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Report of the Task Force on

Water Resources

Eastern Mediterranean and Middle East Climate Change Initiative

Special edition for the June 7th, 2022 Ministerial Meeting in Lemesos, Cyprus.
Published by The Cyprus Institute, www.cyi.ac.cy.

Eastern Mediterranean and Middle East Climate Change Initiative, Report of the Task Force on Water Resources. Received: July 2021.

https://emme-cci.org/

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Water Resources

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Abstract

This report surveys the state of water resources in the Eastern Mediterranean and Middle East (EMME) and the challenges imposed by climate change on a water-scarce region. Reviewing national climate change adaptation strategies and evaluating the effectiveness of water-related adaptation policies and measures across the countries of the region, the report identifies gaps in research, policy and knowledge related to climate adaptation in the water sector.

Hydrologic modelling studies demonstrate that reduced rainfall, higher temperatures and greater evaporative demand will increase water-supply risks and water-quality problems. The climate adaptation measures of national adaptation strategies and plans reveal a good understanding of these threats, but implementation and financing have not kept pace.

The report applies a conceptual framework for achieving climate resilience and water security in the region, which recognises the systemic aspects of climate change, water scarcity and shared water resources in the region. The framework's six lines of action for climate resilience and water security are governance; regional cooperation; finance; research and technology; reconstruction and resilience; and capacity development. Research initiatives should consider the application of the climate-water-energy-food nexus for improving water governance and achieving climate resilience and water security.

Abbreviations

ASR	Aquifer Storage and Recovery
BGR	German Federal Institute for Geosciences and Natural Resources
CEDARE	Center for Environment and Development for the Arab Region and Europe
CORDEX	Coordinated Regional Climate Downscaling Experiment
EC	European Commission
EMME	Eastern Mediterranean and Middle East
ESCWA	Economic and Social Commission for Western Asia
EU	European Union
GCC	Gulf Cooperation Council
GCF	Green Climate Fund
GIZ	German Agency for International Cooperation
IGRAC	International Groundwater Resources Assessment Center
IWRM	Integrated water resources management
MENA	Middle East and North Africa
NDC	Nationally Determined Contribution
RCREEE	Regional Center for Renewable Energy and Energy Efficiency
RICCAR	Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region
SDG	Sustainable Development Goals
UAE	United Arab Emirates
UfM	Union for the Mediterranean
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization UNFCCC United Nations Framework Convention on Climate Change
WEFE	Water-Energy-Food-Ecosystems

Executive summary

Most of the Eastern Mediterranean and Middle East (EMME) region is marked by low rainfall, dry summers and high evapotranspiration. A country's renewable water resources are comprised of the fraction of the rain that flows into streams and surface water bodies or recharge groundwater aquifers, plus the net inflow of surface water and groundwater across the country's borders. Matching water resources with countries' annual per capita water needs for household use, agriculture and industry, natural and manmade water scarcity levels can be identified. Nine of the seventeen EMME countries are below the absolute water scarcity threshold of 500 m^3/year per capita, including all six countries of the Gulf region, Jordan and Palestine. Four others – Cyprus, Egypt, Lebanon and Syria – are below the scarcity threshold of 1,000 m^3/year per capita. This places nearly 200 million people under conditions of water scarcity. Greece, Iraq, Iran and Turkey are currently the only countries above the water scarcity threshold.

These water resources' estimates represent long-term annual averages under a variable climate. These numbers mask the differential water availability over the area of the countries, as well as seasonal water shortages. In many places, the long, dry summer season affects the livelihoods of the rural population. Population growth also continues to shrink the countries' per capita water resources.

In nine of the seventeen EMME countries total annual water withdrawals exceed the total annual renewable water resources, indicating an unsustainable extraction of groundwater resources. Intrusion of seawater in overexploited aquifers has made many coastal aquifers unsuitable for use. Treated sewage water, agricultural drainage water and fossil groundwater resources are supporting the water needs of the countries. The Gulf countries are strongly reliant on desalination, which also accounts for more than 20% of water use in Israel and Cyprus. Desalination is an energy intensive process and is almost completely reliant on fossil energy, which contributes to greenhouse gas emissions and climate change.

Agriculture remains the top water user in the region, accounting for 85% of all water withdrawals. Universal and equitable access to safe and affordable drinking water for all, which is the first Sustainable Development Goal target for water (SDG 6.1), is still far from being achieved. The water problems of the region are aggravated by poor water governance, insufficient financial investments, inadequate hydrologic monitoring system and a scarcity of publicly available data.

The fifth target of SDG 6 emphasises the importance of integrated water resources management (IWRM) as a holistic framework for addressing supply-demands and pressures on water resources within and across different sectors and at different scales. Integrated management ensures that resources are evaluated, developed, used and managed in an equitable, sustainable and efficient manner, in consideration of local political, economic and social realities. SDG 6.5 aims to achieve IWRM at all levels, including through transboundary cooperation, by 2030. The EMME countries depend heavily on shared, transboundary surface water and groundwater resources, yet the cooperation needed for effective water management is insufficient or absent.

Climate change is making the region hotter and drier, imposing additional constraints and challenges for the region. Climate change projections show a 20-40% reduction in precipitation for the Mediterranean countries of the EMME region by the end of the century under the high-emissions RCP8.5 scenario[1]. Climate change projections also show more severe droughts and possible increases in extreme rainfall events. A larger share of the rainfall is expected to fall as extreme events, increasing the stresses on water infrastructure. Hydrologic modelling studies demonstrate that reduced rainfall, higher temperatures and greater evaporative demand will increase water-supply risks, water-quality problems and will affect human and ecosystems' health.

The Water Task Force Report of the "EMME Climate Change Initiative" evaluated the implementation and effectiveness of water-related adaptation policies and measures across the countries of the EMME region and proposed policy and research actions and initiatives to address climate challenges for achieving water security and enhance regional cooperation. A conceptual framework is proposed for achieving climate resilience and water security in the region. The framework recognises the human rights to water and sanitation, in line with the United Nations resolution, and the systemic aspects of climate change, water scarcity and shared water resources. Actions in six areas should guide the region to water security and climate resilience: (i) good governance; (ii) regional cooperation; (iii) financing and investment; (iv) research and technology development; (v) climate resilience and reconstruction; and (vi) capacity building.

Based on a systematic review of the climate adaptation strategies and plans of the EMME region, fifty-four water-related adaptation measures were identified. The measures demonstrate a good understanding of the threats and challenges to the water sector and commonalities across the EMME countries. However, the evaluation of the identified adaptation measures revealed that the implementation and financing of the measures have so

1. RCP8.5 is one of four "representative concentration pathways" for greenhouse gas concentrations defined by the Intergovernmental Panel on Climate Change in 2014. The four pathways were used for climate modeling in the IPCC's Fifth Assessment Report (2014).

far been insufficient. The assessment of the effectiveness of the water-related adaptation measures in the EMME region emphasized the need for improving the use of scientific evidence in decision making for attaining climate resilience and water security in the region. Research initiatives to address the climate-water knowledge gaps in the EMME region should focus on the following issues:

- Implementation of the climate-water-energy-food nexus;
- Expanding, upgrading and automating hydrologic monitoring networks throughout the EMME region;
- Establishment of an open access climate-water database and knowledge hub and improvement of data quality management;
- Economic and environmental cost-benefit analyses of measures to achieve the climate resilience of the water sector across the region;
- Zero-brine and zero-carbon desalination systems;
- Sustainable use of treated sewage water and other marginal water resources, considering the effects and fate of chemicals and emerging contaminants on soils, water and food;
- Development of forecasting, monitoring and alert systems.

Policy initiatives should focus on:

- Improving water governance, including the establishment of national open access databases, development of a water accounting system, regulation of groundwater abstraction, sound water allocation and cuts, with special attention to integrated water resources management (SDG 6.5) and the application of the climate-water-energy-food nexus;
- Regional cooperation, including the shared management of transboundary water resources, the establishment of riparian rights with neighbouring countries and the creation of transboundary organizations;
- Sustainable financing and investment, including integration of public and private finance in the water sector, water pricing and subsidies;
- Reducing water demand, increasing irrigation efficiency, promoting hydroponics, water savings technologies, water metering and network maintenance and reduction of losses
- Improving water supply, including desalination with net zero-carbon, improving waste water treatment, reuse of grey and treated waste water, enhancing recharge of aquifers and rain water harvesting;

- Resilience and reconstruction, including development of river basin management plans and drought plans, improving management of dam water bodies, improving forecasting monitoring and alert systems;
- Capacity building and educational initiatives for the water sector to support water governance capacity, such as the establishment of an UNESCO-IHP Metropolitan ECO-MED Academy;
- Raising awareness and improving school curricula on climate change and water security.

1. Scope and purpose

The Eastern Mediterranean and Middle East (EMME) Climate Change Initiative is a response to growing scientific evidence that the extent of climate change and the severity of its consequences for the EMME region significantly exceed the global average. Recent studies from prominent institutions have classified the region, which is home to nearly 500 million people, as a global hot-spot for climate change and particularly vulnerable to its impacts. Such research, including from the Cyprus Institute and its partners, has also provided important insights into the effects of climate change on water availability, agriculture, weather extremes, public health, ecosystems and tourism, and on humanitarian and security issues, including mass migration of environmental refugees. These effects are of great concern not only to the EMME countries, but to the international community, especially Europe, given the prospect of a humanitarian crisis of unprecedented scale that would likely exacerbate regional geopolitical instabilities in the region.

In March 2019, the Council of Ministers of the Republic of Cyprus approved the EMME Climate Change Initiative, a governmental initiative for coordinating regional actions to ameliorate the impact of global warming across the Mediterranean as well as the development of a comprehensive plan to reduce greenhouse gas emissions in line with the 2015 Paris climate accord. The Initiative has been communicated to the countries of the EMME region, to European Union member states, to the United Nations and to other international organisations.

The aims of the initiative are as follows:

- To establish a common understanding of climate change processes and impacts in the region, to identify gaps in knowledge, and to propose ways to address them
- To determine the most effective, rapid and economical way to achieve the targets of the Paris agreement at the national level
- To develop a policy toolkit for the amelioration of climate change impacts on various sectors
- To enhance regional cooperation and capacity building by promoting international mobility, sharing good practices, developing joint educational programmes, advancing research and innovation, and participating in joint ventures and projects.

Within the framework of the EMME Climate Change Initiative, the Cyprus Institute is responsible for the first phase of the project: building comprehensive scientific foundations and developing a set of actions for policy makers to use to reach the goals of the initiative. The Cyprus Institute and its partners are pursuing this task in part through task forces in 13 scientific areas, including water resources.[2]

Each task force has been asked to produce a report ("white paper") in its area of focus. The thematic reports will inform a comprehensive scientific report that will offer an overarching conclusion, as well as feasible and affordable solutions to address the impacts of climate change in key socioeconomic sectors.

The current report reviews the state of water resources in the EMME region and the challenges imposed by climate change on a region where water is already scarce. Reviewing national climate change adaptation strategies and evaluating the effectiveness of water-related adaptation policies and measures across the countries of the region, the report identifies gaps in research, policy and knowledge related to climate adaptation in the water sector. Policy and research actions and initiatives to address climate challenges for achieving water security and regional cooperation are proposed.

The next section presents the geographic setting of the report, highlighting water resources and their management. Section 3 introduces a conceptual framework for achieving climate resilience and water security in the region, one that recognises the systemic aspects of climate change, water scarcity and shared water resources. The framework's six lines of action for climate resilience and water security are governance; regional cooperation; finance; research and technology; reconstruction and resilience; and capacity development, as adapted from ESCWA (2019a). The proposed actions address the three pillars of sustainable development: social, economic and environmental. Section 4 maps the policy landscape in the six action areas. It reviews national climate change adaptation strategies and presents an expert evaluation of the implementation and effectiveness of water-related adaptation policies and measures in the countries of the EMME region. Policy recommendations are presented in Section 5.

2. These 13 task forces are: The Scientific Basis; Energy Systems; Built Environment; Health; Water resources; Agroforestry and Food Chain; Marine Environment/Resources; Education and Outreach; Migration; Tourism

Enabling Technologies; Development of Green Economy and Innovation; Cultural Heritage

2. Geographic setting

This report addresses the water resources of the 17 counties of the Eastern Mediterranean and Middle East. The EMME region encompasses partly overlapping subsets of Mediterranean countries, Arab countries and Gulf countries on the European, Asian and African continents (Figure 2.1).

The nine Mediterranean countries of the EMME region (Cyprus, Egypt, Greece, Israel, Jordan, Lebanon, Palestine, Syria, Turkey) are among the 26 covered in the recent Mediterranean assessment report prepared by the independent network of Mediterranean Experts on Climate and Environmental Change (MedECC, 2020). MedECC is supported by the United Nations Environment Programme's Mediterranean Action Plan (through its Plan Bleu Regional Activity Centre); the Union for the Mediterranean (through its secretariat); and many other regional, national and local institutions.

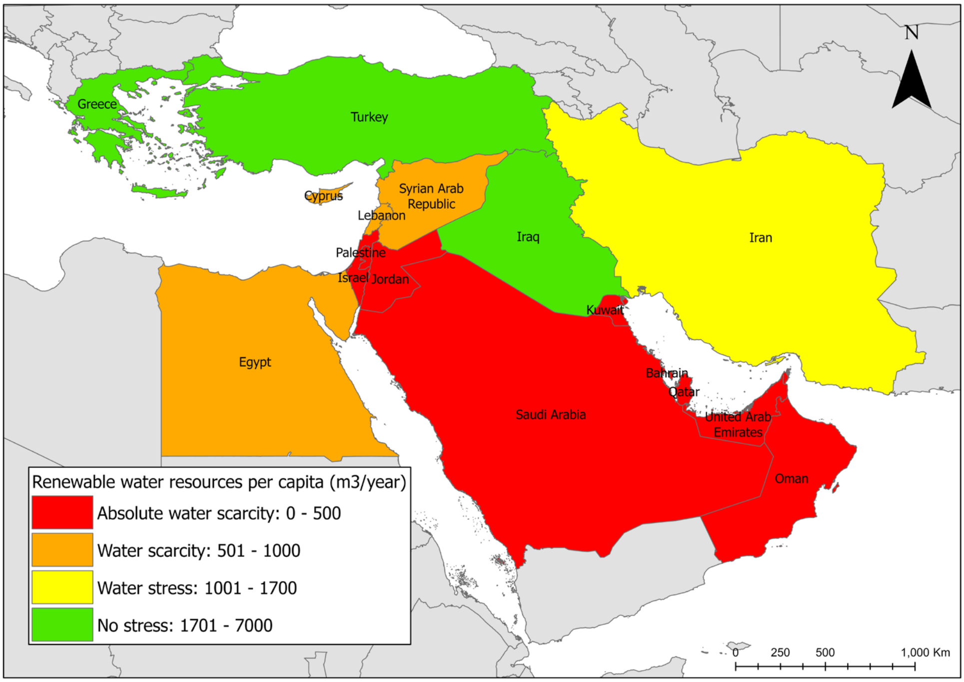
The 12 Arab countries of the EMME region (Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, United Arab Emirates) are among the 20 Arab countries that make up the United Nations Economic and Social Commission for Western Asia. They participate in the Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR), coordinated by the United Nations Economic and Social Commission for Western Asia (ESCWA et al., 2017). This comprehensive study was initiated by the first Arab Ministerial Declaration on Climate Change (2007) and supported by various international, regional and national organisations.

The six Gulf Cooperation Council countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates) have developed a Unified Water Strategy, 2016–2035 (Al-Zubari et al., 2017). The integration of future impacts of climate change, through appropriate adaptation measures in water resources planning and management, is one of the guiding principles of the strategy. The strategy was approved by the Gulf Cooperation Supreme Council in 2016.

Most of the EMME region is marked by low rainfall, dry summers and high evapotranspiration. The annual per capita renewable water resources of the 17 EMME countries are presented in Figure 2.1. The map shows the level of water scarcity experienced by the countries of the region, based on the Falkenmark index. This index relates a country's annual per capita water needs for household use, agriculture and industry to total

FIGURE 2.1. Renewable water resources in the EMME region

Annual, per capita for 17 countries



Source: FAO, 2021.

freshwater resources (Falkenmark et al., 1989; Rockstrom et al., 2009). A country is considered to experience water stress when the renewable water resources fall below 1,700 m^3/year per capita. Below 1,000 m^3/year per capita a country faces water scarcity; below 500 m^3/year, absolute water scarcity.

Nine of the seventeen EMME countries are below the absolute water scarcity threshold of 500 m^3/year per capita, including all six countries of the Gulf region, Jordan and Palestine. Four others – Cyprus, Egypt, Lebanon and Syria – are below the scarcity threshold of 1,000 m^3/year per capita. This places nearly 200 million people under conditions of water scarcity (FAO, 2021). Greece, Iraq, Iran and Turkey are currently the only countries above the water scarcity threshold. However, these annual country averages mask the differential water availability over the area of the countries, as well as seasonal water shortages. In many places, the long, dry summer season affects the livelihoods of the rural population.

A country's renewable water resources are comprised of the fraction of the rain that flows into streams and surface water bodies or recharge groundwater aquifers, plus the net inflow of surface water and groundwater across the country's borders. These water resources' estimates represent long-term annual averages under a variable climate. However, population growth is shrinking the per capita water resources of many countries of the region. For example, under the median growth projection of the United Nations (UNDESA, 2021), the renewable water resources per capita for Egypt would drop from the current 596 m^3/year per capita to 476 m^3/year per capita in 2030. And this number does not account for changes in water resources related to climate change or upstream withdrawals.

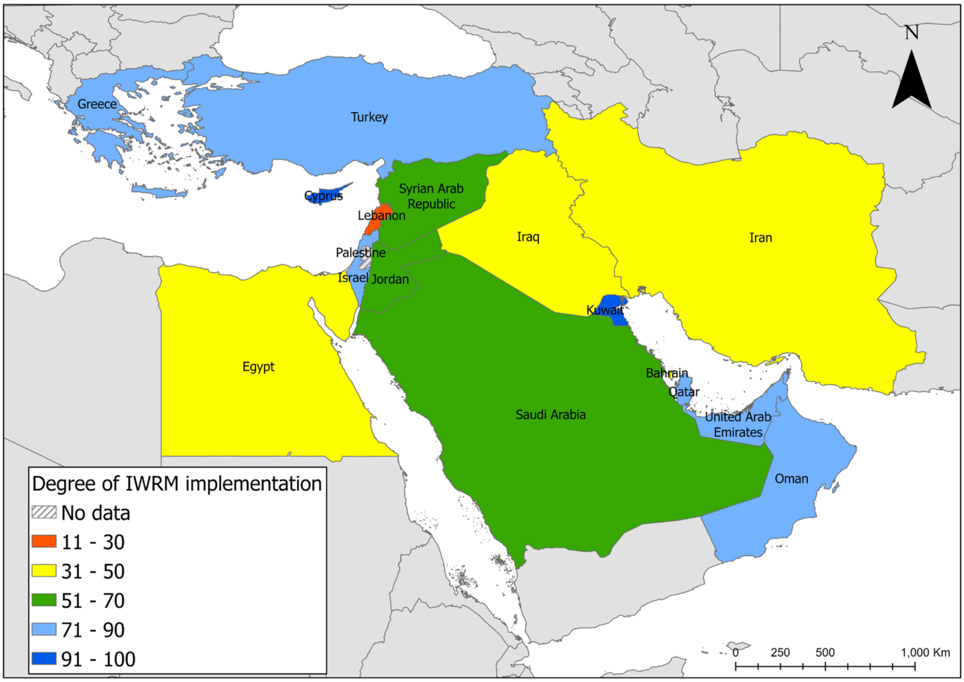
Attention also must be paid to how water resources are managed. Water is essential for sustainable development, as captured in Sustainable Development Goal 6. The fifth target of SDG 6 emphasises the importance of integrated water resources management (IWRM) as a holistic framework for addressing demands and pressures on water resources across different sectors and at different scales. Integrated management ensures that resources are developed, managed and used in an equitable, sustainable and efficient manner, in consideration of local political, economic and social realities. SDG 6.5 aims to achieve integrated management of water resources at all levels, including through transboundary cooperation, by 2030.

Implementation of IWRM involves four main components. Each needs to be considered at the national, subnational, basin and transboundary levels. The first component is the need for an enabling environment, including policy, legal and strategic planning tools. The second is institutions and participation, i.e., the range and roles of political, social, economic and administrative institutions, cross-sectoral coordination, private sector and other stakeholder groups that help support implementation. The third component covers management instruments, i.e., the tools and activities that enable decision makers and users to make rational and informed choices. The fourth component is the financing, which considers investments, infrastructure, recurring costs and revenue raising for development and management of water resources. Progress toward IWRM is measured by means of a self-administered country questionnaire consisting of 33 questions that cover the four components and four levels. The national focal points, who are responsible for the reporting, are advised to engage multiple stakeholder groups to obtain consensus scores and provide justifications for the scores (ESCWA, 2019b).

The SDG 6.5 scores of the EMME region are presented in Figure 2. The status of implementation of IWRM is low or medium-low in Egypt, Iraq, Iran and Lebanon. High or very high scores are reported by Cyprus, Greece, Israel, Kuwait, Qatar and the UAE. Considering the four dimensions of the score, the Mashreq countries score low in financing, and

FIGURE 2.2. Integrated water resources management in the EMME region

Degree of implementation in 17 countries



Source: UNEP, 2021.

medium-low for the other three dimensions. The Gulf countries score medium-low for enabling environment, but medium-high for the other dimensions. Notwithstanding the guidance provided for reporting, these SDG 6.5 scores retain an element of subjectivity (ESCWA, 2019b).

3. Water resources in relation to climate change: a review

The conceptual framework used to assess the climate resilience and security of the region's water resources is based on the framework for water security in the Arab region proposed by ESCWA (2019a). The framework operates across scales and sectors and is guided by the indivisibility and universality of human rights to water, food and development, and the consequences of climate change on these rights. Climate change, water scarcity and shared resources are put forth as systemic conditions that impact the achievement of water security in the EMME region (Figure 3.1). The framework's foundation highlight the relation between water and the social, environmental and economic pillars of sustainable

FIGURE 3.1. Climate resilience and water security framework for the water resources review

Source: Adapted from ESCWA (2019a).

development. Actions in six areas will guide the region to water security and climate resilience: good governance; regional cooperation; financing and investment; research and technology development; climate resilience and reconstruction; and capacity building.

3.1. Regional climate change and precipitation projections

Past changes and future projections of the climate in the EMME region are presented in the report of the EMME Climate Change Initiative's task force on the physical basis of climate change (Lelieveld et al., forthcoming). The report's main finding with implications for water resources is that the combined effect of lower precipitation and higher temperatures may induce severe droughts; these, combined with rapid population growth, are expected to create significant water shortages.

The majority of the EMME region lies in arid and semi-arid climate zones, where the long-term average annual evaporative demand of the atmosphere is at least two times higher than the amount of precipitation (Cherlet et al., 2018). While the steady increase in temperature will increase the evapotranspiration of valuable water from terrestrial agricultural and managed ecosystems and water bodies, changes in precipitation are by far the most important thread for water resources and their management. The concern is not only about changes in amounts, but also in the temporal and spatial distribution of precipitation and in the probabilities, size and duration of the extremes that cause droughts and floods. A short overview of precipitation projections in relation to water resources is presented here.

Projected changes in precipitation for the optimistic RCP2.6 scenario and the business-as-usual RCP8.5 scenario relative to the 1986-2005 reference period were analysed for the EMME Climate Change Initiative using a set of CORDEX-CORE climate projections (Lelieveld et al., forthcoming). The analysis indicated that over the course of the 21st century, precipitation changes under the optimistic RCP2.6 scenario are insignificant. Basically, the RCP2.6 future precipitation simulations are within present-day variability. For the RCP8.5 scenario, the mid-century conditions are similar to RCP2.6 and are mainly characterised by low levels of significance and limited inter-model agreement. However, the signal becomes stronger over time, and a 10-20% decrease in precipitation is projected for the region by the end of the century. For regions adjacent to the Mediterranean Sea (Greece, Turkey, Cyprus, Syria, Lebanon, Israel, Palestine, northern Egypt), the CORDEX set suggests a significant and occasionally robust precipitation decrease (20-40%). Conversely, in the southern regions (parts of the Arabian Peninsula and southern

Egypt) annual precipitation is expected to increase (up to 50%). However, considering the extremely low precipitation in this region, these changes will not bring substantial amounts of rain.

In line with these findings, Driouech et al. (2020) and Spinoni et al. (2020) also found drought increases to be strongest for the end of the century under high-forcing pathways. Increases in the number of consecutive dry days of about 8 days/thousand in the southern Mediterranean and 5 days/thousand in the northern Mediterranean were found by Lionello and Scarascia (2020), based on the analysis of 28 CMIP5 global climate projections for the RCP8.5 scenario.

The intensification of hydrologic cycles owing to global warming is expected to lead to more extreme rainfall events. Several studies have analysed sets of regional and global climate model simulations and identified increases in precipitation extremes for the Mediterranean region (e.g., Toretti et al., 2013; Rajczak and Schär, 2017; Donat et al., 2019). A global increase in daily precipitation extremes for the end of the 21st century (2075-2099) under the RCP8.5 scenario was also found by Kitoh et al. (2016), even in regions such as the Mediterranean, where total precipitation was projected to decrease. These authors used a four-member ensemble simulation with a global atmospheric general circulation model with a 20-kilometre mesh. However, these studies still provide a limited understanding of the manifestation of extremes, especially in the Middle East region.

A more in-depth analysis of precipitation extremes for the Mediterranean region is presented by Zittis et al. (2021), although this study also covers only part of the Middle East region. These authors analysed daily precipitation extremes from a set of 33 regional climate model simulations of the RCP8.5 scenario. They found that throughout the region 100-year daily precipitation extremes for the 21st century exceed the 100-year extremes derived from the second half of the 20th century. However, in the drier parts of the Mediterranean region (less than 500 mm average annual rain), the number of grid cells with statistically significant falling trends in annual daily precipitation maxima in the 21st-century exceeds the number of cells with rising trends. This pattern is reversed in the wetter parts of the region, where more grid cells had statistically significant increasing trends in extremes than decreasing trends. The analysis highlighted that precipitation extremes can occur at any time in any Mediterranean location. The authors also showed that the contribution of the wettest day of the year to the total annual precipitation is expected to increase (5-30%) throughout the region.

These changes in precipitation extremes show that traditional statistical approaches for hydrologic and hydraulic design, which assume a stable climate, can no longer be used (Salas and Obeysekera, 2014). The same holds true for the use of time or temperature as a covariate in the fitting of extreme-value-distribution functions, as in several recent studies (e.g., Cheng et al., 2014; Li et al., 2019); this technique should not be applied to deal with the transient nature of a changing climate in the Mediterranean region. Serinaldi and Kilsby (2015)in this study we review the main tools developed in this field (such as nonstationary distribution functions, return periods, and risk of failure also pointed out that time-varying models may not remain valid for the full lifetime of the relevant infrastructure.

3.2. The impact of climate change on water resources

Studies on the impacts of climate change on water resources in the EMME region are affected by uncertainties in the modelling process and by the coarse nature and bias of climate projections. Statistical downscaling of global or regional climate model simulations for hydrologic studies have shown an imperfect representation of the spatial-temporal distribution of precipitation and modifications of the trends in extremes (e.g., Cameron et al., 2015; Camera et al., 2017). Dynamical downscaling to 1-kilometre resolution has shown good results (e.g., Zittis et al., 2017), but applications with sufficient duration to capture climate variability and modelling uncertainties are still constrained by the high cost of the required computational resources. A further limitation is the scarcity of hydrologic monitoring data for the calibration and evaluation of hydrologic models (RICCAR, 2017).

Runoff and discharge of the headwaters of the Blue Nile in the Ethiopian Highlands was modelled using the Hydrological Predictions for the Environment model for three RCP4.5 and RCP8.5 regional climate model projections (RICCAR, 2017). Results showed a decrease in runoff over time, but with high variation in the results. Similar simulations for the Tigris and Euphrates headwaters showed small increases in winter runoff, even when precipitation changes are negative, followed by reduced runoff during the summer months. This is likely due to less snow storage during the warmer winters. These studies also indicated that the lack of hydrologic monitoring data hampers the use of hydrologic models in the region.

Several recent exercises in hydrologic modelling and analysis show the urgent need for adaption in the water sector. Studies overwhelmingly show that throughout the EMME region changes in precipitation are magnified in water resources, causing hydrologic droughts, reducing streamflow and groundwater recharge, amplifying water-quality problems, and resulting in dramatic increases in reservoir risk levels for water supply and energy production, (e.g., Abbas et al., 2018, 2019; Abdullah and Omari, 2008; Al-Hasani, 2019; Mimikou and Baltas, 2013; Rabi et al., 2003a and 2003b; Qatarneh et al., 2018; Stefanidis et al., 2018).

The findings of these modelling studies are confirmed by a recent large scale analysis based on satellite observations from the Gravity Recovery and Climate Experiment. Liu and co-authors (2020) found a terrestrial loss in water storage of nearly 11 millimetres/year for the Middle East region between 2002 and 2017. Changes were related to the drying of the Caspian Sea, groundwater irrigation and a decrease in precipitation, accompanied by an increase in temperature and evapotranspiration.

3.3. Water scarcity

The statistics reported in Table 3.1 show that more than 50% of the region's annual renewable water resources are withdrawn for use. Even more striking is that in 10 of the 17 EMME countries total annual water withdrawal exceeds the total annual renewable water resources. In all six Gulf countries and Egypt freshwater withdrawals exceed the total annual renewable freshwater resources, indicating an unsustainable extraction of groundwater resources (ESCWA and BGR, 2013; Wada, 2013). Desalination, treated sewage water, agricultural drainage water and fossil groundwater resources are supporting the water needs of the EMME countries. The Gulf countries are strongly reliant on desalination, which also accounts for more than 20% of water use in Israel and Cyprus. As noted, these country-level statistics do not present the temporal and spatial variabilities of water resources, which are resulting in water shortages in all countries of the region.

Agriculture remains the main water user in the region. Agricultural water use, as a percentage of total water use by all sectors, ranges from 32% in Qatar to 92% in Iran. Over the 17 countries of the region, 85% of the total annual water withdrawals is allocated to agriculture. In all six Gulf countries and Egypt, agricultural water use exceeds the annual renewable water resources.

Water scarcity in the region is aggravated by pollution, seasonality, droughts and conflict. Internal displacement and migration have affected people's access to water and sanitation services. Universal and equitable access to safe and affordable drinking water – the first target of the Sustainable Development Goal for water (SDG 6) –is still elusive in the region. According to the latest statistics (FAO, 2021), the percentage of the population with access to drinking water is as low 58% in Palestine and 87% in Iraq. It exceeds 90% in the other fifteen countries, but only five of these countries reach the 100% target (Bahrain, Cyprus, Greece, Israel, Qatar, Turkey).

TABLE 3.1. Water resources and withdrawals by country, source and sector in the EMME region

Country	Renewable water resources 10^9 m^3/yr	Water withdrawal 10^9 m^3/yr	Water withdrawal per source				Water withdrawal per sector		
			Freshwater %	Desalinated water %	Treated wastewater %	Agricultural drainage water %	Agricultural %	Industrial %	Municipal %
Bahrain	0.12	0.43	35.7	55.7	9.0	—	33.3	3.2	63.4
Cyprus	0.78	0.31	69.5	20.9	5.0	—	59.2	5.5	35.4
Egypt	57.50	77.50	82.8	0.3	1.5	15.4	79.2	7.0	13.9
Greece	68.40	11.24	100.0	0.1	0.9	-	80.4	1.9	17.7
Iran	137.05	93.30	99.6	0.2	0.0	-	92.2	1.2	6.6
Iraq	89.86	38.55	100.0	0.0	0.0	0.0	91.5	5.3	3.2
Israel	1.78	2.30	52.0	25.4	22.6	—	54.2	3.1	42.7
Jordan	0.94	1.04	86.5	13.1	0.4	0.0	53.1	3.1	43.8
Kuwait	0.02	1.25	61.6	33.6	6.2	—	62.3	1.9	35.9
Lebanon	4.50	1.84	98.5	2.6	0.1	1.5	38.0	48.9	13.0
Oman	1.40	1.87	87.3	17.6	3.3	—	85.8	7.2	6.9
Palestine	0.84	0.38	76.8	1.1	3.5	—	43.2	8.5	48.3
Qatar	0.06	0.91	27.5	66.3	14.6	5.5	32.0	15.7	52.3
Saudi Arabia	2.40	23.35	90.8	9.3	1.1	-	82.2	4.3	13.5
Syria	16.80	16.76	83.3	—	3.3	13.4	87.5	3.7	8.8
Turkey	211.60	58.96	101.8	0.0	0.0	—	84.9	4.9	10.2
UAE	0.15	4.00	64.1	49.4	13.7	—	82.8	1.7	15.4
Total(10^9 m^3/yr)	**594.19**	**334.01**	**311.9**	**7.0**	**3.6**	**14.2**	**284.6**	**34.7**	**14.7**
Average (%)			**93.4**	**2.1**	**1.1**	**4.3**	**85.2**	**10.4**	**4.4**

Source: FAO, 2021; – no data

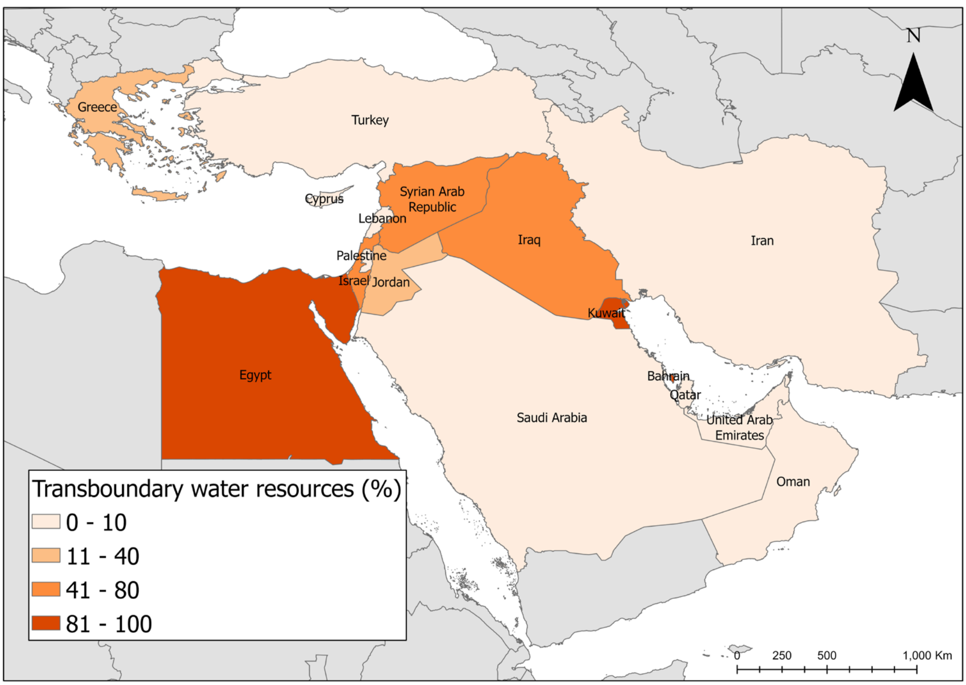
3.4. Shared water resources

Almost all countries in the region depend on transboundary water resources, also referred to as shared water resources, for their water needs. Their dependency, expressed as the share of total renewable water resources originating outside the country, is illustrated in Figure 3.2. The indicator accounts for surface and groundwater inflows but not the possible allocation of water to downstream countries.

Shared surface water basins include the Euphrates and Tigris River Basin, the Jordan River Basin and the Nile River Basin. Continuous and reliable datasets on water flows are important for resolving possible conflicts over water quantity and quality; maintenance of such data is required by the European Union Water Framework Directive. Problems may arise when water is shared between the EU and non-EU states. Greece, for example, is downstream from four transboundary river basins; not all upstream countries are European Union member states (Skoulikaris and Zafirakou, 2019).

Sharing of groundwater resources is even more common than sharing of surface water, although less obvious and even more complex to manage. The transboundary groundwater

FIGURE 3.2. Dependency ratio of the 17 countries of the EMME region
Share of total renewable water resources originating outside each country



Source: FAO, 2021.

resources of the world were mapped and described by IGRAC (2015). Some shared aquifer systems in the EMME region include non-renewable, fossil groundwater resources. Examples including the Disi sandstone aquifer shared by Jordan and Saudi Arabia; the Nubian sandstone aquifer shared by Egypt, Chad, Libya and Sudan; and the Neogene aquifer system underlying Iraq, Kuwait and Saudi Arabia. For the Paleogene and Cretaceous aquifer system, shared by Iraq, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Syria, Bahrain, UAE and Yemen over an an area of 2.1 x 10^6 km^2, Wada and Heinrich (2013) estimated a groundwater depletion of 12 x 10^9 m^3/year.

A comprehensive inventory of the shared water resources of Western Asia (extending from the Red Sea in the west to the Gulf coast in the east, and from the northeastern shore of the Mediterranean Sea to the Gulf of Aden in the south) identified seven shared river basins and twenty-two shared aquifer systems (ESCWA and BGR, 2013). The study found that more than 70% of the area is part of a shared surface or groundwater basin. The inventory revealed that transboundary groundwater systems are often not clearly delineated and recognised as a shared resource. The findings also highlighted the insufficient attention given to water quality and to the connections between groundwater and surface water, which, together with the lack of water data, results in suboptimal water management. The report also noted that the few available cooperation agreements focus on water allocations rather than on shared water management.

3.5. Climate resilience and water security actions

3.5.1. Water governance

Water governance in EU member states Cyprus and Greece has strongly benefitted from the implementation of the EU Water Framework Directive, even though its over-ambitious expectations have been subject to criticism (e.g., Voulvoulis et al., 2017). The Water Framework Directive transcends administrative boundaries and uses river basins as the main water management unit (EC, 2000). It aims to achieve good ecological, chemical and quantitative status of surface water, groundwater and coastal water bodies. The Directive implements the polluter pays principle and applies water pricing as an incentive for the sustainable use of water resources. Over the past two decades, Turkey has also taken important steps towards implementing the EU Water Framework Directive. However, as Harmancioglu and Altinbilek (2020) note, the conflicts between water resources development and sustainability have not been resolved. They report concerns about the low price of irrigation water and the limitations of area-based pricing of irrigation water, which does not facilitate improvements in the efficiency of water use.

In the Arab countries of the region, the Arab Water Security Strategy (2010-2030) and action plan, developed under the Arab Ministerial Water Council and endorsed by the heads of the Arab states in 2016, together represent an important means for regional cooperation on sustainable water management (Zubaidi, 2019). However, institutional, financial and political constraints remain to be addressed and resolved.

3.5.2. Regional cooperation

Comair and Scoullos (2015) presented the 2002 Orontes River Agreement between Syria and Lebanon as an example of hydrodiplomacy, where water is used as an element for negotiation and cooperation among countries. The peaceful resolving of water issues can directly contribute to increased economic benefits and lead to political stability. The Orontes agreement considered the economic and social needs of the water users, as laid out in the United Nations Convention on the law of the non-navigational uses of international watercourses (UN, 1979), to which both countries are a signatory. The authors noted the positive role of technical experts on both sides in initiating and elaborating a benefit-sharing scenario.

In a theoretical contribution to transboundary water cooperation, McLaughlin (2015) recommended the establishment of a regional tier of governance to improve the stability of transboundary water management. This regional tier can lead member states to adopt agreements, while also establishing a set of functional institutional designs that lock states into compliance with a whole legislative output. The additional regional layer can also improve the efficiency of international regulatory frameworks. If the model of governance at the regional level adheres to international agreements following a collective consultation process, then states are more likely to comply with these agreements than if they had signed them alone.

A road map for the creation of a regional mechanism for the management of the shared groundwater resources of the Arabian Peninsula was proposed by Abdulrazzak et al. (2021). The first phase would involve the establishment of national advisory committees and government task forces. Second, an interim Cooperation Council should be formulated, through the GCC Secretariat, supported by a high-level advisory committee. The Cooperation Council should develop a shared vision for the transboundary aquifers based on a common understanding of the water resources. The authors noted that the sharing of data and strengthening of data collection networks will be a cornerstone of this effort. The final phase would be the formation of a ratified Regional Commission for the Transboundary Aquifers, to be the authority for shared groundwater governance in the region. Precautionary planning should be one of the core values of this organization, in consideration of climate change and the competing and conflicting water uses in the region, resulting in the development of sustainable management alternatives for the existing and planned utilization of water (Abdulrazzak et al., 2021).

3.5.3. Financing and investment

The issue of the financial sustainability of the water sector has recently become a topic of attention. A financial strategy for water was endorsed, together with a water policy framework, by the 43 countries of the Union for the Mediterranean in 2019 (UfM, 2019, 2020). Recommendations were developed around four regional priorities for action: 1) water, energy, food and ecosystems nexus, (2) water, employment and migration; 3) sanitary and hygiene conditions; and 4) water and climate action. The financial strategy recommends water sector reform to increase financial sustainability, adoption of incentives to increase water efficiency, and investments in infrastructure for more secure water supplies and availability. However, the responsibility for achieving the objectives of the financial strategy will remain with the member states.

Climate finance governance is a core issue in countries' effort to support mitigation and adaptation actions (Bracking and Leffel, 2021). The Green Climate Fund (GCF), which was formally established during the 2010 United Nations Climate Change Conference in Cancun, is currently the largest finance mechanism in the emerging field of climate finance governance (Bowman and Minas, 2019). The Fund aims to promote the paradigm shift towards low-emission and climate resilient development pathways by financing policies, projects and other activities related to climate mitigation and climate adaptation in developing countries (Green Climate Fund, 2011). The GFC operates as a transfer mechanism through which developed countries provide funds and resources to developing countries to increase climate resilience (Antimiani et al., 2017).

Although the developed countries have agreed to finance the GFC, a consensus on burden sharing has not yet been reached (Cui and Huang, 2018). As a result, the current efforts of the GCF to mobilize finance have failed to meet the needs of developing countries for addressing climate change (Cui et al., 2020). The design of sharing rules based on both historical responsibility and economic capacity could maximize country participation in the fund (Antimiani et al., 2017; Cui and Huang, 2018). Additionally, a fair distribution of resources should be ensured among eligible countries based on their needs and the geographic and economic characteristics (Costantini et al., 2016; Antimiani et al., 2017) including both mitigation and adaptation efforts (Cui et al., 2014).

3.5.4. Research and technology development

Research and technology development for climate resilience and water security can be broadly divided into technologies that aim to increase water supply and technologies that aim to reduce water demand. Over the past two decades, research on non-conventional water resources – such as desalination, treated sewage water, water-harvesting practices and long-distance water transfer – has gained increasing attention (Djuma et al., 2015; UN-Water, 2020).

Research indicates that desalination can be made more feasible using renewable energy and sound disposal or re-use of brine (Sharon and Reddy, 2015; El Kharraz et al., 2018). Brown et al. (2018) highlight the opportunities of marginal water – including treated sewage effluent, oilfield water, brackish groundwater and seawater – to grow salt-tolerant forage crops, microalgae and aquaculture in the Gulf countries. However, an important research issue for the use of treated sewage water in agriculture is the fate of emerging contaminants such as pharmaceuticals in soil, groundwater and crops (e.g., Petrovic et al., 2009; Thiem et al., 2011).

Managed aquifer recharge has been demonstrated to be a suitable technology for capturing and storing surface flows when paired with local hydrologic, hydrogeologic and socio-economic assessments and investigations (e.g., Djuma et al., 2017; Xanke et al., 2020). In the UAE, an aeolian-fluvial sandstone aquifer system is being used for the large-scale strategic storage of desalinated water (10 Mm^3/year). Sampling and modelling investigations of the hydrogeology and hydrogeochemistry of the system indicated that for long-term (10 year) storage recovery rates decline to 60%, after which water quality standards will be exceeded (Stuyfzand et al., 2017).

On the demand site, research on improving the water use efficiency of irrigated agriculture remains an important topic. Research issues include changes in crop patterns, water pricing, improved irrigation scheduling, and sensors and apps for improving irrigation scheduling (e.g., Giannakis et al., 2016). Recent advances in satellite and drone-based remote sensing technologies, in-situ soil and plant sensors, and smart data processing offer important opportunities for optimizing irrigation decision making (e.g., Alexandris et al., 2021; Zinkernagel et al., 2020). Finally, a nexus approach linking climate, water, energy and food has been increasingly recognised as a basis for furthering water security and sustainable development in the EMME region (e.g., Abulibdeh et al., 2019; Markantonis et al., 2019).

3.5.5. Resilience and reconstruction

Roach and Al-Saidi (2021) present examples of promising adaptation efforts in conflict-affected areas. These include the construction of water kiosks in South Sudan and the integration of schools with basic services, such as water, sanitation and hygiene, in Syria. The water kiosks can be either directly connected to the water network or supplied by water tanks. The water utilities who own and operate the kiosks are encouraged to meter the water supply and provide pro-poor, but cost-recovering, prices. The authors show the importance of rethinking aspects of infrastructure development such as interconnectivity, mobility, centralization and missing baselines.

Burak et al. (2021) used long-term monthly precipitation and temperature data to model the water supply system of Istanbul city, including water transfers from outside basins. Simulation results show that water imports alone are not a reliable solution to meet the water demand beyond 2060, when water demand is expected to increase by 30% beyond the present. The authors noted that it is vital to incorporate the extensive measures of IWRM-Water Sensitive City approaches with a diversified water portfolio in short-term decisions, considering that it takes time for people to adopt new behavioural attitudes. Savun-Hekimoğlu et al. (2021) tested five demand forecasting methods and two multi-criteria decision making methods to evaluate five different water supply alternatives for Istanbul, in cooperation with experts and stakeholders from different sectors. The experts identified greywater reuse and rainwater harvesting as the best options, followed by treated sewage water use for urban green areas. Desalination and inter-basin water transfer were considered the least attractive solutions.

3.5.6. Capacity building

The importance of capacity building for the water sector has been indicated by a number of the above authors (e.g., Comair and Scoullos, 2015; Burak et al., 2021). The development and implementation of state of the art technologies for the monitoring, modeling, allocation and treatment of water resources require a highly educated work force. Abdulrazzak et al. (2021) noted that the management of shared water resources will benefit from cooperative research efforts within the scientific and technical community, the strengthening of technical and managerial capacities, the exchange of experiences on successful management practices and outreach and educational programs for water users. Roach and Al-Saidi (2021) noted that for developing and improving infrastructure performance in conflict-ridden areas, the building of local capacities also involves institutional development and building of community trust.

Capacity building is also needed to enable institutions to better leverage funds, especially to access global climate, sustainability and green funds (ESCWA, 2019a). Water economics and financing, economic evaluation methods, economic implications of water policies, cost recovery and financial sustainability are important areas of training for the water sector.

4. Policy landscape

The resilience of natural ecosystems, societies and economies depends on adapting water resources to the reality of climate change. Successful adaptation implies reducing water-related climate vulnerabilities and building capacities that enable governments and societies to mobilise the resources needed to adjust to climate change impacts (Nelson, 2007). This chapter provides an overview of policy measures that foster water-related adaptation in the EMME region and an evaluation of the level of the implementation and the effectiveness of those measures to address the overall water-climate thread, that is, the reduction in renewable water resources and the rise in water demand.

The adaptation plans and reports reviewed in this section include 1) National Adaptation Plans and Strategies; 2) National Energy and Climate Plans; 3) reports of Intended Nationally Determined Contributions (INDCs) and Nationally Determined Contributions (NDCs); and 4) National Communications to the UNFCCC.

4.1. International and European climate adaptation policy frameworks

The United Nations Framework Convention on Climate Change (UNFCCC) established the National Adaptation Plan process under the Cancun Adaptation Framework in 2010. Countries were encouraged to formulate and implement National Adaptation Plans as a way to mainstream climate change risks, assess vulnerabilities and address their medium- and long-term priorities for adapting to climate change.

The signatories to the UNFCCC were invited to communicate what post-2020 climate actions they intended to take, referred to as their Intended Nationally Determined Contributions (INDCs), at the 2013 United Nations Climate Change Conference in Warsaw. The INDCs are the primary means for countries to communicate internationally their contributions, which are not stringent commitments, for addressing climate change in the context of their national priorities, circumstances and capabilities. The INDCs were directly converted to Nationally Determined Contributions (NDCs) upon the ratification of Paris Agreement by each country.[3] The NDCs, which include climate related targets, policies and measures governments intend to implement in response to climate change, are critical elements for implementing the Paris Agreement. National Communications, which are complementary to NDCs, are reports periodically submitted to UNFCCC by states that have

3. https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs/nationally-determined-contributions-ndcs

ratified the Paris Agreement, describing their national profile of greenhouse gas emissions, their potential mitigation and adaptation options, and their needs.[4] In particular, the National Communications describe what can be done, while the NDCs go a step further by outlining the commitments of each country. Countries' National Adaptation Plans, NDCs and National Communications can be mutually reinforcing.

Ten countries of the EMME region (Bahrain, Egypt, Iraq, Iran, Jordan, Kuwait, Lebanon, Oman, Saudi Arabia and Syria) have designated National Designated Authority to have access to GCF resources to implement their NDCs and National Adaptation Plans (Green Climate Fund, 2021). The GCF is currently financing water-related adaptation projects in certain countries (e.g., Bahrain, Egypt, Jordan) as well as multi-country projects.

The European Commission adopted an adaptation strategy in 2013, aiming to make the European Union (EU) more climate-resilient. The EU member states in the EMME region – Greece and Cyprus – completed their adaptation strategies in 2016 and 2014, respectively. The two countries were also required to prepare and submit integrated National Energy and Climate Plans to ensure the achievement of Europe's 2030 energy and climate targets for lowering greenhouse gas emissions, increasing renewable energy sources and making improvements in energy efficiency. The National Energy and Climate Plans set out the initiatives to be undertaken in the context of the national adaptation strategies. The European Commission also supports adaptation in cities through the Covenant of Mayors for Climate and Energy[5].

The Water Framework Directive 2000/60/EC[6] is the core EU legislative instrument for the protection and management of water resources. Greece and Cyprus have adopted the two River Basin Management Plans (2009-2011; 2016-2021), which are the key tools for the implementation of the directive and consequently for national water management policy. Although the directive does not explicitly consider climate change, several of its articles provide a framework to incorporate the effects of climate change in the planning process (Francés et al., 2017). The EU's member states have agreed that planning for climate-related threats and adaptation should be explicitly incorporated in their River Basin Management Plans. The EU Floods Directive 2007/60/EC[7] aims to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. Member states are urged to consider long-term development, including climate change, in their flood-risk management efforts.

4. FCCC/CP/2002/7/Add.2. Guidelines for the preparation of national communications from Parties not included in Annex I to the Convention
5. https://www.covenantofmayors.eu/en/
6. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.
7. Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks.

4.2. National adaptation strategies and plans

4.2.1. European Union countries, Israel and Turkey

Cyprus submitted its sixth national communication to the UNFCCC in 2013 (MARDE, 2013). The report consolidates the country's first six national communications. A seventh report was submitted in 2018 (MARDE, 2018). Cyprus is formulating its climate policy within the framework of the UNFCCC and EU legislation. In this context, the government adopted the Cypriot National Adaptation Strategy and Action Plan in 2017 (decision no. 82.555; MARDE, 2017). The plan provides a holistic framework for adaptation to climate change risks and includes an evaluation of the effects of climate change on 11 vulnerable sectors in Cyprus, including water resources, identified using an innovative multi-criteria analysis technique. Currently, no adaptation strategies are being developed at the sub-regional or local level (European Commission, 2018b). However, in the first (2018) and second (2020) annual reports on implementation of the plan, it is noted that some of the effects of climate change cannot be effectively addressed by the existing measures (MARDE, 2020).

Greece submitted its seventh national communication climate change report in 2017 building on the first six submitted reports (MEEN, 2018). The Greek government adopted its national adaptation strategy in 2016 (MEEN, 2016). With a 10-year time horizon, the strategy outlines broad policy directions and adaptation actions for sectors vulnerable to climate change, including water resources, without analysing and prioritising the corresponding measures and actions. The final selection, prioritisation and scheduling of the adaptation measures and actions falls within the scope of 13 regional adaptation action plans, which, over a 7-year planning cycle, will develop guidelines based on the particularities of each region. Greece has no national adaptation plan apart from its national adaptation strategy and the regional plans; the national adaptation plan will consist of the 13 regional plans (European Commission, 2018a).

The regional action plans analyse the synergies of the proposed adaptation actions with other national and regional policies and plans to mainstream adaptation into planning processes. Considering that the scope of the relevant measures often crosses administrative boundaries and requires a cross-regional approach – as with river basins – some of the adaptation measures may need to be planned at a climate-zone level (MEEN, 2019). To this end, a growing number of local authorities have started developing local adaptation plans, while more than 50 Greek cities have signed the Covenant of Mayors for Climate and Energy (MEEN, 2019) to make their respective areas more resilient. Finally, the establishment of a National Climate Change Adaptation Committee, which will act as the formal coordination and advisory body at national level, is foreseen (MEEN, 2018).

Israel's first (2000), second (2010) and third (2018) climate change communications to the UNFCCC (State of Israel, 2000; 2010; 2018) assess the effects of climate change on water resources and recommend solutions, one of which is to incorporate the consequences of climate change into the country's water economy plans and water pricing. In 2012, the Israeli Water Authority updated its long-term master plan, which includes tools to manage supply and demand. The Israeli Ministry of Environmental Protection is preparing a national program for Israel's adaptation to climate change. An inter-ministerial committee made recommendations for the national climate change adaptation plan in 2017 (State of Israel, 2017); these included 1) implementation of the master plan for the water sector; 2) conservation of water, soil and environmental resources; and 3) ecological management of water resources, purification of streams, and prevention of pollution.

Turkey ratified the UNFCCC in 2004 and signed the Paris Agreement in 2016 but has not yet ratified the agreement. Its INDCs were submitted to the UNFCCC in September 2015. Turkey's National Climate Change Adaptation Strategy and Action Plan appeared in 2011 (Republic of Turkey, 2011). Policy proposals related to climate change are coordinated by the Climate Change Coordination Board under the coordination of the Ministry of Environment and Urbanisation. Turkey submitted its first national communication on climate change to the UNFCCC in 2007 (Republic of Turkey, 2007); the next four reports were submitted together in 2013 (Republic of Turkey, 2013). The sixth, submitted in 2016 (Republic of Turkey, 2016), defined five overarching adaptation objectives and several actions on water resources management. The seventh communication, submitted in 2018 (Republic of Turkey, 2018), assessed the impacts of climate change on river basins for the period 2015-2100 to determine adaptation solutions, including increased storage capacity, development of river basin adaptation plans, and investments in irrigation projects.

4.2.2. Mashreq countries

Egypt has submitted three national communications to the UNFCCC (EEAA 1999; 2010; 2016); a fourth is in progress. The second and the third reports addressed the vulnerability of water resources to climate change. In 2015, Egypt submitted a report on its INDCs. The major action areas identified in Egypt's national communications and INDCs are water storage; irrigation and drainage systems; and awareness raising. The National Council of Climate Change, established by decree in 2015, is leading the adaptation planning process in Egypt, undertaking initiatives to integrate adaptation into development planning. Additional efforts to enhance adaptation include 1) a regional study on climate change adaptation and disaster preparedness in the coastal cities of North Africa (World Bank, 2011); and 2) the development of a Climate Change Risk Management Programme (UNDP, 2013). The GCF is currently financing a coastal flood adaptation project in Egypt

(Enhancing climate change adaptation in the North coast and Nile Delta Regions in Egypt; Budget: 105.2 million USD).

Iraq submitted its initial national communications report to UNFCCC in 2016 (Republic of Iraq, 2016) and its INDCs in November 2015 (Republic of Iraq, 2015). The second national communication is currently in progress. A national environmental strategy and action plan for the period 2013-2017 identified causes and potential solutions to combat desertification, land degradation and drought (Republic of Iraq, 2013). The government of Iraq is currently developing a national adaptation plan to reduce vulnerability to the negative impacts of climate change.

Jordan, a UNFCCC signatory, ratified the convention in 1993 and the Paris Agreement in 2016. The kingdom has submitted three national communications to UNFCCC (MoEnv, 1997; 2009; 2014). Its first INDCs were submitted in 2016; a First Biennial Update Report in 2017 (MoEnv, GEF, UNDP and RSS, 2017). Jordan released its national adaptation plan and an updated NDCs in 2021 (MoEnv, 2021a,b). Like Cyprus, Jordan employed a multi-criteria analysis to prioritise adaptation actions in the water sector and facilitate the participation of stakeholders in the adaptation process (MoEnv, 2021). The GCF has approved to finance a climate change adaptation project in Jordan for improving agricultural water use efficiency (Building resilience to cope with climate change in Jordan through improving water use efficiency in the agriculture sector; Budget: 33.3 million USD).

Lebanon has submitted three national communications (MoE/UNDP/GEF, 1999; 2011; 2016). The first (1999) focused solely on mitigation actions. The third (2016), building on work begun in the second, presented a more detailed analysis of climate change vulnerability, impacts and adaptation capacity. It highlighted the need to formulate a national adaptation framework for the water sector to restructure water governance; implement measures for water resources and infrastructure; improve surface water and groundwater quality; improve equitable access to sustainable water supply; and enhance knowledge and capacity for climate change adaptation. Since the 1990s, environmental governance and related policies and institutions have expanded greatly in Lebanon. The Environmental Protection Law (444/2002) is the overarching legal instrument for environmental protection and management. However, apart from laws 359/1994 and 738/2006 relating to the ratification of the UNFCCC and the Kyoto Protocol, no major Lebanese legislation has yet directly addressed climate change.

Palestine submitted its initial climate change communication to UNFCCC in 2016 (State of Palestine, 2016a). The report identified water and food security as the most pressing issues, with knock-on implications for all sectors, including agriculture, coastal and marine zones, energy, health, industry, tourism and waste. The national adaptation plan developed in 2016 (State of Palestine, 2016b) identifies adaptation solutions for sustainable water management for the Gaza Strip and the West Bank.

Syria submitted its first national communication to UNFCCC in 2010 (Syrian Arab Republic, 2010). Its assessment of climate change impacts on water resources was based on case studies of the Euphrates River and the Zabadani sub-basin and Fijeh spring. The report suggested several measures to ameliorate the effects of climate change on water resources including 1) the preparation of a national water master plan within the framework of integrated water resources management (IWRM); 2) the strengthening of the institutional and technical capacity of water related agencies; 3) enforcement of laws and regulations; and 4) improvement of irrigation efficiency and rain collection techniques. The second national communication is in progress. A national strategy and plan of action for adaptation to climate change remains to be developed (Syrian Arab Republic, 2018).

4.2.3. Arabian Peninsula

The Gulf countries (Bahrain, Kuwait, Qatar, Oman, Saudi Arabia, UAE) are signatories to the UNFCCC and the Paris Agreement. They have shown growing participation in global negotiations owing to the grave climate change threats to the region (Al-Zubari and Alajjawi, 2020).

Bahrain has submitted national communications to the UNFCCC (Kingdom of Bahrain, 2005; 2012; 2020). The initial report contained a general assessment of the impact of sea-level rise on the country's stressed groundwater system. The second included a detailed assessment of the impact of sea-level rise on groundwater, confirming additional pressures on an already overexploited groundwater system. The third national communication assessed the impacts of climate change on the municipal water supply system and the infrastructure of desalination plants. The report highlights the urgent need to formulate a comprehensive and IWRM policy and strategy to manage water resources efficiently and reach a degree of sustainability in the face of climate change. The GCF is currently financing an adaptation project in Bahrain on integrated water resources management (Enhancing climate resilience of the water sector in Bahrain; Budget: 2.3 million USD)

The first national communication of **Kuwait** (State of Kuwait, 2012) focused on the impact of climate change on the municipal water system, highlighting the challenges of climate change in balancing domestic water supply and demand. The second report (State of Kuwait, 2019) assessed policies promoting sustainable water management, highlighting the need to adapt and apply the concept of IWRM, strengthen technical capacity, and promote policies that stabilise the gap between water supply and demand. To address climate change, the Kuwait Environment Public Authority adopted an environmental protection law in 2014 and completed its implementing regulations in 2018.

Oman submitted its first climate change communication in 2013 (Sultanate of Oman, 2013). The report identifies water availability and groundwater depletion as major development constraints and identifies as a governmental priority the balancing of water demand and supply. The second national communication (Sultanate of Oman, 2019) reported a detailed vulnerability assessment conducted on surface water and groundwater, recommending the development and implementation of an IWRM system that reflects the interdependency of water and economic activity. A national strategy for adaptation and mitigation of climate change is being developed; its goal is the sustainable management of water resources.

Qatar has produced only the initial national communication (State of Qatar, 2011). It recognises the challenge that climate change poses for already scarce freshwater resources. The recommendations of the evaluation include the strengthening of technical and institutional capacities, the establishment of a web-based climate change information centre, the raising of public awareness, and a further investigation of mechanisms to narrow the gap between water supply and demand. The country's national development strategy (Qatar NDS, 2018) recognises the urgent need for sustainable water management. A water security policy and strategy and an implementation plan are being developed to provide a strategic vision and action plan towards a water-secure future.

Saudi Arabia submitted its initial climate change communication in 2005 (PME, 2005); the second was submitted in 2011 (PME, 2011). The reports assessed the effects of higher temperatures and lower rainfall on groundwater recharge and water availability and quality. Like the first two reports, the third communication (PME, 2016) assessed the potential effects of climate change on water resources, water quality, water supply and irrigation. These effects are expected to have significant impact on socioeconomic conditions in the kingdom. The report suggests that the development and application of a multi-criteria decision-making tool and decision-support system for IWRM could help close the gap between water supply and demand.

The **UAE** produced its first and second communications in 2007 (UAE, 2007) and 2010 (UAE, 2010), focusing on the vulnerability of surface water and groundwater resources. The main conclusions were that current patterns of water use are unsustainable and that policy on irrigated agriculture needs reconsideration. The third (UAE, 2012) and the fourth (UAE, 2018) communications further reinforced the importance of climate change adaptation as a priority policy. The National Climate Change Plan (UAE, 2017), launched in 2017, is a comprehensive framework to address the causes and impacts of climate change on water resources and to improve the adaptive capabilities within the sector. A top priority is to establish a national adaptation action program to implement prioritised adaptation measures.

4.2.4. Iran

Iran has submitted three national climate change communications to UNFCCC (Islamic Republic of Iran, 2003; 2010; 2017). Iran submitted its INDCs in November 2015 (Islamic Republic of Iran, 2015), before COP21. In May 2017, the government issued a National Strategic Plan on Climate Change that details the impacts of climate change on water resources and sets forth adaptation strategies. The report emphasises the need for significant investment in the water sector to achieve adaptation objectives.

4.3. Water-related adaptation policies and measures in the EMME region

A systematic review of the climate adaptation strategies and plans of the EMME region was conducted to map the existing or planned water-related adaptation measures. The review was based on the adaptation plans and reports introduced and discussed in Section 4.2.

Based on this review, an adaptation matrix for the countries of the EMME region with all existing or planned water-related adaptation measures was constructed. Following the conceptual framework for climate resilience and water security presented in Figure 3.1, the adaptation measures were categorised into six actions, as described below.

- **Water governance** includes measures that 1) enhance the coordination mechanisms among all actors involved in water resources management; 2) mainstream climate change adaptation in development policies; 3) incorporate the water-energy-food-climate nexus in policy making; and 4) promote IWRM using a participatory approach, thereby allowing the active engagement of stakeholders, with an emphasis on the participation of women.
- **Regional cooperation** includes operational arrangements for transboundary cooperation through joint studies; data monitoring and sharing platforms; capacity building; and programmes for the exchange of know-how.
- **Financing and investment** include the formulation of public-private partnerships that can finance water-related adaptation projects and economic instruments to finance water and sanitation-related infrastructure (water tariffs, water services cost-recovery, subsidies, over-consumption penalties).

- **Research and technology development** includes measures that promote technologies and innovative methods for water supply (desalination, wastewater treatment and reuse, artificial recharge of aquifers); demand-side measures aiming to control water demand and increase water productivity and efficiency (irrigation efficiency, water loss reduction); and innovation infrastructures (national and regional hubs for technology development).
- Policies and measures that increase the **resilience of the water sector** to events that can disrupt water services and infrastructure either in the short term (floods, power outages) or long term (drought, pollution). These measures can be broken down into structural and non-structural measures. The latter include IWRM plans, climate change adaptation plans, drought management strategies, and emergency response plans). Structural measures (mainly infrastructure) can be divided into those that 1) increase storage capacity (dams, managed aquifer recharge); 2) multiply water sources (more desalination plants, more groundwater wells); or 3) diversify water sources. Other measures promote the building or expansion of systems for gathering information, monitoring key indicators and issuing early warnings.
- **Capacity building** includes educational courses on water-related climate change, information campaigns, knowledge exchange programmes aiming to enhance the implementation of IWRM strategies, and development programmes targeting women and vulnerable groups.

4.4. Evaluation of water-related adaptation policies and measures

The implementation and effectiveness of the measures taken in the region to mitigate and adapt to a decrease in renewable water resources and an increase in water demand were assessed by the members of the Water Task Force in their respective countries. The level of implementation and the effectiveness of each country's adaptation measures were evaluated using a four-point scale: High (H), Medium (M), Low (L), None (N). These results are presented in Tables 4.1 and 4.2 and an overview is given below.

In total, 54 adaptation measures are included in the adaptation matrices; 14 are **governance**-related measures. Groundwater abstraction is currently regulated in most of the countries of the region with a medium to high effectiveness. Measures for improving data management are also implemented in several countries, however ineffectively.

Two measures relate to **regional cooperation**, namely, the promotion of cooperation and water imports, the effectiveness of which is characterised as medium to low. Five measures relate to the **financing** of water-related adaptation projects, including economic instruments; water pricing is implemented in most of the countries of the region; its effectiveness ranges from low to high.

Eighteen of the 54 adaptation measures relate to **research and technological innovation**; the wastewater reuse measure is implemented in almost all countries of the region, and its effectiveness ranges from low to medium. Desalination is also implemented in most of the region's countries and its effectiveness is characterised as high.

Ten measures aim to increase the **resilience** of the water system to climate events. The construction of dams for increasing storage capacity is promoted in several countries and their effectiveness is characterised from medium to high. Finally, five measures relate to **capacity development**. In particular, awareness raising campaigns are implemented in the majority of the countries and their effectiveness is characterised as medium. Capacity building schemes are also implemented in several countries and their effectiveness ranges from low to high.

The Global Water Partnership reported in a 2018 analysis of the NDCs of 80 developing countries that water drives adaptation action, as 89% of the surveyed countries prioritise investing in water infrastructure, institutions or governance (GWP, 2018). However, countries tend to be most interested in building resilient water infrastructure to secure a climate-proof water supply; few are investing in strengthening water governance either through robust water-management institutions or integrated approaches to water management to make their plans more sustainable in the long-term (GWP, 2019).

TABLE 4.1. Implementation level of water-related adaptation measures, as listed in national climate adaptation reports, in the EMME region

√ = listed; H = high; M = medium; L = low; N = none, according to national experts

	Bahrain[a]	Cyprus[b]	Egypt[c]	Greece[d]	Iraq[e]	Iran[f]	Israel[g]	Jordan[h]	Kuwait[i]	Lebanon[j]	Qatar[k]	Oman[l]	Palestine[m]	Saudi Arabia[n]	Syria[o]	Turkey[p]	UAE[q]	Total
Governance																		
Improving water governance					L	√		M			M	M	M	M				6
Enforcing existing water policies				H				L		L	L	H	M	M	√			8
Promoting policy-supportive research								L		L	M	L	L	M				6
Promoting participatory approaches						√							L	L				3
Governance of riparian rights with neighbouring countries				M	L					M			M	L				5
Equitable allocation of transboundary water resources					L					M			L	N				4
National databases open to all	L				M		√			N			L	M				6
Single national institute for water monitoring data	L												N	L		M		4
Geoportal info on impact of climate change on water resources	L			L						N				L		M		5
Improving data quality and management of databases	L							L		L	L	L	M	M		M		8
Establishing water accounting system	L				N	√		L		N		L		N				6
Regulating groundwater abstraction	H	L		L				H		M	M	M	M-L	M		M		10
Establishing water abstraction protection zones				L				L		L				N				4
Allocating water efficiently		M			M			L					M-H	L				5
Regional cooperation																		
Promoting regional cooperation				M	L	√		M		M		M		L				7
Water imports		N											H	N				3

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TABLE 4.1 (continued)

√ = listed; H = high; M = medium; L = low; N = none, according to national experts

	Bahrain[a]	Cyprus[b]	Egypt[c]	Greece[d]	Iraq[e]	Iran[f]	Israel[g]	Jordan[h]	Kuwait[i]	Lebanon[j]	Qatar[k]	Oman[l]	Palestine[m]	Saudi Arabia[n]	Syria[o]	Turkey[p]	UAE[q]	Total
Financing and investment																		
Increasing private sector participation in water resources management	H				N	√		M		L		H		H				7
Water pricing	M	M		M	L			M	√	M	L	M	M-H	M		M	√	13
Water subsidies	M	L			M			L				H		M			√	7
Overconsumption penalties	L	M			N			L		N		M		M		N		8
Improving system of water fees collection	H			M	L					M			M	H				6
Research and technology development																		
Supply measures																		
Increasing desalination	H	H	√		L	√	√	L	√		H	H	M-L	H			√	13
Improving wastewater treatment	H	M		H	L	√	√	H		L	H	H	L	H				12
Reusing greywater and treated wastewater	M	M	√	N		√	√	L	√	N	M	L	L	L	√	L	√	16
Enhancing artificial recharge of aquifers	L	L		N				M		L	M	L	L	L		L		10
Promoting rainwater harvesting		L	√	L			√	M		L		M	M	L	√	L		11
Inter-basin water transfer projects		H		L	L	√		H		M				L				7
Demand measures																		
Promoting water-saving technologies	L	L					√	L	√	L	L		L	L	√		√	11
Increasing irrigation efficiency		H	√	L	L		√	M	√	L	M	L	M-H	L	√	M		14
Promoting hydroponics	L							L			M	L		M			√	6
Water metering	H	M			M			H		L	M	H	L	M		M	√	11
Replacing/maintaining networks	L	M		L	L			L		L	H	L	M-H	M				10
Reducing water losses	M	M	√	L		√	√	L	√	L	H	L	M	L	√			14

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TABLE 4.1 (continued)

√ = listed; H = high; M = medium; L = low; N = none, according to national experts

	Bahrain[a]	Cyprus[b]	Egypt[c]	Greece[d]	Iraq[e]	Iran[f]	Israel[g]	Jordan[h]	Kuwait[i]	Lebanon[j]	Qatar[k]	Oman[l]	Palestine[m]	Saudi Arabia[n]	Syria[o]	Turkey[p]	UAE[q]	Total
Improving the control/monitoring of water uses	L				L			L		L	M	L	L	M		M		9
Redesigning canal cross-sections			√					N						L				3
Increasing share of renewable energy in overall power supply	H							H			H		L-M	L				5
Reducing overall energy consumption in public water facilities	L							L			M			H				4
Improving aflaj systems maintenance												H		N				2
Cloud seeding and fog collection												M		L				2
Resilience and reconstruction																		
Developing river basin management plans		H		H						L				N		M		5
Drought management plan		H						H		L				L				4
National plans for land use and water bodies				L						L				M				3
Developing national adaptation plan		H		H	M			H		M	M	H	H	L	√			10
Expanding dams and surface water reservoirs		H	√	L	M			H		M	M	M	L	H	√	H		12
Improving forecasting, monitoring and alert systems		M				√	√	L		N	M	M		M		M		9
Early warning system for water and food-borne diseases								L						L				2
Monitoring and controlling food-borne diseases								L			M			N				3
Changing cropping patterns (drought-tolerant crops)		L	√					L			L			L	√	M		7
Managing forest ecosystems				M						N				L				3

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TABLE 4.1 (continued)

√ = listed; H = high; M = medium; L = low; N = none, according to national experts

	Bahrain[a]	Cyprus[b]	Egypt[c]	Greece[d]	Iraq[e]	Iran[f]	Israel[g]	Jordan[h]	Kuwait[i]	Lebanon[j]	Qatar[k]	Oman[l]	Palestine[m]	Saudi Arabia[n]	Syria[o]	Turkey[p]	UAE[q]	Total
Capacity building																		
Awareness-raising campaigns		M	√	L		√	√	L	√	L	H	L	M-L	M		M	√	14
Farm training				L	N					L		M	M	M				6
Education				M	M			L		M	M	M		M				7
Capacity building in water sector workforce	L				M			L	√	M	L	M	M	L	√			10
Training experts in the water sector to write successful proposals to international climate funds								L			L			H				3

a. Bahrain's Initial Communications to UNFCCC (2005); Bahrain's Second National Communication to UNFCCC (2012); Bahrain's Third National Communication to UNFCCC (2020); Bahrain's Green Climate Fund project: Enhancing climate resilience of the water sector in Bahrain.
b. Cyprus Sixth National Communication accompanied by the Biennial Report under the UNFCCC (2013); National Strategy for Adaptation to Climate Change (2017); Cyprus Seventh National Communication & Third Biennial Report - under the United Nations Framework Convention on Climate Change (2018); Cyprus' Integrated National Energy and Climate Plan (2020); River Basin Management Plan of Cyprus for the Implementation of the Directive 2000/60/EE (Period 2016-2021).
c. The Arab Republic of Egypt: Initial National Communication on Climate Change to the UNFCCC (1999); Egypt Second National Communication to the UNFCCC (2010); Egypt Third National Communication to the UNFCCC (2016).
d. Greece's Seventh National Communication to UNFCCC (2018); Report on the technical review of the Seventh National Communication of Greece (2019); Hellenic Republic National Energy and Climate Plan (2019); Fourth Biennial Report under the United Nations Framework Convention on Climate Change (2020).
e. Iraq's Initial National Communication to the UNFCCC (2016); National Environmental Strategy and Action Plan (2013-2017); UNEP (2020). Iraq's National Adaptation Plan process for climate change resilience 2020-2030; RICCAR (2017). Arab Climate Change Assessment Report.
f. Initial National Communication to the UNFCCC (2003); Second National Communication to the UNFCCC (2010); Intended Nationally Determined Contribution (2015); Third National Communication to the UNFCCC (2017).
g. Israel's Initial National Communication on Climate Change to UNFCCC (2000); Israel's Second National Communication on Climate Change to UNFCCC (2010); Israel's preparations for adaptation to climate change: Recommendations for national strategy and action plan; Israel's Third National Communication on Climate Change to UNFCCC (2018).
h. Jordan's Third National Communication on Climate Change (2014); Intended Nationally Determined Contribution (2015); MoH (2012) National Climate Change Health Adaptation Strategy and Action Plan of Jordan. Ministry of Health, Amman, Jordan; MoEnv (2021) National Adaptation Plan to Climate Change in Jordan. Ministry of Environment. Amman, Jordan.
i. Kuwait's Initial National Communication to UNFCCC (2012); Kuwait's Second National Communication to UNFCCC (2019); Climate Risks and Vulnerability Profile Kuwait (2019).
j. Lebanon's Initial National Communication Report to the UNFCCC (1999); Lebanon's Second National Communication to the UNFCCC (2011); Lebanon's Intended Nationally Determined Contribution (2015); Lebanon's Third National Communication to the UNFCCC (2016).
k. Initial National Communication to the UNFCCC (2011); Qatar Intended Nationally Determined Contributions Report (2015); Qatar Second National Development Strategy 2018-2022 (2018).
l. Oman's Initial National Communication to the UNFCCC (2013); Oman's Second National Communication to the UNFCCC (2019); http://www.fao.org/nr/water/aquastat/countries_regions/OMN/index.stm; http://www.unep.or.jp/ietc/publications/techpublications/techpub-8f/C/Oman1.asp; http://www.omanpwp.com/PDF/7YS%202016-2022%20Final%20.pdf; https://waterinventory.org/sites/waterinventory.org/files/chapters/Chapter-14-Umm-er-Radhuma-Dammam-Aquifer-System-South-web.pdf; https://www.kas.de/en/web/remena/single-title/-/content/desalination-an-alternative-to-alleviate-water-scarcity-in-the-mena-region; https://www4.unfccc.int/sites/SubmissionsStaging/NationalReports/Documents/520417_Oman-NC2-1-Oman%202nd%20National%20Communication%20(17%20November%202019)%20-%20Final.pdf.
m. Palestine's Initial Communication to UNFCCC (2016); National Adaptation Plan to Climate Change (2016).
n. First National Communication of the Kingdom of Saudi Arabia to UNFCCC (2005); Second National Communication of the Kingdom of Saudi Arabia to UNFCCC (2011); Third National Communication of the Kingdom of Saudi Arabia to UNFCCC (2016)
o. Initial National Communication to the UNFCCC (2011); Nationally Determined Contributions Under Paris Agreement on Climate (2018).
p. First National Communication on Climate Change under UNFCCC (2007); Turkey's National Climate Change Adaptation Strategy and Action Plan (2011); Turkey's Fifth National Communication under UNFCCC (2013); Sixth National Communication of Turkey under the UNFCCC (2016); Seventh National Communication of Turkey under the UNFCCC (2018); Climate Change Strategy 2010-2023.
q. First National Communication to UNFCCC (2007); Second National Communication to UNFCCC (2010); Third National Communication to UNFCCC (2012); Fourth National Communication to UNFCCC (2018); National Climate Change Plan of the United Arab Emirates 2017-2050 (2017).

TABLE 4.2. Effectiveness of water-related adaptation measures, as listed in national climate adaptation reports, in the EMME region

√ = listed; H = high; M = medium; L = low; N = none, according to national experts

	Bahrain	Cyprus	Egypt	Greece	Iraq	Iran	Israel	Jordan	Kuwait	Lebanon	Qatar	Oman	Palestine	Saudi Arabia	Syria	Turkey	UAE
Governance																	
Improving water governance	H				L	√		L			M	M	M	L			
Enforcing existing water policies	H			M				H		H	L	M	M	M	√		
Promoting policy-supportive research								H		M	M	L	L	M			
Promoting participatory approaches						√							L	L			
Governance of riparian rights with neighbouring countries				L	L					L			M	L			
Equitable allocation of transboundary water resources					L					M			L	N			
National databases open to all	L				M		√			H			L	M			
Single national institute for water monitoring data	L													L		H	
Geoportal info on impact of climate change on water resources	L			H						H				L		H	
Improving data quality and management of databases	L							L		M	L	L	M	L		H	
Establishing water accounting system	L				N	√				M		L		L			
Regulating groundwater abstraction	H	H		H				H		H	M	M	M-L	M		H	
Establishing water abstraction protection zones				M				M		M				L			
Allocating water efficiently		M			M			M					M-H	L			
Regional cooperation																	
Promoting regional cooperation				M	L	√		M		M		M		L			
Water imports		L											H	N			

(Continued next page)

TABLE 4.2 (continued)

√ = listed; H = high; M = medium; L = low; N = none, according to national experts

	Bahrain	Cyprus	Egypt	Greece	Iraq	Iran	Israel	Jordan	Kuwait	Lebanon	Qatar	Oman	Palestine	Saudi Arabia	Syria	Turkey	UAE
Financing and investment																	
Increasing private sector participation on water resources management	M				N	√		L		M		H		H			
Water pricing	M	H		H	L			H	√	H	L	H	M-H	M		M	√
Water subsidies		M			M			L				L					√
Overconsumption penalties		M			N			L		L		H		M		L	
Improving system of water fees collection				M	L					M			M	L			
Research and technology development																	
Increasing desalination	H	H	√		L	√	√	H	√		H	H	M-L	H			√
Improving wastewater treatment	M	H		L	L	√	√	L		H	M	H	L	H			
Reusing greywater and treated wastewater	L	M	√	M		√	√	L	√	M	M	L	L	L	√	M	√
Enhancing artificial recharge of aquifers	L	M		M				L		H	M	L	L	L		M	
Promoting rainwater harvesting	L	M	√	H			√	H		H		M	M	L	√	M	
Inter-basin water transfer projects		H		H	L	√		H		H				L			
Promoting water saving technologies		L					√	L	√	M	L		L	M	√		√
Increasing irrigation efficiency		H	√	H	L		√	H	√	H	M	L	M-H	L	√	H	
Promoting hydroponics	M							M			M	H		L			√
Water metering	H	M			L			L		H	L	M	L	M		H	√
Replacing/maintaining networks		H		H	L			H		H	H	M	M-H	L			
Reducing water losses	M	H	√	H		√	√	H	√	H	H	L	M	L	√		
Improving the control/monitoring of water uses					L			H		M	M	L	L	L		H	
Redesigning canal cross-sections			√											N			
Increasing share of renewable energy in overall power supply	L							M			M		L-M	L			

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TABLE 4.2 (continued)

√ = listed; H = high; M = medium; L = low; N = none, according to national experts

	Bahrain	Cyprus	Egypt	Greece	Iraq	Iran	Israel	Jordan	Kuwait	Lebanon	Qatar	Oman	Palestine	Saudi Arabia	Syria	Turkey	UAE
Reducing overall energy consumption in public water facilities	M							M			M			L			
Improving aflaj systems maintenance												M		M			
Cloud seeding and fog collection												M		L			
Resilience and reconstruction																	
Developing river basin management plans		M		M						M				N		H	
Drought management plan		M						H		H				L			
National plans for land use and water bodies				M						M				M			
Developing national adaptation plan		M		M	M			M		M	M	M	H	L	√		
Expanding dams and surface water reservoirs		M	√	M	M			M		H	H	M	L	H	√	H	
Improving forecasting, monitoring and alert systems		M				√	√	L		H	L	L		L		H	
Early warning system for water and food-borne diseases								H						L			
Monitoring and controlling food-borne diseases								H			M			N			
Changing cropping patterns (drought-tolerant crops)		M	√					L			L			L	√	M	
Managing forest ecosystems				L						M				L			
Capacity building																	
Awareness-raising campaigns		H	√	M		√	√	M	√	M	M	M	M-L	L		H	√
Farm training				M	N					M		M	M	M			
Education				H	L			M		H	L	M		M			
Capacity building in water sector workforce	L				M			L	√	H	L	M	M	L	√		
Training experts in the water sector to write successful proposals to international climate funds								M			L			H			

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5. Proposed policy and research initiatives

As the world's most water-scarce region, EMME is expected to experience strong adverse impacts of climate change. Thus it is in the interest of all countries to enhance the adaptability of the water sector. The large gap between water supply and demand in the region – a gap that is expected to widen with climate and socioeconomic change – highlights the need for ambitious institutional, technological and financial policies. The water sector cannot be considered in isolation from the broader socioeconomic system. Understanding the interactions and interdependencies between water, agriculture and energy is key to the successful adaptation of water resources to climate change. A nexus approach is required to capture the linkages across all involved sectors to exploit positive synergies and effectively manage trade-offs.

In consideration of current climate-water conditions and research gaps (Section 3), and in response to the review of the measures contained in national adaptation strategies and plans (Section 4), this section identifies policy and research initiatives for climate resilience and water security in the EMME region. The initiatives are aligned across the six actions of the conceptual framework: good governance, regional cooperation, financing and investment, research and technology development, climate resilience and reconstruction, and capacity building.

5.1. Governance

Strategies for adapting water resources to climate change must be embedded within existing national water policies and sectoral policies. To ensure this, national authorities must be willing and able to mainstream climate change adaptation in development policies and to practice close coordination and cooperation within the concerned water ministry and with ministries and operators responsible for water resources, water supply, desalination, sanitation and wastewater treatment, agriculture, energy, and the environment, especially where climate change and the resilience of water resources to it are concerned.

Over the past 20 years, the European Union countries have gained substantial experience with the implementation of the Water Framework Directive. The Directive include, amongst other things: the improvement of qualitative and quantitative status of water resources, the analysis of human impacts and economics of water uses; the monitoring of water resources; the recovery of financial, economic and environmental cost of water services; the development of a program of measures; public consultation and information (EC, 2000). A regional institution – such as a new Mediterranean Water Agency – could coordinate the necessary actions and enhance water governance in the EMME region.

5.1.1. The nexus of water, energy, food and climate

The interconnectedness of water, energy, food and climate has commanded growing attention in policy-making and research communities in the EMME region over the last few years, particularly with respect to the achievement of the Sustainable Development Goals. However, much more needs to be done to integrate the nexus concept in decision-making about climate change. Attempting to achieve security in one of these sectors independently, without addressing trade-offs with the others, will endanger sustainability and security. More research must be done to exploit these linkages by pooling multidisciplinary competences and demonstrating to policy makers the co-benefits and trade-offs between water, energy, agricultural and food policies. Examples include the use of solar power in irrigation (solar pumping) and domestic water supply (solar desalination), and water-energy trade-offs in district cooling. Promoting "water diplomacy" among scientists, policy makers, the public and private sector can further enhance and advance the water-energy-food-climate nexus and avoid potential negative economic and social effects of adaptation measures (e.g., water pricing) in sensitive sectors such as agriculture.

5.1.2. Gender-responsive adaptation policies

Mainstreaming gender considerations in water-related sectors is a necessary step in improving water governance. Identifying the barriers and constraints to gender responsiveness, and the ample opportunities to promote gender equality in climate action, can enhance efforts towards water security and climate resilience. Capacity building is required at all levels to design and implement gender-responsive climate change policies and strategies, and to ensure that financing mechanisms for mitigation and adaptation reach women and men equally.

5.2. Regional cooperation

5.2.1. Enhancing transboundary water cooperation

The promotion of transboundary cooperation through joint climate change impact assessments on shared river basins and groundwater systems, as well as data platforms at the basin level, including surface water, groundwater and maritime water, can contribute to the achievement of the sustainable development goals in the region, but can also lead to the avoidance of future conflicts about these resources. These efforts can extend and link existing studies and collaborations on transboundary water resources in the region (e.g., RICCAR, ESCWA). ESCWA (2019b) also noted that the cooperation and exchange of information and experiences between countries, could contribute to the improvement of integrated water resources management and the formulation and adaptation of bilateral and multi-lateral agreements.

5.2.2. A knowledge hub for climate data and information

A major constraint in the EMME region for improving scientific research on water resources management is the availability and accessibility of climate and water data. Most of the national adaptation water strategies in the region highlight the importance of the availability and accessibility of such data for the formulation of the action plans. The building of a knowledge hub can link all existing climate data portals in the region (e.g., RICCAR, ESCWA, FAO, GIZ) in one designated network that will facilitate data exchange and accessibility between institutions in the region and outside, with endorsement and committed cooperation by all EMME region countries. The created knowledge hub can be operated either by a strong local institution or by a partnership of institutions or by a new institution (e.g., a Mediterranean Water Agency) in the EMME region.

5.3. Financing and investment

One of the stiffest challenges to water security in the region has stemmed from insufficient financing of water-related infrastructure. Private financing and investment are underutilised in the region's water sector, but this need not be the case. The appeal of greater investment may lead to capacity development and sustainable market-based solutions. The formulation of regulatory frameworks that can promote public-private partnerships, through incentives, could help meet the cross-sectoral challenges of the water-energy-food-climate nexus and the financing of water-related adaptation projects. Such partnerships can allow scientists, policy makers, businessmen and stakeholders to consult and agree on the best adaptation measures to be adopted and implemented across country borders.

The Private Sector Facility of the GCF plays a pivotal role in mobilizing private sector engagement in water-related adaptation projects through the provision of financial instruments, such as loans, grants, tax incentives and risk sharing for addressing the consequences of market imperfections. Therefore, raising the public finance of the GCF can strengthen the enabling environment for investment and promote private investment in adaptation projects. Strengthening the transparency and accountability of adaptation finance by ensuring that those who finance adaptation and those benefiting from it are involved in the decision-making process, can increase its effectiveness and efficiency.

5.4. Research and technology development

In the past few decades, most of the countries in the EMME region have taken steps to enhance the adaptation of water resources to climate change, but those measures tended to focus on supply-side management. To parry the effects of climate change and achieve water security it is imperative to diversity and integrate action to control water supply *and* demand, considering financial affordability for users, social acceptance, environmental consequences, economic sustainability, ecosystem services and transboundary issues.

Non-conventional water resources, such as desalinated water and reusable wastewater, are already playing a key role in narrowing the gap between demand and supply in the region (UN-Water, 2020). Desalinated water could secure domestic water supplies, while reuse of wastewater could increase water supplies for agriculture and green infrastructure. However, holistic policies to promote the use of unconventional water resources are needed, including health and safety regulations, investments in desalination and water treatment facilities, and awareness raising.

Many have called for the creation of regional observatories for non-conventional water resources such as desalination (Loic Fauchon, 2019; El Kharraz 2020). Specific areas of research for the individual technologies are presented below.

Desalination is an energy-intensive process that relies predominantly on fossil fuels, which results in the emission of air pollutants and greenhouse gases that further exacerbate climate change (Missimer and Maliva, 2018). More research on the efficient use of renewable energy sources, such as solar technologies (Georgiou et al., 2016), as a viable alternative to conventionally driven seawater desalination is sorely needed (Tzen and Morris, 2003; Ahmadi et al., 2020).

A major environmental impact of desalination arises from the large volume of brine produced. Managing brine is expensive. For that reason, most desalination plants discharge it untreated. More in-depth research on the negative effects of the brine on ecosystems and marine biodiversity is needed. Improving the management of brine could convert this environmental concern into an economic opportunity for further investment in desalination. This is particularly evident for countries such as Saudi Arabia, UAE, Kuwait and Qatar, which produce large volumes of brine with relatively low efficiency (Jones et al., 2019).

Wastewater reuse is complicated by the unknown long-term effects on human health of emerging contaminants, notably pharmaceuticals, that are present in wastewater, in soils, and, ultimately, in groundwater. Research to increase the efficacy of wastewater treatment technologies to overcome environmental pollution is needed (Rasheed et al., 2019).

Groundwater recharge and aquifer storage management can involve surface water, treated sewage water and desalinated water. The proper use of surface runoff to recharge aquifers can protect water resources against pollution and evapotranspiration. Local investigations should be undertaken to identify suitable locations and to assess runoff water quantities, aquifer characteristics, economic feasibility and water exploitation.

Cultural heritage preservation has been acknowledged as fundamental for the sustainable development of the region (Cernea, 2001). The region is extremely rich in water-based cultural heritage, such as groundwater tunnels (*aflaj*, *qanat*, chain of wells), stream diversions, aqueducts, storage and water-harvesting reservoirs, water mills, springs, oases and salt lakes. The maintenance and restoration of traditional water-management systems, either to improve their functionality or to develop educational attractions, or both, can contribute to the appreciation of our shared cultural water heritage and support sustainable tourism.

Ecosystems conservation is often closely linked to cultural heritage preservation. The Dead Sea basin, one of the world's unique ecosystems, is an important example. The Dead Sea is currently facing severe challenges, including the risk of complete dryness and the risk of a major environmental disaster. Integrated management of aquatic ecosystems and cultural heritage that places heritage at the focus of the strategic planning can contribute to the alleviation of the above-mentioned risks.

5.5. Resilience and reconstruction

Most of the countries in the region lack an integrated **drought-management system** that includes 1) a drought-management strategy; 2) information systems; 3) monitoring and early warning systems; and 4) mitigation and adaptation plans. Monitoring and early warning systems are the cornerstones for better drought preparedness to raise the region's resilience to climate change. Close cooperation among government departments devoted to water, agriculture, the environment and meteorology – under the umbrella of institutions devoted to disaster risk reduction and accompanied by efforts to build capacity in the use of earth observation technologies for operational water management – would surely enhance the efficacy of the integrated drought management.

Similarly, **flood management plans** need to be developed and implemented to protect the region against the impacts of future rainfall extremes, which are often made worse by increasing urbanisation. Future flood risks need to be modelled and flood hazard areas need to be mapped, with the use of high resolution downscaling of rainfall extremes from climate change simulations. Changes in land use zonation and the development of early warning systems need to be considered. The creation of green corridors and linear parks along rivers can contribute to flood mitigation and urban cooling (Giannakis et al., 2016).

Increasing the capacity of **water storage reservoirs** can improve the resilience of water supply systems and also provide flood protection. However, attention must be given to sediment load control as well as environmental flow requirements for downstream ecosystems and groundwater recharge. The possibilities of dam reservoir releases for downstream recharge of aquifers should be investigated. Interdisciplinary studies are needed to develop and optimise the dynamic management of water reservoirs.

5.6. Capacity building

The EMME region currently possesses inadequate institutional and individual capabilities for the integrated planning and management of the water sector. Institutional weaknesses, lack of coordinated governance and conflicting objectives among actors all constrain climate adaptation. The acute vulnerability of the region's water sector amplifies uncertainty in the planning and management of its water resources. To make the most of scarce resources, the countries of the region should promote the coordinated development and management of water, land and other related resources to maximise economic and social welfare without compromising the sustainability of vital ecosystems. To improve the resilience of water resources management, capacity must be built.

Capacity building should span all scales, from local to national to regional, adopting a participatory approach that encourages the **active involvement of all relevant stakeholders**. Capacity building is required at all levels, from policy makers to water professionals, scientists, non-governmental organisations, communities and water users, to enhance the effectiveness of water policies to meet climate resilience and water security objectives. Financing mechanisms for water resources adaptation need to consider the gender dimension.

Information and awareness campaigns are required to engage and broaden public understanding of local water resources and of the impacts of climate change – and to encourage behavioural change across the region. Enhancing the awareness of individuals, organisations, and institutions on climate change vulnerability, impacts and adaptation can be a starting point to build individual and institutional capacity for planning and implementing adaptation. Efforts to encourage wiser use of water resources must be structured so that the results reach women and men equally.

Education on water-related climate change should be integrated across school curricula at all levels. High school and elementary school education alike should include modules on water resources and water use, thus encouraging students to study water science and technology. Universities should offer curricula that cover an integrated understanding of climate, water and environment, including water resources, water uses, economics, policies and social sciences.

The establishment of a Metropolitan "ECO-MED" Academy under the auspices of UNESCO-IHP could support governance-related capacity building in fast growing Mediterranean and Middle East cities to effectively meet the regional SDGs. Educational activities would be centred on 1) establishing common standards for monitoring water flow and water quality; 2) setting goals for sustainable management of transboundary water resources; 3) adapting regional eco-development strategies to face climate change impacts and the effects of extreme drought; 4) providing sustainable sanitation; and 5) undertaking depollution projects and preservation measures in Mediterranean coastal ecosystems. More specifically, the agenda of the Metropolitan "ECO-MED" Academy would be focused on providing interested stakeholders in the Mediterranean member states, local governments, public service operators, local and global financial sectors, relevant UN organisations, hydrological institutes, universities, municipalities, technical experts, local communities, and other interested stakeholders with 1) locally adapted professional development programs; 2) systems to monitor transboundary coastal ecosystems, map pollution, and assess risks; 3) regional knowledge bases and databases on the state of coastal ecosystems and their aquifers; 4) media support for public education at all levels; 5) academic research and development capabilities; and 6) shared information systems.

6. Summary and recommendations

Most of the countries of the EMME region face severe water scarcity. Freshwater is often extracted beyond sustainable limits and with little consideration of environmental flows and ecosystem requirements. Reliance on fossil groundwater resources and their high rates of exploitation raises strong sustainability concerns for the future. Some countries of the region depend strongly on shared, transboundary water resources, with insufficient cooperation to underpin shared water management. Agriculture remains the main water user in the region, accounting for 85% of all water withdrawals. Universal and equitable access to safe and affordable drinking water for all (Sustainable Development Goal 6.1) is still far from achieved and is especially low in Palestine (58%), in Iraq (87%) and among refugee communities that have been displaced by conflict. The water problems of the region are aggravated by poor water governance, insufficient financial investments and the scarcity of hydrologic monitoring systems and of publicly available data.

Climate change projections show a 20-40% reduction in precipitation for the Mediterranean countries of the EMME region by the end of the century under the high-emissions RCP8.5 scenario of the Intergovernmental Panel on Climate Change. Hydrologic modelling studies indicate that lower rainfall and higher temperatures and evapotranspiration will be amplified in water resources, increasing supply risks and quality problems. The climate adaptation measures contained in national adaptation strategies and plans display a good understanding of the threats to the water sector posed by climate change. However, the half-hearted implementation and financing of those measures raises concern.

Regional research and policy initiatives have been supported through various mechanisms and institutions and should continue in the short, medium (2030) and long terms (2050). These initiatives can be summarised as follows:

- Improvement of water governance, with special attention to integrated water resources management (SDG 6.5) and the application of the climate-water-energy-food nexus
- Expansion, upgrading and automation of hydrologic monitoring networks throughout the region
- Development of data and knowledge portals for open access to all water and climate data

- Research to monitor and model hydrologic characteristics, water use, and impacts of climate change – and to improve shared management of transboundary water resources
- Research on the safe and sustainable use of treated sewage water and other marginal water resources
- Research initiatives to support economic and environmental cost-benefit analyses of adaptation measures intended to increase the climate resilience of the water sector across the region
- Research on the sustainable integration of public and private finance in the water sector
- Awareness-raising activities on climate change and water security, and improvement of school curricula
- Educational initiatives, such as the establishment of a Metropolitan ECO-MED Academy under UNESCO-IHP auspices to support local water governance capacity
- Cooperative research and development to increase universal access to safe and affordable drinking water (SDG 6.1).

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