# Assignment Report

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## 1 Introduction

South Korea lies in a relatively stable region, tectonically speaking. The earthquakes in this region are predominantly intraplate. The Korean Peninsula is classified as a low-hazard region, probably because historical earthquakes were not considered and there is extremely low modern seismicity. Therefore, it is crucial to explore contemporary and historical earthquake catalogs to address seismic hazard problems unique to the Korean Peninsula.

Seismic hazard will also involve information about population centres in the region. In this study, the aim is to cover both aspects of hazard assessments by first carrying out GIS processing of population data to estimate the population density at various administrative levels and then carrying out a brief seismicity analysis for South Korea.

## 2 Population density of South Korea - Insights from GIS analysis

A step-by-step description of the process of obtaining, cataloging and processing population data for South Korea is shown below.

1. We download the population data from World population website. The source of the population data is *doi:10.5258/SOTON/WP00685*

2. The population data is in raster form stored as a GeoTiff file format.

3. The Shapefiles are downloaded from Diva-gis.org. The data is in shapefiles with "ADM1" referring to Province level data and "ADM2" referring to district level boundaries.

4. The function is written here is called population_density() and accepts the population data in raster format along with a folder name of the country and administrative level along with projection that the user requires.

5. We use the built-in polygon object rea calculator function in the Geopandas package in Python to plot and calculate the areas of various administrative levels.

6. The user can choose any one of the following projections

    - Africa_Albers_Equal_Area_Conic
    - Africa_Albers_Equal_Area_Conic
    - Europe_Albers_Equal_Area_Conic
    - Asia_North_Albers_Equal_Area_Conic
    - Asia_South_Albers_Equal_Area_Conic
    - North_America_Albers_Equal_Area_Conic
    - South_America_Albers_Equal_Area_Conic

7. The output is saved as a jpg file called population_density.jpg as shown below. It is clear from the figure that cities like Seoul in the north and Gwangju in the south show a much denser population when compared to the countryside. This would imply that these regions would face much more damage should they be subject to earthquake shaking.

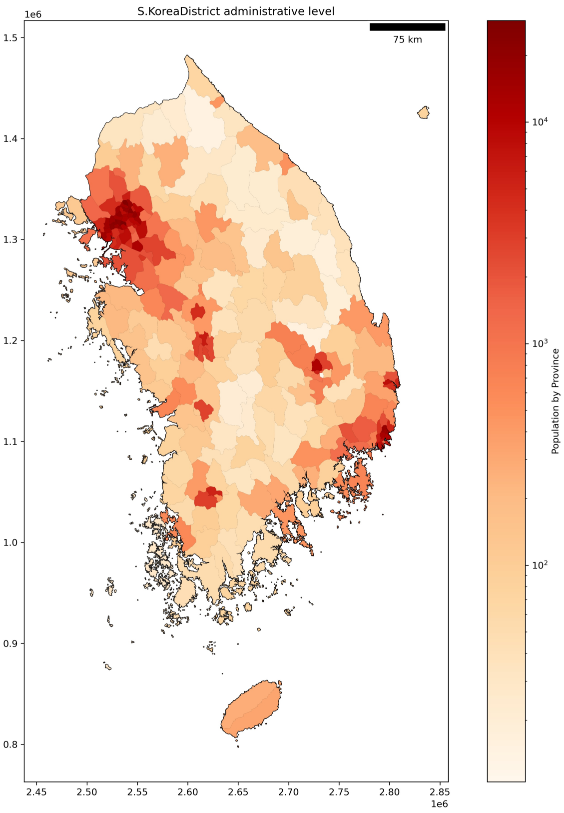



Figure 1: An example of the output that can be expected at distric level showing the population density coloured in log scale.

# 3 Seismicity Characterization of South Korea

Now it is imperative to understand the distribution and characterization of seismicity in South Korea in order. We must first build a catalog of earthquakes for the region. Various data sources are available. For the purpose of this study, we use data from two notable sources; IRIS and ISC-GEM world seismicity catalogs. To obtain data from the ISC-GEM we use OBSPY to select a specific range of latitude and longitude.

```
from obspy.core.event import read_events
# obspy event class has a method to read events from a catalogue
from obspy import UTCDateTime
# obspy class to handle time
from obspy.clients.fdsn import Client
# object that sets up an FDSN client

#setting the source as ISC
iscclient=Client("ISC")

#Defining the range of bounds
starttime =UTCDateTime("1904-01-01T00:00:00")
endtime= UTCDateTime("2020-10-31T00:00:00")
minlat=33
maxlat=39
minlon=126
maxlon=129.5
minmag=1

#using Obspy to directly obtain the catalogue from ISC
#specifically within the range.

events = iscclient.get_events(minlatitude=minlat,maxlatitude=maxlat, \
minlongitude=minlon,maxlongitude=maxlon,starttime=starttime, \
endtime=endtime,mindepth=0,maxdepth=30, minmagnitude=minmag)


events.write('./events.dat',format="ZMAP")
```

"ZMAP" format is gridded data in an ASCII format. This format is then called into the program using pandas.readcsv function. The data is in the to the format Longitude, Latitude, DecimalYear, Month, Day, Magnitude, Depth[km], Hr, Min, Sec

Data from the IRIS catalogue is downloaded from the website. The data is downloaded as .dat. This file, however, includes a few events outside South Korea. To correct for this, we filter the data using awk.

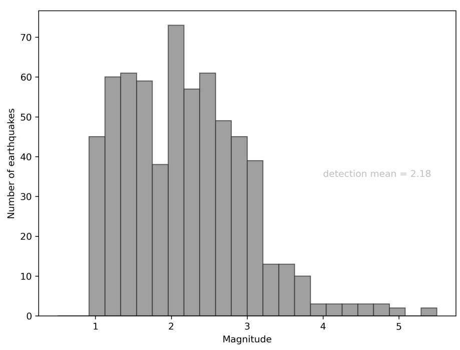
```
awk -F'|' '{if($13=="SOUTH KOREA") print $0;}' iris_events.dat>iris_SKorea.dat
```

The next step is to ensure that all the data downloaded is homogeneous in its magnitude. The Iris catalogue contains a mixture of magnitudes, whereas the ISC magnitude contains only Mw events.

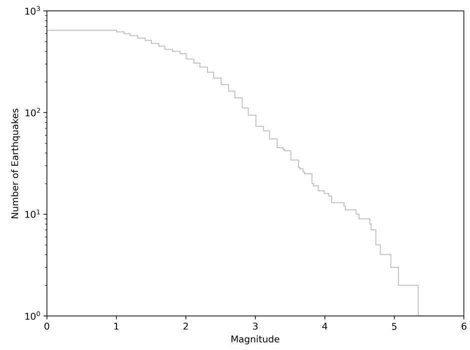
Declustering is the process of removing events that are part of the aftershock sequence following a large earthquake. These events can skew the catalogue as it disturbs the background seismicity. There are several ways to carry out this process. In this assignment, I have manually removed events around the largest events by comparing the temporal proximity and distribution of the events around the Mw 5+ events. The magnitude of completeness is the lowest magnitude above which events can be reliably recorded. There are several ways to calculate it. Here we calculate it two ways.

1. Mean of the catalog.: In this technique, if we have a nearly Gaussian distribution, then the mean of the mean Moment value of the distribution can be assumed to be the magnitude of completeness. Utilising the mean calculation, we get $M_c = 2.18$

2. Graphically from the Annual frequency graph: The graph of the cumulative number of events vs Magnitude. At this point, the graph begins to descend marks the magnitudes above which the events can be reliably measured. In the current catalogue, this would be around $M_c \approx 2$ . However, this is an approximate value and much less reliable.




(a) Histogram of the events




(b) Cumulative events vs Magnitude of events in the catalogue

Figure 2: Differing methods of viewing the events in the catalog and $M_c$ estimation

The next step is the calculate the Gutenberg Richter parameters. The Gutenberg-Richter equation provides a relationship between magnitude and the total number of earthquakes in a given region. The relationship in its simplest form is given by

$$log_{10}N = a - bM \tag{1}$$

In this study, we calculate the values by maximum likelihood and least-squares technique. The least-squares technique counts the number of events per magnitude or N(M) and then fits a least-square line to log(N)vs M line. The maximum likelihood method calculates b value as

$$b = \frac{log_{10}e}{\bar{M} - M_{min}} \tag{2}$$

The b value obtained by least squares is 0.57, and maximum-likelihood method estimates the b-value at 0.37. The mismatch is not uncommon in small catalogs such as this one. The two ways converge for more extensive catalogs.

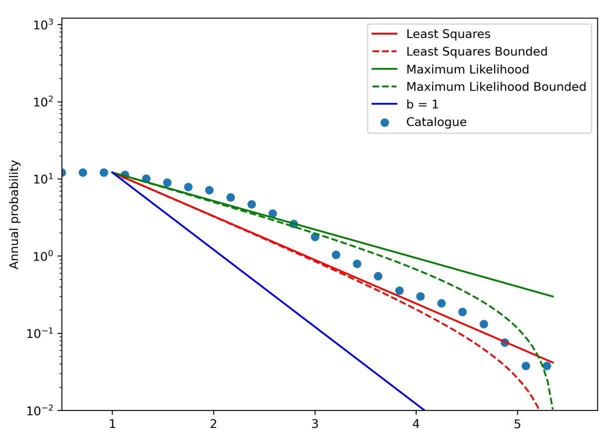



Figure 3: Comparison of annual probabilities from various b-value estimates.

The events in this catalog most likely include intraplate earthquakes and these typically have b-values in the range of 0.4 to 0.7.
(source: `http://www.eq.ccu.edu.tw/lab/lab105/public_html/members/master/93/GR.pdf`)

# 4 Conclusion

South Korea has long been thought of have low seismic hazards. However, when observing the seismic catalog the importance of including historic seismicity becomes apparent. Future work could consist of adding more events from older catalogs and more events from local networks to provide a better insight into the seismic characterisation of the region.