Global Ecological Footprint (2016)

July 14, 2025

[197]:

```
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
```

[198]:

```
df = pd.read_csv(r'../data/countries.csv')

print(df.head())
print(df.info())
```

```
               Country                    Region  Population (millions)   HDI  \
0          Afghanistan  Middle East/Central Asia                  29.82  0.46
1              Albania   Northern/Eastern Europe                   3.16  0.73
2              Algeria                    Africa                  38.48  0.73
3               Angola                    Africa                  20.82  0.52
4  Antigua and Barbuda             Latin America                   0.09  0.78

  GDP per Capita  Cropland Footprint  Grazing Footprint  Forest Footprint  \
0        $614.66                0.30               0.20              0.08
1      $4,534.37                0.78               0.22              0.25
2      $5,430.57                0.60               0.16              0.17
3      $4,665.91                0.33               0.15              0.12
4     $13,205.10                 NaN                NaN               NaN

   Carbon Footprint  Fish Footprint  ...  Cropland  Grazing Land  Forest Land  \
0              0.18            0.00  ...      0.24          0.20         0.02
1              0.87            0.02  ...      0.55          0.21         0.29
2              1.14            0.01  ...      0.24          0.27         0.03
3              0.20            0.09  ...      0.20          1.42         0.64
4               NaN             NaN  ...       NaN           NaN          NaN

   Fishing Water  Urban Land  Total Biocapacity  \
0           0.00        0.04               0.50
1           0.07        0.06               1.18
2           0.01        0.03               0.59
3           0.26        0.04               2.55
4            NaN         NaN               0.94

   Biocapacity Deficit or Reserve  Earths Required  Countries Required  \
0                           -0.30             0.46                1.60
1                           -1.03             1.27                1.87
2                           -1.53             1.22                3.61
3                            1.61             0.54                0.37
4                           -4.44             3.11                5.70

   Data Quality
0             6
1             6
2             5
3             6
4             2

[5 rows x 21 columns]
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 188 entries, 0 to 187
Data columns (total 21 columns):
 #   Column                          Non-Null Count  Dtype  
---  ------                          --------------  -----  
 0   Country                         188 non-null    object 
 1   Region                          188 non-null    object 
 2   Population (millions)           188 non-null    float64
 3   HDI                             172 non-null    float64
 4   GDP per Capita                  173 non-null    object 
 5   Cropland Footprint              173 non-null    float64
 6   Grazing Footprint               173 non-null    float64
 7   Forest Footprint                173 non-null    float64
 8   Carbon Footprint                173 non-null    float64
 9   Fish Footprint                  173 non-null    float64
 10  Total Ecological Footprint      188 non-null    float64
 11  Cropland                        173 non-null    float64
 12  Grazing Land                    173 non-null    float64
 13  Forest Land                     173 non-null    float64
 14  Fishing Water                   173 non-null    float64
 15  Urban Land                      173 non-null    float64
 16  Total Biocapacity               188 non-null    float64
 17  Biocapacity Deficit or Reserve  188 non-null    float64
 18  Earths Required                 188 non-null    float64
 19  Countries Required              188 non-null    float64
 20  Data Quality                    188 non-null    object 
dtypes: float64(17), object(4)
memory usage: 31.0+ KB
None
```

[199]:

```python
# Missing values are checked for each column
print("Missing values:\n", df.isna().sum())
```

```
Missing values:
 Country                            0
Region                             0
Population (millions)              0
HDI                               16
GDP per Capita                    15
Cropland Footprint                15
Grazing Footprint                 15
Forest Footprint                  15
Carbon Footprint                  15
Fish Footprint                    15
Total Ecological Footprint         0
Cropland                          15
Grazing Land                      15
Forest Land                       15
Fishing Water                     15
Urban Land                        15
Total Biocapacity                  0
Biocapacity Deficit or Reserve     0
Earths Required                    0
Countries Required                 0
Data Quality                       0
dtype: int64
```

[200]:

```python
#Full summary of missing values for all columns
missing_summary = df.isna().sum()

#Print all columns with their missing value counts
print("Full missing value report:\n", missing_summary)

#Filter only columns that have missing values
missing_columns = missing_summary[missing_summary > 0]
print("\nColumns with missing values:\n", missing_columns)
```

```
Full missing value report:
 Country                            0
Region                             0
Population (millions)              0
HDI                               16
GDP per Capita                    15
Cropland Footprint                15
Grazing Footprint                 15
Forest Footprint                  15
Carbon Footprint                  15
Fish Footprint                    15
```

```
Total Ecological Footprint         0
Cropland                          15
Grazing Land                      15
Forest Land                       15
Fishing Water                     15
Urban Land                        15
Total Biocapacity                  0
Biocapacity Deficit or Reserve     0
Earths Required                    0
Countries Required                 0
Data Quality                       0
dtype: int64

Columns with missing values:
 HDI                   16
GDP per Capita        15
Cropland Footprint    15
Grazing Footprint     15
Forest Footprint      15
Carbon Footprint      15
Fish Footprint        15
Cropland              15
Grazing Land          15
Forest Land           15
Fishing Water         15
Urban Land            15
dtype: int64
```

[201]:

```python
#Clean and convert 'GDP per Capita' to numeric
df["GDP per Capita"] = df["GDP per Capita"].replace('[\$,]', '', regex=True)
df["GDP per Capita"] = pd.to_numeric(df["GDP per Capita"], errors='coerce')

#List the columns to fill using regional mean
columns_to_fill = [
    "HDI", "GDP per Capita", "Cropland Footprint", "Grazing Footprint", "Forest␣
 ↪Footprint",
    "Carbon Footprint", "Fish Footprint", "Cropland", "Grazing Land", "Forest␣
 ↪Land",
    "Fishing Water", "Urban Land"]

#Fill missing values by region mean
for col in columns_to_fill:
    df[col] = df.groupby("Region")[col].transform(lambda x: x.fillna(x.mean()))
```

[202]:

```
# Missing values are checked for each column
print("Missing values:\n", df.isna().sum())
```

```
Missing values:
 Country                             0
Region                             0
Population (millions)              0
HDI                                0
GDP per Capita                     0
Cropland Footprint                 0
Grazing Footprint                  0
Forest Footprint                   0
Carbon Footprint                   0
Fish Footprint                     0
Total Ecological Footprint         0
Cropland                           0
Grazing Land                       0
Forest Land                        0
Fishing Water                      0
Urban Land                         0
Total Biocapacity                  0
Biocapacity Deficit or Reserve     0
Earths Required                    0
Countries Required                 0
Data Quality                       0
dtype: int64
```

[203]:

```
#the average Human Development Index (HDI) for each region
avg_hdi_by_region = df.groupby("Region")["HDI"].mean()
print(avg_hdi_by_region)
```

```
Region
Africa                      0.515714
Asia-Pacific                0.687500
European Union              0.864615
Latin America               0.720433
Middle East/Central Asia    0.726957
North America               0.910000
Northern/Eastern Europe     0.788333
Name: HDI, dtype: float64
```

[204]:

```
#Computes the total population (in millions) in each region
total_pop_by_region = df.groupby("Region")["Population (millions)"].sum()
print(total_pop_by_region)
```

```
Region
Africa                        1034.640
Asia-Pacific                  3880.170
European Union                 503.980
Latin America                  605.410
Middle East/Central Asia       405.586
North America                  352.400
Northern/Eastern Europe        238.180
Name: Population (millions), dtype: float64
```

[205]:

```
#Cleans and converts GDP per Capita to float, then calculates the regional␣
 ↪average
df["GDP per Capita"] = df["GDP per Capita"].replace('[\$,]', '', regex=True).
 ↪astype(float)
avg_gdp_by_region = df.groupby("Region")["GDP per Capita"].mean()
print(avg_gdp_by_region)
```

```
Region
Africa                         2668.142400
Asia-Pacific                  12192.205000
European Union                35819.146923
Latin America                  8376.773125
Middle East/Central Asia      16368.722273
North America                 57498.900000
Northern/Eastern Europe       21373.183333
Name: GDP per Capita, dtype: float64
```

[206]:

```
#the top 10countries with the highest total carbon footprint
top_carbon = df.groupby("Country")["Carbon Footprint"].sum().nlargest(10)
print(top_carbon)
```

```
Country
Luxembourg                  12.65
Qatar                        9.57
Kuwait                       6.89
Trinidad and Tobago          6.89
United Arab Emirates         6.37
Bahrain                      6.19
Singapore                    5.91
United States of America     5.90
Oman                         5.80
Bermuda                      5.45
Name: Carbon Footprint, dtype: float64
```

[207]:

```
#the average cropland usage footprint per region
avg_cropland_by_region = df.groupby("Region")["Cropland Footprint"].mean()
print(avg_cropland_by_region)
```

```
Region
Africa                      0.389600
Asia-Pacific                0.598667
European Union              0.982917
Latin America               0.450000
Middle East/Central Asia    0.598696
North America               1.295000
Northern/Eastern Europe     0.708182
Name: Cropland Footprint, dtype: float64
```

[208]:

```
#Sums the total ecological biocapacity available in each region
total_biocapacity_by_region = df.groupby("Region")["Total Biocapacity"].sum()
print(total_biocapacity_by_region)
```

```
Region
Africa                      117.66
Asia-Pacific                 93.29
European Union               94.87
Latin America               372.98
Middle East/Central Asia     22.41
North America                19.90
Northern/Eastern Europe      34.59
Name: Total Biocapacity, dtype: float64
```

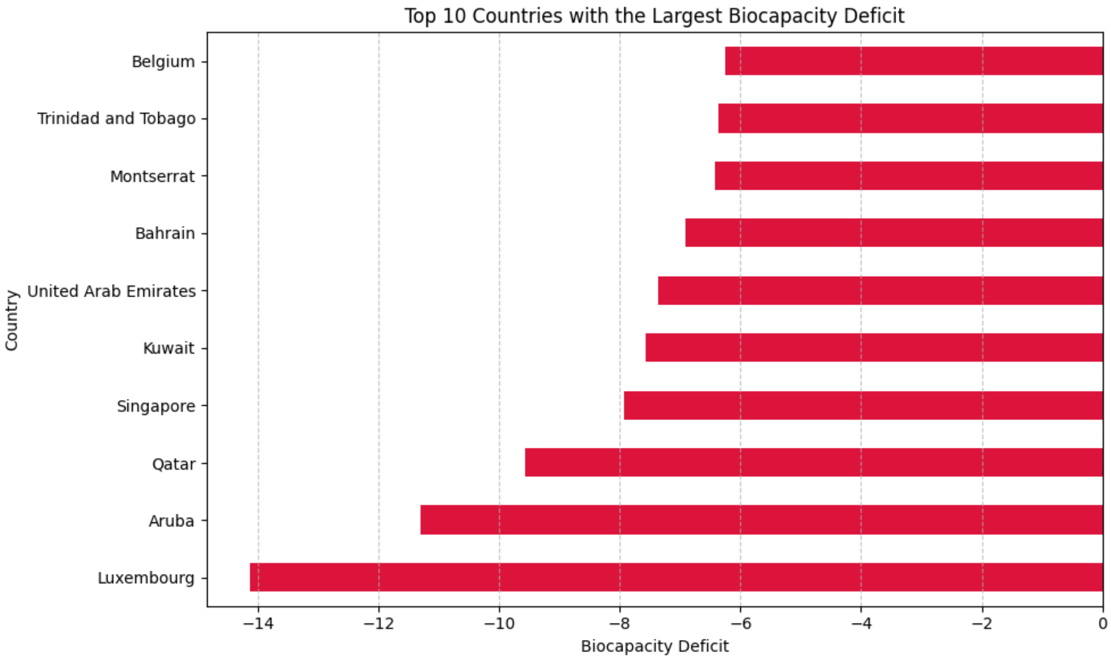
[209]:

```
#the 10 countries with the most negative biocapacity balance (deficit)
top_deficit = df.groupby("Country")["Biocapacity Deficit or Reserve"].min().
 ↪nsmallest(10)
print(top_deficit)
```

```
Country
Luxembourg             -14.14
Aruba                  -11.31
Qatar                   -9.56
Singapore               -7.92
Kuwait                  -7.58
United Arab Emirates    -7.37
Bahrain                 -6.91
Montserrat              -6.42
Trinidad and Tobago     -6.36
Belgium                 -6.25
Name: Biocapacity Deficit or Reserve, dtype: float64
```

[210]:

```
plt.figure(figsize=(10, 6))
top_deficit.plot(kind='barh', color='crimson')
plt.title("Top 10 Countries with the Largest Biocapacity Deficit")
plt.xlabel("Biocapacity Deficit")
plt.ylabel("Country")
plt.grid(axis='x', linestyle='--', alpha=0.7)
plt.tight_layout()
plt.show()
```



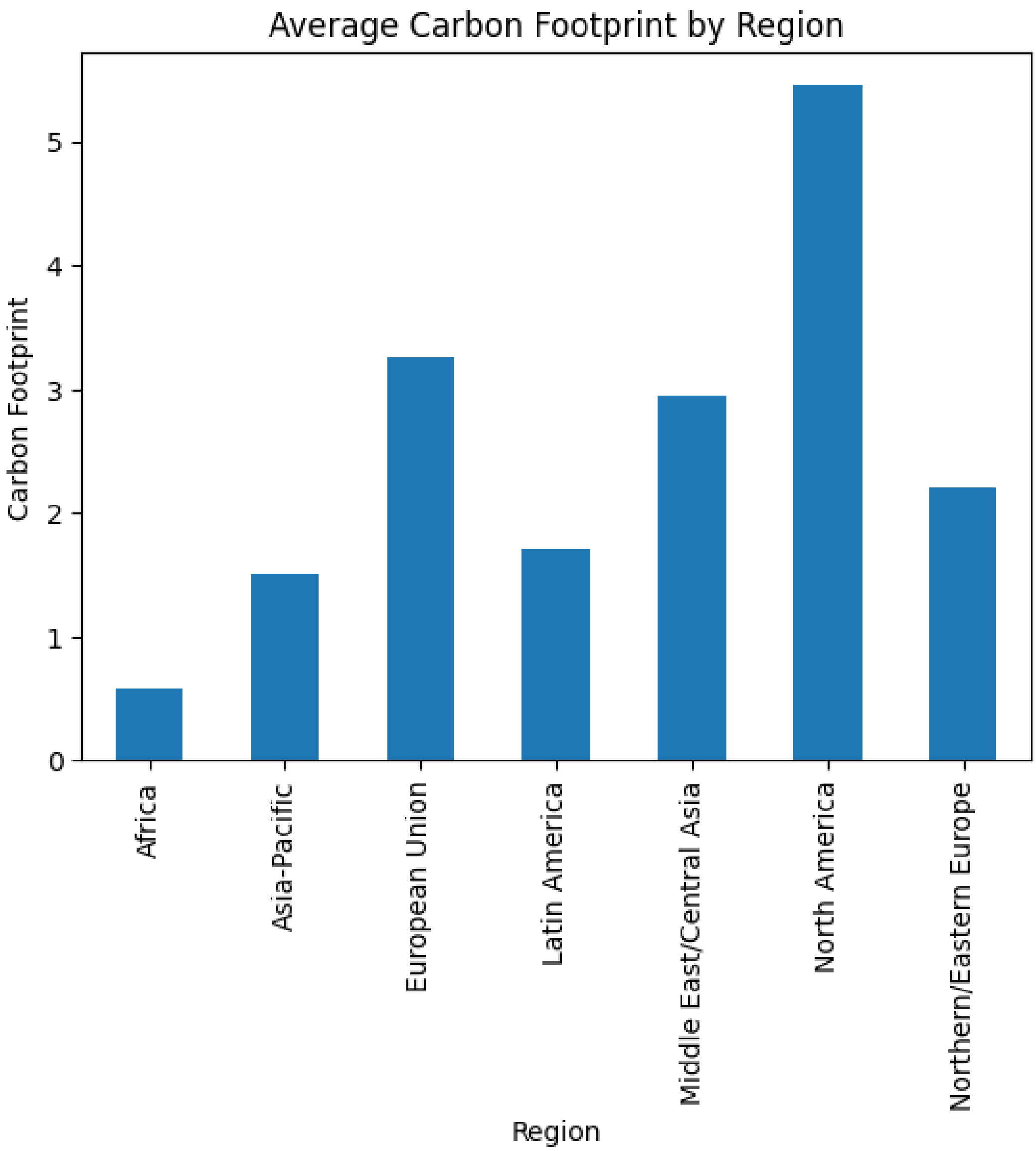
[211]:

```
#how average carbon footprint varies by population size
carbon_by_pop = df.groupby("Population (millions)")["Carbon Footprint"].mean()
print(carbon_by_pop.head())
```

```
Population (millions)
0.00    1.709394
0.01    1.514000
0.03    1.709394
0.05    3.340000
0.06    4.505000
Name: Carbon Footprint, dtype: float64
```

[212]:

```
df.groupby("Region")["Carbon Footprint"].mean().plot(kind="bar")
plt.title("Average Carbon Footprint by Region")
plt.ylabel("Carbon Footprint")
plt.show()
```



[213]:

```
#how fish footprint varies with HDI levels
fish_by_hdi = df.groupby("HDI")["Fish Footprint"].mean()
print(fish_by_hdi.head())
```

```
HDI
0.34    0.020000
0.37    0.020000
```

```
0.39    0.012500
0.40    0.150000
0.41    0.036667
Name: Fish Footprint, dtype: float64
```

[214]:

```
#the percentage of countries with a biocapacity deficit in each region
deficit_by_region = df[df["Biocapacity Deficit or Reserve"] < 0].
 ↪groupby("Region")["Country"].count() / df.groupby("Region")["Country"].count()␣
 ↪* 100
print(deficit_by_region)
```

```
Region
Africa                        59.615385
Asia-Pacific                  69.696970
European Union                84.615385
Latin America                 61.538462
Middle East/Central Asia     100.000000
North America                 66.666667
Northern/Eastern Europe       83.333333
Name: Country, dtype: float64
```

[215]:

```
#the relationship between income level and forest usage footprint
forest_by_gdp = df.groupby("GDP per Capita")["Forest Footprint"].mean()
print(forest_by_gdp.head())
```

```
GDP per Capita
276.69    0.45
338.63    0.51
379.38    0.46
397.38    0.75
410.91    0.26
Name: Forest Footprint, dtype: float64
```

[216]:

```
#Converts data quality to numeric and calculates average per region
df["Data Quality"] = pd.to_numeric(df["Data Quality"], errors='coerce')
avg_quality_by_region = df.groupby("Region")["Data Quality"].mean()
print(avg_quality_by_region)
```

```
Region
Africa                      5.350000
Asia-Pacific                5.500000
European Union              5.333333
Latin America               4.791667
Middle East/Central Asia    5.583333
North America               5.500000
Northern/Eastern Europe     5.416667
Name: Data Quality, dtype: float64
```

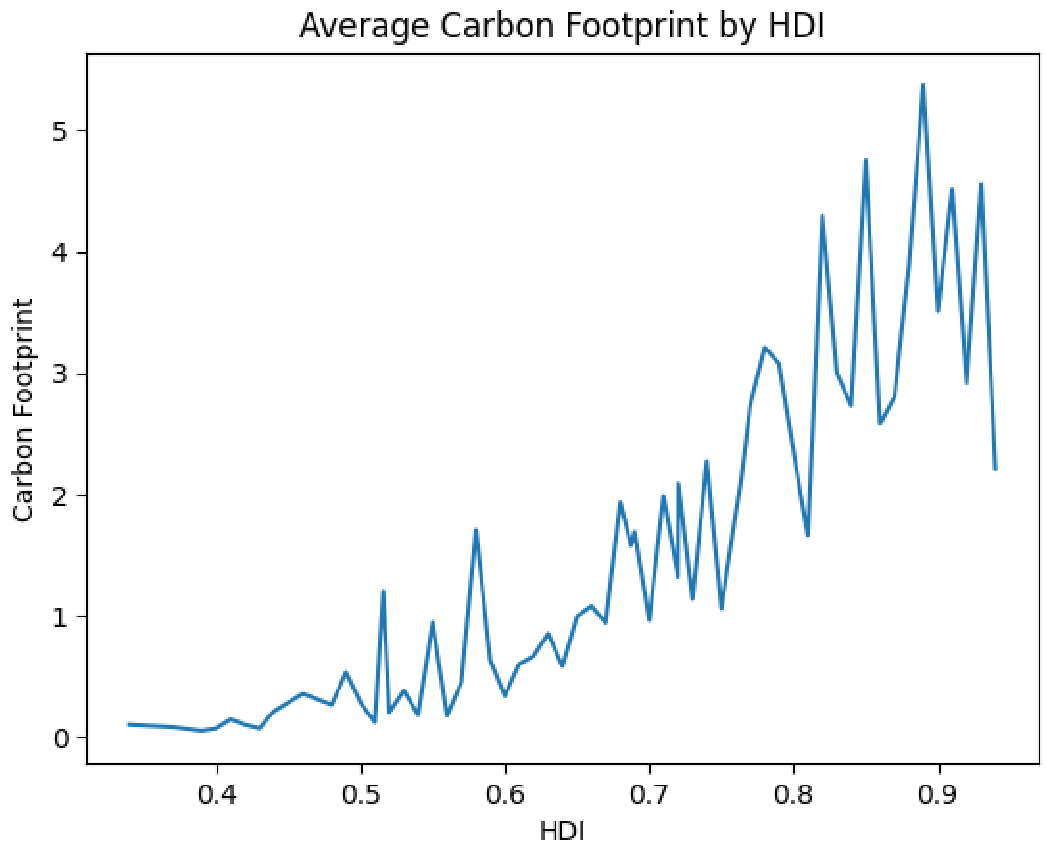
[217]:

```
#countries based on HDI ranges and counts how many fall into each bin
hdi_bins = pd.cut(df["HDI"], bins=[0, 0.5, 0.7, 1])
hdi_dist = df.groupby(hdi_bins, observed=False)["Country"].count()
print(hdi_dist)
```

```
HDI
(0.0, 0.5]     33
(0.5, 0.7]     52
(0.7, 1.0]    103
Name: Country, dtype: int64
```

[218]:

```
df.groupby("HDI")["Carbon Footprint"].mean().plot(kind="line")
plt.title("Average Carbon Footprint by HDI")
plt.ylabel("Carbon Footprint")
plt.show()
```



[219]:

```python
#Shows how the average number of Earths required changes with population size
earths_by_pop = df.groupby("Population (millions)")["Earths Required"].mean()
print(earths_by_pop.head())
```

```
Population (millions)
0.00    4.490
0.01    1.445
0.03    1.650
0.05    2.850
0.06    3.295
Name: Earths Required, dtype: float64
```

[220]:

```python
#Sums cropland footprint for each region
total_cropland_by_region = df.groupby("Region")["Cropland Footprint"].sum()
print(total_cropland_by_region)
```

```
Region
Africa                        20.259200
Asia-Pacific                  19.756000
European Union                25.555833
Latin America                 17.550000
Middle East/Central Asia      13.770000
North America                  3.885000
Northern/Eastern Europe        8.498182
Name: Cropland Footprint, dtype: float64
```

[221]:

```python
#the top 10 countries with the largest grazing land footprint
top_grazing = df.groupby("Country")["Grazing Footprint"].sum().nlargest(10)
print(top_grazing)
```

```
Country
Mongolia      3.47
Bolivia       1.69
Mauritania    1.20
Paraguay      1.10
Bahamas       1.05
Uruguay       0.98
Botswana      0.89
Brazil        0.85
Argentina     0.79
Luxembourg    0.76
Name: Grazing Footprint, dtype: float64
```

[222]:

```
#average forest footprint per region
forest_by_region = df.groupby("Region")["Forest Footprint"].mean()
print(forest_by_region)
```

```
Region
Africa                        0.310000
Asia-Pacific                  0.374000
European Union                0.641667
Latin America                 0.360909
Middle East/Central Asia      0.160870
North America                 0.935000
Northern/Eastern Europe       0.460909
Name: Forest Footprint, dtype: float64
```

[223]:

```
#how carbon footprint correlates with data quality ratings
carbon_by_quality = df.groupby("Data Quality")["Carbon Footprint"].mean()
print(carbon_by_quality)
```

```
Data Quality
2.0    1.488729
4.0    1.125455
5.0    1.844242
6.0    1.492500
Name: Carbon Footprint, dtype: float64
```

[224]:

```
#the link between available biocapacity and ecological pressure (countries␣
 ↪required)
countries_by_biocap = df.groupby("Total Biocapacity")["Countries Required"].
 ↪mean()
print(countries_by_biocap.head())
```

```
Total Biocapacity
0.05    159.47
0.13     44.05
0.18     20.18
0.19     19.81
0.21      9.91
Name: Countries Required, dtype: float64
```

[225]:

```
#how many countries have a carbon footprint exceeding 1 Earth
high_carbon = len(df[df["Carbon Footprint"] > 1])
print(f"Countries with Carbon Footprint > 1: {high_carbon}")
```

```
Countries with Carbon Footprint > 1: 109
```

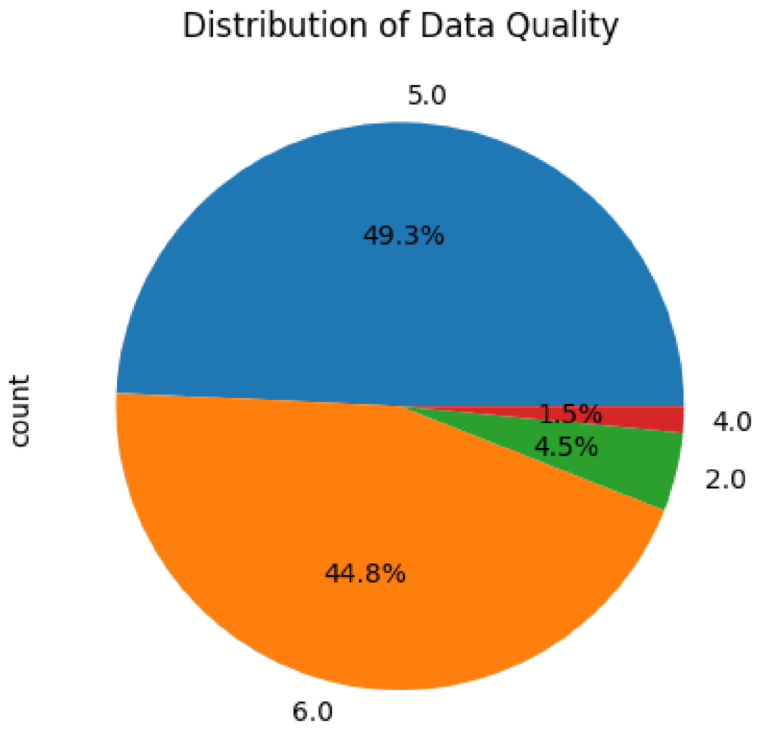
[226]:

```
#the percentage of countries in each region that have a biocapacity surplus
surplus_by_region = df[df["Biocapacity Deficit or Reserve"] > 0].
 ↪groupby("Region")["Country"].count() / df.groupby("Region")["Country"].count()␣
 ↪* 100
print(surplus_by_region)
```

```
Region
Africa                         38.461538
Asia-Pacific                   30.303030
European Union                 15.384615
Latin America                  38.461538
Middle East/Central Asia             NaN
North America                  33.333333
Northern/Eastern Europe        16.666667
Name: Country, dtype: float64
```

[227]:

```
df["Data Quality"] = pd.to_numeric(df["Data Quality"], errors='coerce')
df["Data Quality"].value_counts().plot(kind="pie", autopct='%1.1f%%')
plt.title("Distribution of Data Quality")
plt.show()
```



[228]:

```
#the average fish resource footprint per region
fish_by_region = df.groupby("Region")["Fish Footprint"].mean()
print(fish_by_region)
```

```
Region
Africa                        0.093800
Asia-Pacific                  0.232333
European Union                0.115833
Latin America                 0.132424
Middle East/Central Asia      0.064348
North America                 0.120000
Northern/Eastern Europe       0.060000
Name: Fish Footprint, dtype: float64
```

[229]:

```
#how much urban land usage correlates with HDI
urban_by_hdi = df.groupby("HDI")["Urban Land"].mean()
print(urban_by_hdi.head())
```

```
HDI
0.34    0.0300
0.37    0.0400
0.39    0.0375
0.40    0.0500
0.41    0.0500
Name: Urban Land, dtype: float64
```

[230]:

```
#the forest footprint for all countries in each region
total_forest_by_region = df.groupby("Region")["Forest Footprint"].sum()
print(total_forest_by_region)
```

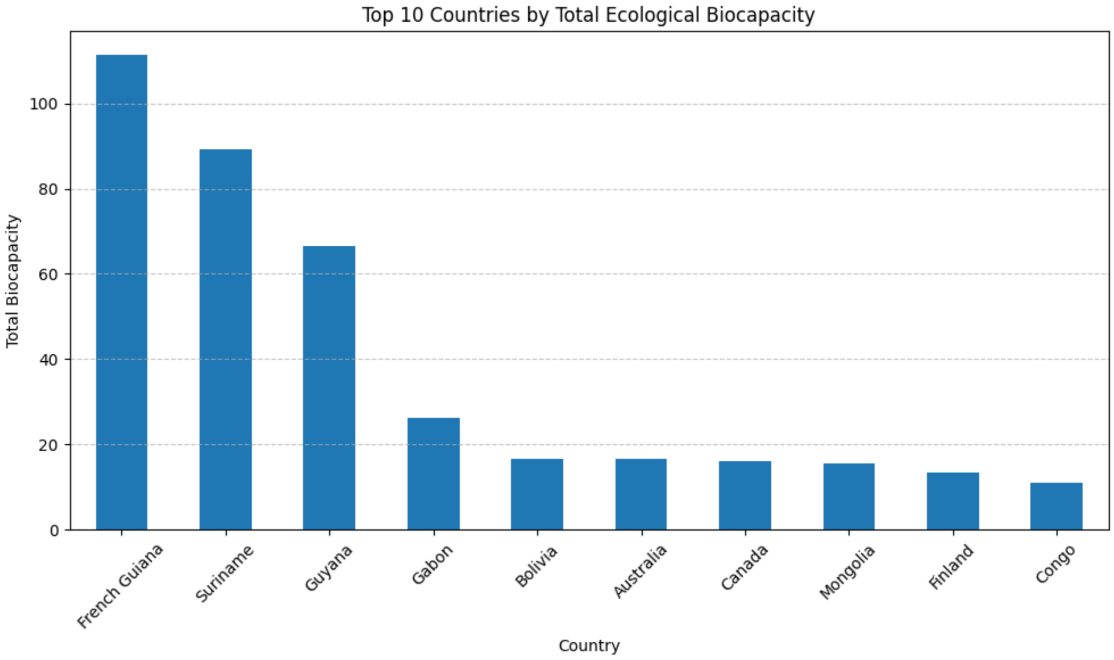
```
Region
Africa                        16.120000
Asia-Pacific                  12.342000
European Union                16.683333
Latin America                 14.075455
Middle East/Central Asia       3.700000
North America                  2.805000
Northern/Eastern Europe        5.530909
Name: Forest Footprint, dtype: float64
```

[231]:
```
# Top 10 countries with the highest total ecological biocapacity
top_biocapacity = df.groupby("Country")["Total Biocapacity"].sum().nlargest(10)
print(top_biocapacity)
```

```
Country
French Guiana    111.35
Suriname          89.33
Guyana            66.58
Gabon             26.31
Bolivia           16.73
Australia         16.57
Canada            16.01
Mongolia          15.66
Finland           13.44
Congo             10.91
Name: Total Biocapacity, dtype: float64
```

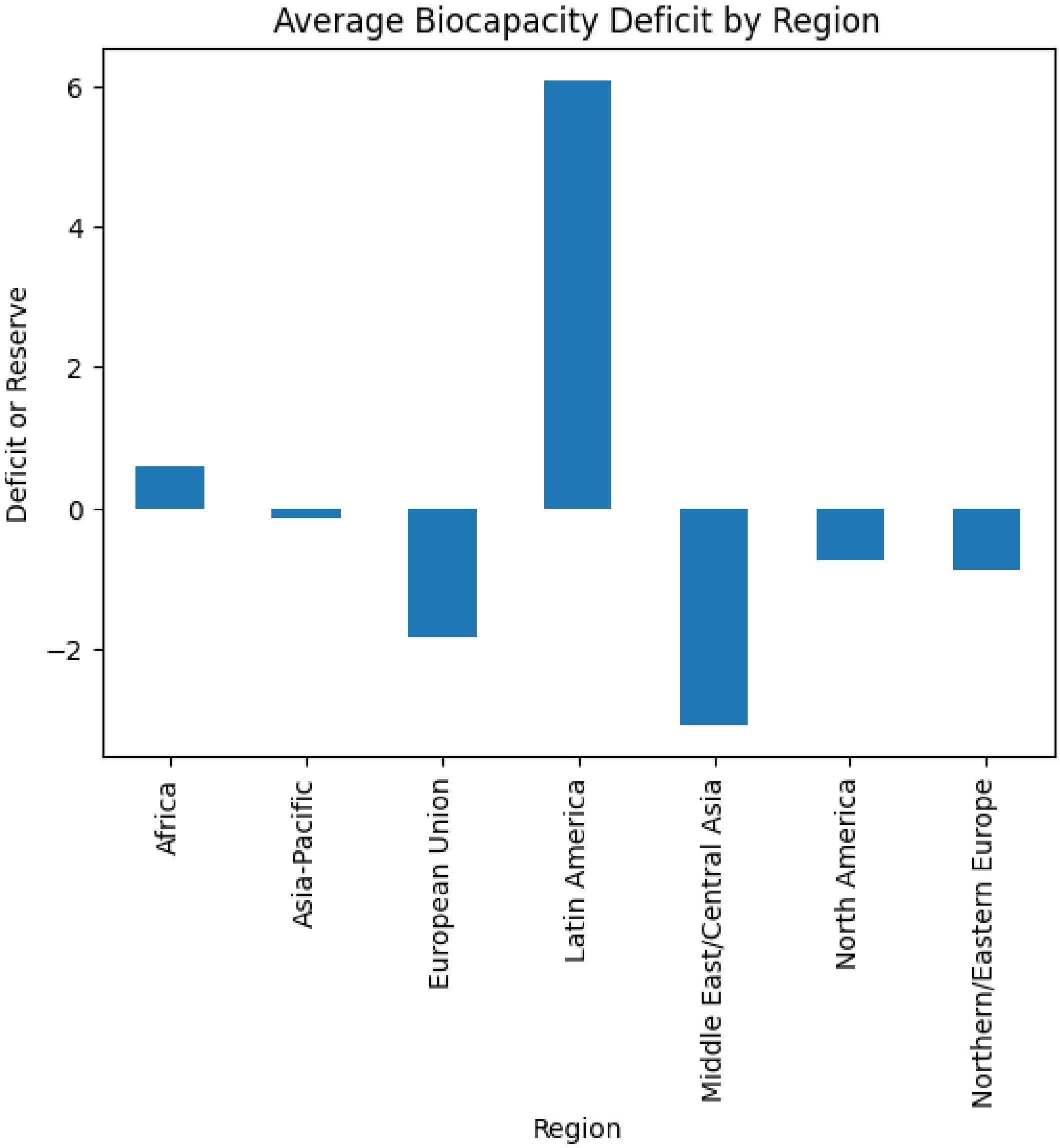
[232]:
```
plt.figure(figsize=(10, 6))
top_biocapacity.plot(kind='bar')

plt.title("Top 10 Countries by Total Ecological Biocapacity")
plt.xlabel("Country")
plt.ylabel("Total Biocapacity")
plt.xticks(rotation=45)
plt.grid(axis='y', linestyle='--', alpha=0.7)
plt.tight_layout()
plt.show()
```



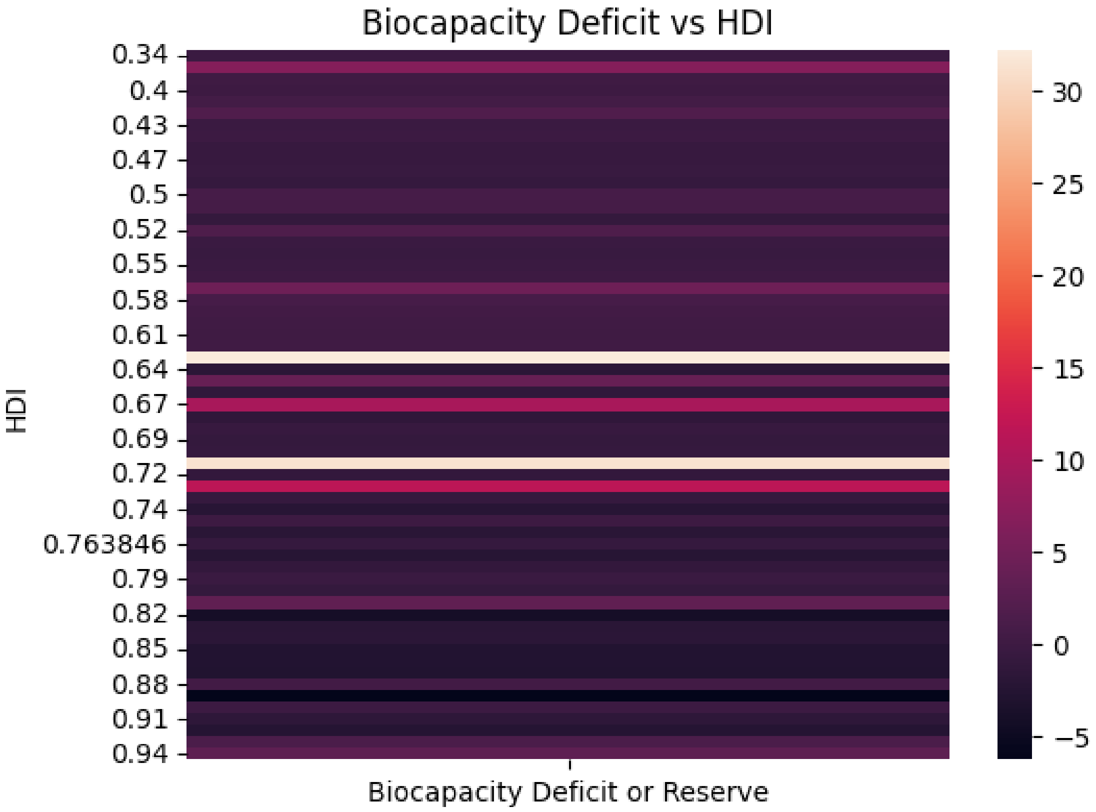
[233]:

```
df.groupby("Region")["Biocapacity Deficit or Reserve"].mean().plot(kind="bar")
plt.title("Average Biocapacity Deficit by Region")
plt.ylabel("Deficit or Reserve")
plt.show()
```



[234]:

```
pivot = df.pivot_table(values="Biocapacity Deficit or Reserve", index="HDI",␣
 ↪aggfunc="mean")
sns.heatmap(pivot)
plt.title("Biocapacity Deficit vs HDI")
plt.show()
```


Biocapacity Deficit vs HDI
HDI
Biocapacity Deficit or Reserve