Emissions

June 24, 2019

1 Evolution of the carbon dioxide emissions over years

Photo by Carlos "Grury" Santos

```
In [1]: # needed libs
        import numpy as np
        import pandas as pd
        import matplotlib.pyplot as plt
        import seaborn as sns
        import folium
        import requests
```

```
In [2]: import warnings
        warnings.simplefilter(action='ignore', category=FutureWarning)
        pd.set_option('display.max_columns', 100)
```

2 Introduction

Carbon dioxide (chemical formula CO 2) [...] is the most significant long-lived greenhouse gas in Earth's atmosphere. Since the Industrial Revolution anthropogenic emissions – primarily from use of fossil fuels and deforestation – `have rapidly increased its concentration in the atmosphere`, leading to global warming [...].

Source - Wikipedia

Goal: This analysis will show the evolution of CO 2 emissions over the last decades. It's organized in two steps : firstffffffffffffffffffffff, What are the countries with the highest emissions ?

---

3 Different datasets aggregation

3.1 Informations per capita

The dataset `CO2_per_capita.csv` comes from the github repo of Cabonmap for more infos on where the data come from, please visite their website and graphics which are very instructives. An other dataset can be found here

```
In [3]: # Load the CSV file  / ParserError: Error tokenizing data. C error: Expected 1 fields
        df = pd.read_csv('input/CO2_per_capita.csv', delimiter=';')
        df.head()
```

```
Out[3]:   Country Name Country Code  Year  CO2 Per Capita (metric tons)
        0        Aruba          ABW  1960                           NaN
        1        Aruba          ABW  1961                           NaN
        2        Aruba          ABW  1962                           NaN
        3        Aruba          ABW  1963                           NaN
        4        Aruba          ABW  1964                           NaN
```

Columns names are self explanatory.

```
In [4]: df.Year.unique()
```

```
Out[4]: array([1960, 1961, 1962, 1963, 1964, 1965, 1966, 1967, 1968, 1969, 1970,
               1971, 1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981,
               1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1992,
               1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003,
               2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011])
```

3.2 Country codes and continents

This dataset consists of list of countries by continent. Continent codes and country codes are also included. Credits : JohnSnowLabs via Datahub.io

```
In [5]: df_continent = pd.read_csv('input/country-and-continent-codes-list-csv_csv.csv')
        df_continent.head()
```

```
Out[5]:   Continent_Name Continent_Code                                 Country_Name  \
        0           Asia             AS              Afghanistan, Islamic Republic of
        1         Europe             EU                          Albania, Republic of
        2     Antarctica             AN  Antarctica (the territory South of 60 deg S)
        3         Africa             AF      Algeria, People's Democratic Republic of
        4        Oceania             OC                                American Samoa

          Two_Letter_Country_Code Three_Letter_Country_Code  Country_Number
        0                      AF                       AFG             4.0
        1                      AL                       ALB             8.0
        2                      AQ                       ATA            10.0
        3                      DZ                       DZA            12.0
        4                      AS                       ASM            16.0
```

```
In [6]: # select only interesting cols
        df_continent = df_continent[['Continent_Name', 'Three_Letter_Country_Code']]
        # rename them
        df_continent.columns = ['Continent', 'Country Code']
        # merge two df
        df = pd.merge(df, df_continent, on='Country Code')
        df.head()
```

```
Out[6]:   Country Name Country Code  Year  CO2 Per Capita (metric tons)      Continent
        0        Aruba          ABW  1960                           NaN  North America
        1        Aruba          ABW  1961                           NaN  North America
        2        Aruba          ABW  1962                           NaN  North America
        3        Aruba          ABW  1963                           NaN  North America
        4        Aruba          ABW  1964                           NaN  North America
```

```
In [7]: df_continent.shape
```

```
Out[7]: (262, 2)
```

```
In [8]: df_continent.isnull().sum()
```

```
Out[8]: Continent       0
        Country Code    4
        dtype: int64
```

3.3 Countries population over years

This database presents population and other demographic estimates and projections from 1960 to 2050. They are disaggregated by age-group and sex and covers more than 200 economies. Here i'll keep only relevant infos for our analysis. The db come from worldbank.org

```
In [9]: df_population = pd.read_csv('input/Population-EstimatesData.csv')

        # keep only total population
        df_population = df_population[df_population['Indicator Name'] == 'Population, total']

        # keep only corresponding years and remove unecessary cols
        df_population = df_population.drop(columns=['Country Name', 'Indicator Name', 'Indicat
               '2014', '2015', '2016', '2017', '2018', '2019', '2020', '2021', '2022',
               '2023', '2024', '2025', '2026', '2027', '2028', '2029', '2030', '2031',
               '2032', '2033', '2034', '2035', '2036', '2037', '2038', '2039', '2040',
               '2041', '2042', '2043', '2044', '2045', '2046', '2047', '2048', '2049',
               '2050', 'Unnamed: 95'])
        df_population.head()
```

```
Out[9]:     Country Code          1960          1961          1962          1963  \
        166          ARB  9.249093e+07  9.504450e+07  9.768229e+07  1.004111e+08
        341          CSS  4.198307e+06  4.277802e+06  4.357746e+06  4.436804e+06
        516          CEB  9.140176e+07  9.223274e+07  9.300950e+07  9.384002e+07
        691          EAR  9.792874e+08  1.002524e+09  1.026587e+09  1.051415e+09
        866          EAS  1.040034e+09  1.043597e+09  1.058046e+09  1.083797e+09

                     1964          1965          1966          1967          1968  \
        166  1.032399e+08  1.061750e+08  1.092306e+08  1.124069e+08  1.156802e+08
        341  4.513246e+06  4.585777e+06  4.653919e+06  4.718167e+06  4.779624e+06
        516  9.471580e+07  9.544099e+07  9.614634e+07  9.704327e+07  9.788402e+07
        691  1.077037e+09  1.103433e+09  1.130587e+09  1.158571e+09  1.187274e+09
```

```
866  1.109192e+09  1.135651e+09  1.165546e+09  1.194209e+09  1.223467e+09

             1969          1970          1971          1972          1973  \
166  1.190165e+08  1.223984e+08  1.258074e+08  1.292694e+08  1.328634e+08
341  4.839881e+06  4.900059e+06  4.960647e+06  5.021359e+06  5.082049e+06
516  9.860663e+07  9.913455e+07  9.963526e+07  1.003572e+08  1.011127e+08
691  1.216766e+09  1.247053e+09  1.278138e+09  1.310016e+09  1.342709e+09
866  1.256390e+09  1.289320e+09  1.323021e+09  1.354873e+09  1.385130e+09

             1974          1975          1976          1977          1978  \
166  1.366968e+08  1.408433e+08  1.453324e+08  1.501331e+08  1.551837e+08
341  5.142246e+06  5.201705e+06  5.260062e+06  5.317542e+06  5.375393e+06
516  1.019399e+08  1.028606e+08  1.037761e+08  1.046169e+08  1.053294e+08
691  1.376073e+09  1.410094e+09  1.444720e+09  1.480010e+09  1.516216e+09
866  1.415205e+09  1.442315e+09  1.466537e+09  1.489432e+09  1.512228e+09

             1979          1980          1981          1982          1983  \
166  1.603925e+08  1.656895e+08  1.710520e+08  1.764901e+08  1.820058e+08
341  5.435143e+06  5.497756e+06  5.564200e+06  5.633661e+06  5.702754e+06
516  1.059486e+08  1.065767e+08  1.071915e+08  1.077700e+08  1.083261e+08
691  1.553704e+09  1.592674e+09  1.633180e+09  1.675079e+09  1.718098e+09
866  1.535457e+09  1.558242e+09  1.581867e+09  1.607789e+09  1.633686e+09

             1984          1985          1986          1987          1988  \
166  1.876108e+08  1.933103e+08  1.990938e+08  2.049425e+08  2.108448e+08
341  5.766957e+06  5.823242e+06  5.870023e+06  5.908886e+06  5.943661e+06
516  1.088535e+08  1.093607e+08  1.098466e+08  1.102964e+08  1.106867e+08
691  1.761829e+09  1.805996e+09  1.850487e+09  1.895290e+09  1.940220e+09
866  1.658311e+09  1.683505e+09  1.710226e+09  1.738329e+09  1.766707e+09

             1989          1990          1991          1992          1993  \
166  2.167874e+08  2.247354e+08  2.308299e+08  2.350372e+08  2.412861e+08
341  5.979907e+06  6.021614e+06  6.070204e+06  6.124265e+06  6.181538e+06
516  1.108016e+08  1.107431e+08  1.104695e+08  1.101115e+08  1.100419e+08
691  1.985084e+09  2.031828e+09  2.076398e+09  2.120567e+09  2.164508e+09
866  1.794458e+09  1.821518e+09  1.847580e+09  1.871877e+09  1.895331e+09

             1994          1995          1996          1997          1998  \
166  2.474359e+08  2.550297e+08  2.608435e+08  2.665751e+08  2.722351e+08
341  6.238576e+06  6.292827e+06  6.343683e+06  6.392040e+06  6.438587e+06
516  1.100216e+08  1.098642e+08  1.096262e+08  1.094220e+08  1.092383e+08
691  2.208444e+09  2.252579e+09  2.297015e+09  2.341634e+09  2.386185e+09
866  1.918823e+09  1.941909e+09  1.964618e+09  1.986766e+09  2.008138e+09

             1999          2000          2001          2002          2003  \
166  2.779629e+08  2.838320e+08  2.898504e+08  2.960266e+08  3.024345e+08
341  6.484510e+06  6.530691e+06  6.577216e+06  6.623792e+06  6.670276e+06
516  1.090610e+08  1.084478e+08  1.076600e+08  1.069598e+08  1.066242e+08
```

```
691  2.430487e+09  2.474601e+09  2.518353e+09  2.561813e+09  2.605067e+09
866  2.028093e+09  2.047139e+09  2.065520e+09  2.082948e+09  2.099537e+09

             2004          2005          2006          2007          2008  \
166  3.091620e+08  3.162647e+08  3.237733e+08  3.316538e+08  3.398255e+08
341  6.716373e+06  6.761932e+06  6.806838e+06  6.851221e+06  6.895315e+06
516  1.063317e+08  1.060419e+08  1.057725e+08  1.053787e+08  1.050019e+08
691  2.648272e+09  2.691528e+09  2.734860e+09  2.778276e+09  2.821797e+09
866  2.115551e+09  2.131356e+09  2.147021e+09  2.162088e+09  2.177418e+09

             2009          2010          2011
166  3.481451e+08  3.565089e+08  3.648959e+08
341  6.939534e+06  6.984096e+06  7.029022e+06
516  1.048005e+08  1.044214e+08  1.041740e+08
691  2.865440e+09  2.909411e+09  2.953406e+09
866  2.192343e+09  2.207155e+09  2.221935e+09
```

```
In [10]: df_population.shape
```

```
Out[10]: (259, 53)
```

There are many missing value here, so a little cleaning is needed first

```
In [11]: #df_population.isnull().sum()
         #df_population[df_population['1960'].isnull()]
```

```
In [12]: df_population = df_population.drop(index=5066)

         cols_with_nan = ['1960', '1961', '1962', '1963', '1964',
             '1965', '1966', '1967', '1968', '1969', '1970', '1971', '1972', '1973', '1974', '1
             '1978', '1979', '1980', '1981', '1982', '1983', '1984','1985', '1986', '1987', '19
         idx = [36916, 44791]

         df_population.loc[idx, cols_with_nan] = df_population.loc[idx, '1990']
```

```
In [13]: df_population.loc[37616] = df_population.loc[37616].fillna(df_population.loc[37616, '1
```

```
In [14]: df_population = df_population.melt(id_vars=["Country Code"],
                     #value_vars :  Column(s) to unpivot. If not specified, uses all columns th
                     value_name="Population")

         # Create a unique key for future join
         #df_population['key'] = df_population['Country Code'] + str(df_population['variable']
         #df_population.head()
```

```
In [15]: df_population = df_population.rename(index=str, columns={"variable": "Year"})
         df_population.Year = df_population.Year.astype('int')
         df_population.head()
```

```
Out[15]:   Country Code  Year    Population
         0          ARB  1960  9.249093e+07
         1          CSS  1960  4.198307e+06
         2          CEB  1960  9.140176e+07
         3          EAR  1960  9.792874e+08
         4          EAS  1960  1.040034e+09
```

Aggregation of all datasets

```
In [16]: df = pd.merge(df, df_population, on=['Country Code', 'Year'])
         df.head()
```

```
Out[16]:   Country Name Country Code  Year  CO2 Per Capita (metric tons)  \
         0        Aruba          ABW  1960                           NaN
         1        Aruba          ABW  1961                           NaN
         2        Aruba          ABW  1962                           NaN
         3        Aruba          ABW  1963                           NaN
         4        Aruba          ABW  1964                           NaN

                Continent  Population
         0  North America     54211.0
         1  North America     55438.0
         2  North America     56225.0
         3  North America     56695.0
         4  North America     57032.0
```

```
In [17]: # let's check values
         #temp[temp['Country Name'] == 'France']
```

4 First insights / data cleaning

Number of lines, types of values, irrelevant or weird values...

```
In [18]: df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 11388 entries, 0 to 11387
Data columns (total 6 columns):
Country Name                    11388 non-null object
Country Code                    11388 non-null object
Year                            11388 non-null int64
CO2 Per Capita (metric tons)    9233 non-null float64
Continent                       11388 non-null object
Population                      11385 non-null float64
dtypes: float64(2), int64(1), object(3)
memory usage: 622.8+ KB
```

```
In [19]: df.shape
```

```
Out[19]: (11388, 6)
```

```
In [20]: df.duplicated().sum()
```

```
Out[20]: 0
```

```
In [21]: df.loc[[2650, 2651, 10502, 10503]]
```

```
Out[21]:       Country Name Country Code  Year  CO2 Per Capita (metric tons) Continent  \
         2650        Cyprus          CYP  2011                      6.735376    Europe
         2651        Cyprus          CYP  2011                      6.735376      Asia
         10502       Turkey          TUR  2011                      4.383105    Europe
         10503       Turkey          TUR  2011                      4.383105      Asia

                 Population
         2650     1124835.0
         2651     1124835.0
         10502   73409455.0
         10503   73409455.0
```

```
In [22]: df = df.drop(index=[2651, 10503])
         df.shape
```

```
Out[22]: (11386, 6)
```

```
In [23]: df.isnull().sum()
```

```
Out[23]: Country Name                       0
         Country Code                       0
         Year                               0
         CO2 Per Capita (metric tons)    2155
         Continent                          0
         Population                         3
         dtype: int64
```

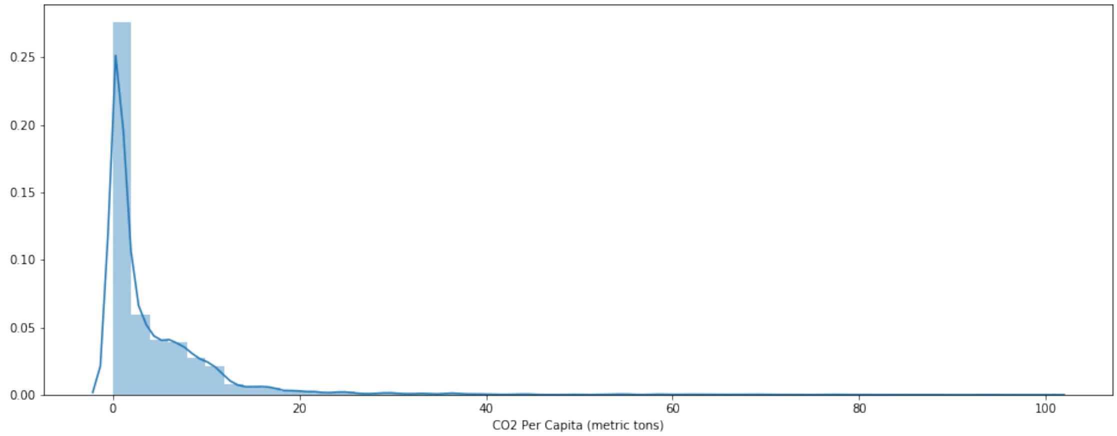
```
In [24]: # Nb of different countries
         df['Country Name'].nunique()
```

```
Out[24]: 212
```

```
In [25]: # Nb of years
         df['Year'].nunique()
```

```
Out[25]: 52
```

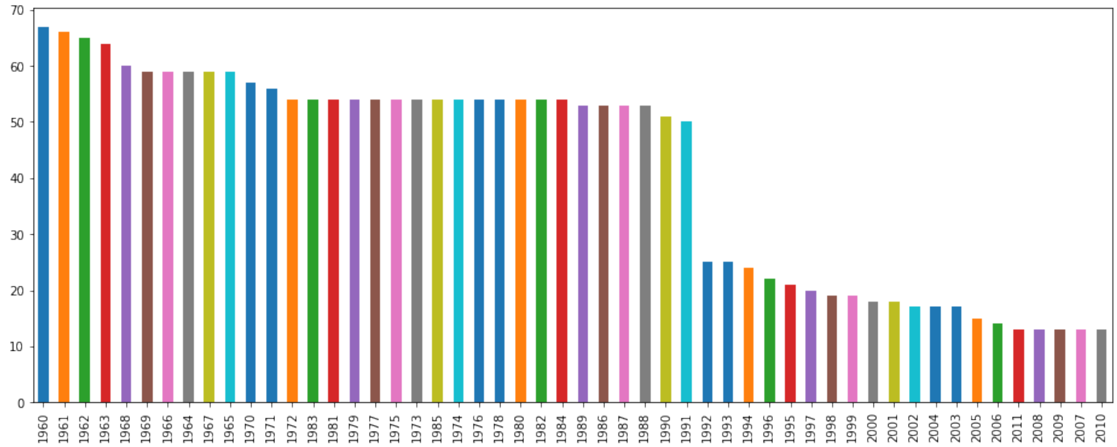
```
In [26]: plt.figure(figsize=(16, 6))
         sns.distplot(df['CO2 Per Capita (metric tons)'].dropna())
         # same thing but longer
         #sns.distplot(df[df['CO2 Per Capita (metric tons)'].notnull()]['CO2 Per Capita (metri
         plt.show()
```



- At first glance, there are many years/countries with little emissions while very few countries seem to produce a lot of CO2... Let's check this later with other plots.
- There is not any abnormal negative values. Now, where are the missing values i.e in which countries are there only missing values ? What is the proportion of Nan per country...

```
In [27]: df[df['CO2 Per Capita (metric tons)'].isna()]['Year'].value_counts().plot(kind='bar',
```

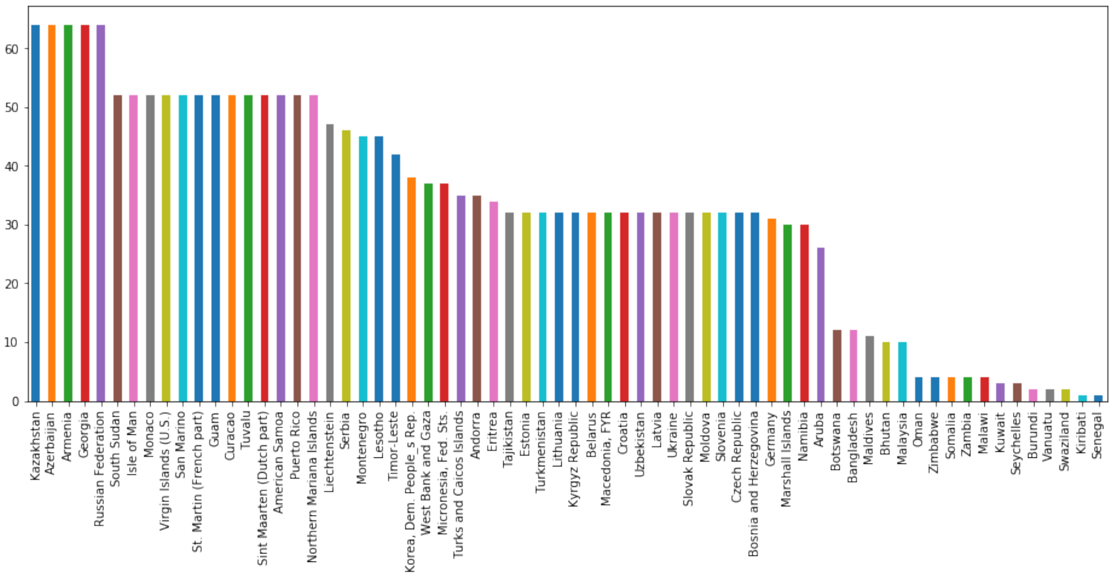
```
Out[27]: <matplotlib.axes._subplots.AxesSubplot at 0x7fb7fe888e10>
```



It seems that emissions were not fully recorded before the 90's... Let's dig a little deeper.

```
In [28]: # Countries by number of missing values - there are 52 years in the record
         df[df['CO2 Per Capita (metric tons)'].isna()]['Country Name'].value_counts().plot(kin
```

```
Out[28]: <matplotlib.axes._subplots.AxesSubplot at 0x7fb7fe7576a0>
```



On the bar plot above, one can see that * exept Ukraine, Russia, Croatia, Germany * countries with at least 20 missing values for 52 years of record are not big countries.

Therefore, they can be omitted in our analysis.

```
In [29]: # retrieve countries with a least 20 years of missing values
         temp_df = df[df['CO2 Per Capita (metric tons)'].isna()]['Country Name'].value_counts(
         countries_with_na = pd.DataFrame(temp_df).index
         countries_with_na
```

```
Out[29]: Index(['Kazakhstan', 'Azerbaijan', 'Armenia', 'Georgia', 'Russian Federation',
                'South Sudan', 'Isle of Man', 'Monaco', 'Virgin Islands (U.S.)',
                'San Marino', 'St. Martin (French part)', 'Guam', 'Curacao', 'Tuvalu',
                'Sint Maarten (Dutch part)', 'American Samoa', 'Puerto Rico',
                'Northern Mariana Islands', 'Liechtenstein', 'Serbia', 'Montenegro',
                'Lesotho', 'Timor-Leste', 'Korea, Dem. People_s Rep.',
                'West Bank and Gaza', 'Micronesia, Fed. Sts.',
                'Turks and Caicos Islands', 'Andorra', 'Eritrea', 'Tajikistan',
                'Estonia', 'Turkmenistan', 'Lithuania', 'Kyrgyz Republic', 'Belarus',
                'Macedonia, FYR', 'Croatia', 'Uzbekistan', 'Latvia', 'Ukraine',
                'Slovak Republic', 'Moldova', 'Slovenia', 'Czech Republic',
                'Bosnia and Herzegovina', 'Germany', 'Marshall Islands', 'Namibia',
                'Aruba', 'Botswana', 'Bangladesh', 'Maldives', 'Bhutan', 'Malaysia',
                'Oman', 'Zimbabwe', 'Somalia', 'Zambia', 'Malawi', 'Kuwait',
                'Seychelles', 'Burundi', 'Vanuatu', 'Swaziland', 'Kiribati', 'Senegal'],
               dtype='object')
```

```
In [30]: # removing countries with more than 20 missing values
         df = df[~df['Country Name'].isin(countries_with_na)]
         df.shape
```

```
Out[30]: (7694, 6)
```

```
In [31]: # filling remaining missing values with an interpolation
         df = df.interpolate()
```

```
In [32]: # check if there isn't any Nan anymore
         df.isnull().sum()
```

```
Out[32]: Country Name                    0
         Country Code                    0
         Year                            0
         CO2 Per Capita (metric tons)    0
         Continent                       0
         Population                      0
         dtype: int64
```

---

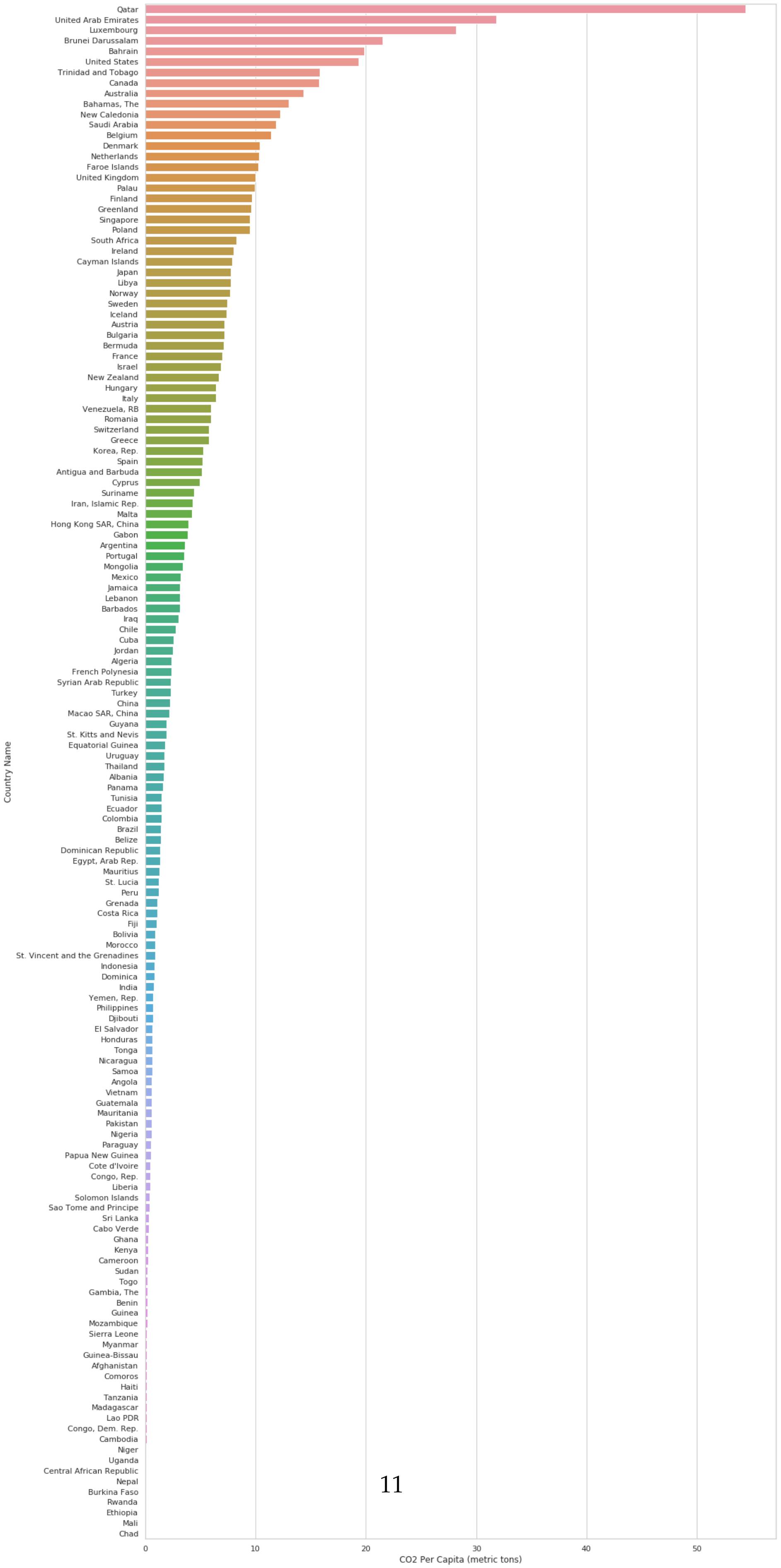
5 Analysis per capita

5.1 Which countries have the highest emissions historically ?

```
In [33]: df_hist = pd.DataFrame(df.groupby(by='Country Name', as_index=False)['CO2 Per Capita
         df_hist = df_hist.sort_values(by=['CO2 Per Capita (metric tons)'], ascending=False)
         df_hist.head()
```

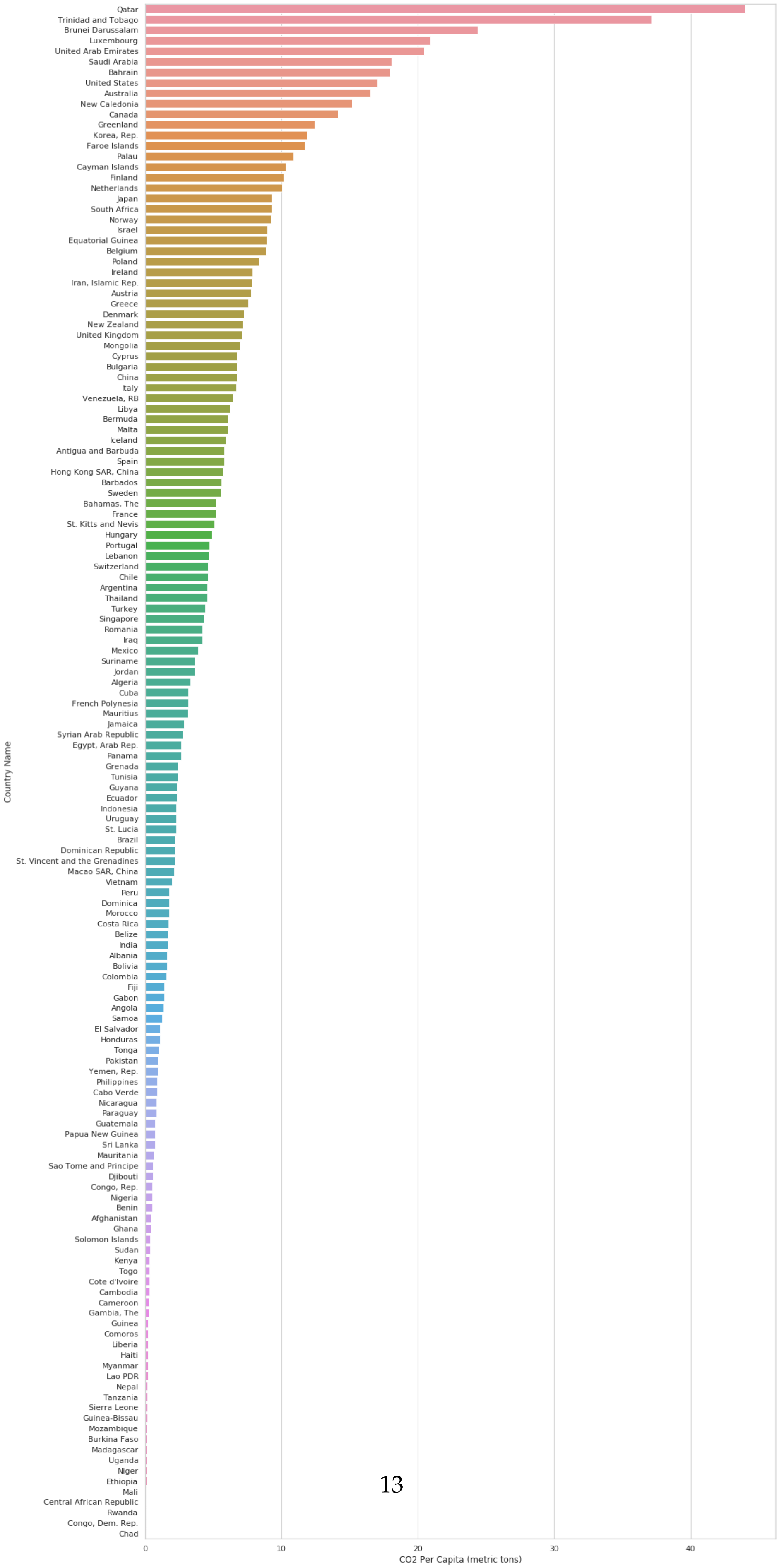
```
Out[33]:              Country Name  CO2 Per Capita (metric tons)
         111                 Qatar                     54.423341
         139  United Arab Emirates                     31.844877
         82             Luxembourg                     28.196509
         17      Brunei Darussalam                     21.497854
         9                 Bahrain                     19.867874
```

```
In [34]: sns.set(style="whitegrid")
         plt.figure(figsize=(16, 40))
         sns.barplot(x="CO2 Per Capita (metric tons)",
                     y="Country Name",
                     data=df_hist)
         plt.show()
```


Qatar
United Arab Emirates
Luxembourg
Brunei Darussalam
Bahrain
United States
Trinidad and Tobago
Canada
Australia
Bahamas, The
New Caledonia
Saudi Arabia
Belgium
Denmark
Netherlands
Faroe Islands
United Kingdom
Palau
Finland
Greenland
Singapore
Poland
South Africa
Ireland
Cayman Islands
Japan
Libya
Norway
Sweden
Iceland
Austria
Bulgaria
Bermuda
France
Israel
New Zealand
Hungary
Italy
Venezuela, RB
Romania
Switzerland
Greece
Korea, Rep.
Spain
Antigua and Barbuda
Cyprus
Suriname
Iran, Islamic Rep.
Malta
Hong Kong SAR, China
Gabon
Argentina
Portugal
Mongolia
Mexico
Jamaica
Lebanon
Barbados
Iraq
Chile
Cuba
Jordan
Algeria
French Polynesia
Syrian Arab Republic
Turkey
China
Macao SAR, China
Guyana
St. Kitts and Nevis
Equatorial Guinea
Uruguay
Thailand
Albania
Panama
Tunisia
Ecuador
Colombia
Brazil
Belize
Dominican Republic
Egypt, Arab Rep.
Mauritius
St. Lucia
Peru
Grenada
Costa Rica
Fiji
Bolivia
Morocco
St. Vincent and the Grenadines
Indonesia
Dominica
India
Yemen, Rep.
Philippines
Djibouti
El Salvador
Honduras
Tonga
Nicaragua
Samoa
Angola
Vietnam
Guatemala
Mauritania
Pakistan
Nigeria
Paraguay
Papua New Guinea
Cote d'Ivoire
Congo, Rep.
Liberia
Solomon Islands
Sao Tome and Principe
Sri Lanka
Cabo Verde
Ghana
Kenya
Cameroon
Sudan
Togo
Gambia, The
Benin
Guinea
Mozambique
Sierra Leone
Myanmar
Guinea-Bissau
Afghanistan
Comoros
Haiti
Tanzania
Madagascar
Lao PDR
Congo, Dem. Rep.
Cambodia
Niger
Uganda
Central African Republic
Nepal
Burkina Faso
Rwanda
Ethiopia
Mali
Chad
Country Name
0
10
20
30
40
50
CO2 Per Capita (metric tons)

5.2 Which countries have the highest emissions lately ?

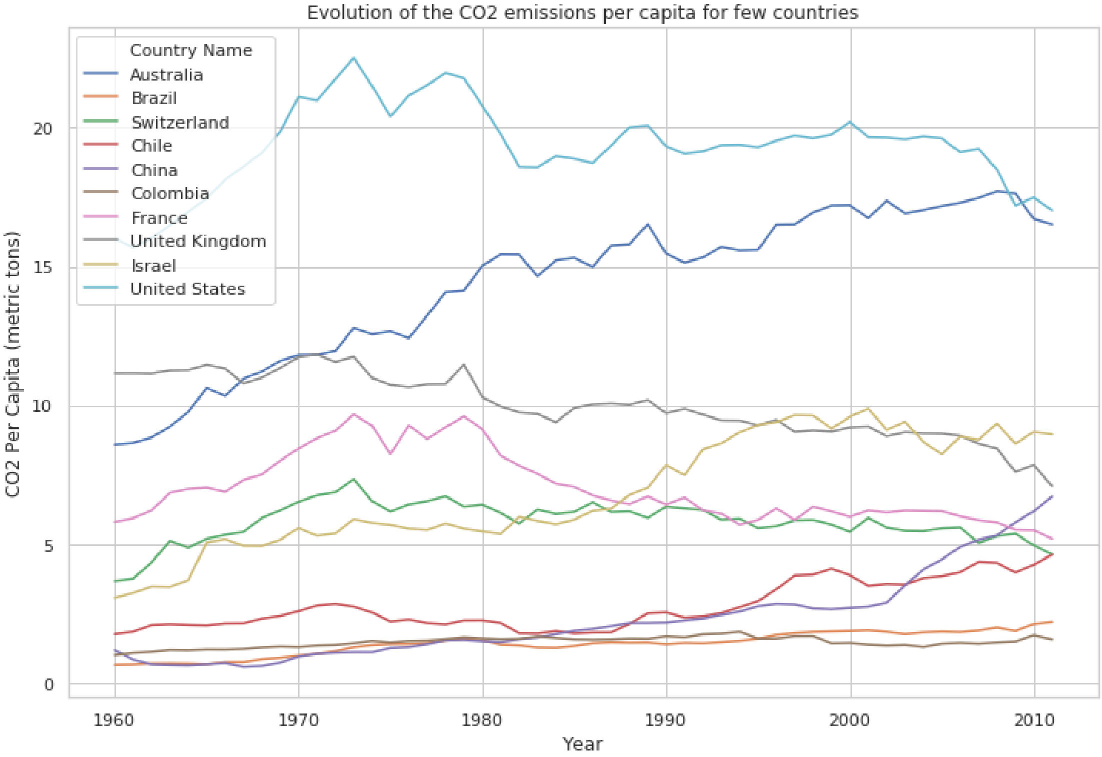
```
In [35]: # for instance in year 2011
         df_lately = df[df.Year == 2011]
         df_lately = df_lately.sort_values(by=['CO2 Per Capita (metric tons)'], ascending=Fals
         plt.figure(figsize=(16, 40))
         ax = sns.barplot(x="CO2 Per Capita (metric tons)", y="Country Name", data=df_lately)
```


Qatar
Trinidad and Tobago
Brunei Darussalam
Luxembourg
United Arab Emirates
Saudi Arabia
Bahrain
United States
Australia
New Caledonia
Canada
Greenland
Korea, Rep.
Faroe Islands
Palau
Cayman Islands
Finland
Netherlands
Japan
South Africa
Norway
Israel
Equatorial Guinea
Belgium
Poland
Ireland
Iran, Islamic Rep.
Austria
Greece
Denmark
New Zealand
United Kingdom
Mongolia
Cyprus
Bulgaria
China
Italy
Venezuela, RB
Libya
Bermuda
Malta
Iceland
Antigua and Barbuda
Spain
Hong Kong SAR, China
Barbados
Sweden
Bahamas, The
France
St. Kitts and Nevis
Hungary
Portugal
Lebanon
Switzerland
Chile
Argentina
Thailand
Turkey
Singapore
Romania
Iraq
Mexico
Suriname
Jordan
Algeria
Cuba
French Polynesia
Mauritius
Jamaica
Syrian Arab Republic
Egypt, Arab Rep.
Panama
Grenada
Tunisia
Guyana
Ecuador
Indonesia
Uruguay
St. Lucia
Brazil
Dominican Republic
St. Vincent and the Grenadines
Macao SAR, China
Vietnam
Peru
Dominica
Morocco
Costa Rica
Belize
India
Albania
Bolivia
Colombia
Fiji
Gabon
Angola
Samoa
El Salvador
Honduras
Tonga
Pakistan
Yemen, Rep.
Philippines
Cabo Verde
Nicaragua
Paraguay
Guatemala
Papua New Guinea
Sri Lanka
Mauritania
Sao Tome and Principe
Djibouti
Congo, Rep.
Nigeria
Benin
Afghanistan
Ghana
Solomon Islands
Sudan
Kenya
Togo
Cote d'Ivoire
Cambodia
Cameroon
Gambia, The
Guinea
Comoros
Liberia
Haiti
Myanmar
Lao PDR
Nepal
Tanzania
Sierra Leone
Guinea-Bissau
Mozambique
Burkina Faso
Madagascar
Uganda
Niger
Ethiopia
Mali
Central African Republic
Rwanda
Congo, Dem. Rep.
Chad
Country Name
0
10
20
30
40
CO2 Per Capita (metric tons)

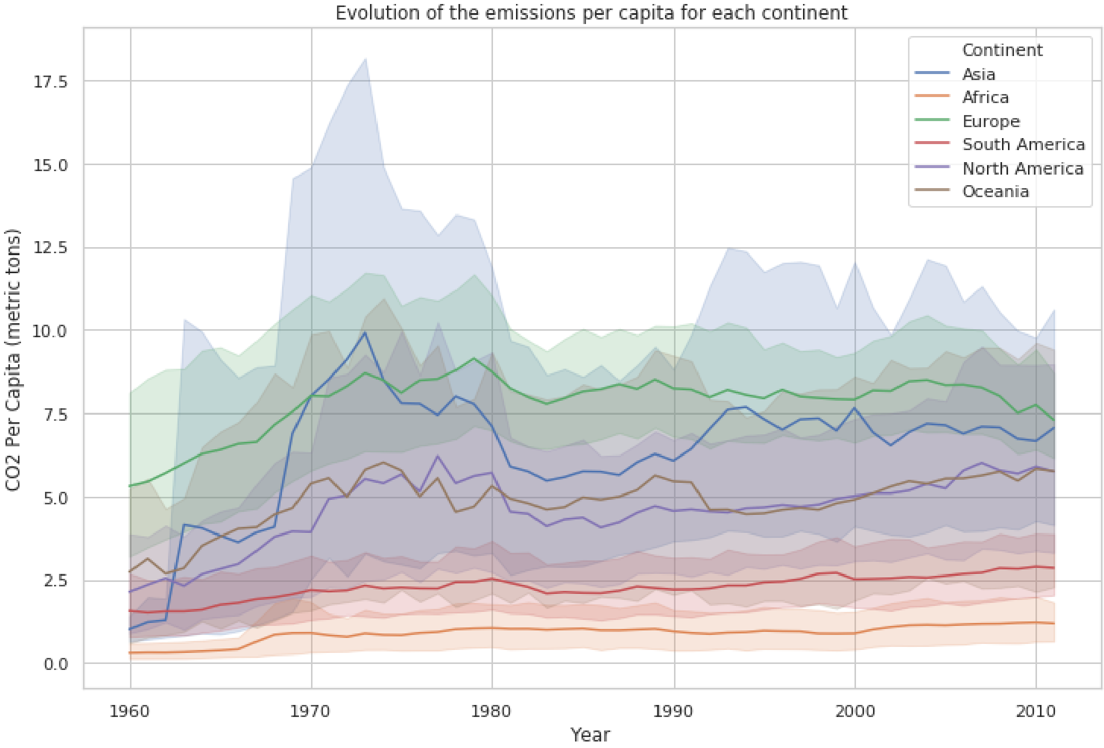
5.3 Are the annual emissions decreasing or increasing ?

Let's select few countries to show the evolution

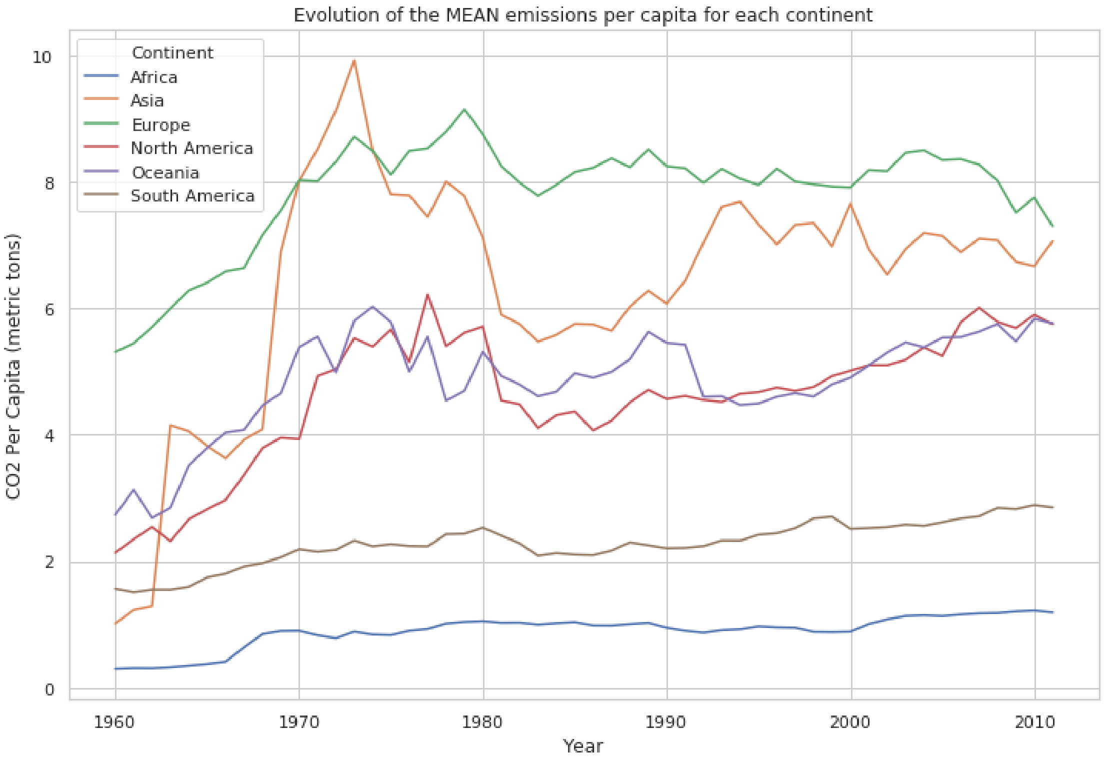
```
In [36]: selected_countries = ['France', 'Israel', 'Switzerland', 'Chile', 'China',
                               'Colombia', 'United Kingdom', 'United States', 'Brazil', 'Austra
         plt.figure(figsize=(12, 8))
         sns.lineplot(x="Year",
                      y="CO2 Per Capita (metric tons)",
                      hue="Country Name",
                      data=df[df["Country Name"].isin(selected_countries)])
         plt.title('Evolution of the CO2 emissions per capita for few countries')
         plt.show()
```



```
In [37]: plt.figure(figsize=(12, 8))
         plt.title('Evolution of the emissions per capita for each continent')

         sns.lineplot(x="Year",
                      y="CO2 Per Capita (metric tons)",
                      hue="Continent",
                data=df)

plt.show()
```



```
In [38]: df_mean = pd.DataFrame(df.groupby(by=['Continent', 'Year'], as_index=False)['CO2 Per C

         plt.figure(figsize=(12, 8))
         plt.title('Evolution of the MEAN emissions per capita for each continent')

         sns.lineplot(x="Year",
                      y="CO2 Per Capita (metric tons)",
                      hue="Continent",
                      data=df_mean)

         plt.show()
```



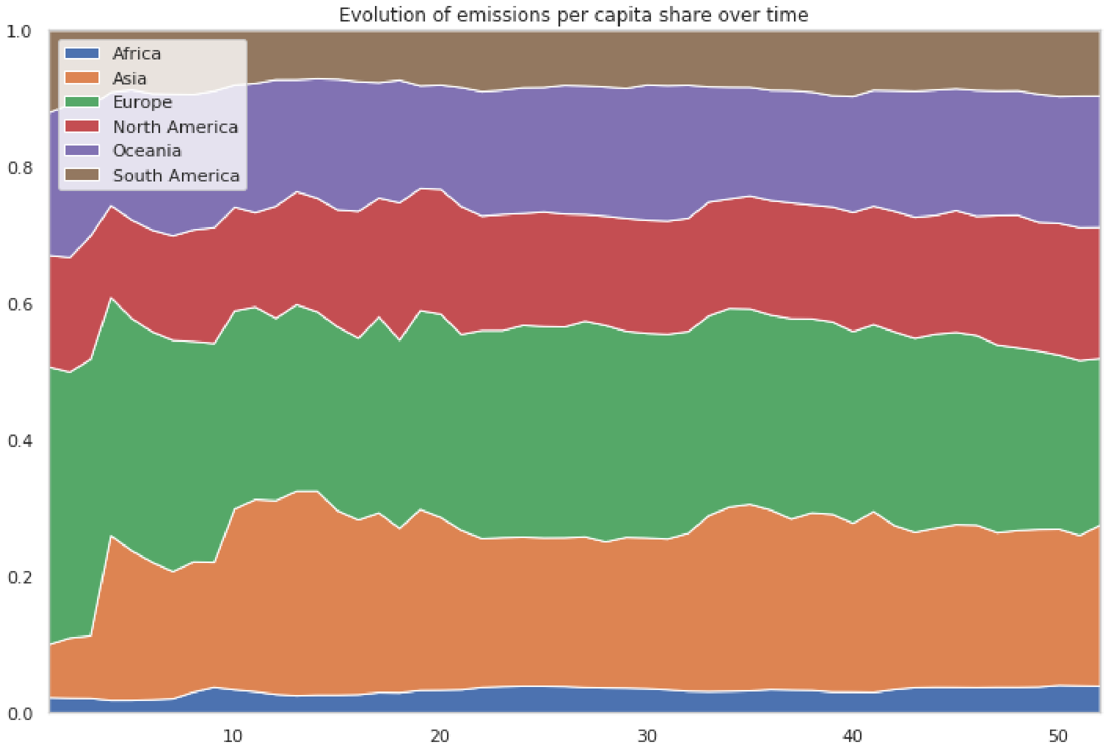
```
In [39]: df_mean.head()

Out[39]:   Continent  Year  CO2 Per Capita (metric tons)
         0    Africa  1960                      0.298993
         1    Africa  1961                      0.310182
         2    Africa  1962                      0.308247
         3    Africa  1963                      0.323735
         4    Africa  1964                      0.348756
```

5.4 Evolution of emission share

```
In [40]: df_mean_pivot = pd.pivot_table(df_mean, index='Year', values='CO2 Per Capita (metric
         df_mean_pivot.head()

Out[40]: Continent    Africa      Asia    Europe  North America   Oceania  \
         Year
         1960       0.298993  1.015958  5.310022       2.134758  2.734202
         1961       0.310182  1.230886  5.445797       2.348035  3.131762
         1962       0.308247  1.290272  5.703817       2.543537  2.683807
         1963       0.323735  4.151895  5.997686       2.315408  2.848258
         1964       0.348756  4.054674  6.281629       2.664622  3.515654

         Continent  South America
```

```
Year
1960          1.563707
1961          1.508886
1962          1.549366
1963          1.549151
1964          1.595202
```

```
In [41]: df_mean_perc = df_mean_pivot.divide(df_mean_pivot.sum(axis=1), axis=0)

         plt.figure(figsize=(12, 8))

         # Make the plot
         plt.stackplot(range(1,53),
                       df_mean_perc['Africa'],
                       df_mean_perc["Asia"],
                       df_mean_perc["Europe"],
                       df_mean_perc["North America"],
                       df_mean_perc["Oceania"],
                       df_mean_perc["South America"],
                       labels=['Africa','Asia','Europe','North America','Oceania','South Ameri

         # Formatting the plot
         plt.legend(loc='upper left')
         plt.margins(0,0)
         plt.title('Evolution of emissions per capita share over time')
         plt.show()
```



5.5 World map

```
In [42]: # create a map
         m = folium.Map()
```

```
In [43]: countries_list = list(df["Country Name"].unique())

         # removing names that are not recognized by the API
         rem = ['Congo, Dem. Rep.', 'Congo, Rep.', 'Egypt, Arab Rep.', 'French Polynesia', 'Ho
               'Iran, Islamic Rep.', 'Korea, Rep.', 'Lao PDR', 'Macao SAR, China', 'New Caledo
                'Venezuela, RB', 'Yemen, Rep.']

         for c in rem:
             countries_list.remove(c)

         countries_list.sort()
         countries_list
```

```
Out[43]: ['Afghanistan',
          'Albania',
          'Algeria',
          'Angola',
          'Antigua and Barbuda',
          'Argentina',
          'Australia',
          'Austria',
          'Bahamas, The',
          'Bahrain',
          'Barbados',
          'Belgium',
          'Belize',
          'Benin',
          'Bermuda',
          'Bolivia',
          'Brazil',
          'Brunei Darussalam',
          'Bulgaria',
          'Burkina Faso',
          'Cabo Verde',
          'Cambodia',
          'Cameroon',
          'Canada',
          'Cayman Islands',
          'Central African Republic',
          'Chad',
          'Chile',
          'China',
          'Colombia',
          'Comoros',
          'Costa Rica',
          "Cote d'Ivoire",
          'Cuba',
          'Cyprus',
          'Denmark',
          'Djibouti',
          'Dominica',
          'Dominican Republic',
          'Ecuador',
          'El Salvador',
          'Equatorial Guinea',
          'Ethiopia',
          'Faroe Islands',
          'Fiji',
          'Finland',
          'France',
          'Gabon',
          'Gambia, The',
          'Ghana',
          'Greece',
          'Greenland',
          'Grenada',
          'Guatemala',
          'Guinea',
          'Guinea-Bissau',
          'Guyana',
          'Haiti',
          'Honduras',
          'Hungary',
          'Iceland',
          'India',
          'Indonesia',
          'Iraq',
          'Ireland',
          'Israel',
          'Italy',
          'Jamaica',
          'Japan',
          'Jordan',
          'Kenya',
          'Lebanon',
          'Liberia',
          'Libya',
          'Luxembourg',
          'Madagascar',
          'Mali',
          'Malta',
          'Mauritania',
          'Mauritius',
          'Mexico',
          'Mongolia',
          'Morocco',
          'Mozambique',
          'Myanmar',
          'Nepal',
          'Netherlands',
          'New Zealand',
          'Nicaragua',
          'Niger',
          'Nigeria',
          'Norway',
          'Pakistan',
          'Palau',
          'Panama',
          'Papua New Guinea',
          'Paraguay',
          'Peru',
          'Poland',
          'Portugal',
          'Qatar',
          'Romania',
          'Rwanda',
          'Samoa',
          'Sao Tome and Principe',
          'Saudi Arabia',
          'Sierra Leone',
          'Singapore',
          'Solomon Islands',
          'South Africa',
          'Spain',
          'Sri Lanka',
          'St. Kitts and Nevis',
          'St. Lucia',
          'St. Vincent and the Grenadines',
          'Sudan',
          'Suriname',
          'Sweden',
          'Switzerland',
          'Syrian Arab Republic',
          'Tanzania',
          'Thailand',
          'Togo',
          'Tonga',
          'Trinidad and Tobago',
          'Tunisia',
          'Turkey',
          'Uganda',
          'United Arab Emirates',
          'United Kingdom',
          'United States',
          'Uruguay',
          'Vietnam']
```

```
In [44]: def get_boundingbox_country(country, output_as='boundingbox'):
             """
             get the bounding box of a country in EPSG4326 given a country name

             Parameters
             ----------
             country : str
                 name of the country in english and lowercase
             output_as : 'str
                 chose from 'boundingbox' or 'center'.
                  - 'boundingbox' for [latmin, latmax, lonmin, lonmax]
                  - 'center' for [latcenter, loncenter]

             Returns
             -------
             output : list
                 list with coordinates as str
             """
             # create url
             url = '{0}{1}{2}'.format('http://nominatim.openstreetmap.org/search?country=',
                                      country,
                                      '&format=json&polygon=0')
             response = requests.get(url).json()[0]

             # parse response to list
             if output_as == 'boundingbox':
                 lst = response[output_as]
                 output = [float(i) for i in lst]
             if output_as == 'center':
                 lst = [response.get(key) for key in ['lat','lon']]
                 output = [float(i) for i in lst]
             return output

         # Example
         print("Coordinates of France are long={} and lat={}".format(
                     get_boundingbox_country("El Salvador", output_as="center")[0],
                     get_boundingbox_country("El Salvador", output_as="center")[1]))
```

```
Coordinates of France are long=13.8000382 and lat=-88.9140683
```

```
In [45]: df_lately[df_lately['Country Name'] == 'Turkey']['CO2 Per Capita (metric tons)']

Out[45]: 10502    4.383105
         Name: CO2 Per Capita (metric tons), dtype: float64
```

```
In [46]: for country in countries_list:
             resp = get_boundingbox_country(country, output_as="center")
             long, lat = resp[0], resp[1]
             emission = float(df_lately[df_lately['Country Name'] == country]['CO2 Per Capita
             folium.Circle(
                         location=[long, lat],
                         popup=country,
                         radius=100 * emission
                         ).add_to(m)
```

```
In [47]: m

Out[47]: <folium.folium.Map at 0x7fb7fe5182e8>
```

6 Analysis per whole country emission

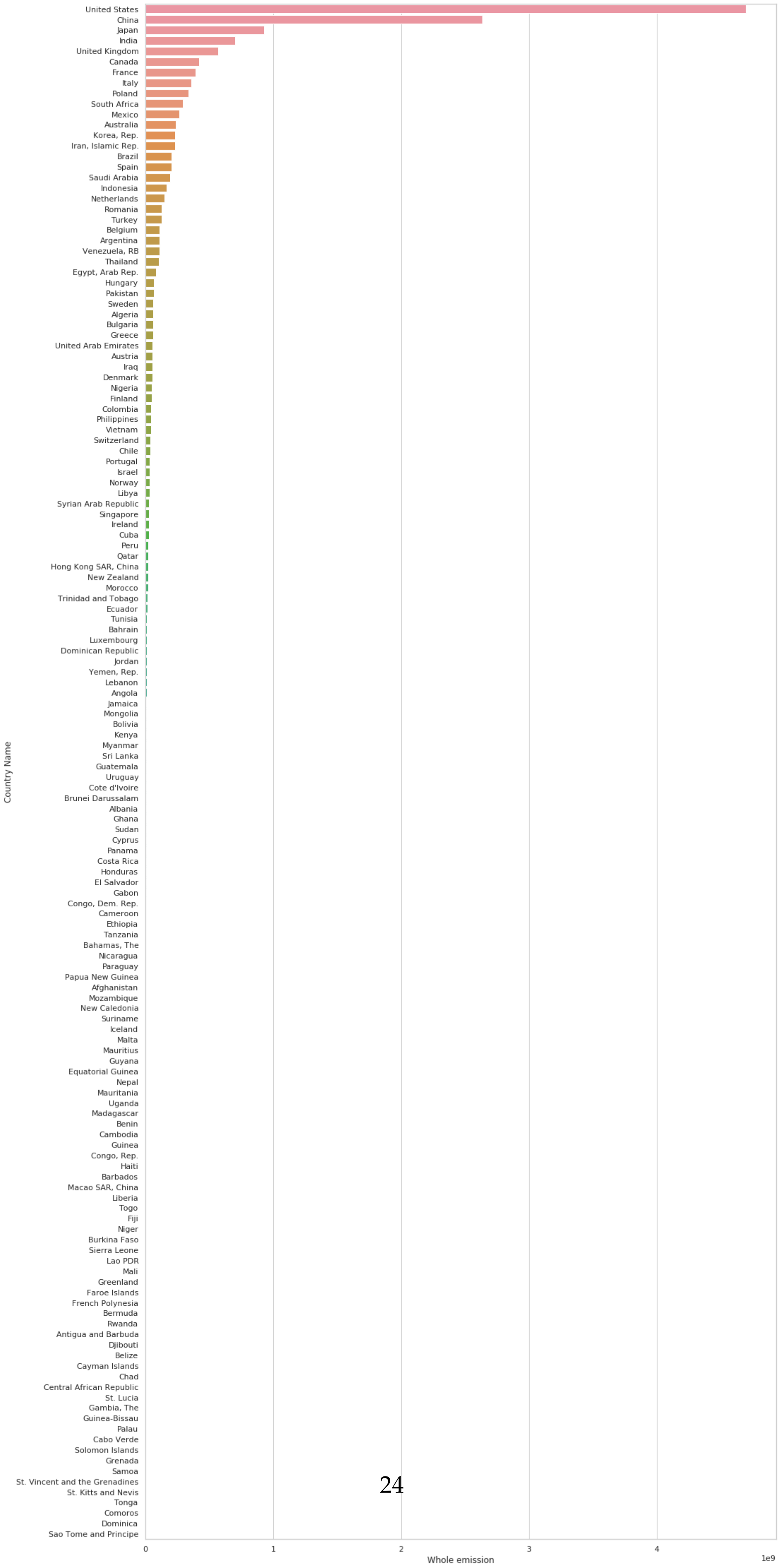
6.1 Which countries have the highest emissions historically ?

```
In [48]: df['Whole emission'] = df['CO2 Per Capita (metric tons)'] * df['Population']
         df.head()

Out[48]:    Country Name Country Code  Year  CO2 Per Capita (metric tons) Continent  \
         52  Afghanistan          AFG  1960                      0.046068      Asia
         53  Afghanistan          AFG  1961                      0.053615      Asia
         54  Afghanistan          AFG  1962                      0.073781      Asia
         55  Afghanistan          AFG  1963                      0.074251      Asia
         56  Afghanistan          AFG  1964                      0.086317      Asia

             Population  Whole emission
         52   8996351.0   414442.773324
         53   9166764.0   491475.529354
         54   9345868.0   689550.645811
         55   9533954.0   707909.126949
         56   9731361.0   839977.440205
```

```
In [49]: df_hist = pd.DataFrame(df.groupby(by='Country Name', as_index=False)['Whole emission'
         df_hist = df_hist.sort_values(by=['Whole emission'], ascending=False)
         df_hist.head()

Out[49]:        Country Name  Whole emission
         141   United States    4.699988e+09
```

```
28              China    2.639401e+09
74              Japan    9.278755e+08
66              India    7.040976e+08
140  United Kingdom    5.702256e+08
```

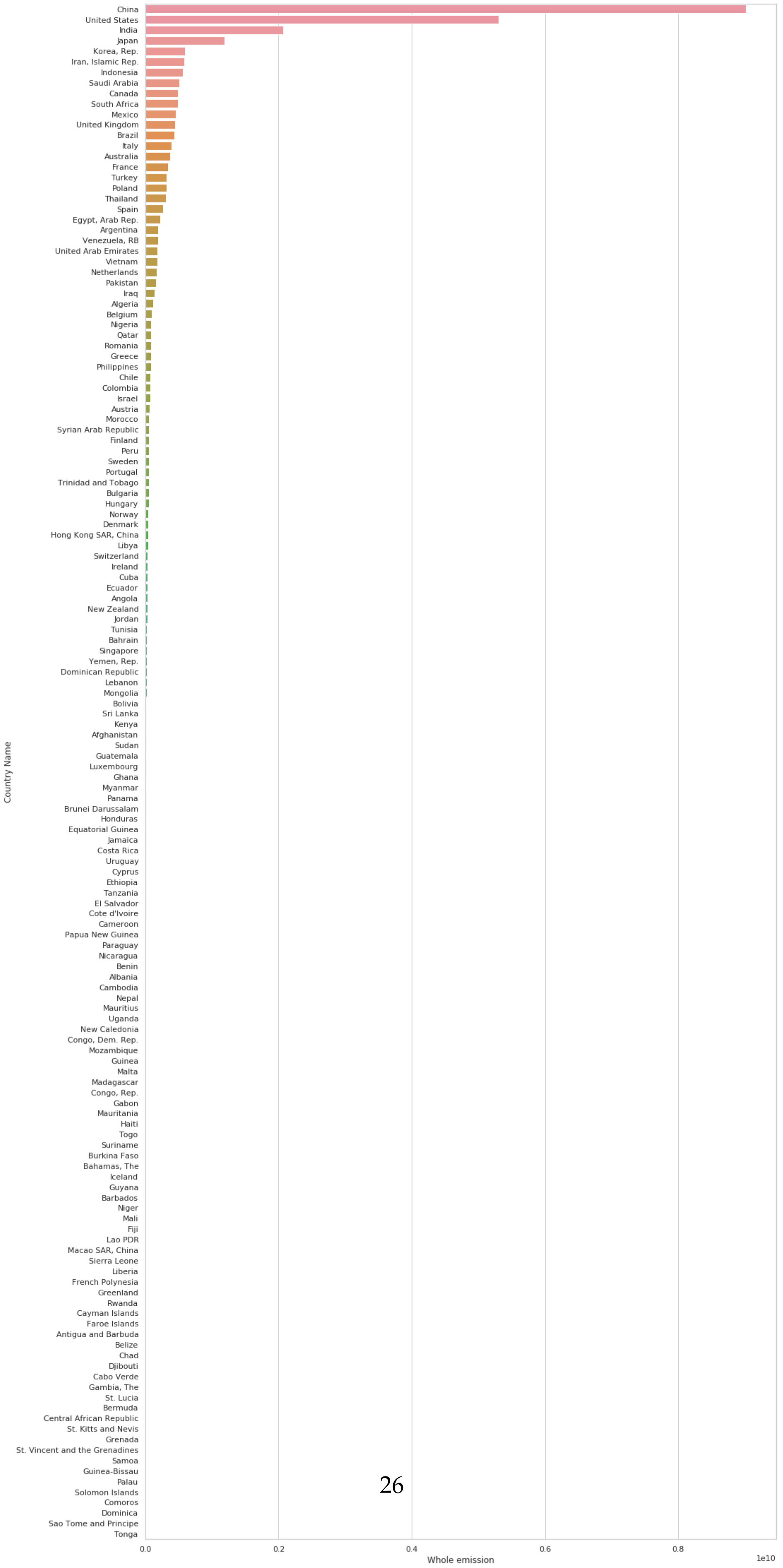
```
In [50]: sns.set(style="whitegrid")
         plt.figure(figsize=(16, 40))
         sns.barplot(x="Whole emission",
                     y="Country Name",
                     data=df_hist)
         plt.show()
```



United States
China
Japan
India
United Kingdom
Canada
France
Italy
Poland
South Africa
Mexico
Australia
Korea, Rep.
Iran, Islamic Rep.
Brazil
Spain
Saudi Arabia
Indonesia
Netherlands
Romania
Turkey
Belgium
Argentina
Venezuela, RB
Thailand
Egypt, Arab Rep.
Hungary
Pakistan
Sweden
Algeria
Bulgaria
Greece
United Arab Emirates
Austria
Iraq
Denmark
Nigeria
Finland
Colombia
Philippines
Vietnam
Switzerland
Chile
Portugal
Israel
Norway
Libya
Syrian Arab Republic
Singapore
Ireland
Cuba
Peru
Qatar
Hong Kong SAR, China
New Zealand
Morocco
Trinidad and Tobago
Ecuador
Tunisia
Bahrain
Luxembourg
Dominican Republic
Jordan
Yemen, Rep.
Lebanon
Angola
Jamaica
Mongolia
Bolivia
Kenya
Myanmar
Sri Lanka
Guatemala
Uruguay
Cote d'Ivoire
Brunei Darussalam
Albania
Ghana
Sudan
Cyprus
Panama
Costa Rica
Honduras
El Salvador
Gabon
Congo, Dem. Rep.
Cameroon
Ethiopia
Tanzania
Bahamas, The
Nicaragua
Paraguay
Papua New Guinea
Afghanistan
Mozambique
New Caledonia
Suriname
Iceland
Malta
Mauritius
Guyana
Equatorial Guinea
Nepal
Mauritania
Uganda
Madagascar
Benin
Cambodia
Guinea
Congo, Rep.
Haiti
Barbados
Macao SAR, China
Liberia
Togo
Fiji
Niger
Burkina Faso
Sierra Leone
Lao PDR
Mali
Greenland
Faroe Islands
French Polynesia
Bermuda
Rwanda
Antigua and Barbuda
Djibouti
Belize
Cayman Islands
Chad
Central African Republic
St. Lucia
Gambia, The
Guinea-Bissau
Palau
Cabo Verde
Solomon Islands
Grenada
Samoa
St. Vincent and the Grenadines
St. Kitts and Nevis
Tonga
Comoros
Dominica
Sao Tome and Principe
Country Name
0
1
2
3
4
1e9
Whole emission

6.2 Which countries have the highest emissions lately ?

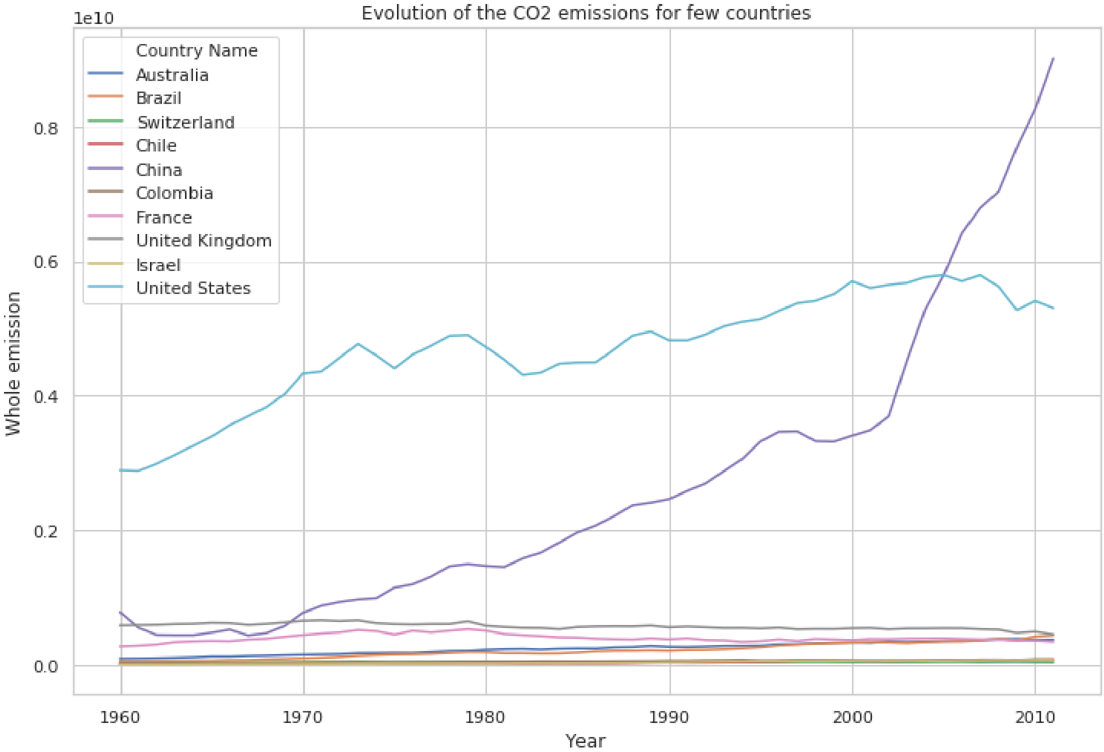
```
In [51]: # for instance in year 2011
         df_lately = df[df.Year == 2011]
         df_lately = df_lately.sort_values(by=['Whole emission'], ascending=False)
         plt.figure(figsize=(16, 40))
         sns.barplot(x='Whole emission', y="Country Name", data=df_lately)
         plt.show()
```


China
United States
India
Japan
Korea, Rep.
Iran, Islamic Rep.
Indonesia
Saudi Arabia
Canada
South Africa
Mexico
United Kingdom
Brazil
Italy
Australia
France
Turkey
Poland
Thailand
Spain
Egypt, Arab Rep.
Argentina
Venezuela, RB
United Arab Emirates
Vietnam
Netherlands
Pakistan
Iraq
Algeria
Belgium
Nigeria
Qatar
Romania
Greece
Philippines
Chile
Colombia
Israel
Austria
Morocco
Syrian Arab Republic
Finland
Peru
Sweden
Portugal
Trinidad and Tobago
Bulgaria
Hungary
Norway
Denmark
Hong Kong SAR, China
Libya
Switzerland
Ireland
Cuba
Ecuador
Angola
New Zealand
Jordan
Tunisia
Bahrain
Singapore
Yemen, Rep.
Dominican Republic
Lebanon
Mongolia
Bolivia
Sri Lanka
Kenya
Afghanistan
Sudan
Guatemala
Luxembourg
Ghana
Myanmar
Panama
Brunei Darussalam
Honduras
Equatorial Guinea
Jamaica
Costa Rica
Uruguay
Cyprus
Ethiopia
Tanzania
El Salvador
Cote d'Ivoire
Cameroon
Papua New Guinea
Paraguay
Nicaragua
Benin
Albania
Cambodia
Nepal
Mauritius
Uganda
New Caledonia
Congo, Dem. Rep.
Mozambique
Guinea
Malta
Madagascar
Congo, Rep.
Gabon
Mauritania
Haiti
Togo
Suriname
Burkina Faso
Bahamas, The
Iceland
Guyana
Barbados
Niger
Mali
Fiji
Lao PDR
Macao SAR, China
Sierra Leone
Liberia
French Polynesia
Greenland
Rwanda
Cayman Islands
Faroe Islands
Antigua and Barbuda
Belize
Chad
Djibouti
Cabo Verde
Gambia, The
St. Lucia
Bermuda
Central African Republic
St. Kitts and Nevis
Grenada
St. Vincent and the Grenadines
Samoa
Guinea-Bissau
Palau
Solomon Islands
Comoros
Dominica
Sao Tome and Principe
Tonga
Country Name
0.0
0.2
0.4
0.6
0.8
1e10
Whole emission

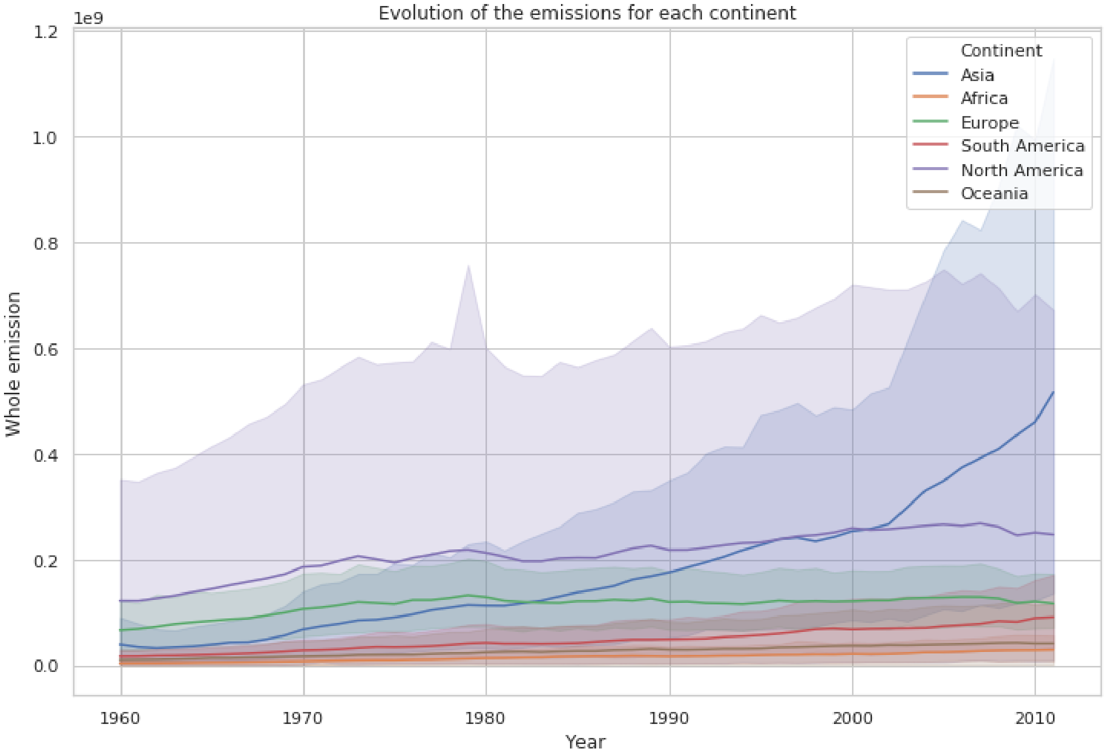
6.3 Are the annual emissions decreasing or increasing ?

Let's select few countries to show the evolution

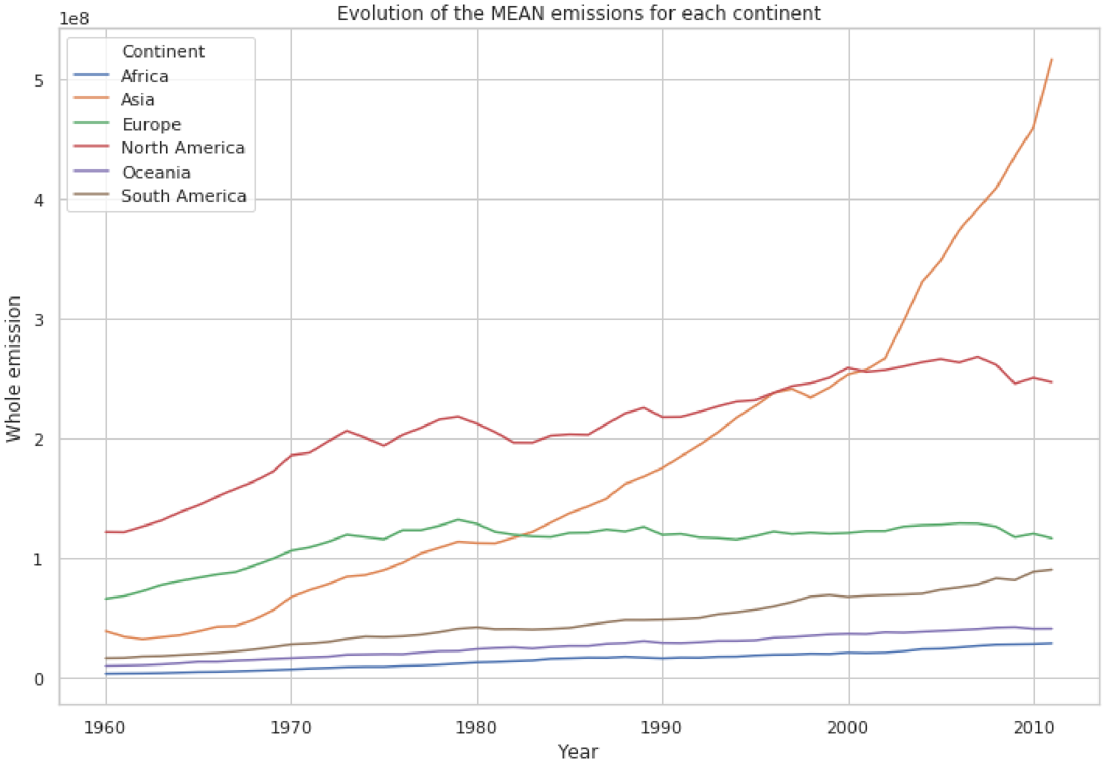
```
In [52]: selected_countries = ['France', 'Israel', 'Switzerland', 'Chile', 'China',
                              'Colombia', 'United Kingdom', 'United States', 'Brazil', 'Austra
         plt.figure(figsize=(12, 8))
         sns.lineplot(x="Year",
                      y='Whole emission',
                      hue="Country Name",
                      data=df[df["Country Name"].isin(selected_countries)])
         plt.title('Evolution of the CO2 emissions for few countries')
         plt.show()
```



```
In [53]: plt.figure(figsize=(12, 8))
         plt.title('Evolution of the emissions for each continent')

         sns.lineplot(x="Year",
                      y='Whole emission',
                      hue="Continent",
                 data=df)
plt.show()
```



```
In [54]: df_mean = pd.DataFrame(df.groupby(by=['Continent', 'Year'], as_index=False)['Whole emi

         plt.figure(figsize=(12, 8))
         plt.title('Evolution of the MEAN emissions for each continent')

         sns.lineplot(x="Year",
                      y='Whole emission',
                      hue="Continent",
                      data=df_mean)

         plt.show()
```



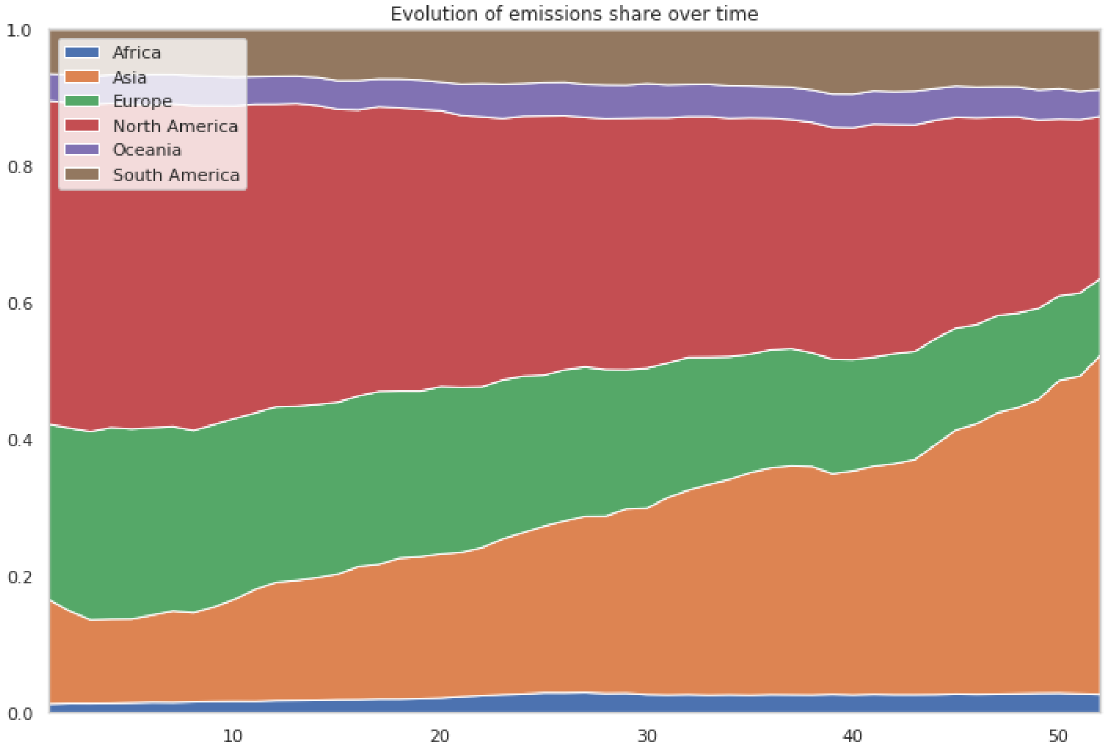
6.4 Evolution of emission share

```
In [55]: df_mean_pivot = pd.pivot_table(df_mean, index='Year', values='Whole emission', columns
         df_mean_pivot.head()
```

```
Out[55]: Continent          Africa          Asia        Europe  North America  \
         Year
         1960        3.536444e+06  3.928689e+07  6.609129e+07   1.219828e+08
         1961        3.695651e+06  3.453619e+07  6.850683e+07   1.217903e+08
         1962        3.804803e+06  3.239489e+07  7.269145e+07   1.265432e+08
         1963        4.057752e+06  3.418465e+07  7.773613e+07   1.316383e+08
         1964        4.494858e+06  3.575509e+07  8.103279e+07   1.384992e+08

         Continent         Oceania  South America
         Year
         1960        1.010739e+07   1.660111e+07
         1961        1.037739e+07   1.681596e+07
         1962        1.072653e+07   1.796754e+07
         1963        1.145539e+07   1.827552e+07
         1964        1.240671e+07   1.917087e+07
```

```
In [56]: df_mean_perc = df_mean_pivot.divide(df_mean_pivot.sum(axis=1), axis=0)
```

```
plt.figure(figsize=(12, 8))

# Make the plot
plt.stackplot(range(1,53),
              df_mean_perc['Africa'],
              df_mean_perc["Asia"],
              df_mean_perc["Europe"],
              df_mean_perc["North America"],
              df_mean_perc["Oceania"],
              df_mean_perc["South America"],
              labels=['Africa','Asia','Europe','North America','Oceania','South Ameri

# Formatting the plot
plt.legend(loc='upper left')
plt.margins(0,0)
plt.title('Evolution of emissions share over time')
plt.show()
```



6.5 World map