

Automated generation  
of  
Equal Area Cartograms (hexmaps) at any scale

Bruce Mitchell MSc  
ONS GeoCentre  
June 2019

# Automated generation of Equal Area Cartograms (hexmaps)

## WHY MIGHT YOU BE INTERESTED?

- Do you need to display data on a map?
- Is the geography you need to map made up of sub-units of widely differing sizes?
- Are the most interesting data to be found in the smaller areas?
- Alternatively, are your data located at point that are by turns tightly concentrated and widely scattered?

If the above apply, then this is definitely for you.

We have created a tool written in Python to create equal area cartograms (EACs) based on hexagonal grids. The purpose is to get around the visual dominance of large areas on maps, and the tendency for smaller areas to be overlooked. This document explains the nature of the problem and considers alternative solutions before turning to hexmaps.

The ONS approach has been successfully tested on a wide range of geographies with an extreme range of scales.

We explain how to set up the script and your data to run on any PC running 64-bit Windows 7 or 10.

We then go through some examples to demonstrate how the methodology works.

We are separately developing an R-based method for automating the production of [square-based](#) (waffle chart) EACs.

## Acknowledgements

I conceived both projects in 2016-2017 and worked out the hexmap methodology with [George Tzelepis](#). George wrote the original code in ArcPy for ESRI's ArcGIS. He subsequently ported the product over to Python, but development was then critically delayed by IT issues within ONS. George left ONS and ceased active development in May 2018. Since then, a way has been found around the IT issues and this has allowed me to test and further develop the code.

So, in the first rank, I must thank George Tzelepis for doing the heavy lifting of working out how to convert my original ideas into code – not once, but twice – and working out the geometry. Further thanks are due to Andy Harfoot of [Geodata Institute](#) (University of Southampton) who has also assisted with the crystallising some of the ideas and correcting some of the code. I'd also like to thank ONS Geography managers Andy Tait, Nick O'Rourke, Chris Gale and Alistair Calder for their support and patience over the project's long gestation

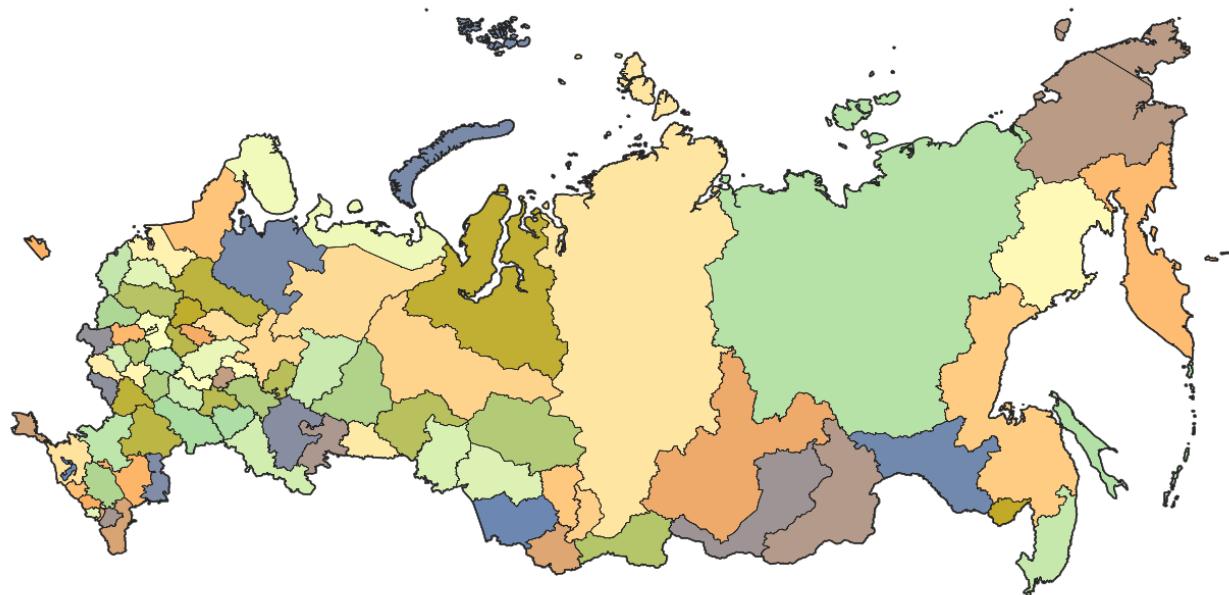
## ***Introduction***

Thematic mapping draws attention to statistical difference across space. Statistical values of interest are often attached to sub-areas of the overall geography, and this may reveal significant spatial variations. However, administrative divisions commonly encompass a range of unit sizes, from small urban districts to large rural expanses.

## **The tyranny of large areas**

When seen together on a map, larger units tend to dominate and the smaller to recede. The eye is drawn to large areas. Think of Canada, Australia and Russia, where huge areas, often relatively sparse in socio-economic statistics, acquire visual dominance at the expense of the smaller and often more populated areas. Those familiar with the geostatistics behind any given map may be able to apply a mental filter to compensate, but the fact remains that the areas where the chief interest of your story resides may be small and hard to see.

## **Districts of Russia**



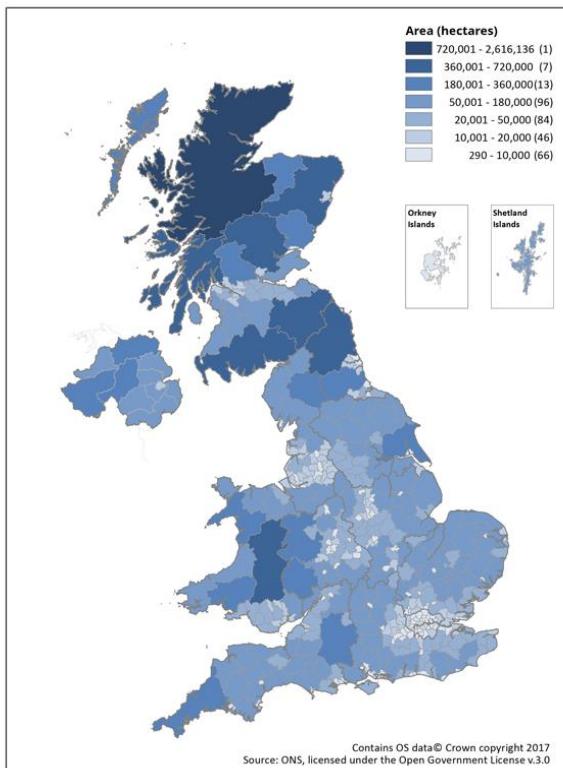
Here in the UK it is a similar story. Local Authority Districts (LADs) in the UK range in size from the 290 hectares of the City of London to the 2.6 million hectares of the Highlands of Scotland – but the two are administratively equivalent. On a national map, the City of London is completely invisible.

British statistical geographies (Census output areas) are just as vulnerable to the issue as the administrative geographies. They are based on population thresholds, so are made up of units (instances) which are small where the population is dense, and large where it is spread thinly. At the middle level [MSOA (EW), DataZones (Sc) and Small Areas (NI)], they range from just over 1 hectare (ha) to 180,000 ha,

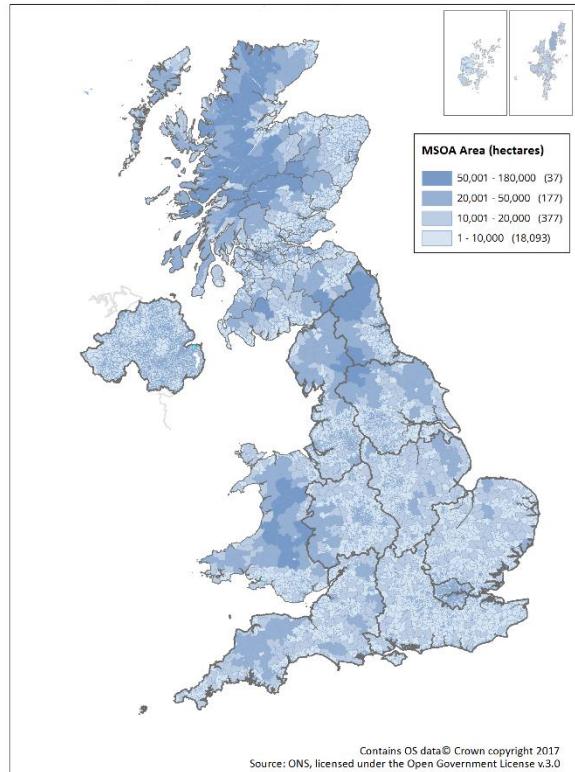
## Impact upon thematic cartography

One of the most common thematic map types is the choropleth, where individual areas are shaded or coloured according to statistical value. It is often said that you should not use choropleth maps for count data – the reason being that large areas often have a lot of data in them (you are likely to find more trees in a large forest than in a small one). The point is demonstrated by the following three ‘by area’ maps, where the count is square kilometres.

Local Authorities by area (hectares)  
United Kingdom, 2013



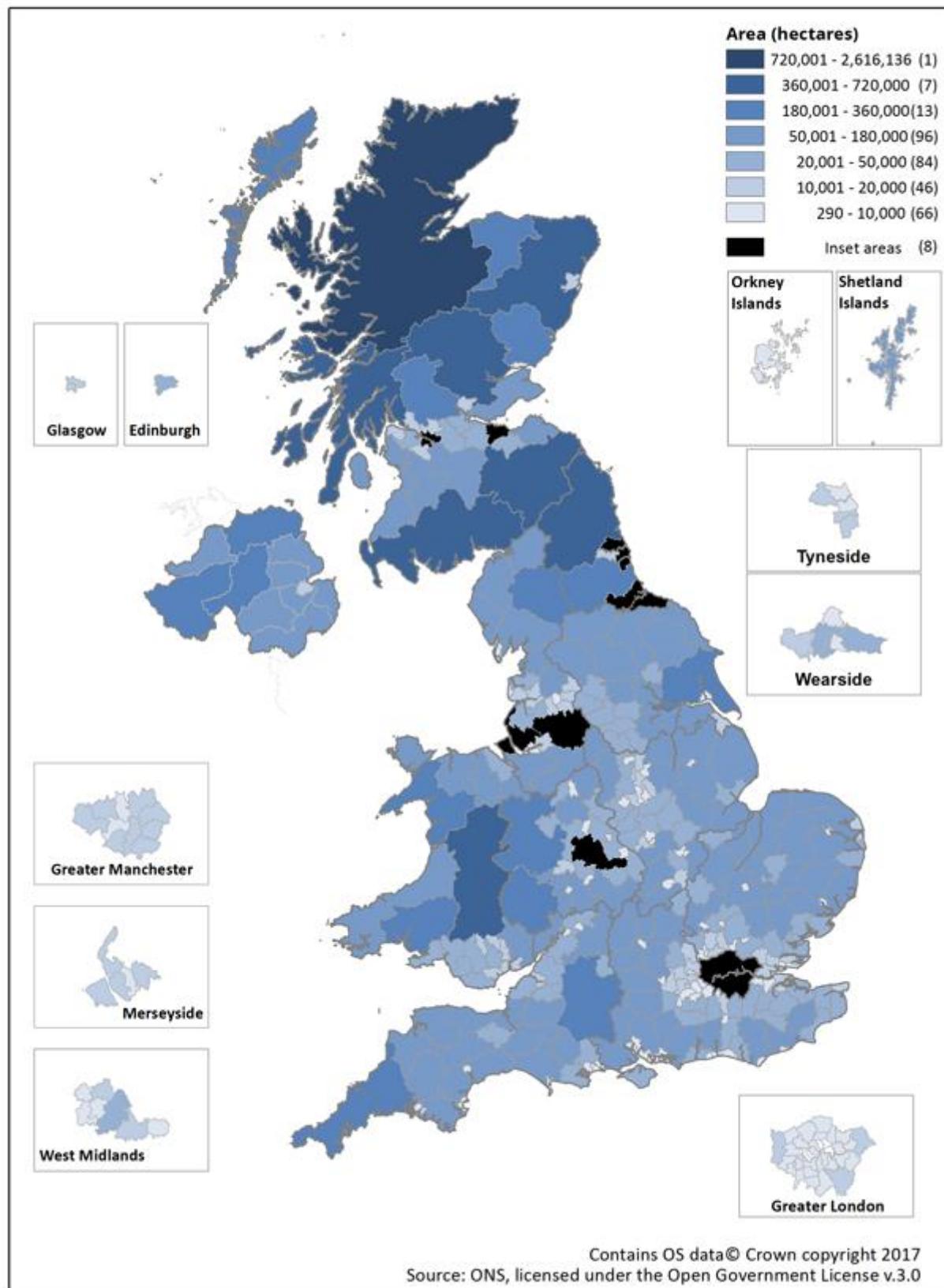
MSOAs (EW), Data Zones (Sc), Small Areas (NI) by area  
United Kingdom, 2013



One is usually encouraged to use rate data for choropleths instead (e.g. percentage of one species of tree in the forest) as that were the perfect solution. But the tyranny of large areas persists regardless of your data type – a larger forest is more visible.

There are ways around this: one can provide larger-scale (blown-up) inset maps of selected areas alongside a national map. This moderates the problem but does not solve it. Indeed, small areas that are not selected for inset mapping may be pushed further into the background.

# Local Authorities by area (hectares) United Kingdom, 2013



## Cartograms

But it is possible to set aside the visual dominance of large areas altogether. One can scale the territories not according to their actual geographic area, but according to a value of statistical interest. This is known as a cartogram – a hybrid statistical graph / map, a compromise by which the viewer gains more immediate access to the data but loses some of the geographical context.

Cartograms exist in [many forms](#); they may preserve, or ignore, shape, contiguity and orientation. They are often shown together with a conventional map to aid navigation and interpretation. They can powerfully convey general impressions (see the examples below from Benjamin Henning's '[WorldMapper](#)'<sup>1</sup>), but it's hard to derive specific values, and next to impossible to assess whether differently shaped areas represent the same statistical value. Also, a new cartogram must be drawn for each new variable, refreshing the navigational challenge every time.

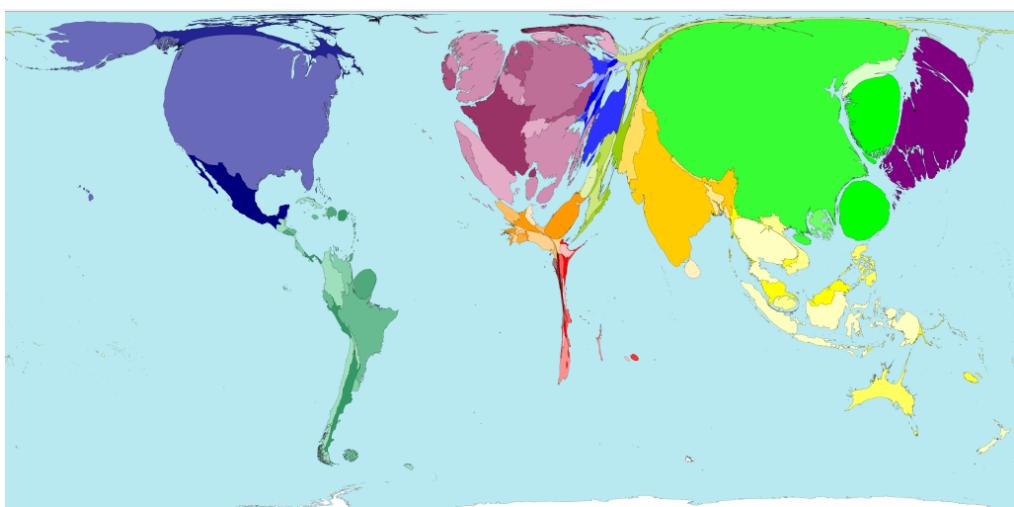


Figure 1: Wealth, 2015

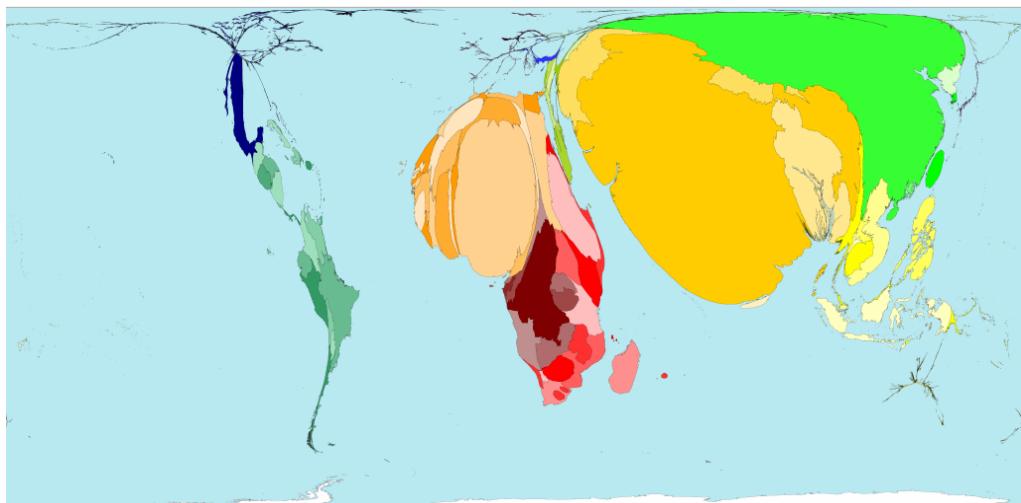


Figure 2: The Wretched Dollar (up to \$1 a day)

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<sup>1</sup> <http://www.worldmapper.org/>

## ***The Equal Area Cartogram***

Our favoured approach is the equal area cartogram (EAC). Here, every district is represented with an identical geometric object of equal size and shape, and therefore, area. No area is inherently (dis)advantaged, as the base geometric representation of all is the same. Once generated, the EAC provides a single standard layout that can be linked to countless datasets to generate as many thematic maps as desired.

## **The ONS hexmapping tool**

Within this project, we have concentrated upon automatic hexmap generation using Python. Our code runs quickly and can operate on any polygon dataset at any scale.

We have tested the product on a wide range of distinctive and challenging geographies. These include countries with predominantly north-south extent (Chile, Italy, Norway), countries with east-west extent (Russia, USA), irregular shapes (Croatia), exclaves (Russia's Kaliningrad), doughnuts (Germany - Berlin within Brandenburg), complex archipelagos (Indonesia). It works on all, regardless of projection or scale. Indeed, it works equally well on all the stars within ten parsecs of Sol (our sun) and a tiny detail from an electron microscope image of the brain of a fly.

As your input geography is imported, its projection is noted: it is then turned into pure geometry for the hexmap creation and then re-exported back to its original projection. Two hexmap variants are available. The **basic** variant overlays the original input geography and the two may be used together. The **compressed** hexmap is designed to stand alone, without the original geography or a base map. However, because it is in the same projection as the original input geography and the basic hexmap, you may overlay them for testing purposes, to assess the effectiveness of the compression.

Speed of execution depends upon your PC's resources and the complexity of the input spatial dataset: for over ¾ of tested geographies, the compressed hexmap is created within ten seconds. Only three took more than one minute – the 1,973 Cantons of France (138s); the 1,385 NUTS3 units of the WEU and EFTA (150 s) and the 7,201 MSOAs of England and Wales (40 minutes).

## **Using the tool**

### **A. PREREQUISITES**

This product has been tested on Python 3.7.2 using Spyder 3.3.4 within Anaconda Navigator 1.9.7, running under 64-bit Microsoft Windows 7 and 10.<sup>2</sup> I do not make any promises about any other permutations.

#### *Python libraries*

- Time; numpy v1.1.6.2; matplotlib; scipy; shapely; geopandas

#### *Installing the Python libraries*

At the Anaconda prompt, enter the following commands. The stated order appears to be significant.

```
conda install -c conda-forge scipy  
conda install -c conda-forge geopandas  
conda update -n base conda  
conda install -c conda-forge fiona  
conda install -c conda-forge setuptools  
conda install -c conda-forge shapely
```

#### *Further information on these libraries:*

- <https://anaconda.org/conda-forge/scipy>
- <https://anaconda.org/conda-forge/geopandas>
- <https://anaconda.org/conda-forge/fiona>
- <https://anaconda.org/conda-forge/setuptools>
- <https://anaconda.org/conda-forge/shapely>

The input geography must be an **ESRI shapefile** of **polygon** type. Point datasets may be accommodated by first generating buffers of dimensions appropriate to the dataset's spatial scale

Support for OGC GeoPackage (.gpkg) is being developed but has not yet been implemented.

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<sup>2</sup> NOTE: It is not possible to get this to work on a PC running within the ONS network. You must have unrestricted access to the Internet to allow the installation of the **Python libraries**.

## B. SETUP

The code comprises five separate Python scripts:

### B1. SETUP FILES

#### *HexTool\_Setup.py*

Used to set up:

- ROOT\_FOLDER
- Input path (INPUT\_POLYGON\_PATH)
- Output paths (OUTPUT\_IMAGE\_PATH, OUTPUT\_HEXMAP\_PATH)
- Choice of geography file – UK or Elsewhere
- Hexmap type – BASIC or COMPRESSED
- Adjustment to gravity function (F\_CORRECTION)
- Output file format

#### *HexTool\_Geographies\_UK.py* or *HexTool\_Geographies\_Elsewhere.py*

Used to set up Input geography and hexmap settings

- a. GEOGRAPHY\_NAME (input geography)
- b. HEXSIZE (width - in units of the input geography's projection) of the hexagons forming the hexmap.
- c. HEXORIENTATION ('pointy-uppy' or 'flatty-uppy').
- d. COMPRESSION\_FACTOR for compressed hexmaps.

*Note: optimal values for b, c and d are currently obtained through trial and error.*

### B2. CORE CODE

#### *HexTool\_Basic.py*

This applies mathematical procedures to the centroids of the input geography and creates hexagons at those locations as defined by the parameters (above).

The optimal HEXSIZE value is where all the hexagons are either within the boundary of the input geography or overlap it by a minimal amount.

It is recommended to generate a basic hexmap top determine the optimal HEXSIZE value before proceeding to a compressed hexmap.

### B3. CORE CODE WITH COMPRESSION

#### *HexTool\_Compressed.py*

This version of the code is identical apart from additional geometric sections that scale the output hexagons onto a smaller space. The distance between distant locations is reduced by a scaling factor that affects locations more distant from the centroid of centroids to a greater degree than it does locations closer in. The key consideration is that the output still retains a close similarity to the original spatial distribution of the input geography centroids.

## B4. SETUP PROCEDURE

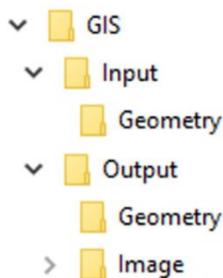
Within script "HexTool\_Setup.py"

### PATHS AND FOLDERS

The **ROOT\_FOLDER** depends upon the PC you are running the program from. Examples:

ROOT_FOLDER = r'C:/HEXMAPS/'	- ONS - ONS27797
ROOT_FOLDER = r'D:/HEXMAPS/'	- ONS - geoCentaurs
ROOT_FOLDER = r'G:/HEXMAPS/'	- HOME - MESH II

For any other PC, create the 'HEXMAPS' ROOT\_FOLDER in desired location, along with the following **sub-folders**, and add to the HexTool\_Parameters.py script a line of code like those above:



The following three PATH variables depend upon the ROOT\_FOLDER and folder structure as above.

```
INPUT_POLYGON_PATH = ROOT_FOLDER + 'GIS/Input/Geometry/'  
OUTPUT_IMAGE_PATH = ROOT_FOLDER + 'GIS/Output/Image/'  
OUTPUT_HEXMAP_PATH = ROOT_FOLDER + 'GIS/Output/Geometry/'
```

### GEOGRAPHY

Activate either 'import HexTool\_Geographies\_UK' or 'import HexTool\_Geographies\_Elsewhere'

### HEXMAP TYPE

Activate either 'import HexTool\_Basic' or "import HexTool\_Compressed"

### GRAVITY FUNCTION CORRECTION (F\_CORRECTION)

In the 'Compressed' script, the 'gravity function' pulls the centroids towards the CxC. Its power increases with increasing distance \* from the CxC. F\_CORRECTION = 0.1 and should not be changed.

### OUTPUT FILE TYPE

This is currently set to ESRI shapefiles (shp).

OGC GeoPackage(gpkg) and GeoJSON output can also be specified, but this has not been implemented.

## B5. SETUP PROCEDURE – FOR A BASIC HEXMAP

Within script “*HexTool\_Geographies\_UK.py*” or “*HexTool\_Geographies\_Elsewhere.py*”

### INPUT POLYGON and PARAMETERS

1. Choose your GEOGRAPHY\_NAME. Ensure that this is present – as a shapefile – in the INPUT\_POLYGON\_PATH folder.
2. Select a value for HEXSIZE. The optimal value is dependent upon:
  - a. The distance units of the input geography polygon shapefile's projection (e.g. decimal degrees, miles, meters, microns).
  - b. *The E-W and N-S extents, in those distance units, of the input geography.*
  - c. *The number of polygons in the input geography.*
3. Set HEXORIENTATION to 1 (vertical, or 'pointy-uppy') – generally more suitable for geographies with an EAST-WEST extent (Greater London), or to 2 (horizontal, or 'flatty-uppy') - for geographies with NORTH-SOUTH extent (the UK).
4. There must be a value for COMPRESSION\_FACTOR, even if it not called. Default value '3'.

## B6. SETUP PROCEDURE – FOR A COMPRESSED HEXMAP

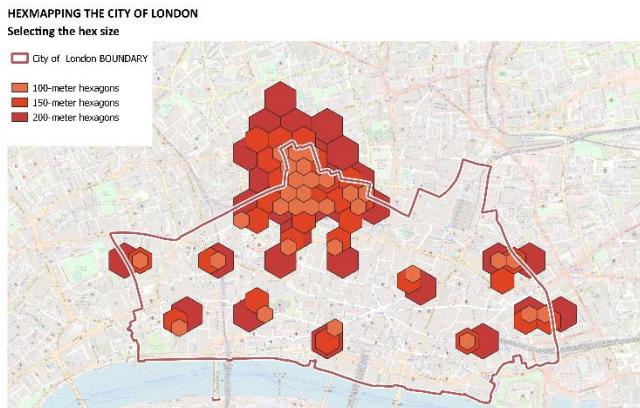
Within script “*HexTool\_Geographies\_UK.py*” or “*HexTool\_Geographies\_Elsewhere.py*”

Follow steps 1 – 3 as above.

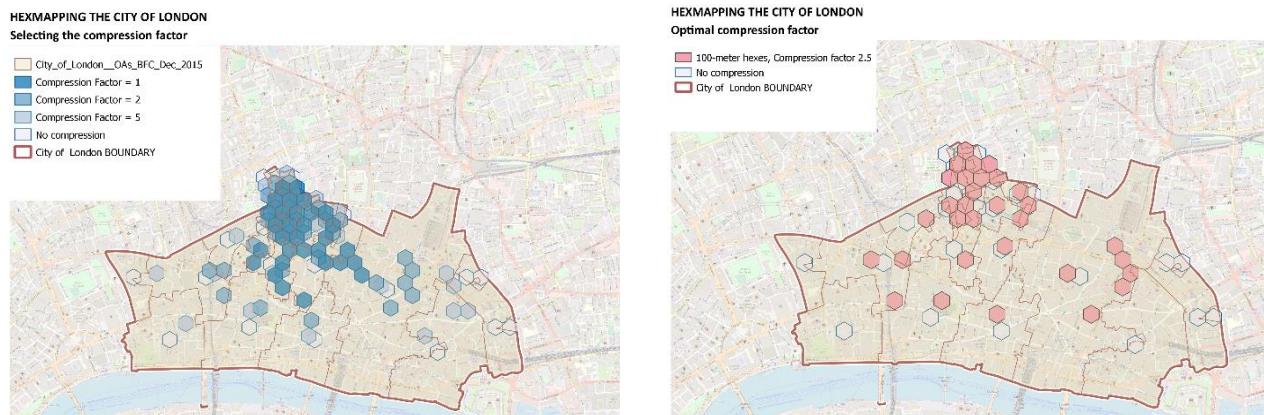
1. Set COMPRESSION\_FACTOR to an appropriate value.
  - a. Logically permissible values extend from 1,000 (almost no perceptible compression) to 1 (extreme compression). Best results usually in the range 1.4 to 4.0.
  - b. The optimal value produces the smallest, most compact version of the original pattern that is still recognisable as such.

***RETURN TO AND RUN script “*HexTool\_Setup.py*”***

## Examples

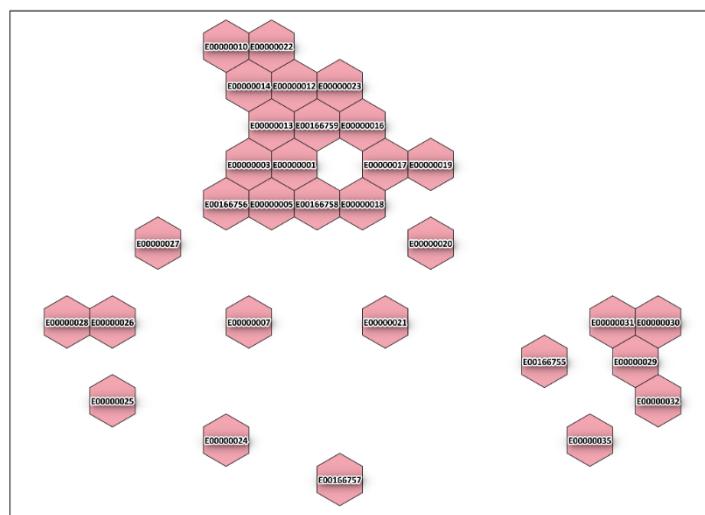


Here, several versions of the **basic** hexmap have been generated, each with a different hex-size. Here, the results for 100, 150 and 200 meters are shown. HEXSIZE = 100 meters produces a basic hexmap where all hex centroids are within the original boundary polygon.



Retaining the parameter values from the **basic** hexmap, several compressed hexmaps are now created, with varying COMPRESSION\_FACTOR values applied to the 100-meter hexagons. A favourable result for this geography is gained with COMPRESSION\_FACTOR = 1.8.

Census Output Areas (2011) in the City of London: CF = 1.8

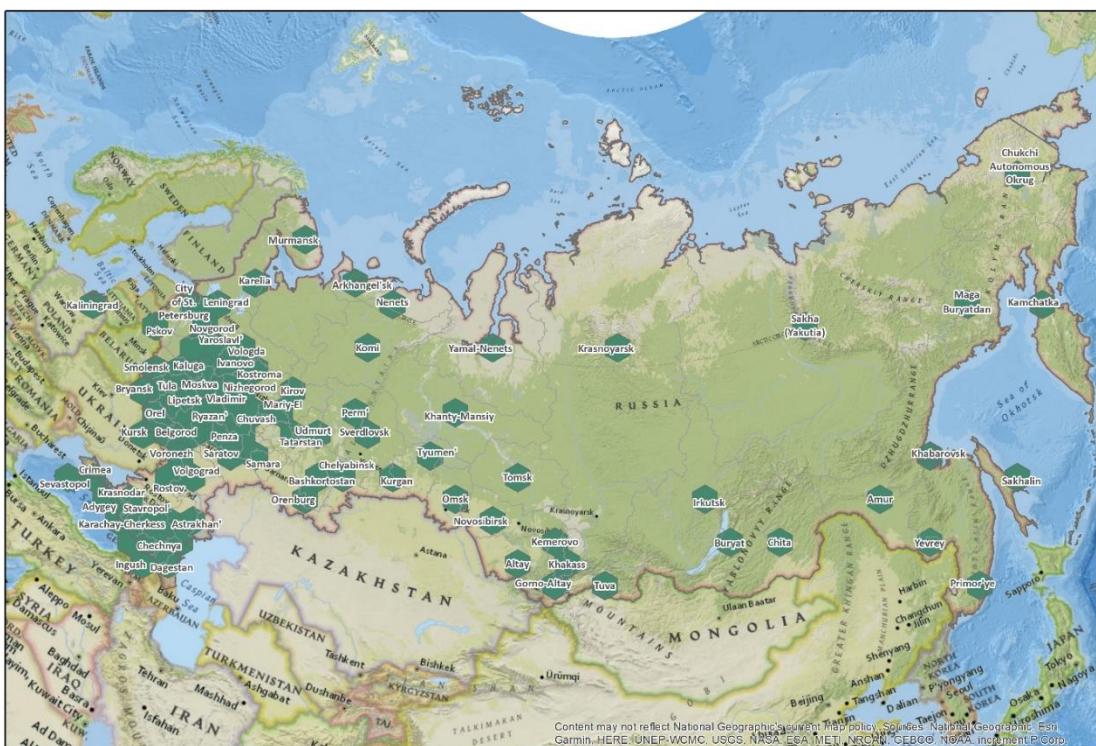


## The Compression Algorithm

How the compression works can perhaps most effectively be shown on the example of districts in the Russian Federation. This is on account of its very skewed composition = there are 85 districts of which the smallest (Sevastopol) is 616 sq.km. The largest (Sakha (Yakutia)) covers over 3 million sq.km. 30 districts are over 100,000 km sq. km. in area, and these are all in the north or east. In addition, Kaliningrad and Sevastopol + the Crimea) are detached from mainland Russia.

As we have already seen, a choropleth map of this geography will be dominated by the large Siberian areas, while the small areas will be all but invisible. However, socio-economic data is likely to be concentrated in the smaller areas. A hexmap will equalise the visual impact of each district, but without compression, will leave large gaps due to the enormous distances involved.

On the basic hexmap, each hexagon is rooted to the geometric centroid of its district:

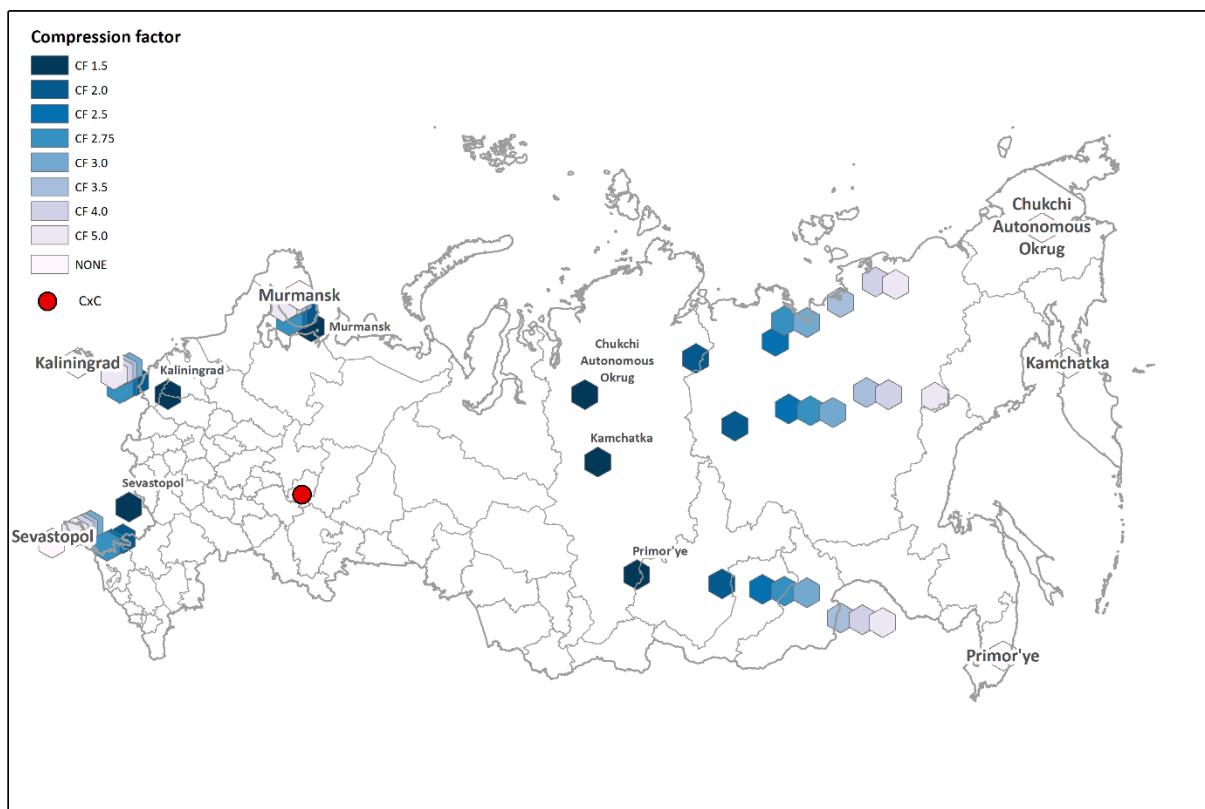


The geographical distribution is faithfully represented and the hexmap *accurately overlays on a basemap*. But in the case of Russian districts, the hex size that best achieves this (each hex being 190,000 km top to bottom [they're pointy-uppy]) means that there's an enormous amount of empty space, and this results in small hexagons whose labels are hard to read. It would also be hard to interpret any thematic data that was pinned to them (by colour). So, this is a geography for which a compressed hex map would make perfect sense.

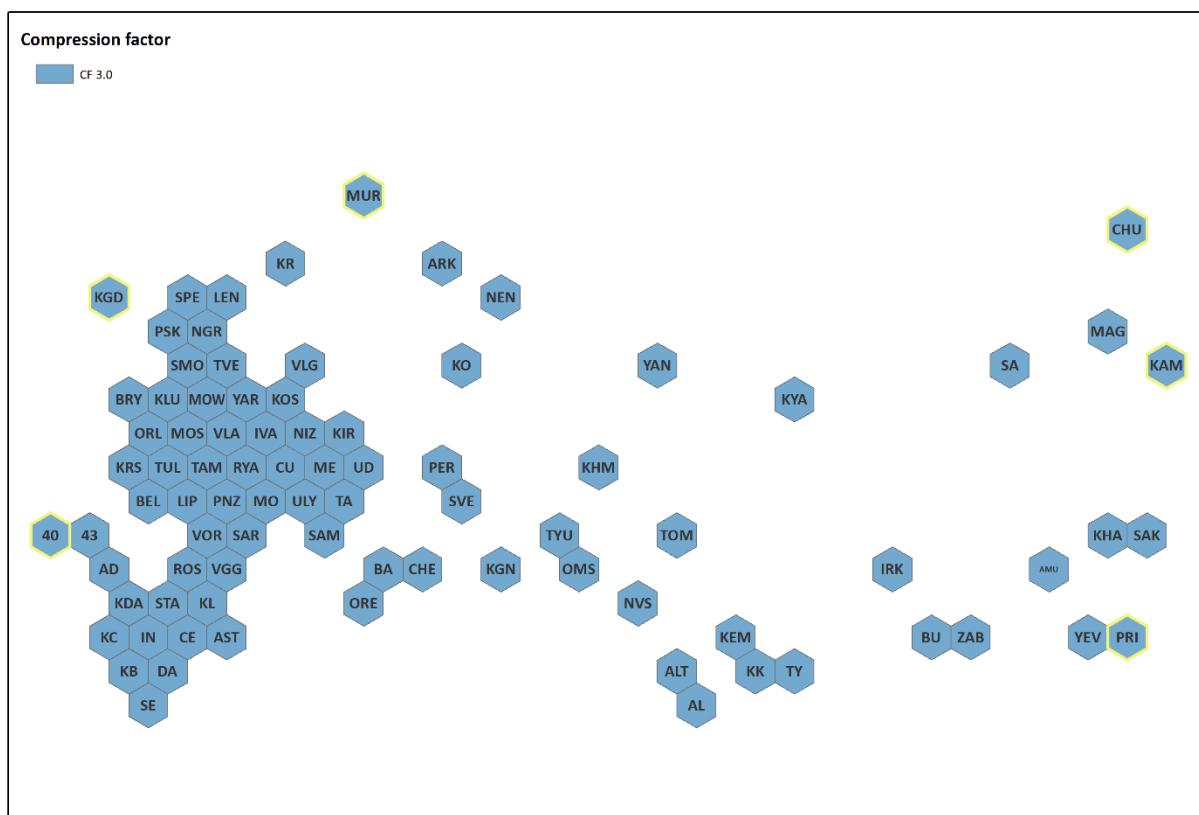
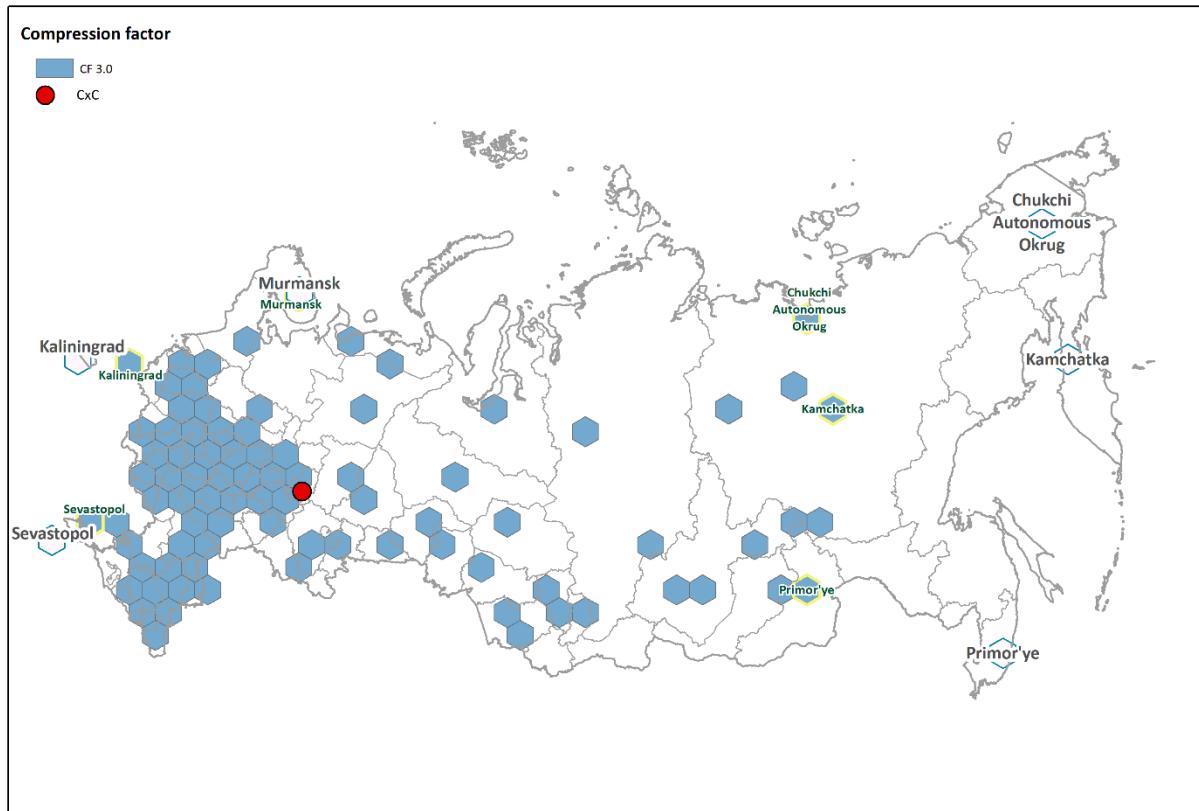
We drop the basemap but for the moment leave the boundaries for reference. Six peripheral districts are labelled - these will have furthest to travel towards the centroid of centroids (CxC).



As the Compression Factor is adjusted (remember that CF=1,000 is practically no compression, while 1 is extreme compression), the gravitational attraction of the CxC varies.



At CF = 3.0, the pattern remains recognisably that of the districts of the Russian Federation – we still have the concentration of districts in western Russia, Kaliningrad Oblast is still separated, the Crimea and Caucasus are distinct, as is the scatter eastwards across the Urals into Asia. Yet now, we can zoom to the hexmap layer – so making the hexagons larger and their labelling clearer.



## **Complex archipelagos**

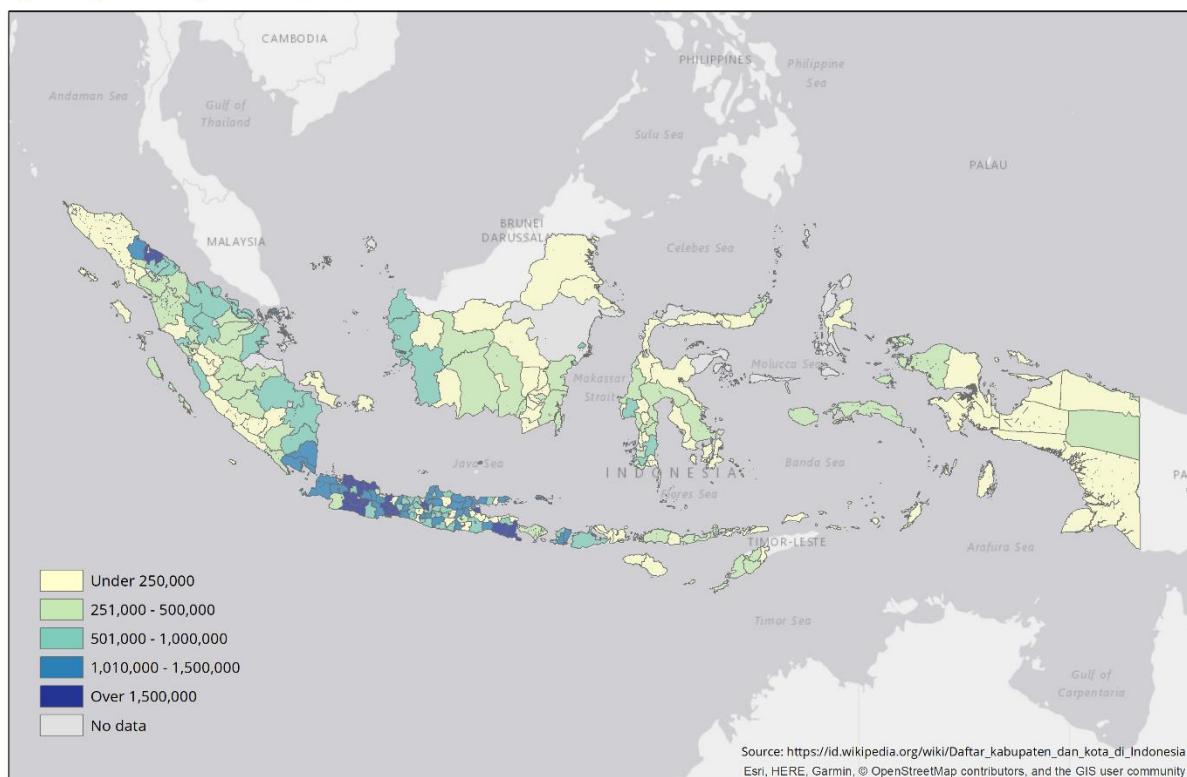
The program also works with highly complex and regionally differentiated geographies such as Indonesia.

Here, 270 Kabupaten or ‘regencies’ are distributed across a huge number of islands. There is considerable variation in size, generally being large on the islands of Borneo and New Guinea, but tiny on the densely inhabited island of Java. This is a classic example of the shortcomings of choropleth mapping. In terms of mapping socio-economic data at this administrative level, Java will always be disadvantaged.

Producing a simple hexmap will leave large spaces, especially in the less-densely populated Borneo and New Guinea.

### **Indonesia, Population**

**By Kabupaten (Regencies) and cities, 2015**

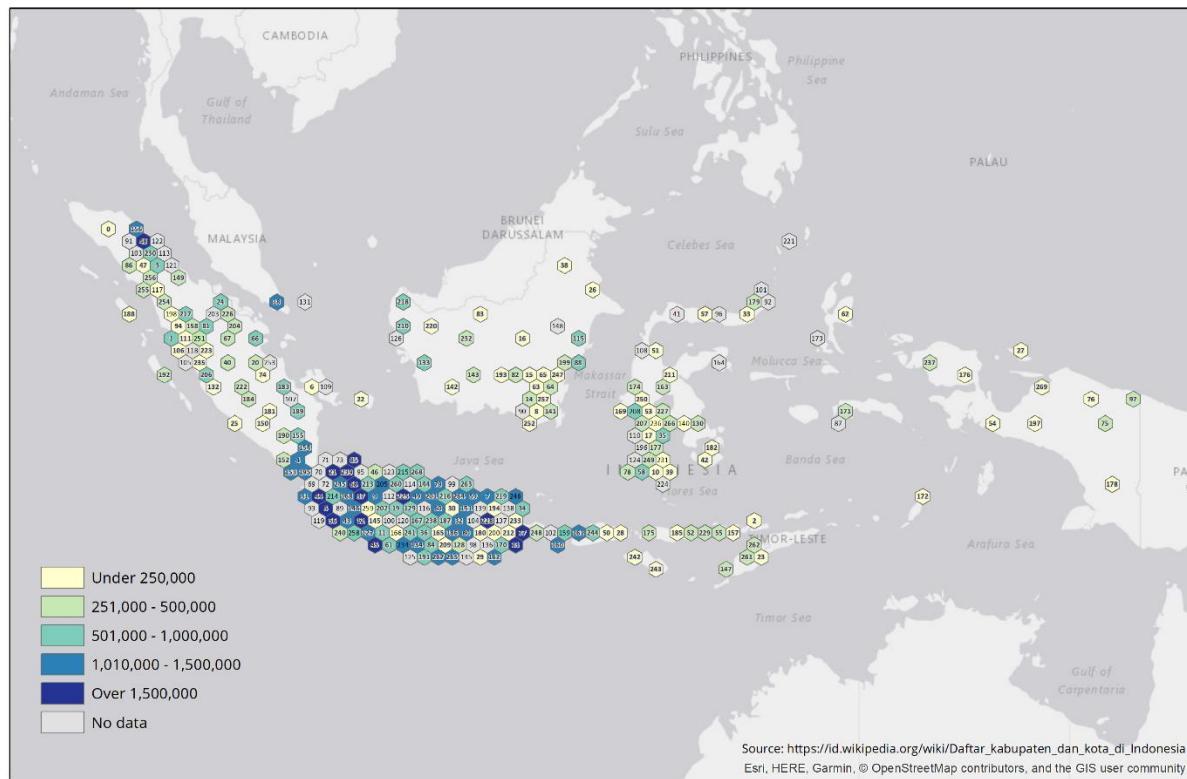


An uncompressed hexmap (HEXSIZE = 0.6 decimal degrees) will result in the concentration of regencies on Java expanding well beyond the island’s coast, while great spaces exist between the hexes representing the extensive regencies on Borneo and New Guinea. As with Russia, the HEXSIZE required to accommodate this diverse geography means that effective labelling is very challenging.

With a COMPRESSION FACTOR of CF=3 the large gaps are reduced while clearly retaining the overall pattern. One can then zoom into the map and label it far more effectively.

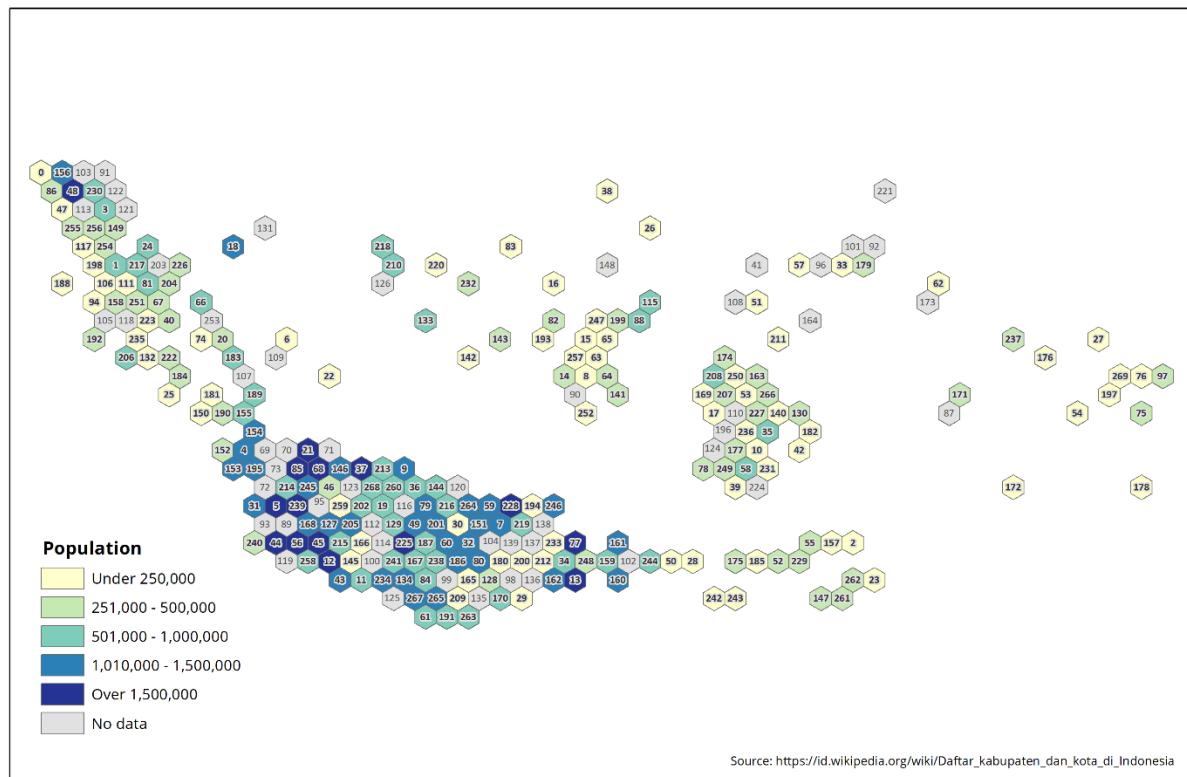
# Indonesia, Population

By Kabupaten (Regencies) and cities, 2015



# Indonesia, Population

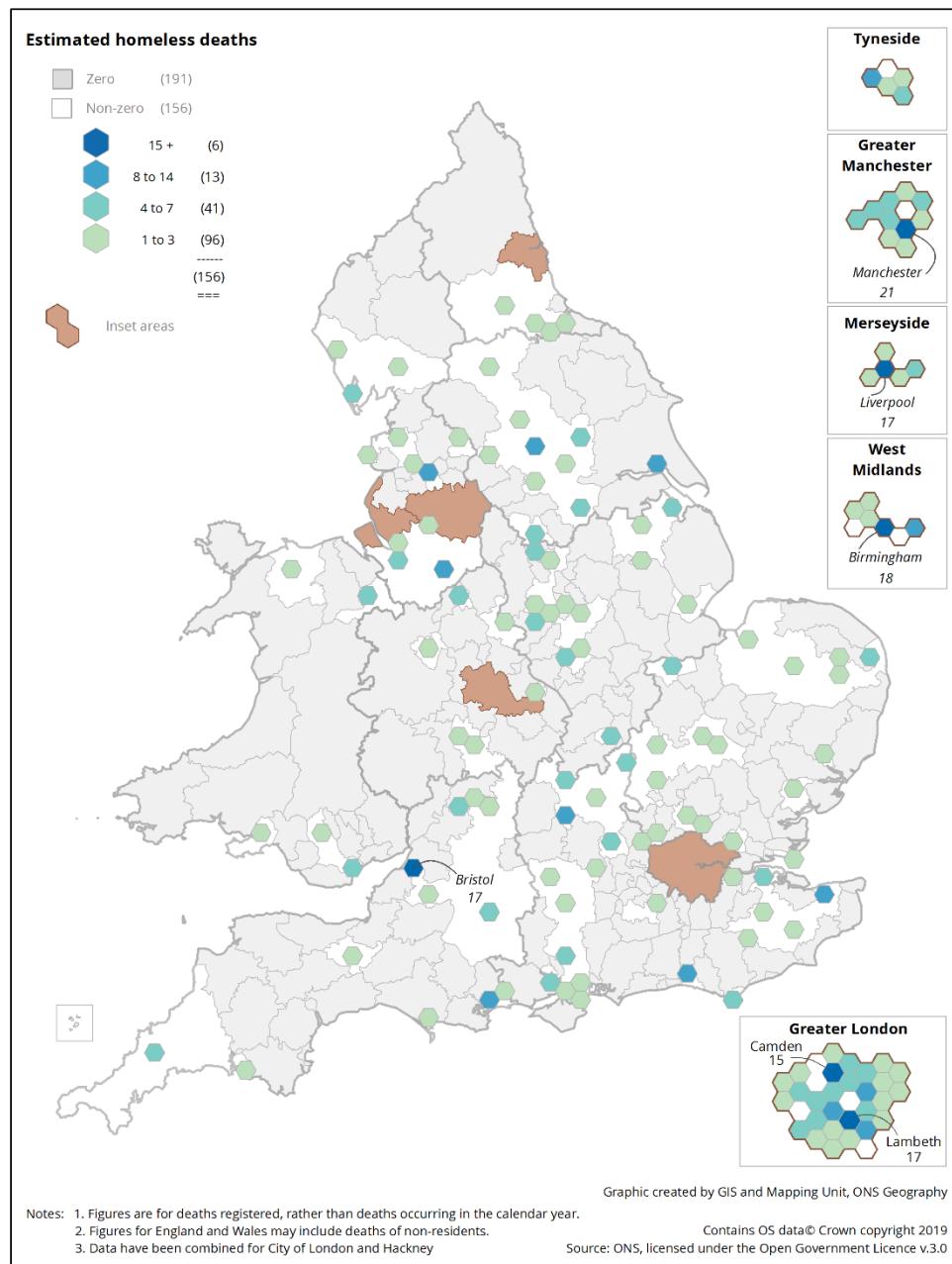
By Kabupaten (Regencies) and cities, 2015



Where clusters of spatial units could cause unreasonable distortions of the overall pattern, these can be extracted to inset maps alongside the general map. Unlike the earlier example, areas not selected for inset mapping are not disadvantaged.

## Deaths of homeless people (estimated), in 2017

Local Authority Districts (LADs), 2017, England and Wales



*Figure 3 Deaths of Homeless People (est.) 2017. Basic hexmap.*

Furthermore, generating individual hexmaps for the inset areas results in a better approximation to their actual shape than can be achieved by creating a single overall hexmap. Both basic and compressed hexmap variants (with the inset areas extracted) can more accurately display the areas around the periphery of the inset areas (see around London).

# Deaths of homeless people (estimated), in 2017

## Local Authority Districts (LADs), 2017, England and Wales

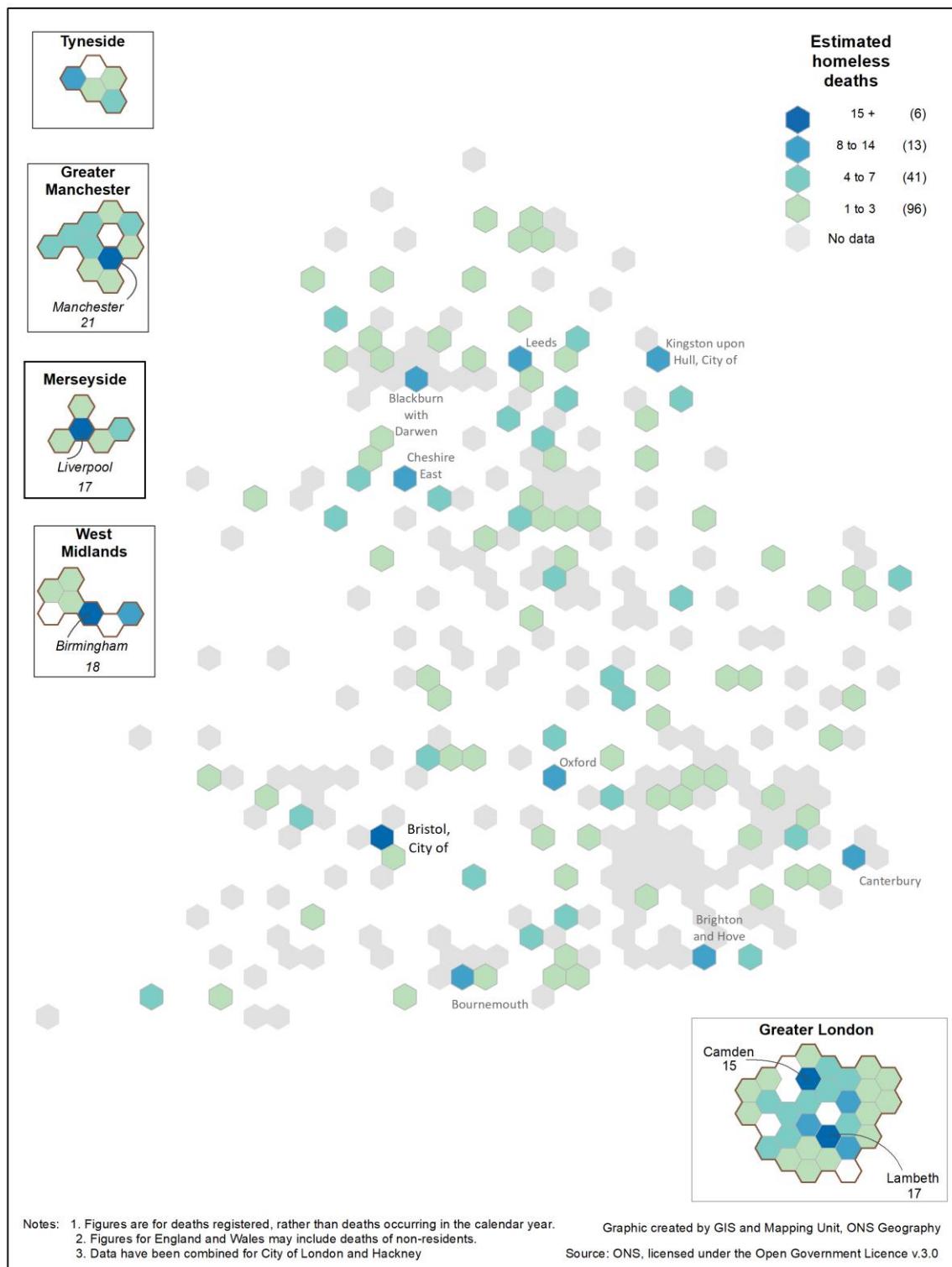
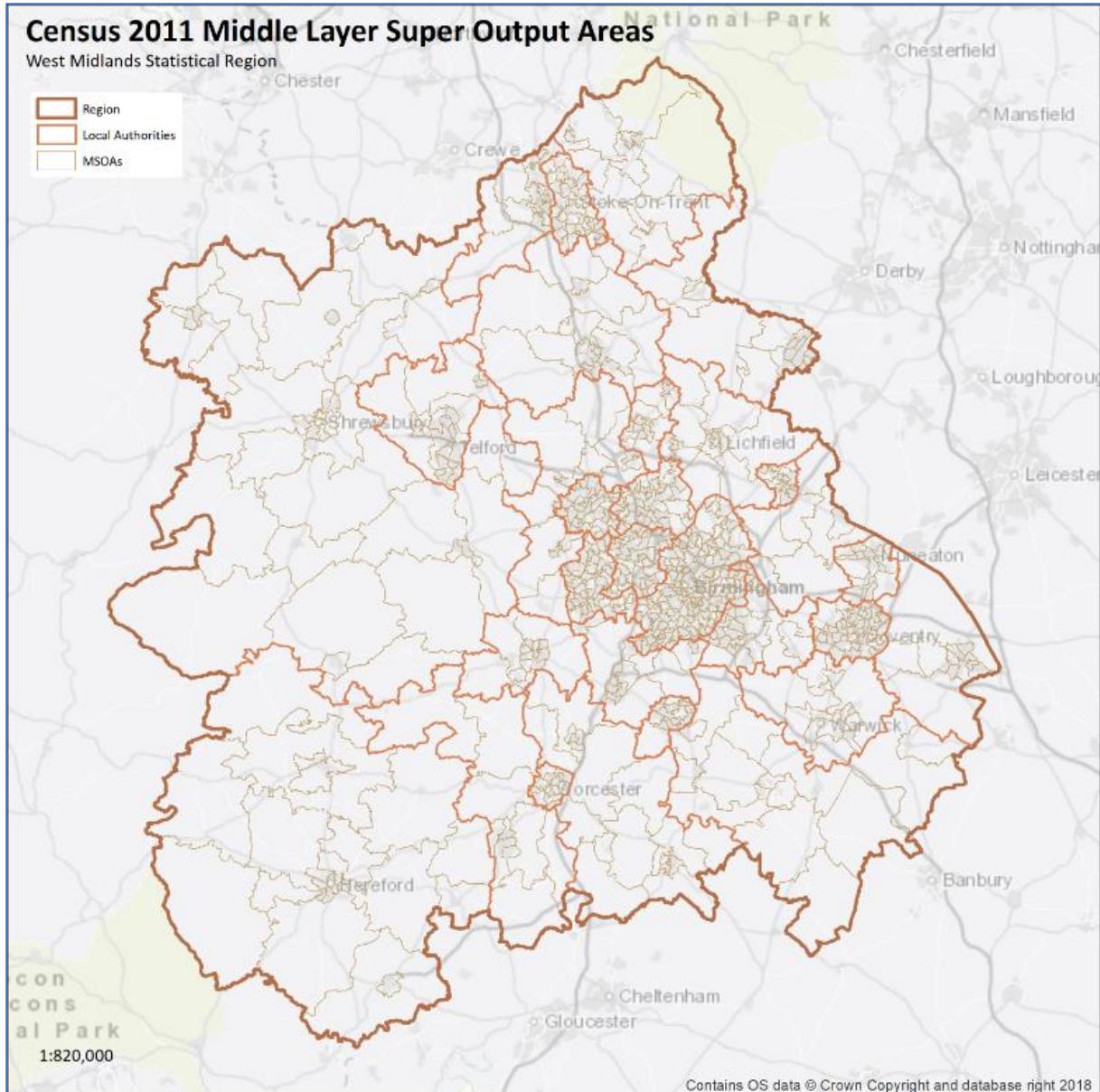


Figure 4: Deaths of Homeless People (est.) 2017. Compressed hexmap.

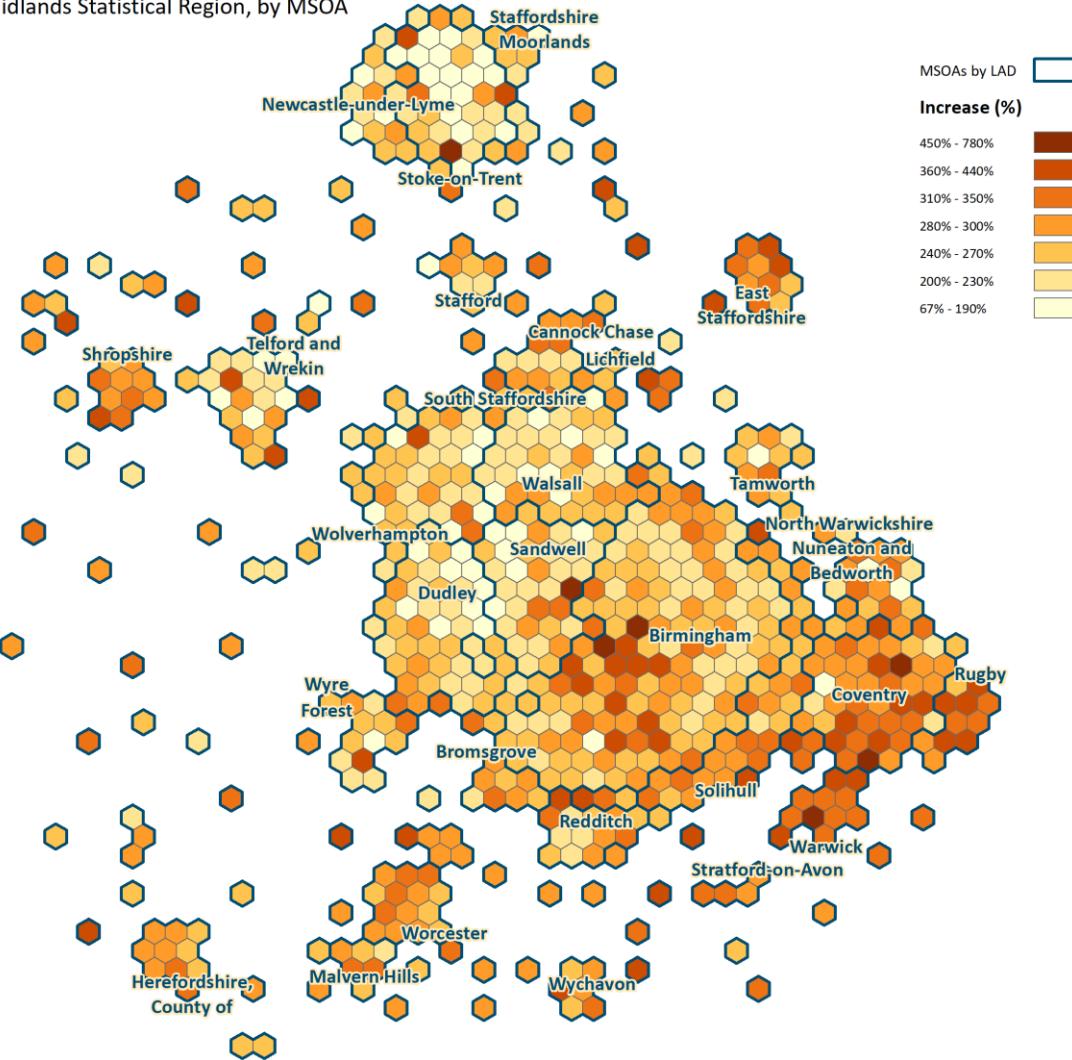


The West Midlands region encompasses some of the most rural and some of the most urban parts of England, giving rise to a 700-fold size difference between smallest and largest of the 735 MSOAs in the region. It is therefore not practicable to produce an MSOA-level choropleth, graduated or proportional symbol, or basic hexmap of the entire region (scale 1:820,000).

On the other hand, a compressed hexmap can succeed, as the compression permits a zoomed-in view, equating to a scale of 1:525,000.

## Percentage change in residential property prices paid, 1995-2017

West Midlands Statistical Region, by MSOA



1:525,000

Contains National Statistics data © Crown copyright and database right [2019]

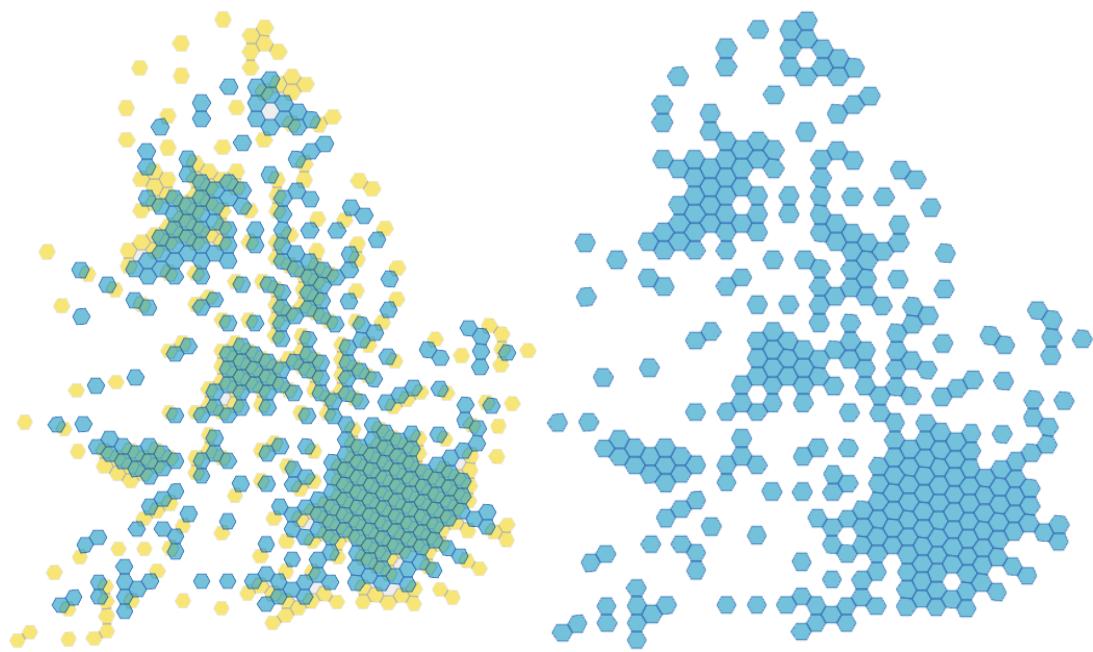
## ***Regional and multiple compression***

For some hierarchical geographies (e.g. Local Authorities within regions within countries) with distinct spatial patterns, and where it may be important to retain these, it may be desirable to initially generate regional hexmaps before combining these into a hexmap for the whole geography. Projection, HEXSIZE and other parameters must be common across all regions.

But each regional hexmap will have its own CxC drawing the individual hexes inwards, and this will cause gaps to open up between regions. The datasets should then be merged into a single shapefile, and the gaps can then be manually removed by shifting the hexes of one region towards the other, respecting the common hexagonal mesh.



If excessive space between the individual hexagons on a compressed hexmap is disturbing, this may be reduced by one or more further round(s) of compression.



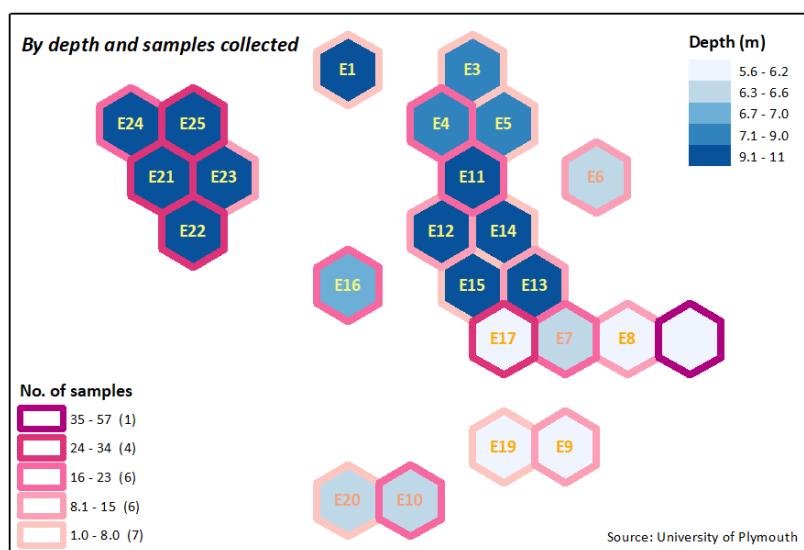
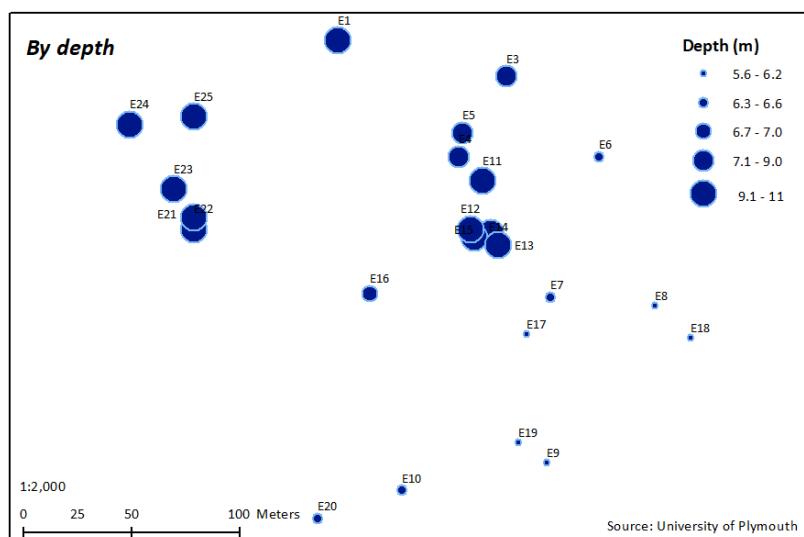
## Other scales

### Local

The methodology may have applicability well beyond the scales normally used for cartography, and well beyond social geostatistics. Whether the application of this techniques to data at these scales, and which are inherently three-dimensional, is helpful or even appropriate, must be left to the relevant subject experts. We offer it as a proof of concept.

Our first example is a set of marine biology sample points in a small part of Plymouth harbour, used with permission of Dr Benjamin Ciotti of the University of Plymouth's School of Marine Biology. The x-y location of each sampled point was recorded along with depth and data on the various species found there. Given the clustering and dispersal of the sampling points, employing proportional symbols in their actual locations would be inefficient, with both large gaps and overlaps. The sampling data may be communicated more effectively with a compressed hexmap.

Marine biology sampling points, Plymouth Harbour



## Microscopic

Zooming right in, we have generated a compressed hexmap from an electron microscope image of the brain of a fly. In the absence of spatial data on the image (covering 4mm<sup>2</sup>), and purely as a proof of concept, I converted the image file to vectors and applied a simple Cartesian coordinate system. I then created and mapped a simple (and meaningless) 8-value categorical scale.

Stanford's Transmission Electron Microscopy - Fly Brain - random classifications

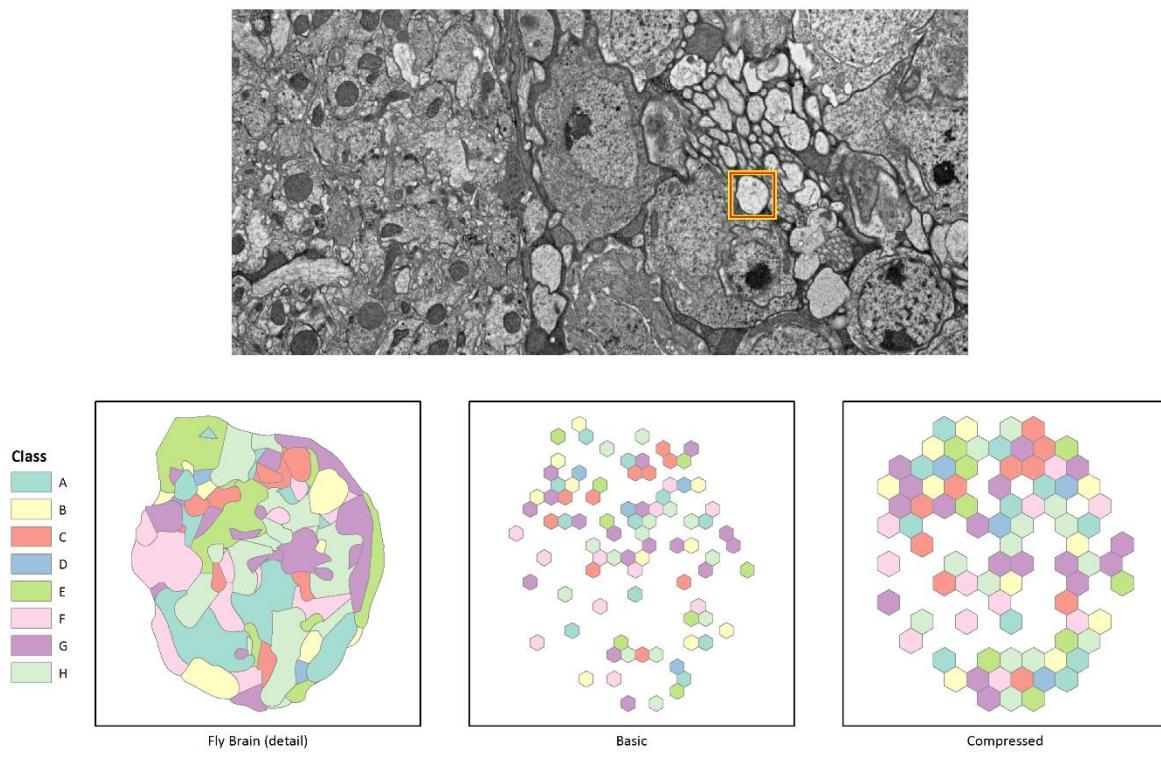
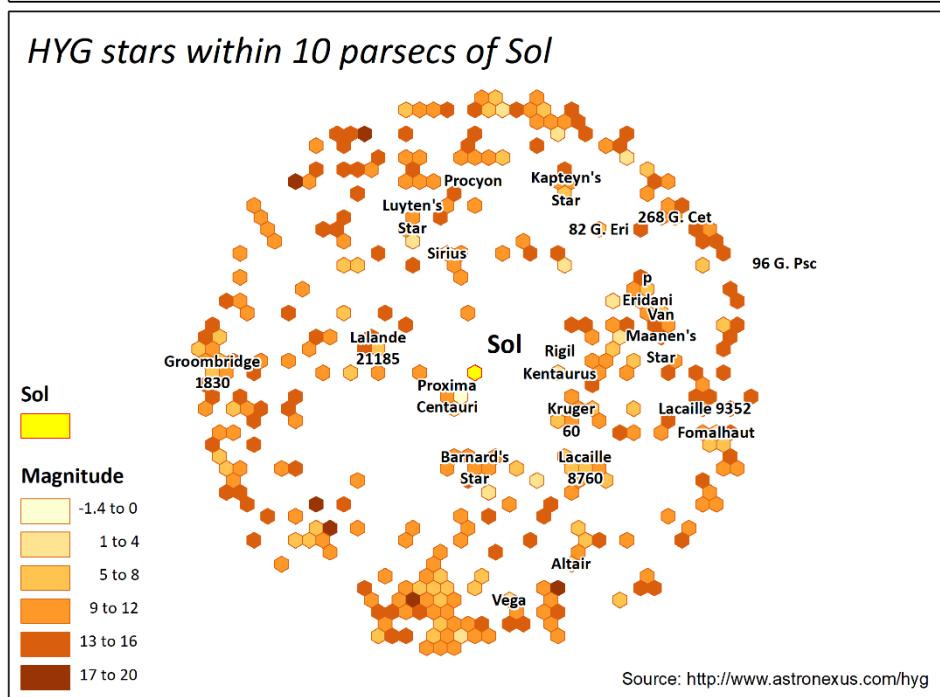
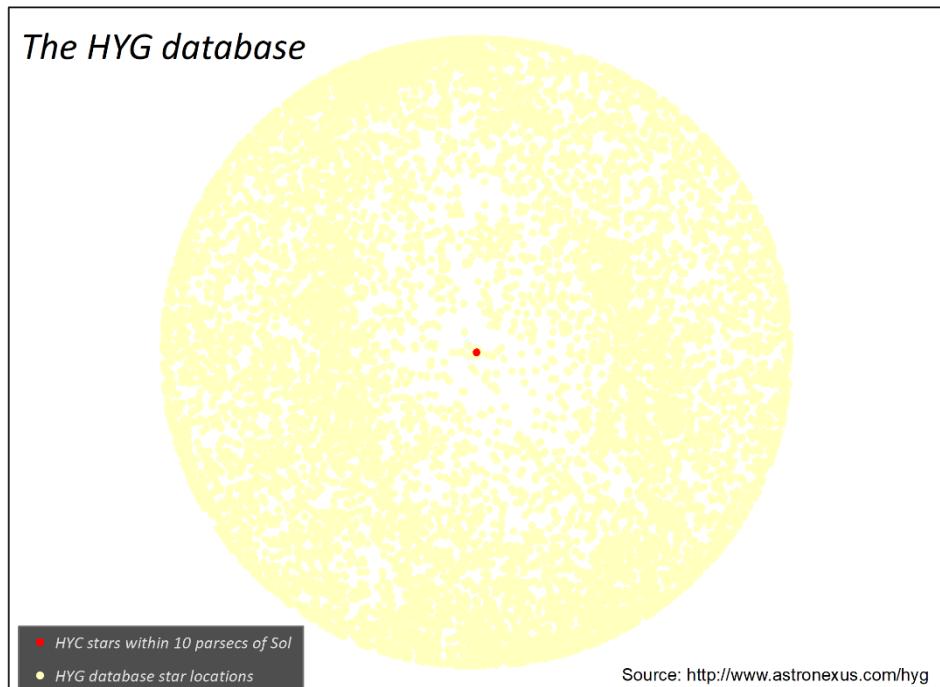


Figure 5: Transmission Electron Microscopy – Fly brain at x1200 magnification (detail)<sup>3</sup>

<sup>3</sup> <https://microscopy.stanford.edu/>

## Cosmic

Looking further afield, the technique may also be used at the cosmic scale. The [HYG Database](#) is a meta-catalogue containing over 120,000 stars. It includes the x,y,z, Cartesian coordinates of the star (in a system based on the equatorial coordinates as seen from Earth), distance from earth and a range of other fields. Once a suitable buffer is generated for each point to create polygons, a compressed hexmap may easily be generated for any subset of the catalogue. We have generated a compressed hexmap of all the stars within ten parsecs of Sol (our sun).<sup>4</sup>



<sup>4</sup> One parsec = 3.26 light years. The Milky Way galaxy is 30 kiloparsecs (kpc) across, and Sol is 8kpc from the galactic centre.

## **Summary**

We have created a tool that can be used to quickly and efficiently create hex-based equal area cartograms from any dataset that includes cartesian or projected coordinates, regardless of the scale.

It is most suitable for datasets where the area of polygons, or the distances between points, is highly variable.

The script requires a polygon input. A point dataset must first be converted to polygon by generation of buffers.

Your polygon dataset must then be placed in the INPUT\_POLYGON folder, whose location is defined in script 'HexTool\_Setup.py'.

Within 'HexTool\_Setup.py', select **basic** or **compressed** hexmap.

It must also be added to 'HexTool\_Geographies.py' as GEOGRAPHY\_NAME. You also have to select values for HEXSIZE, HEXORIENTATION and COMPRESSION\_FACTOR. Note that a value is required for COMPRESSION\_FACTOR even if you are creating a **basic** hexmap. Use '3' as the default.

Run 'HexTool\_Setup.py'.

Geometry and image files will be generated and placed in the output folders specified.

Play with the HEXSIZE, HEXORIENTATION and COMPRESSION\_FACTOR parameters until you are satisfied.

Note: if you use a decimal for the COMPRESSION\_FACTOR, e.g. 2.5, while the folder for the output will be named correctly (e.g. ID\_KABUPATEN\_EPSG\_4326\_WGS84\_0.6\_1\_CF2.5\_hexmap), the name of the shapefile within it will be curtailed to the decimal (e.g.

ID\_KABUPATEN\_EPSG\_4326\_WGS84\_0.6\_1\_CF2). If you try several options (e.g. CH+ 2.8, 2.6, 2.4) they will all be in separate, correctly named folders, but will have identical filenames.

## **Recommended testing:**

First: try out some of the geographies supplied with this tool with the parameters as set up in the Python script 'HexTool\_Geographies\_UK.py' or 'HexTool\_Geographies\_Elsewhere.py'.

Then see what happens when you alter HEXSIZE, HEXORIENTATION and COMPRESSION\_FACTOR.

Add some of your own data (as ESRI shapefile) to the INPUT\_POLYGON\_PATH and to the appropriate 'HexTool\_Geographies\_....py' folder. Experiment with the three parameters.

## **DESIRABLE OPTIMISATIONS**

- Currently, the optimal values for hex size, hex orientation and the compression factor must all be obtained by trial and error. It should be possible to calculate optimal values by reference to the perimeter envelope of the input geography, the number of spatial entities within it and the units of the spatial reference system (projection).
- The transformation function could be refined with the inclusion of a friction function to supplement the existing gravity function. There is something similar in D3.js
- The tool should be able to accept as input any spatial file format recognised by Fiona, but it's currently set up only to accept ESRI shapefiles as input and to write output also only to shapefile. Adding other formats at both ends (e.g. geopackage, geoJSON) – has been experimented with but not implemented.
- The basic and compressed code began as a single script, remain essentially the same and should really be merged back into each other, incorporating a conditional IF COMPRESSED HEXMAP – ACTIVATE COMPRESSION CODE – ELSE SKIP clause. Otherwise there's double the maintenance. A 'compressed' switch should be added to the parameters.
- Some of the linear code ought to be rewritten as functions
- As a cosmetic touch, perhaps a completion bar / hourglass / sound on completion could be added.
- Under some circumstances, multithreading would help.

## **ERRORS**

### **ATTRIBUTEERROR: 'FLOAT' OBJECT HAS NO ATTRIBUTE '\_\_GEO\_INTERFACE\_\_'**

CAUSE: GEOGRAPHY\_NAME has an unknown projection, or HEXSIZE too small.

Solutions: choose and apply appropriate projection for the geography, change HEXSIZE

### **DRIVERERROR: PATH/FILENAME.SHP: NO SUCH FILE OR DIRECTORY.**

CAUSE: typos. Can also occur if you use multiple Python interpreters on the scripts

Solutions: check your typing. Stick with one interpreter!

### **VALUEERROR: THE SECOND INPUT GEOMETRY IS EMPTY**

CAUSE: The HEXSIZE value is not appropriate for the combination of geography extent and

geometry unit. Example: global decimal degree extent -180 to + 180 but HEXSIZE = 60000

Solutions: change HEXSIZE to appropriate scale. Check the axes on the INPUT\_POLYGON.png to see the min/max x and y. HEXSIZE should be something like the min/max RANGE divided by the number of map units.

### **VALUEERROR: THE TRUTH VALUE OF AN ARRAY WITH MORE THAN ONE ELEMENT IS AMBIGUOUS. USE A.ANY() OR A.ALL()**

CAUSE: failing to delete variables at the end of the scripts.

### **'MAXIMUM ALLOWED SIZE EXCEEDED'**

CAUSE: COMPRESSION\_FACTOR = 0. Must be at least 1. Min 1.5 recommended.

### **ATTRIBUTEERROR: MODULE 'HEXTOPOLYSETUP' HAS NO ATTRIBUTE 'INPUT\_POLYGON\_PATH'**

This error paired with occasional double-running of the script. It's to do with:

**import HexTool\_core\_coreOnly.py** and **import HexTool\_core\_withTransform.py**.

These scripts both '**import HexTool\_Setup as parameters**' and

**INPUT\_POLYGON\_PATH = parameters.INPUT\_POLYGON\_PATH**

**OUTPUT\_IMAGE\_PATH = parameters.OUTPUT\_IMAGE\_PATH**

**OUTPUT\_HEXMAP\_PATH = parameters.OUTPUT\_HEXMAP\_PATH**

**OUTPUT\_FILE\_TYPE = parameters.OUTPUT\_FILE\_TYPE**

... but both are run from **HexTool\_Setup.py**