Geogenic signatures detectable in topsoils of urban and rural domains in the London region, UK, using parent material classified data

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SUPPLEMENTARY MATERIAL

Geology of the London Region

The description that follows is derived from Ellison et al. (2004), BGS (2011) and Royse et al. (2012).

Cretaceous

The Wealden Group mudstones are the oldest bedrocks exposed at the surface 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 grained 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 northwest 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 succeeding parts of the Lambeth Group are 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 and silts. A minor clay unit (Swinley Clay Member) crops out in the south-west of the London region whilst the sand and sand-silt 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 10 cm 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 a once-continuous till sheet that extends north and north-east from the London region 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 braid plain (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 brick making 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 distinctive floodplains are 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 1), the head deposits are classified as clayey or sands and gravels. The latter occur over the Stanmore Gravel and overlying post-diversionary River Terrace deposits.

References

BGS 2011. London Earth. http://www.bgs.ac.uk/gbase/londonearth.html (last accessed on 7 January 2013).

Ellison, R.A., Woods, M.A., Allen, D.J., Forster, A., Pharaoh, T.C. and King, C., 2004. Geology of London. Memoir of the British Geological Survey, Sheets 256 (North London), 257 (Romford), 270 (South London) and 271 (Dartford) (England and Wales). British Geological Survey, Keyworth, Nottingham.

Royse, K.R., de Freitas, M., Burgess, W.G., Cosgrove, J., Ghail, R.C., Gibbard, P., King, C., Lawrence, U., Mortimore, R.N., Owen, H., Skipper, J., 2012. Geology of London, UK. P Geologist Assoc 123, 22-45.

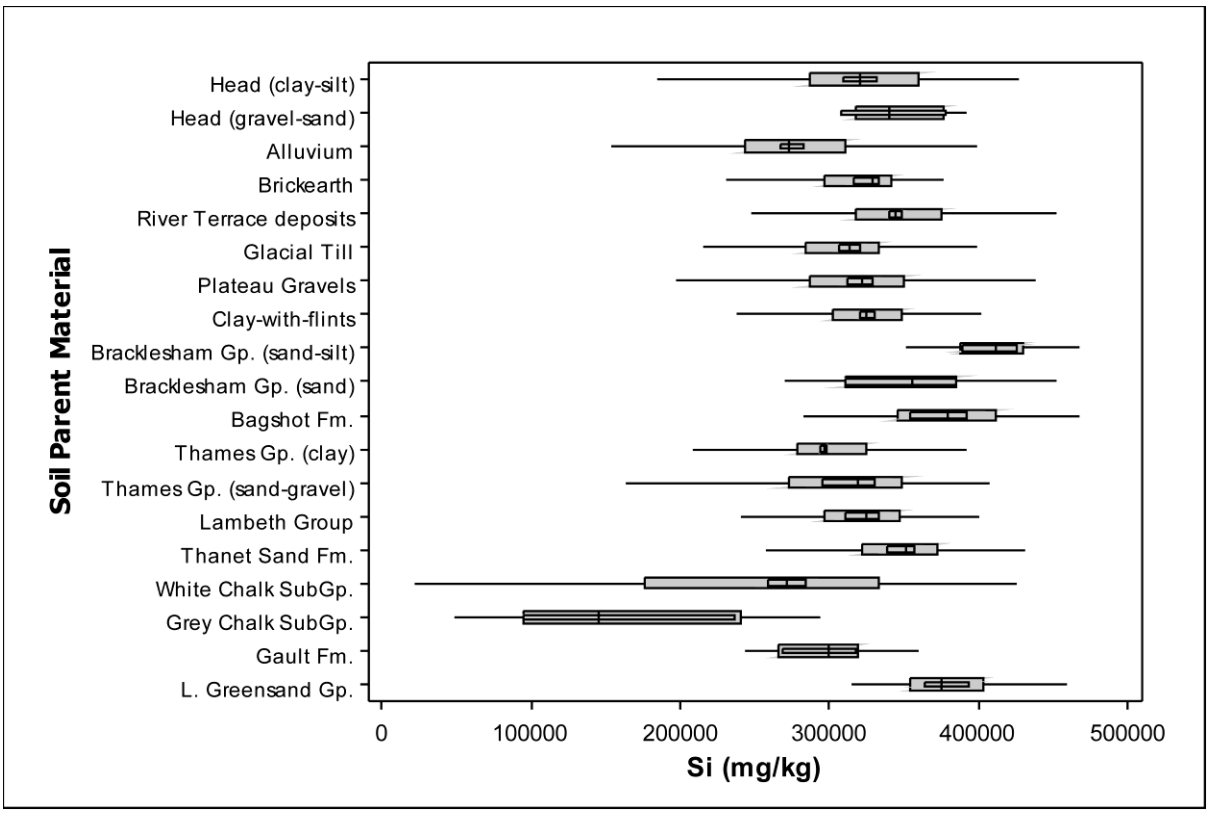

Figure 1 Boxplot of Si in topsoils from rural domain (n = 3245)

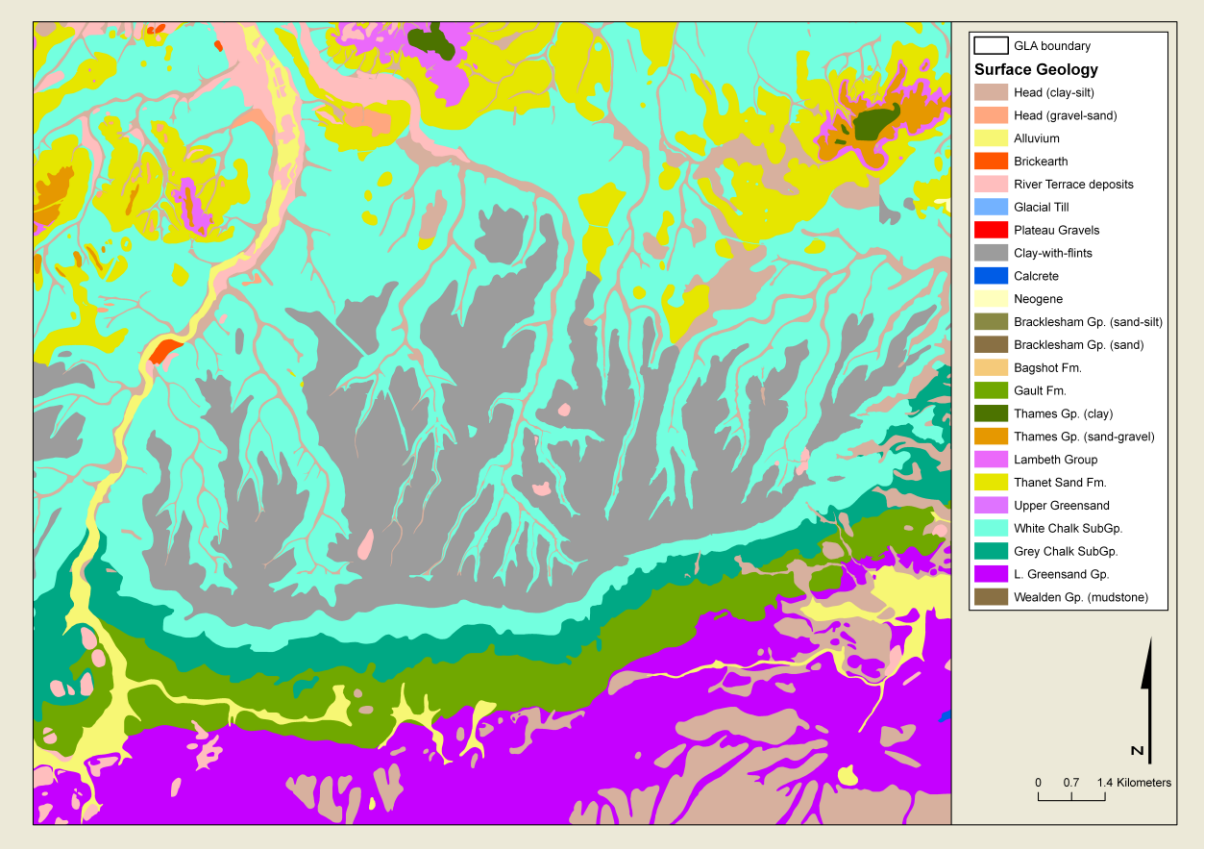

Figure 2 Simplified Soil Parent Material map of the south east sector of the London region

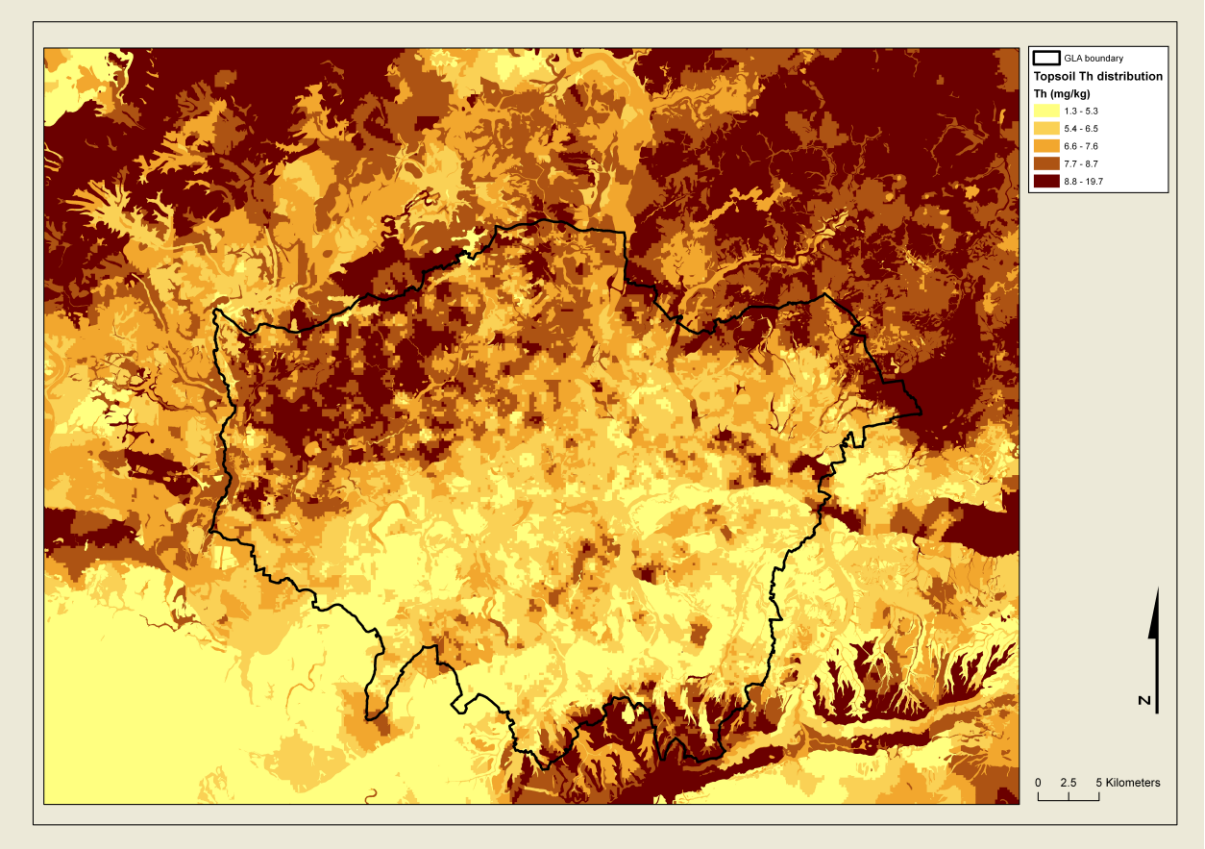

Figure 3 Topsoil Th interpolated to 200 m-PM grid

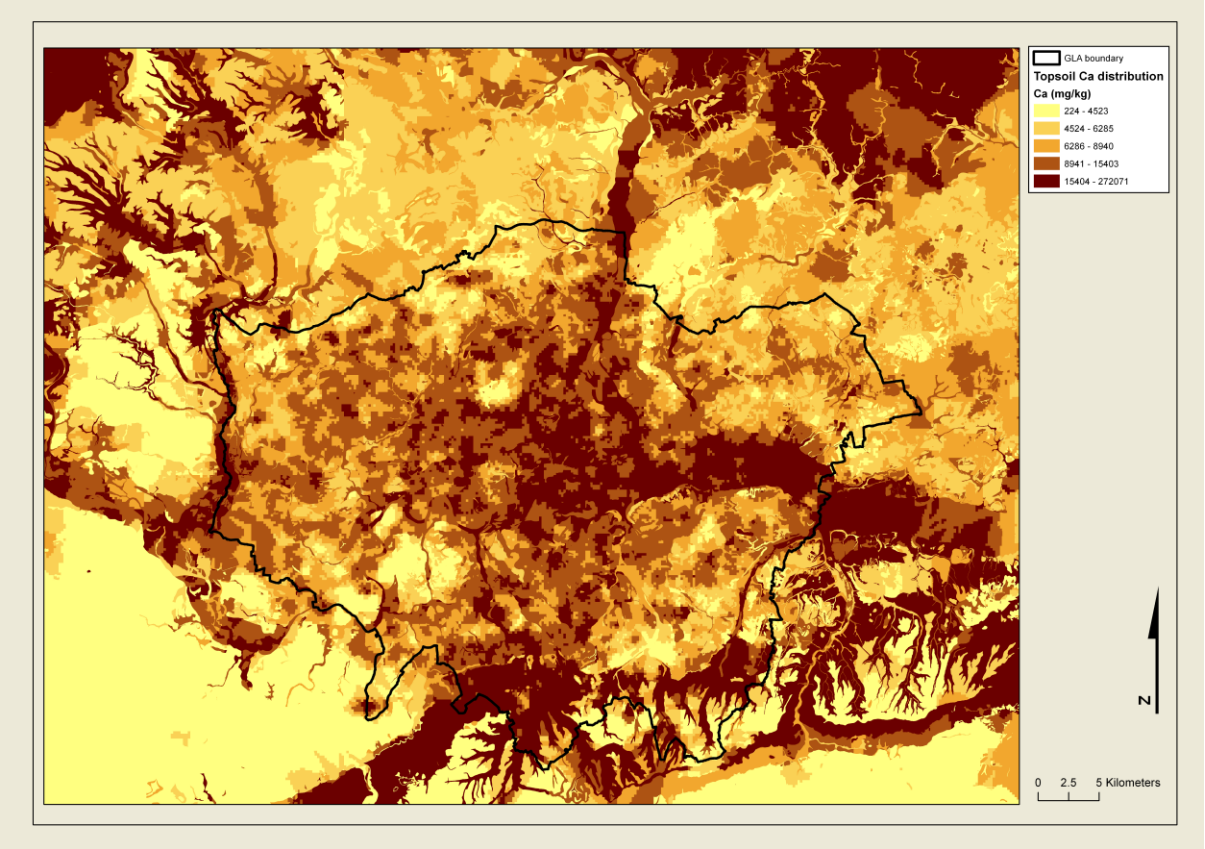

Figure 4 Topsoil Ca interpolated to 200 m-PM grid

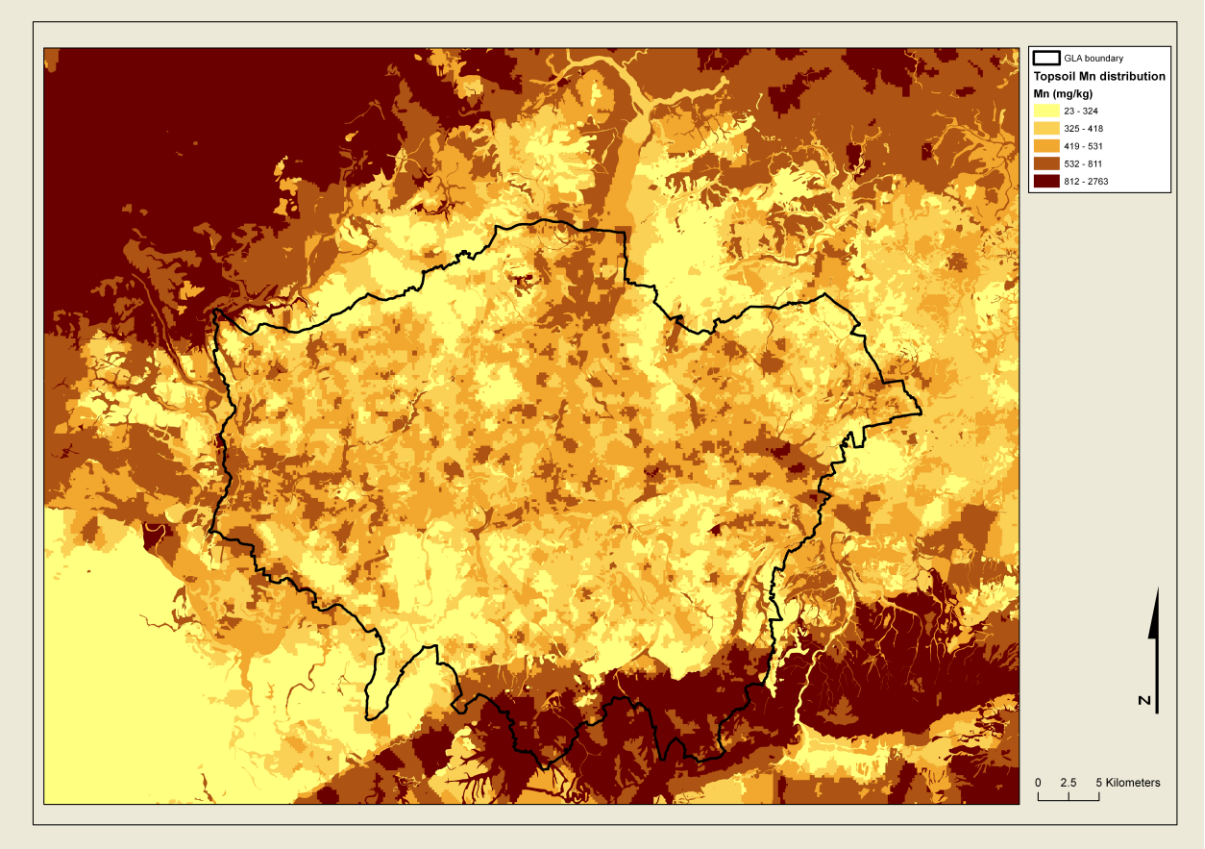

Figure 5 Topsoil Mn interpolated to 200 m-PM grid

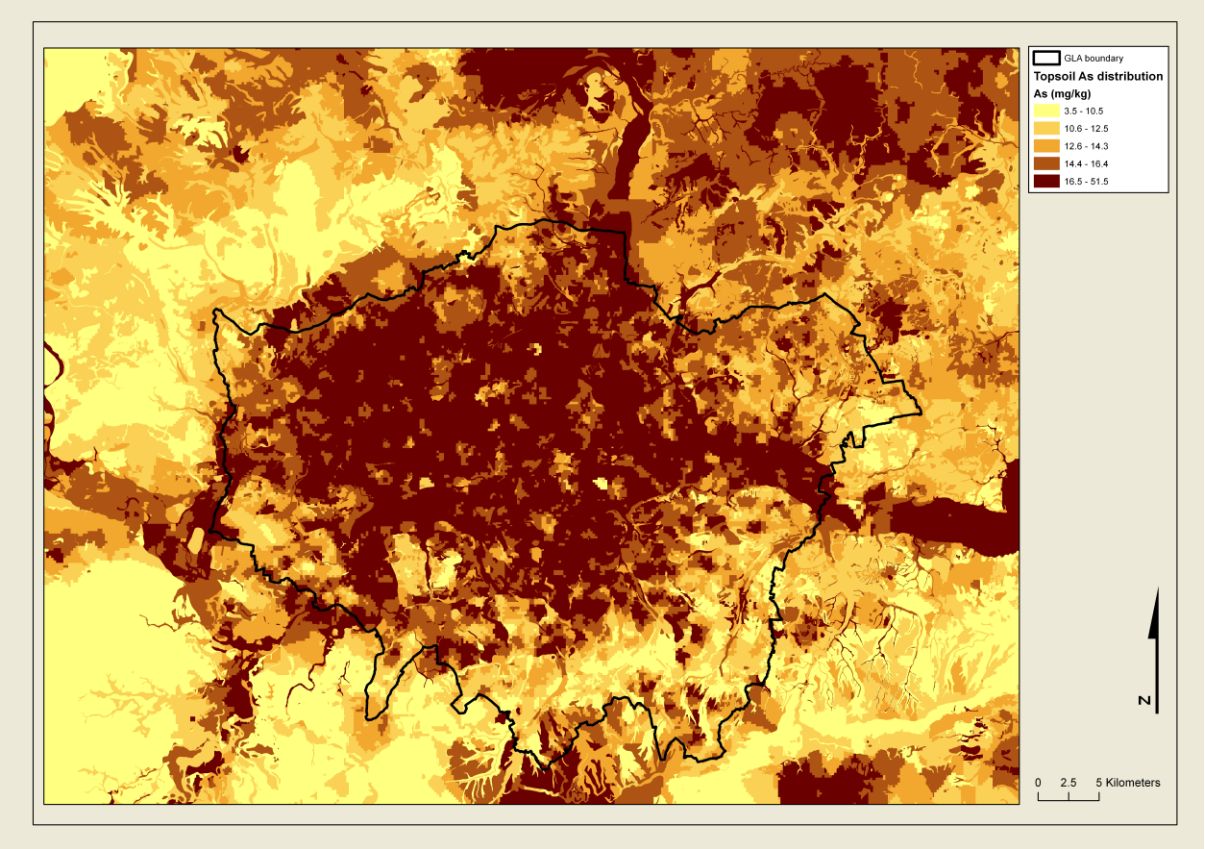

Figure 6 Topsoil As interpolated to 200 m-PM grid

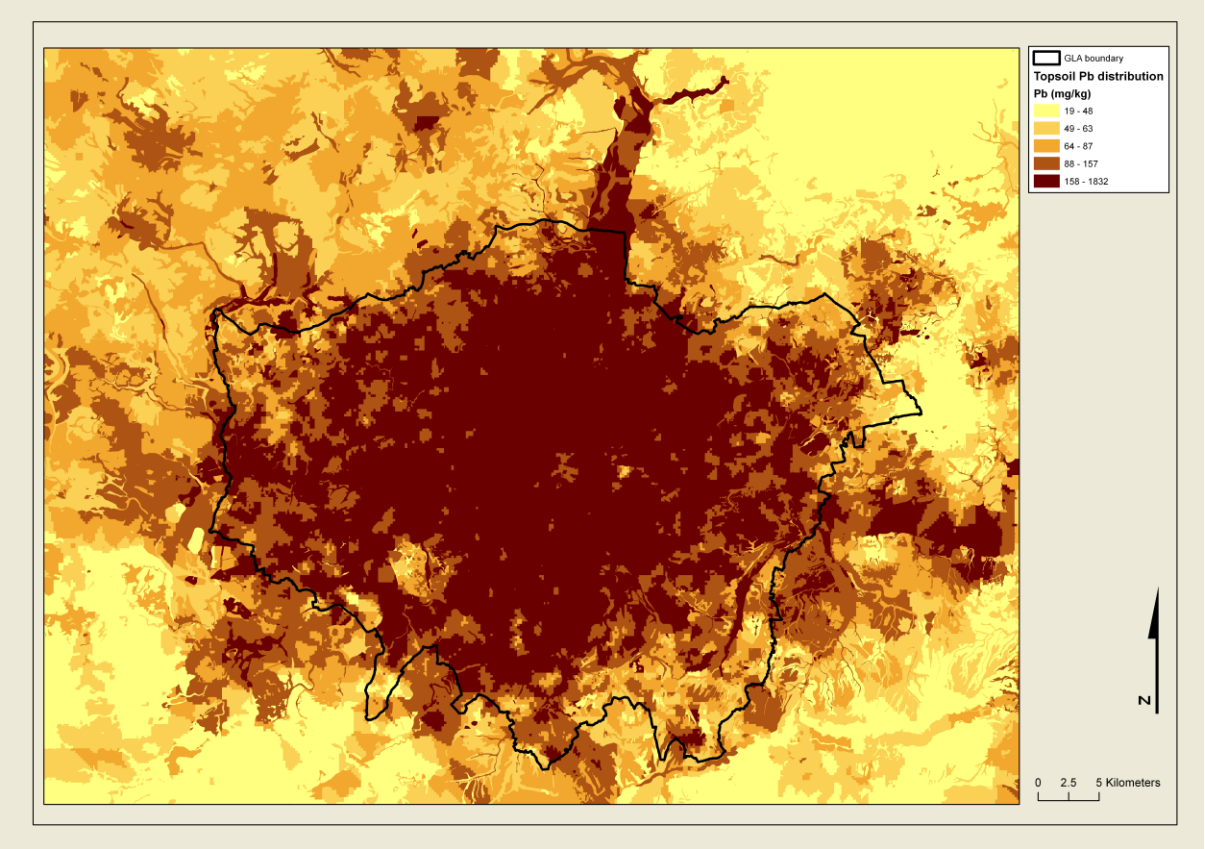

Figure 7 Topsoil Pb interpolated to 200 m-PM grid

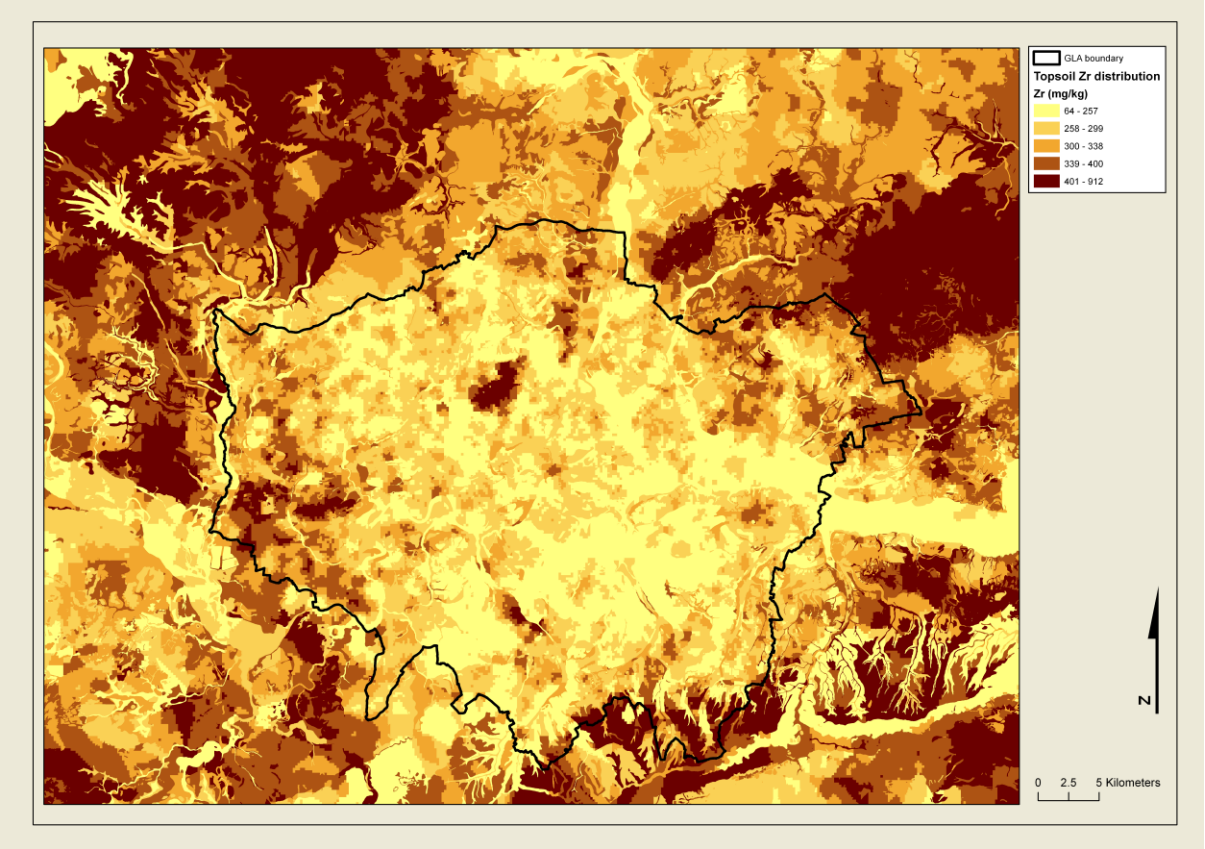

Figure 8 Topsoil Zr interpolated to 200 m-PM grid