



Proceeding Paper Vulnerability and Exposure of Mediterranean Coastal Cities to Climate Change-Related Phenomena[†]

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Abstract: The extreme events that the planet is experiencing are indisputable proof of climate change. Effective strategies are required to reduce the exposure and vulnerability of cities to such risks. This work aims to contribute to the cultural and technical debate on the governance of urban transformations for limiting the impacts related to global warming, focusing on the cities of the Mediterranean Sea. The research shows how social and economic characteristics influence the response of cities to climate change-related hazards. This consideration reinforces the idea of seeking integrated solutions to improve the resilience of coastal urban areas within the entire basin.

Keywords: Mediterranean cities; climate change; vulnerability; adaptation; resilience



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1. Introduction

The impacts of climate change seriously threaten cities across the planet. Despite occupying only 2% of the Earth's surface, urban systems are responsible for 60-80% of greenhouse gas (GHG) emissions due to their high concentration of activities and inhabitants. Cities are required to face a double challenge: mitigating the effects of climate change on the one hand, and adapting their structures (grey, green and blue) to inevitable extreme phenomena on the other. Cities must therefore organise their response by coordinating the subsystems of which it is composed, adapting to ongoing climate change, and increasing their resilience [1,2] to extreme weather events, which will become increasingly frequent and intense. Therefore, effective and efficient strategies are required to reduce their exposure and vulnerability to the risks of this unprecedented phenomenon in human history and prevent potential damage to the urban population. The populations living in the poorest countries would pay the highest price because they have fewer resources to invest in increasing the adaptation of their urban and territorial systems to global warming and because of their geographical location (almost always in tropical or equatorial areas). The following graph (Figure 1) highlights how the major cities in developing countries, mostly located in Africa and Asia, and characterised by the highest rates of demographic change projected for 2018–2035, are the most vulnerable to the impacts of climate change.

Climate change projections indicate that global warming conditions in the Mediterranean Sea could be substantially altered, as the Intergovernmental Panel on Climate Change (IPCC) [3] forecasts an increase in surface temperature of around 1.3 °C in 2021–2050 compared to 2011. In general, countries in climate-sensitive areas would pay a heavy bill, just like those bordering the Mediterranean.

Scientific research results and the chronicles of devastating extreme weather and climate events show how immediate and integrated responses are needed to meet this challenge, not only to limit the scale and scope of these phenomena but to reduce their impact on highly anthropic systems.



Figure 1. Percentage change in population in the world's major cities compared to the climate change vulnerability index (2018).

This contribution summarises the first step of a more extensive research work, which intends to develop decision-support tools to identify climate change adaptation solutions, considering different Mediterranean cities' climatic, social, economic, and political peculiarities. The paragraph following this introduction presents the natural hazards related to climate change in the Mediterranean. Next, the network of Mediterranean cities is described in detail to highlight their exposures and vulnerabilities. After reviewing the initiatives already developed and implemented to increase the resilience of cities, the gaps and limitations of the scientific literature in the field and spatial planning strategies to respond to this challenge are highlighted.

2. Climate Risks for Mediterranean Cities

The Mediterranean basin is one of the most sensitive regions to global warming and has been defined as a "Hot-spot" [4], based on the results of global climate change projection scenarios. The latest report of the IPCC [3] highlights that the Mediterranean is among the most vulnerable in the world regarding the impacts of climatic and meteorological phenomena. The global panorama underlines the need to estimate the possible consequences for this region, which will be increasingly hot and dry. During the 20th century, the air temperature in the basin was observed to have increased significantly, by $1.5 \,^{\circ}\text{C}-4 \,^{\circ}\text{C}$ [5]. Over the same period, and with a clear acceleration since 1970, temperatures in southwestern Europe (the Iberian Peninsula, southern France) have increased by around 2 $\,^{\circ}\text{C}$. The same phenomenon has been recorded in North Africa, although it is more difficult to quantify given the discontinuity of the natural and man-made environments in the area. A key element for the climate of the Mediterranean region is the presence of the sea, which represents vital energy and moisture resource for the atmosphere, although the recorded anomalies of the Sea Surface Temperature (SST) govern, at least partially, the air temperature and precipitation phenomena for the surrounding areas [6–8].

Awareness of the impacts of these phenomena on Mediterranean cities has also affected Euro-partnership policies to the extent that new priorities have been defined for the coming decades, intending to strengthen interregional and international cooperation. Among the main cooperation, priorities are actions to mitigate global warming and adapt the region to the resulting phenomena, the development of sustainable economies, digital transformation and civil protection of inhabited settlements [9].

The Mediterranean basin is located in a transition zone between the subtropical and mid-latitude climate areas. The basin territories are characterised by complex and heterogeneous orography and dense and extensive population centres. The Mediterranean is a shallow sea, so its waters warm at higher rates than those of the oceans [10]: in recent years, the temperature of surface waters has increased by as much as 1.4 °C (as of 2018), compared to the temperatures recorded at the end of the last century, reaching up to 30 °C in summer, while that of deep waters by 0.2 °C.

Among the consequences of overheating in the entire Mediterranean basin, much more frequent and intense heat waves have been recorded, as well as longer periods of drought. Another effect, not negligible for coastal cities and the region's blue economy, is the significant rise in sea level. In the last two decades, a rise of 3 cm has been recorded every ten years. This is not an outlier compared to the global trend, and climate experts say it is mainly due to the North Atlantic Oscillation (NAO), i.e., the atmospheric variability between the Andorra and Iceland, responsible for climate change phenomena over a large area of the northern hemisphere. However, this is important data, compared to the increases in 1945–2000 and 1970–2006, when 0.7 mm and 1.1 mm per year were respectively recorded. In addition, the Mediterranean Sea will suffer from significant acidification due to an increased concentration of CO_2 in the atmosphere: the pH of the waters is predicted to decrease from 0.018 to 0.028 units every ten years [11–13]. Even if we succeed in limiting the rise in temperature to below 2 °C, as set out in the Paris Agreement, the Mediterranean region will still feel the dramatic effects of this phenomenon. Researchers and scientists predict that these changes will result in more frequent heatwaves and more frequent hot days, characterised by temperatures above the seasonal average [14,15]. In particular, return periods of heatwaves in the eastern Mediterranean region could decrease from two years to less than one year. In addition, a 10–15% rainfall reduction is expected for southern France, north-western Spain and the Balkans, and up to 30% for Turkey and Portugal. The scenarios are considerably more dramatic if the temperature increase is to be between 2 °C and 4 °C: by 2080, the whole of southern Europe will suffer from widespread decreases in precipitation, up to 30% (especially in spring and summer months), and even ice absence over the Balkans [16]. A 1 °C increase may result in a 4% decrease in rainfall for much of the Mediterranean region, especially the southern part. At the same time, precipitation is expected to increase considerably, by up to 10–20%, for all seasons except summer. Global trends estimated by the IPCC predict that sea-level rise will be between 52 and 98 cm, compared to the current average level [17]. In contrast, a semi-empirical model developed by Vermeer and Rahmstorf [18] predicts a sea-level rise between 75 and 190 cm.

For the Mediterranean, the contributions of water transport across the Strait of Gibraltar, regional changes in river outflows, significant land movements in the eastern part of the basin, and the potential increase in salinity can all influence sea level rise to various degrees. Long-term predictions are therefore very imprecise and unreliable. In any case, even limiting global warming to below 2 °C will result in significant differences in sea surface height, up to 10 cm: the coasts of southern Italy could be largely inundated by 2100; the coastlines of the Mediterranean Sea, more generally, could undergo substantial changes [19].

The impacts on the infrastructures and economies of cities that have lived off the resources offered by the sea for centuries could be further compromised if we consider that these changes will combine with other environmental phenomena, which are not negligible.

It is necessary to consider that the Middle East and North African populations quadrupled between 1960 and 2015. Urbanisation increased from 35 to 65% [20]. Implementing new

irrigation techniques has allowed the intensification of agricultural activity, but land use management could change further, leading to consequences, especially for water resources.

In addition, unless local improvements in wastewater treatment are made, air and water pollution have increased due to growing urbanisation, private transport, and other factors. Political conflicts also have inevitable and dramatic impacts on the environment, as do continuing migration flows, which plague already poor economies and deplete their capability to adapt to climate change.

The combination of natural and anthropogenic hazards, identified in this paragraph, represents the main challenge for urban systems living on the Mediterranean Sea in the coming decades. Some researchers state that the impacts of climate change on the Mediterranean basin are not only accentuated compared to global trends, as shown above, but have been strongly underestimated [21].

3. The Network of Mediterranean Cities

A total of twenty-one countries border the Mediterranean; eleven are in Europe, from west to east, Spain, France, Monaco, Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania, Greece and Malta; the remaining ten are equally divided between Asia, with Turkey, Syria, Lebanon, Israel and Cyprus, and Africa, with Egypt, Libya, Tunisia, Algeria and Morocco. In this sea, which is local and global, different humanities live and come into conflict, claiming aspects of differentiation. Small and large compete, pushing the locals towards the preservation and, therefore, the survival of indigenous values; subjective and collective face each other, sometimes arriving, in the best of cases and over long periods, at mediations and mixings, like liquids of different colours placed in communicating vessels [22]. The Mediterranean is a synonym of common identities, the meeting of religions and the destinies of civilisations, natural environments, diets and foods, cultures and arts, mythologies and physical-somatic characters, formae urbis and climatic typicalities, but also drastic differences between wealth and poverty, models of modernity and profoundly different rights of citizenship. From a cultural point of view, the Mediterranean, unlike other seas, has always had a predetermined and, over time, immutable vocation: that of representing, more than itself, the lands that surround it, the cultures and populations that were born and developed there. Indeed, perspectives on the Mediterranean region significantly differ whether one looks at it from Beirut or Marseilles, Tunis or Athens, Cairo or Barcelona, Istanbul or Naples.

The strategic role that the Mediterranean has played over the decades in the geopolitical chessboard of international relations derives from the profound interrelationship between its central geographical position and the crossroads of civilisations. Moreover, the Mediterranean is undergoing a profound urban transformation linked to population growth, an increase in the rate of urbanisation and profound social and economic changes. This transformation is particularly evident in cities. In a context characterised by a high degree of fragmentation and scarce financial resources, cities in the North and South Mediterranean manage and will have to continue managing often contradictory objectives. The changes in the western world are global; they belong to continents and countries even in other hemispheres. Thus, their effects are local, with direct repercussions on individual territories, determining and conditioning their economy and social destiny. The solutions necessarily involve global and local considerations and compromises and consequently require a general political direction and vision that is scarcely thought out and pursued by the most influential countries. On the one hand, they are trying to achieve greater integration in a globalised economy, but they need to meet the needs of local communities in a sustainable urban environment, in line with the United Nations Sustainable Development Goals (UNSDGs).

In this complex political, economic and cultural framework, cities are configured as main characters of territorial and community identity policies. The future, similar to the prosperous past of the Mediterranean, lies in its cities, symbols of identity and potential, centres of innovation and knowledge, cultural areas with significant heritage and public assets, and heterogeneous resources, which require new cultural, economic and development policies with a strong internationalisation component and projected towards accessions to highly specialised global networks. Indeed, all the countries bordering the Mediterranean are affected by intense and different urbanisation processes. Today, there are many cities with more than a million inhabitants (19 if we consider only coastal cities), and very positive urban growth is expected in the future for all the countries on the southern shore.

On the whole, the coasts of the Mediterranean basin already appear to be densely urbanised, although with considerable differences, which must be taken into account better to understand current and future problems [23]. At the same time, scholars and researchers agree that there is no single model of the Mediterranean city, but "there are numerous European, Arab, Turkish and Balkan cities that are also the Mediterranean, manifesting common characteristics" [24]. The Mediterranean is, therefore, a place where there are cities that express their belonging to this region in every corner, and others in which only a few edges survive that are increasingly surrounded by features that have little to do with the classically understood Mediterranean characteristics, but which are nevertheless the Mediterranean. Each urban centre represents an indispensable strength, and their union could become the foundation of a future Mediterranean, as advocated by the Euro-Mediterranean partnership policies. It is natural to identify coastal cities, but inland cities, even the most northern (Lyon) or eastern (Ankara) ones (Figure 2), tend to express the most Mediterranean side of themselves, thanks to their multi-ethnic connotation.



Figure 2. Mediterranean cities (authors' elaboration).

The night satellite shot of the Mediterranean allows us to synthetically capture the forms of urbanisation along its shores [25]. In particular, the northern shore from Spain to Italy appears densely populated, but according to significantly different settlement types. Starting from the west coast, from Andalusia to the Valencia region, we observe a territory mainly dominated by voids, not urbanised, even though it is a region with a tourist vocation. The settlements show a decidedly centralised configuration, with urban islands linked by a weak network of small coastal centres. Among the most important cities are Gibraltar, Malaga, Granada, Almeria, Cartagena, Murcia, Alicante, and Valencia's metropolitan area.

This configuration changes radically at the mouth of the river Ebro, from Barcelona to Florence. From more diffuse and filamentary urbanisation, cities have a linear conurbation, a sign of the southern European space's organisation intersects with the settlement line of the Rhone. Within this line, we can recognise greater centres such as the urban areas of Barcelona, Perpignan, Montpellier, Nimes, Aix-en-Provence, Marseille, Toulon, Nice, Genoa, La Spezia, Pisa and Livorno. The characteristic of this linear conurbation is that it is not large cities that dominate the coastal space, but a very concentrated settlement pattern on a small coastal corridor, with a strong infrastructure. This structure tends to lose its significance along the second part of the Tyrrhenian coast: settlements appear to be rarefied, concentrated in small units, except for the large metropolitan areas of Rome and Naples, which, by polarising the intense development of the central Tyrrhenian regions, lead to the formation of the strongest urban macro-region in the European Mediterranean arc, with around eight million inhabitants (almost double the Barcelona-Marseille bipole). Significant urban areas are also found along the Calabrian and Sicilian coasts, with a more linear and non-metropolitan settlement pattern. This connotation is even more evident along the Adriatic coast, from Brindisi to Trieste, with a few exceptions in correspondence with geo-environmental obstacles such as the Gargano promontory and the Po delta. The night-time satellite image of Italy shows a profound split in urban morphologies between western and eastern Italy, synonymous with other economic and social differences.

Moreover, the Adriatic Sea acts as a physical separator for the Balkan coastal systems, whose city model is intermediate between the linear conurbation and the urban islands. Unlike the Italian side, along the coast of former Yugoslavia and Albania, geography offers insurmountable resistance to urban centres' transverse and longitudinal connection. The southern shore appears decidedly less urbanised: the settlements take on an enclave configuration, with urban centres arranged at regular intervals and micro-constellations of smaller centres. The roots of Tangier, Algiers, Melilla, Tunis, Nabul, Suza, Tripoli and Benghasi can be traced back to the history of the Phoenicians and Punic people, which were transformed into outposts by the Roman colonisation, and then became hubs on the trans-Saharan routes at the time of Islamic civilisation. There is a significant similarity with the urban island structure of the Iberian coast, probably a consequence of the eight centuries of common Arab domination. Another characteristic of the southern shore of the Mediterranean is that the settlement area extends deep from the coast, particularly in Morocco. An exception to this structure is the area of the Nile delta, with very high population density but surrounded by the desert emptiness of the banks of the Red Sea and the Sinai Peninsula. To underline the difference between the urban layouts of the Mediterranean cities, it is enough to refer to the population residing in cities, whose global average value is 54%: only 40% of the African population resides in urbanised areas, against 75% of Europeans. Further on, the urban configuration returns to a densely inhabited filament, characterised by the continuity of small and medium-sized centres (Gaza, Tel Aviv, Haifa, Beirut, Tripoli), and parallel to a second guideline inland, about a hundred kilometres away, which connects cities such as Amman, Damascus, Homs, Hama, Aleppo and Gaziantep. Finally, the shores of Turkey and Greece have many similarities, especially in terms of the orography and the rugged coastline. Here the settlement morphology returns to urban islands, markedly rarefied in the Mediterranean Sea, with few links to the hinterland, while more concentrated on the shores of the Aegean.

Studying the countries of the Mediterranean and their undoubted role in the challenges of the 21st century, including adaptation to climate change, means being able to know a continuous link, which goes beyond national borders, which brings the substance of inland populations, work and wealth to the sea in the proliferation of ports, and then to the trajectories of the ship routes that connect and contaminate, bring and import, in an incessant and vital flow.

Given this, the Mediterranean is a sensitive area, not only from a climatic point of view. Nevertheless, the Mediterranean has been a laboratory of fruitful religious and cultural intertwining, a land of mediation capable of suggesting avenues of civil, political and, consequently, economic development [26]. Hence, the response to the climate crisis in Mediterranean cities must be the result of mutual dialogue if it is to be effective.

4. Conclusions

Given the dramatic consequences foreseen by climatic scenarios, by the end of the XXI century, the cities on the Mediterranean coast cannot fail to respond jointly to the call for action. On one hand the overlapping of different cultures, histories, and urban and economic structures contributed to an increasingly prosperous economic and cultural environment in the Mediterranean; on the other hand, long-standing and new dynamics, such as the spread of the new coronavirus, others that are re-emerging after years of dormant investigation, such as the Israeli-Palestinian issue, have definitely fractured the framework of priorities of the nations and cities of the Mediterranean coast. In light of this, the scientific community and citizens have the difficult task of guiding the action of stakeholders and policymakers. In some territorial contexts, this task may be even more difficult. How far are we from this change of path?

Albeit this contribution represents the first step in more extensive research work, it contributes to raising awareness that the Mediterranean issue must be fully included in the political agenda of the countries bordering the *mare nostrum*, by improving cultural and scientific knowledge on climate change, highlighting the extent to which cities are exposed to the phenomena expected in the coming decades and underlining the heterogeneous vulnerabilities of urban systems belonging to a common history and destiny.

However, the proposed path seems to be the right one: to make the countries of the basin share the importance of a common and participated vision of the problems of the Mediterranean area, and be able to elaborate ideas and projects for a future of civil, economic, social and religious coexistence of all its populations.

Despite the difficulties and tensions, the political initiatives promoted by the European Union have multiplied, based on cooperation agreements and financial protocols, with the aim of rebalancing trade, establishing financial and technical cooperation actions, and revitalising the cultural heritage and human sciences. These actions, which can be traced back to the notion of global partnership, had an important point of reference in the Barcelona Conference, November 1995, which brought together the foreign ministers of the 15 States than members of the European Union and those of 12 Mediterranean States. The Barcelona Conference marks the first major turning point in policies for and towards the Mediterranean since for the first time, the Euro-Mediterranean Partnership is openly talked about, officially introducing the geopolitical entity "The Mediterranean" [27].

The centrality of cultural heritage for the definition and representation of the countries' identity was reaffirmed. Despite the numerous initiatives, however, the outcome of the Barcelona Conference is not positive: instead of bringing the two shores of the Mediterranean closer, they have moved further apart, and trade between homogeneous areas, which had been invested in and hoped for, has not registered significant results [28–30].

Although this research represents a first step towards defining decision supports tools to enhance the climate resilience of coastal cities, these findings contribute in several ways to understanding Mediterranean issues and provide a basis for further research activities.

One of the most significant findings of such research concerns understanding the existence of different Mediterranean city domains considering the urban, social and economic characteristics that distinguish them. Albeit Mediterranean cities may aim to achieve the same goal, ad hoc strategies and solutions need to be designed and implemented to be effective. The cities of the Mediterranian basin can be grouped into main four quadrants, with similar features, that will potentially be the fertile ground for customised and, at the same time, integrated measures to pursue climate resilience.

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