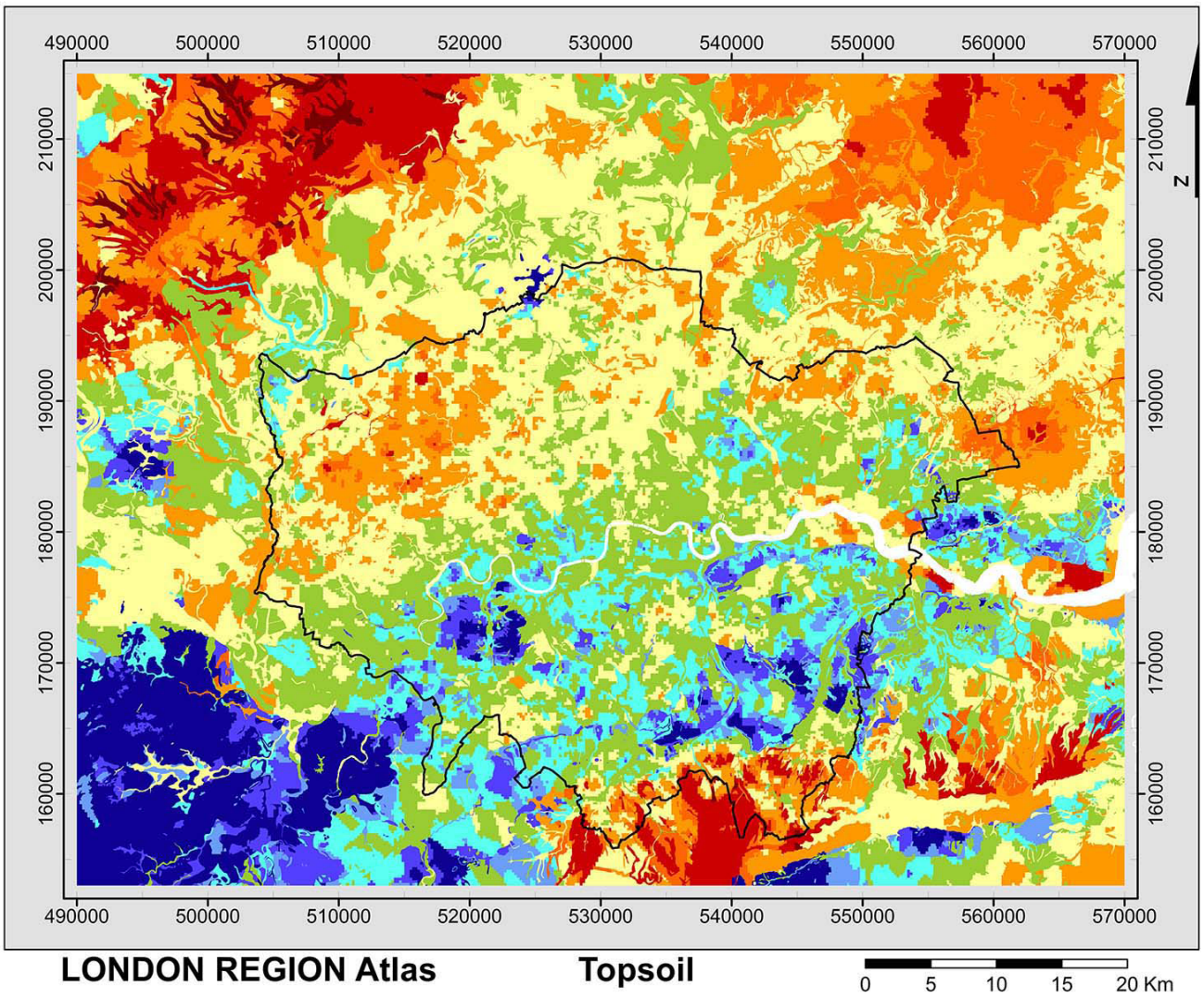
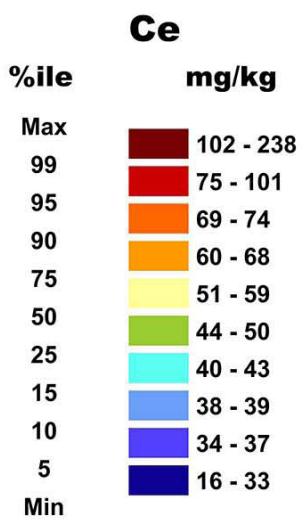
Cerium: LRA





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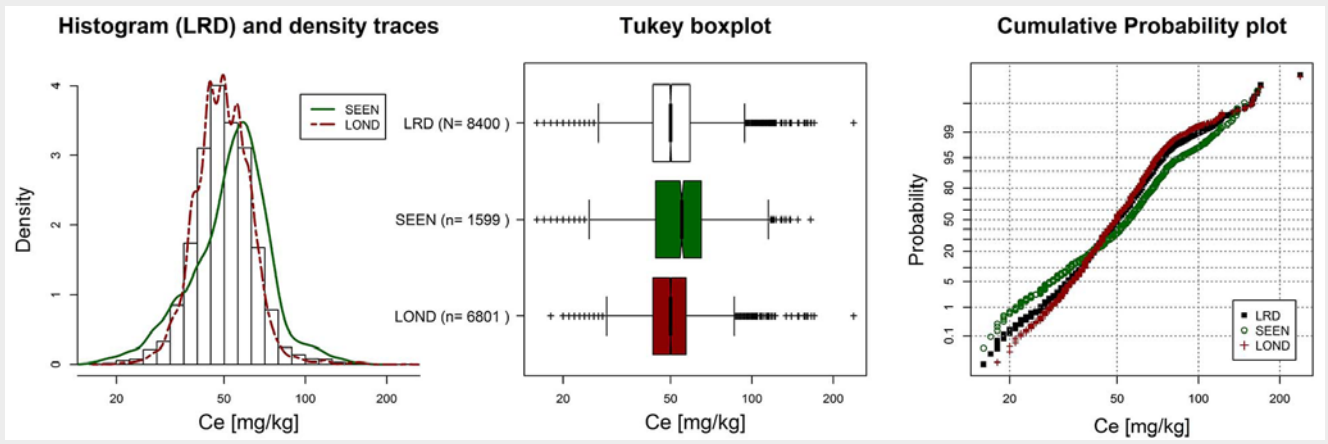
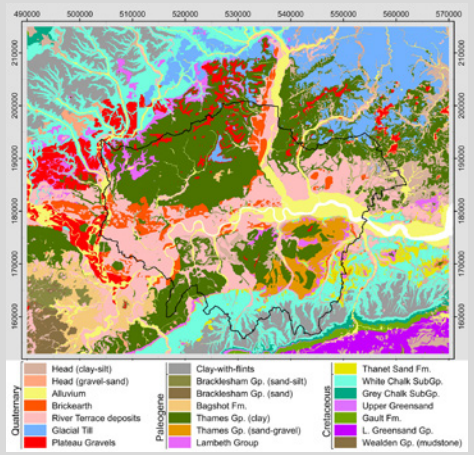
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets

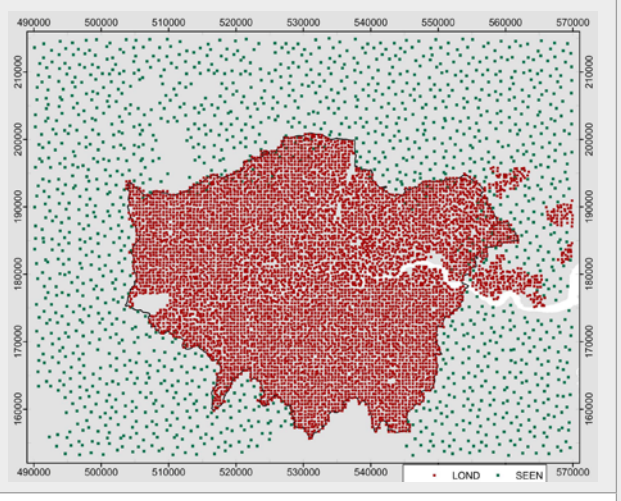


Ce [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1)	0	0	0
minimum	16	16	18
Q25	43	44	43
median	**50**	**55**	**50**
Q75	59	65	57
Q95	74	86.1	70
Q99	101	117	91
maximum	238	165	238
MAD	**11.9**	**14.8**	**10.4**
CVR%	23.7	27	20.8
mean	51.8	55.7	50.9
SD	14.2	18.3	12.9
CV%	27.5	32.8	25.4
GM	50.1	52.8	49.5
GSD	1.29	1.39	1.26
powers	1.17	1.01	1.12
skewness	1.93	1.04	2.27

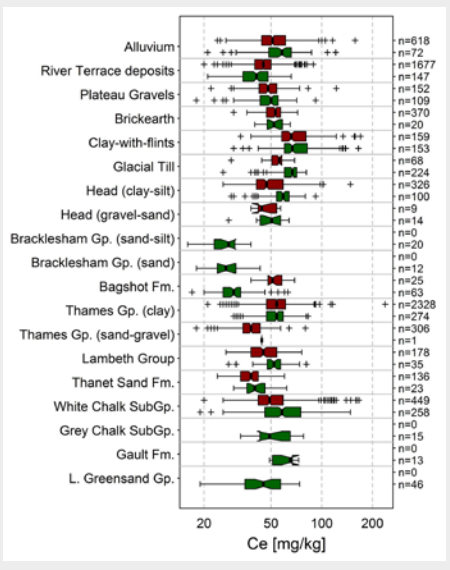
Simplified GEOLOGY
(adapted from DiGMapGB-50)



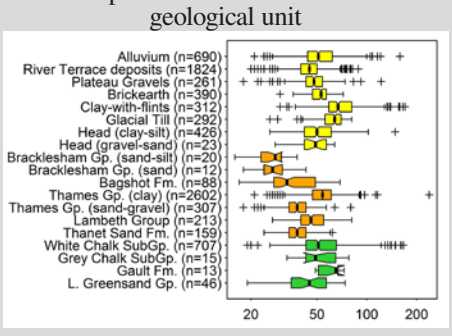
Sample locations



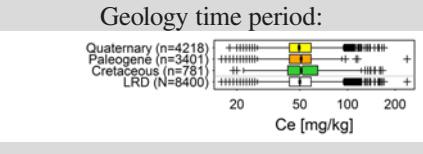
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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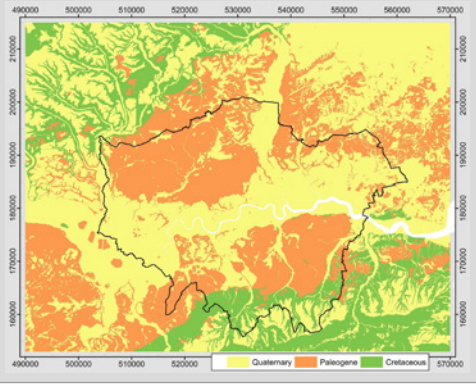

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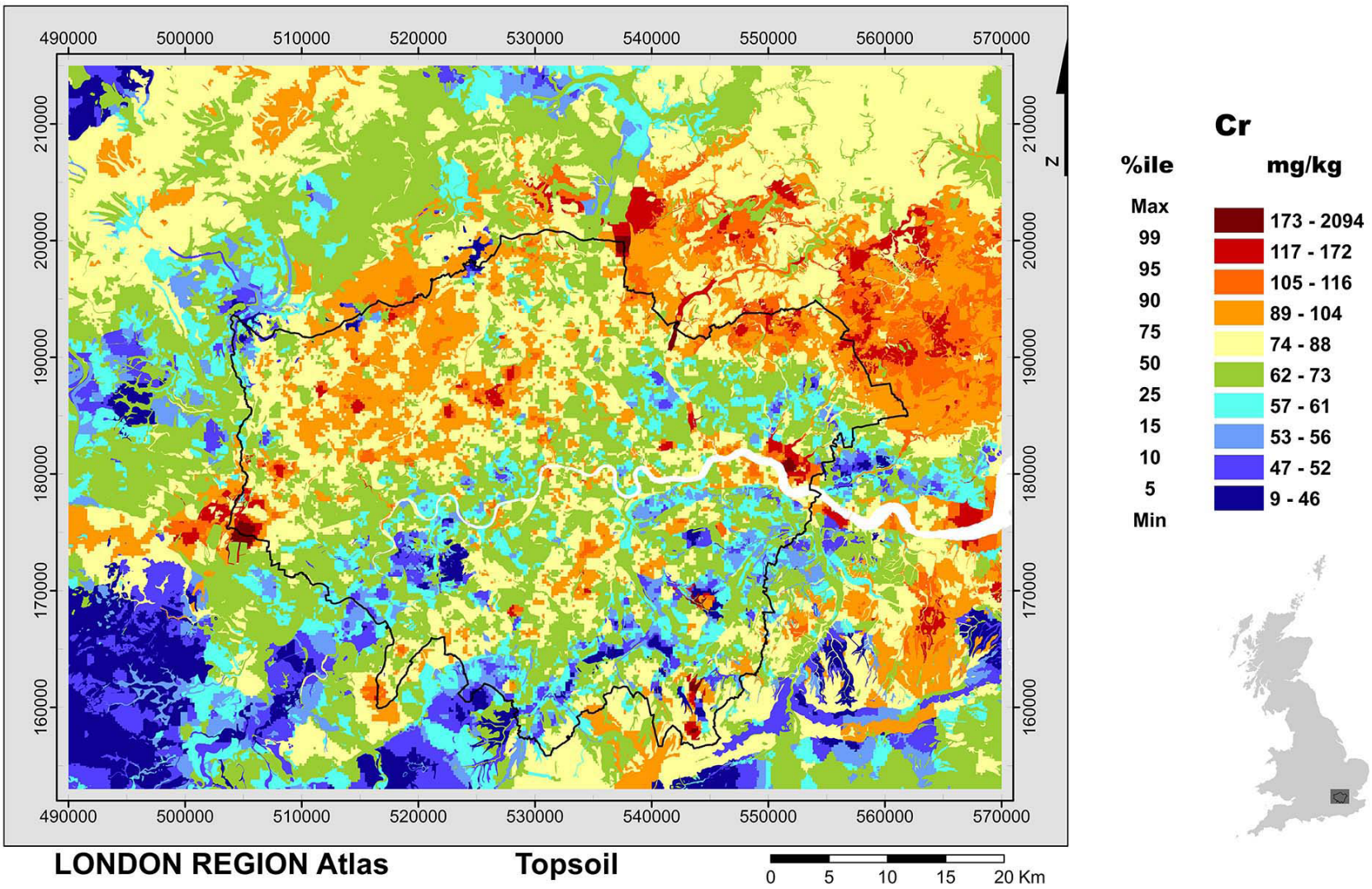
Chromine: LRA



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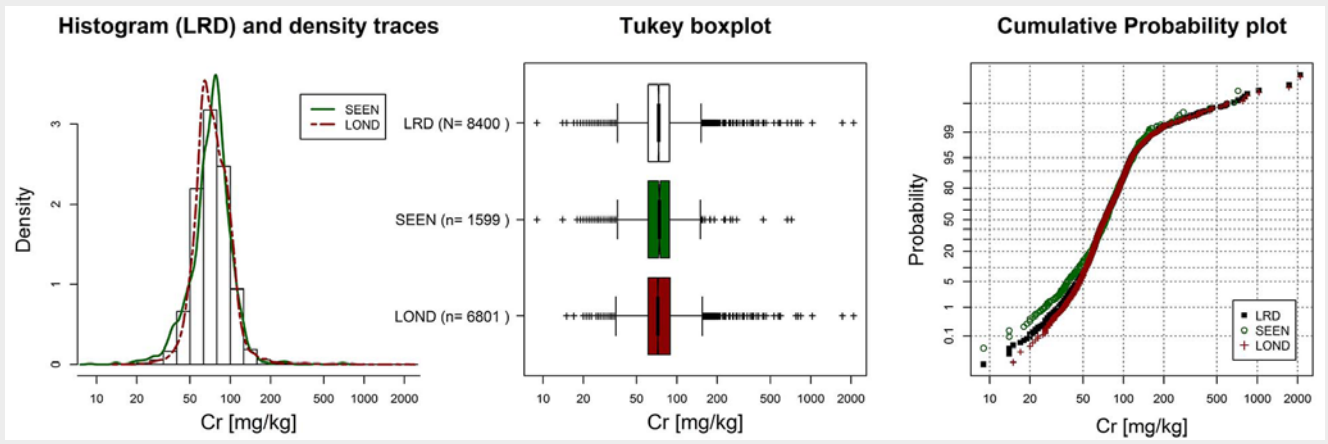
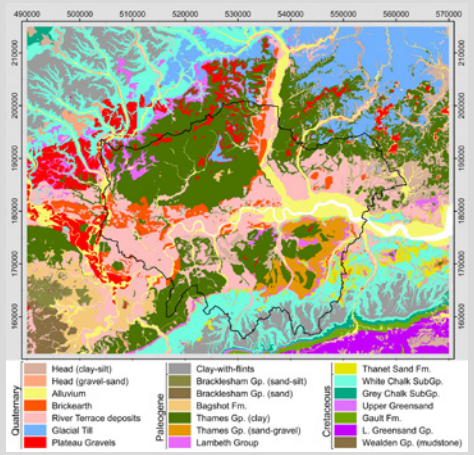
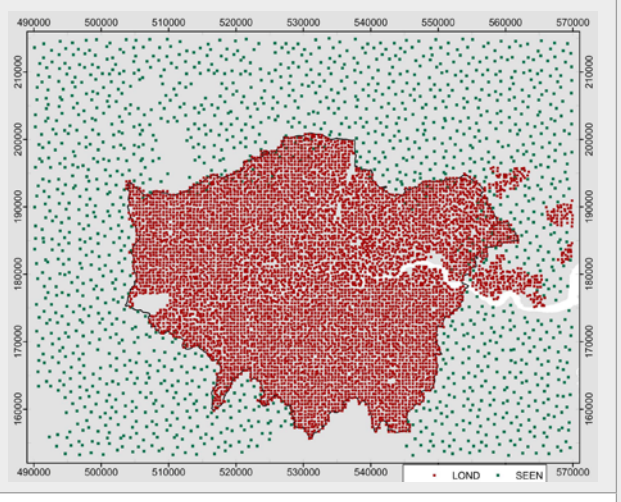


Cr [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (3)	0	0	0
minimum	9	9	15
Q25	61	61	61
median	**73**	**74**	**72**
Q75	88	88	89
Q95	115.8	118	115
Q99	172	154.7	177
maximum	2094	718	2094
MAD	**19.3**	**19.3**	**19.3**
CVR%	26.4	26	26.8
mean	77.9	76.5	78.2
SD	45.4	34.7	47.6
CV%	58.3	45.3	60.8
GM	73.3	71.8	73.6
GSD	1.38	1.42	1.37
powers	2.37	1.9	2.14
skewness	20.74	8.38	21.5

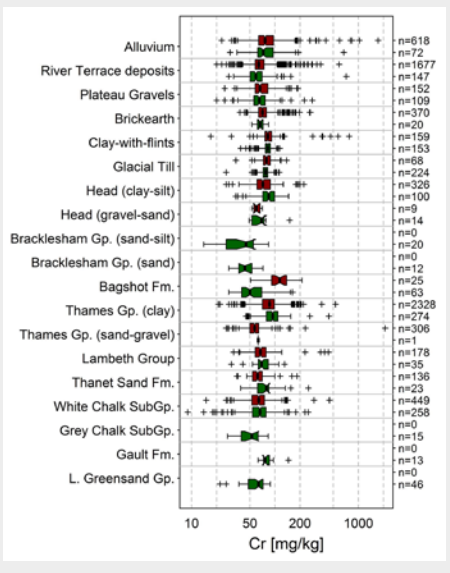
Simplified GEOLOGY (adapted from DiGMapGB-50)



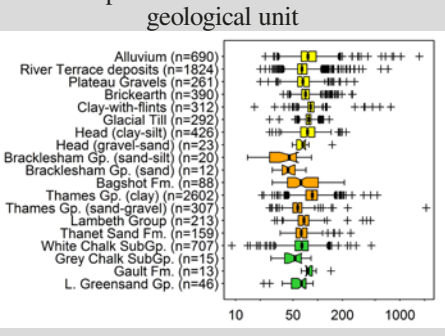
Sample locations



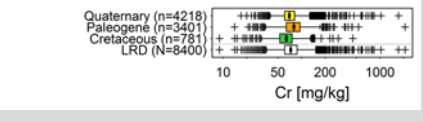
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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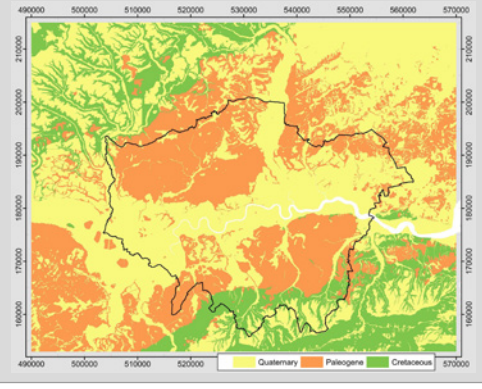

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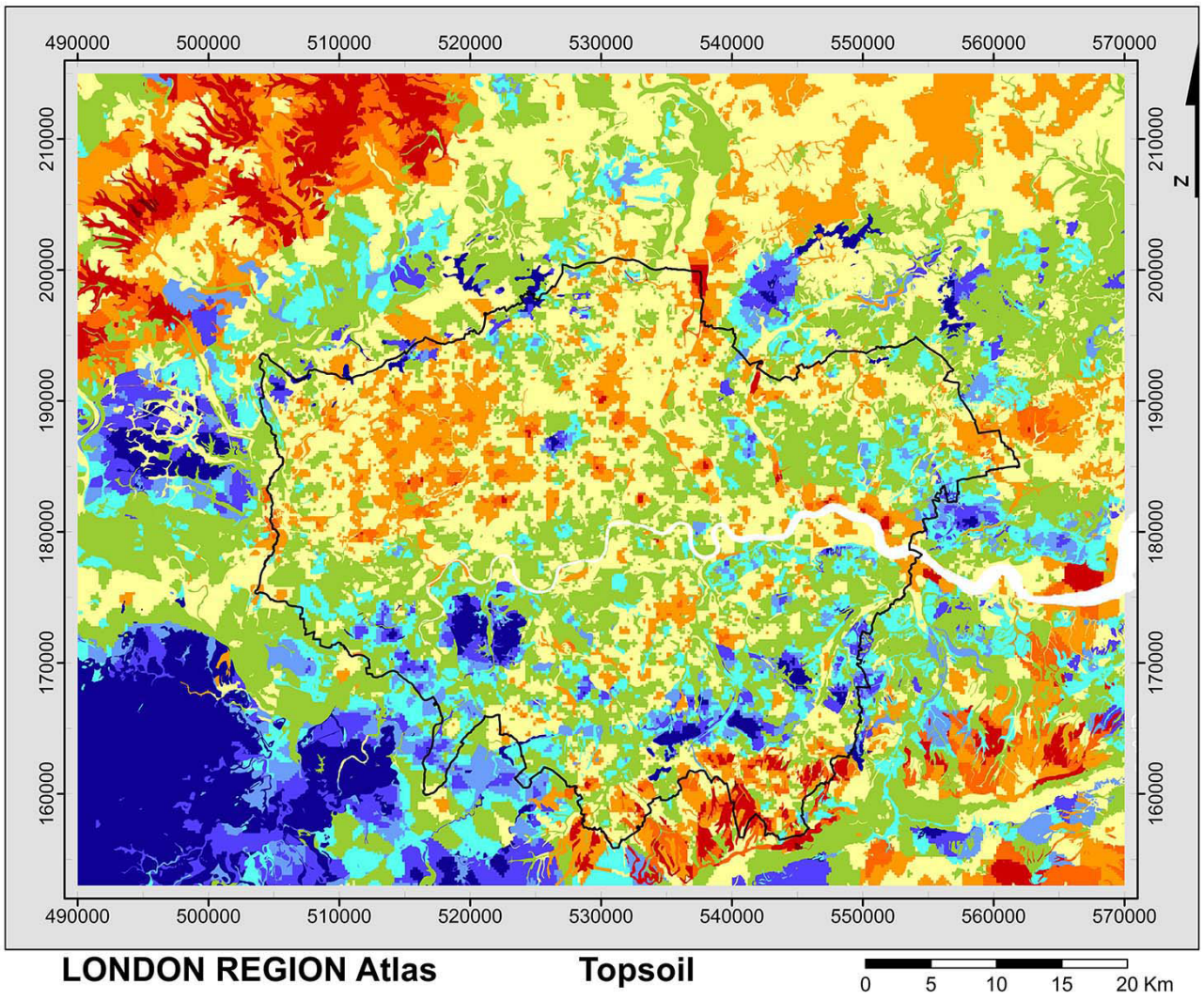
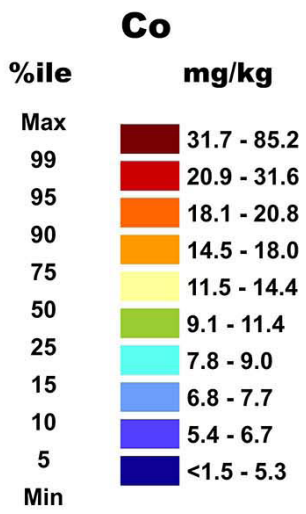
Cobalt: LRA





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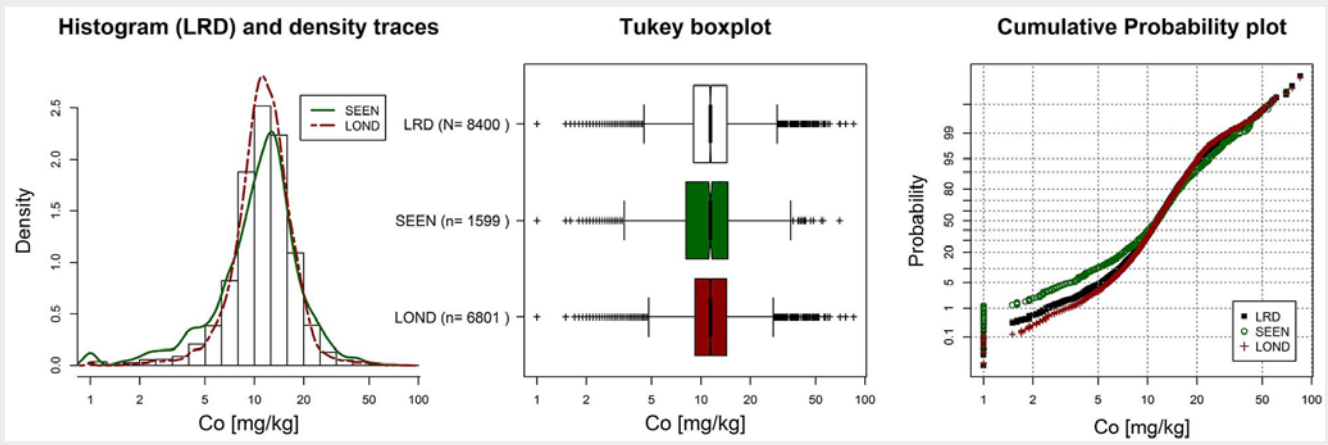
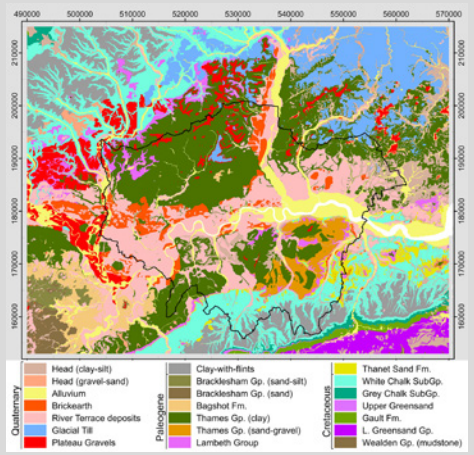
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets

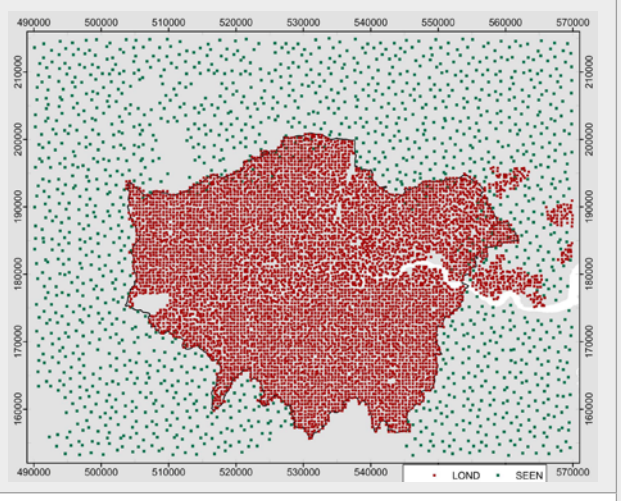


Co [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1.5)	0.32	1.19	0.12
minimum	<1.5	<1.5	<1.5
Q25	9	8.1	9.2
median	**11.4**	**11.4**	**11.4**
Q75	14.4	14.6	14.3
Q95	20.8	23.7	20.2
Q99	31.6	36.4	30.6
maximum	85.2	69.9	85.2
MAD	**3.9**	**4.9**	**3.7**
CVR%	33.8	42.9	32.5
mean	12.2	12.1	12.2
SD	5.5	6.6	5.2
CV%	45.5	55	43
GM	11.1	10.4	11.3
GSD	1.57	1.82	1.5
powers	1.93	1.84	1.93
skewness	2.63	1.94	2.91

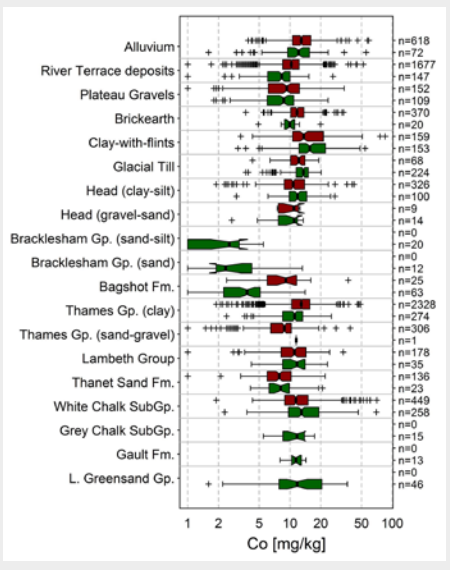
Simplified GEOLOGY (adapted from DiGMapGB-50)



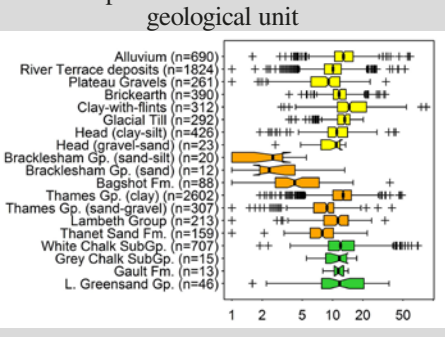
Sample locations



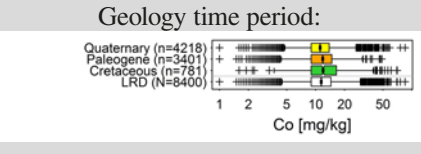
LOND and SEEN topsoil concentrations over each geological unit



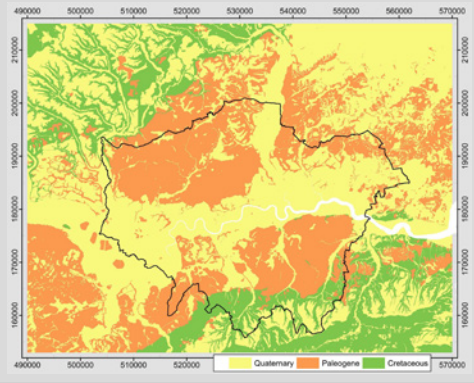
LRD topsoil concentrations over each geological unit



Geology time period:



At each site a composite topsoil (5–20 cm depth) sample comprising five subsamples was collected from the corners and centre of a 20 x 20 m square. After collection samples were air/oven dried and sieved to <2 mm before analysis to determine the total contents of more than 50 chemical elements by X-ray fluorescence spectrometry (XRFS).



Each geochemical map was prepared by interpolating the point data using the parent material mapping method (Appleton et al., 2013[1]). The LRA area was subdivided into 200 x 200 m squares and intercepted with the geology (parent material) polygons, thereby creating the basic 200 m-PM polygons. For each 200 m-PM polygon the average concentration based on the four nearest samples over the same PM was computed (see further explanation in Materials and methods and references therein). As the maps (produced in ArcGIS 10.1) show estimated concentrations, there is a degree of uncertainty due to variability in soil composition. The element concentration colour ramp is based on percentile classes of the LRD dataset distribution. The tables and graphs were generated running R (R x 64 3.1.0) in RStudio (Version 0.98.977). The LRD, LOND and SEEN surveys are represented by the colours black/white, dark green and dark red respectively. Quaternary, Palaeogene and Cretaceous geological time periods are represented by soft yellow, orange and lime green colours respectively. For further information go to Univariate statistics and graphics.

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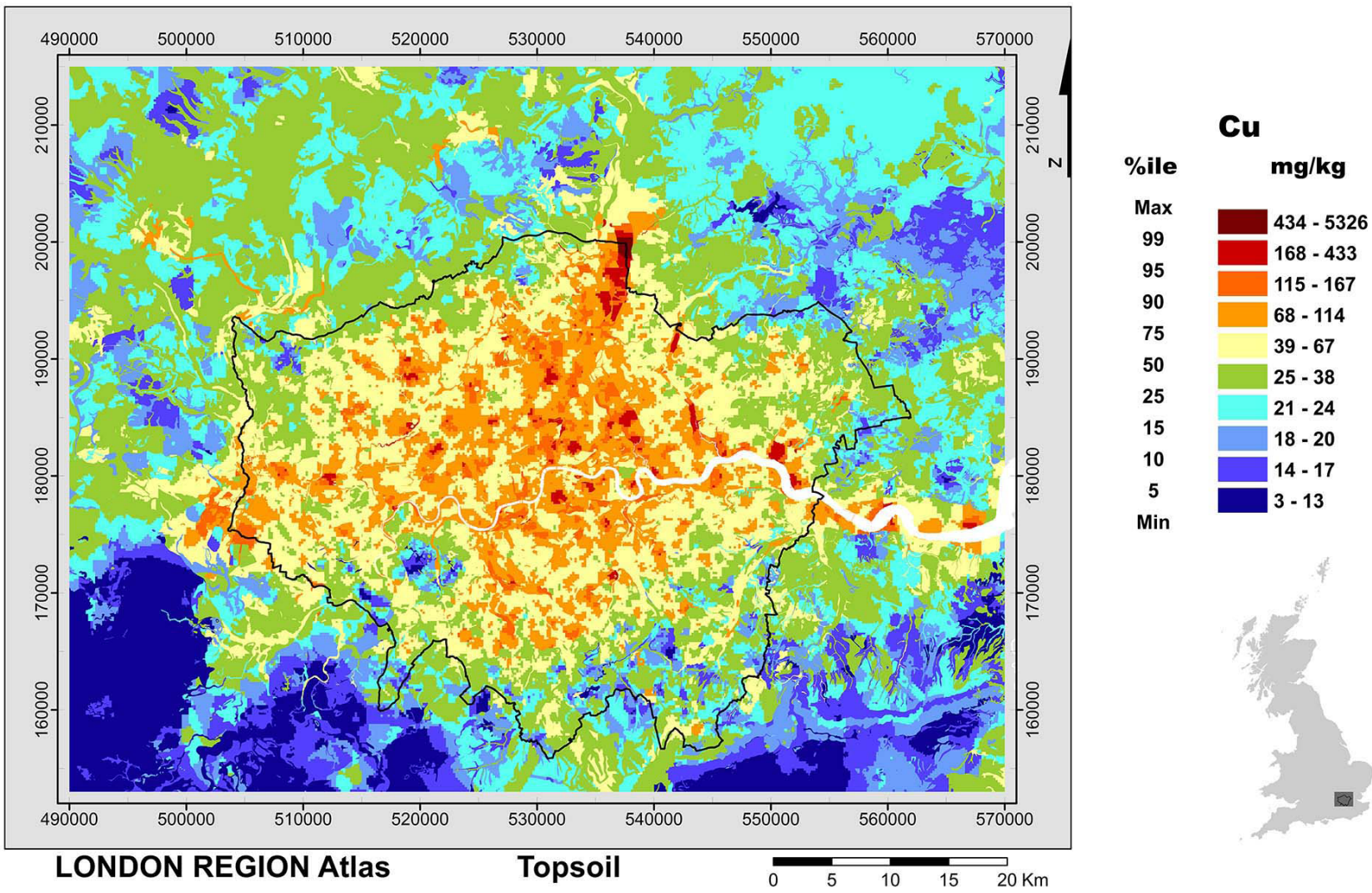
Copper: LRA



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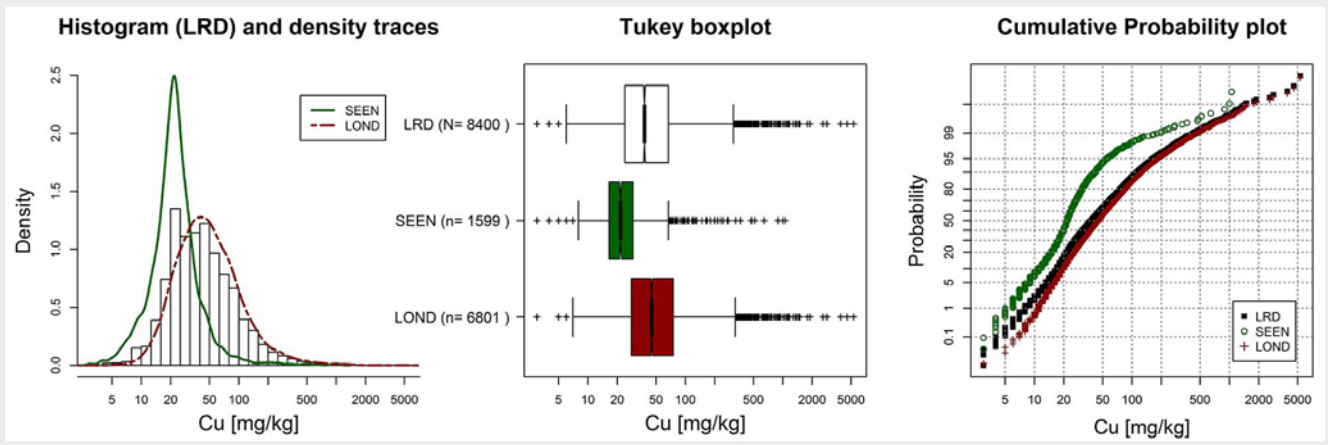
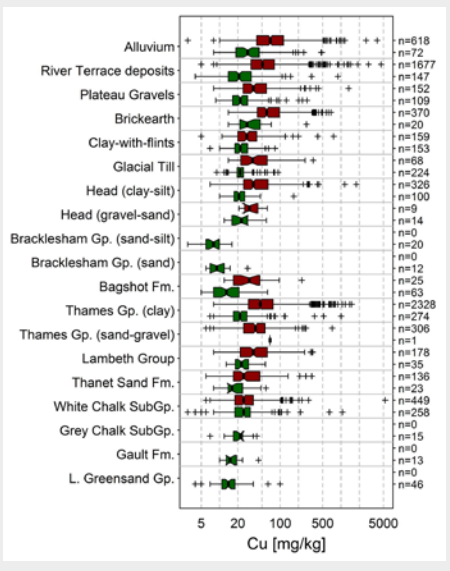
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



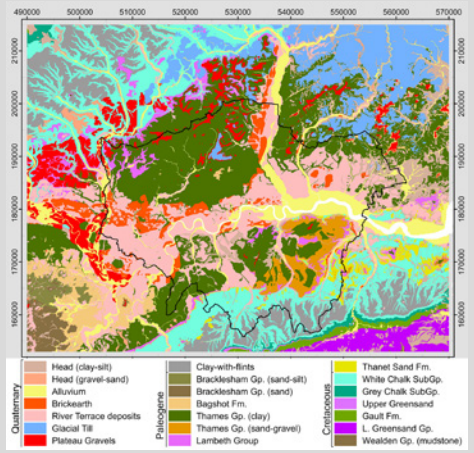
Cu [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1.3)	0	0	0
minimum	3	3	3
Q25	24	16.5	28
median	**38**	**21.6**	**45**
Q75	67	29	75
Q95	167	54.8	184
Q99	433	180.4	461
maximum	5326	1055	5326
MAD	**25.7**	**8.3**	**29.7**
CVR%	67.7	38.4	65.9
mean	63.5	29.2	71.6
SD	132	54.3	143.1
CV%	207.8	186.2	199.9
GM	41.7	22.1	48.4
GSD	2.23	1.83	2.15
powers	3.25	2.55	3.25
skewness	19.82	12.95	18.9

Sample locations

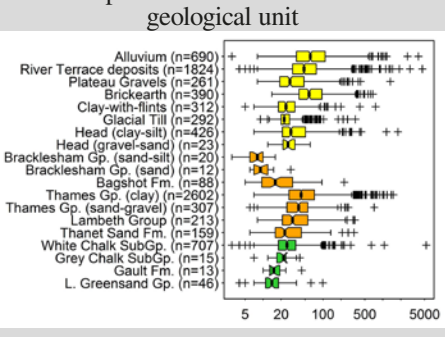
LOND and SEEN topsoil concentrations over each geological unit



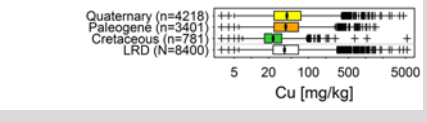
Simplified GEOLOGY (adapted from DiGMapGB-50)



LRD topsoil concentrations over each geological unit



Geology time period:



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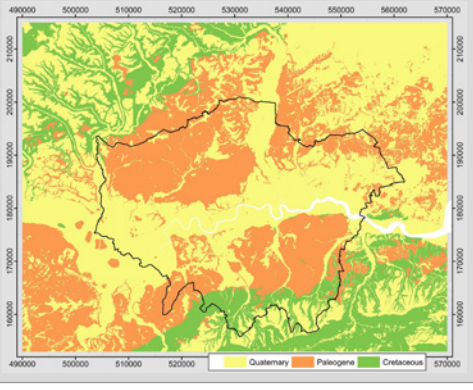

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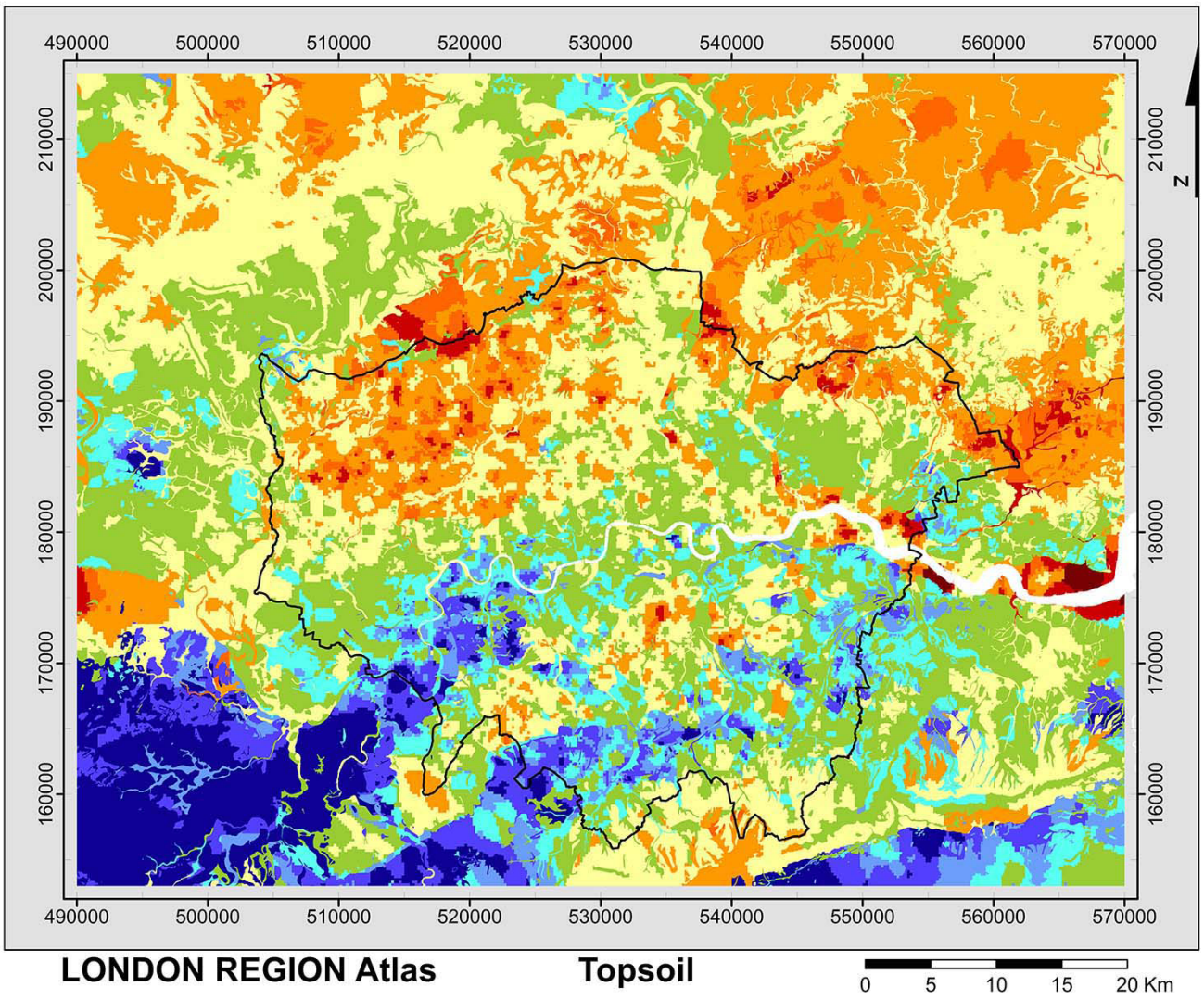
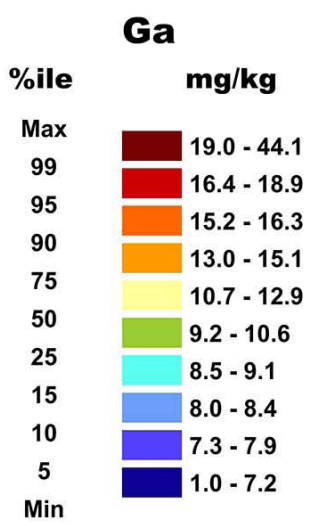
Gallium: LRA





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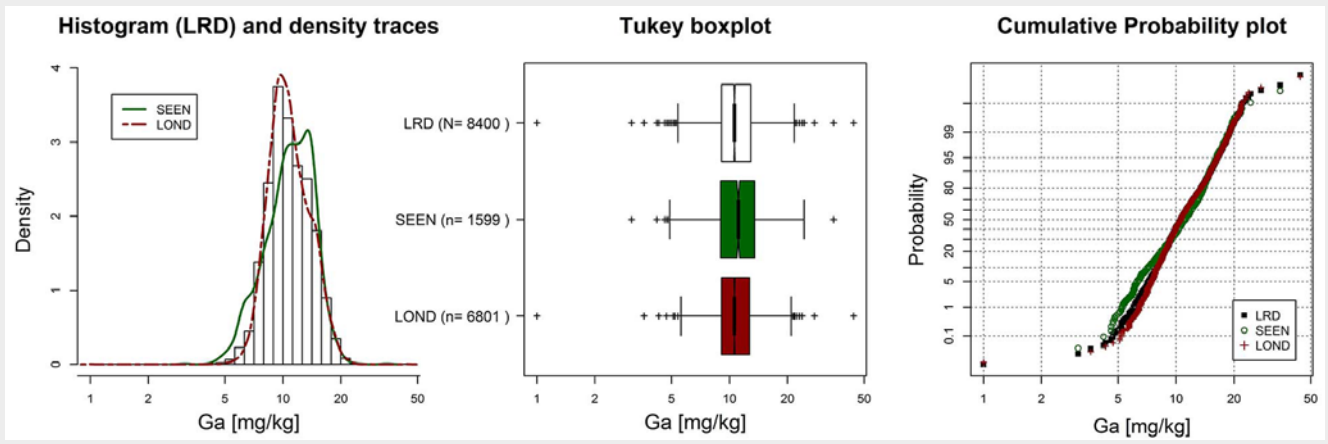
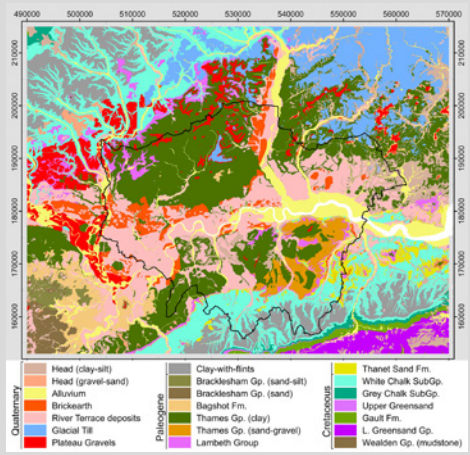
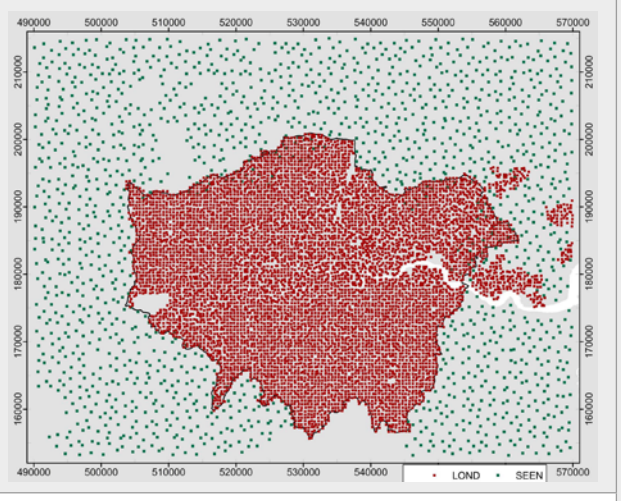


Ga [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1)	0	0	0
minimum	1	3.1	1
Q25	9.1	9	9.1
median	**10.6**	**11.1**	**10.6**
Q75	12.9	13.5	12.7
Q95	16.3	16.2	16.4
Q99	18.9	18.9	18.9
maximum	44.1	34.7	44.1
MAD	**2.7**	**3.4**	**2.5**
CVR%	25.2	30.7	23.8
mean	11.1	11.2	11.1
SD	2.9	3.1	2.8
CV%	25.9	27.7	25.5
GM	10.8	10.8	10.8
GSD	1.29	1.34	1.28
powers	1.64	1.05	1.64
skewness	0.91	0.48	1.04

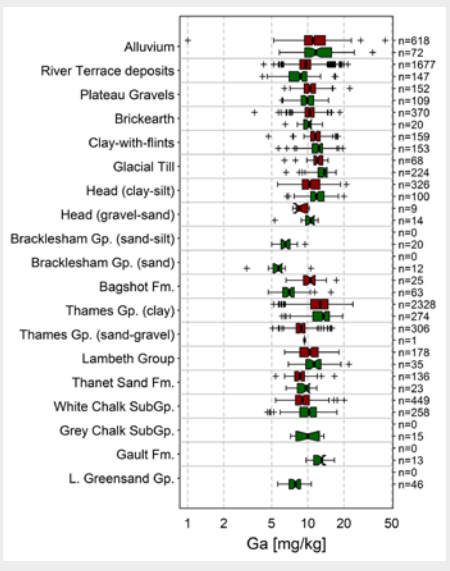
Simplified GEOLOGY (adapted from DiGMapGB-50)



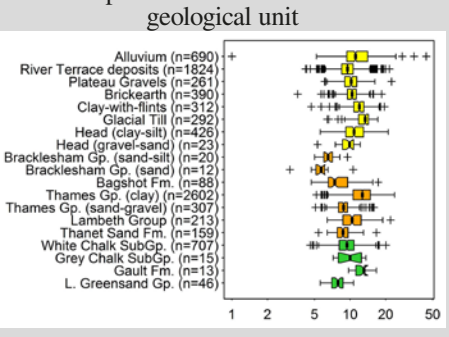
Sample locations



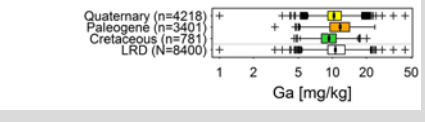
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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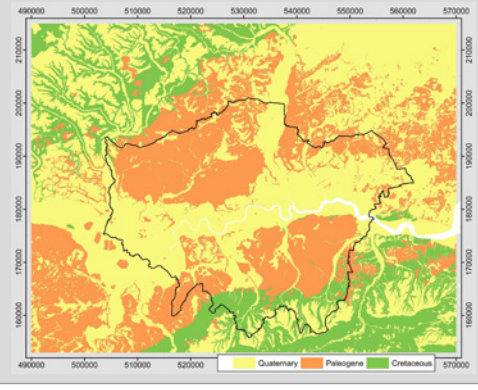

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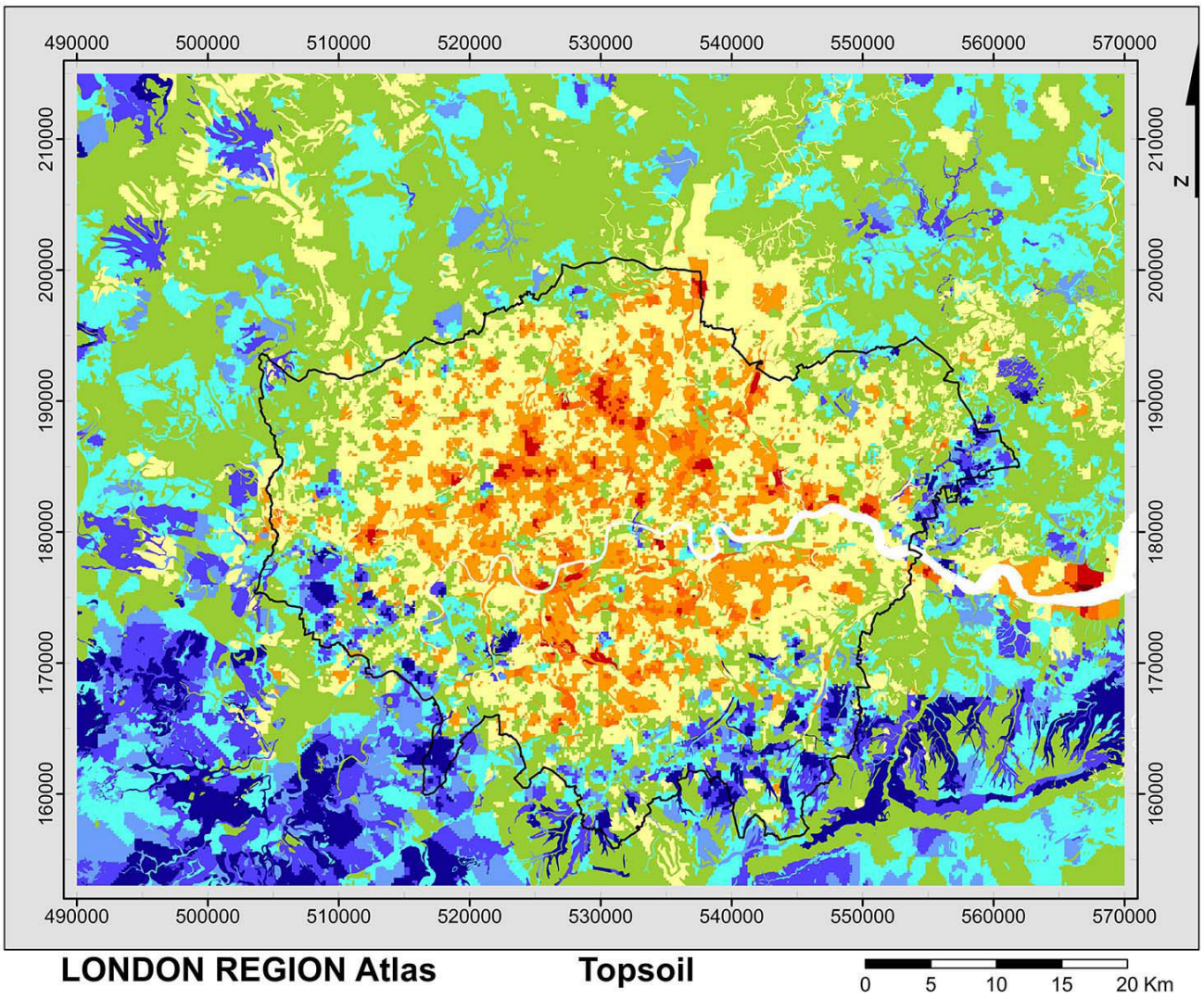
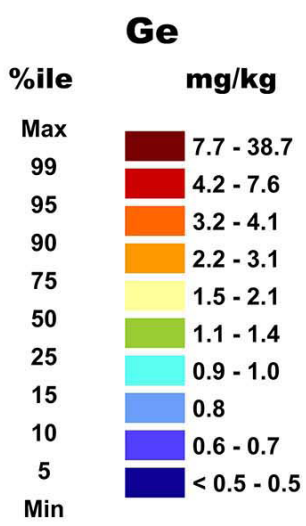
Germanium: LRA





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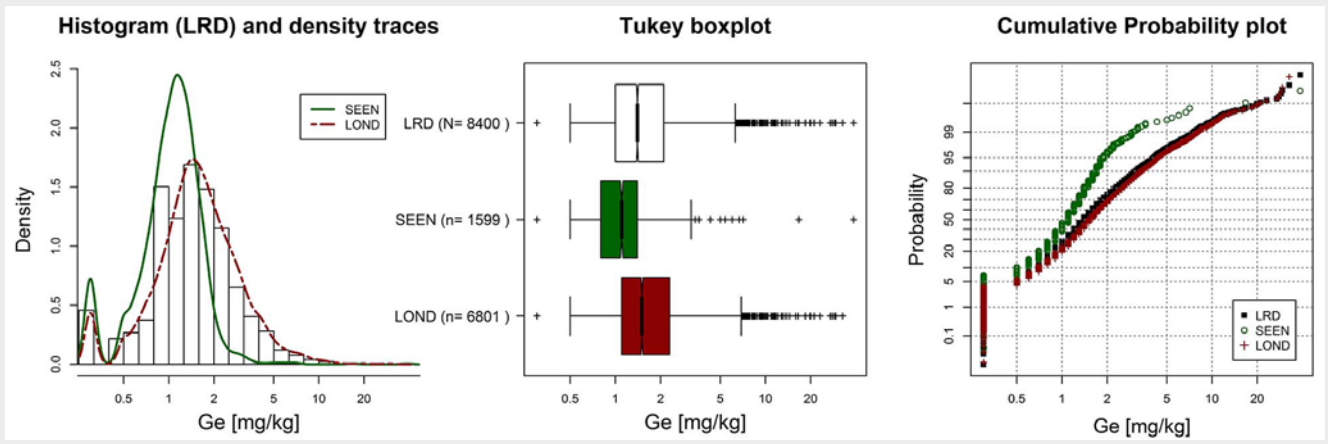
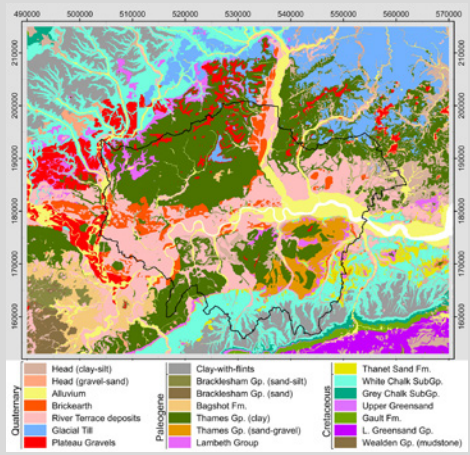
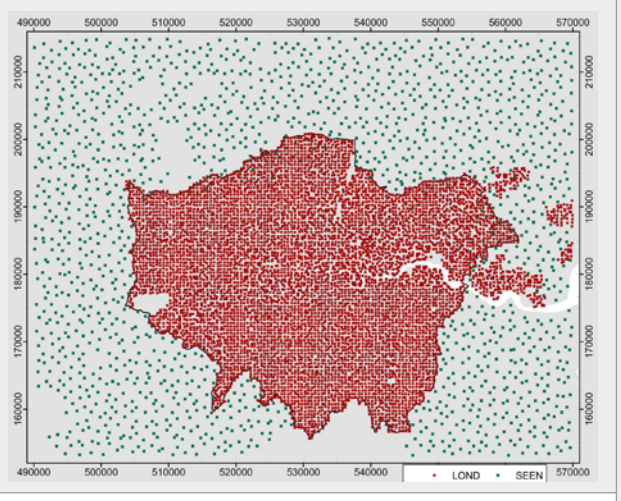


Ge [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.5)	4.57	6.82	4.04
minimum	<0.5	<0.5	<0.5
Q25	1	0.8	1.1
median	**1.4**	**1.1**	**1.5**
Q75	2.1	1.4	2.3
Q95	4.1	1.9	4.3
Q99	7.6	2.9	8.1
maximum	38.7	38.7	32.7
MAD	**0.7**	**0.4**	**0.7**
CVR%	52.9	40.4	49.4
mean	1.8	1.2	1.9
SD	1.6	1.2	1.7
CV%	91.4	99.9	87.6
GM	1.4	1	1.5
GSD	1.92	1.65	1.93
powers	2.11	2.11	2.04
skewness	7.17	23.22	6.05

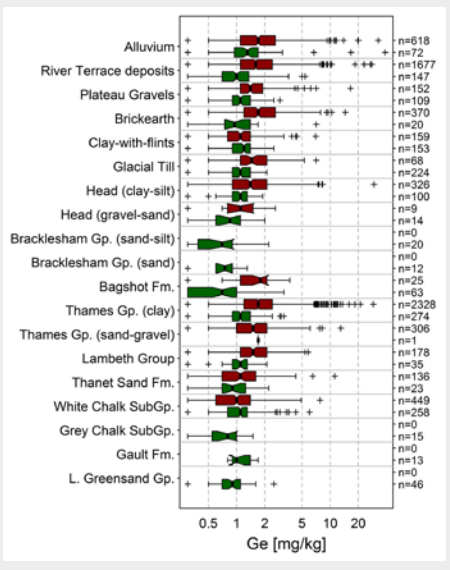
Simplified GEOLOGY (adapted from DiGMapGB-50)



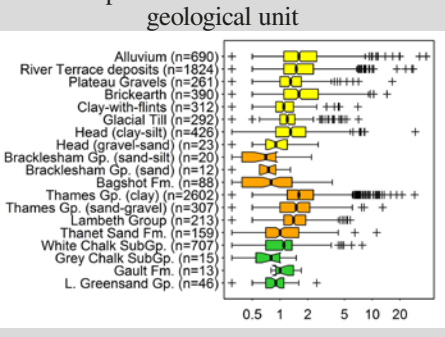
Sample locations



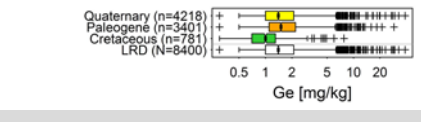
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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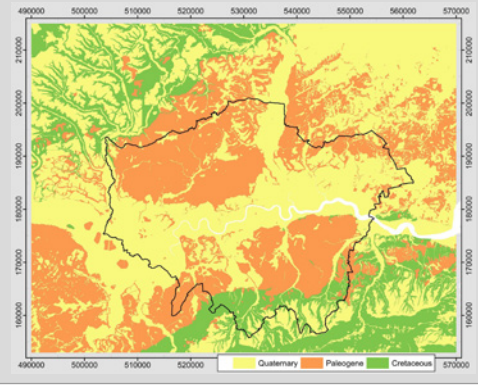

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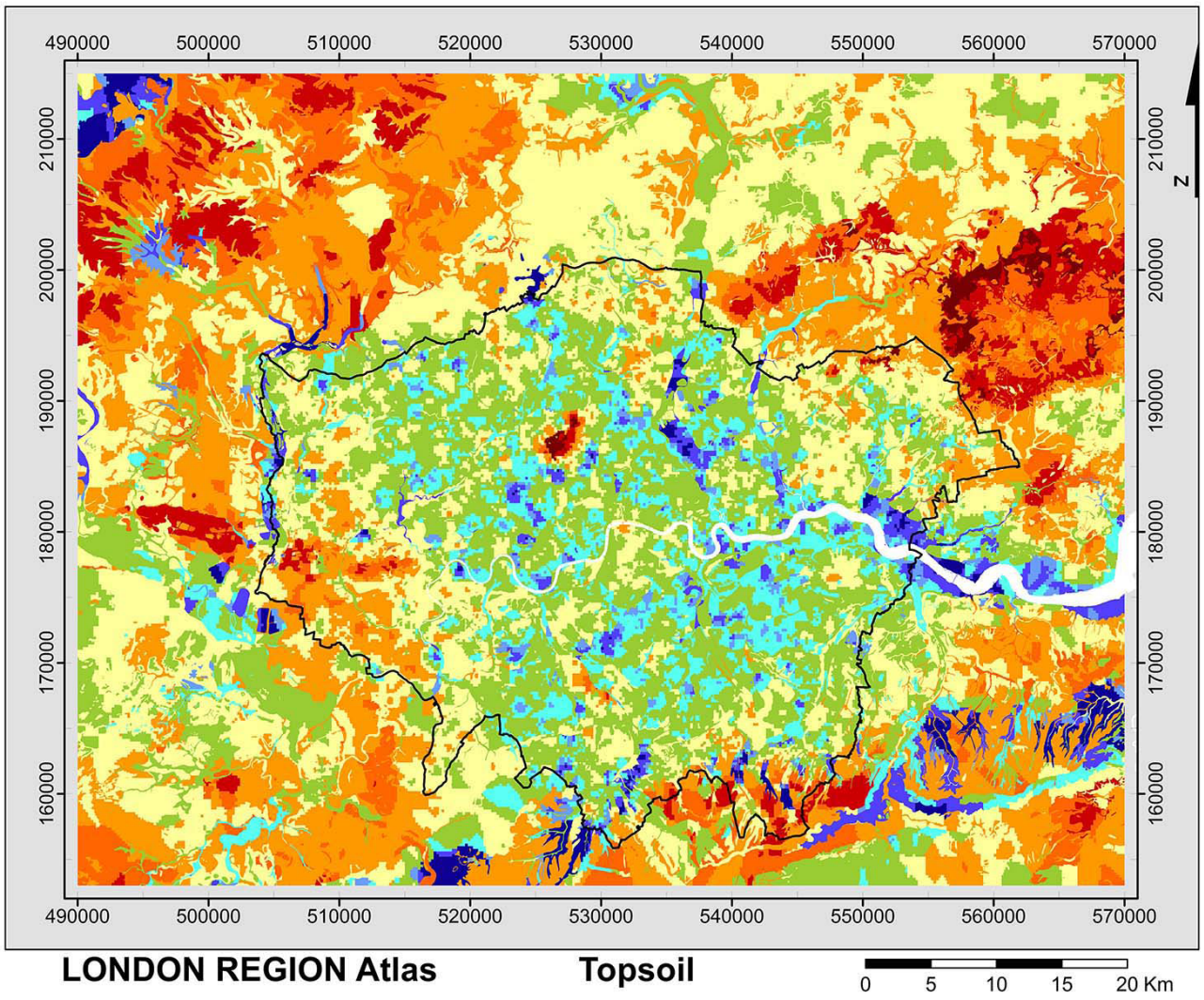
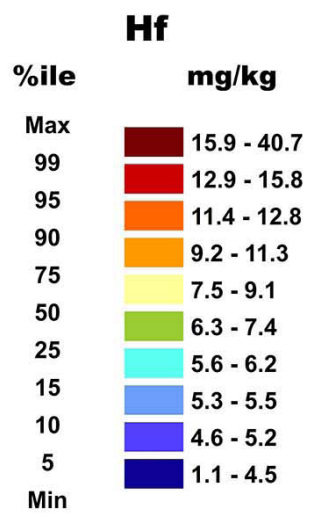
Hafnium: LRA





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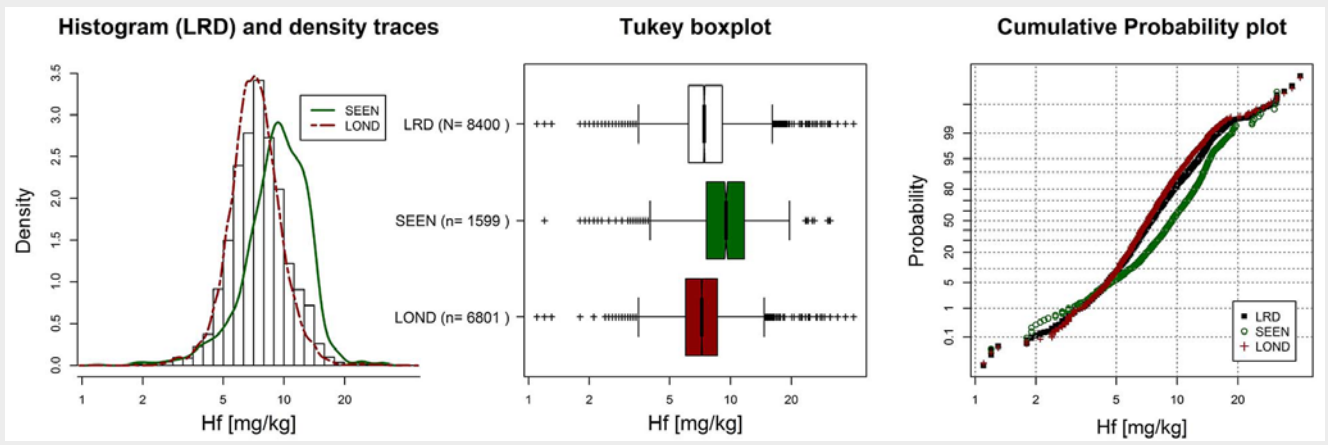
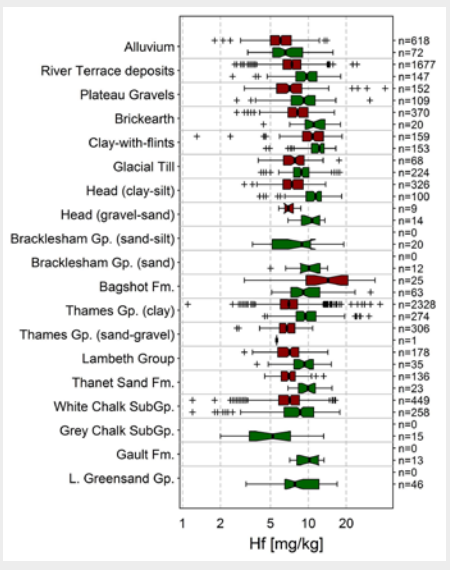
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



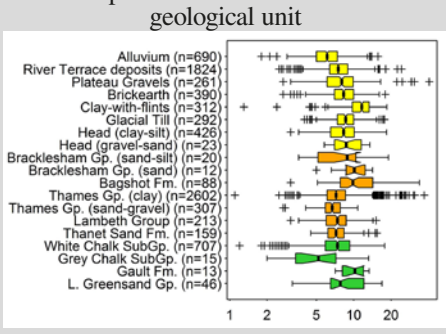
Hf [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1)	0	0	0
minimum	1.1	1.2	1.1
Q25	6.2	7.6	6
median	**7.4**	**9.5**	**7.2**
Q75	9.1	11.7	8.6
Q95	12.8	14.5	11.5
Q99	15.8	18.7	14.6
maximum	40.7	31.2	40.7
MAD	**2.1**	**3.1**	**1.9**
CVR%	28	32.8	26.8
mean	7.9	9.7	7.5
SD	2.7	3.2	2.4
CV%	34.5	33.5	32.1
GM	7.5	9.1	7.2
GSD	1.38	1.43	1.34
powers	1.57	1.41	1.57
skewness	2.02	0.94	2.58

Sample locations

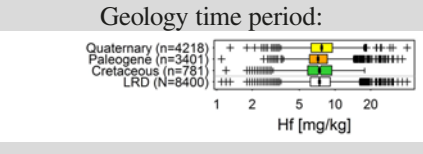
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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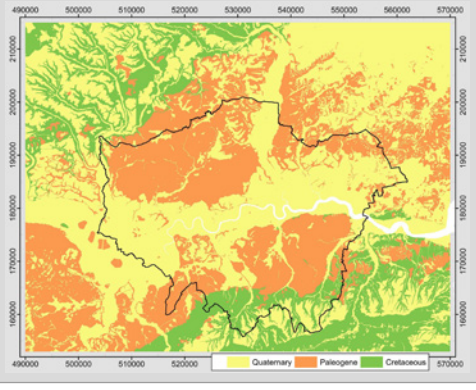

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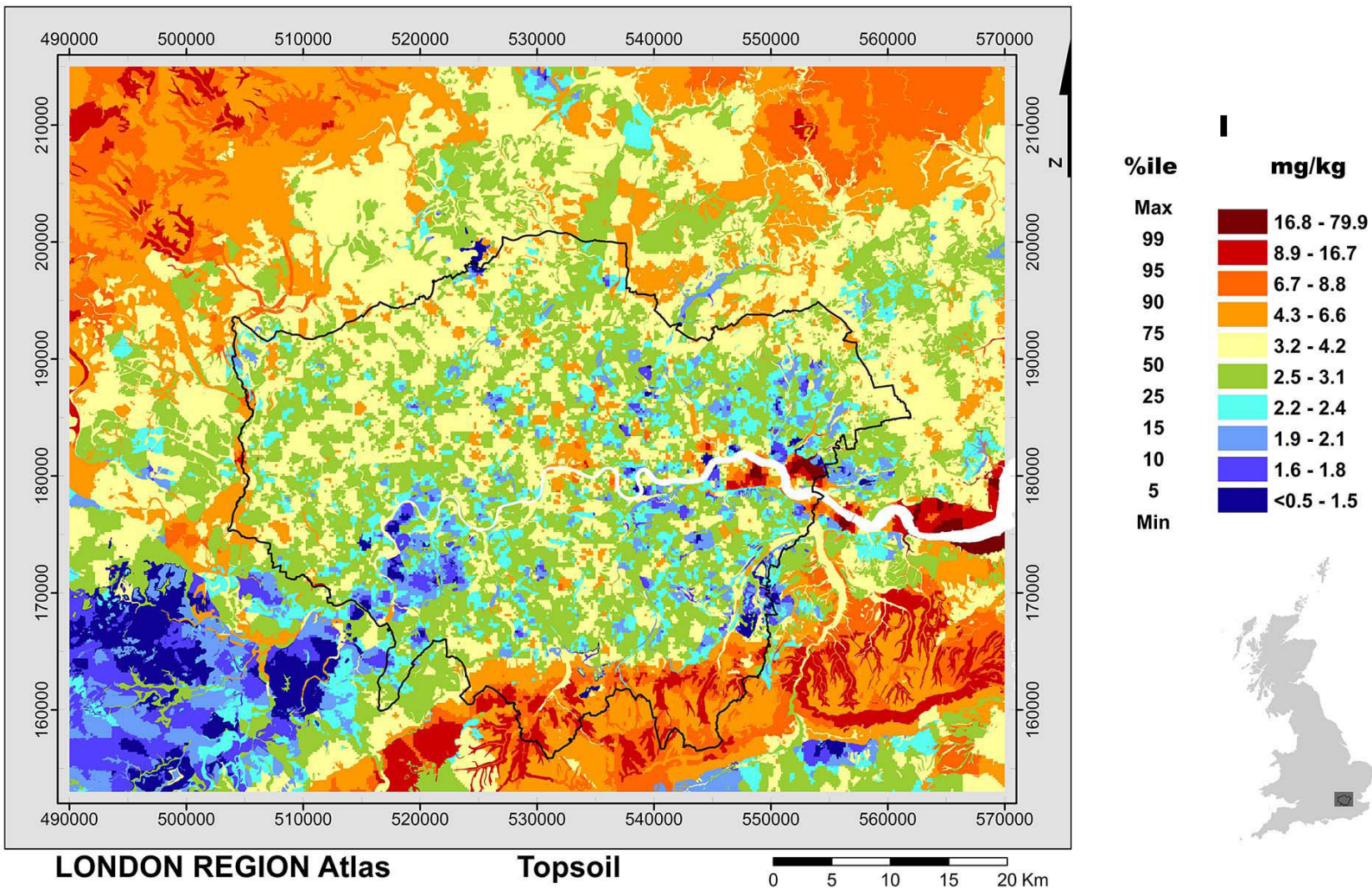
Iodine: LRA



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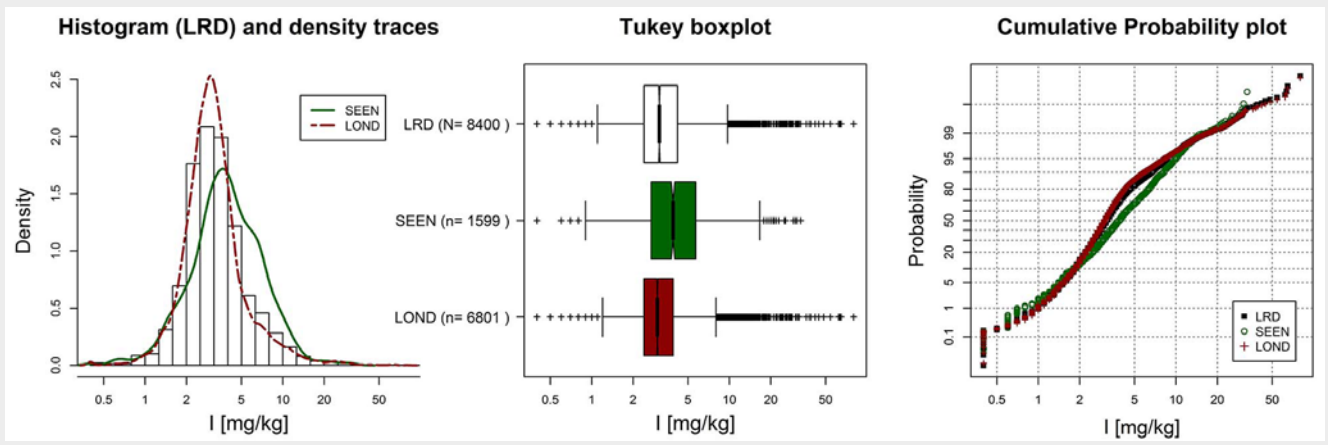
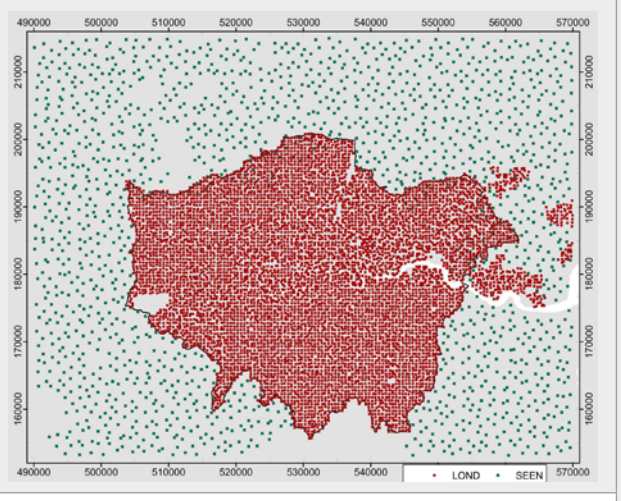
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets

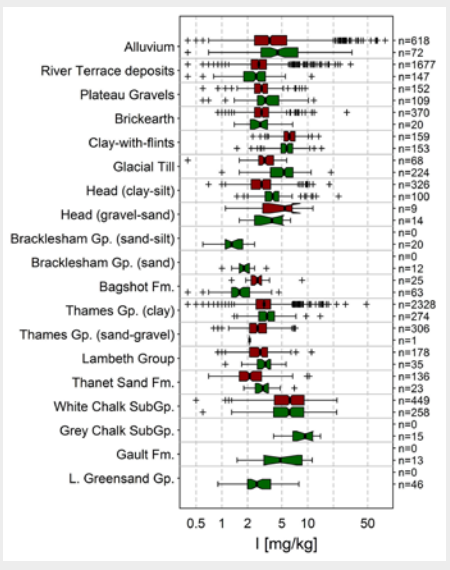


I [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.5)	0.18	0.19	0.18
minimum	<0.5	<0.5	<0.5
Q25	2.4	2.7	2.4
median	**3.1**	**3.9**	**3**
Q75	4.2	5.7	3.9
Q95	8.8	10	8.2
Q99	16.7	15.5	16.8
maximum	79.9	32.9	79.9
MAD	**1.2**	**2.1**	**1**
CVR%	38.3	53.2	34.6
mean	3.9	4.6	3.7
SD	3.4	3.1	3.4
CV%	86.5	68.1	91.2
GM	3.3	3.9	3.2
GSD	1.72	1.82	1.68
powers	2.3	1.92	2.3
skewness	7.12	3.03	8.01

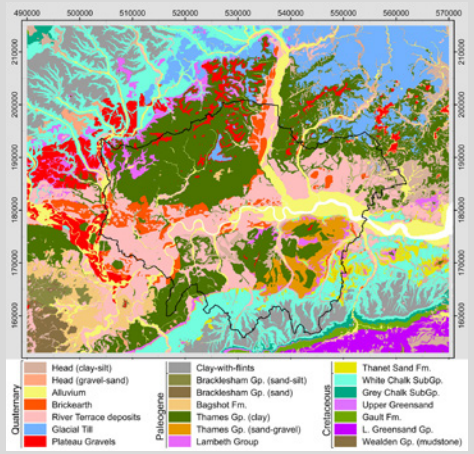
Sample locations



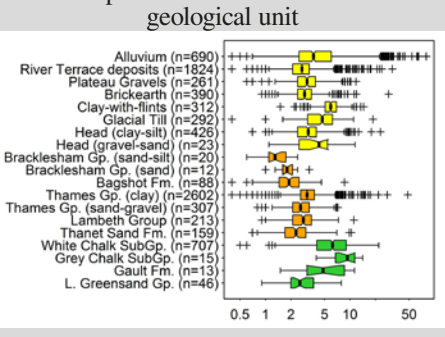
LOND and SEEN topsoil concentrations over each geological unit



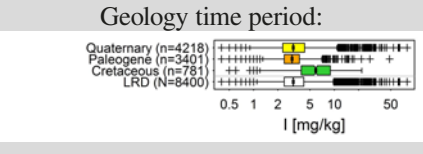
Simplified GEOLOGY (adapted from DiGMapGB-50)



LRD topsoil concentrations over each geological unit



Geology time period:



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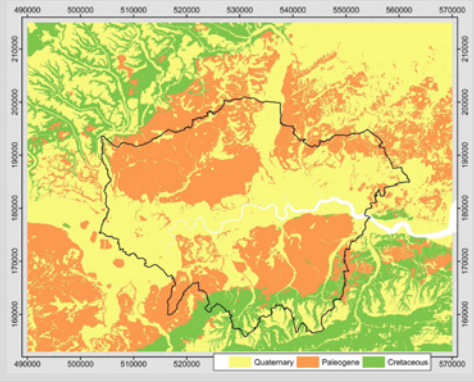

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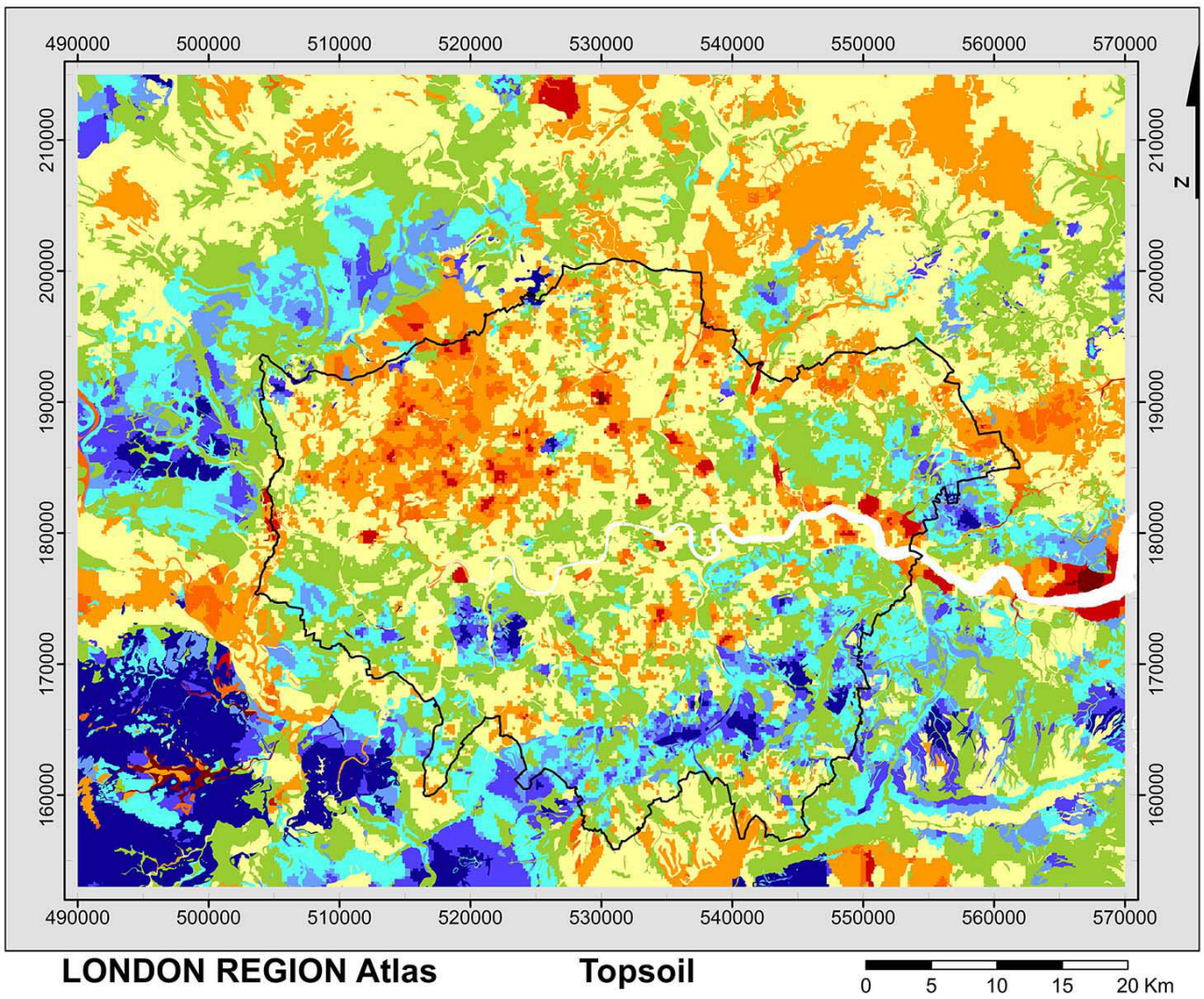
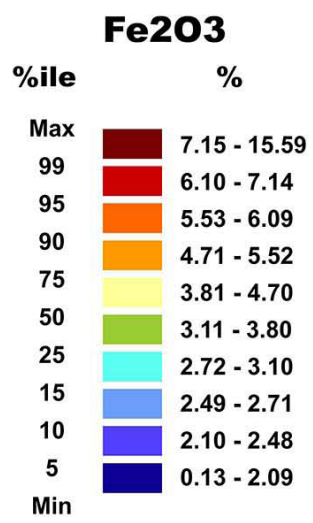
Iron: LRA





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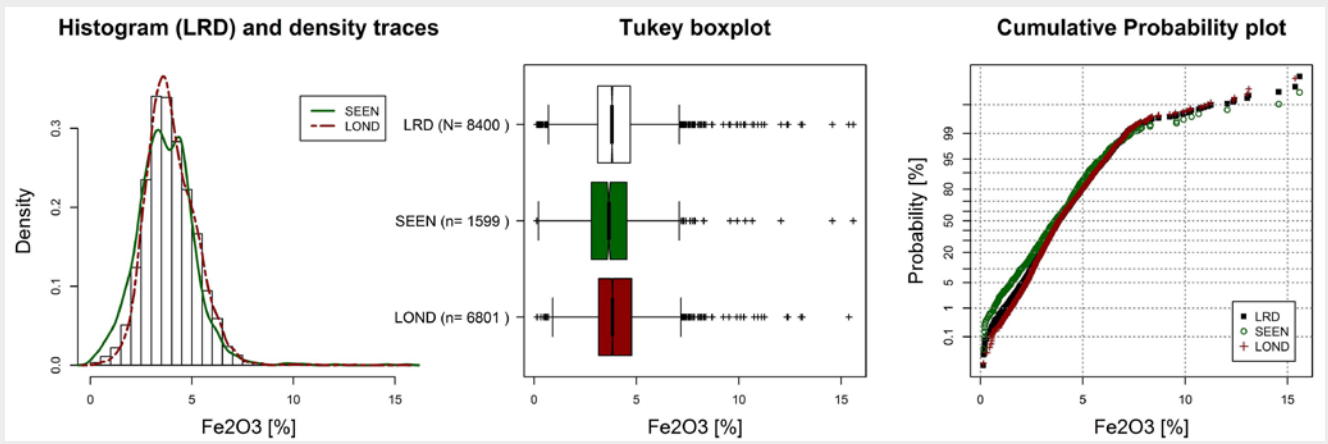
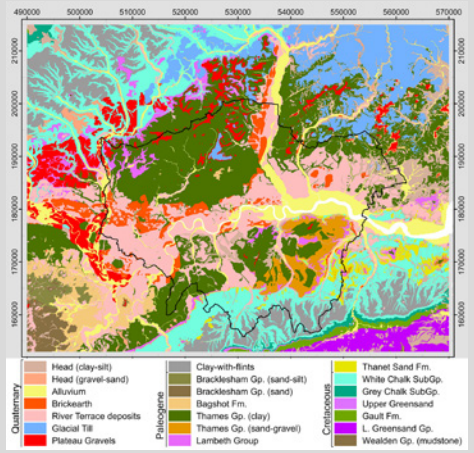
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



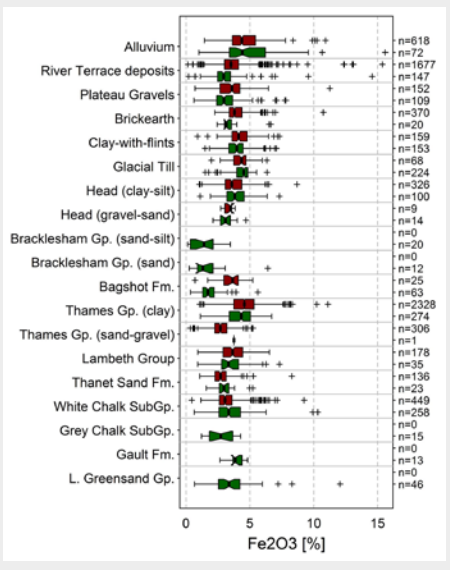
Simplified GEOLOGY (adapted from DiGMapGB-50)



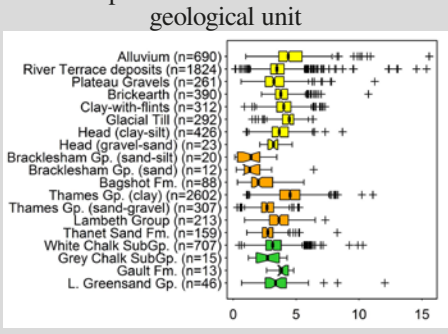
Fe2O3 [%]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.01)	0	0	0
minimum	0.13	0.13	0.15
Q25	3.1	2.8	3.15
median	**3.8**	**3.65**	**3.82**
Q75	4.7	4.53	4.76
Q95	6.09	5.9	6.11
Q99	7.14	7.31	7.12
maximum	15.59	15.59	15.37
MAD	**1.17**	**1.29**	**1.14**
CVR%	30.8	35.3	29.9
mean	3.93	3.7	3.98
SD	1.27	1.42	1.23
CV%	32.4	38.3	30.9
GM	3.71	3.39	3.79
GSD	1.43	1.59	1.39
powers	2.08	2.08	2.01
skewness	0.87	1.06	0.85

Sample locations

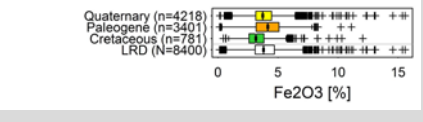
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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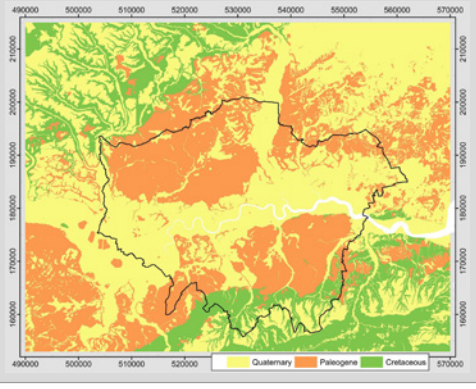

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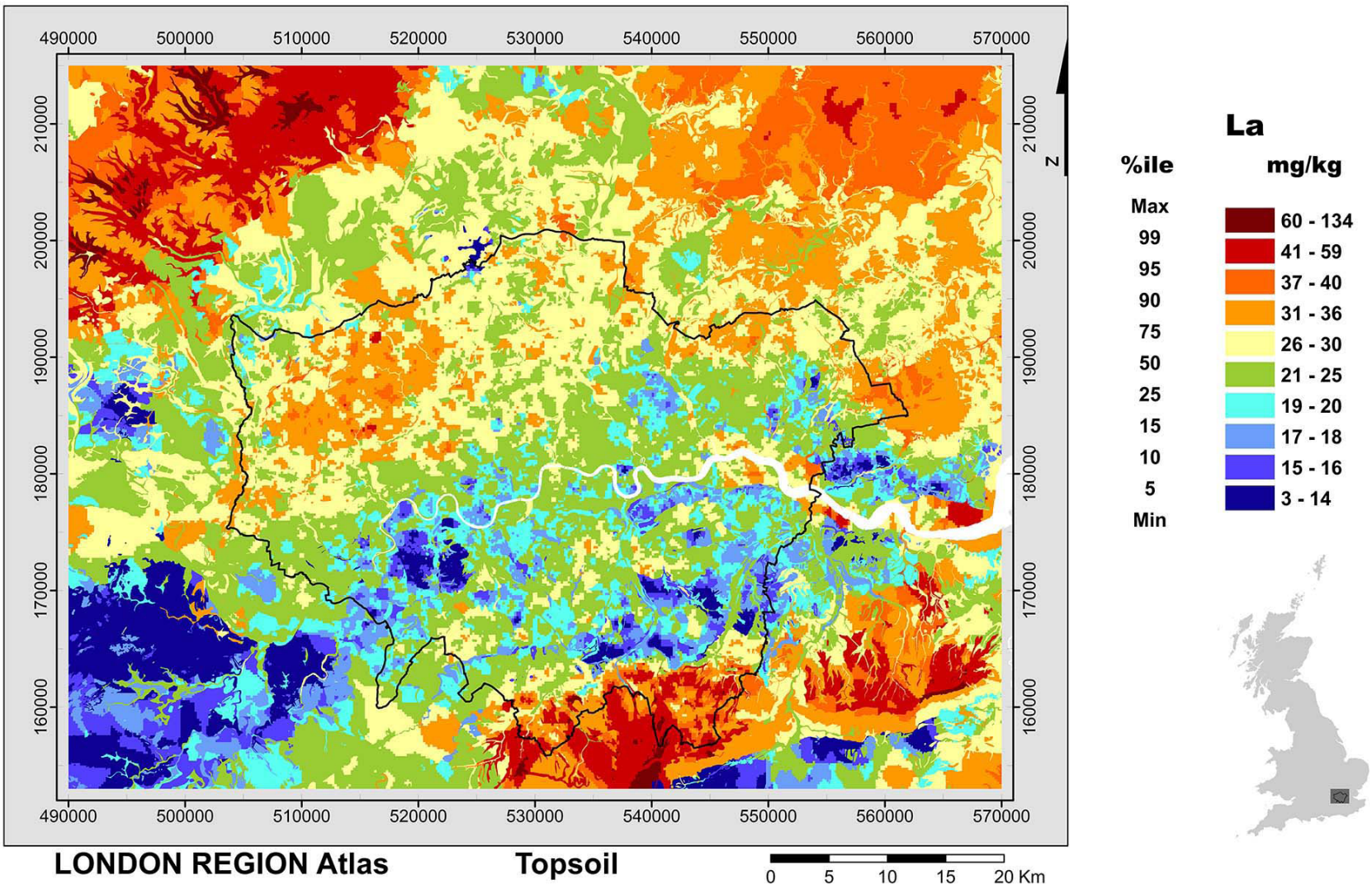
Lanthanum: LRA



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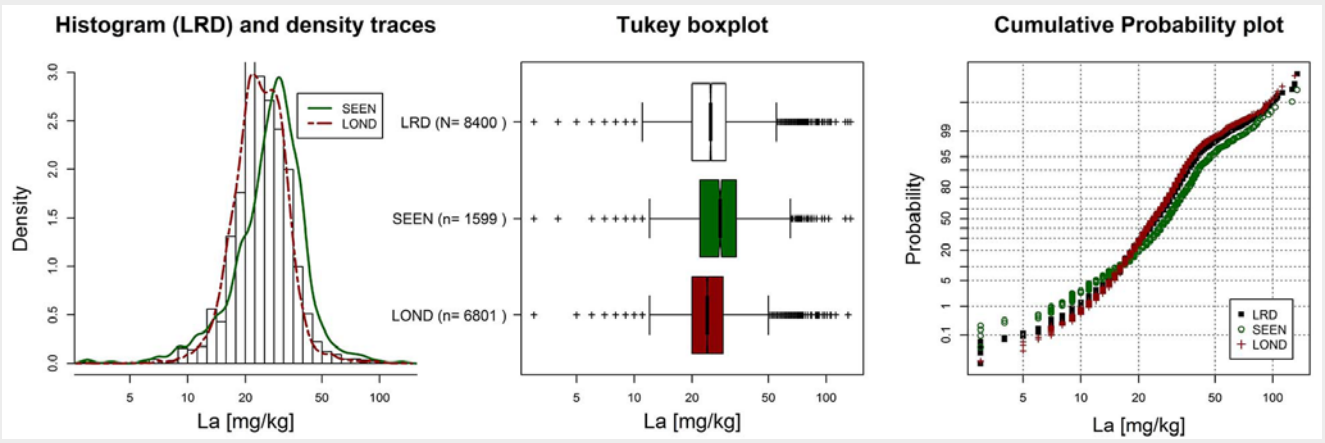
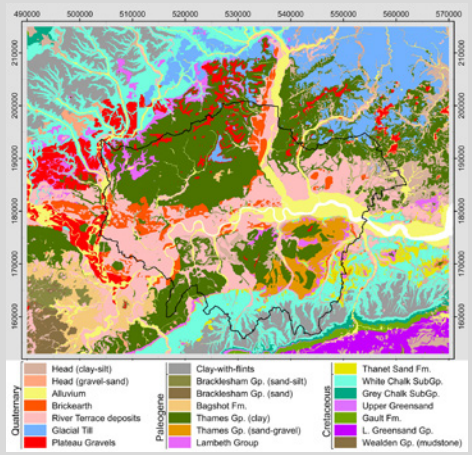


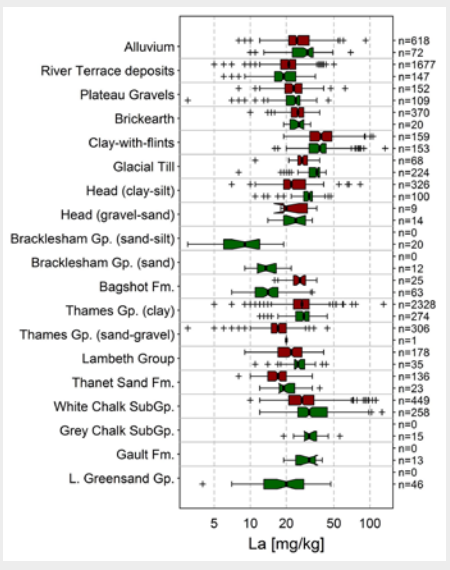
La [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1)	0	0	0
minimum	3	3	3
Q25	20	22	20
median	**25**	**28**	**24**
Q75	30	34	29
Q95	40	47	38
Q99	59	73	55
maximum	134	134	130
MAD	**7.4**	**8.9**	**7.4**
CVR%	29.7	31.8	30.9
mean	25.9	29	25.1
SD	9.6	12.1	8.7
CV%	37	41.5	34.7
GM	24.4	26.7	23.9
GSD	1.41	1.53	1.37
powers	1.65	1.65	1.64
skewness	2.41	1.94	2.49

Simplified GEOLOGY (adapted from DiGMapGB-50)

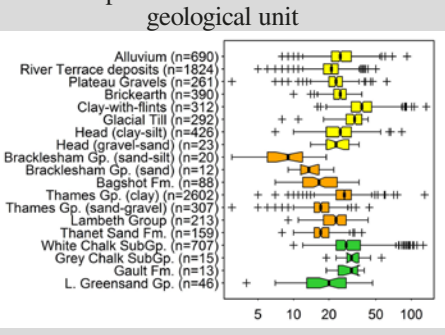


Sample locations

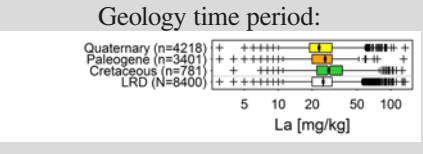
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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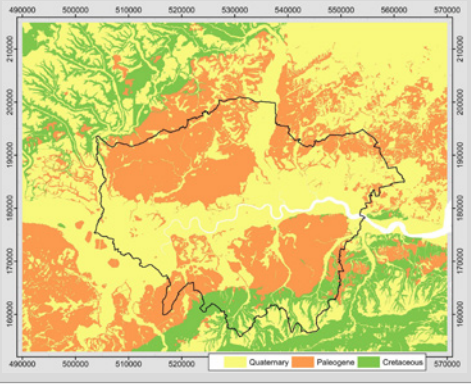

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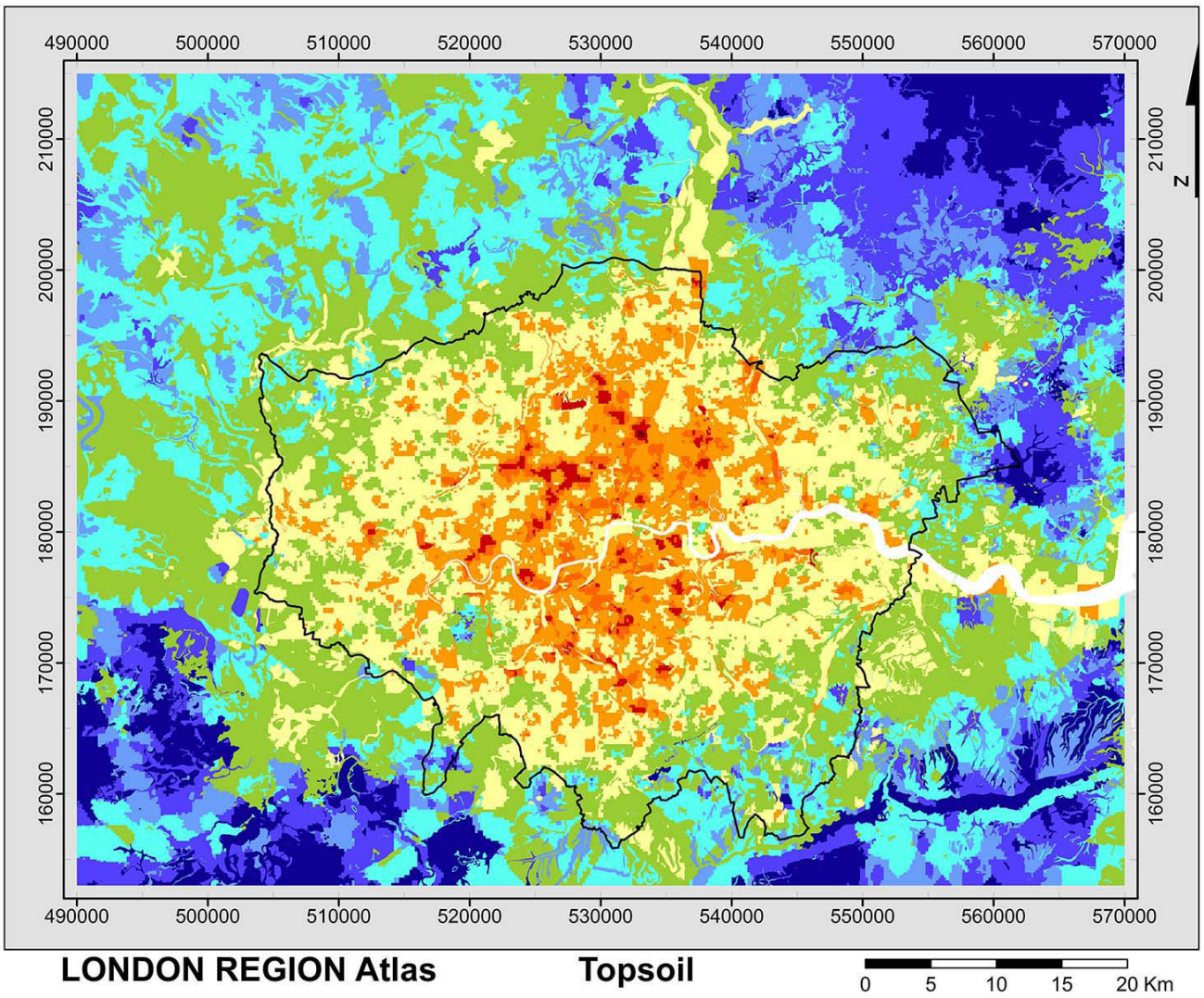
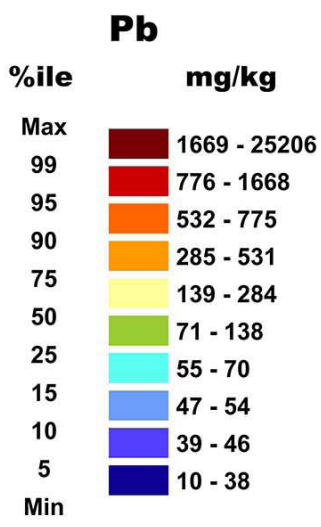
Lead: LRA





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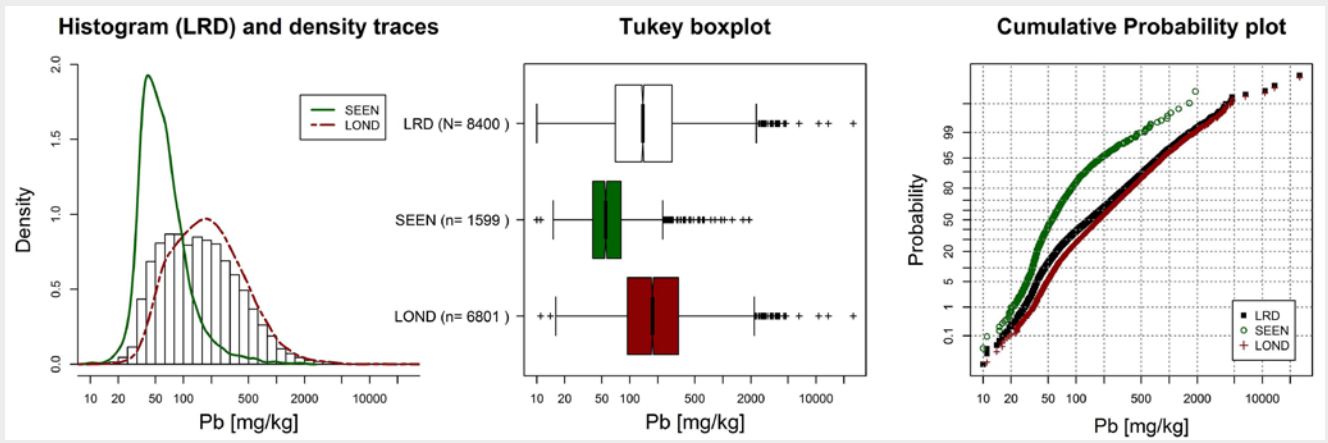
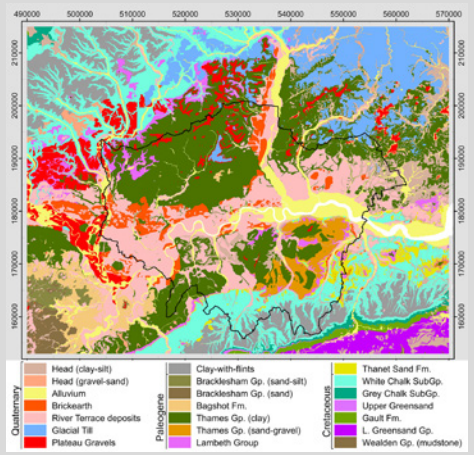
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets

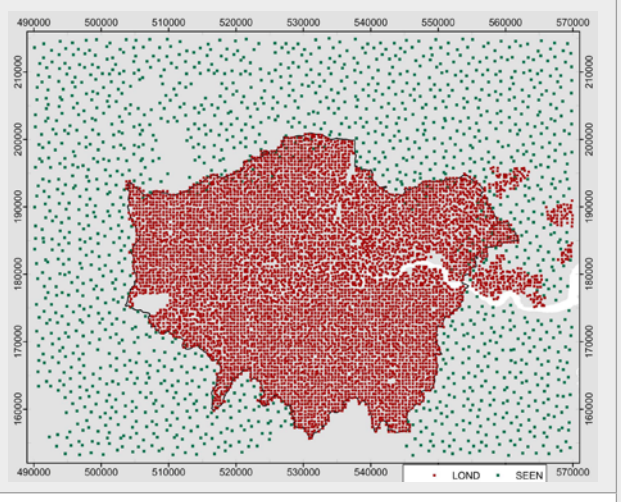


Pb [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1.3)	0	0	0
minimum	10	10	11
Q25	70	40	94
median	**138**	**55**	**175**
Q75	284	80.5	332
Q95	775	184.1	845
Q99	1668.1	484.2	1864
maximum	25206	1914	25206
MAD	**121.6**	**25.2**	**145.3**
CVR%	88.1	45.8	83
mean	250.7	78.5	291.2
SD	477.2	104.8	519.6
CV%	190.3	133.4	178.4
GM	148.8	60.8	183.7
GSD	2.59	1.82	2.45
powers	3.4	2.28	3.36
skewness	22.97	8.94	21.73

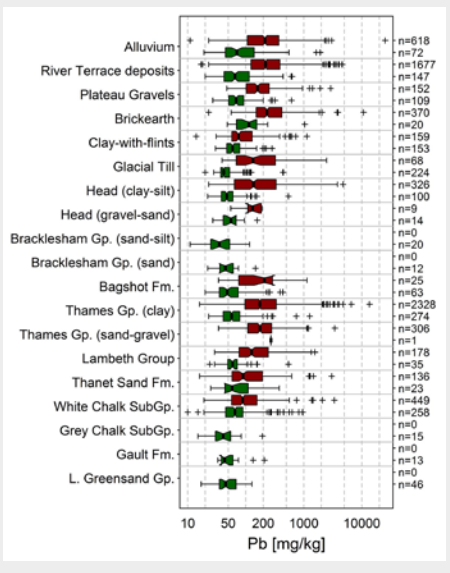
Simplified GEOLOGY (adapted from DiGMapGB-50)



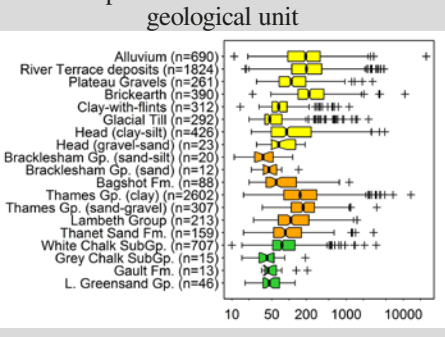
Sample locations



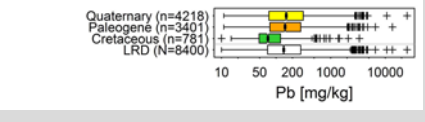
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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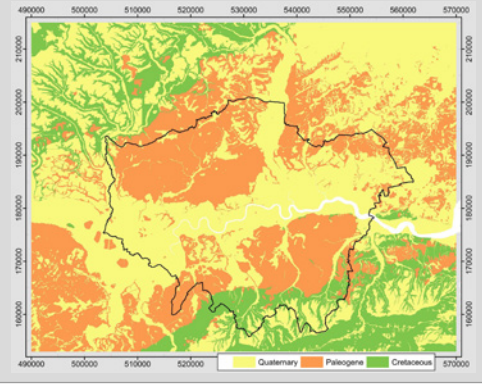

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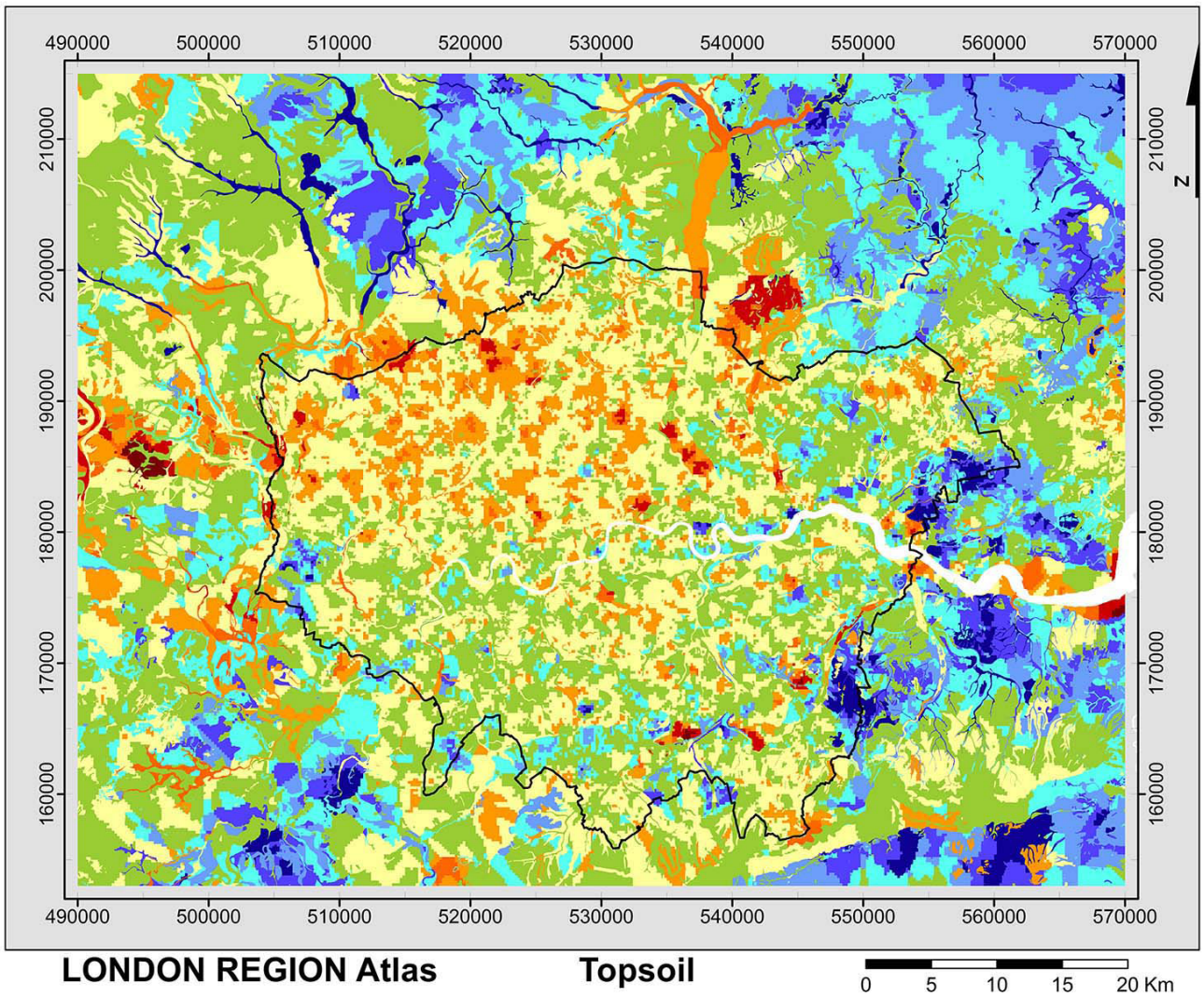
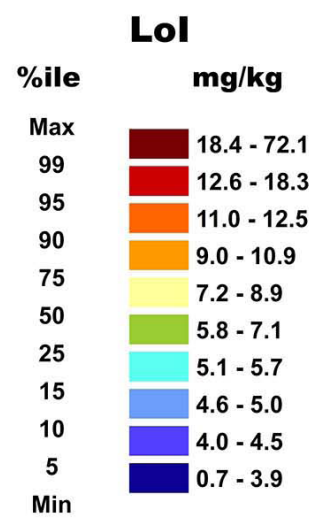
Loss on ignition: LRA





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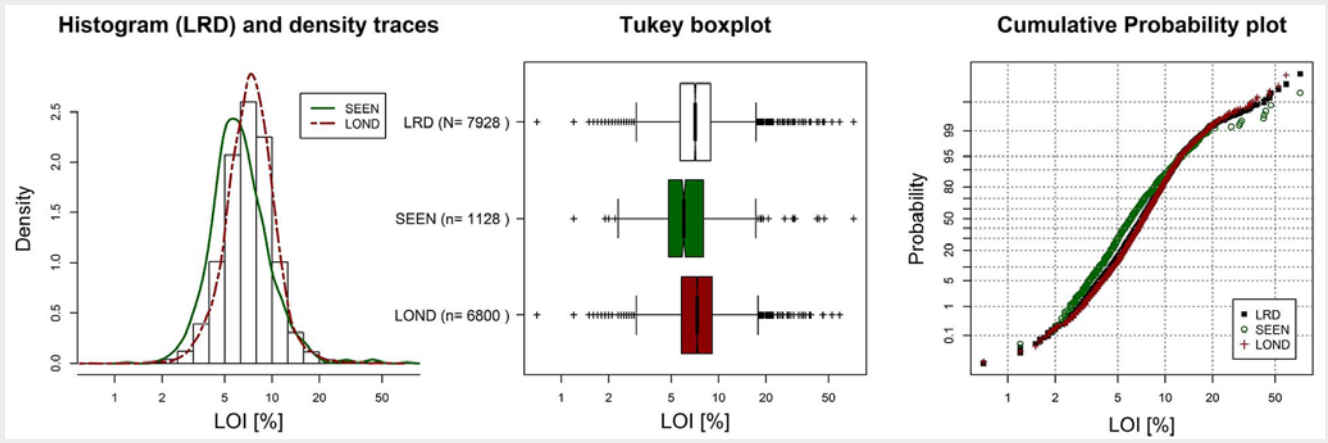
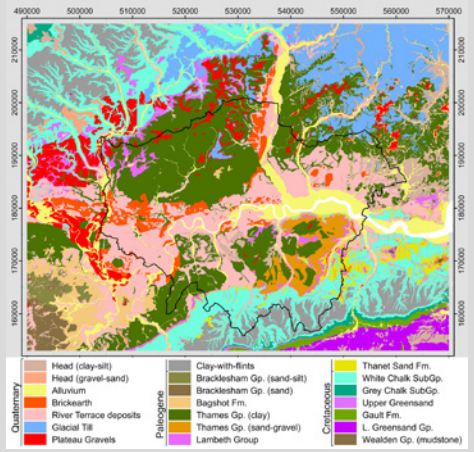
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



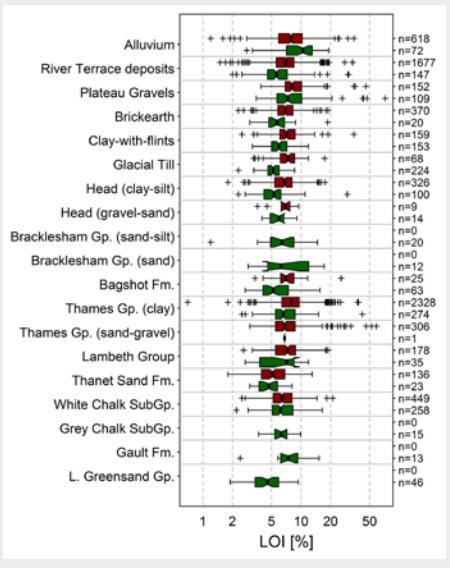
Simplified GEOLOGY (adapted from DiGMapGB-50)



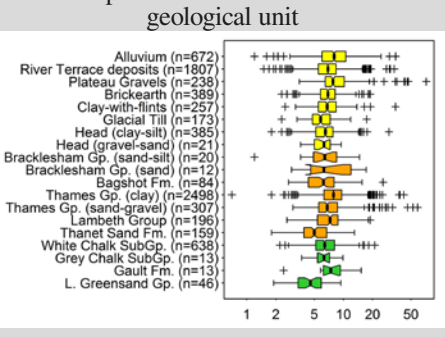
LOI [%]	statistical parameters		
	LRD	SEEN	LOND
N	7928	1128	6800
%<LLD (0.01)	0	0	0
minimum	0.7	1.2	0.7
Q25	5.7	4.8	5.8
median	**7.1**	**6**	**7.3**
Q75	8.9	8	9.1
Q95	12.5	12.8	12.5
Q99	18.3	18.67	18.3
maximum	72.1	72.1	58.7
MAD	**2.37**	**2.08**	**2.37**
CVR%	33.4	34.6	32.5
mean	7.64	6.92	7.76
SD	3.35	4.27	3.15
CV%	43.8	61.7	40.6
GM	7.11	6.24	7.26
GSD	1.45	1.53	1.43
powers	2.01	1.78	1.92
skewness	4.27	6.29	3.46

Sample locations

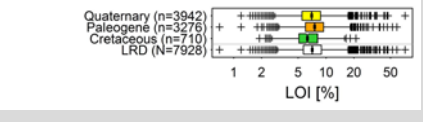
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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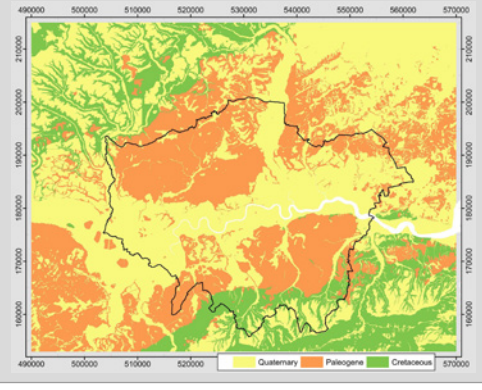

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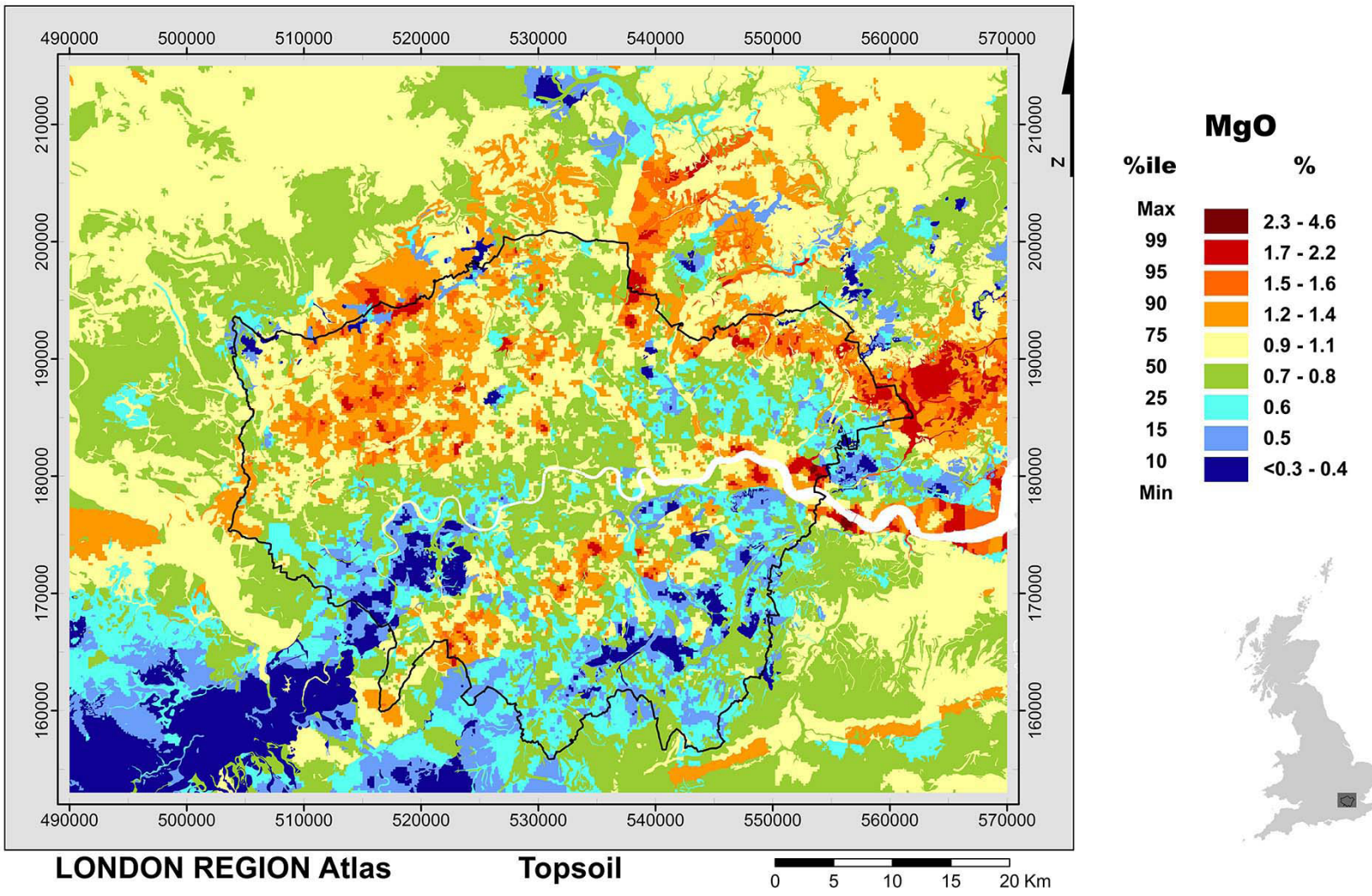
Magnesium: LRA



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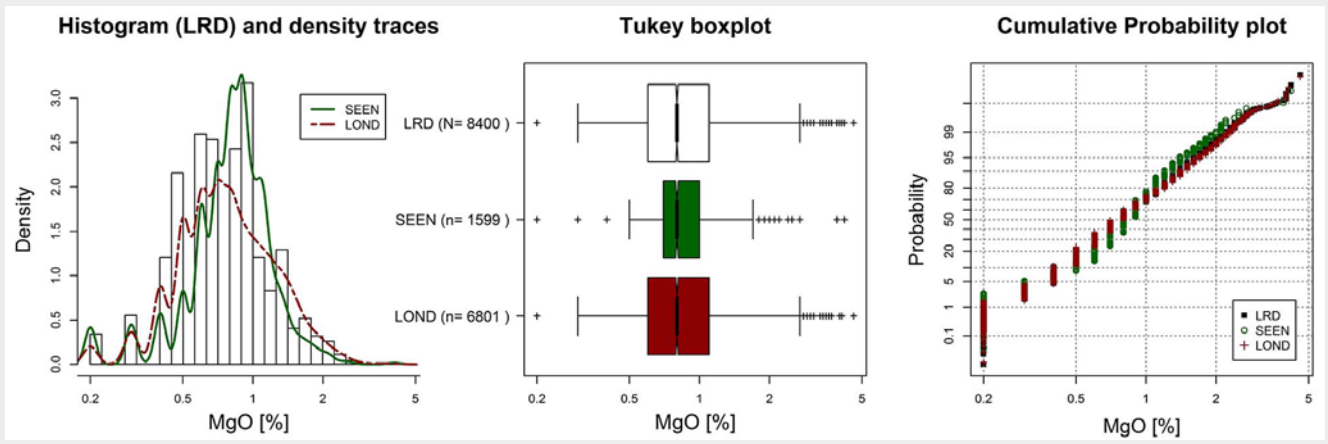
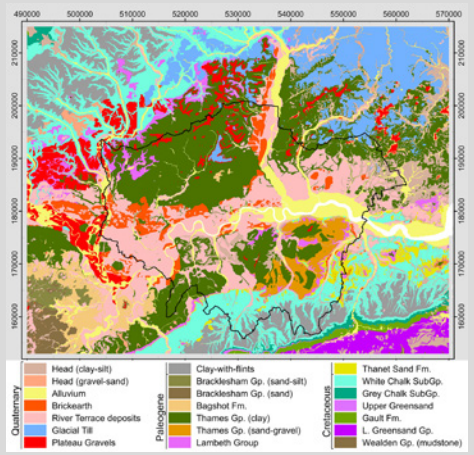
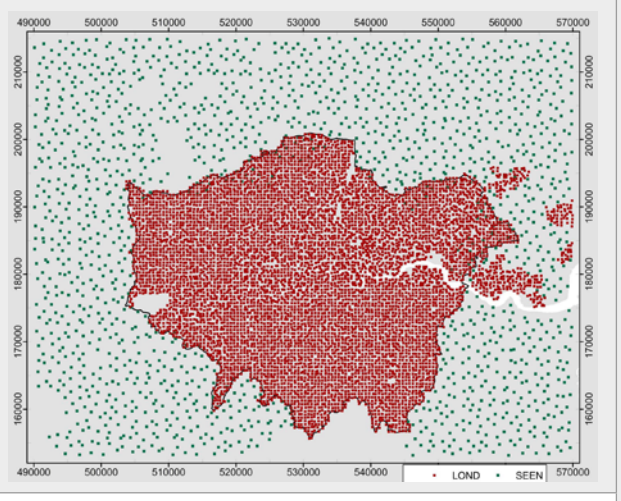


MgO [%]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.3)	1.71	2.5	1.53
minimum	<0.3	<0.3	<0.3
Q25	0.6	0.7	0.6
median	**0.8**	**0.8**	**0.8**
Q75	1.1	1	1.1
Q95	1.6	1.4	1.7
Q99	2.2	2	2.3
maximum	4.6	4.2	4.6
MAD	**0.3**	**0.3**	**0.3**
CVR%	37.1	37.1	37.1
mean	0.9	0.9	0.9
SD	0.4	0.3	0.4
CV%	48.5	40.6	50.2
GM	0.8	0.8	0.8
GSD	1.59	1.53	1.61
powers	1.36	1.32	1.36
skewness	1.65	1.78	1.62

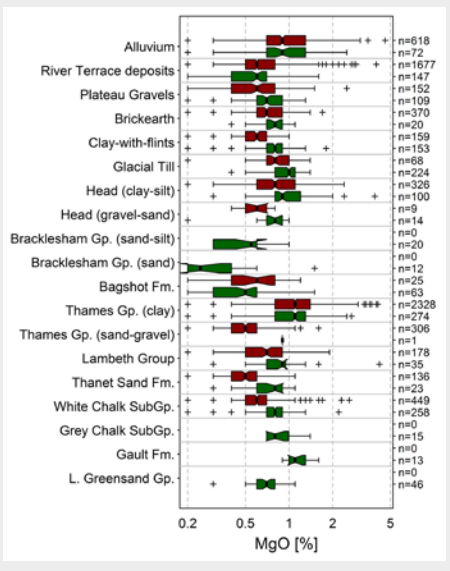
Simplified GEOLOGY (adapted from DiGMapGB-50)



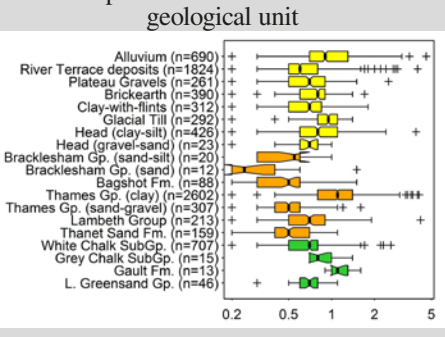
Sample locations



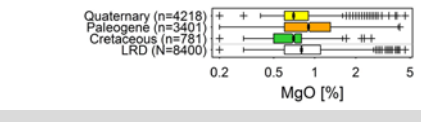
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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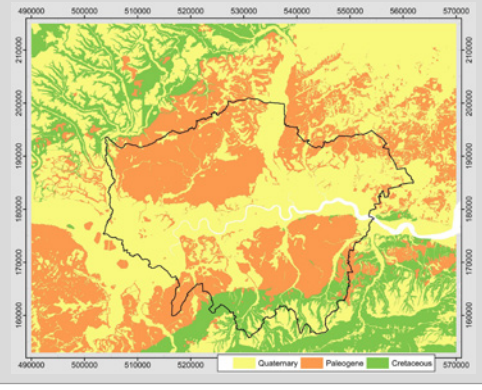

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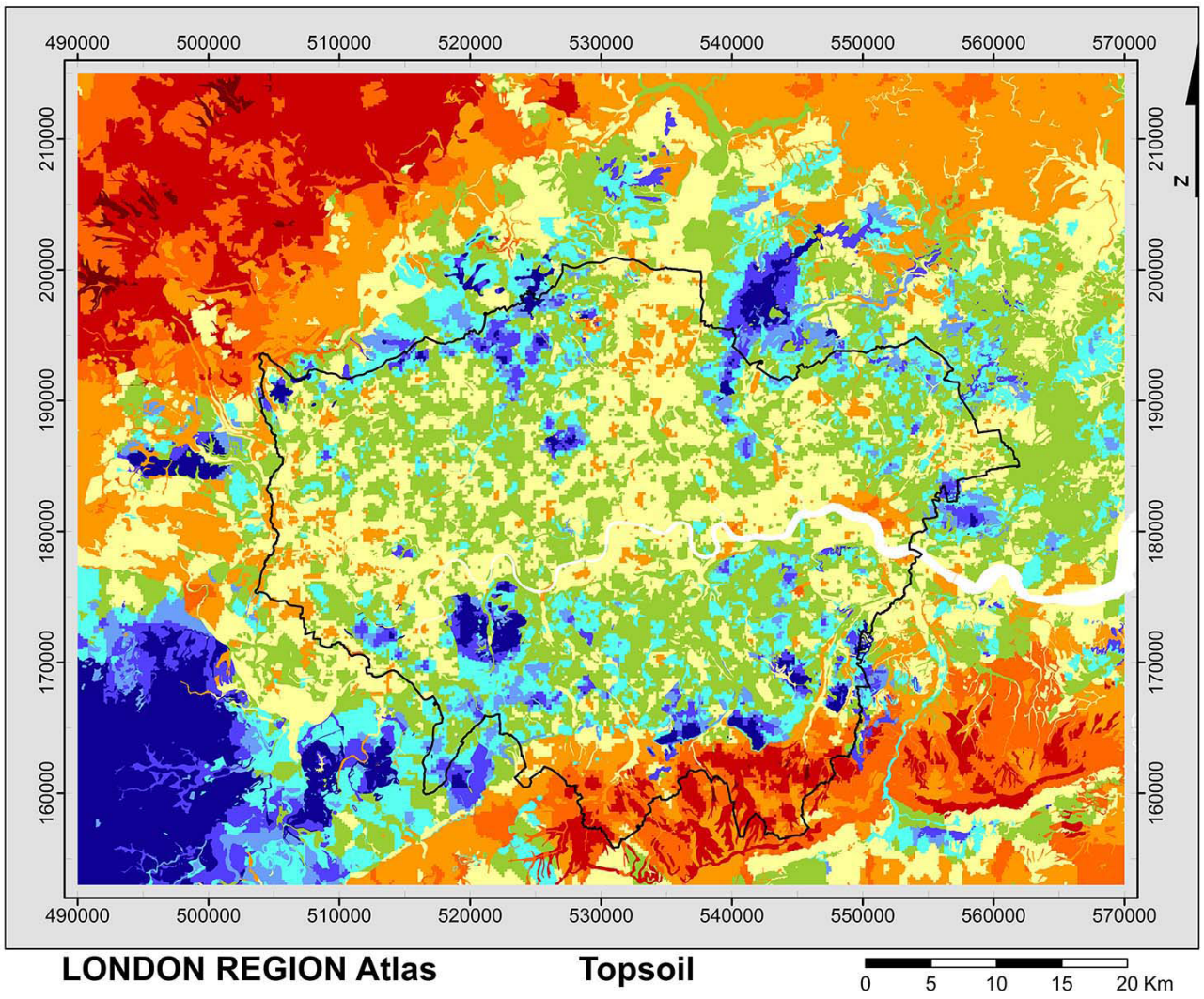
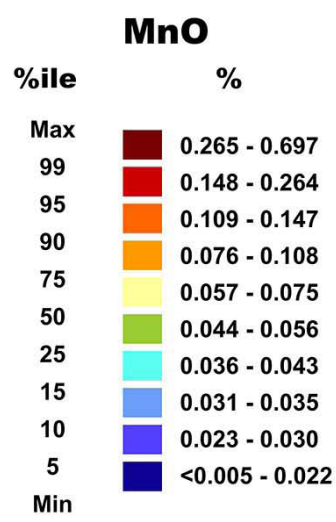
Manganese: LRA





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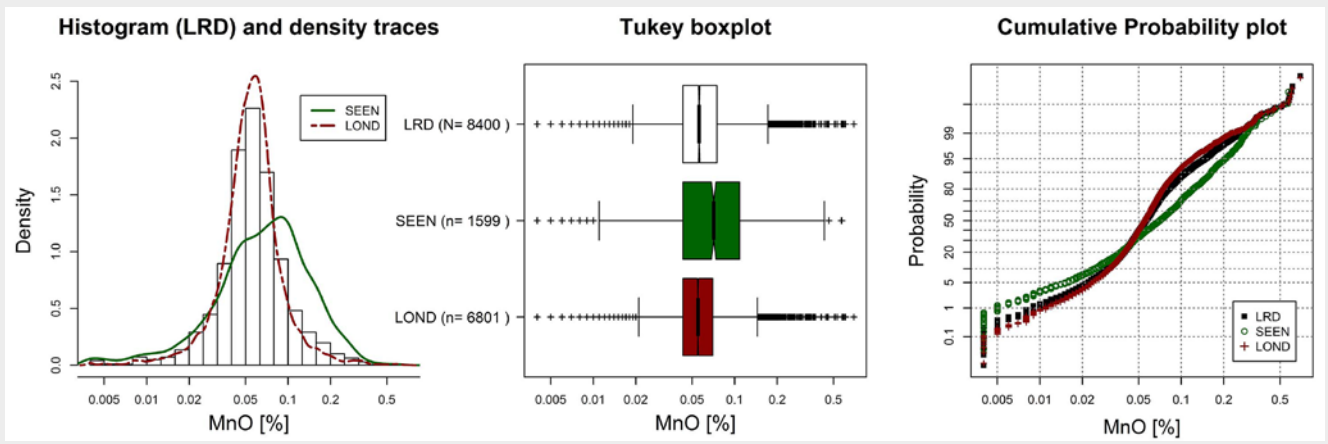

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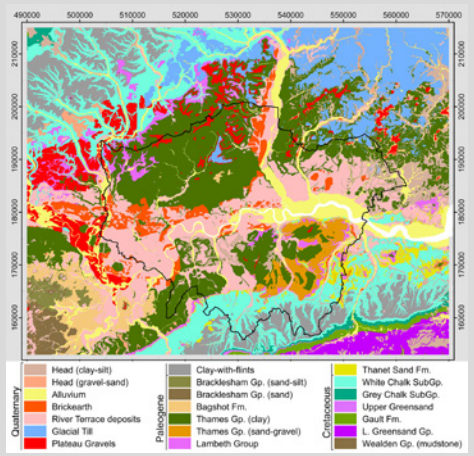
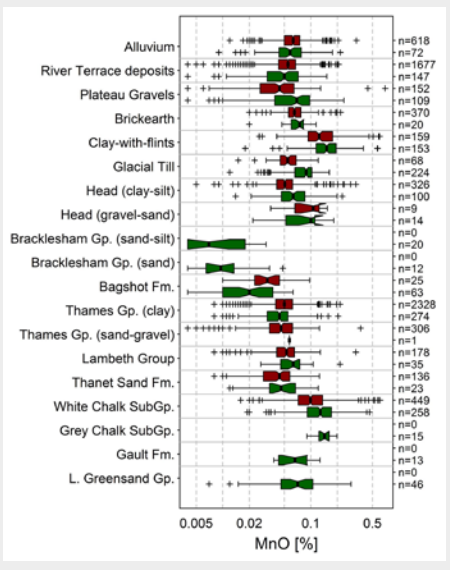


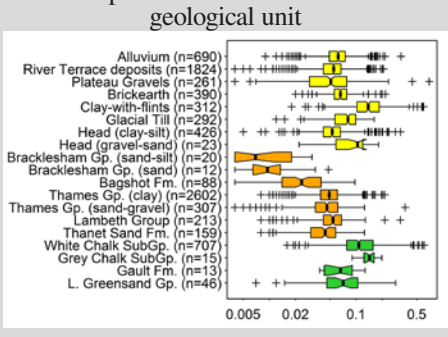
MnO [%]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.005)	0.24	0.75	0.12
minimum	<0.005	<0.005	<0.005
Q25	0.043	0.043	0.043
median	**0.056**	**0.071**	**0.055**
Q75	0.075	0.108	0.07
Q95	0.147	0.205	0.12
Q99	0.264	0.29	0.226
maximum	0.697	0.573	0.697
MAD	**0.022**	**0.047**	**0.019**
CVR%	39.7	66.8	35
mean	0.066	0.085	0.062
SD	0.047	0.063	0.041
CV%	70.7	73.6	66.6
GM	0.056	0.065	0.054
GSD	1.79	2.21	1.67
powers	2.24	2.16	2.24
skewness	4.01	1.98	5.23

Sample locations

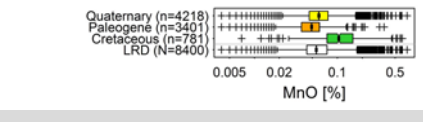
LOND and SEEN topsoil concentrations over each geological unit



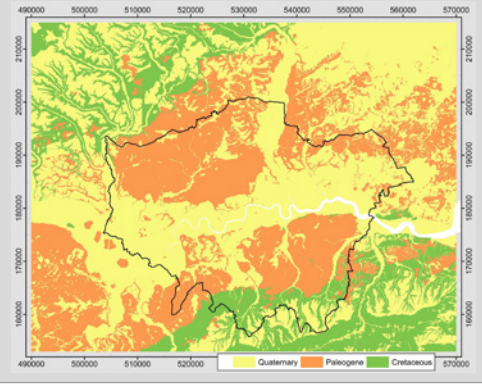
LRD topsoil concentrations over each geological unit



Geology time period:



At each site a composite topsoil (5–20 cm depth) sample comprising five subsamples was collected from the corners and centre of a 20 x 20 m square. After collection samples were air/oven dried and sieved to <2 mm before analysis to determine the total contents of more than 50 chemical elements by X-ray fluorescence spectrometry (XRFS).



Each geochemical map was prepared by interpolating the point data using the parent material mapping method (Appleton et al., 2013[1]). The LRA area was subdivided into 200 x 200 m squares and intercepted with the geology (parent material) polygons, thereby creating the basic 200 m-PM polygons. For each 200 m-PM polygon the average concentration based on the four nearest samples over the same PM was computed (see further explanation in Materials and methods and references therein). As the maps (produced in ArcGIS 10.1) show estimated concentrations, there is a degree of uncertainty due to variability in soil composition. The element concentration colour ramp is based on percentile classes of the LRD dataset distribution. The tables and graphs were generated running R (R x 64 3.1.0) in RStudio (Version 0.98.977). The LRD, LOND and SEEN surveys are represented by the colours black/white, dark green and dark red respectively. Quaternary, Palaeogene and Cretaceous geological time periods are represented by soft yellow, orange and lime green colours respectively. For further information go to Univariate statistics and graphics.

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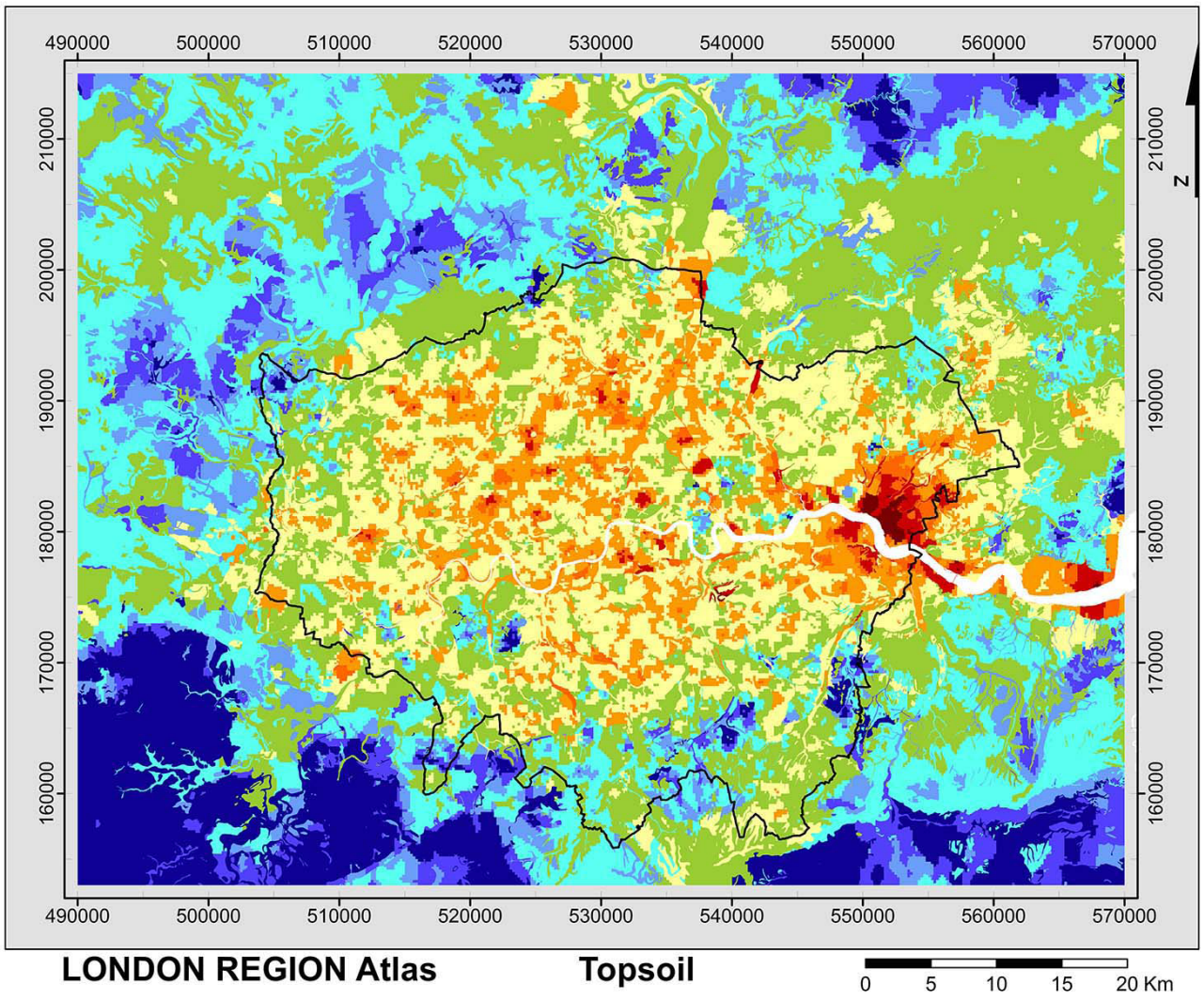
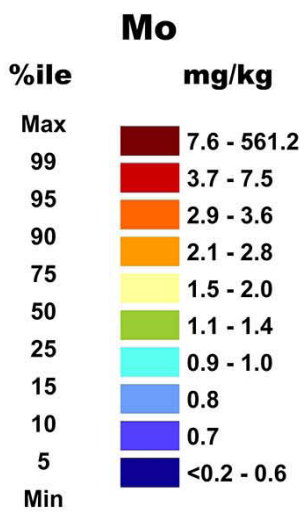
Molybdenum: LRA





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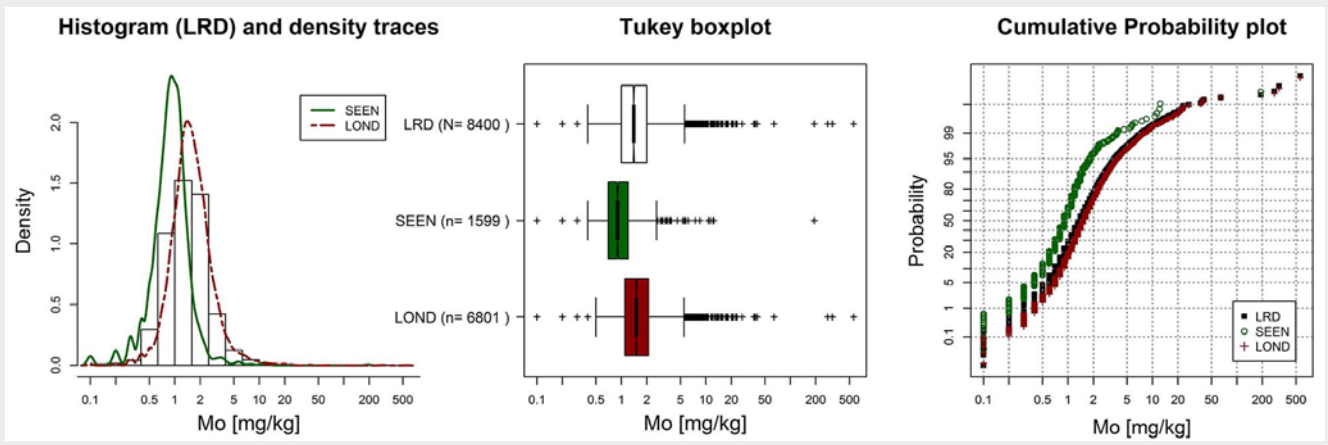
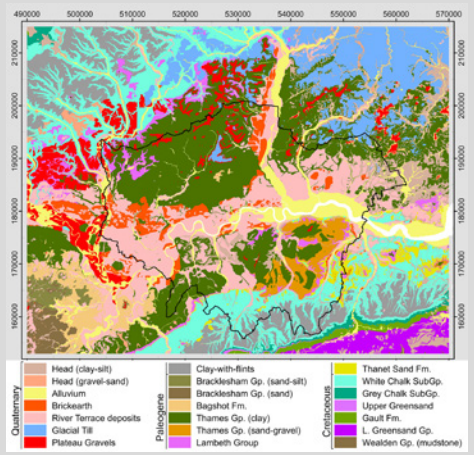
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



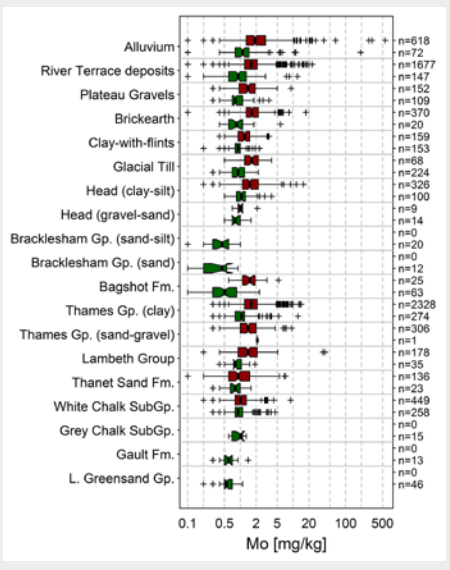
Simplified GEOLOGY (adapted from DiGMapGB-50)



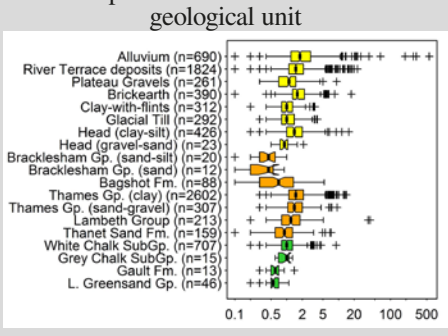
Mo [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.2)	0.21	0.69	0.1
minimum	<0.2	<0.2	<0.2
Q25	1	0.7	1.1
median	**1.4**	**0.9**	**1.5**
Q75	2	1.2	2.1
Q95	3.6	1.8	3.8
Q99	7.5	3.8	7.8
maximum	561.2	192.2	561.2
MAD	**0.7**	**0.3**	**0.7**
CVR%	52.9	32.9	49.4
mean	1.9	1.1	2
SD	8.1	4.8	8.7
CV%	432.6	424.7	424.7
GM	1.4	0.9	1.6
GSD	1.83	1.7	1.77
powers	3.75	3.28	3.75
skewness	52.72	38.34	51.3

Sample locations

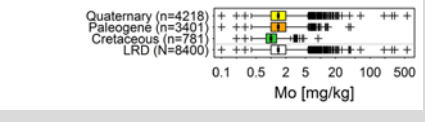
LOND and SEEN topsoil concentrations over each geological unit



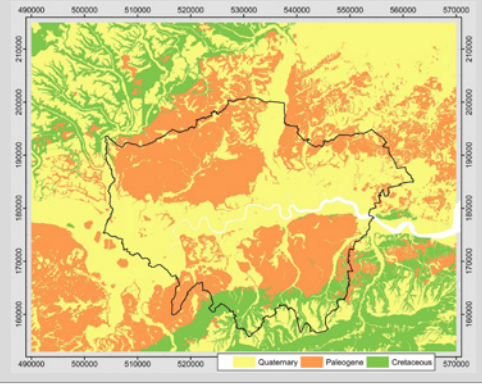
LRD topsoil concentrations over each geological unit



Geology time period:



At each site a composite topsoil (5–20 cm depth) sample comprising five subsamples was collected from the corners and centre of a 20 x 20 m square. After collection samples were air/oven dried and sieved to <2 mm before analysis to determine the total contents of more than 50 chemical elements by X-ray fluorescence spectrometry (XRFS).



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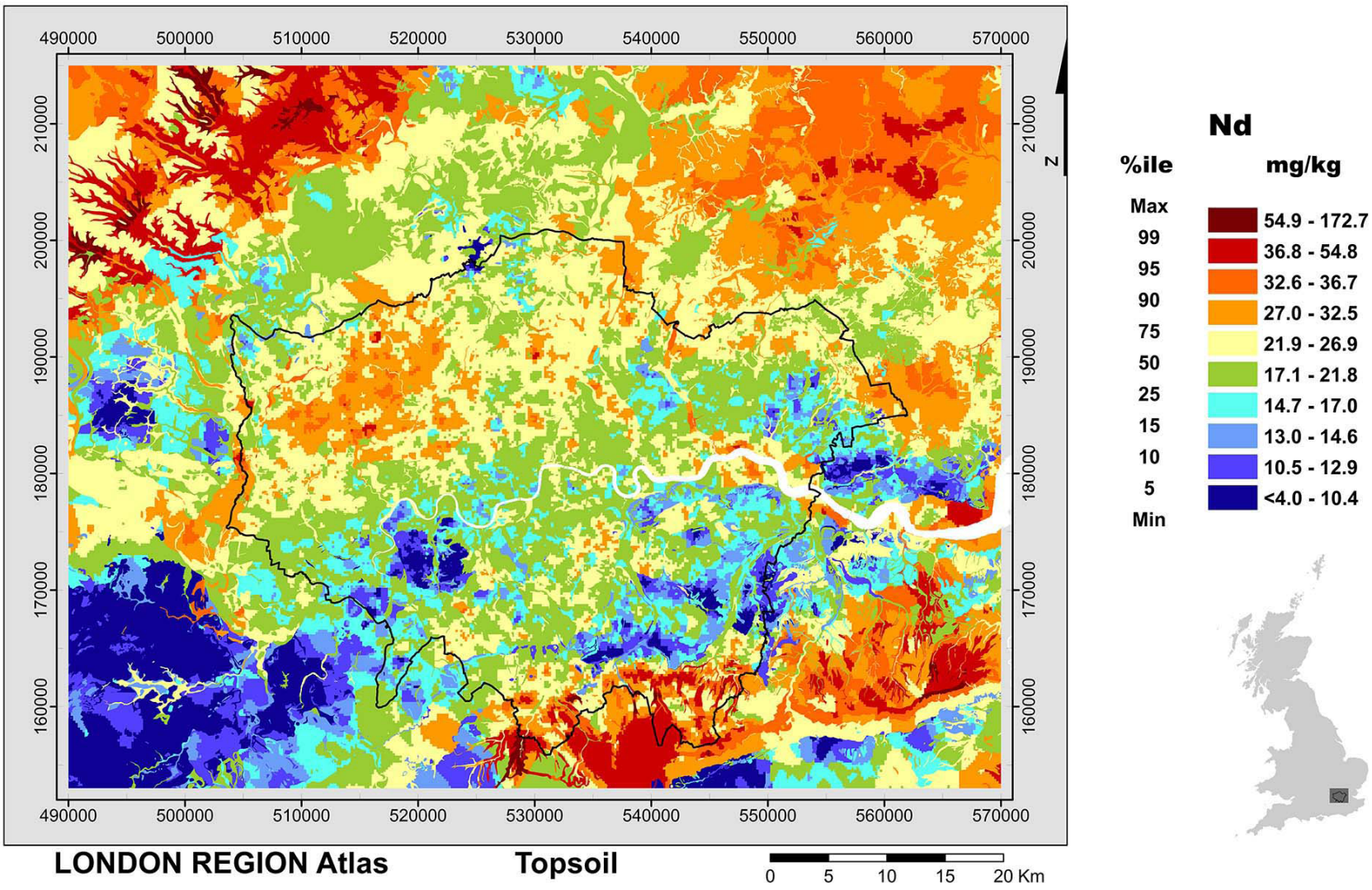
Neodymium: LRA



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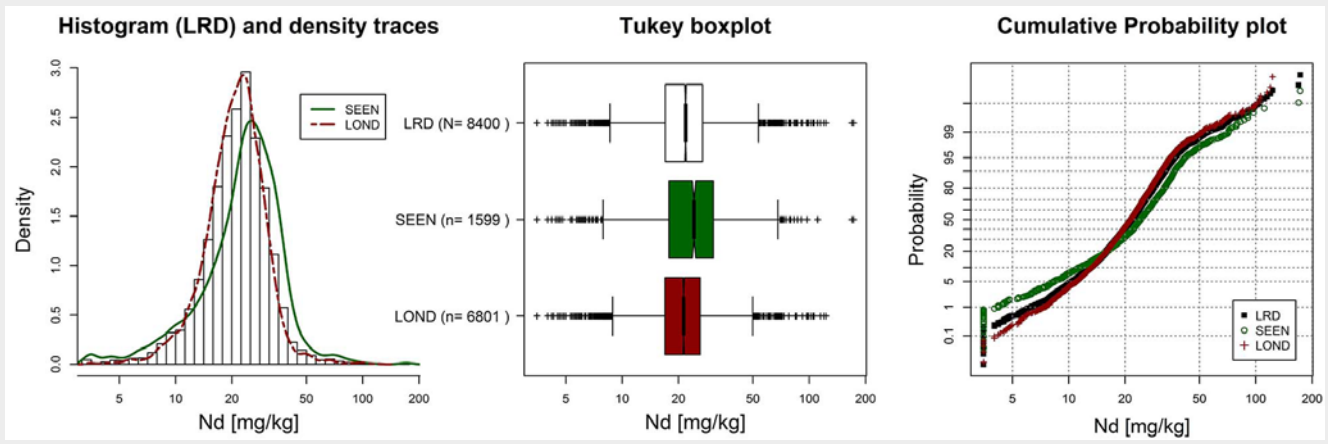
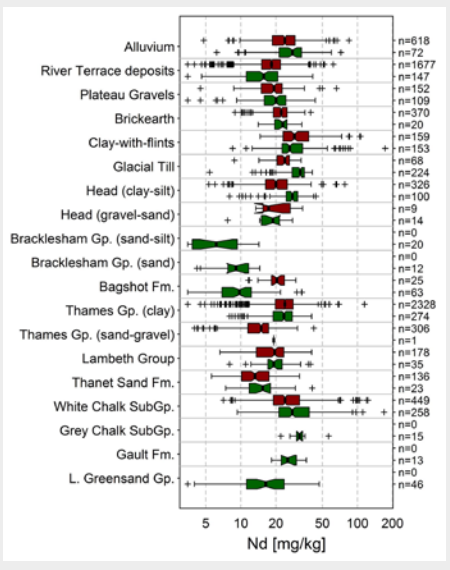
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



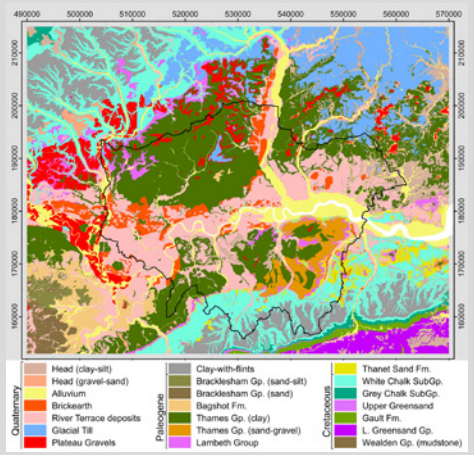
Nd [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (4)	0.23	0.88	0.07
minimum	<4	<4	<4
Q25	17	17.8	16.9
median	**21.8**	**24.2**	**21.3**
Q75	26.9	30.7	26.1
Q95	36.7	41.7	34.7
Q99	54.8	71.2	51.4
maximum	172.7	172.7	122.8
MAD	**7.3**	**9.6**	**6.7**
CVR%	33.3	39.8	31.3
mean	22.7	25.1	22.2
SD	9.7	12.6	8.7
CV%	42.5	50.3	39.4
GM	21	22.3	20.7
GSD	1.49	1.66	1.45
powers	1.69	1.69	1.55
skewness	3.05	3.08	2.7

Sample locations

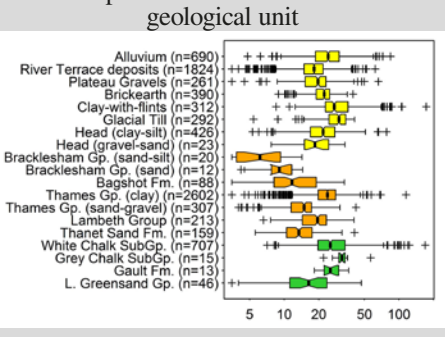
LOND and SEEN topsoil concentrations over each geological unit



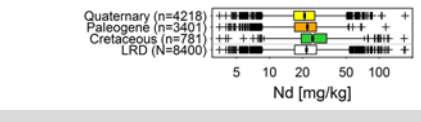
Simplified GEOLOGY (adapted from DiGMapGB-50)



LRD topsoil concentrations over each geological unit



Geology time period:



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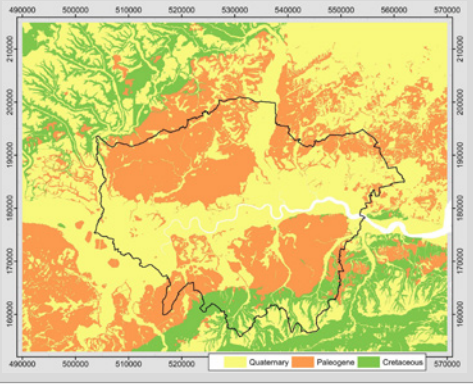

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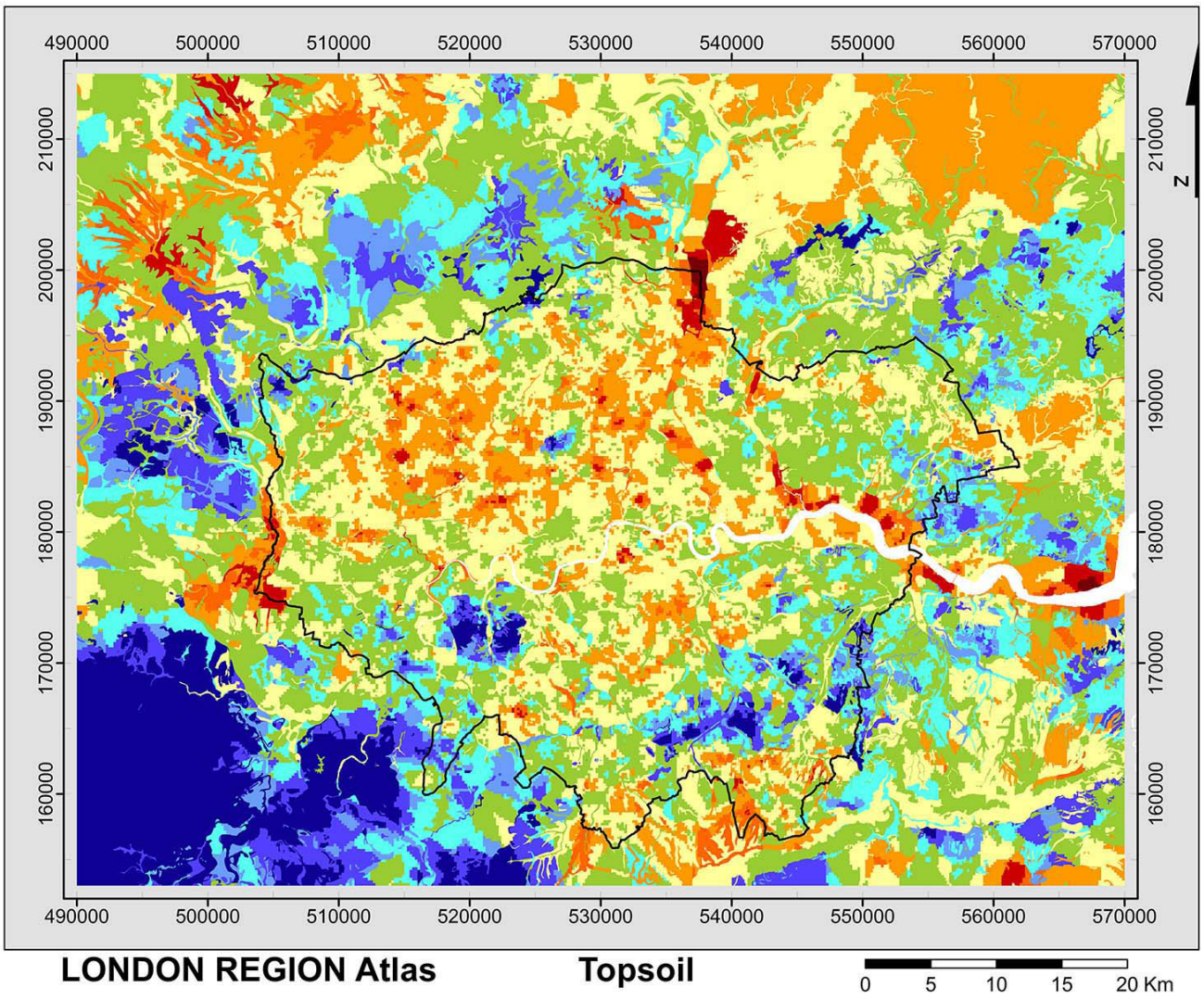
Nickel: LRA



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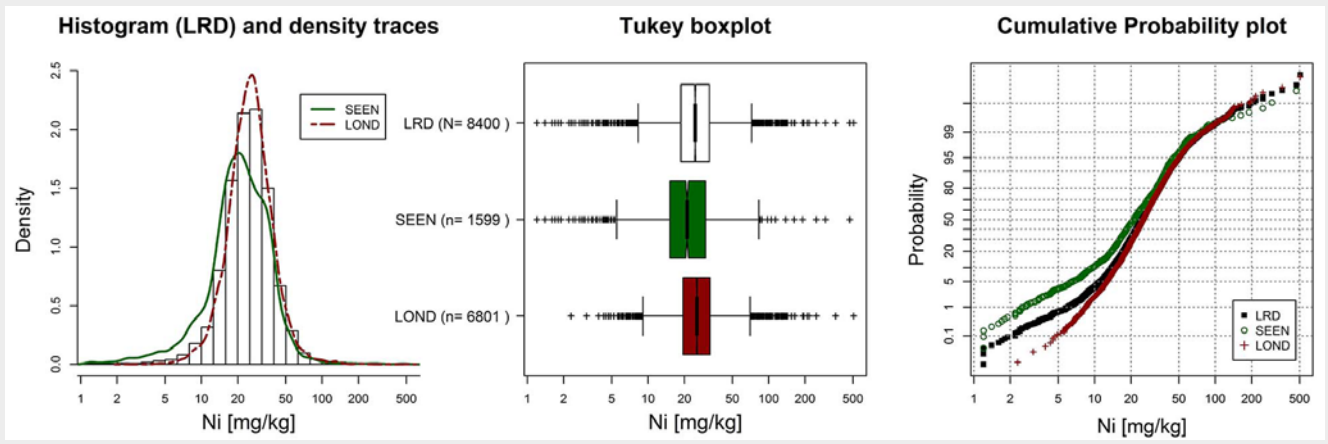
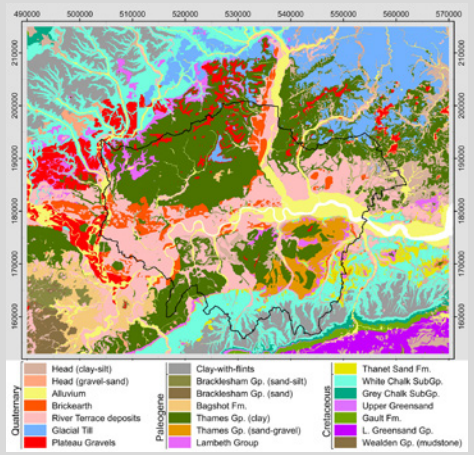
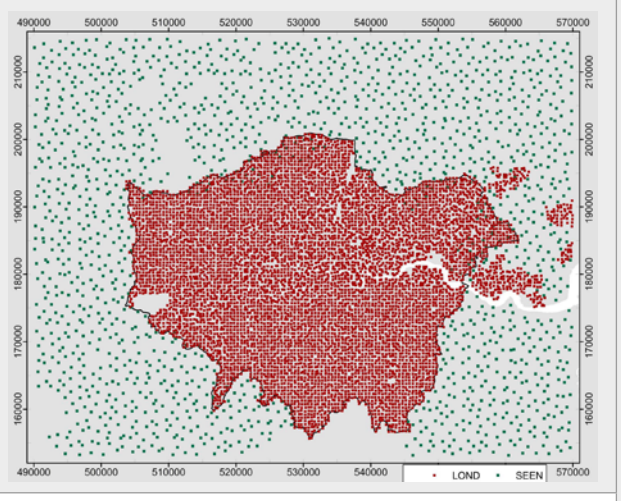


Ni [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1.3)	0.04	0.19	0
minimum	<1.3	<1.3	2.3
Q25	18.7	15.2	19.5
median	**24.6**	**21.1**	**25.4**
Q75	32.2	30	32.6
Q95	49.6	45.6	50.2
Q99	78.3	74.6	79
maximum	505.6	469.4	505.6
MAD	**9.8**	**10.4**	**9.3**
CVR%	39.8	49.2	36.8
mean	27.2	24.1	27.9
SD	16.8	20	15.9
CV%	61.8	82.7	57
GM	24.2	20.1	25.3
GSD	1.62	1.86	1.54
powers	2.62	2.59	2.34
skewness	8.77	10.39	8.05

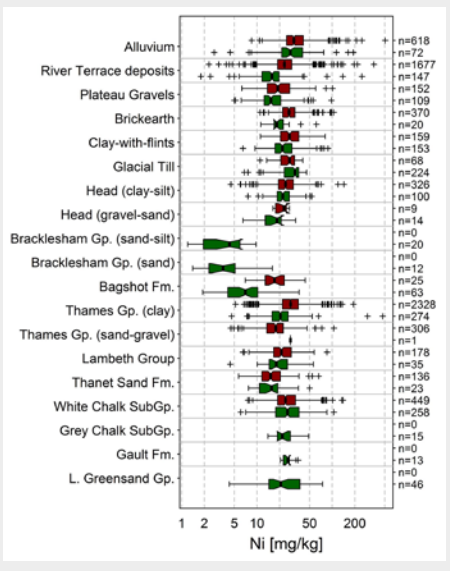
Simplified GEOLOGY (adapted from DiGMapGB-50)



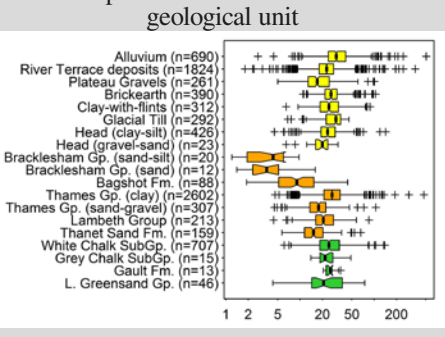
Sample locations



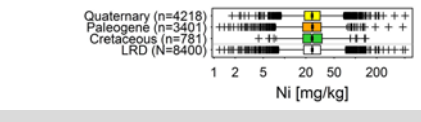
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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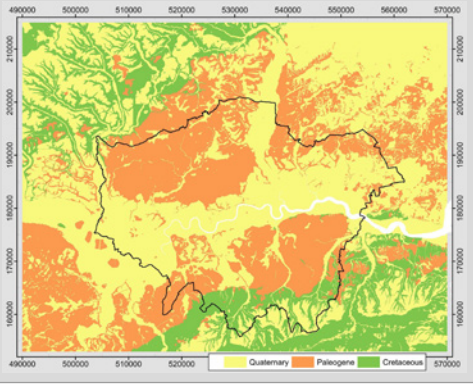

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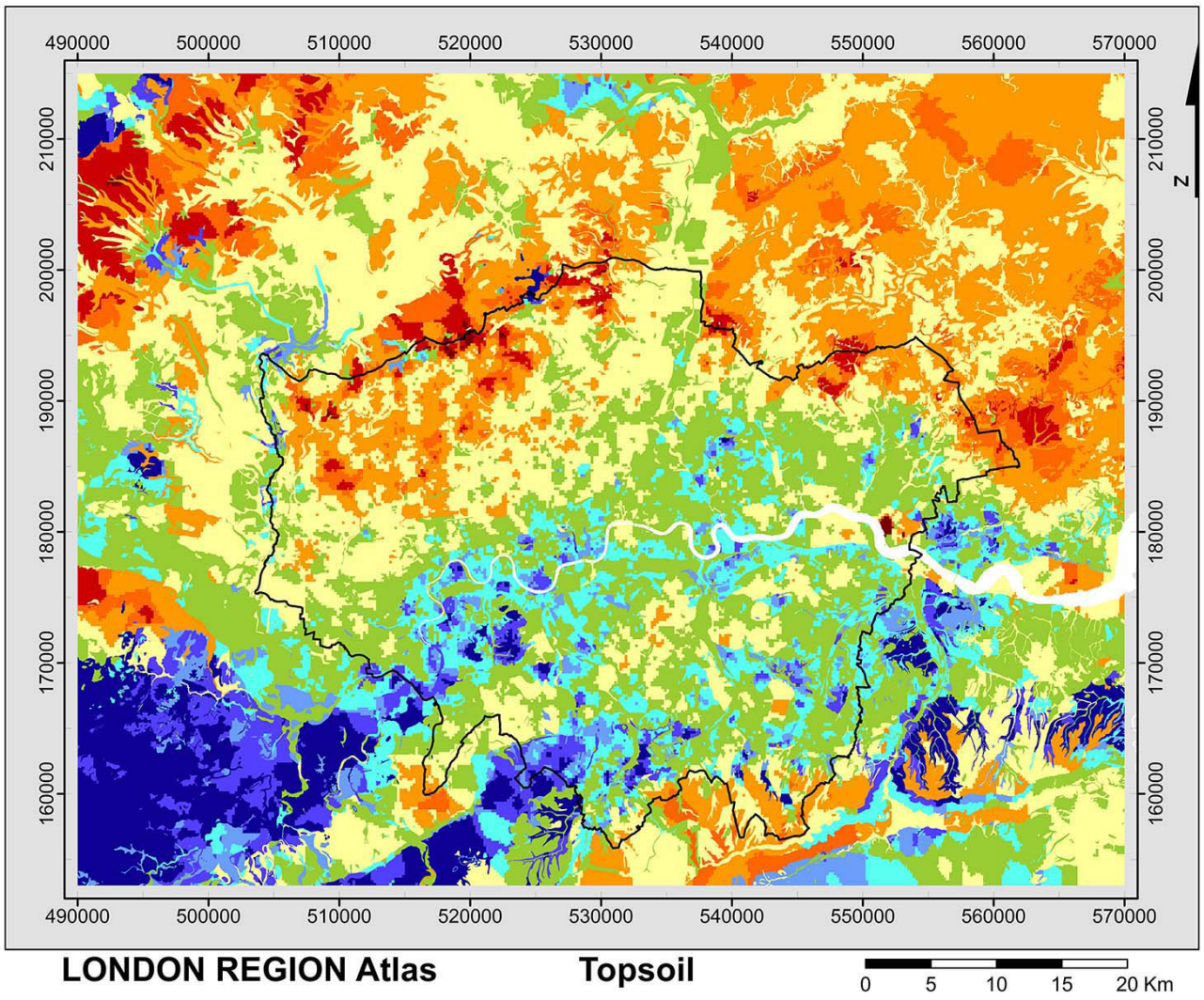
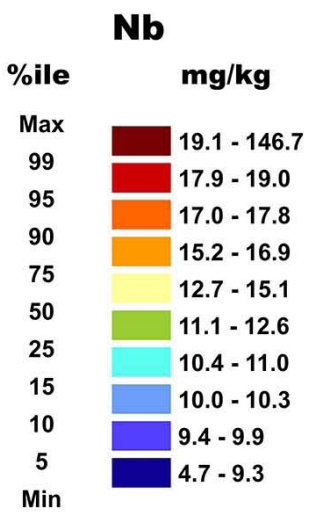
Niobium: LRA





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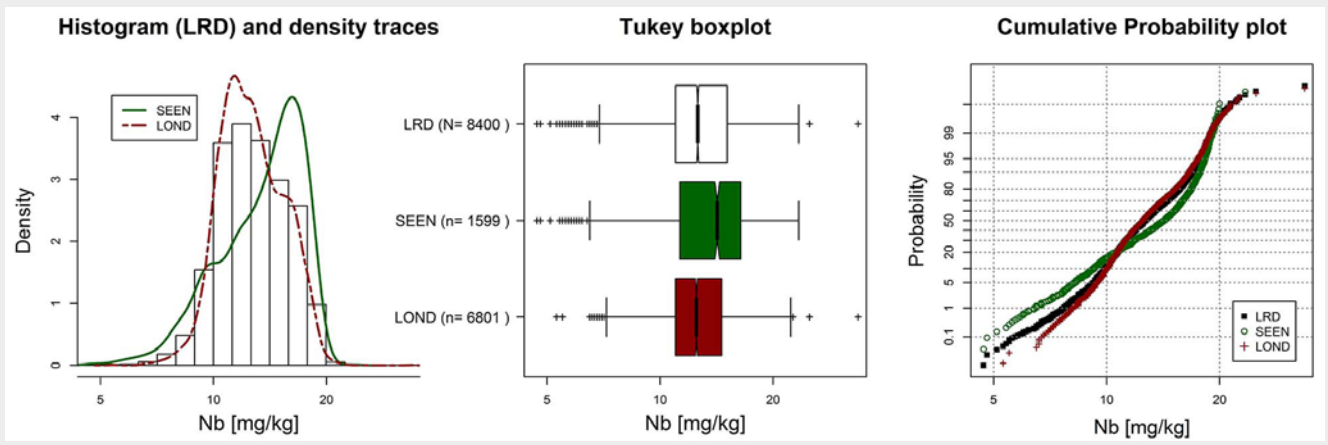
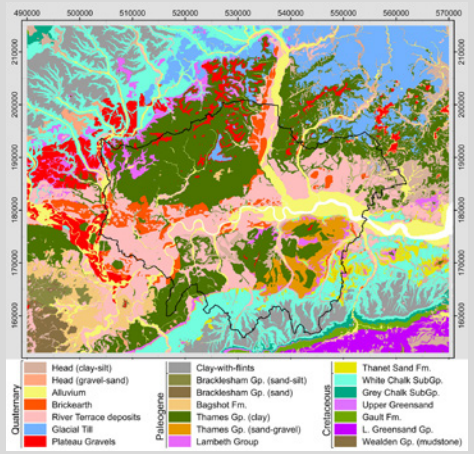
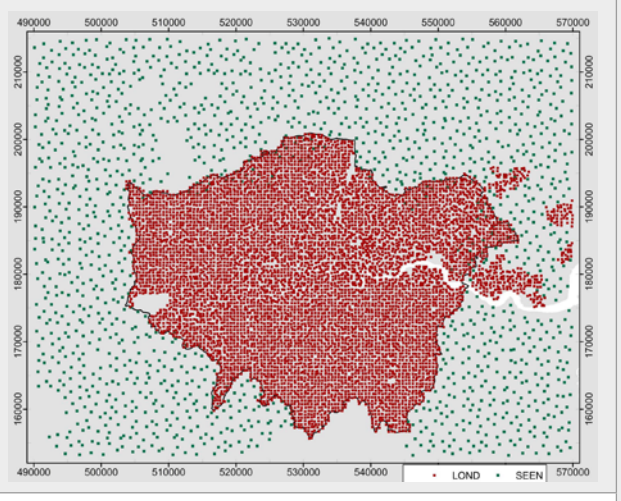


Nb [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1)	0	0	0
minimum	4.7	4.7	5.3
Q25	11	11.3	11
median	**12.6**	**14.2**	**12.5**
Q75	15.1	16.4	14.6
Q95	17.8	18.3	17.5
Q99	19	19.1	18.8
maximum	146.7	23.4	146.7
MAD	**2.8**	**3.7**	**2.5**
CVR%	22.4	26.1	20.2
mean	13.1	13.8	12.9
SD	3.1	3.2	3
CV%	23.5	23.3	23.4
GM	12.8	13.3	12.6
GSD	1.23	1.29	1.22
powers	1.49	0.7	1.44
skewness	10.08	-0.35	13.25

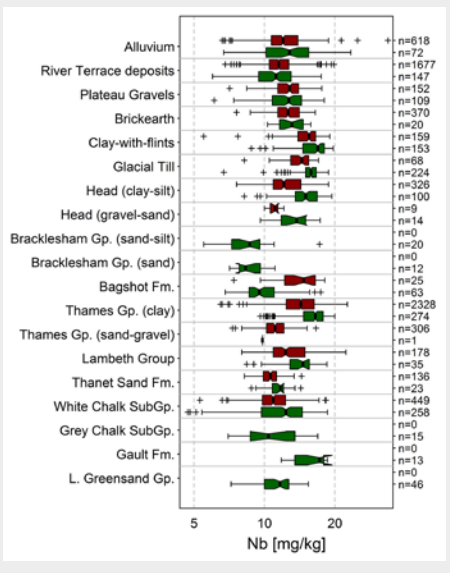
Simplified GEOLOGY (adapted from DiGMapGB-50)



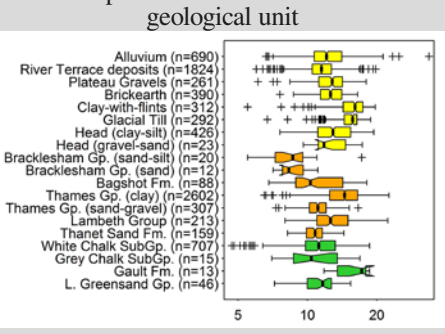
Sample locations



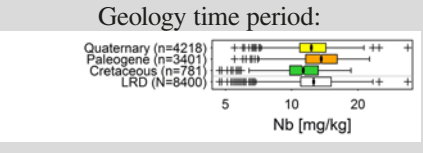
LOND and SEEN topsoil concentrations over each geological unit



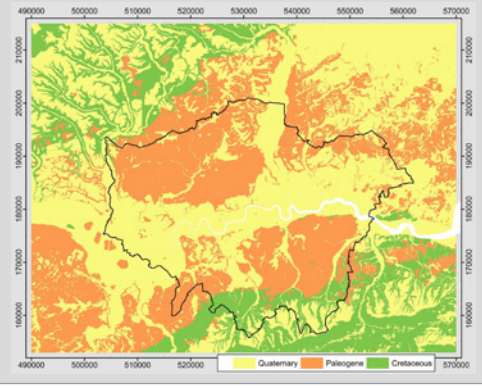
LRD topsoil concentrations over each geological unit



Geology time period:



At each site a composite topsoil (5–20 cm depth) sample comprising five subsamples was collected from the corners and centre of a 20 x 20 m square. After collection samples were air/oven dried and sieved to <2 mm before analysis to determine the total contents of more than 50 chemical elements by X-ray fluorescence spectrometry (XRFS).



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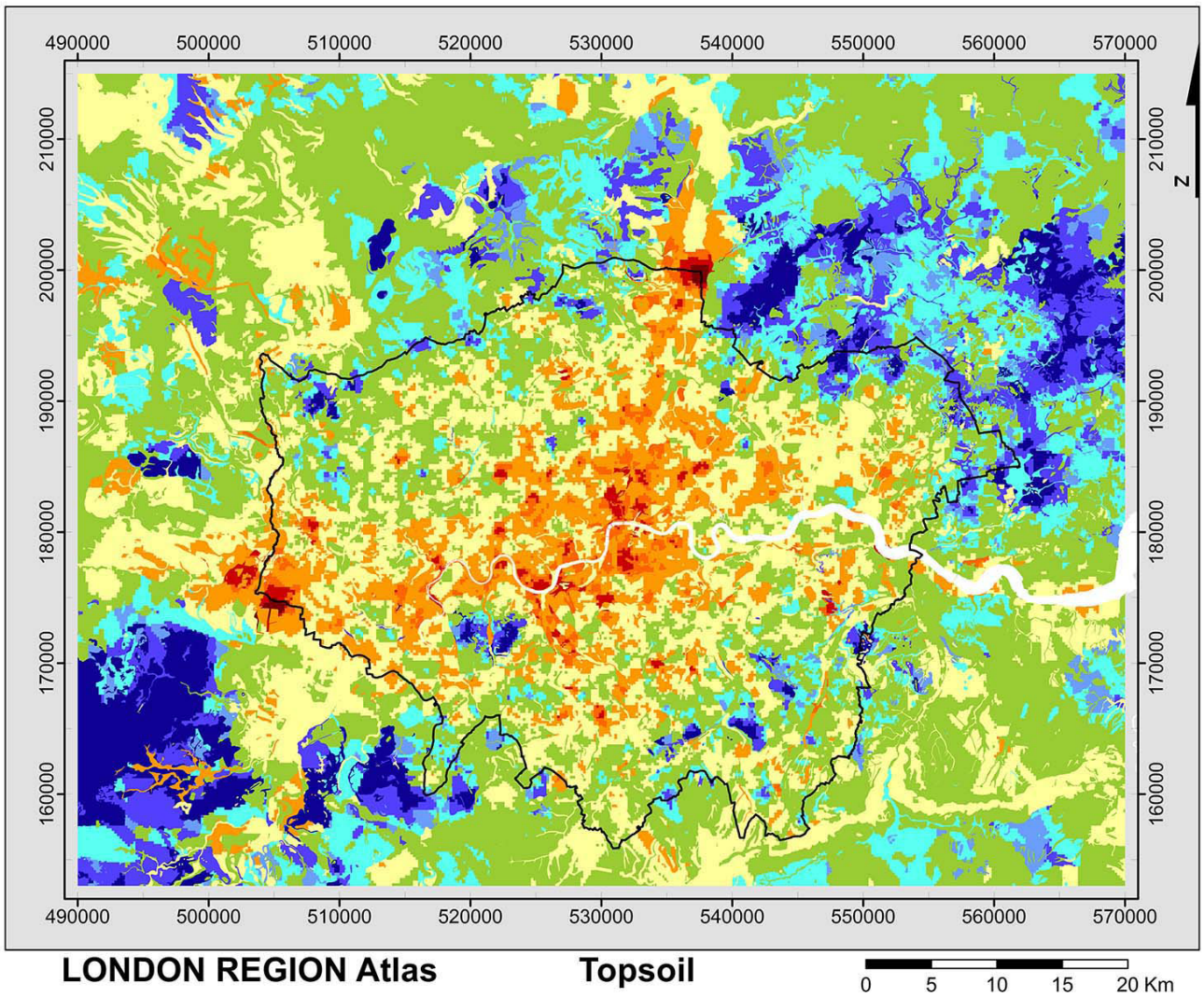
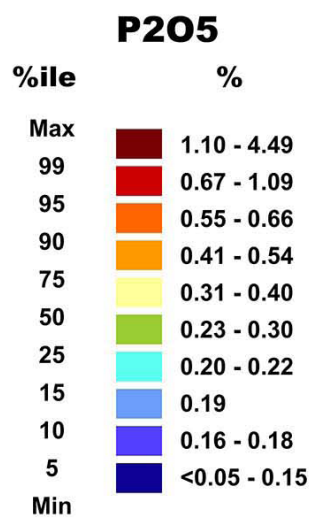
Phosphorus: LRA





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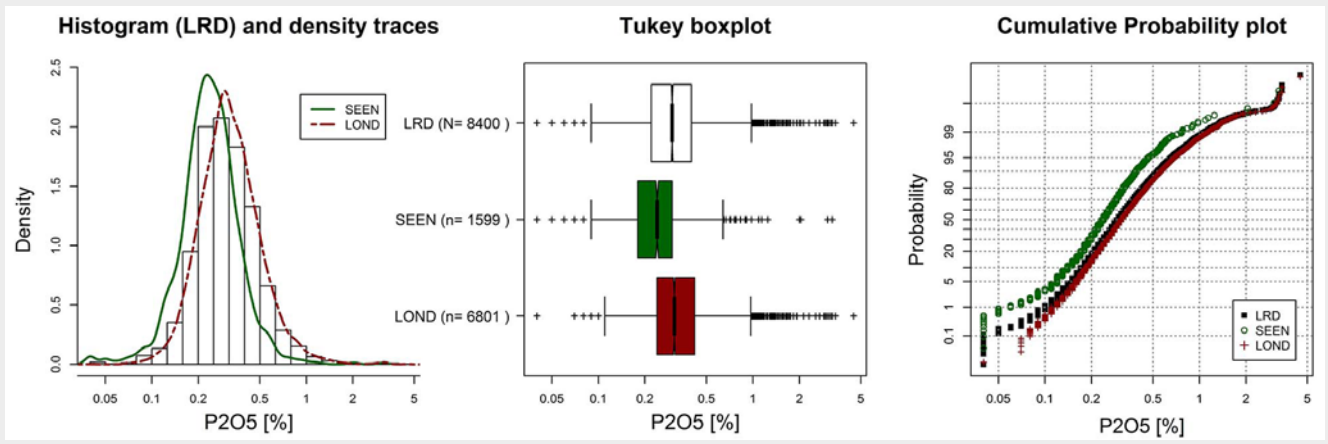
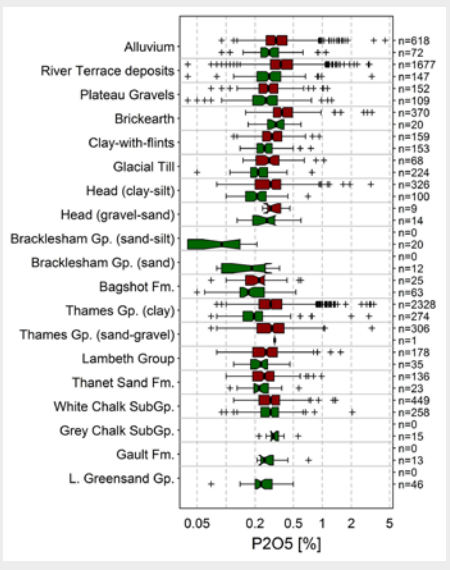
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



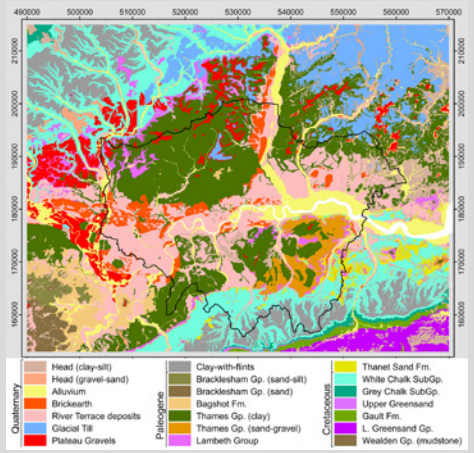
P2O5 [%]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.05)	0.12	0.56	0.01
minimum	<0.05	<0.05	<0.05
Q25	0.22	0.18	0.24
median	**0.3**	**0.24**	**0.31**
Q75	0.4	0.3	0.42
Q95	0.66	0.47	0.69
Q99	1.09	0.77	1.13
maximum	4.49	3.26	4.49
MAD	**0.12**	**0.09**	**0.13**
CVR%	39.5	37.1	43
mean	0.34	0.26	0.36
SD	0.22	0.17	0.23
CV%	64.3	64.3	62.7
GM	0.3	0.24	0.32
GSD	1.6	1.57	1.58
powers	2.05	1.91	2.05
skewness	5.82	8.36	5.67

Sample locations

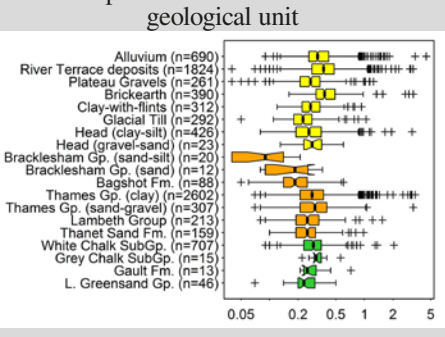
LOND and SEEN topsoil concentrations over each geological unit



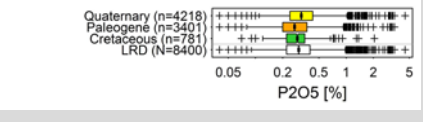
Simplified GEOLOGY (adapted from DiGMapGB-50)



LRD topsoil concentrations over each geological unit



Geology time period:



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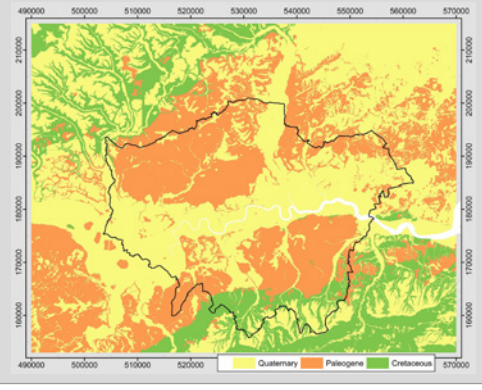

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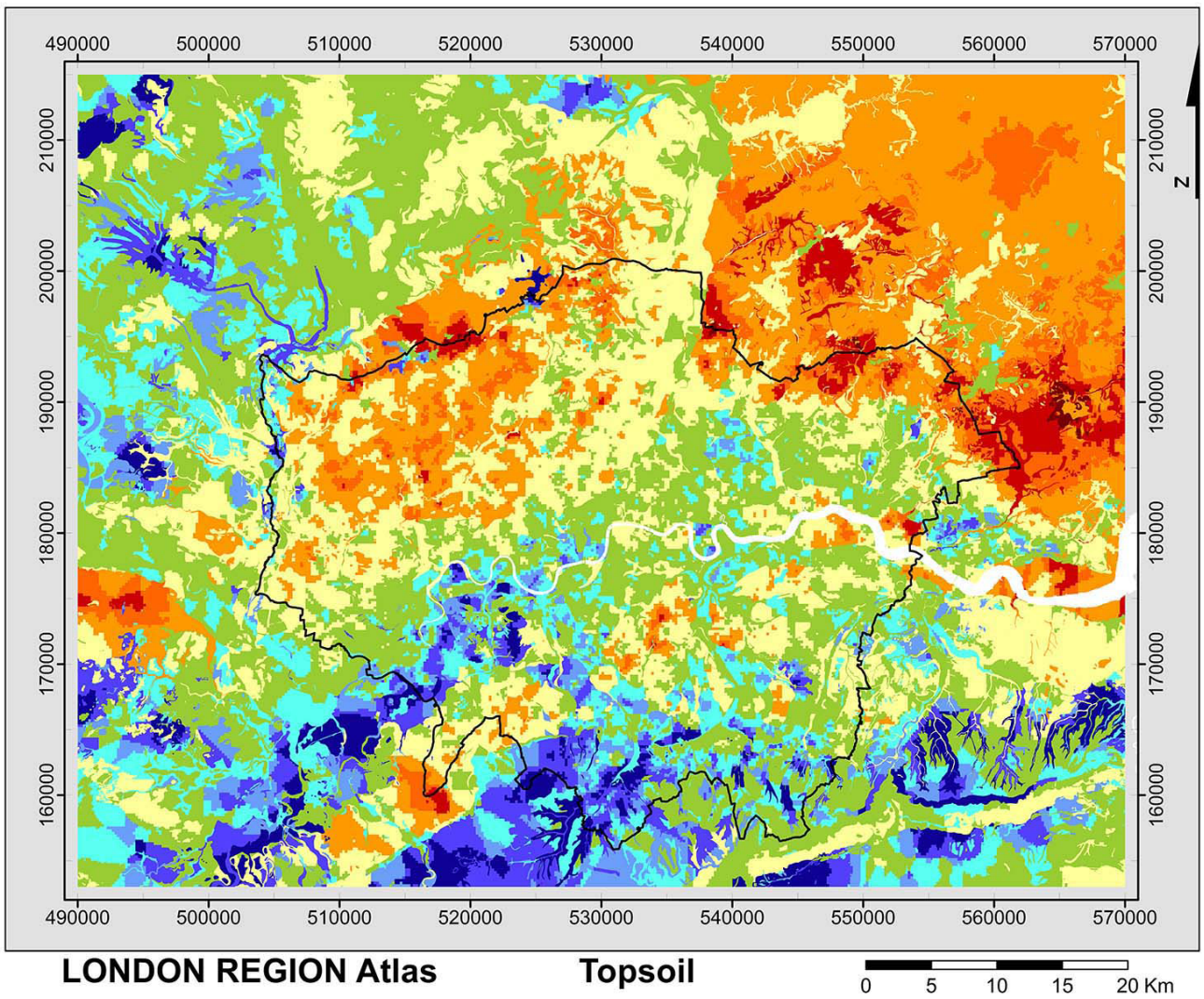
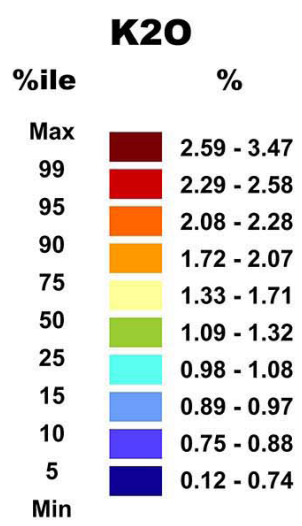
Potassium: LRA





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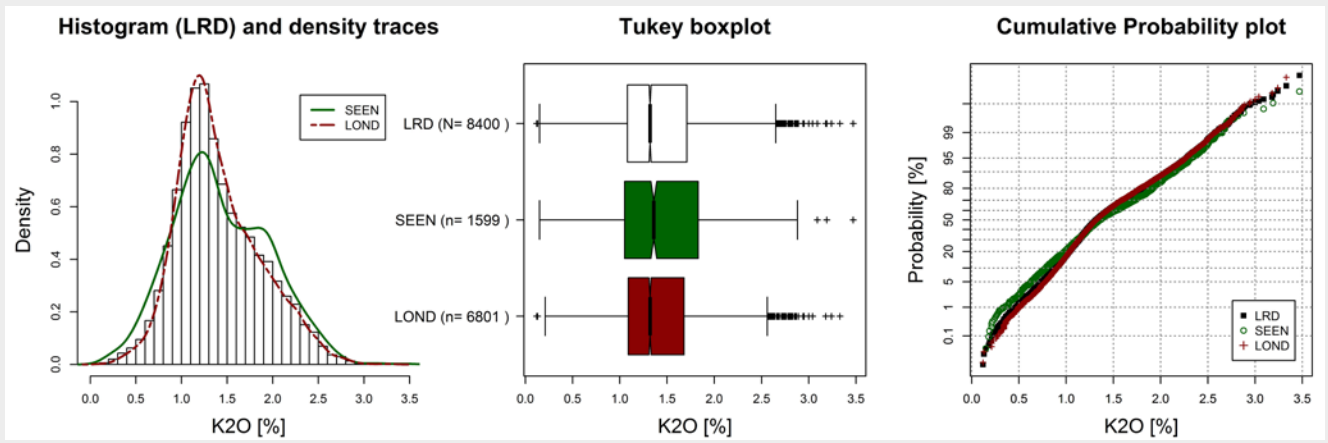
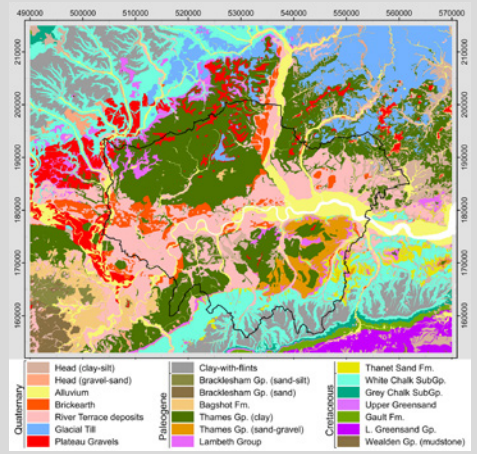
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



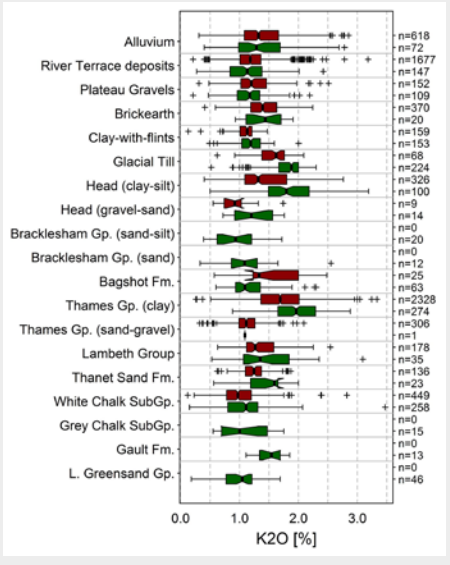
Simplified GEOLOGY (adapted from DiGMapGB-50)



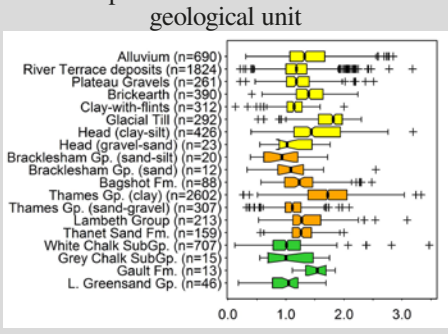
K2O [%]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.01)	0	0	0
minimum	0.12	0.15	0.12
Q25	1.08	1.05	1.09
median	**1.32**	**1.36**	**1.32**
Q75	1.71	1.83	1.68
Q95	2.28	2.32	2.27
Q99	2.58	2.65	2.57
maximum	3.47	3.47	3.33
MAD	**0.43**	**0.55**	**0.42**
CVR%	32.6	40.3	31.4
mean	1.41	1.43	1.4
SD	0.47	0.52	0.45
CV%	33.2	36.6	32.2
GM	1.33	1.32	1.33
GSD	1.42	1.52	1.4
powers	1.46	1.36	1.44
skewness	0.52	0.26	0.59

Sample locations

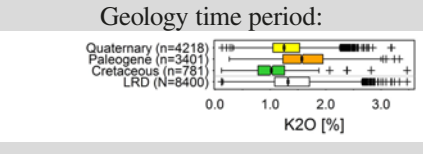
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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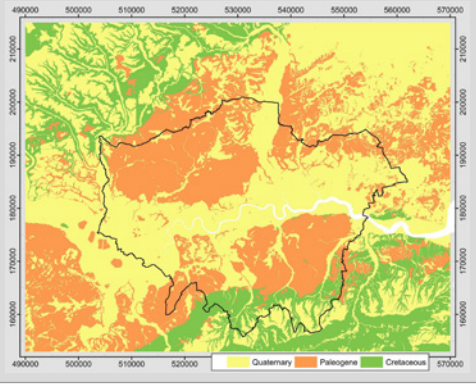

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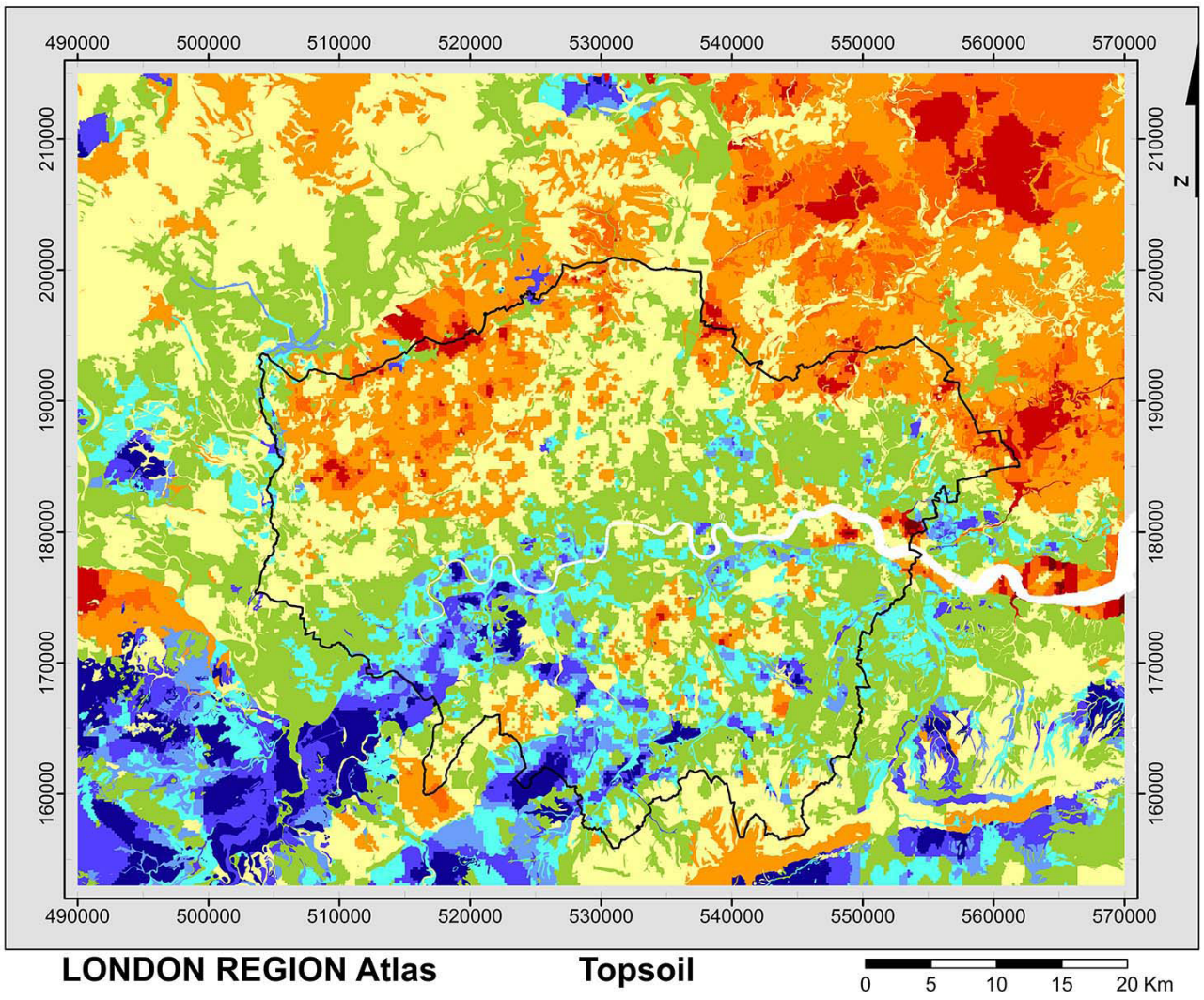
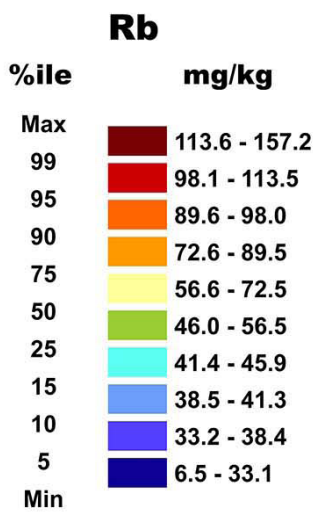
Rubidium: LRA





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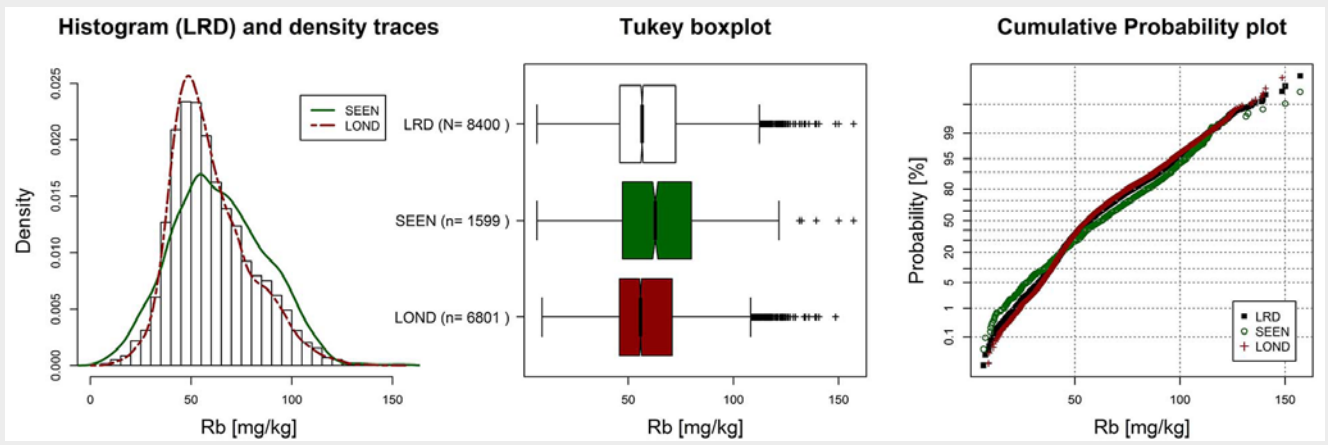
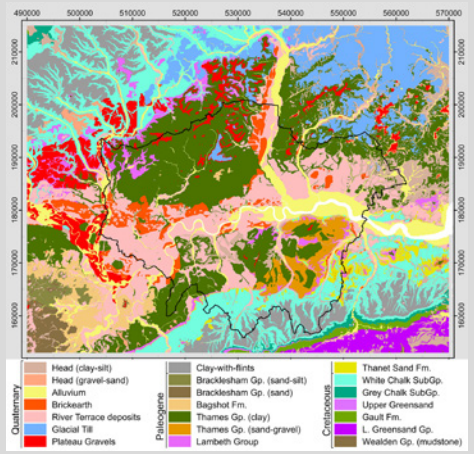
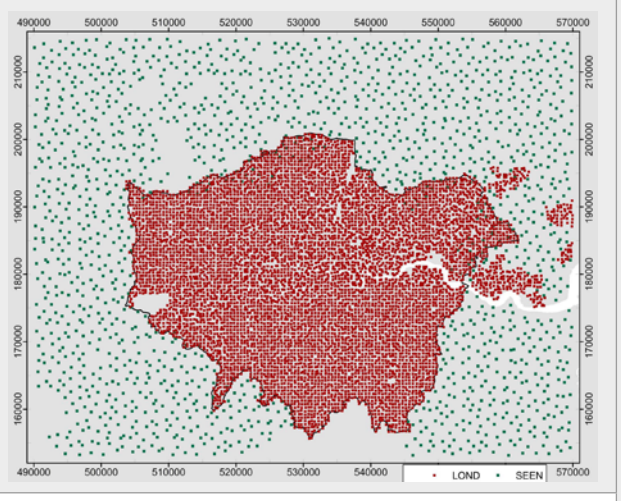


Rb [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1)	0	0	0
minimum	6.5	6.5	8.9
Q25	45.9	47.2	45.8
median	**56.5**	**62.8**	**55.8**
Q75	72.5	80	70.8
Q95	98	103	96.4
Q99	113.5	114.1	112.9
maximum	157.2	157.2	148.6
MAD	**18.7**	**24.2**	**17.3**
CVR%	33.1	38.5	31.1
mean	60.3	63.8	59.5
SD	20.1	23	19.3
CV%	33.4	36.1	32.4
GM	57	59.1	56.5
GSD	1.41	1.52	1.39
powers	1.38	1.38	1.22
skewness	0.64	0.21	0.77

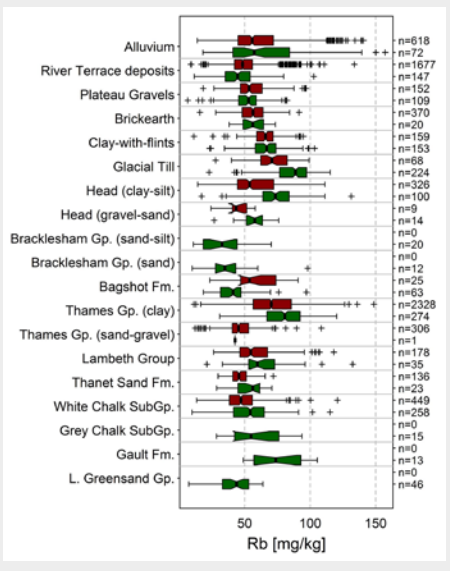
Simplified GEOLOGY (adapted from DiGMapGB-50)



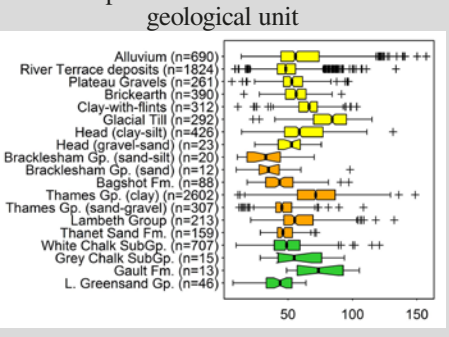
Sample locations



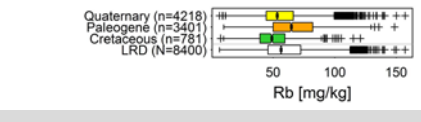
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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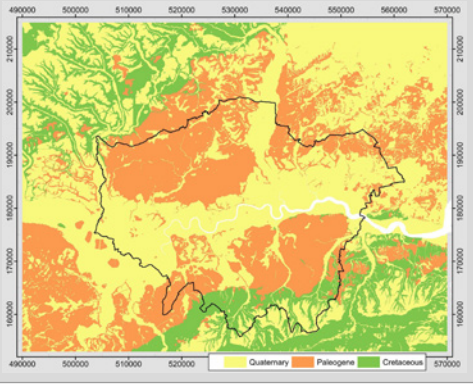

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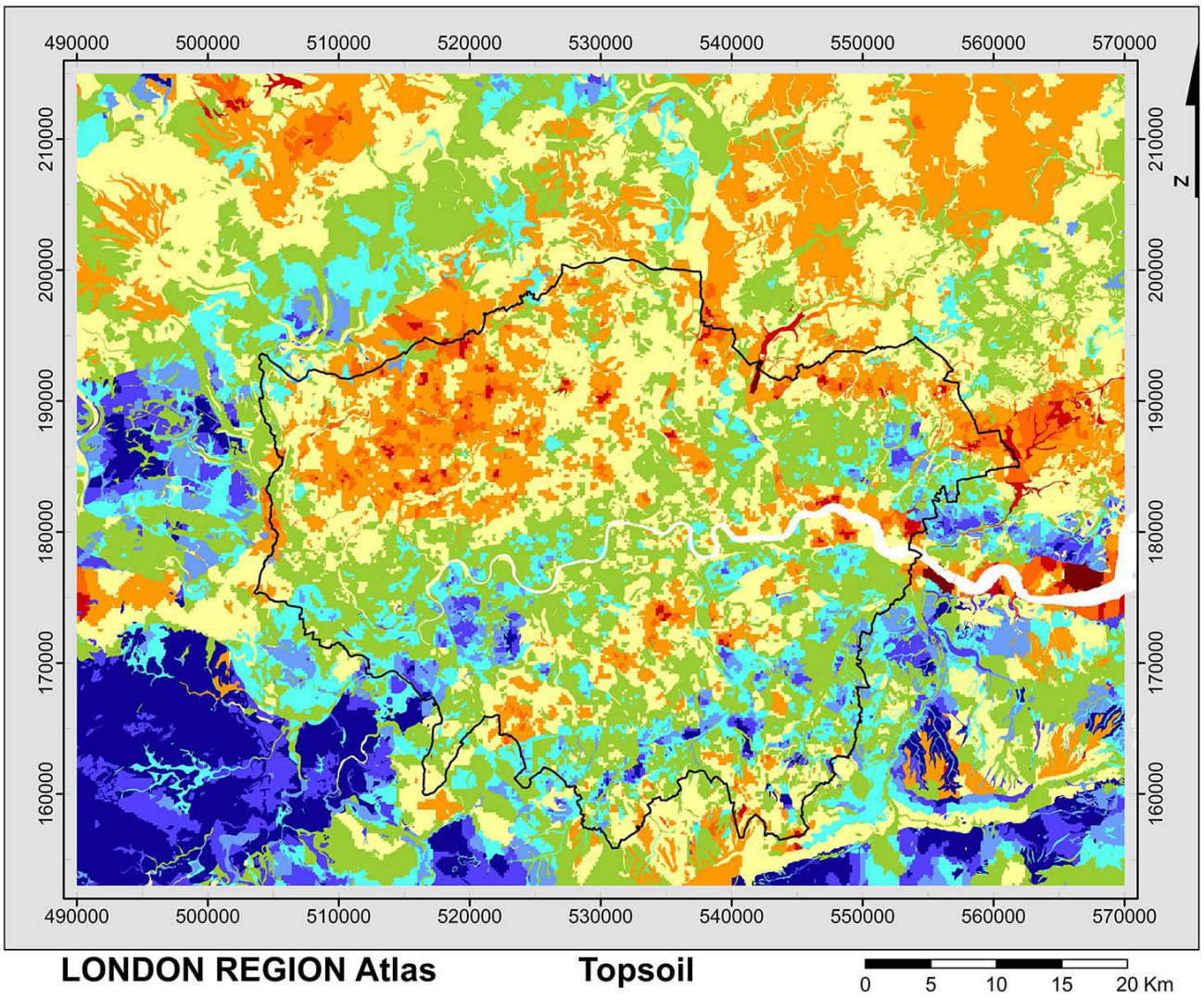
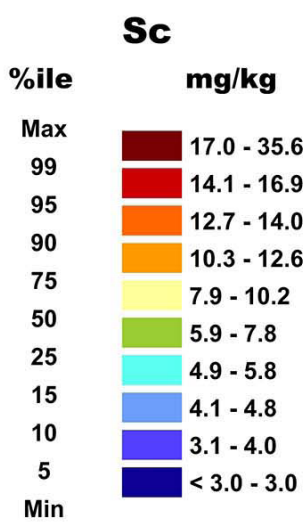
Scandium: LRA





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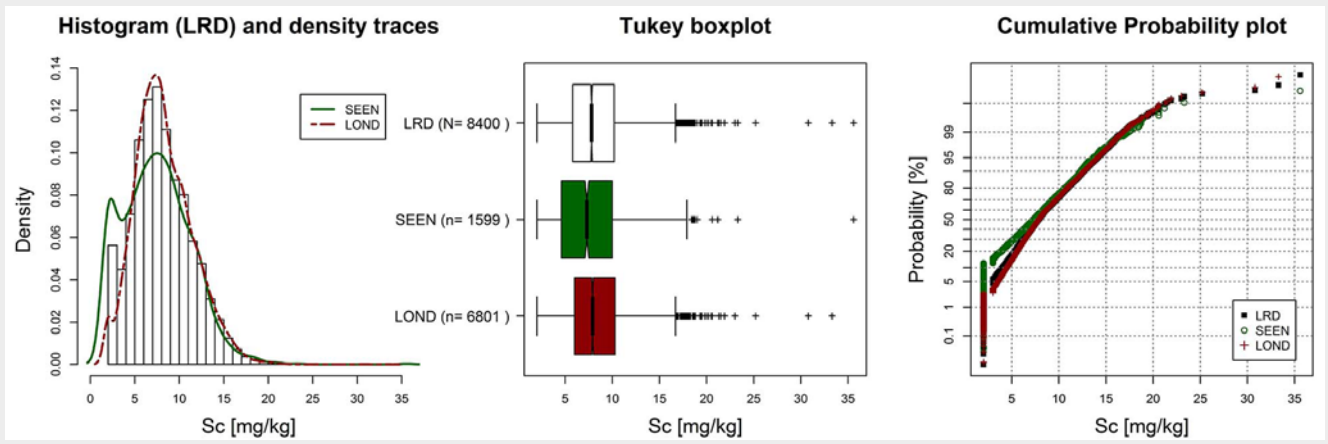
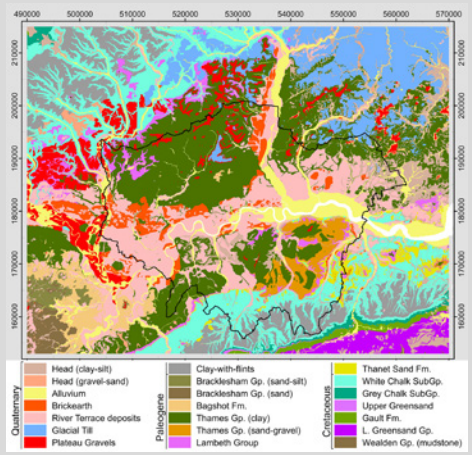


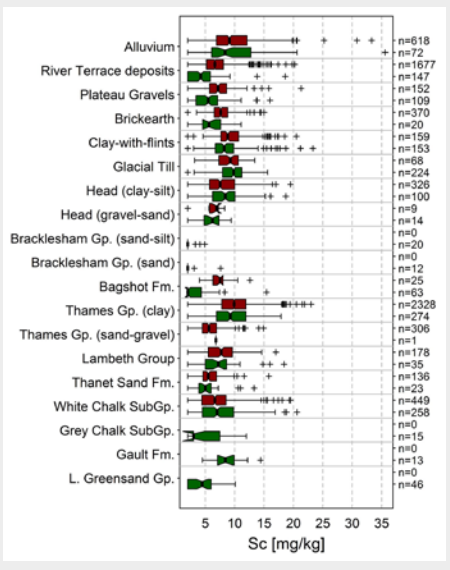
Sc [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (3)	4.45	12.38	2.59
minimum	<3	<3	<3
Q25	5.8	4.6	6
median	**7.8**	**7.3**	**7.9**
Q75	10.2	10	10.3
Q95	14	13.7	14.1
Q99	16.9	17.3	16.8
maximum	35.6	35.6	33.3
MAD	**3.3**	**4**	**3.1**
CVR%	41.8	54.8	39.4
mean	8.1	7.5	8.3
SD	3.4	3.8	3.2
CV%	41.5	50.6	39.2
GM	7.4	6.4	7.6
GSD	1.6	1.81	1.54
powers	1.25	1.25	1.22
skewness	0.61	0.65	0.66

Simplified GEOLOGY (adapted from DiGMapGB-50)

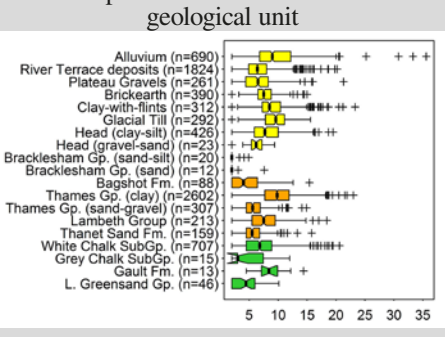


Sample locations

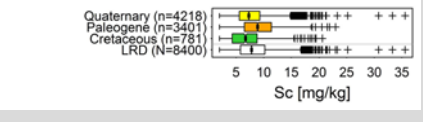
LOND and SEEN topsoil concentrations over each geological unit



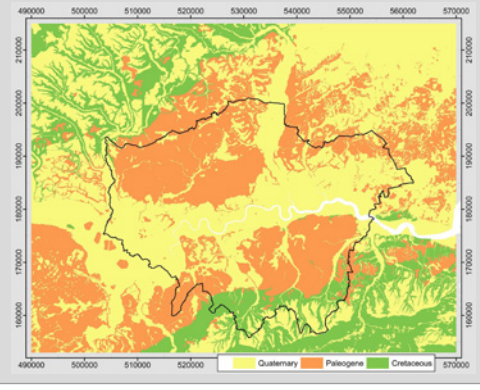
LRD topsoil concentrations over each geological unit



Geology time period:



At each site a composite topsoil (5–20 cm depth) sample comprising five subsamples was collected from the corners and centre of a 20 x 20 m square. After collection samples were air/oven dried and sieved to <2 mm before analysis to determine the total contents of more than 50 chemical elements by X-ray fluorescence spectrometry (XRFS).



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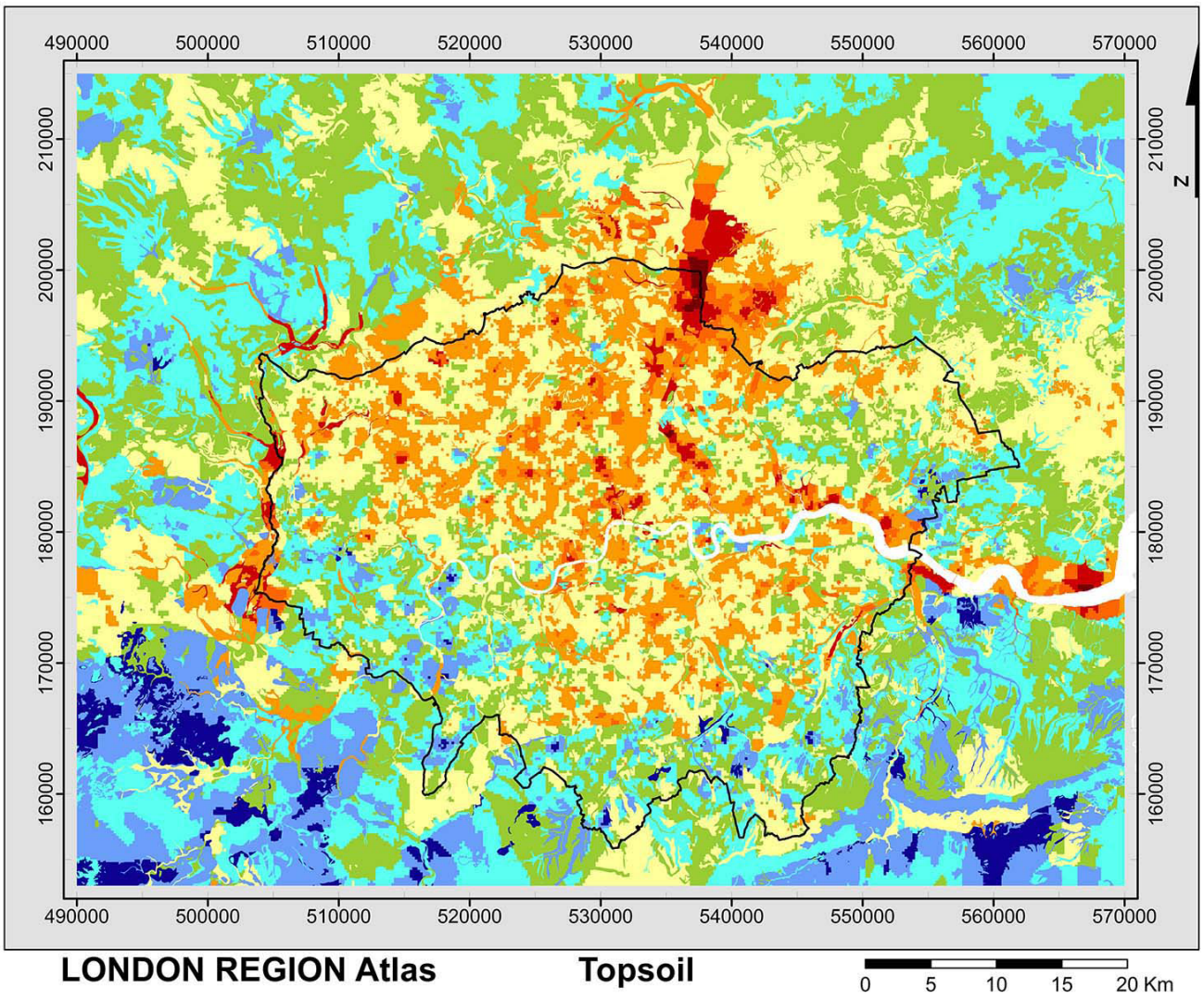
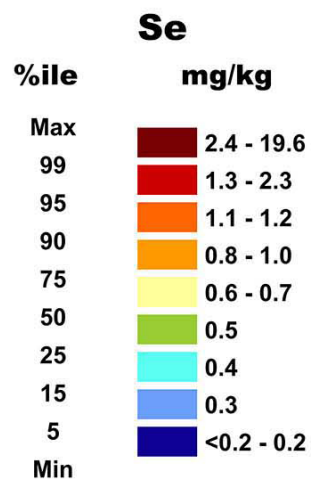
Selenium: LRA





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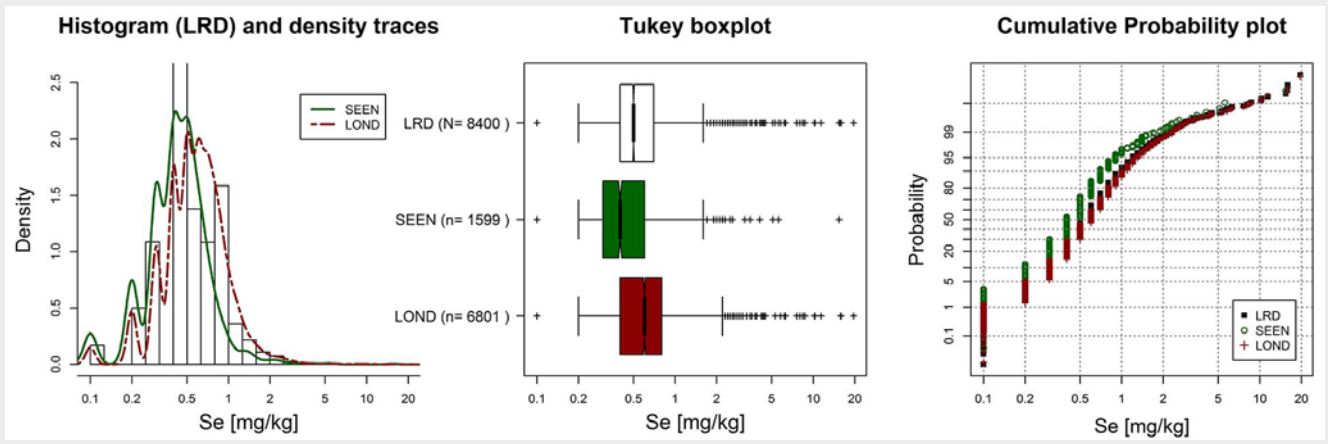
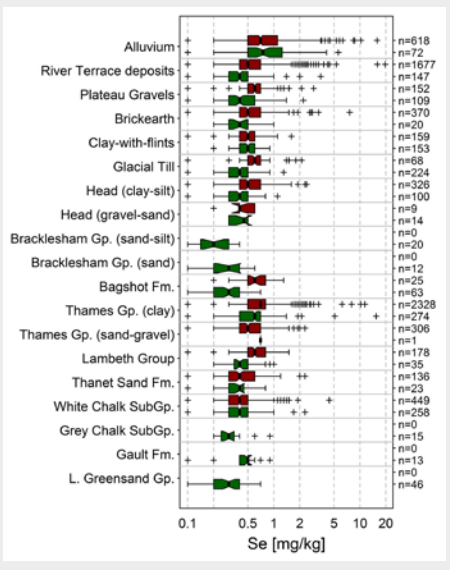
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



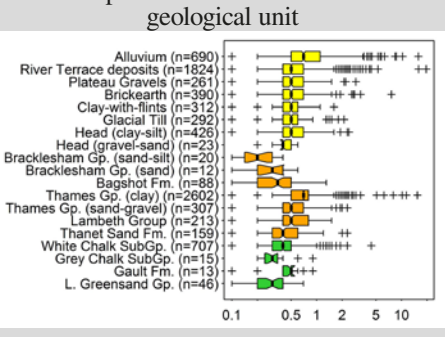
Se [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.2)	1.67	3.19	1.31
minimum	<0.2	<0.2	<0.2
Q25	0.4	0.3	0.4
median	**0.5**	**0.4**	**0.6**
Q75	0.7	0.6	0.8
Q95	1.2	0.9	1.3
Q99	2.3	1.7	2.3
maximum	19.6	15.4	19.6
MAD	**0.3**	**0.1**	**0.3**
CVR%	59.3	37.1	49.4
mean	0.6	0.5	0.7
SD	0.6	0.5	0.6
CV%	92.6	101.4	90.1
GM	0.5	0.4	0.6
GSD	1.72	1.69	1.71
powers	2.29	2.19	2.29
skewness	14.12	18.07	13.75

Sample locations

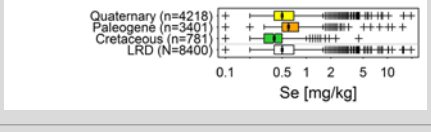
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



At each site a composite topsoil (5–20 cm depth) sample comprising five subsamples was collected from the corners and centre of a 20 x 20 m square. After collection samples were air/oven dried and sieved to <2 mm before analysis to determine the total contents of more than 50 chemical elements by X-ray fluorescence spectrometry (XRFS).

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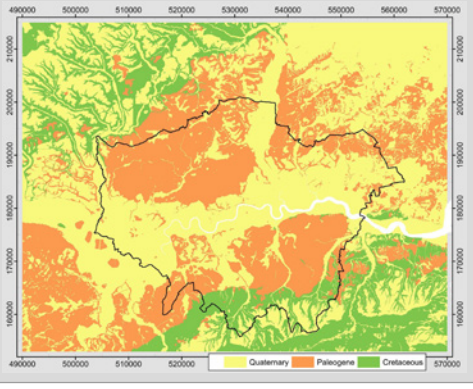

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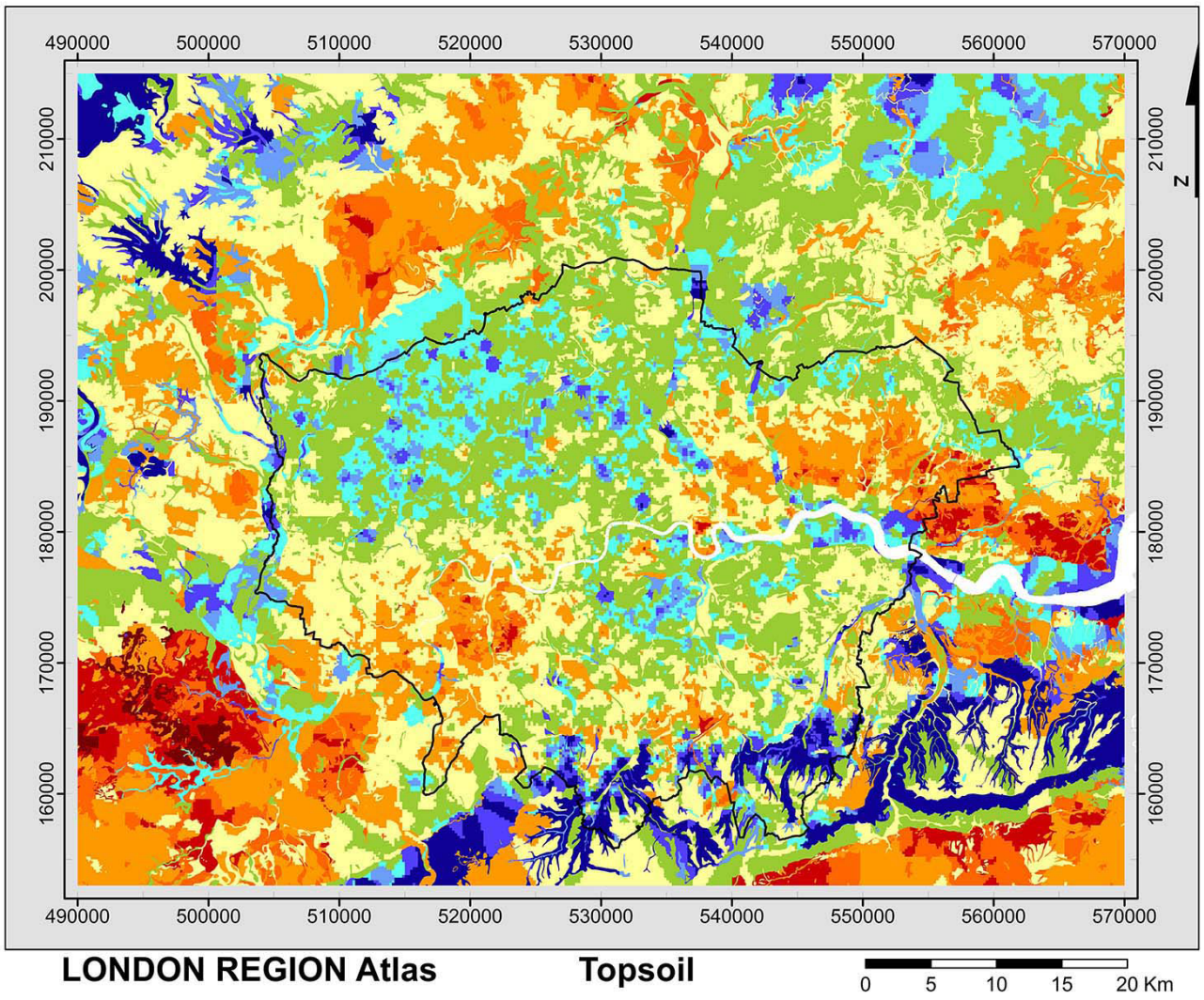
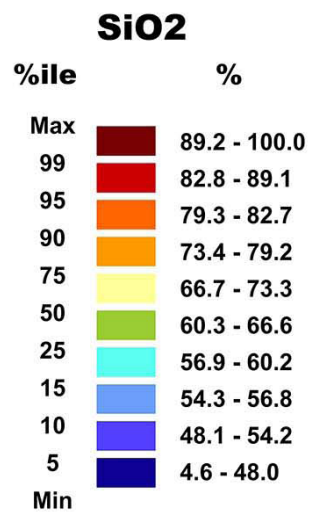
Silicon: LRA





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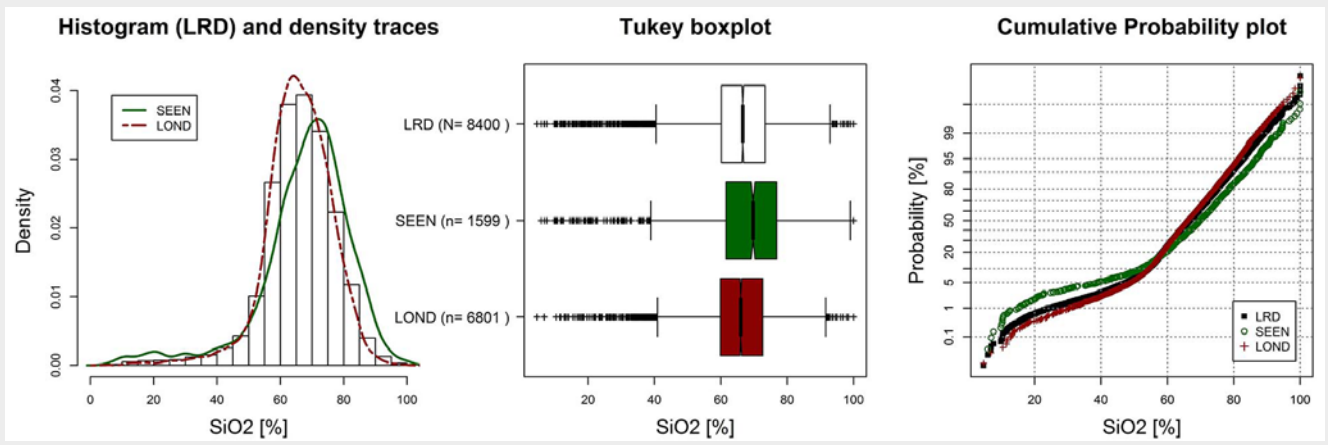
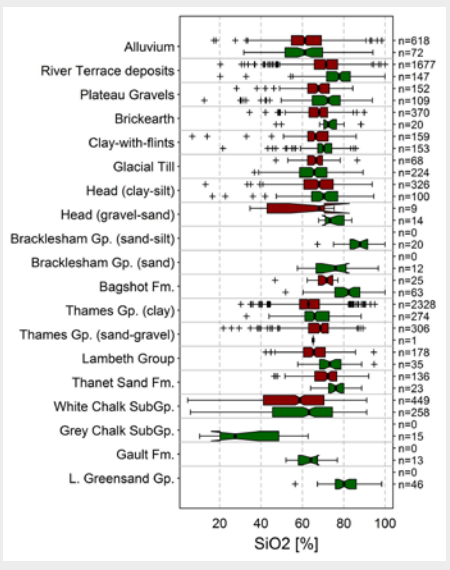
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



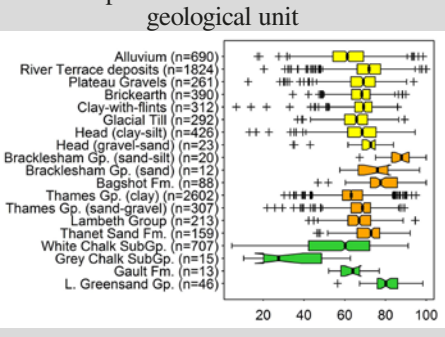
SiO2 [%]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.1)	0	0	0
minimum	4.6	5.9	4.6
Q25	60.2	61.6	59.9
median	**66.6**	**69.7**	**66**
Q75	73.3	76.8	72.6
Q95	82.7	86.9	81.4
Q99	89.1	93.5	87.1
maximum	100	100	100
MAD	**9.8**	**11.3**	**9.3**
CVR%	14.7	16.2	14.2
mean	66.1	67.7	65.7
SD	11.4	14.7	10.5
CV%	17.3	21.6	16
GM	64.8	65.3	64.7
GSD	1.25	1.37	1.22
powers	1.34	1.23	1.34
skewness	-1.04	-1.37	-0.9

Sample locations

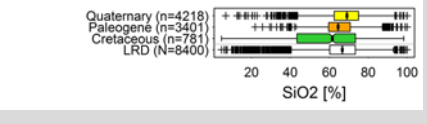
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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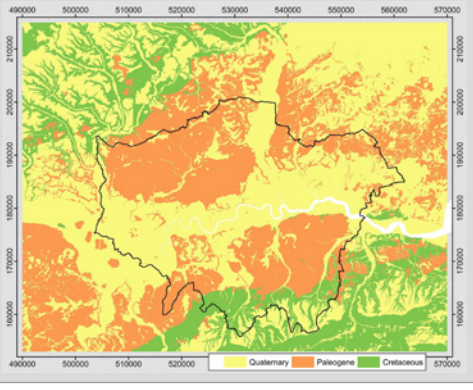

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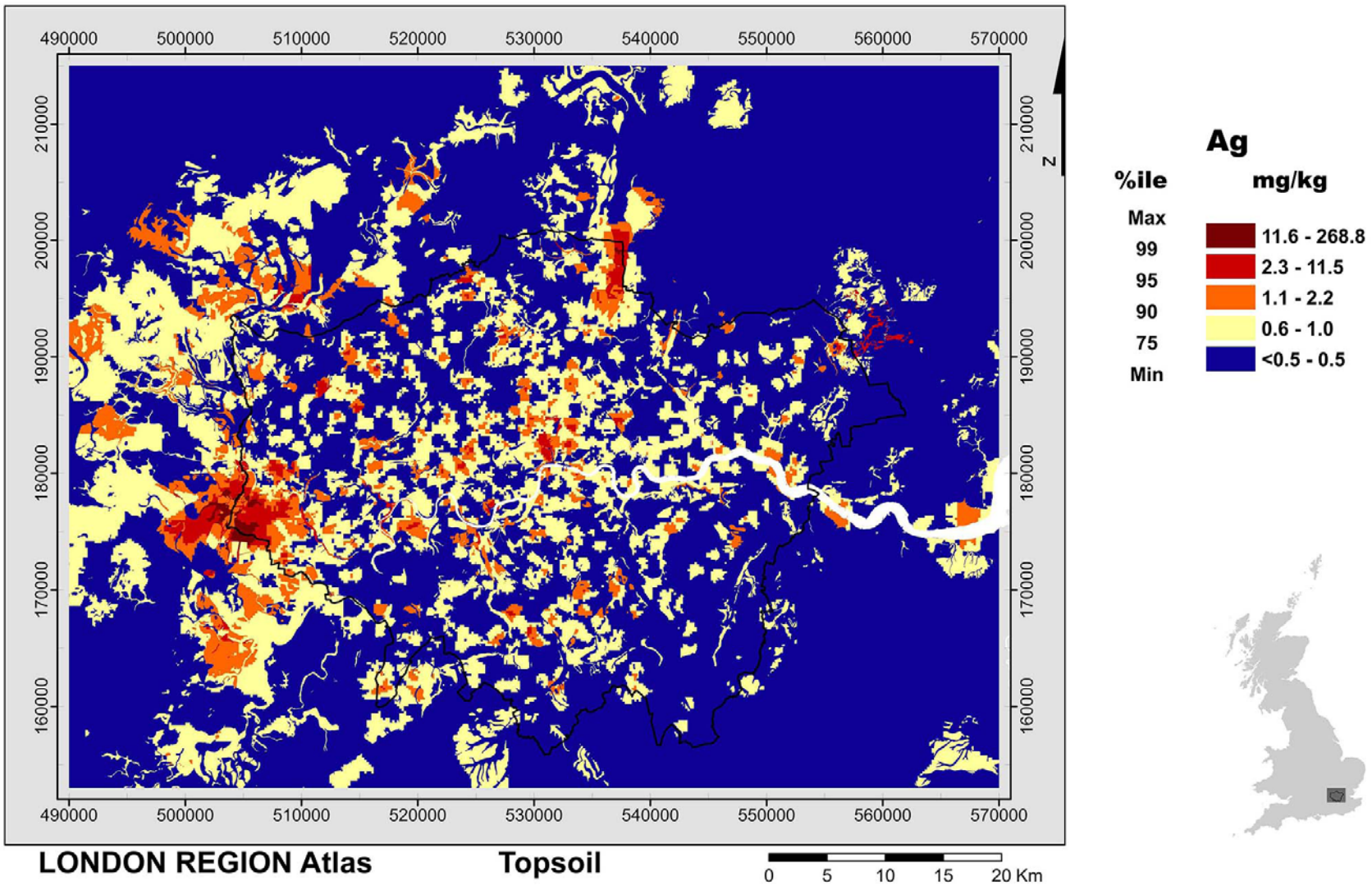
Silver: LRA



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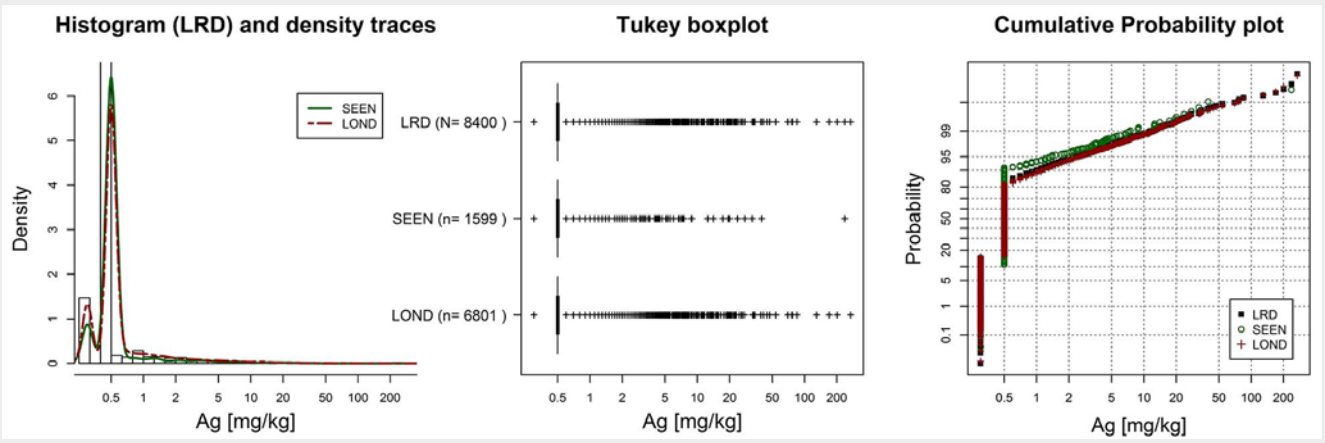

Ag [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.5)	14.67	10.94	15.54
minimum	<0.5	<0.5	<0.5
Q25	0.5	0.5	0.5
median	**0.5**	**0.5**	**0.5**
Q75	0.5	0.5	0.5
Q95	2.2	1.4	2.5
Q99	11.5	7.3	12.4
maximum	268.8	237.2	268.8
MAD	**0**	**0**	**0**
CVR%	0	0	0
mean	1.1	0.9	1.1
SD	5.8	6.2	5.7
CV%	552	681.6	525.9
GM	0.6	0.5	0.6
GSD	1.95	1.74	1.99
powers	2.95	2.9	2.95
skewness	30.48	34.39	29.21

At each site a composite topsoil (5–20 cm depth) sample comprising five subsamples was collected from the corners and centre of a 20 x 20 m square. After collection samples were air/oven dried and sieved to <2 mm before analysis to determine the total contents of more than 50 chemical elements by X-ray fluorescence spectrometry (XRFS).

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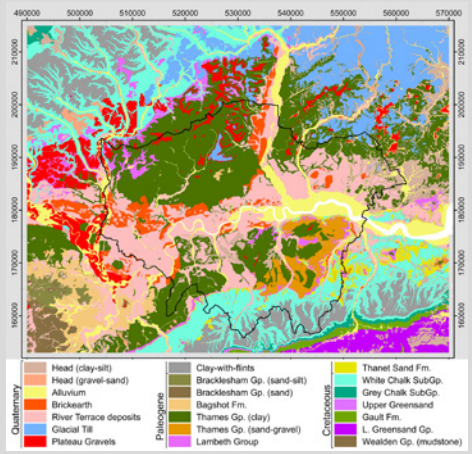
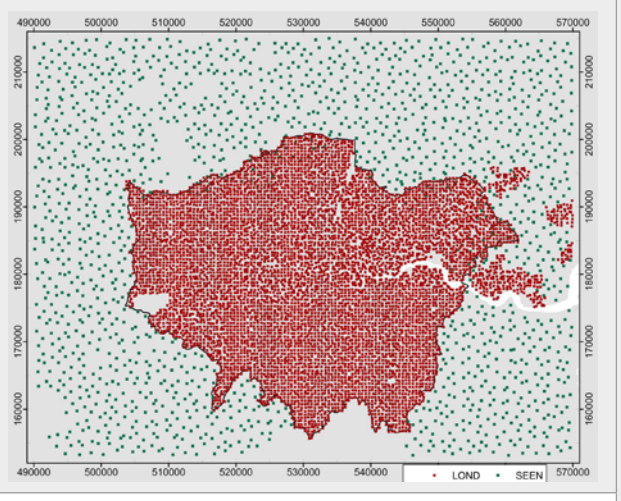
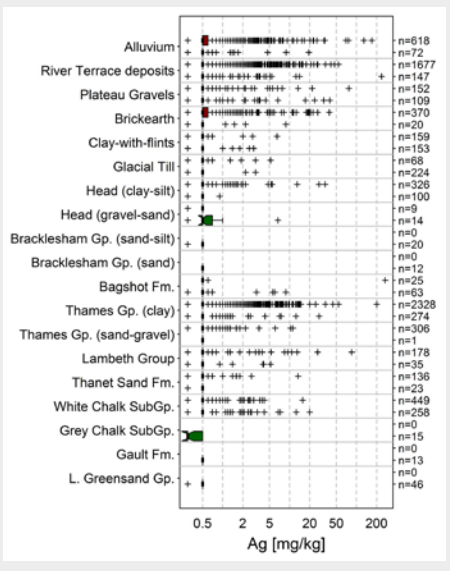


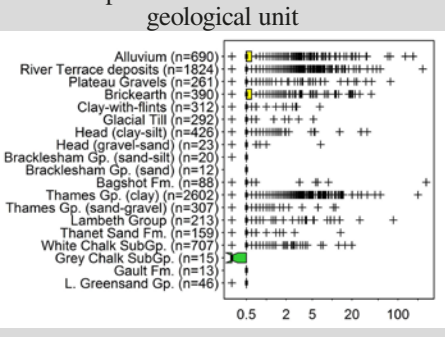
Sample locations



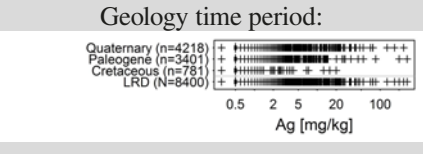
LOND and SEEN topsoil concentrations over each geological unit

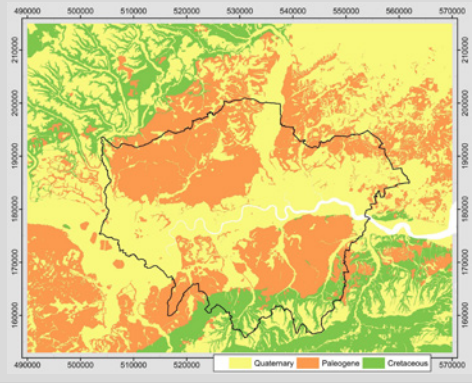


LRD topsoil concentrations over each geological unit



Geology time period:





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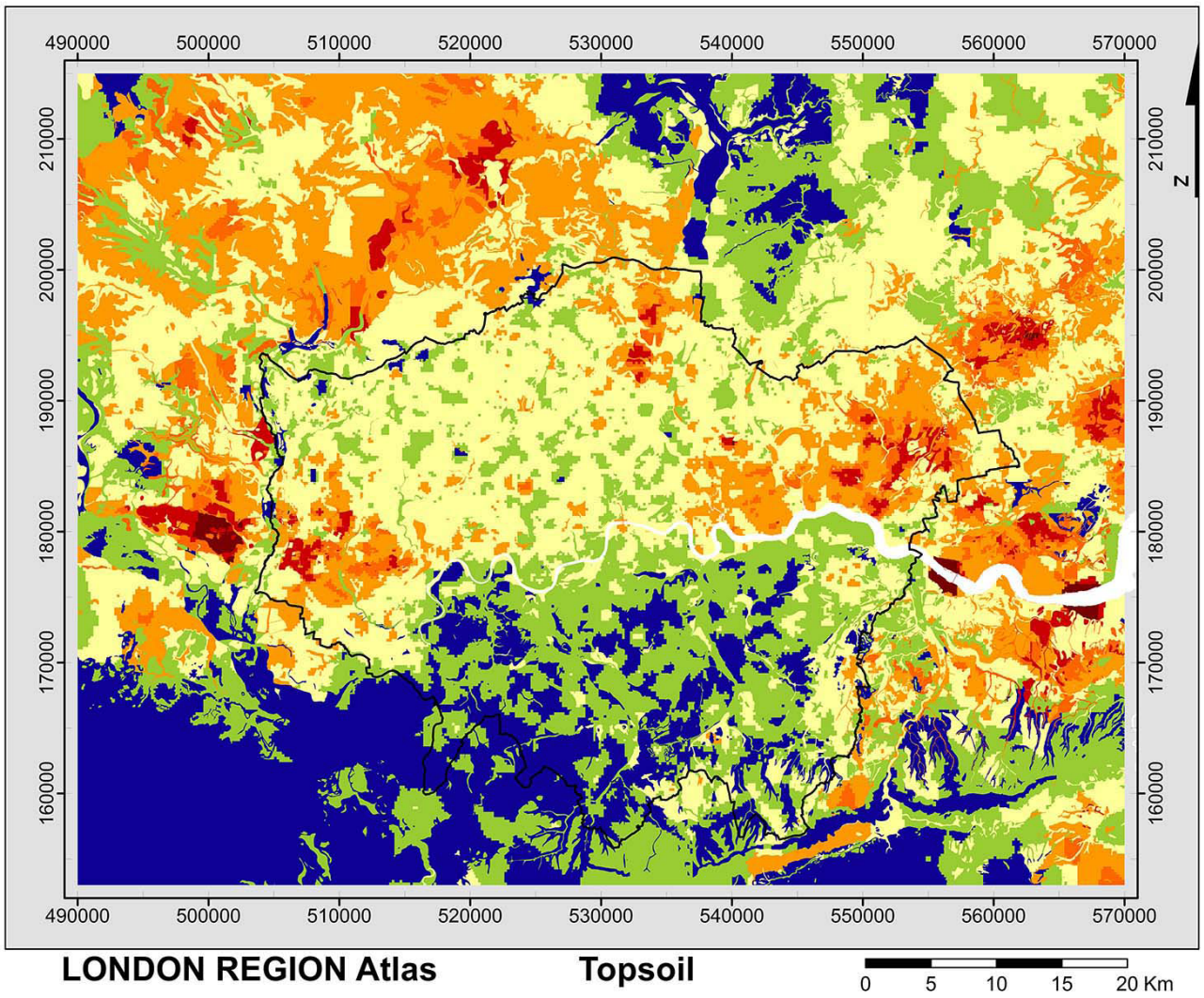
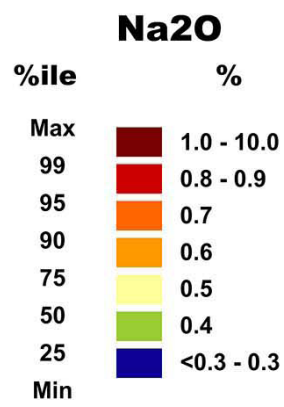
Sodium: LRA





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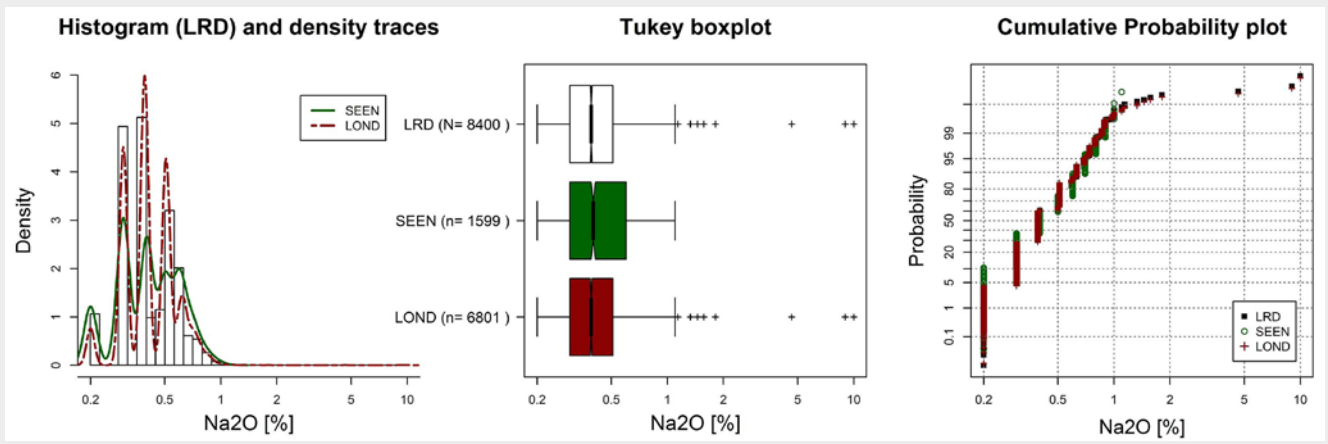
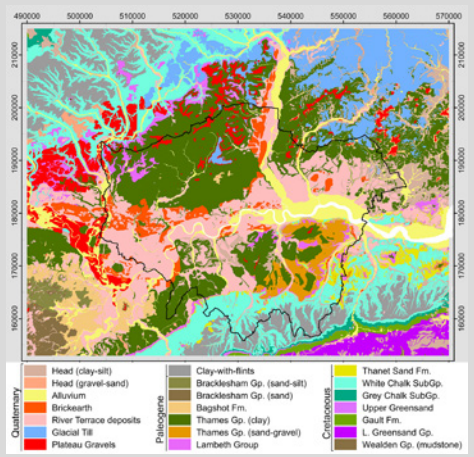
The London Region Atlas (LRA) covers a rectangular area of 80 x 62 km, from British National Grid coordinates: Easting 490 000 to 570 000 and Northing 153 000 to 215 000. The LRA was produced using the London Region Dataset (LRD, n=8400), created from two geochemical surveys (LOND and SEEN) carried out by the Geochemical Baseline Survey of the Environment (G-BASE) project during 2008 and 2009 for LOND, and from 2005 to 2009 for SEEN. The LOND survey is an urban soil geochemical survey based on 6801 sampling sites, 93% of which are located within the GLA, at a sampling density of 1 per 0.25 km². SEEN is a south-east England rural soil survey done at a sampling density of 1 per 2 km². A total of 1599 of the SEEN samples are included in the LRA area. As these are rural samples, 95% of them are outwith the GLA limit.

Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



Simplified GEOLOGY (adapted from DiGMapGB-50)

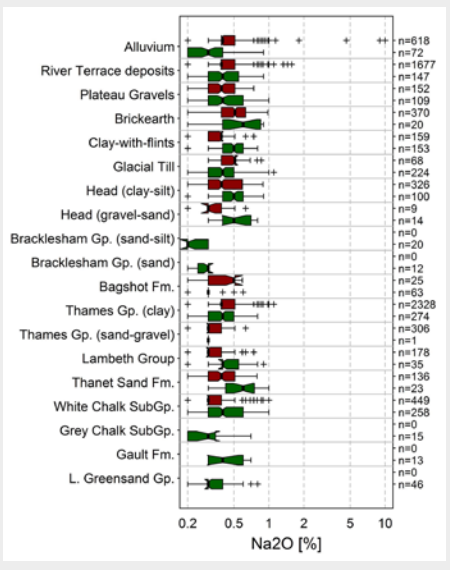


Na2O [%] statistical parameters

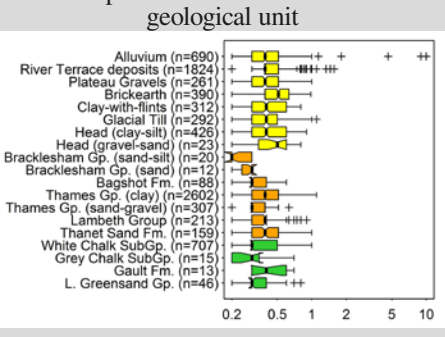
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.3)	5.32	10.44	4.12
minimum	<0.3	<0.3	<0.3
Q25	0.3	0.3	0.3
median	**0.4**	**0.4**	**0.4**
Q75	0.5	0.6	0.5
Q95	0.7	0.7	0.7
Q99	0.9	0.9	0.9
maximum	10	1.1	10
MAD	**0.1**	**0.1**	**0.1**
CVR%	34.2	37.1	34.2
mean	0.4	0.4	0.4
SD	0.2	0.2	0.2
CV%	47.5	37.8	49.5
GM	0.4	0.4	0.4
GSD	1.39	1.47	1.38
powers	1.7	0.74	1.7
skewness	21.36	0.65	23.21

Sample locations

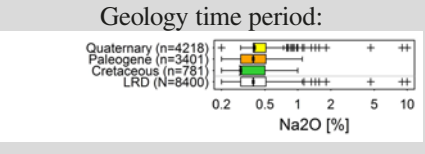
LOND and SEEN topsoil concentrations over each geological unit



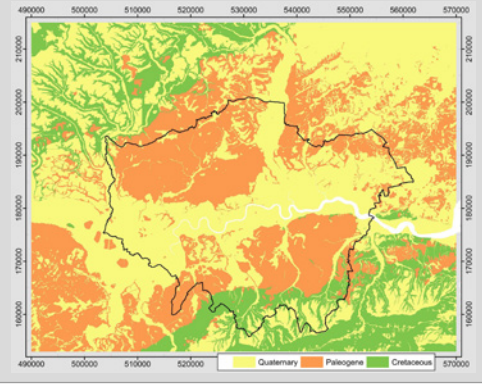
LRD topsoil concentrations over each geological unit



Geology time period:



At each site a composite topsoil (5–20 cm depth) sample comprising five subsamples was collected from the corners and centre of a 20 x 20 m square. After collection samples were air/oven dried and sieved to <2 mm before analysis to determine the total contents of more than 50 chemical elements by X-ray fluorescence spectrometry (XRFS).



Each geochemical map was prepared by interpolating the point data using the parent material mapping method (Appleton et al., 2013[1]). The LRA area was subdivided into 200 x 200 m squares and intercepted with the geology (parent material) polygons, thereby creating the basic 200 m-PM polygons. For each 200 m-PM polygon the average concentration based on the four nearest samples over the same PM was computed (see further explanation in Materials and methods and references therein). As the maps (produced in ArcGIS 10.1) show estimated concentrations, there is a degree of uncertainty due to variability in soil composition. The element concentration colour ramp is based on percentile classes of the LRD dataset distribution. The tables and graphs were generated running R (R x 64 3.1.0) in RStudio (Version 0.98.977). The LRD, LOND and SEEN surveys are represented by the colours black/white, dark green and dark red respectively. Quaternary, Palaeogene and Cretaceous geological time periods are represented by soft yellow, orange and lime green colours respectively. For further information go to Univariate statistics and graphics.

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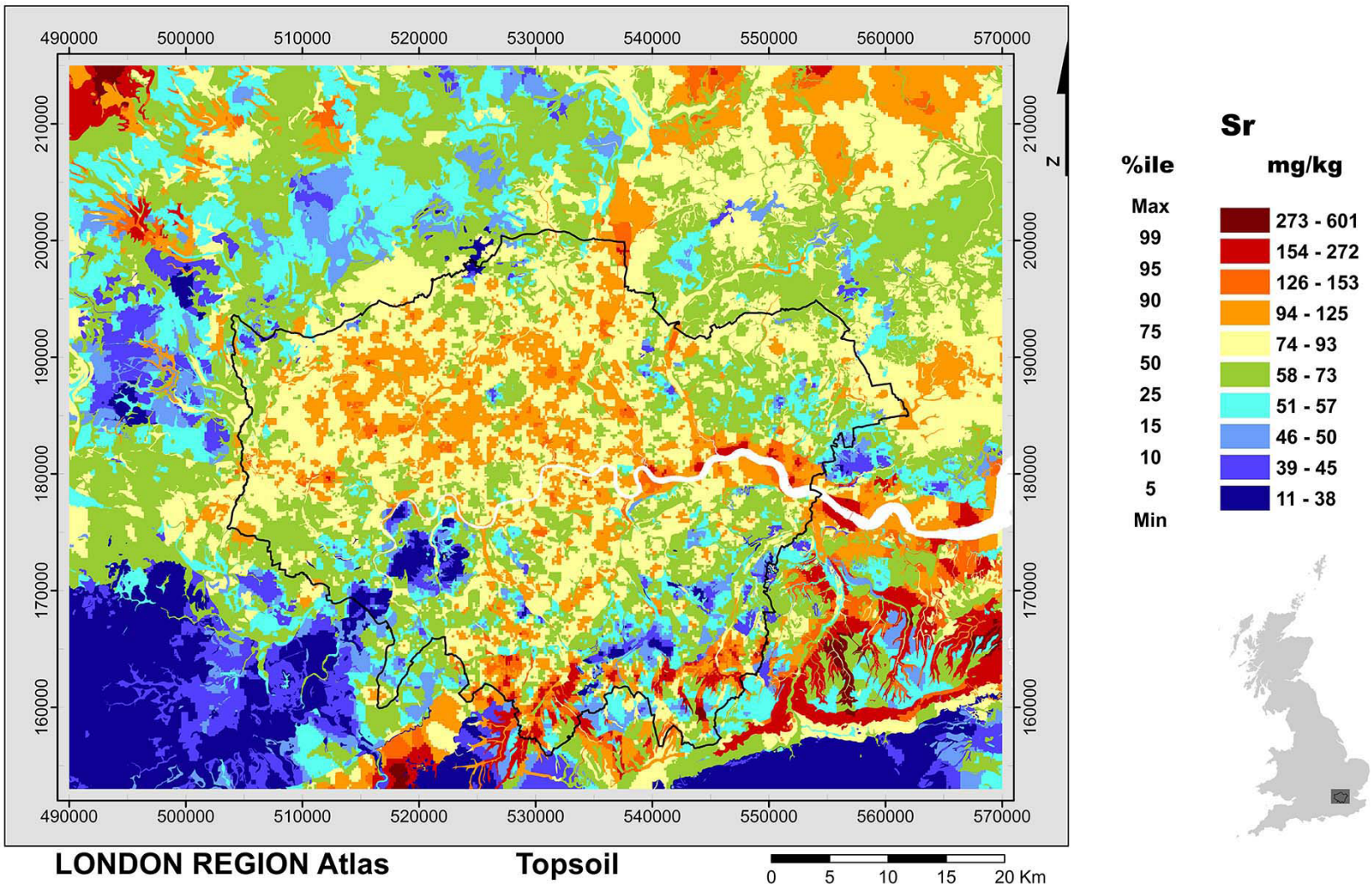
Strontium: LRA



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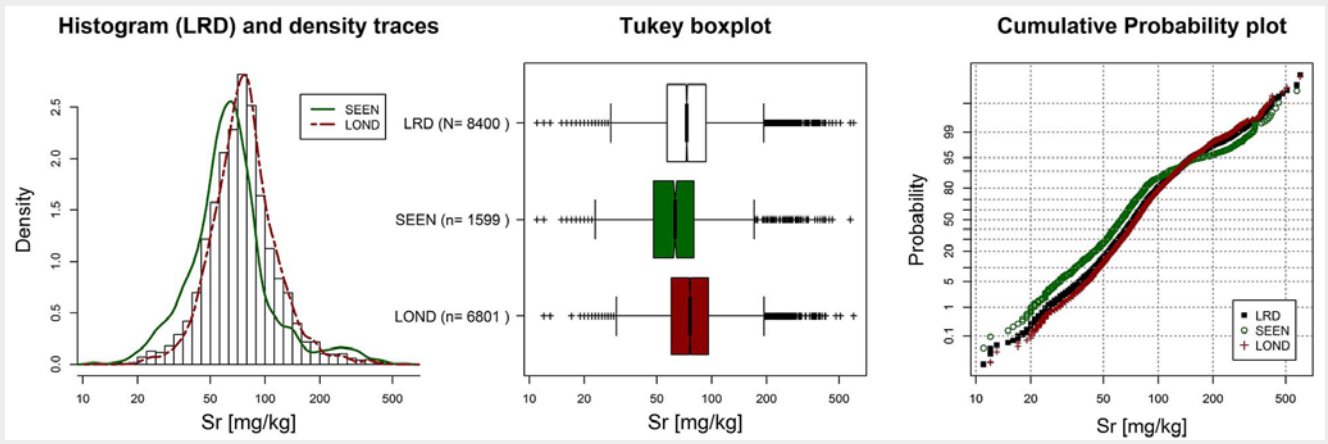
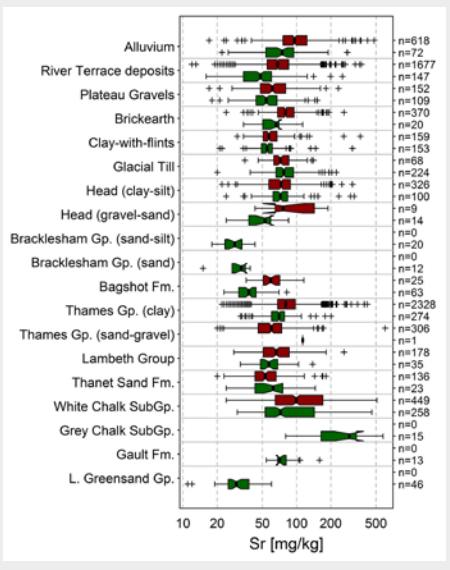
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



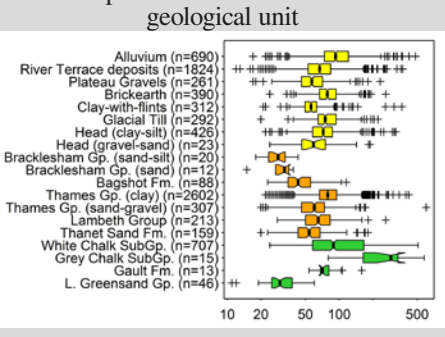
Sr [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1)	0	0	0
minimum	11	11	12
Q25	57	48	60
median	**73**	**63**	**76**
Q75	93	80	96
Q95	153	171.2	152
Q99	272	330	254
maximum	601	576	601
MAD	**25.2**	**22.2**	**25.2**
CVR%	34.5	35.3	33.2
mean	82.2	75.1	83.9
SD	44.4	54.9	41.4
CV%	54	73	49.3
GM	74.2	64.3	76.8
GSD	1.55	1.68	1.5
powers	1.74	1.72	1.7
skewness	3.23	3.53	3.09

Sample locations

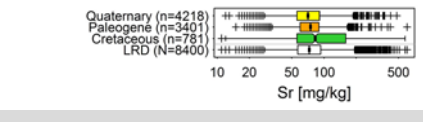
LOND and SEEN topsoil concentrations over each geological unit



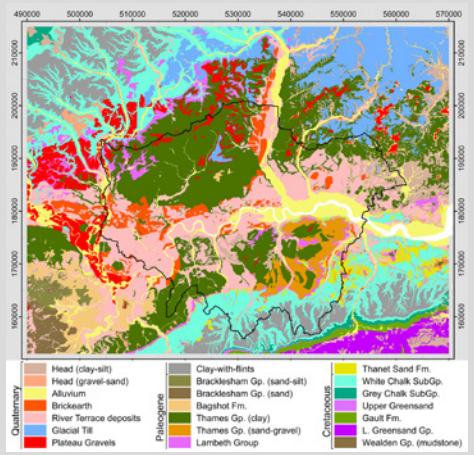
LRD topsoil concentrations over each geological unit



Geology time period:



Simplified GEOLOGY (adapted from DiGMapGB-50)



At each site a composite topsoil (5–20 cm depth) sample comprising five subsamples was collected from the corners and centre of a 20 x 20 m square. After collection samples were air/oven dried and sieved to <2 mm before analysis to determine the total contents of more than 50 chemical elements by X-ray fluorescence spectrometry (XRFS).

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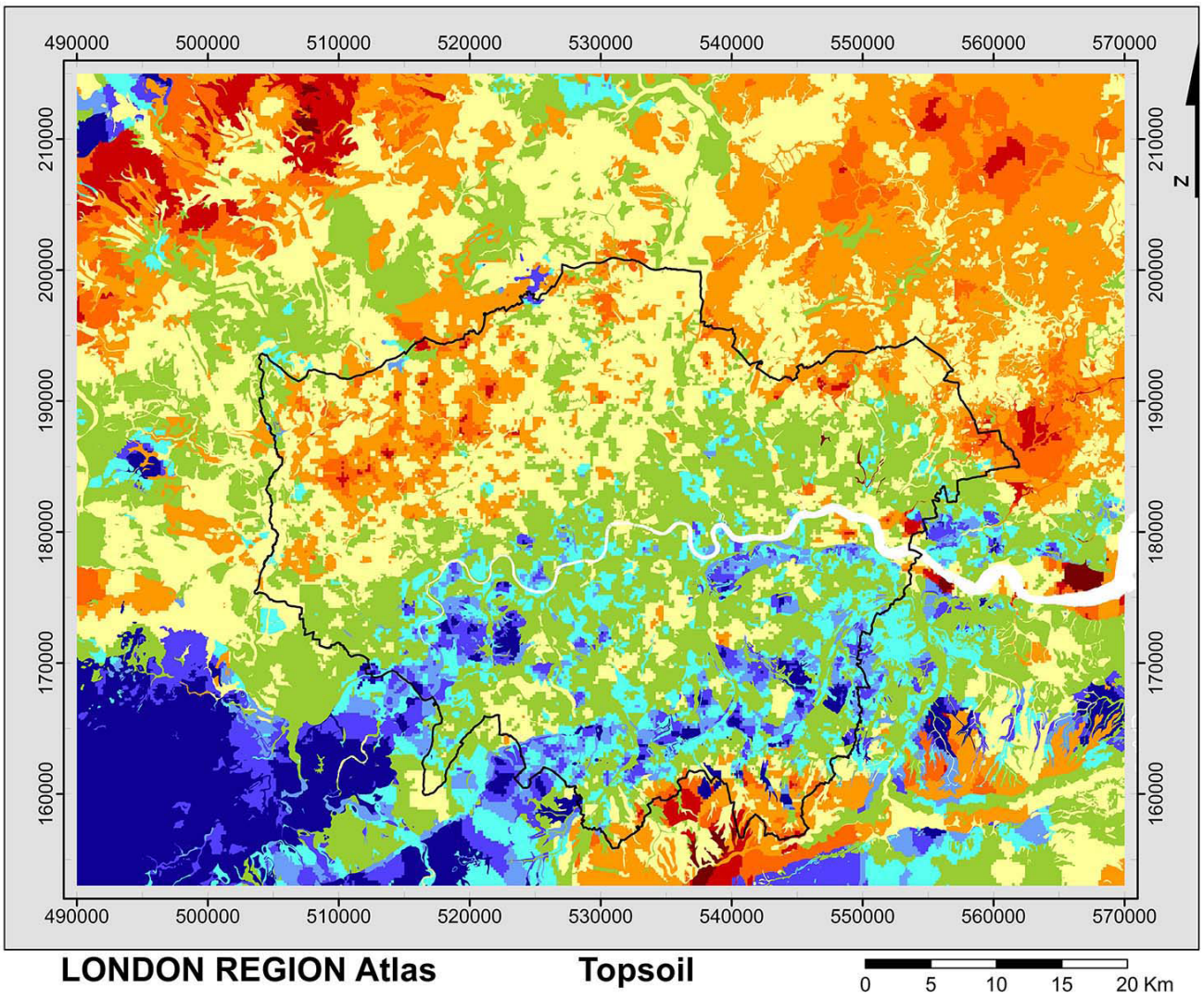
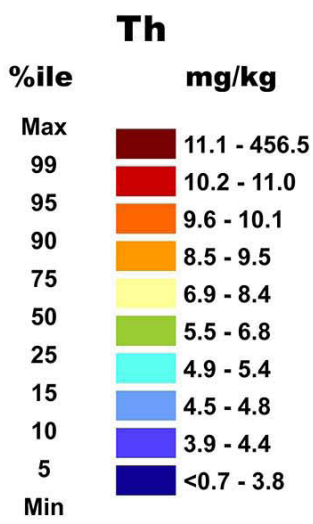
Thorium: LRA





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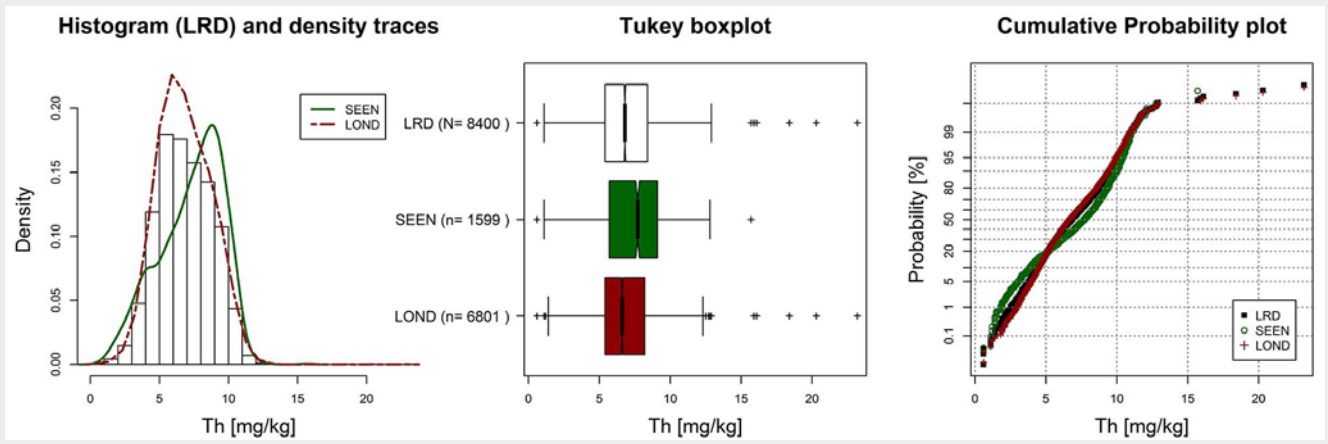
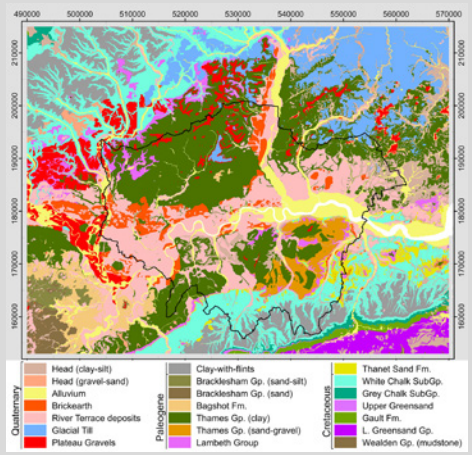
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



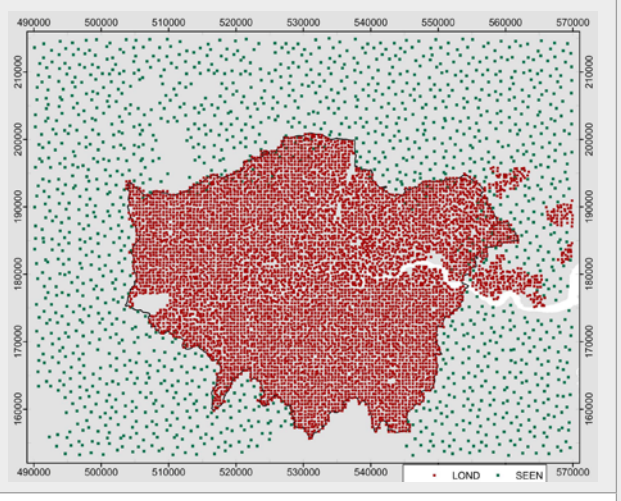
Th [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.7)	0.04	0.06	0.03
minimum	<0.7	<0.7	<0.7
Q25	5.4	5.7	5.4
median	**6.8**	**7.7**	**6.6**
Q75	8.4	9.1	8.2
Q95	10.1	10.4	9.9
Q99	11	11	11
maximum	456.5	15.7	456.5
MAD	**2.2**	**2.4**	**2.1**
CVR%	32.7	30.8	31.4
mean	7	7.3	6.9
SD	5.3	2.3	5.8
CV%	76.1	31.6	83.9
GM	6.6	6.8	6.5
GSD	1.38	1.49	1.35
powers	2.88	1.42	2.88
skewness	72.99	-0.49	69.53

At each site a composite topsoil (5–20 cm depth) sample comprising five subsamples was collected from the corners and centre of a 20 x 20 m square. After collection samples were air/oven dried and sieved to <2 mm before analysis to determine the total contents of more than 50 chemical elements by X-ray fluorescence spectrometry (XRFS).

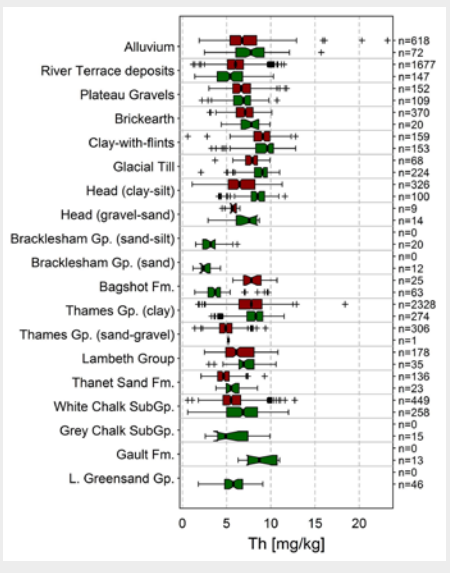
Simplified GEOLOGY (adapted from DiGMapGB-50)



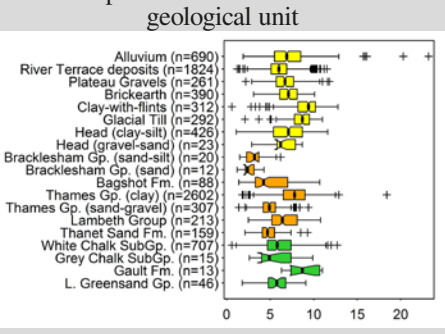
Sample locations



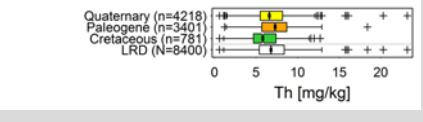
LOND and SEEN topsoil concentrations over each geological unit

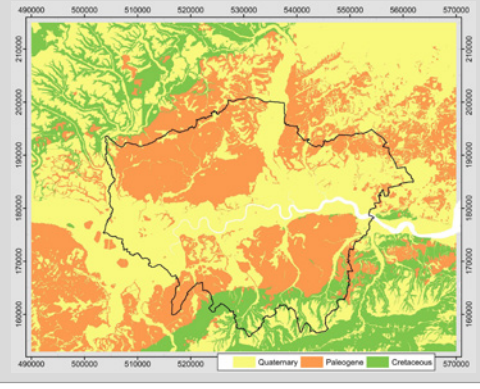


LRD topsoil concentrations over each geological unit



Geology time period:





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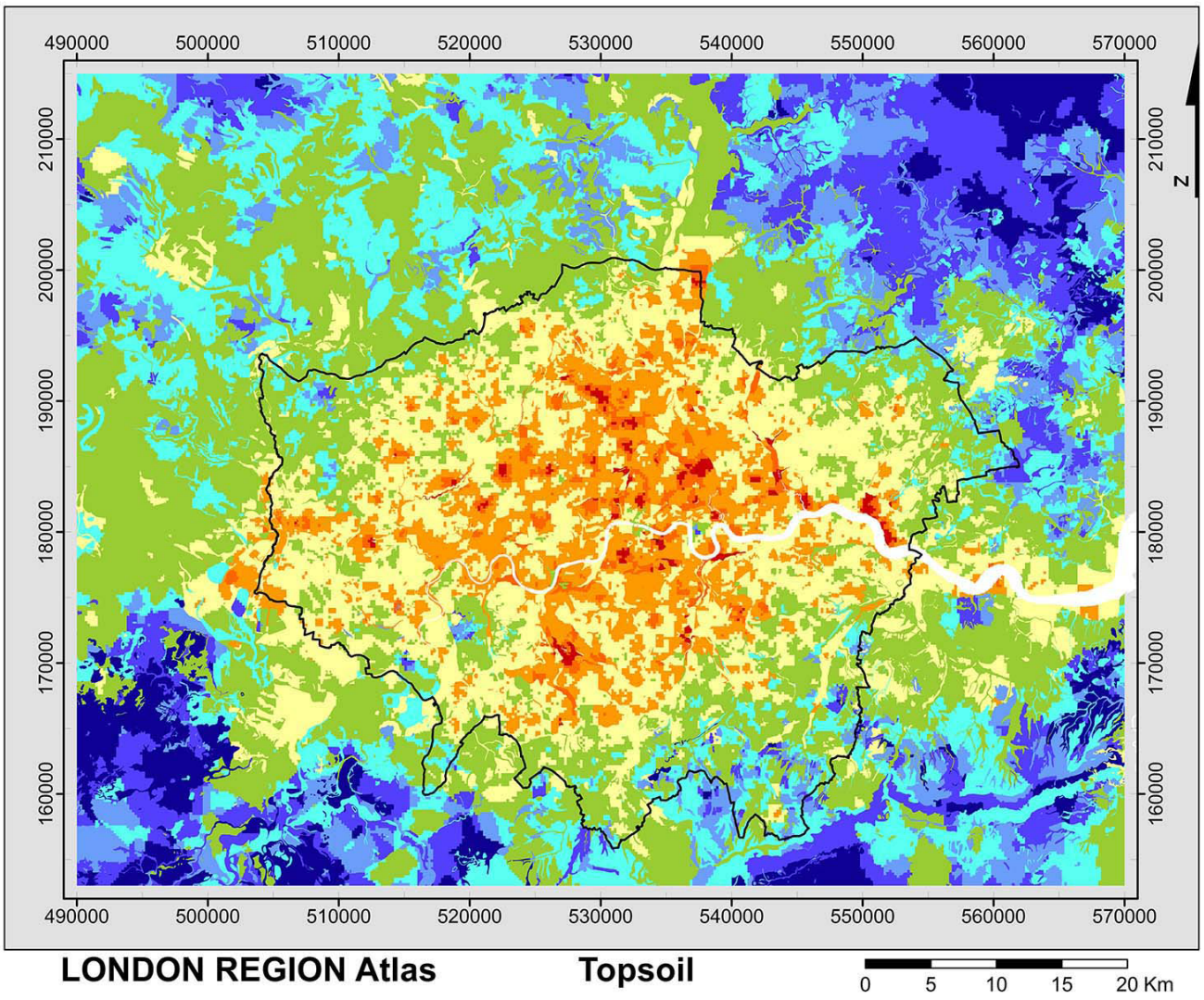
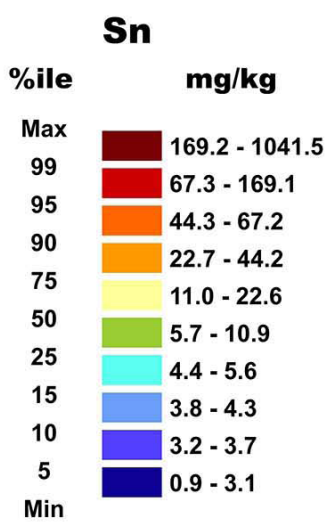
Tin: LRA





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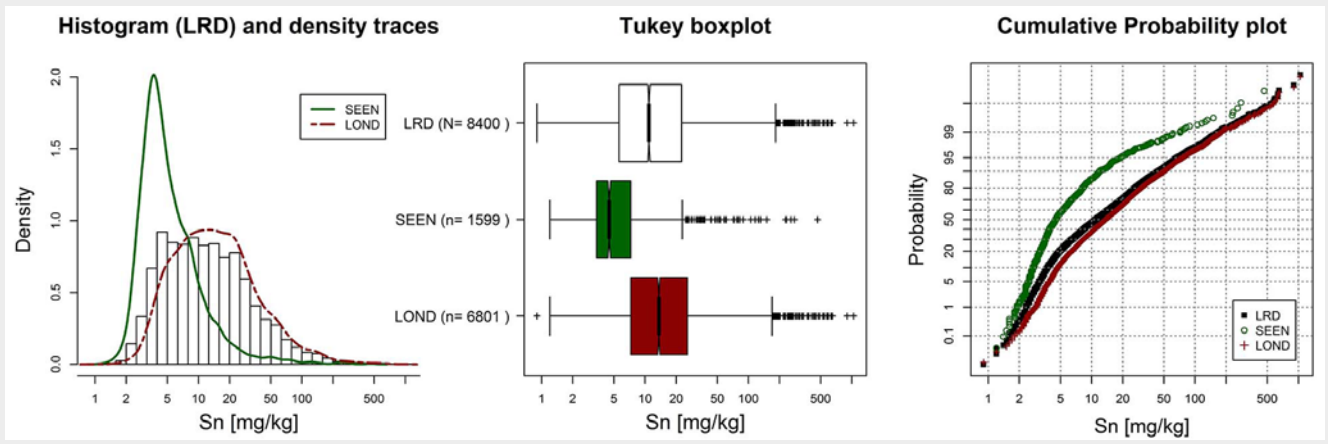
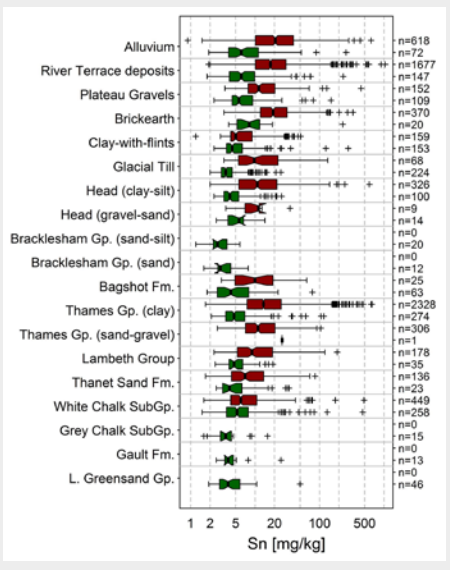


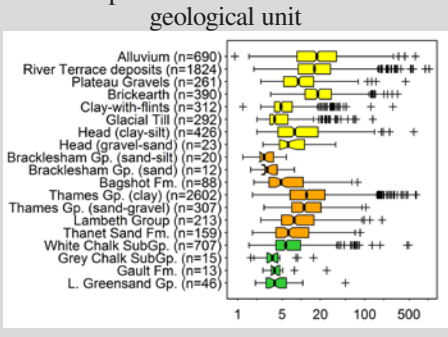
Sn [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.5)	0	0	0
minimum	0.9	1.2	0.9
Q25	5.6	3.4	7.3
median	**10.9**	**4.5**	**13.6**
Q75	22.6	7.3	25.7
Q95	67.2	18.9	75.9
Q99	169.1	71.8	181.1
maximum	1041.5	466.5	1041.5
MAD	**9.6**	**2.2**	**11.4**
CVR%	88.4	49.4	83.9
mean	21.5	8.1	24.6
SD	40	19.7	42.8
CV%	186.2	243.5	173.9
GM	12.1	5.3	14.6
GSD	2.64	2	2.52
powers	3.06	2.59	3.06
skewness	9.24	13.59	8.83

Sample locations

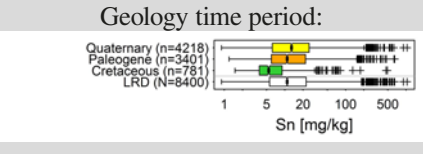
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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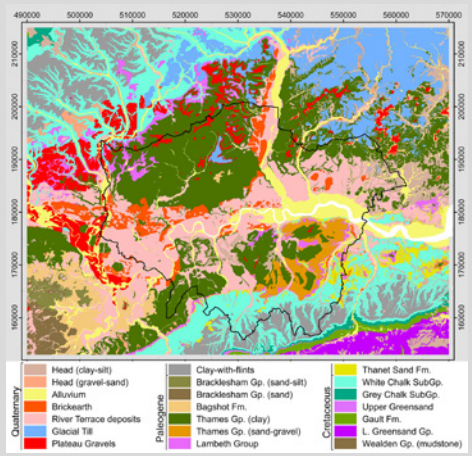
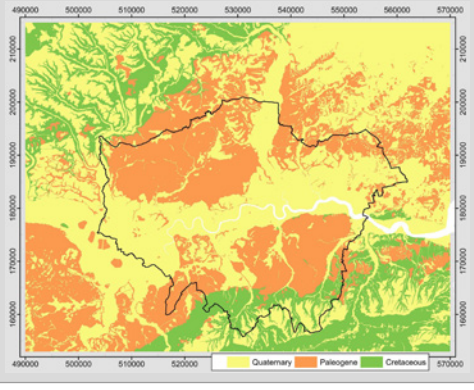
Simplified GEOLOGY (adapted from DiGMapGB-50)





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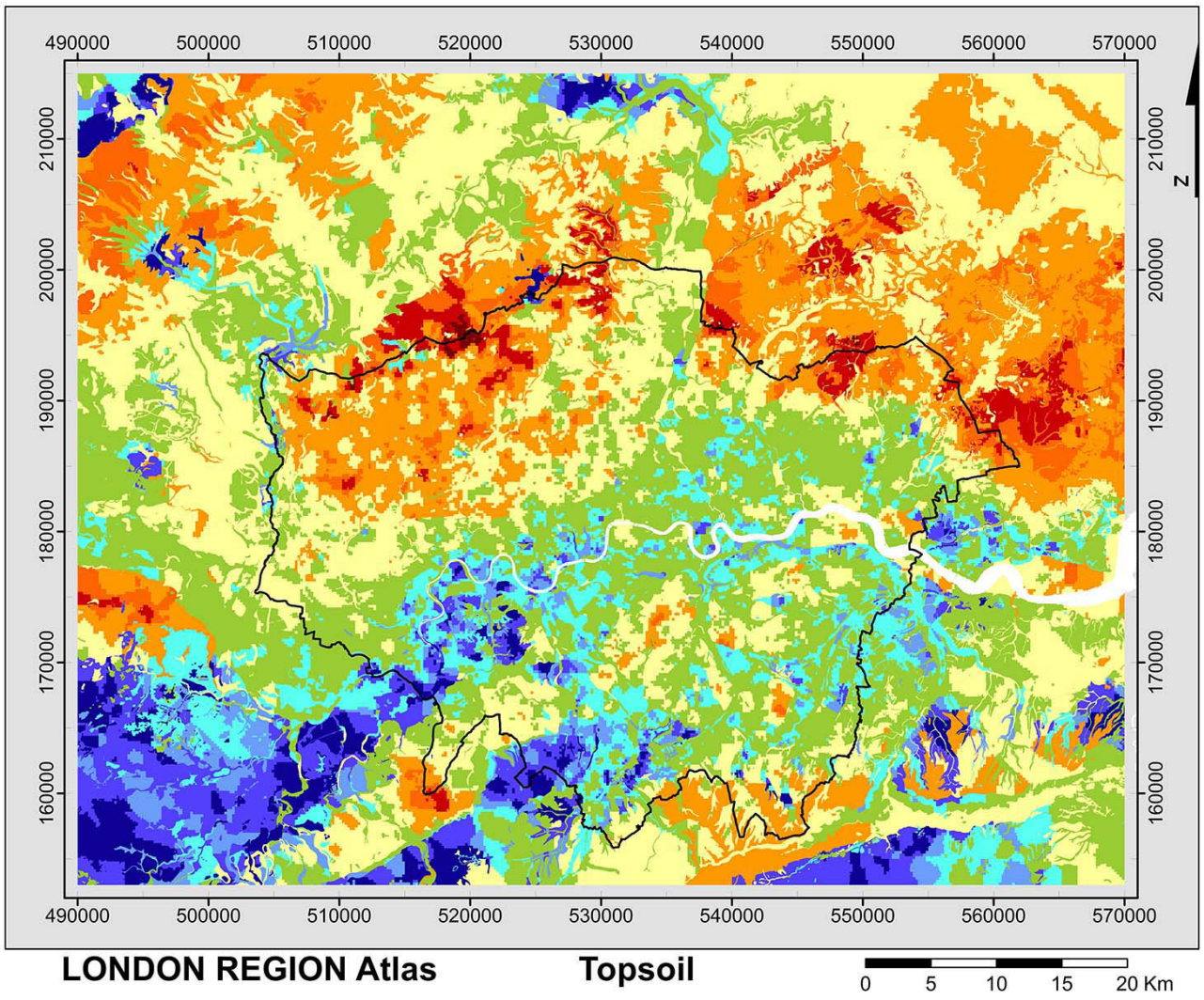
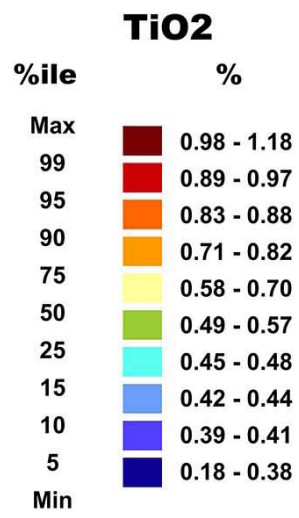
Titanium: LRA





The black outline represents geographical limit of the Greater London Authority (GLA). Areas in white represent tidal waters of the River Thames.

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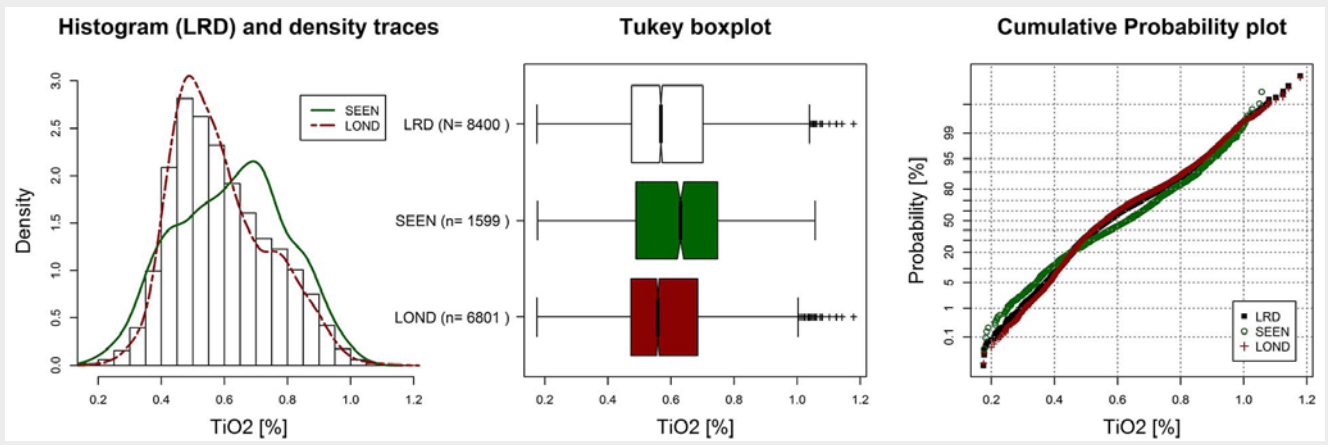
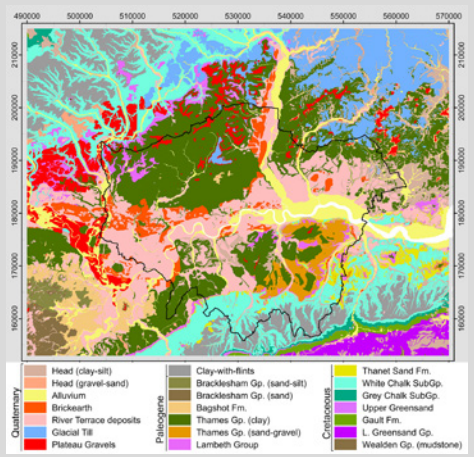
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



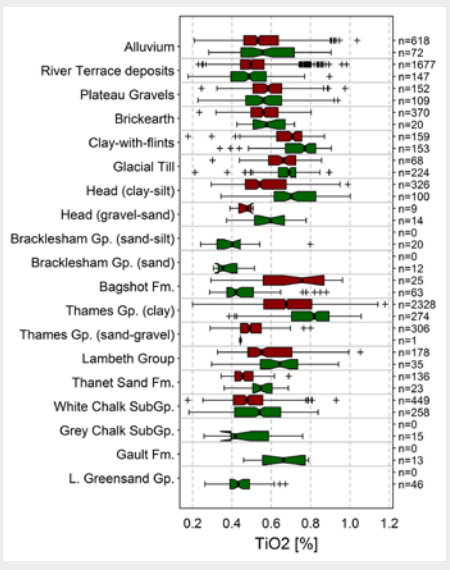
Simplified GEOLOGY (adapted from DiGMapGB-50)



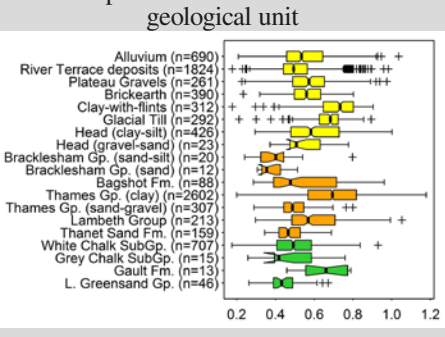
TiO2 [%]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.01)	0	0	0
minimum	0.18	0.18	0.18
Q25	0.48	0.49	0.47
median	**0.57**	**0.63**	**0.56**
Q75	0.7	0.75	0.68
Q95	0.88	0.9	0.87
Q99	0.97	0.98	0.96
maximum	1.18	1.06	1.18
MAD	**0.16**	**0.19**	**0.15**
CVR%	28.2	30.6	26.3
mean	0.59	0.62	0.59
SD	0.16	0.17	0.15
CV%	26.5	28.1	25.9
GM	0.57	0.59	0.57
GSD	1.31	1.36	1.29
powers	0.83	0.78	0.83
skewness	0.44	-0.05	0.57

Sample locations

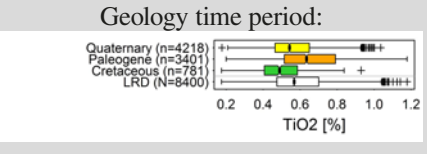
LOND and SEEN topsoil concentrations over each geological unit



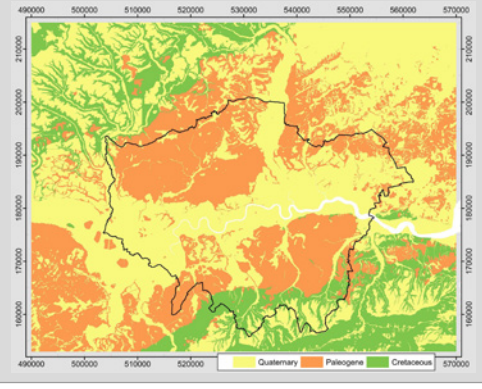
LRD topsoil concentrations over each geological unit



Geology time period:



At each site a composite topsoil (5–20 cm depth) sample comprising five subsamples was collected from the corners and centre of a 20 x 20 m square. After collection samples were air/oven dried and sieved to <2 mm before analysis to determine the total contents of more than 50 chemical elements by X-ray fluorescence spectrometry (XRFS).



Each geochemical map was prepared by interpolating the point data using the parent material mapping method (Appleton et al., 2013[1]). The LRA area was subdivided into 200 x 200 m squares and intercepted with the geology (parent material) polygons, thereby creating the basic 200 m-PM polygons. For each 200 m-PM polygon the average concentration based on the four nearest samples over the same PM was computed (see further explanation in Materials and methods and references therein). As the maps (produced in ArcGIS 10.1) show estimated concentrations, there is a degree of uncertainty due to variability in soil composition. The element concentration colour ramp is based on percentile classes of the LRD dataset distribution. The tables and graphs were generated running R (R x 64 3.1.0) in RStudio (Version 0.98.977). The LRD, LOND and SEEN surveys are represented by the colours black/white, dark green and dark red respectively. Quaternary, Palaeogene and Cretaceous geological time periods are represented by soft yellow, orange and lime green colours respectively. For further information go to Univariate statistics and graphics.

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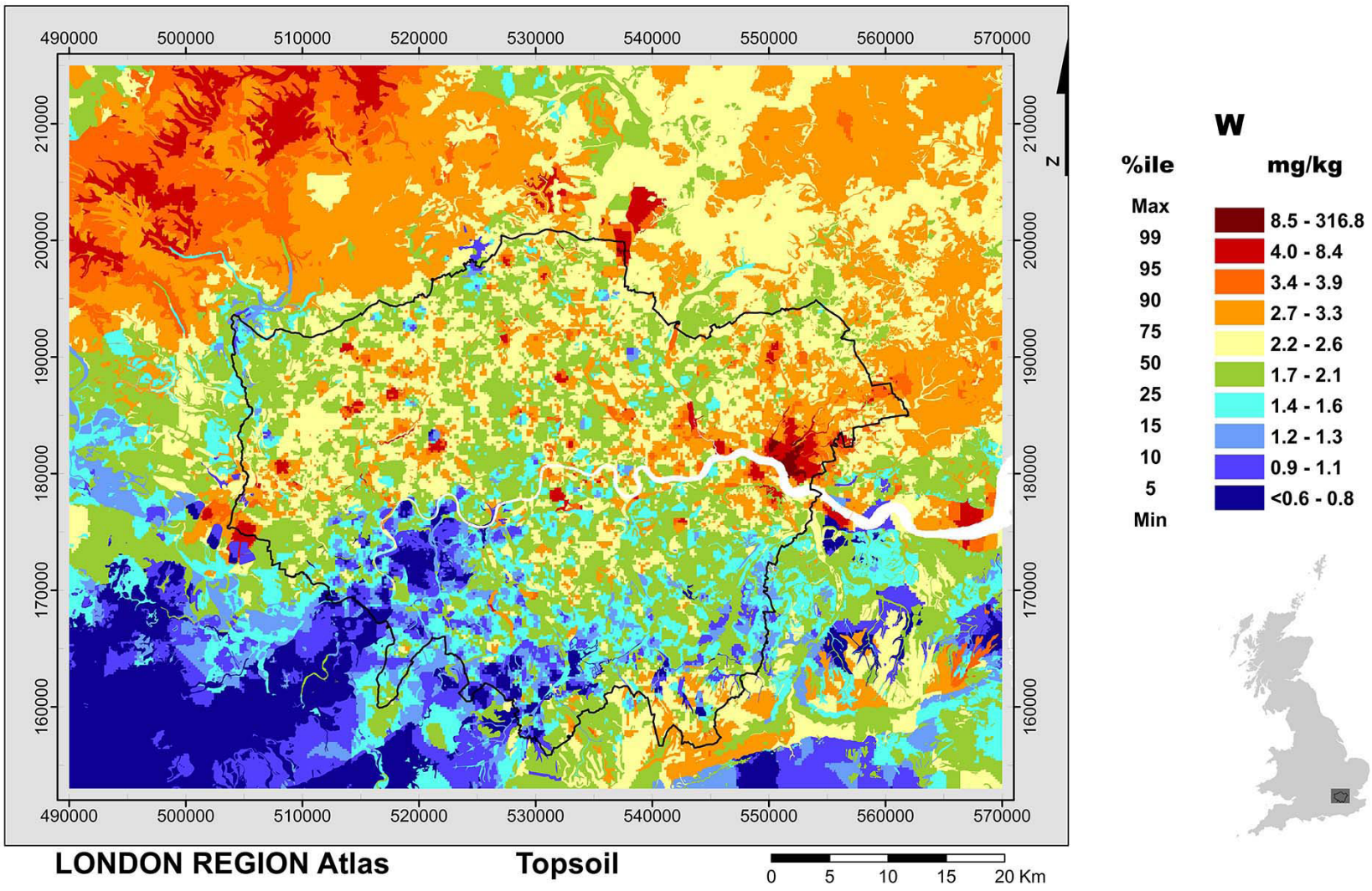
Tungsten: LRA



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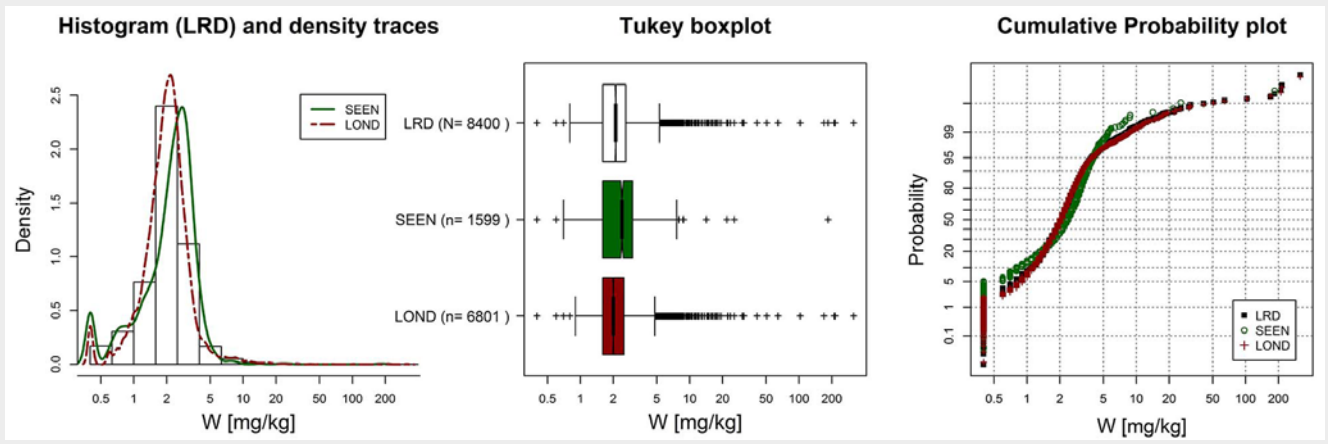
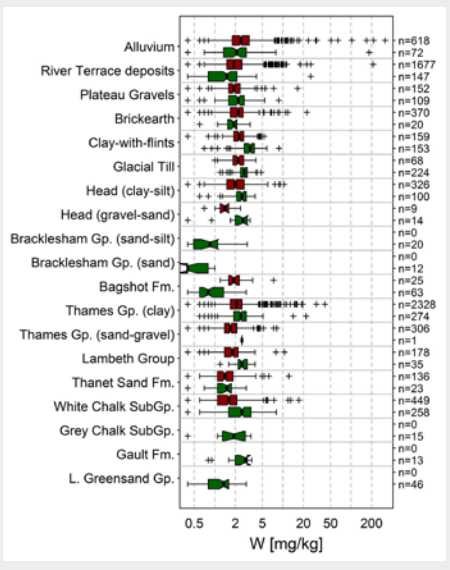
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



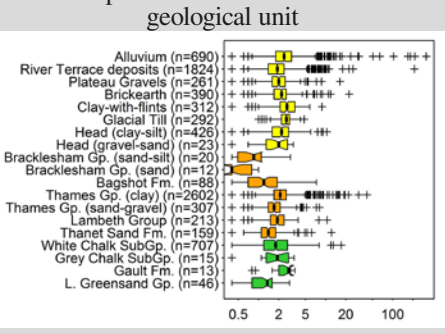
W [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.6)	2.61	5.07	2.03
minimum	<0.6	<0.6	<0.6
Q25	1.6	1.6	1.6
median	**2.1**	**2.4**	**2**
Q75	2.6	3	2.5
Q95	3.9	4	3.9
Q99	8.4	5.5	8.7
maximum	316.8	184.6	316.8
MAD	**0.7**	**1**	**0.7**
CVR%	35.3	43.2	37.1
mean	2.4	2.5	2.4
SD	5.8	4.8	6.1
CV%	241.8	193.1	252.4
GM	2	2	2
GSD	1.7	1.83	1.67
powers	2.9	2.66	2.9
skewness	37.17	35.25	36.96

Sample locations

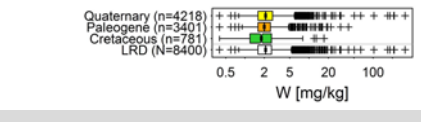
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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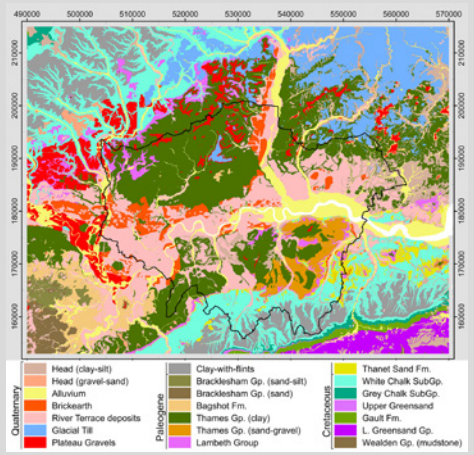
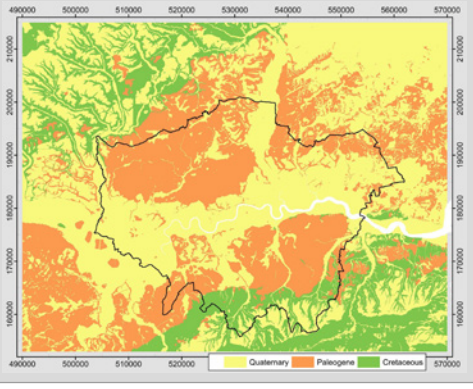
Each geochemical map was prepared by interpolating the point data using the parent material mapping method (Appleton et al., 2013[1]). The LRA area was subdivided into 200 x 200 m squares and intercepted with the geology (parent material) polygons, thereby creating the basic 200 m-PM polygons. For each 200 m-PM polygon the average concentration based on the four nearest samples over the same PM was computed (see further explanation in Materials and methods and references therein). As the maps (produced in ArcGIS 10.1) show estimated concentrations, there is a degree of uncertainty due to variability in soil composition. The element concentration colour ramp is based on percentile classes of the LRD dataset distribution. The tables and graphs were generated running R (R x 64 3.1.0) in RStudio (Version 0.98.977). The LRD, LOND and SEEN surveys are represented by the colours black/white, dark green and dark red respectively. Quaternary, Palaeogene and Cretaceous geological time periods are represented by soft yellow, orange and lime green colours respectively. For further information go to Univariate statistics and graphics.

Simplified GEOLOGY (adapted from DiGMapGB-50)





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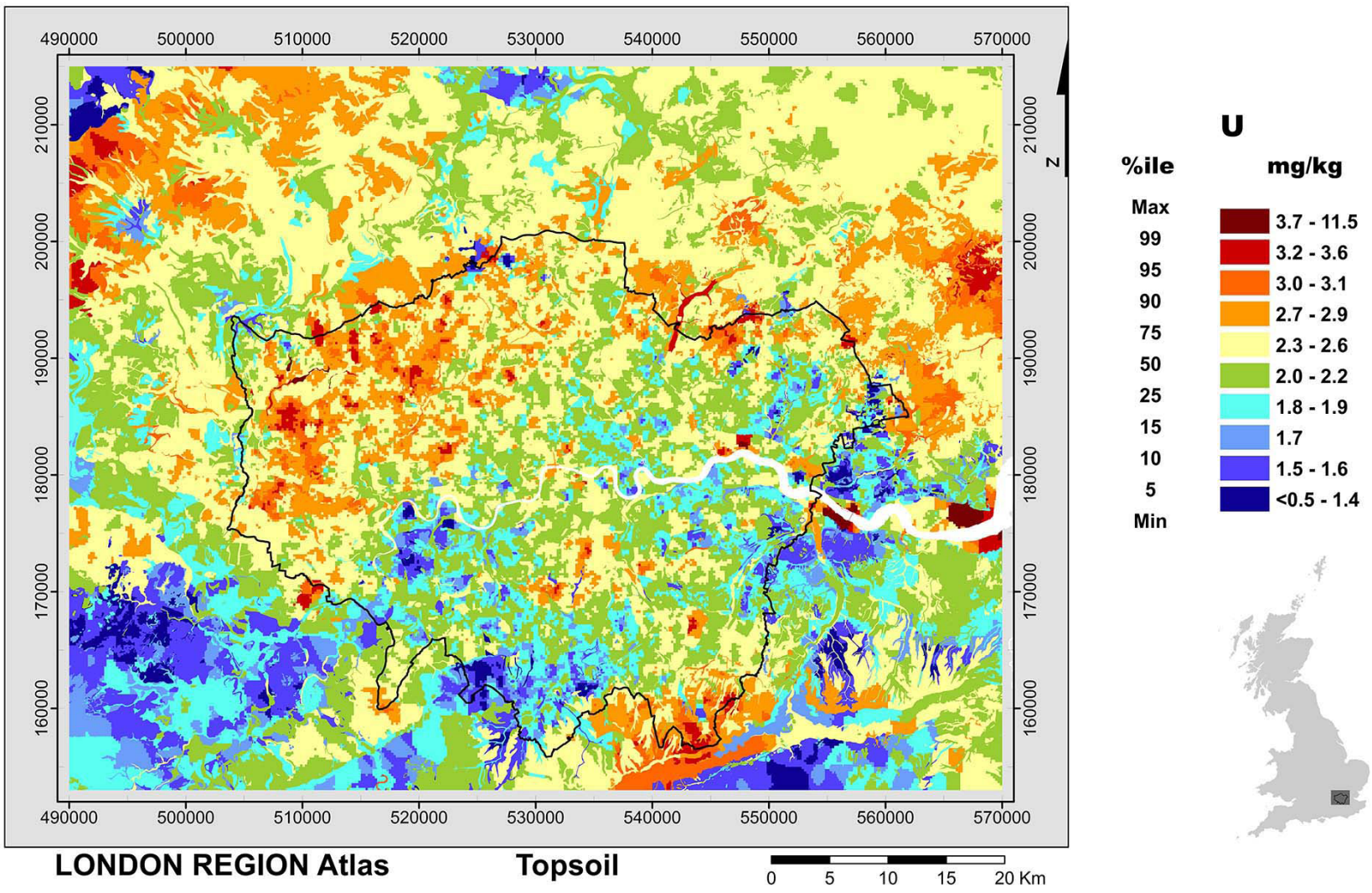
Uranium: LRA



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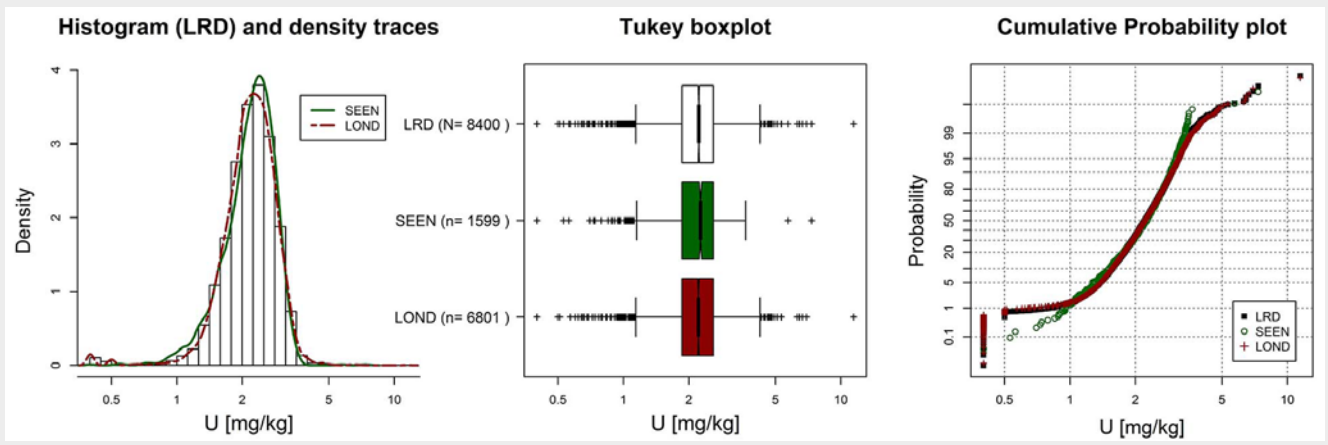
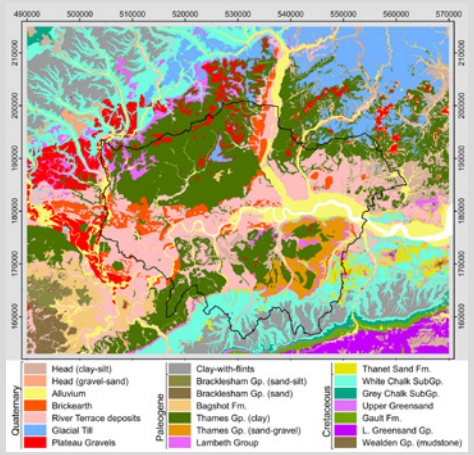


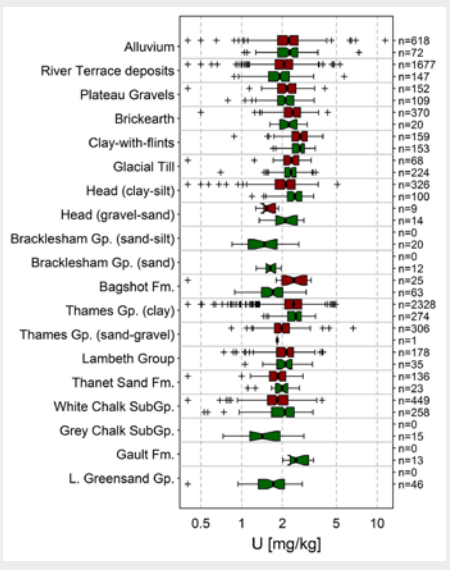
U [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (0.5)	0.51	0.06	0.62
minimum	<0.5	<0.5	<0.5
Q25	1.9	1.9	1.9
median	**2.2**	**2.3**	**2.2**
Q75	2.6	2.6	2.6
Q95	3.1	3.1	3.2
Q99	3.6	3.4	3.6
maximum	11.4	7.3	11.4
MAD	**0.5**	**0.5**	**0.5**
CVR%	24.7	23.6	24.2
mean	2.2	2.2	2.2
SD	0.6	0.6	0.6
CV%	26.1	24.9	26.4
GM	2.2	2.2	2.1
GSD	1.34	1.31	1.34
powers	1.46	1.26	1.46
skewness	0.88	0.43	0.96

Simplified GEOLOGY (adapted from DiGMapGB-50)

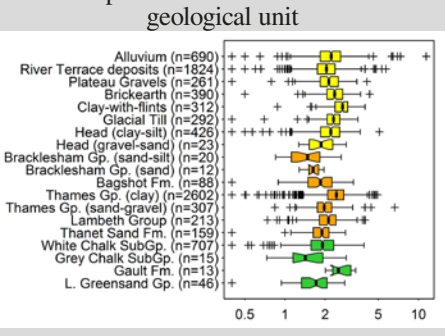


Sample locations

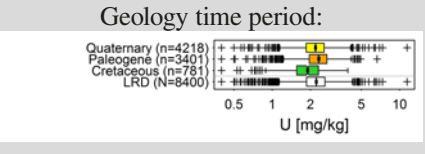
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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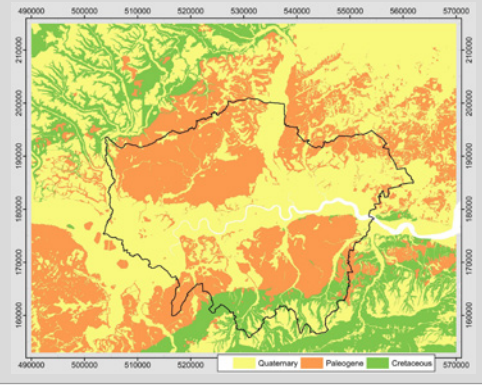

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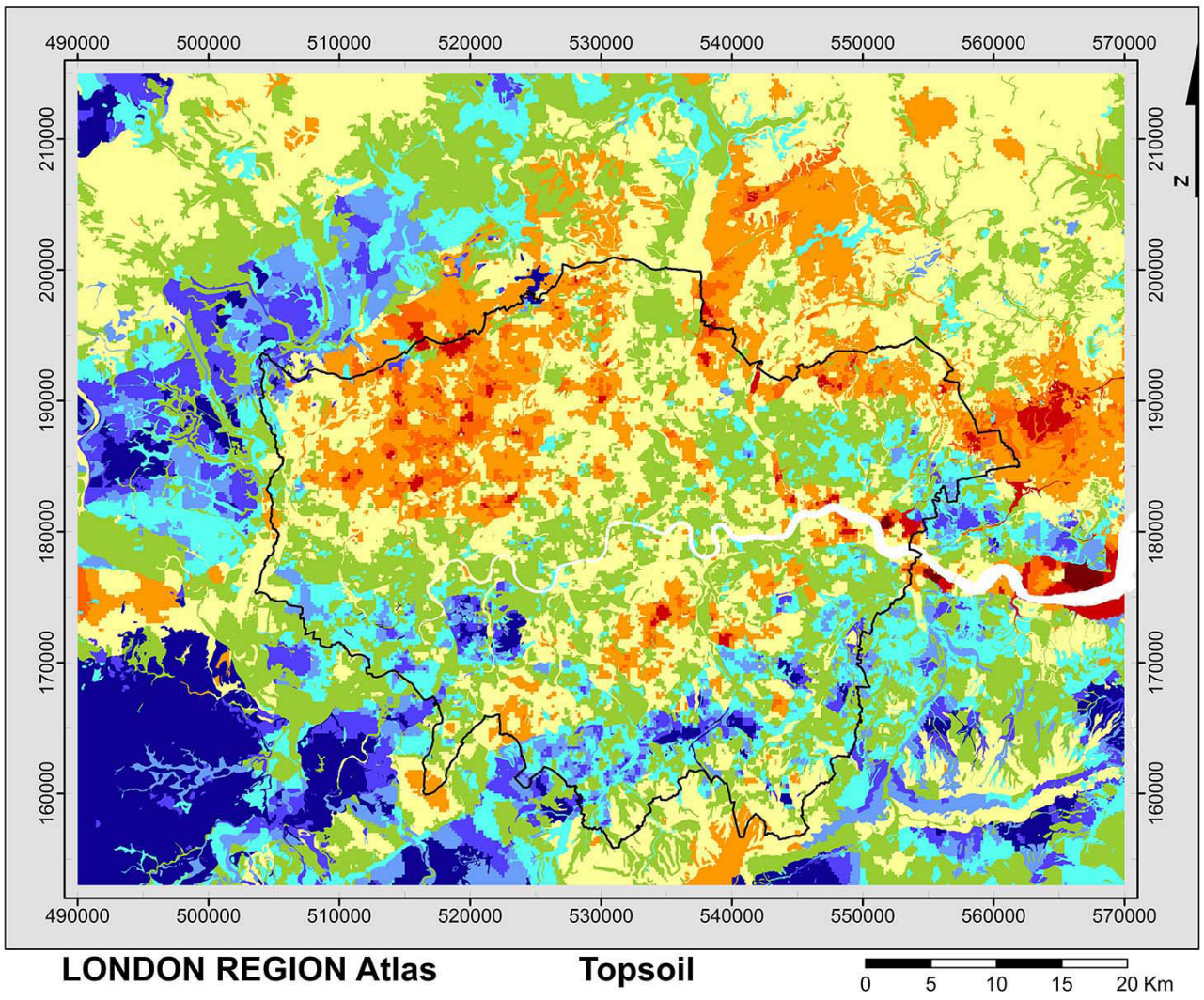
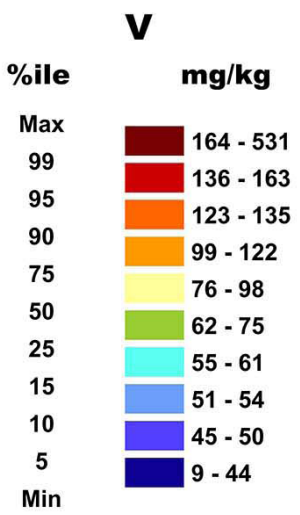
Vanadium: LRA





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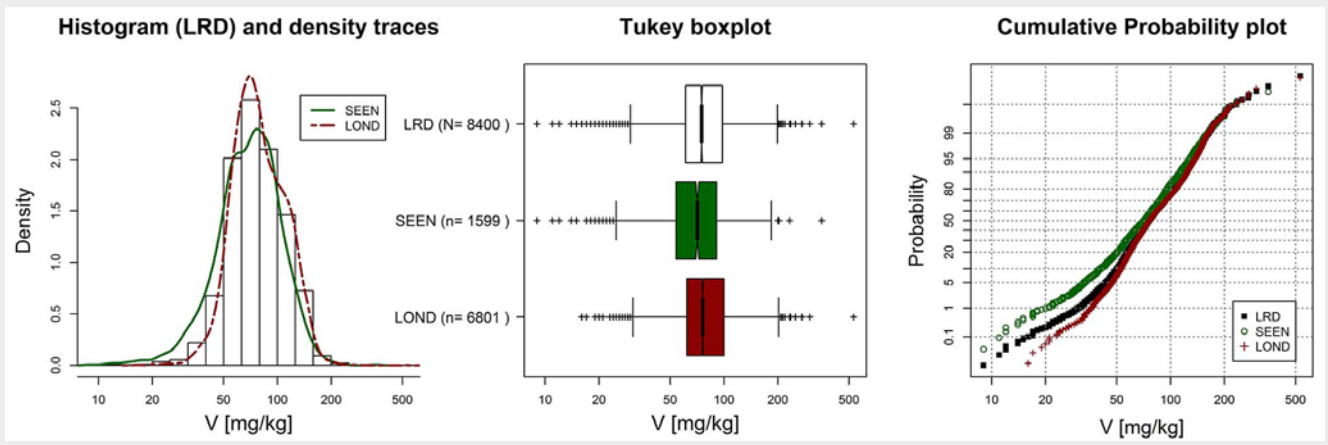
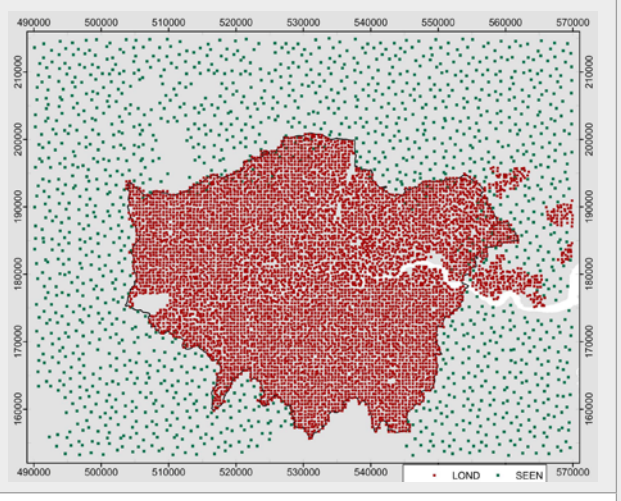
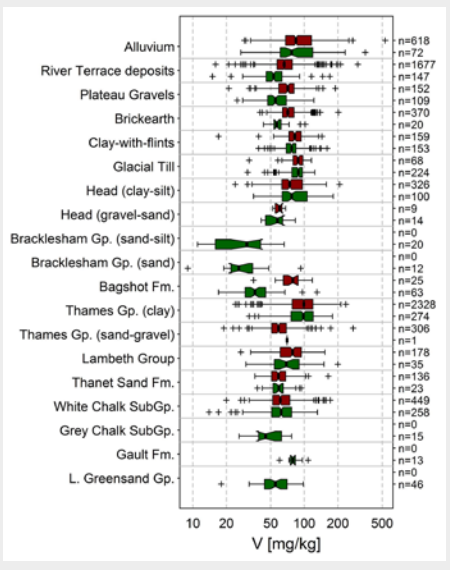


V [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (3)	0	0	0
minimum	9	9	16
Q25	61	54	62
median	**75**	**71**	**76**
Q75	98	91	100
Q95	135	128	137
Q99	163	161	163
maximum	531	352	531
MAD	**25.2**	**26.7**	**25.2**
CVR%	33.6	37.6	33.2
mean	81.4	74.5	83.1
SD	29.7	30.1	29.3
CV%	36.4	40.4	35.3
GM	76.5	68.6	78.4
GSD	1.43	1.52	1.4
powers	1.77	1.59	1.52
skewness	1.41	1.24	1.5

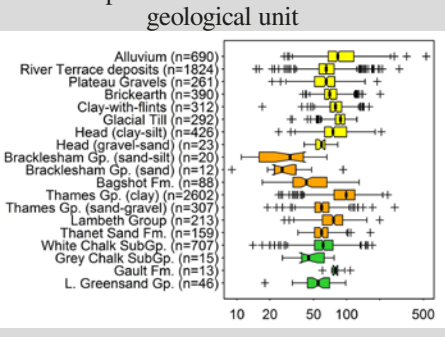
Sample locations



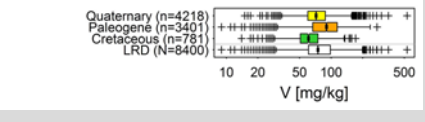
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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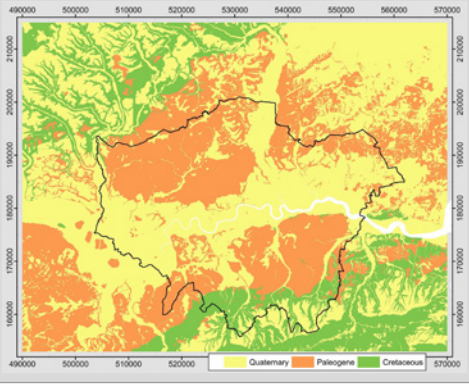

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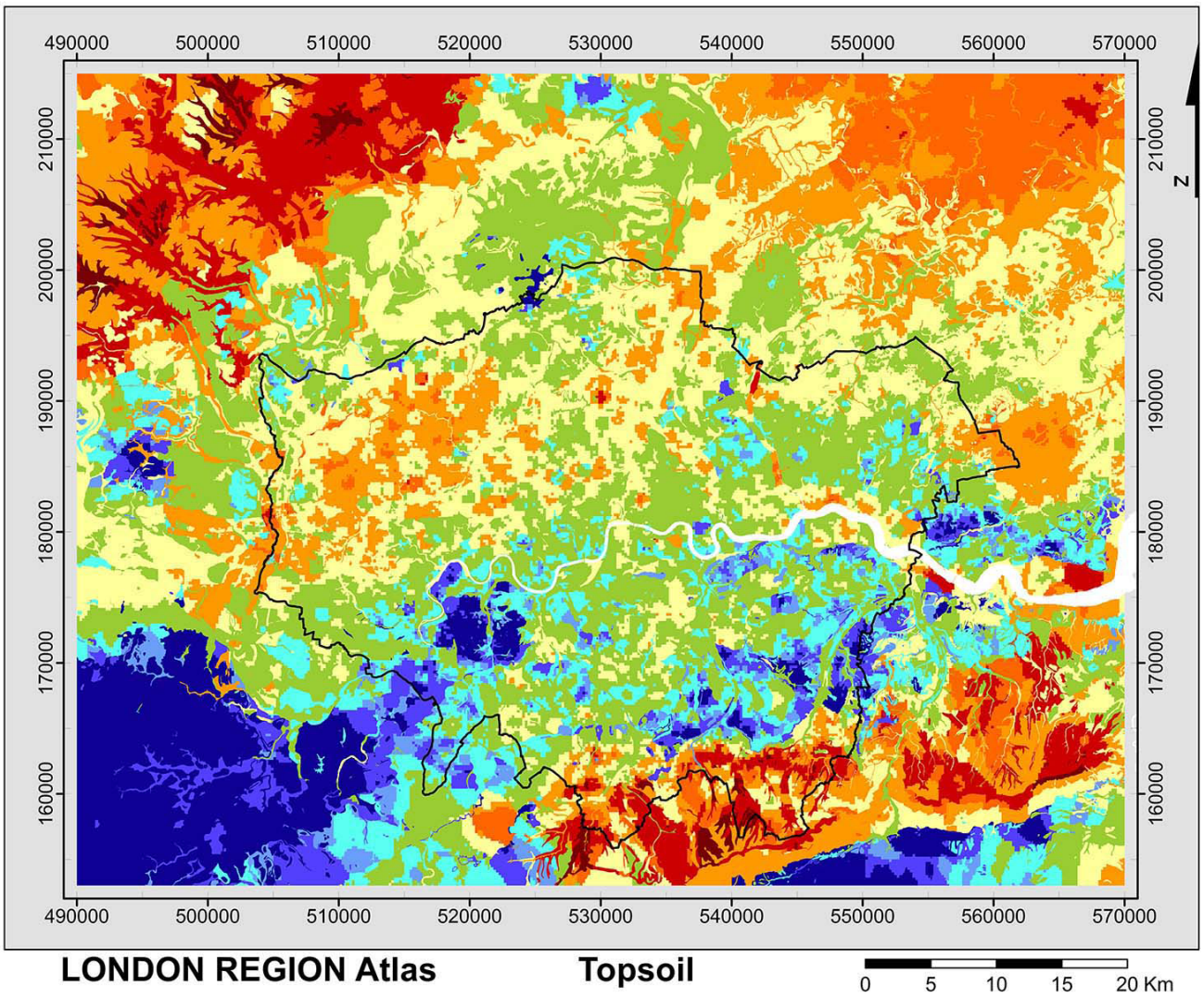
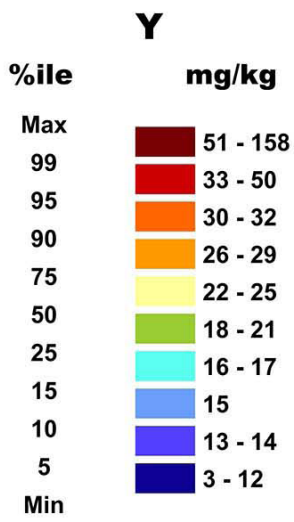
Yttrium: LRA





The black outline represents geographical limit of the Greater London Authority (GLA). Areas in white represent tidal waters of the River Thames.

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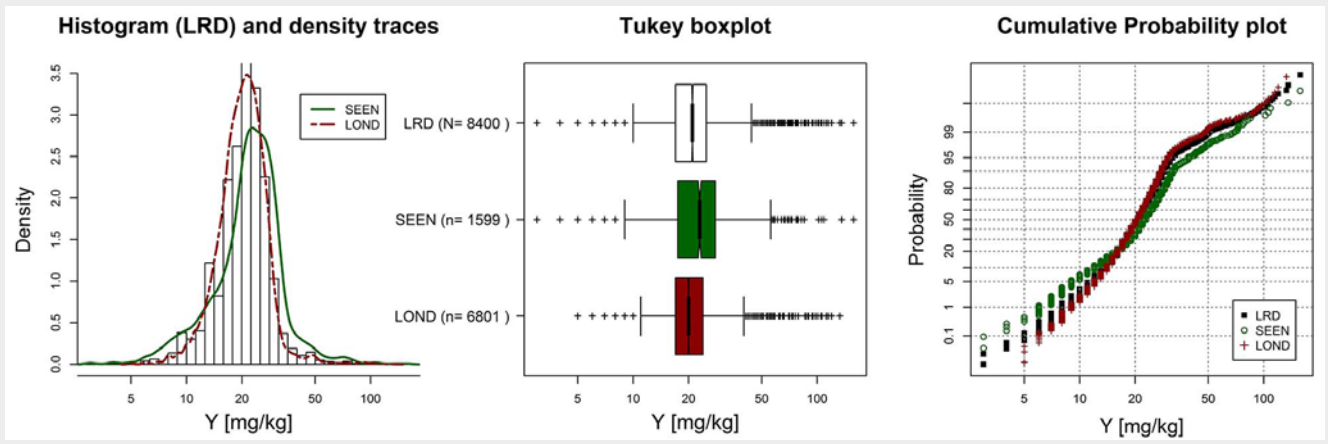
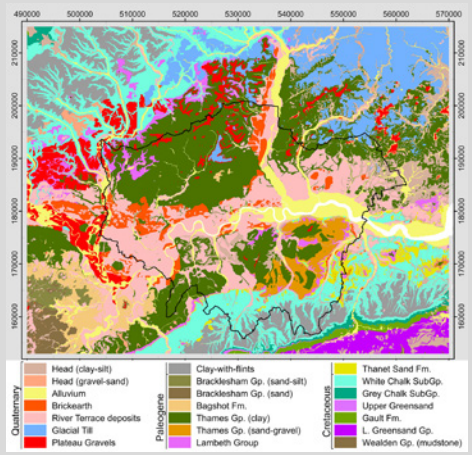
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets

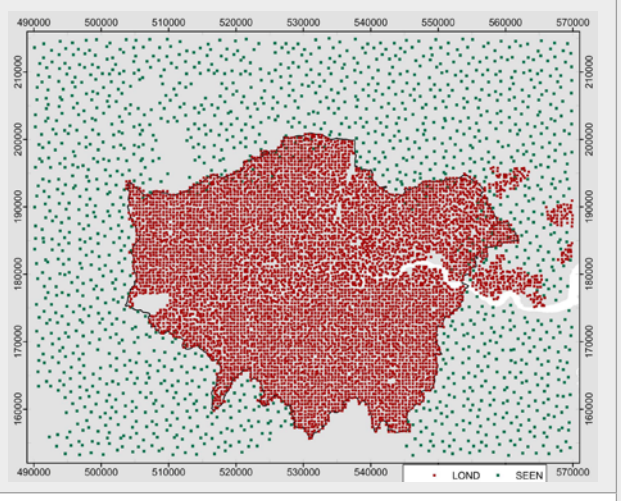


Y [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1)	0	0	0
minimum	3	3	5
Q25	17	17.5	17
median	**21**	**23**	**20**
Q75	25	28	24
Q95	32	39	30
Q99	50	69	48
maximum	158	158	133
MAD	**5.9**	**7.4**	**5.9**
CVR%	28.2	32.2	29.7
mean	21.6	23.5	21.1
SD	8.5	11.3	7.6
CV%	39.3	48.1	35.9
GM	20.3	21.4	20.1
GSD	1.4	1.55	1.35
powers	1.72	1.72	1.42
skewness	4.16	3.46	4.24

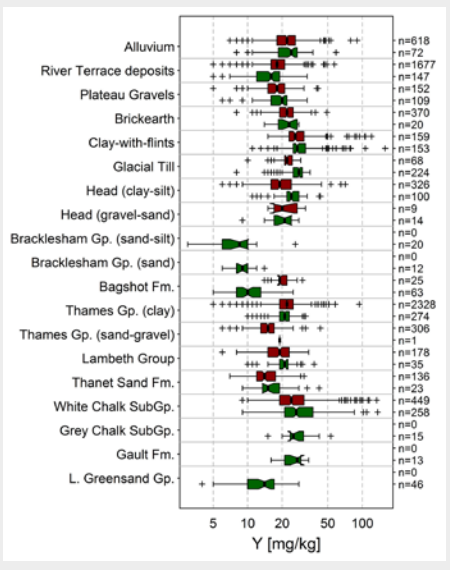
Simplified GEOLOGY (adapted from DiGMapGB-50)



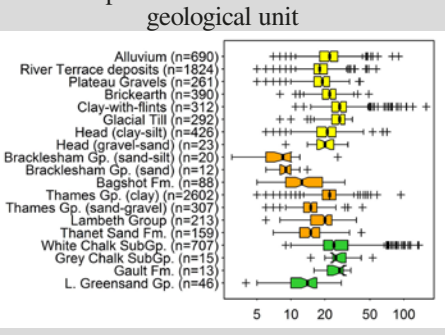
Sample locations



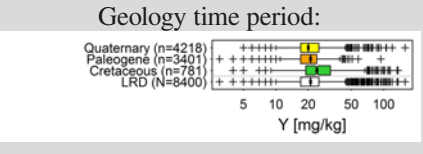
LOND and SEEN topsoil concentrations over each geological unit



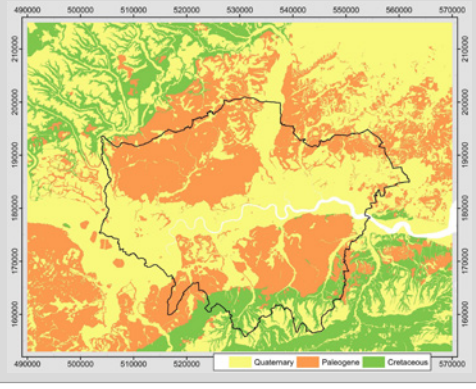
LRD topsoil concentrations over each geological unit



Geology time period:



At each site a composite topsoil (5–20 cm depth) sample comprising five subsamples was collected from the corners and centre of a 20 x 20 m square. After collection samples were air/oven dried and sieved to <2 mm before analysis to determine the total contents of more than 50 chemical elements by X-ray fluorescence spectrometry (XRFS).



Each geochemical map was prepared by interpolating the point data using the parent material mapping method (Appleton et al., 2013[1]). The LRA area was subdivided into 200 x 200 m squares and intercepted with the geology (parent material) polygons, thereby creating the basic 200 m-PM polygons. For each 200 m-PM polygon the average concentration based on the four nearest samples over the same PM was computed (see further explanation in Materials and methods and references therein). As the maps (produced in ArcGIS 10.1) show estimated concentrations, there is a degree of uncertainty due to variability in soil composition. The element concentration colour ramp is based on percentile classes of the LRD dataset distribution. The tables and graphs were generated running R (R x 64 3.1.0) in RStudio (Version 0.98.977). The LRD, LOND and SEEN surveys are represented by the colours black/white, dark green and dark red respectively. Quaternary, Palaeogene and Cretaceous geological time periods are represented by soft yellow, orange and lime green colours respectively. For further information go to Univariate statistics and graphics.

Reference

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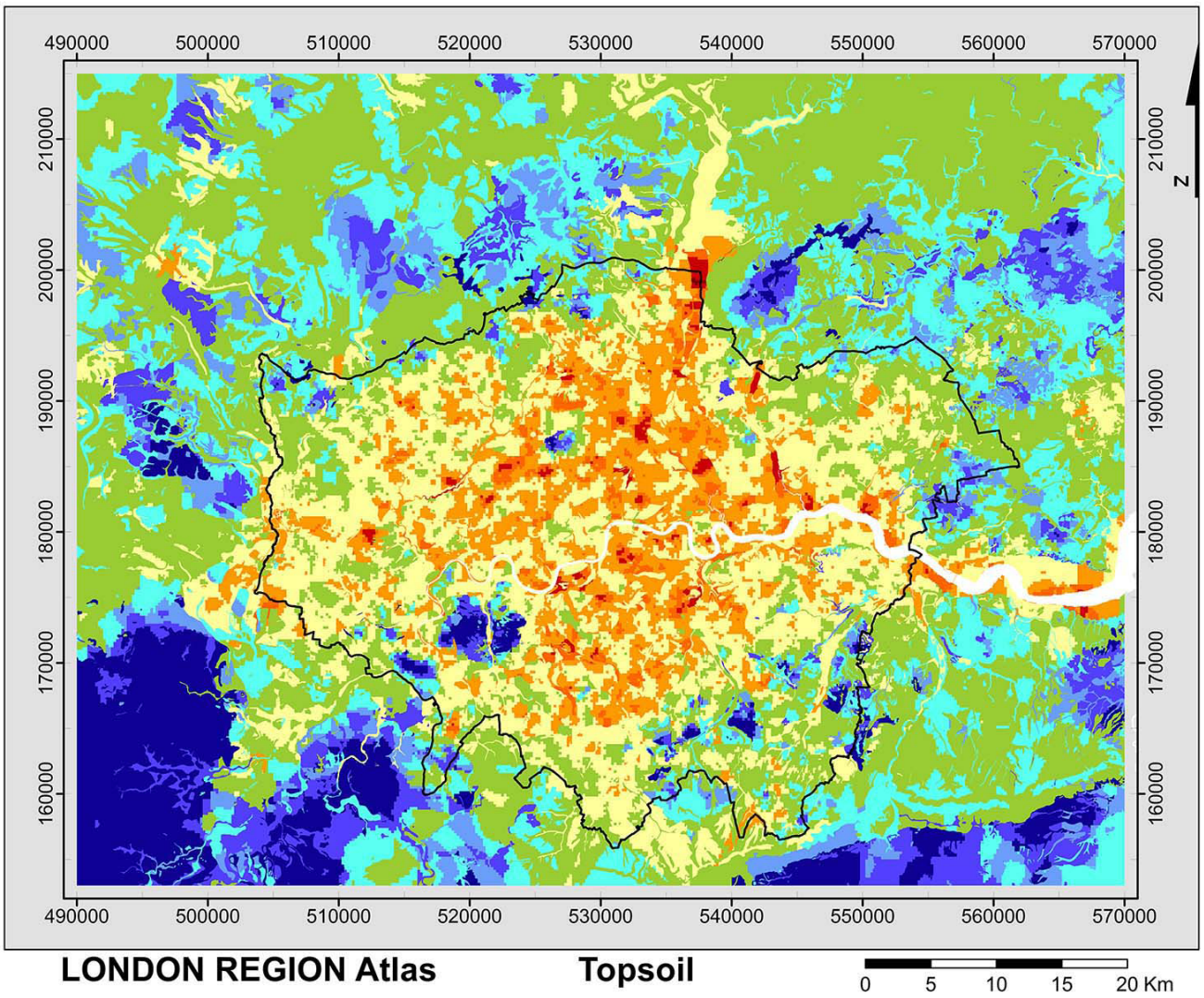
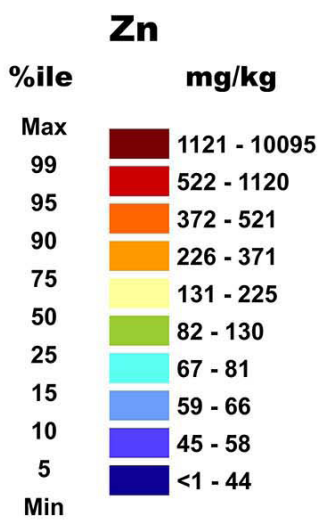
Zinc: LRA





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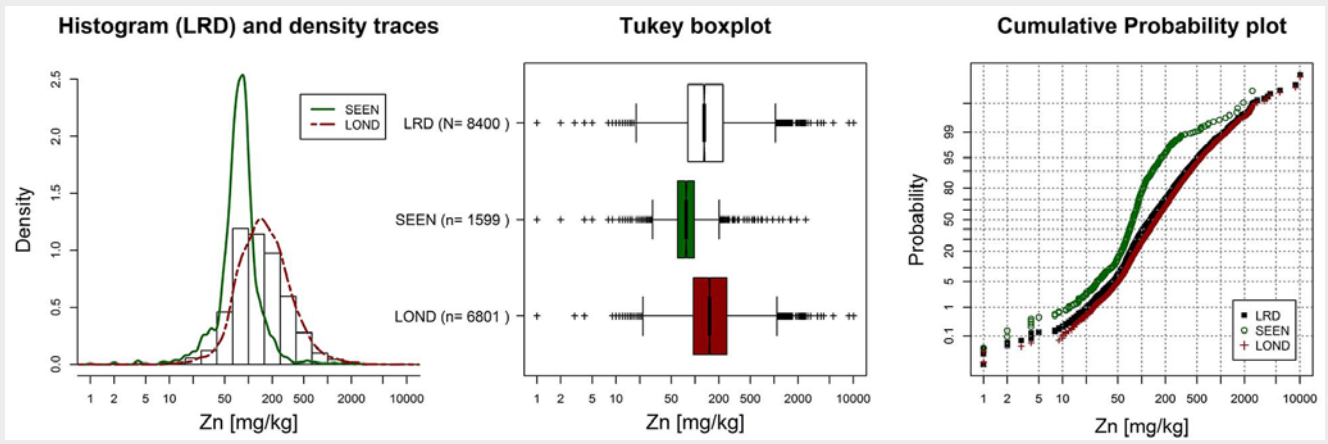
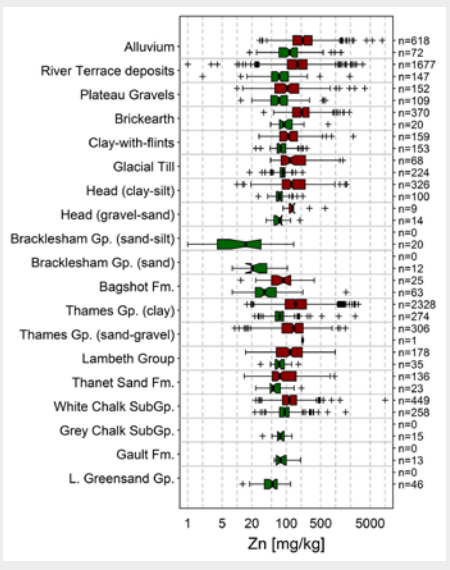
Summary statistics for the LONDON REGION topsoil dataset (LRD) and the SEEN and LOND subsets



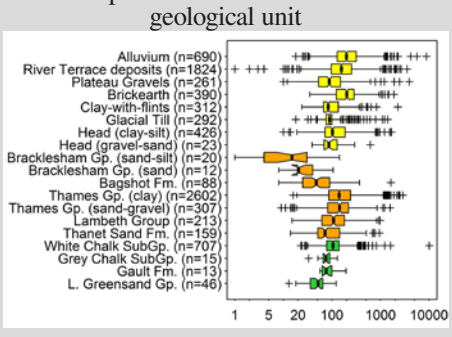
Zn [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1.3)	0.04	0.06	0.03
minimum	<1.3	<1.3	<1.3
Q25	81	60	95
median	**130**	**77**	**152**
Q75	225	98	252
Q95	521	176	563
Q99	1120	446	1214
maximum	10095	2505	10095
MAD	**89**	**27**	**102**
CVR%	68.4	34.7	67.3
mean	195	94	219
SD	269	120	288
CV%	138	127.8	131.7
GM	137	76	158
GSD	2.21	1.84	2.15
powers	4	3.4	4
skewness	13.89	11.81	13.57

Sample locations

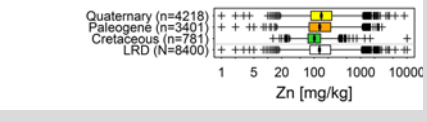
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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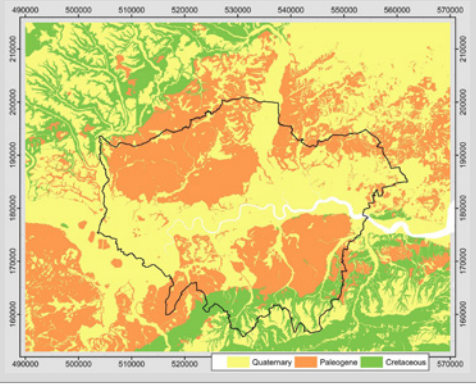

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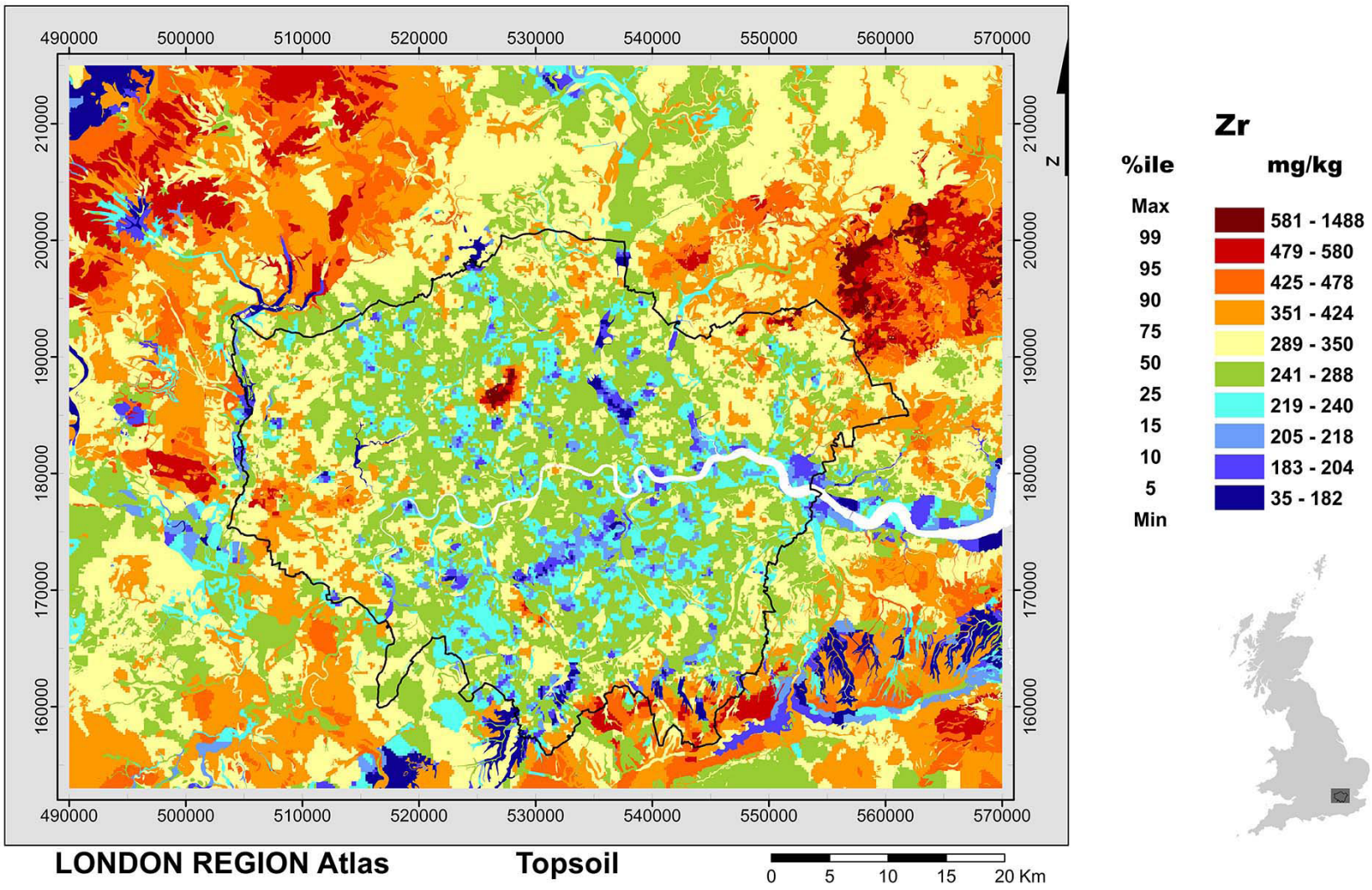
Zirconium: LRA



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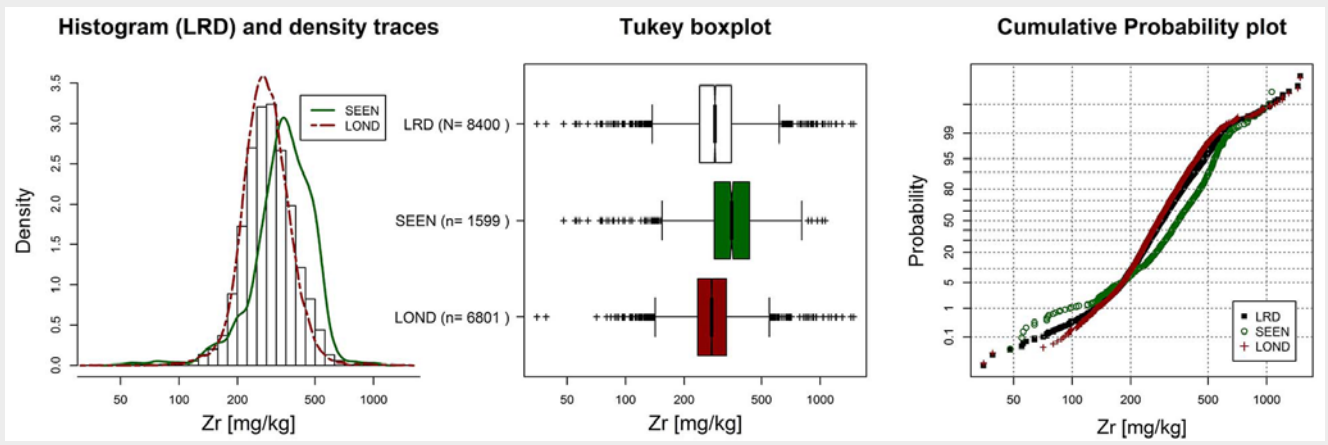
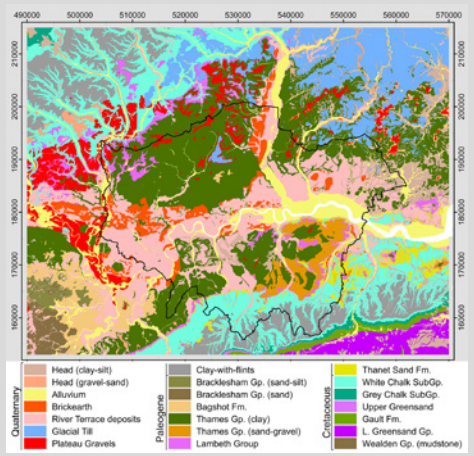
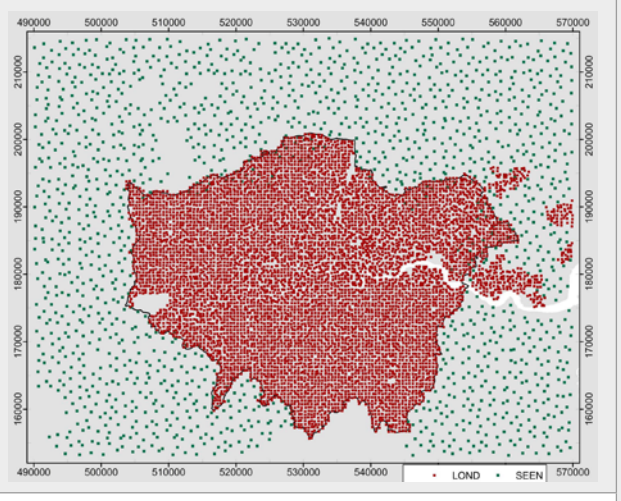


Zr [mg/kg]	statistical parameters		
	LRD	SEEN	LOND
N	8400	1599	6801
%<LLD (1)	0	0	0
minimum	35	48	35
Q25	240	286	235
median	**288**	**351**	**277**
Q75	350	434	330
Q95	478	537	437
Q99	580	646	552
maximum	1488	1062	1488
MAD	**79**	**107**	**70**
CVR%	27.3	30.4	25.2
mean	304	360	291
SD	99	115	89
CV%	32.4	32.1	30.7
GM	290	340	279
GSD	1.36	1.43	1.32
powers	1.63	1.34	1.63
skewness	2.02	0.59	2.71

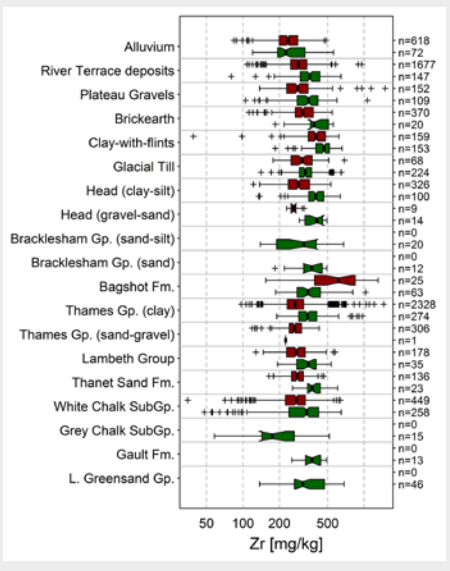
Simplified GEOLOGY
(adapted from DiGMapGB-50)



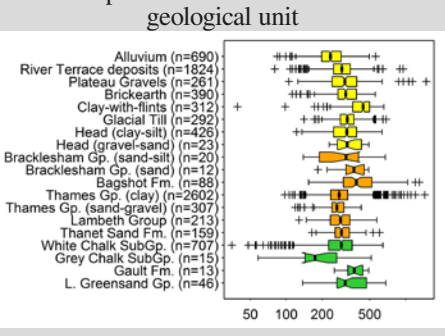
Sample locations



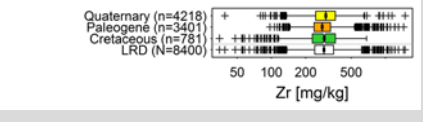
LOND and SEEN topsoil concentrations over each geological unit



LRD topsoil concentrations over each geological unit



Geology time period:



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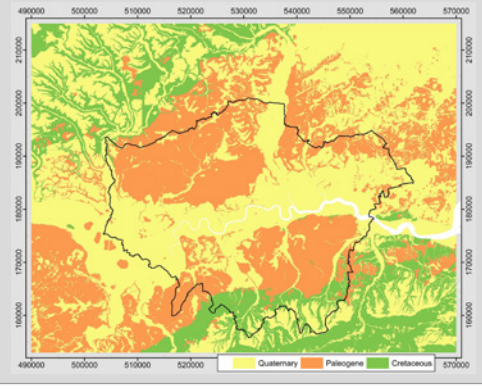

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