CASA0005 Geographic Information Systems and Science

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Chapter 1

Welcome

Welcome to the CASA0005 Geographic Information Systems and Science online pratical handbook. This website is hosted on Github and holds all the practical instructions and data. All data used within the practicals is aviaiable online, however occasionally websites can undergo maintenance or be inaccessible due to political facors such as the government shutdowns.

If you need the practical data you can access it from my github repository here: https://github.com/andrewmaclachlan/CASA0005

Practical data is divided into the relevant sessions, although sometimes i'll refer to a dataset used within a previous week.

1.1 The world of GIS

Spatial analysis can yield fascinating insights into geographical relationships. However, at times it can be difficult to work with. You will get lots of error messages and have software crash. The academic staff are here to help you work through these practicals but we do not know everything. It's a good idea to become familar with online sources of help, such as:

- Stack Exchange https://stackexchange.com/
- QGIS documemtation https://docs.qgis.org/3.4/en/docs/index.html
- R documentation https://www.rdocumentation.org/
- ArcGIS help pages https://support.esri.com/en

1.2 Getting Started

One of the issues with GIS is that many of the files we will be working with are quite large. Fortunately, in recent years, UCL has seriously beefed up the storage available for students. You now get 100GB of free storage, which should be plenty for the work you will be doing this year! The Bartlett faculty has several gigabytes of storage space available on their central servers, so before we get started, we will connect to our N drive to carry out all of our practical work over the coming weeks.

1.3 Offline viewing

If you are unable to access the internet to view this github website most web browsers allow you to save webpages for offline viewieng.

Insturctions for Google Chrome are provided here: https://support.google.com/chrome/answer/7343019?co=GENIE.Platform%3DDesktop&hl=en&oco=1

Chapter 2

Practical 1 – Geographic Information

2.1 Learning outcomes

By the end of this practical you should be able to:

- Describe and explain GIS data formats and databases
- Source and pre-process spatial data
- Load and undertaken some basic manipulcation of spatial data in: ArcMap, QGIS and R
- Evaluate the (dis)advantages of each GIS you have used

2.2 The Basics of Geographic Information

Geographic data, geospatial data or geographic inforamtion is data that identifies the location of features on Earth. There are two main types of data which are used in GIS applications to represent the real world. **Vectors** that are composed of points, lines and polygons and **rasters** that are grids of cells with individual values.

In the above example the features in the real world (e.g. lake, forest, marsh and grassland) have been represented by points, lines and polygons (vector) or discrete grid cells (raster) of a certain size (e.g. 1 x 1m) specifying land cover type.

2.2.1 Important GIS data formats

There are a number of commonly used geographic data formats that store vector and raster data that you will come across during this course and it's important to understand what they are, how they represent data and how you can use them.

2.2.1.1 Shapefiles

Perhaps the most commonly used GIS data format is the shapefile. Shapefiles were developed by ESRI (http://www.esri.com/) – one of the first and now certainly the largest commercial GIS company in the world. Despite being developed by a commercial company, they are mostly an open format and can be used (read and written) by a host of GIS Software applications.

A shapefile is actually a collection of files – at least three of which are needed for the shapefile to be displayed by GIS software. They are:

1. `.shp` - the file which contains the feature geometry
2. `.shx` - an index file which stores the position of the feature IDs in the `.shp` file
3. `.dbf` - the file that stores all of the attribute information associated with the coordinates – this might be the name of the shape or some other information associated with the feature
4. `.prj` - the file which contains all of the coordinate system information (the location of the shape on Earth's surface). Data can be displayed without a projection, but the `.prj` file allows software to display the data correctly where data with different projections might be being used

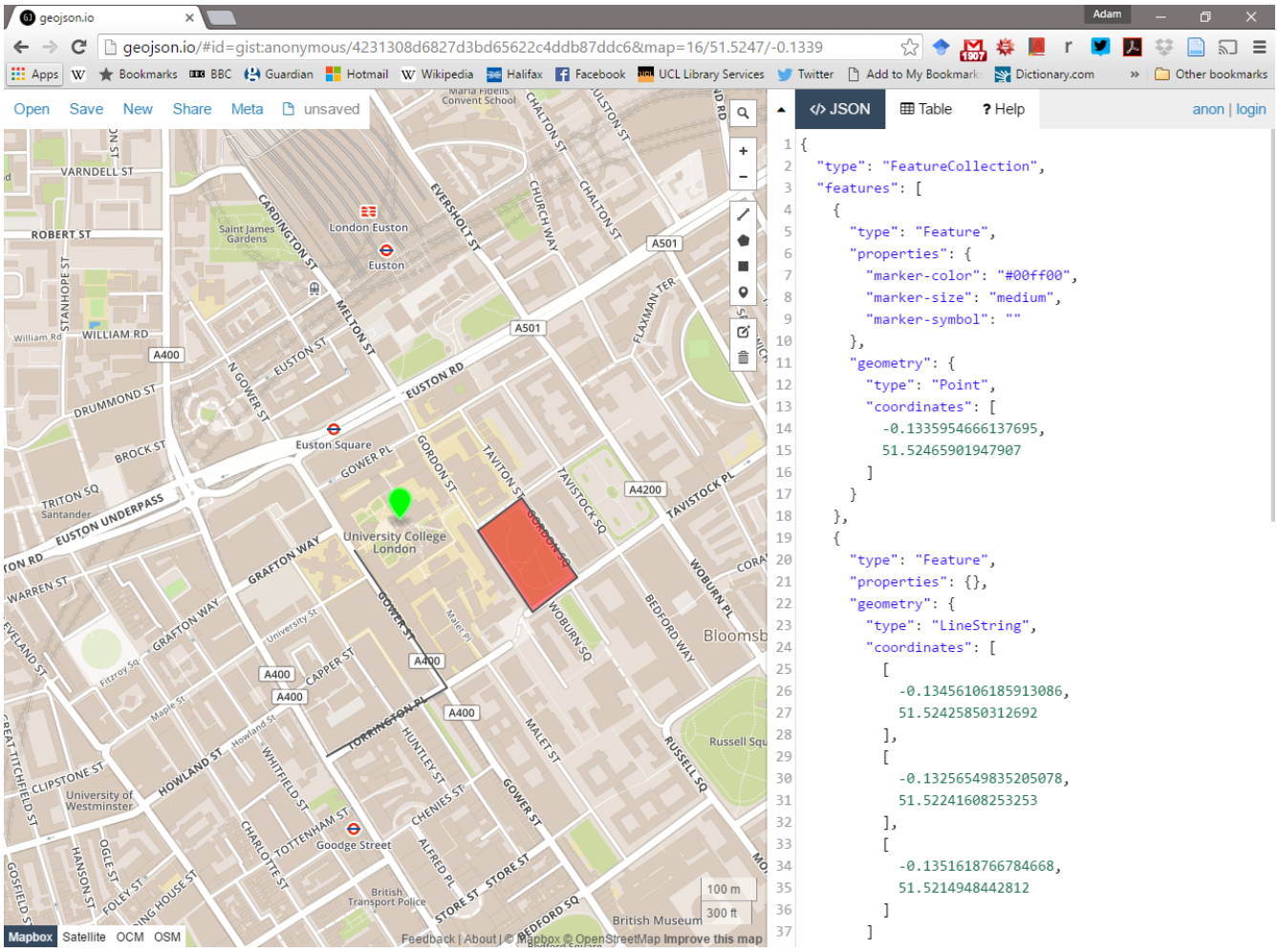
2.2.1.2 GeoJSON

GeoJSON (Geospatial Data Interchange format for JavaScript Object Notation, http://geojson.org/) is becoming an increasingly popular spatial data format, particularly for web-based mapping as it is based on JavaScript Object Notation. Unlike a shapefile in a GeoJSON, the attributes, boundaries and projection information are all contained in the same file.

2.2.1.3 Shapefile and GeoJSON

We're now going to explore a shapefile (`.shp`) and GeoJSON (`.geojson`) in action.

Go to: http://geojson.io/#map=16/51.5247/-0.1339



1. Using the drawing tools to the right of the map window, create 3 objects: a point, line and a polygon as I have done above. Click on your polygon and colour it red and colour your point green
2. Using the 'Save' option at the top of the map, save two copies of your new data – one in `.geojson` format and one in `.shp` format
3. Open your two newly saved files in a text editor such as notepad or notepad++. For the shapefile you might have to unzip the folder then open each file individually. What do you notice about the similarities or differences between the two ways that the data are encoded?

2.2.1.4 Raster data

Most raster data is now provided in GeoTIFF (`.tiff`) format, which stands for Geostarionary Earth Orbit Tagged Image File. The GeoTIFF data format was created by NASA and is a standard public domain format. All necesary inforamtion to establish the location of the data on Earth's surface is embedded into the image. This includes: map projection, coordinate system, ellipsoid and datum type.

2.2.1.5 Other data formats

Aforementioned data types and formats are likely to be the ones you predominately encounter. However there are several more used within spatial analysis. Theres include:

Vector

- GML (Geography Markup Language – gave birth to KML) - http://www.opengeospatial.org/standards/gml

Raster

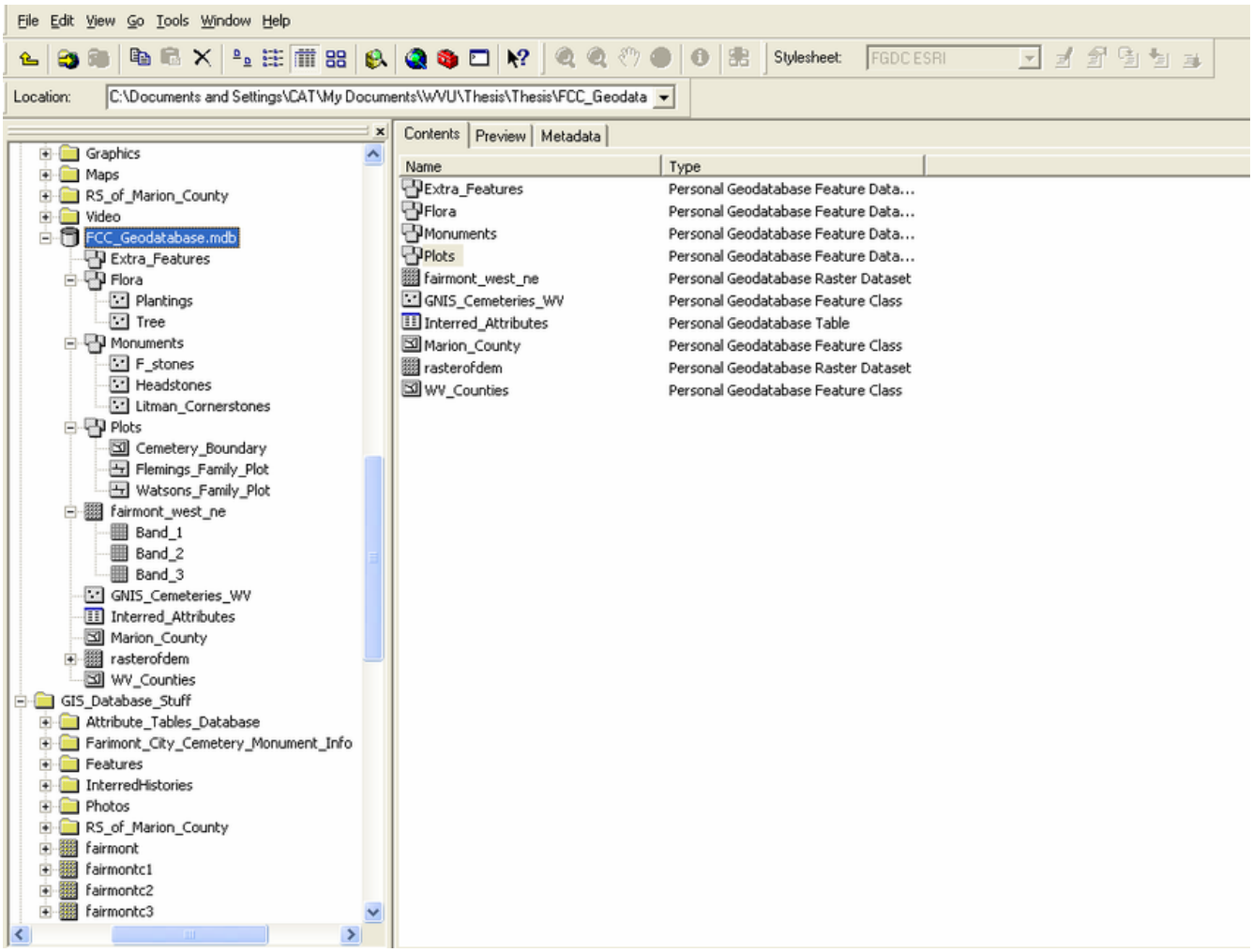
- Band SeQuential (BSQ) - technically a method for encoding data but commonly refered to as BSQ.
- Hierarchical Data Format (HDF)
- Arc Grid

There are normally valid reasons for storing data in one of these other formats. For example, BSQ are raster data with a seperate text header file (`.hdr`) providing geographic spatial reference information. Earth observation data often monitors the electromagenitc spectrum in bands. Humans see in the visible range of the spectrum and our vision is composed of red, green and blue wavelengths. If we wanted to analyse just the red wavelength the BSQ format would let us *read in* only that data. In comaprsion a GeoTIFF might come with all the data 'packaged' in one file and when doing analysis over thousands of images would significantly slow things down. That said you can now often find GeoTIFFs seperated in a similar format to BSQ and it's fairly straightforward to convert between raster formats.

2.2.1.6 Geodatabase

A geodatabase is a collection of geographic data held within a database. Geodatabases were developed by ESRI to overcome some of the limitations of shapefiles. They come in two main types: Personal (upto 1 TB) and File (limited to

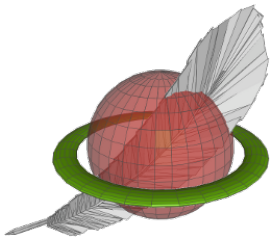
250 - 500 MB), with Personal Geodatabases storing everything in a Microsoft Access database (`.mdb`) file and File Geodatabases offering more flexibility, storing everything as a series of folders in a file system. In the example below we can see that the FCC_Geodatabase (left hand pane) holds multiple points, lines, polygons, tables and raster layers in the contents tab.



2.2.1.7 GeoPackage

A GeoPackage is an open, standards-based, platform-independent, portable, self-describing, compact format for transferring geospatial data. It stores spatial data layers (vector and raster) as a single file, and is based upon an SQLite database, a widely used relational database management system, permitting code based, reproducible and transparent workflows. As it stores data in a single file it is very easy to share, copy or move.

2.2.1.8 SpatiaLite



SpatialLite is an open-source library that extends SQLite core. Support is fairly limited and most software that supports SpatiaLite also supports GeoPackage, as they both build upon SQLite. It doesn't have any clear advantage over GeoPackage, however it is unable to support raster data.

2.2.1.9 PostGIS

PostGIS is an opensource database extender for PostrgeSQL. Essentially PostgreSQL is a database and PostGIS is an add on which permits spatial functions. The advantages of using PostGIS over a GeoPackage are that it allows users to

access the data at the same time, can handle large data more efficiently and reduces processing time. In this example (https://medium.com/@GispoLearning/learn-spatial-sql-and-master-geopackage-with-qgis-3-16b1e17f0291) calcualting the number of bars per neighbourhood in Leon, Mexico the processing time reduced from 1.443 seconds (SQLite) to 0.08 seconds in PostGIS. However, data stored in PostGIS is much harder to share, move or copy.

2.2.1.10 What will I use

The variety of data formats can see a bit overwhelming. But don't worry, most of the time you'll be using shapefiles, GeoPackages or raster data.

2.3 Data

The volume of geographic information which is freely available for use in the UK is increasing exponentially and spatially referenced data can often be found in many different places. In this practical we're going to use data from the London data store — a free and open data-sharing portal provided by the Greater London Authrotiy (GLA), also known as City Hall that is the devovled regional governance body of London.

We are going to get spatial data of the London boroughs and join flytipping (the illegal deposit of waste, commonly on road verges) data that is provided as a `.csv` file. `.csv` stands for comma-separated values (CSV) — it uses a comma to separate each value.

At the end of this document I'll also run through some common sources of data that will stand you in good stead (be advantagous) for the rest of the course.

2.3.1 File paths

In your N drive: create a new folder called GIS and within this a subfolder called wk1. It is up to you how you organise your files. Make sure you change the file paths within where appropraite to your own.

2.3.2 Data download

Firstly we need to get a spatial outline of the London boroughs. The geographic boundaries that are used in the UK are a complex, often inter-related, but ever changing mass of areas. For anyone new to the UK (or indeed not a trained quantitative geographer), it can be quite a daunting task to attempt to understand all of the boundaries that are in use. Fortunately the Office

for National Statistics (ONS) has an online beginners guide to UK geography. If you need more information on the vast array of different UK geographies, this is the place to start: http://geoportal.statistics.gov.uk/datasets/a-beginners-guide-to-uk-geography-2018-v1-0

- Spatial Data

1. To get the data go to: https://data.london.gov.uk/
2. Seach for Statistical GIS Boundary Files for London
3. Download the statistical-gis-boundaries-london.zip
4. Unzip the data and save it to your wk1 folder.

- CSV data

1. On the same website search for fly-tipping incidents
2. Download the `.csv` file

2.3.3 Data pre-processing

Question Open the `.csv` in Excel, what do you notice about how the data is stored?

Answer The year is a column and for each area the values are repeated for different years. In our analysis it is easier to have the different years as a coloumn and populated for each area. So, we want to go from this…

	A	B	C	D	E	F	G	H	I	J
7	E0900000	Bromley	2011-12	2,222	306	16	9	16	2	
8	E0900000	Camden	2011-12	6,679	5,541	465	31	55	1	
9	E0900000	Croydon	2011-12	2,740	31	17	6	4	0	
10	E0900000	Ealing	2011-12	4,964	6,727	3,852	82	193	4	
11	E0900001	Enfield	2011-12	19,486	7,262	191	4,483	478	5	
12	E0900001	Greenwich	2011-12	5,120	6,344	19	974	36	1	
13	E0900001	Hackney	2011-12	1,030	2,332	22	18	171	0	
14	E0900001	Hammersmith and Fulham	2011-12	5,700	6,944	0	389	3,300	2	
15	E0900001	Haringey	2011-12	15,713	8,817	1,455	280	796	18	
16	E0900001	Harrow	2011-12	8,037	1,053	177	0	6	6	
17	E0900001	Havering	2011-12	2,972	13,970	7,354	657	1,264	0	
18	E0900001	Hillingdon	2011-12	4,398	5,120	60	2,208	144	0	
19	E0900001	Hounslow	2011-12	17,059	1,234	8	0	0	0	
20	E0900001	Islington	2011-12	2,048	6,959	1,119	3,595	610	0	
21	E0900002	Kensington and Chelsea	2011-12	5,482	4,773	0	120	0	0	
22	E0900002	Kingston Upon Thames	2011-12	239	0	0	0	0	0	
23	E0900002	Lambeth	2011-12	1,696	598	0	212	31	0	
24	E0900002	Lewisham	2011-12	15,757	789	164	101	22	15	
25	E0900002	Merton	2011-12	2,526	1,279	171	255	42	2	
26	E0900002	Newham	2011-12	40,499	9,593	1	8,876	234	0	
27	E0900002	Redbridge	2011-12	5,110	6,114	3,172	66	286	0	
28	E0900002	Richmond Upon Thames	2011-12	3,208	2,610	645	16	1	1	
29	E0900002	Southwark	2011-12	16,823	0	0	0	0	0	
30	E0900002	Sutton	2011-12	1,479	1,255	65	120	112	0	
31	E0900003	Tower Hamlets	2011-12	6,184	3,251	790	1,079	297	0	
32	E0900003	Waltham Forest	2011-12	4,456	17,182	252	991	6,031	0	
33	E0900003	Wandsworth	2011-12	1,561	8,226	4,609	255	0	366	
34	E0900003	Westminster	2011-12	14,694	8,367	1,943	5,622	0	0	
35	E0900000	City of London	2012-13	449	1,492	658	245	3	0	
36	E0900000	Barking and Dagenham	2012-13	2,417	2,122	123	49	56	0	
37	E0900000	Barnet	2012-13	1,697	1,828	264	67	0	0	
38	E0900000	Bexley Council	2012-13	1,038	627	38	47	0	0	
39	E0900000	Brent	2012-13	6,911	2,232	182	184	268	12	

To this...

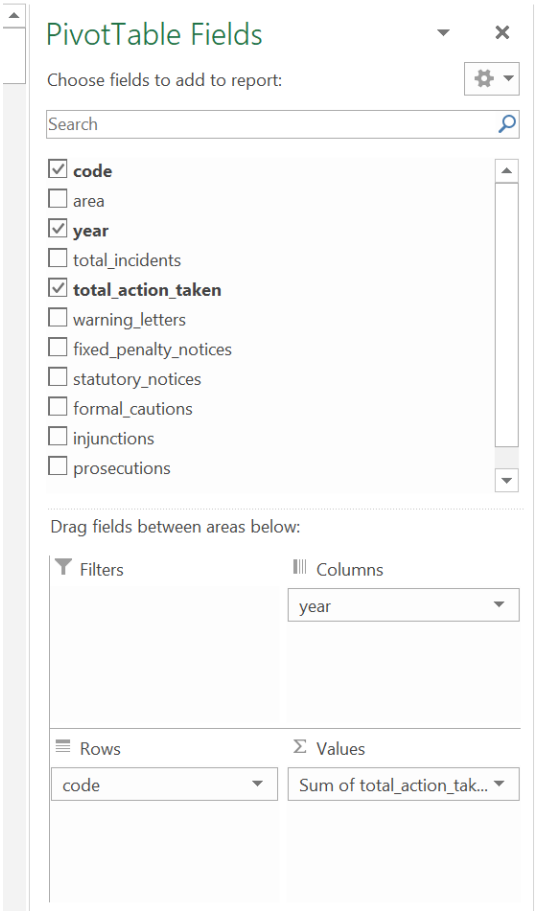
	A	B	C	D	E	F	G	H
1	**Sum of total_incidents**							
2	**Row Labels**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**
3	E09000001	527	449	530	369	627	1731	1826
4	E09000002	3665	2417	1282	2564	2361	2423	2628
5	E09000003	1450	1697	1779	11615	5999	7029	6153
6	E09000004	980	1038	1078	1162	1110	1480	2105
7	E09000005	7272	6911	7001	12912	13198	17340	18609
8	E09000006	2222	2495	2809	3377	3343	3246	3067
9	E09000007	6679	11477	10950	8308	7268	6778	12170
10	E09000008	2740	11150	15113	18560	0	24797	19198
11	E09000009	4964	6352	5765	7257	7032	14270	13610
12	E09000010	19486	17871	31692	50121	70930	75614	3900
13	E09000011	5120	5170	12765	14324	10712	7960	8411
14	E09000012	1030	599	7635	6008	6917	3267	9821
15	E09000013	5700	7079	9011	9208	10829	14870	18652
16	E09000014	15713	12398	31045	25709	34975	33333	23549
17	E09000015	8037	6228	8429	7072	8462	6835	9626
18	E09000016	2972	2842	3620	2914	3726	4061	4655
19	E09000017	4398	4506	1995	1817	7267	7766	7181
20	E09000018	17059	13934	15864	16282	19809	22973	17063
21	E09000019	2048	2231	2634	3166	4174	3011	2588
22	E09000020	5482	6075	6934	6603	6105	9029	9852
23	E09000021	239	126	339	956	1263	1528	1349
24	E09000022	1696	1454	1206	4056	2493	3427	3433
25	E09000023	15757	10604	9152	6747	5514	1931	3562
26	E09000024	2526	3098	3064	3819	2816	3113	8878
27	E09000025	40499	28443	67930	70192	32718	19917	15206
28	E09000026	5110	6986	8939	11066	10864	12461	
29	E09000027	3208	2608	2871	2903	3723	5253	4701
30	E09000028	16823	25894	26638	25583	21359	17131	15741
31	E09000029	1479	1512	1264	1575	1478	2296	2683
32	E09000030	6184	3732	5201	6671	4555	6287	7465
33	E09000031	4456	3951	4723	6127	6798	6772	7678

fly_tipping_borough Sheet4

As we are going to use this dataset in ArcMap, QGIS and R I've done it in Excel using a pivot table.

1. Go to Insert > PivotTable
2. Select the original table and create a PivotTable in a new worksheet
3. The PivotTable Field box will appear, experiment with the different fields in each of the areas

I've used the following:



Note how I've altered the total_action_taken to the sum of... as the original was displaying incorrectly, to do so:

1. Click on drop down button for total_action_taken > Value Field Settings > select Count

It's important to think about what data we actually need in the next step and it's good practice to avoid data redundancy where possible.

Spoiler The spatial data we have downloaded already contains borough name, so we don't need it twice. However, we do need a field to link the two datasets on. You could use borough name, but when using text fields sometimes input variations can affect joins. For example, you had the University of Manchester in one dataset and Manchester University in another the join would fail. Consequntly it's usually best to join datsets on a code field.

Now save the Excel sheet that contains the pivot table as a new `.csv`. Make sure that the first row of data holds the coloumn titles. Remove all empty rows.

When saving the file also avoid any special characters (e.g. -) and spaces, use an underscore instead of spaces.

Warning Spatial software (especially ArcGIS) does not like file names with spaces or special characters.

2.3.4 Data loading

Now it's time to load, inspect and do some basic manipulation of this data. As mentioned in the lecture there are several GIS software 'types', here we will repeat the same process across ArcGIS, QGIS and R. Each system has specific benefits, but in general there has been a recent shift towards the use of QGIS and R, both being opensource. ArcGIS was the first major spatial analysis software produced by the Environmental Systems Research Institute, Inc. (Esri), founded in 1969 by Jack Dangermond. Due to its high cost and lack of customisation it is now less commonly used within the research community.

2.3.5 ArcGIS

2.3.5.1 Basics

ArcGIS should be installed as a standard programme in the UCL desktop and you can navigate to it from the Windows start button.

2.3.5.1.1 Installing ArcGIS on your own computer

As a UCL student, you can install ArcGIS on your own computer. This is easy if you have a PC, but if you have a Mac this can be trickier as Arc will only run in a PC environment. If you have a Mac, the options open to you are either to:

a) Run ArcGIS through the Desktop@UCL application - http://www.ucl.ac.uk/isd/services/computers/remote-access/desktop
b) Duel boot your machine using bootcamp, install Windows (7 or 8 is fine) and then install Arc onto the Windows partition.
c) Install some kind of virtualisation software such as Parallels (http://www.parallels.com/ca/products/desktop/) or VMware (http://www.vmware.com/products/fusion/), and run Arc on a virtual windows machine

If you can, it is preferable to run Arc on Bootcamp as virtualisation software can be slow, but the Desktop@UCL facility should suffice for this course. ArcGIS (Version 10.6 is the latest at time of writing, but may have already been superseded) can be downloaded from the UCL Software Database for free — https://swdb.ucl.ac.uk/.

2.3.5.1.2 Getting Help

ArcGIS is a huge and complex piece of software, but thankfully is has an excellent help system – depending on the version you are using (they are all quite similar anyway) you can access the online help system here:

- http://resources.arcgis.com/en/help/main/10.2/
- http://resources.arcgis.com/en/help/main/10.1/

2.3.5.1.3 ArcGIS

ArcGIS is actually a whole suite of software built and maintained by ESRI (http://www.esri.com/software/arcgis).Within the ArcGIS for Desktop suite you will find the following programmes:

- **ArcCatalog — Similar to Windows Explorer, ArcCatalog allows you to manage your GIS files, folders and geodatabases**