LIFE EXPECTANCY AND ENVIRONMENT IN THE MEDITERRANEAN AREA: STATISTICAL RELATIONSHIPS AND SPURIOUS CORRELATIONS

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Abstract. Several interrelated factors are behind the good health and life expectancy of local populations. Today, large datasets are available at UN level to analyse the relationships between economic, social and environmental factors. All dimensions that are now considered essential for a sound assessment of the sustainability of national development paths.
Using a clustering analysis, this study focuses on the Mediterranean area to highlight how variations in life expectancy across the region are shaped by factors such as economic conditions, healthcare systems and political stability of the countries, rather than climate or physical geography alone. The application of multivariate techniques allows evaluating the multiple relationship among the indicators nowadays available in the WB statistical databases, taking into account the limitations in the data while their correlations, eventual connections or spurious correlations.
The paper highlights further data and development needed in the future. Based on present results, some useful conclusions for policy are drowned.

1. Introduction

In this paper we identify common factors in countries having similar health profiles and similar life expectancies, of the population living at the border of the Mediterranean Sea.

The region is a special geographical area where three continents meet (Europe, Africa and Asia), with different populations' history and of long-lasting migration. Furthermore, climate and natural conditions diverge moving from the south of Europe and the Balkans to the Middle East and North Africa. Despite this environmental diversity, research shows that further factors play a dominant role in determining health outcomes.

Healthcare systems, political stability, and economic growth have a far more significant impact on life expectancy than physical geographic conditions.

A study by Wilkinson and Pickett (2006) highlights the role of income inequality in determining health outcomes, showing that countries with more equitable wealth distribution tend to have higher life expectancies. Similarly, research by Mackenbach et al. (2019) demonstrates that countries with robust healthcare systems

and greater access to medical care, such as Norway, tend to experience longer lifespans, regardless of their geographic location. Additionally, studies on political stability, such as one by Franco et al. (2004), have found that stable governance and reduced conflict contribute significantly to better health outcomes and longer life expectancy, as seen in Japan, compared to unstable regions like Syria or Afghanistan. These findings emphasise that life expectancy is more closely linked to social, economic, and political determinants than to physical geography.

Similarly, in the Mediterranean area we expect to find the same factors behind life expectancy dishomogeneity. Using data from the World Development Indicators (WDI) provided by the World Bank and available for most of the political entities, eventually integrated with further statistical sources, our goal is to identify groups with similar life expectancy and to demonstrate that, within each group, they share common characteristics at the political, economical and social level, not just in terms of climate factors.

2. Political Subdivision and Geographical Overview of the Mediterranean Area

Numerous countries of different sizes overlook the Mediterranean, from city states (Gibraltar and Monaco), islands (Malta and Cyprus) to large countries that extend well beyond the Mediterranean Sea towards the Sahara Desert (Algeria, Libya, Egypt) or other seas (Turkiye, France, Spain). The political entities in the region are 24, not all fully recognized at UN and international level: North Cyprus and Palestine have still a limited international status.

The main political agglomeration of the region can be identified in the northern part of the sea, the European Union (EU) which include 7 countries (Spain, France, Italy, Malta, Slovenia, Croatia, Greece and Cyprus) plus 4 additional candidates (Bosnia -Herzegovina, Montenegro, Albania and Turkiye).

At the south of the sea, we have a second political union: the Arab League, with 8 members (Morocco, Algeria, Tunisia, Libya, Egypt, Palestine, Lebanon and Syria).

The different national coalitions reported above reflect cultural history and political identity (European and Maghreb-Middle Eastern), resulting in different social and economic conditions.

In addition, the area also experiences diverse climates, from the temperate conditions of northern countries to the hot, arid climates of southern nations. Island nations have distinct microclimates influenced by the sea, further contributing to the region's environmental diversity.

Table 1 − *Dimensional, development and climatic indicators of the Mediterranean countries (Year 2023, last available.*

Country	Cooling Degree Day (CDD)	GDP per capita (current US$)	CO2 emissions	Population, total (thousands)	Surface (sq. Km) (thousands)	Population density (pop. Per km2)	Population growth (annual %)
Albania	809.8°	8368	1.5°	2746.0	28750†	102.6†	-1.1
Algeria	5135.0°	5260	3.7°	45606.5	2381741†	18.5†	1.6
Bosnia and Herzegovina	394.6°	8426	6.3°	3210.8	51210†	63.9†	-0.7
Croatia	663.1°	21460	3.9°	3853.2	88070†	69.3†	-0.1
Cyprus	2593.7°	34701	5.5°	1260.1	9250†	134.7†	0.7
Egypt, Arab Rep.	4022.2°	3513	2.0°	112716.6	1001450†	109.8†	1.5
France	455.0°	44461	4.0°	68170.2	549087†	123.8†	0.3
Gibraltar	NA	NA	NA	32.7	10†	3266.9†	0.1
Greece	1236.8°	22990	4.8°	10361.3	131960†	82.0†	-0.6
Israel	2828.0°	52262	6.3°	9756.7	22070†	433.1†	2.1
Italy	888.5°	38373	4.7°	58761.1	302068†	200.0†	-0.3
Lebanon	1572.9°	3824	3.8°	5353.9	10450†	546.7†	-2.5
Libya	3879.4°	7330	6.7°	6888.4	1759540†	3.8†	1.1
Malta	1830.4°	37882	3.1°	553.2	320†	1620.4†	4.1
Monaco	691.9°	24086*	NA	36.3	90†	17603.6†	-0.5
Montenegro	404.3°	12017	4.1°	616.2	13810†	46.0†	-0.2
Morocco	2412.6°	3672	1.8°	37840.0	446550†	83.1†	1.0
North Cyprus							
Palestine							
Slovenia	328.8°	32164	5.9°	2120.9	20480†	104.7†	0.4
Spain	1010.3°	32677	4.3°	48373.3	505965†	94.9†	1.2
Syrian Arab Republic	3292.0°	421†	1.2°	23227.0	185180†	116.1†	4.9
Tunisia	2997.1°	3895	2.4°	12458.2	163610†	78.9†	0.8
Turkiye	1114.3°	12986	4.9°	85326.0	785350†	109.3†	0.4

*Last available year: *= 2022; †= 2021; °= 2020.*
Data from World Bank database; missing data of Monaco, North-Cyprus and Palestine from national authorities and CIA data.

Table 1 presents an overview of the dimensional, development, and climatic indicators of Mediterranean countries, A cooling degree day (CDD) is a measurement designed to track energy use. It is the number of degrees that a day's average temperature is above 18°C (65°F). Daily degree days are accumulated to obtain annual values. Cooling degree days can describe the overall need for cooling. The CDDs values highlight distinct climate patterns across the Mediterranean countries. Algeria (CDD: 5,135), Libya (CDD: 3,879.4), and Egypt (CDD: 4,022.2) experience hot arid climates with extremely high cooling demands. Israel (CDD: 2,828) and Cyprus (CDD: 2,593.7) also have high CDD values, reflective of their hot Mediterranean climates, while southern European countries, such as Italy (CDD: 888.5) and Greece (CDD: 1,236.8), have more moderate CDD values, indicating

warm but less extreme summers. In contrast, northern Mediterranean countries such as France (CDD: 454.9) and Slovenia (CDD: 328.8) experience cooler summers, with much lower cooling demands.

Economically, there is significant variation in GDP per capita, with Monaco ($240,862) as an extreme outlier, while Syria ($421) and Lebanon ($3,824) have much lower figures, reflecting their economic difficulties. GDP per capita does not consistently align with population density or country size. For example, Cyprus and Malta have relatively different population densities (134.7 and 1,620.4 people/km², respectively), yet their GDP per capita differs ($34,701 for Cyprus and $37,882 for Malta).

CO2 emissions show a different pattern, largely linked to industrial activity. Libya (6.68 CO2 tons) and Bosnia and Herzegovina (6.31 CO2 tons) have among the highest CO2 emissions, likely due to their reliance on fossil fuels and industrial sectors. Israel (6.35 CO2 tons) and Cyprus (5.47 CO2 tons) also show high emissions. In contrast, Egypt (1.96 CO2 tons) and Tunisia (2.41 CO2 tons) maintain relatively low CO2 emissions, likely due to less industrialization. France (3.95 CO2 tons) has moderate emissions, potentially owing to its reliance on nuclear energy.

Population growth also varies significantly. Some countries, like Israel (2.1%) and Malta (4.1%), are experiencing robust growth, while others, particularly in Southern Europe, like Italy (-0.3%) and Greece (-0.6%), are seeing population decline. Notably, higher population growth does not correspond to higher GDP per capita; for example, Syria, with a high growth rate of 4.9%, has one of the lowest GDP per capita figures, reflecting the impact of conflict and instability.

Neighbouring Mediterranean countries can show contrasts in their economic and demographic indicators. For example, Italy and France, though geographically close, differ in GDP per capita ($38,373 vs. $44,461), with Italy having a higher population density but lower economic output. In North Africa, Algeria and Morocco also show differences: Algeria has a larger land area and lower population density but a higher GDP per capita ($5,260 vs. $3,672). Similarly, Israel and Lebanon differ sharply—Israel has a much higher GDP per capita ($52,262 vs. $3,824) despite both having high population densities. These differences highlight how geographic proximity does not always translate to similar economic and demographic outcomes.

3. Life expectancy the Mediterranean Area

If we want to study the health conditions of the population living in this area and after analysing the factors underlying the differences that we will find, a widely

available statistical indicator is the life expectancy at birth. This indicates the number of years a new-born infant would live if the mortality patterns prevailing at the time of its birth were to stay the same throughout his life (World Bank, 2024).

Figure 1 – *Life expectancy across Mediterranean countries in 2022.*

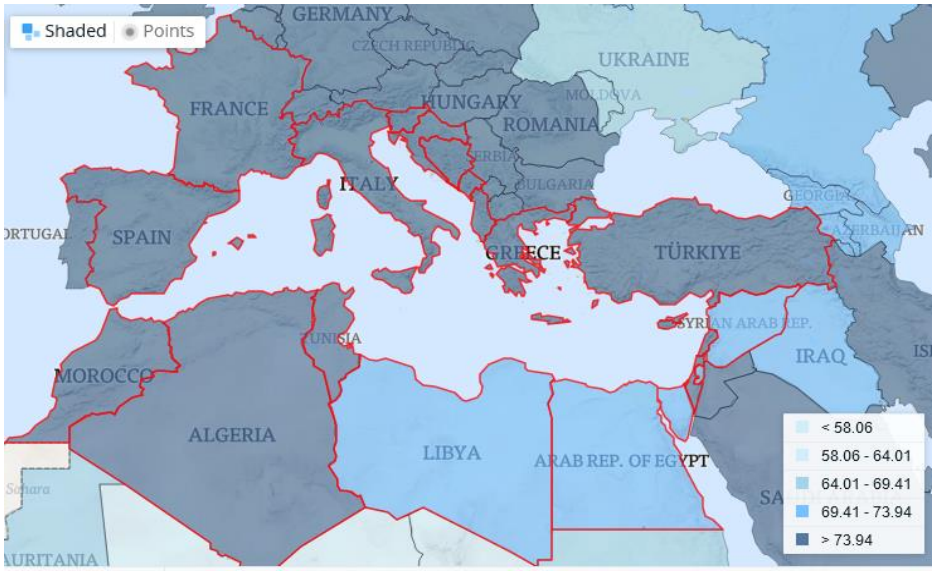


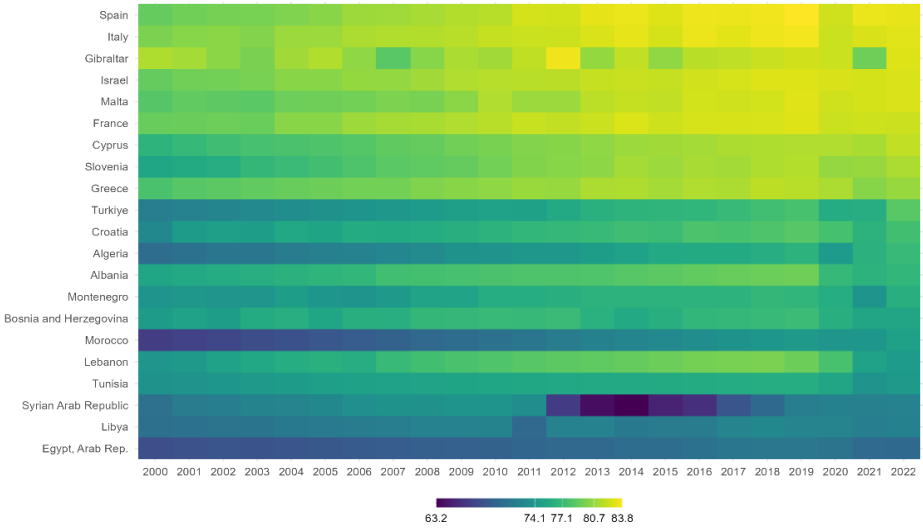
Figure 1 shows the life expectancy across Mediterranean countries in 2022 and Figure 2 between 2000 to 2022

In 2022, life expectancy varied significantly across Mediterranean countries. Spain showed the highest life expectancies at 83.2 years. Similarly, France and Italy also had high life expectancies, reinforcing the trend in Southern Europe. In contrast, Egypt and Morocco exhibited lower life expectancies, around 70 to 72 years.

Over time, life expectancy across Mediterranean countries has generally improved, but the pace of this improvement has also varied significantly. In Spain, France, and Italy, life expectancy has steadily risen. Similarly, Slovenia and Croatia have shown steady gains in life expectancy, although slightly lower than their Western European neighbours. In contrast, North African and Middle Eastern countries, like Egypt and Morocco, have seen slower improvements in life expectancy over the years. Egypt, for instance, reached around 70 years in 2022, a modest increase compared to European countries. Conflict and instability in Syria have also contributed to more erratic changes in life expectancy, with significant fluctuations during the years. For example, during the Syrian Civil War in 2014, life expectancy dropped to 63.1 and in Libya, during the Arab Spring and Civil War in

2011, life expectancy was 70.1. Additionally, in 2020 - 2021, life expectancy decreased across all countries due to the COVID-19 pandemic.

Figure 2 – *Life expectancy across Mediterranean countries between 2000 and 2022.*



4. Climate and Life Expectancy: Impact of Cooling Degree Days

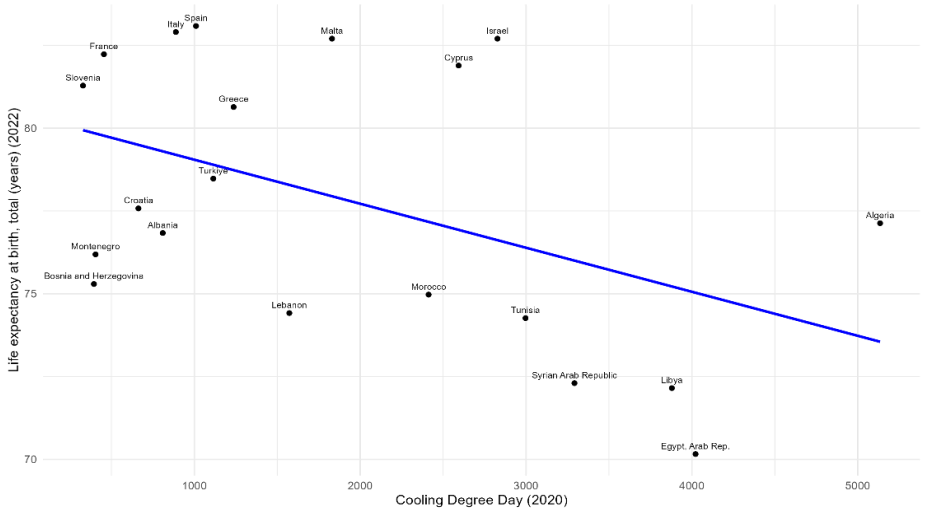
An ANOVA test revealed statistically significant differences in life expectancy among the Mediterranean countries (Table 2).

Table 2 - *ANOVA results for differences in life expectancy among Mediterranean countries.*

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Country	20	7225	361.3	137.6	<2e-16
Residuals	462	1213	2.6		

A first research hypothesis is if the inequality of this indicator depends on the climate conditions of the countries. A possible indicator is the CDD in the countries.

Figure 2 − *Life expectancy at Bird (total) (Year 2022) and CDD (Year 2020) in the Mediterranean area.*



Among countries with high CDD (above 2,500), Libya and Egypt show lower life expectancy (around 71-72 years), while Algeria has a slightly higher one (76.9 years). Israel stands out with a much higher life expectancy (81.6 years). Among countries with moderate CDD (between 1,000 and 2,499), Spain (83.1 years) shows the highest life expectancy, in contrast with Lebanon (78.8 years). Even in the lowest CDD group (below 999), disparities are evident, ranging from the highest life expectancy in France (83.0 years) to the lowest in Bosnia and Herzegovina (77.1 years).

There appears to be a limited negative correlation (r = 0.45) (Figure 3), suggesting that higher temperatures (leading to more cooling degree days) may be moderately associated with reduced life expectancy. However, given the moderate strength of this relationship and the potential high dispersion of data across countries, further analysis is needed to assess its robustness.

5. Identifying Socioeconomic and Health Patterns Across Mediterranean Countries

A clustering analysis was conducted to identify distinct clusters of countries with similar life expectancy. A K-means clustering was performed on life expectancy data in 2022 with k=3 (the optimal number of clusters was determined using the Elbow

Method), effectively grouping the countries into three distinct clusters based on their life expectancy trends.

The three clusters (High Life Expectancy, Medium Life Expectancy and Low Life Expectancy) are shown in Figure 2.

Figure 3 − *Socioeconomic and Health Patterns across the three clusters of Mediterranean Countries.*

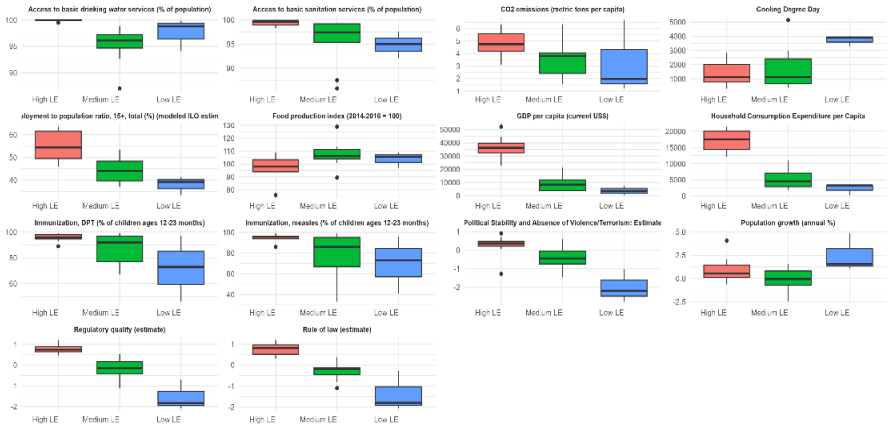


Figure 3 shows the socioeconomic and health patterns across the three clusters.

Countries with High Life Expectancy (between 80.6 and 83.1 years) have strong economies with a GDP per capita ranging between $20,000 and $50,000, stable political conditions, and robust governance, marked by high regulatory quality and rule of law. Health systems are well-developed, providing near-universal access to clean water and sanitation, and high immunization rates above 90%. CO2 emissions are moderate, typically between 4 and 6 metric tons per capita. Socially, employment rates are high and food production is secure.

Countries with Medium Life Expectancy (between 74.3 and 78.5 years) have moderately developed economies, with GDP per capita ranging from $10,000 to $20,000, along with relatively stable governance, though not as robust as high-life-expectancy nations. Access to water and sanitation is good but not universal, and immunisation rates remain high, though slightly lower. CO2 emissions are moderate, reflecting industrial development. Employment rates and food security are mixed.

Countries with Medium Life Expectancy (between 70.2 and 72.3 years) have lower GDP per capita, often below $10,000, and experience weaker governance and higher political instability. Health infrastructure is more limited, with less than 90% of the population having access to clean water and sanitation, and immunisation rates

are lower. CO2 emissions vary but tend to be lower due to less industrialization. Employment is high but often in informal sectors and food production is less secure.

Countries with high life expectancy show a wide range of CDD, from 328.8 in Slovenia to 2828 in Israel. Similarly, countries with medium life expectancy also display variation, with CDD values ranging from 394.6 in Bosnia and Herzegovina to 5135 in Algeria. Notably, some medium-life-expectancy countries, like Algeria, have higher CDD values than any high-life-expectancy country, while others, like Bosnia, have much lower values, close to those of high-life-expectancy nations. Overall, there is no clear distinction in CDD between the high and medium life expectancy groups, indicating that CDD does not strongly differentiate between these categories.

6. Data Issues and Methodological Approach

We extracted the data for this study from the World Development Indicators (WDI) database, a comprehensive source of global development data maintained by the World Bank. We gathered a wide range of indicators covering various domains, including health, environment, economy, and social factors, for the years 2000 to 2023 using the WDI package in R. Indicators with more than 15% missing data were excluded from further analysis to ensure the reliability of the results. This threshold was chosen to balance dataset completeness with the need to retain a sufficient number of indicators.

We further decide to restrict the descriptive analysis of each cluster to selected variables (showed in Figure 3) allowing for a focused investigation into the factors that potentially correlate with life expectancy.

Each variable was chosen based on its potential to influence health outcomes and quality of life. For instance, access to water and sanitation directly impacts public health, while GDP per capita and employment rates reflect economic conditions that often correlate with access to healthcare and social services. Similarly, variables like CO2 emissions and Cooling Degree Days provide insight into environmental conditions, which can affect health through pollution and climate extremes. Governance indicators, such as political stability, regulatory quality, and the rule of law, capture the societal structures that can enhance or hinder life expectancy through governance and social welfare.

We used only the latest available data, even though the year of the data varies across variables. CO2 emissions and Cooling Degree Day data go back to 2020, but given the nature of these variables, significant changes are not expected between 2020 and 2022.

Regarding COVID-19, while the pandemic caused disruptions in various sectors, it likely had a limited direct effect on variables like CO2 emissions and Cooling Degree Days in the long term. CO2 emissions may have temporarily dropped due to lockdowns, but they have generally rebounded quickly post-pandemic, while Cooling Degree Days are driven by climatic factors, largely unaffected by short-term events like the pandemic.

The study focused on Mediterranean countries and includes: Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Montenegro, Morocco, Slovenia, Spain, Syria, Tunisia, and Turkey. Monaco and Gibraltar were excluded due to their small size and limited data availability. Palestine was not included due to a lack of data and no distinction was made between Cyprus and North Cyprus (following the World Bank classification).

7. Conclusions

Life expectancy is considered in this article as a main indicator of health conditions in different Mediterranean countries.The three groups identified through cluster analysis highlight the multiple factors shaping population health, offering insights into how socio-economic and environmental characteristics are shared among countries with similar life expectancy. The findings from this analysis provide guidance for policymakers regarding which instruments should be prioritised to improve health and promote sustainable development in the region.

The results demonstrate that economic factors, such as GDP per capita, along with access to basic services, like clean water and sanitation, play crucial roles in shaping life expectancy. Governance instruments, including regulatory quality and the rule of law, are also strong determinants, suggesting that robust political institutions and effective policies contribute positively to health outcomes. These findings imply that policy interventions aimed at strengthening healthcare systems, improving access to essential services, and fostering economic growth will have the most direct impact on increasing life expectancy. On the other hand, climatic factors, even if correlated with life expectancy, are not connected with this indicator considering the differences we found in neighbouring countries, resulting in spurious correlations.

Despite the evidence found in this analysis, there are some limitations. The data used vary in availability across countries and years, and some potential confounding variables, such as detailed health behaviours or cultural factors, were not included. Finally, data are needed for all the political entities in the region, even if very small or with limited political status, as Malta, Gibraltar, Palestine and North-Cyprus, along with the internal variability of these indicators.

In conclusion, addressing the socio-economic and governance drivers of health will be key to improving life expectancy, achieving sustainable development in the Mediterranean region.

Additionally, future research is necessary to determine the relationships and factors directly associated with life expectancy, and to better understand how these factors influenced health outcomes over time.

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