Climate Change Environmental and Social challenges in the Mediterranean Basin

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Abstract

The Mediterranean region is a unique ecological hotspot, straddling Europe, Africa, and the Middle East. It is currently experiencing rapid climate change, warming 20% faster than the global average. Its ecosystems—ranging from coastal wetlands to semi-arid landscapes—are highly vulnerable to rising temperatures, altered precipitation, and extreme weather events. These environmental changes are driving desertification, biodiversity loss, and rising sea levels, while socio-economic challenges such as water scarcity, food insecurity, and migration intensify the crisis. Raising awareness and fostering outreach are crucial for mobilizing collective action to address these interconnected challenges and protect both the environment and local communities.

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Introduction

Characterized by warm, dry summers and mild, wet winters, the Mediterranean basin hosts a rich biodiversity and supports a variety of ecosystems, from coastal wetlands to semi-arid landscapes (Bondel & Aronson, 1999). However, climate change is increasingly disrupting these delicate environments. Rising temperatures, altered precipitation patterns, and extreme weather events are becoming more frequent, posing significant threats to both natural ecosystems and human societies (IPCC AR6 CCP4, 2023). The Mediterranean is warming at a rate 20% faster than the global average, making it particularly vulnerable to desertification, biodiversity loss, and sea level rise (IPCC AR6 CCP4, 2023). Additionally, socio-economic challenges such as water scarcity, food security, and climate-driven migration further compound the crisis. Understanding the complexities of climate change in the Mediterranean is essential for developing mitigation and adaptation strategies that can protect its environment and the livelihoods of the millions who depend on it.

Anthropogenic climate change is primarily driven by the increasing levels of greenhouse gases (GHGs) in the atmosphere (Dilmore & Zhang, 2018). Its primary direct consequence is global warming. **However, climate change is NOT just global warming.**

The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental body of the United Nations, established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) that is dedicated to providing the world with objective, scientific information relevant to understanding the scientific basis of the risk of human-induced climate change, its natural, political, and economic impacts and risks, and possible response options. According to the sixth Assessment Report (AR6) of the IPCC, the physical effects of climate change include rising temperatures and declining precipitations, ocean warming, acidification, and deoxygenation, sea-level rise, and higher rates of extreme weather events. This will and is already exacerbating existing pressures on limited water resources and inducing desertification and land degradation, especially in the Eastern Mediterranean, causing dramatic environmental and social issues. Population pressure and water-intensive activities such as irrigation already impose stress on water supplies, posing dangers to human health, ecosystems, and national economies of countries. Moreover, projected sea-level rise will affect densely populated coastal regions.

Particularly severe impacts are projected for the Middle East and North Africa (MENA) countries which are already facing environmental degradation, water scarcity, food insecurity worsening economic and societal instabilities (Namdar et al., 2021). When acknowledging that these countries, during the last decade, experienced exponential population growths, it becomes easy to understand how these factors could contribute to security risks and conflicts in the region.

Projections and impacts of future climate change in the Mediterranean

Temperature changes

Ocean warming occurs primarily due to the increased concentration of greenhouse gases in the atmosphere, which trap more heat and raise global temperatures. As the Earth's atmosphere warms, so do the surface waters of the oceans, which absorb much of this excess heat. This is exacerbated by the thermal expansion of seawater, meaning as temperatures rise, the volume of seawater increases, contributing to sea level rise. Additionally, changes in ocean circulation patterns, such as the weakening of major currents, can further amplify regional warming. These shifts in ocean temperature can lead to disruptions in marine ecosystems, including coral bleaching, changes in species distribution, and altered fish migration patterns.

According to the Intergovernmental Panel on Climate Change's Sixth Assessment Report (IPCC AR6), the Mediterranean region is projected to experience significant climatic changes by the end of the 21st century. Under high-emission scenarios, temperature increases in the Mediterranean during the summer season are projected to range from approximately 1.22°C to 8.49°C, depending on the specific model and RCP scenario considered (Cos et al., 2022). These projections underscore the critical need for adaptive strategies to mitigate the environmental and socio-economic impacts of climate change in the Mediterranean region. Climate changes will lead to shorter winters, dryer, longer and hotter summers, more frequent heat wave occurrence, and more variability and extreme weather events occurrence. Heat waves are periods of excessively hot weather which are usually measured relative to usual weather in the area and relative to normal temperature from a season. The increase in the frequency of this phenomenon will cause at the end of the century the extension of the summer with a consequent reduction of the winter season (IPCC AR6 C4, 2023).

Ocean acidification

Due to increasing concentrations of carbon dioxide in the atmosphere, CO_2 is actively being absorbed by the ocean, where it reacts with seawater to form carbonic acid (H_2CO_3). Almost immediately, carbonic acid dissociates to form bicarbonate ions (HCO^{3-}) and hydrogen ions (H^+). As the concentration of hydrogen ions increases, the water becomes more acidic, and, as this happens, the concentration of CO_3^{2-} in seawater decreases (Doney et al., 2009).

"*Linkages between the build-up of atmospheric CO_2 and the slowing of coral calcification due to ocean acidification. Approximately 25% of the CO_2 emitted by humans in the period*

2000 to 2006 was taken up by the ocean where it combined with water to produce carbonic acid, which releases a proton that combines with a carbonate ion. This decreases the concentration of carbonate, making it unavailable to marine calcifiers such as corals". – (Hoegh-Guldberg et al., 2007)

These surplus of hydrogen ions reacts with carbonate ions to form more bicarbonate. As carbonate becomes less abundant, calcifying organisms have more difficulty building and maintaining their shells and skeletons. Increased acidity can even cause some carbonate shells and skeletons to dissolve.

Oxygen deoxygenation

Both observations and numerical models indicate that oxygen is declining in the modern open and coastal oceans, including estuaries and semi-enclosed seas (Gregoire et al., 2019). Since the middle of the last century, there has been an estimated 1%–2% decrease (that is, 2.4–4.8 Pmol or 77 billion–145 billion tons) in the global ocean oxygen inventory, while, in the coastal zone, many hundreds of sites are known to have experienced oxygen concentrations that impair biological processes or are lethal for many organisms (IPCC AR6, 2023). Climate models predict declines in oceanic dissolved oxygen produced by global warming (Bates & Johnson, 2020). Reduced oxygen levels may have dramatic consequences for ecosystems and coastal economies (Stramma et al., 2008).

Changes in precipitation

In terms of precipitation, the Mediterranean is expected to see a decrease in annual rainfall, particularly during the summer months. This reduction in precipitation, coupled with higher temperatures, is likely to exacerbate drought conditions and increase the risk of desertification in vulnerable areas. According to the ACACIA Project climate scenarios (IPCC, baseline period: 1961-1990), summer precipitations in 2080 will have declined between 23-35% in Southern Europe and around 60% in North Africa.

Extreme wheather events and hazards

In Europe and North Africa average precipitation reduction is associated with a reduced number of precipitation days (Christensen et al., 2004). For the future, a significant prolongation of very long dry spells is expected by end of the century (Voss et al., 2002) and considerable drying over western Mediterranean and North Africa (Beniston et al., 2007). In

Northern Africa, the risk of extreme events, in particular droughts, is likely to increase (Schilling et al., 2020).

Projected sea-level rise

The two main causes of future sea-level rise, both caused by the increase in temperatures, are the melting of ice and the thermal expansion of oceans. The IPCC's AR6 predicted an average sea-level rise of 0.3-2.0 m by 2100. Towards the end of the twenty-first century, projected sea level rise will deeply affect low-lying coastal areas worldwide.

Impact of climate change on water supply and water-related conflicts

Water is the resource most directly and strongly negatively affected by climatic changes. MENA region is already one of the regions with high water scarcity and severe droughts and The North African countries are either termed water stressed or water scarce, with Algeria and Tunisia facing the highest level of water scarcity while in Egypt and Morocco water is less scarce (Schilling et al., 2012). Higher temperatures and less precipitations will likely strongly reduce the overall water availability.

Water scarcity is a key factor in conflicts, particularly in the Middle East, where the Jordan River is a shared but contested resource among Israel, Jordan, Palestine, and Syria (Salameh et al., 2021). Tensions over water have been exacerbated by geopolitical conflicts, such as the 1967 Six-Day War, which resulted in Israel's occupation of the Golan Heights and the West Bank, pushing Palestinian communities further from vital water sources. More recently, Israel's plans to annex the Jordan Valley and northern Dead Sea highlight the strategic importance of water in territorial disputes.

Beyond the Middle East, water shortages are intensifying in Southern Europe and North Africa due to climate change. Rising temperatures are expected to significantly reduce summer water availability. These shortages will impact agriculture, forestry, and hydroelectric power, exacerbating socio-economic instability. Globally, increasing water demand due to population growth is a major challenge.

Impact of climate change on human migration

African countries are experiencing an exponential growth of the population which wight directly on food security and water demand. The discrepancies in income and development

between Southern Europe and the North African MENA countries are a major driver for people to migrate across the Mediterranean Sea. With a rising warming and decreasing precipitation, it may be increasingly difficult to sustain the living standards and provide development opportunities for a growing population (Wodon et al., 2014).

Population pressures are amplified by migration from the Sahel region (Wodon et al., 2014). The Sahel is the ecoclimatic and biogeographic realm of transition in Africa between the Sahara to the north and the Sudanian savanna to the south. Having a semi-arid climate, it stretches across the south-central latitudes of Northern Africa between the Atlantic Ocean and the Red Sea. The Sahel mainly receives a low to very low amount of precipitation annually. The steppe has a very long, prevailing dry season and a short rainy season. The precipitation is also extremely irregular and varies considerably from season to season.

According to WBGU (2008), the increase in drought, soil degradation and growing water scarcity in combination with high population growth, unstable institutions, poverty or a high level of dependency on agriculture means that there is a particularly significant risk of environmental migration occurring and increasing in scale (Schellnhuber, 2010). The number of *climate refugees* is predicted to dramatically rise, up to several hundred millions globally. These numbers have been questioned as speculative and exaggerated, lacking justification and empirical evidence. A comprehensive study (Black et al., 2011) shows that migration has to be considered as a multicausal and complex process that precludes isolating environmental factors from other migration drivers. However, as of right now, environmental factors do not entitle the refugee status.

References

Bates, N. R., & Johnson, R. J. (2020). Acceleration of ocean warming, salinification, deoxygenation and acidification in the surface subtropical North Atlantic Ocean. *Communications Earth & Environment*, *1*(1), 1–12. https://doi.org/10.1038/s43247-020-00030-5

Beniston, M., Stephenson, D. B., Christensen, O. B., Ferro, C. A. T., Frei, C., Goyette, S., Halsnaes, K., Holt, T., Jylhä, K., Koffi, B., Palutikof, J., Schöll, R., Semmler, T., & Woth, K. (2007). Future extreme events in European climate: An exploration of regional climate model projections. *Climatic Change*, *81*(1), 71–95. https://doi.org/10.1007/s10584-006-9226-z

Black, R., Adger, W. N., Arnell, N. W., Dercon, S., Geddes, A., & Thomas, D. (2011). The effect of environmental change on human migration. *Global Environmental Change*, *21*, S3–S11. https://doi.org/10.1016/j.gloenvcha.2011.10.001

Bondel, J., & Aronson, J. (1999). Biology and Wildlife of the Mediterranean Region. *Oxford University Press*, *38*(13), 1723–1724. https://doi.org/10.1080/0022293031000156213

Christensen, J. H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., Jones, R., Kolli, R. K., Kwon, W.-T., Mearns, L., Menéndez, C. G., Räisänen, J., Rinke, A., Sarr, A., Whetton, P., Arritt, R., Benestad, R., Beniston, M., Bromwich, D., … Giorgi, F. (2004). *Regional Climate Projections*.

Cos, J., Doblas-Reyes, F., Jury, M., Marcos, R., Bretonnière, P.-A., & Samsó, M. (2022). The Mediterranean climate change hotspot in the CMIP5 and CMIP6 projections. *Earth System Dynamics*, *13*(1), 321–340. https://doi.org/10.5194/esd-13-321-2022

Dilmore, R., & Zhang, L. (2018). Greenhouse Gases and Their Role in Climate Change. In V. Romanov (Ed.), *Greenhouse Gases and Clay Minerals: Enlightening Down-to-Earth Road Map to Basic Science of Clay-Greenhouse Gas Interfaces* (pp. 15–32). Springer International Publishing. https://doi.org/10.1007/978-3-319-12661-6_2

Doney, S. C., Fabry, V. J., Feely, R. A., & Kleypas, J. A. (2009). Ocean Acidification: The Other CO2 Problem. *Annual Review of Marine Science*, *1*(Volume 1, 2009), 169–192. https://doi.org/10.1146/annurev.marine.010908.163834

Gregoire, M., Gilbert, D., Oschlies, A., & Rose, K. (2019). *What is ocean deoxygenation?* (D. Laffoley & J. M. Baxter, Eds.; pp. 1–21). IUCN. http://dx.doi.org/10.2305/IUCN.CH.2019.13.en

Hoegh-Guldberg, O., Mumby, P. J., Hooten, A. J., Steneck, R. S., Greenfield, P., Gomez, E., Harvell, C. D., Sale, P. F., Edwards, A. J., Caldeira, K., Knowlton, N., Eakin, C. M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R. H., Dubi, A., & Hatziolos, M. E. (2007). Coral Reefs Under Rapid Climate Change and Ocean Acidification. *Science*, *318*(5857), 1737–1742. https://doi.org/10.1126/science.1152509

IPCC AR6 C4. (2023). *Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (1st ed.). Cambridge University Press. https://doi.org/10.1017/9781009325844

IPCC AR6 CCP4. (2023). *Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (1st ed.). Cambridge University Press. https://doi.org/10.1017/9781009325844

Namdar, R., Karami, E., & Keshavarz, M. (2021). Climate Change and Vulnerability: The Case of MENA Countries. *ISPRS International Journal of Geo-Information*, *10*(11), Article 11. https://doi.org/10.3390/ijgi10110794

Salameh, M. T. B., Alraggad, M., & Harahsheh, S. T. (2021). The water crisis and the conflict in the Middle East. *Sustainable Water Resources Management*, *7*(5), 69. https://doi.org/10.1007/s40899-021-00549-1

Schellnhuber, H. J. (2010). *Climate Change as a Security Risk* (0 ed.). Routledge. https://doi.org/10.4324/9781849775939

Schilling, J., Freier, K. P., Hertig, E., & Scheffran, J. (2012). Climate change, vulnerability and adaptation in North Africa with focus on Morocco. *Agriculture, Ecosystems & Environment*, *156*, 12–26. https://doi.org/10.1016/j.agee.2012.04.021

Schilling, J., Hertig, E., Tramblay, Y., & Scheffran, J. (2020). Climate change vulnerability, water resources and social implications in North Africa. *Regional Environmental Change*, *20*(1), 15. https://doi.org/10.1007/s10113-020-01597-7

Stramma, L., Johnson, G. C., Sprintall, J., & Mohrholz, V. (2008). Expanding Oxygen-Minimum Zones in the Tropical Oceans. *Science*, *320*(5876), 655–658. https://doi.org/10.1126/science.1153847

Voss, R., May, W., & Roeckner, E. (2002). Enhanced resolution modelling study on anthropogenic climate change: Changes in extremes of the hydrological cycle. *International Journal of Climatology*, *22*(7), 755–777. https://doi.org/10.1002/joc.757

Wodon, Q., Burger, N., Grant, A., & Liverani, A. (2014, June). *Climate Change, Migration, and Adaptation in the MENA Region* [MPRA Paper]. https://mpra.ub.uni-muenchen.de/56927/