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Unravelling the Implications of Climate Change for Energy, Food, and Water Security

Sustainability Research Paper

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Global climate change is becoming more severe, as evidenced by the global mean temperature reaching a record high of 1.45 ± 0.12 °C above the pre-industrial levels in 2023.[01] Ocean temperatures and sea levels are also at record highs: average global sea surface temperature for February 2024 over 60°S–60°N was 21.06°C, the highest record for any month in the dataset.[01] At the same time, Antarctic sea ice and glaciers are reaching record lows.[02] These changes in climatic parameters are causing long-term shifts in weather patterns and more frequent extreme weather events. As a result, critical resources such as water availability as well as energy production and food security are being affected.[01] This paper examines the impacts of climate change on energy, food, and water security, and explores potential solutions to reduce vulnerability and improve resilience.

SUSTAINABILITY RESEARCH PAPER

This research paper is part of a 12-month series published by the Al-Attiyah Foundation every year. Each in-depth research paper focuses on a current sustainability topic that is of interest to the Foundation's members and partners. The 12 technical papers are distributed to members, partners, and universities, as well as made available on the Foundation's website.

03 EXECUTIVE SUMMARY

- Global climate is becoming more severe with several climate parameters reaching record levels in the past months, e.g. global mean temperature reached a record high of 1.45 ± 0.12 °C above the pre-industrial levels in 2023, average global sea surface temperature over 60°S–60°N was 21.06°C in February 2024, the highest record ever.
- The MENA region, characterised by arid climate and existing scarce freshwater supplies, is particularly affected by climate change. Temperature increase in the region is higher than the global average. Recent climate impacts include severe droughts in Morocco and Tunisia and significant flooding in the Arabian Peninsula.
- The region is strongly reliant on irrigation for the agriculture sector and freshwater for the cooling of thermal power plants, and therefore particularly vulnerable to climate change. Eleven MENA countries are among the most water-stressed in the world, highlighting the serious challenges of water management.
- High population growth in the MENA region is increasing demand for food, water and energy, therefore putting additional pressure on already scarce resources. Electricity demand for cooling will increase, straining power grids. Agriculture, the largest water user, will need more irrigation and urban water demand will increase. Agricultural yields could fall by as much as 30% by mid-century due to hotter, drier conditions, and coastal areas are at risk from flooding and erosion, affecting both agricultural and energy production. At the same time, urban water use is projected to increase.

- Climate resilient technologies and policies will be crucial. Short-term measures include more water-efficient power plants and advanced cooling technologies The region also need to diversify its energy mix with renewable energy sources requiring little water, such as solar and wind technologies. Decentralised renewable energy systems which are more resilient than grids to extreme weather events are also offering interesting opportunities. Improving water security through increased water use efficiency and the identification of new water sources like desalination and the use treated wastewater will also be key for the region. Food security should be tackled not only at the production stage, e.g. with the implementation of sustainable land management practices such as agroecology and agroforestry, but also considering the whole value chain, e.g. reducing post-harvest losses.
- Given the interconnectedness of energy, water and food sectors, integrated and transversal policies are essential, taking into consideration regional environmental and cultural contexts.
- Political instability and regional conflicts pose further challenges to improving water, energy and food security, highlighting the need for strong governance and cooperation to build resilience to climate change related impacts.

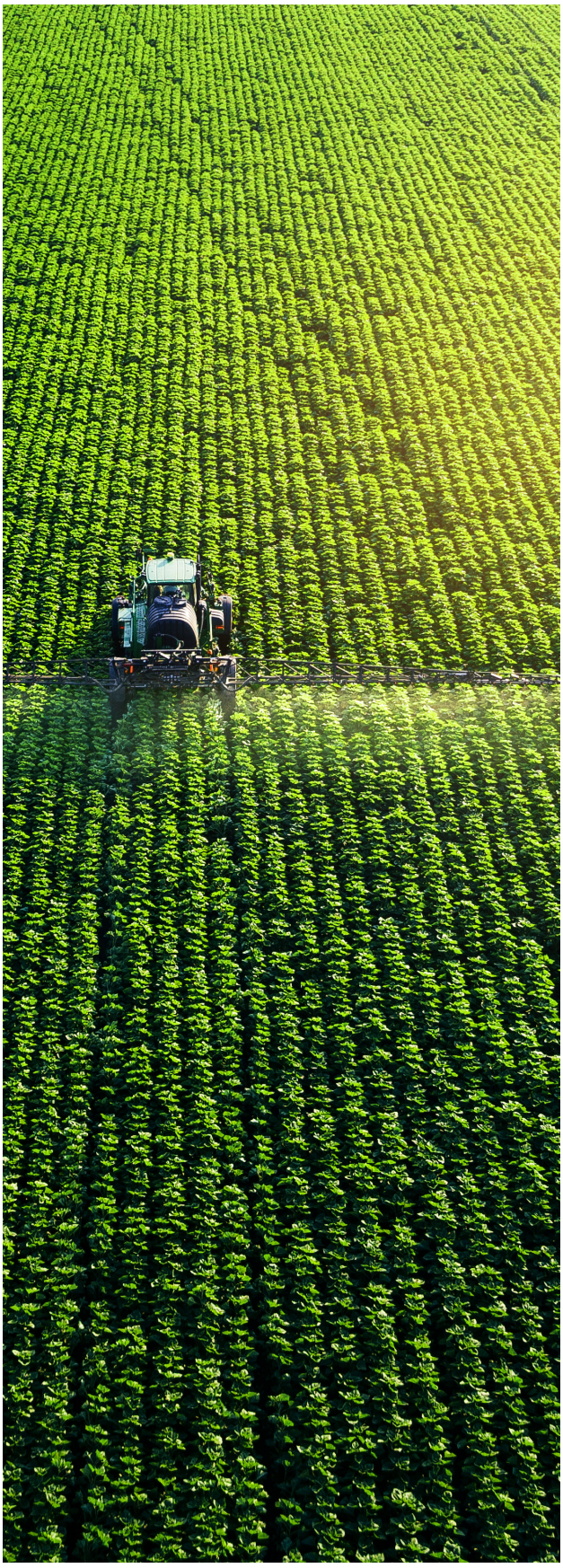
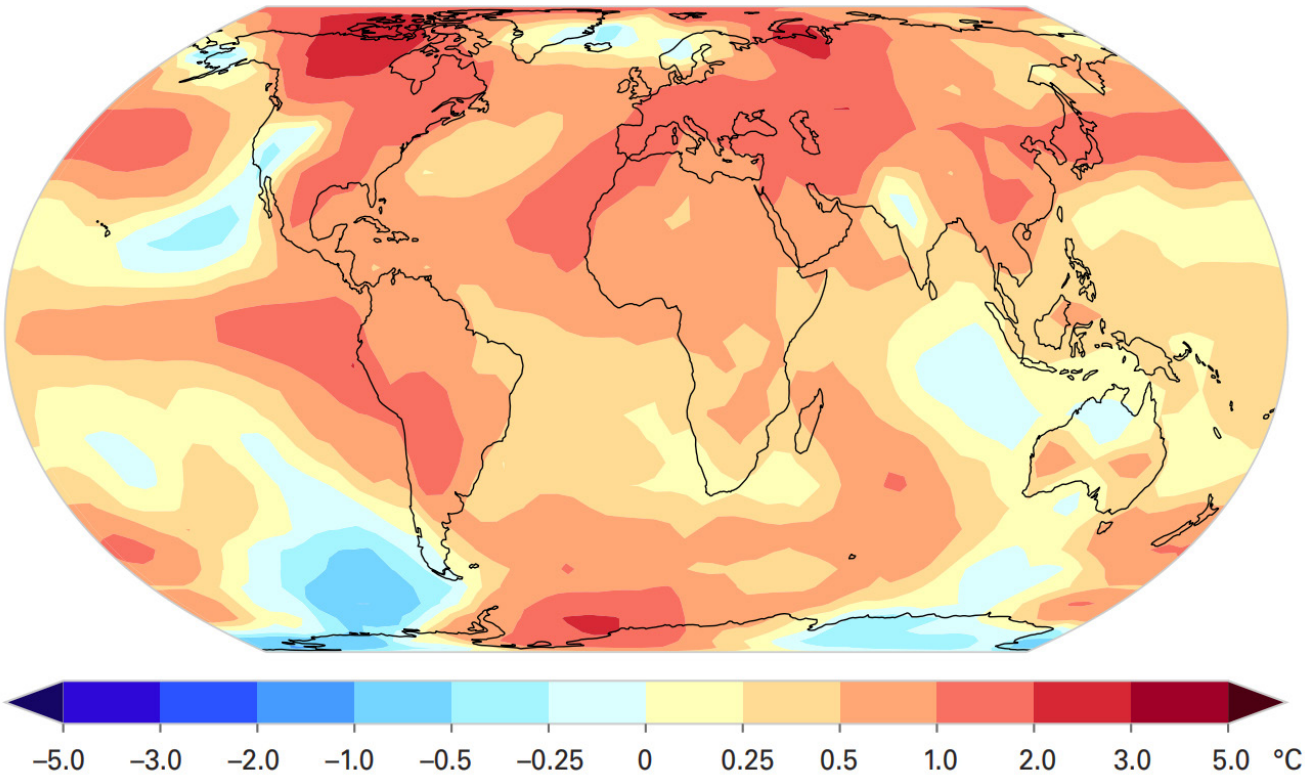


Figure 1 - Mean Near-Surface Temperature Anomalies for the Year 2023



Source: (WMO, 2024)[01]

Global impacts

In 2023, unprecedented weather extremes were reached, making it for instance the hottest year since records began 174 years ago. The global average temperature rose to a record high of 1.45 ± 0.12°C above pre-industrial levels. This is aligned with a longer term trend, as the decade from 2014 to 2023 is now recognised as the warmest 10-year period on record.[01] The alarming and sustained rise in temperature is accelerating the melting of polar ice caps and glaciers, further contributing to sea-level rise.[01] However, as illustrated by Figure 1, the mean surface temperature anomalies vary significantly across the globe.

In addition, frequency and severity of a large set of climate hazards has also increased over the past years and affect regions all over the world. Heatwaves have become more intense and prolonged, affecting human health, agriculture and infrastructure.[01,11] Prolonged droughts lead for instance to reduced crop yields and water scarcity, exacerbating hunger and thirst in vulnerable regions[01,05,11] Conversely, severe flooding disrupts communities, damages infrastructure and contaminates water supplies, posing additional health risks.[12,13]

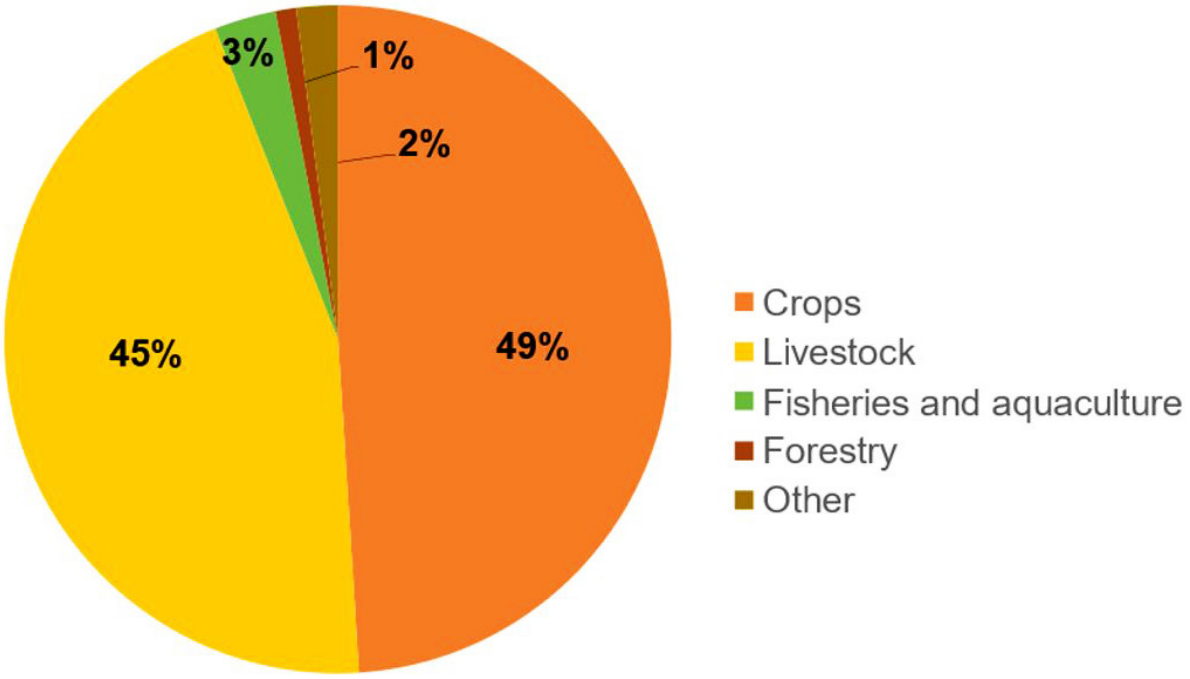
As the IPCC AR6 report clearly stated, climate change impacts are becoming increasingly complex and more difficult to manage. Multiple climate hazards will occur at the same time and various climate and non-climate related risks will interact, resulting in compounding overall risk and risks cascading across sectors and regions.[14]

The energy sector is particularly affected by those risk. Climate change impacts affect different parts of the electricity value chain including supply and demand, infrastructure, and transportation.[15] Decreasing rainfall and more frequent droughts pose ongoing risks to the energy sector by reducing the effectiveness of thermal power plants that rely on freshwater for cooling. These changes are also straining power generation and transmission networks by increasing peak electricity demand and reducing operational efficiency.[10] Electricity grids are also highly vulnerable to windstorms and flooding. Renewable energy technologies are also affected by climate change impacts, with a reduction of efficiency of solar panels under high temperatures and a reduction in hydroelectricity production during droughts due to reduced water inflow and after intense rainfall events due to increased sedimentation in the reservoir[16]. Additionally, basic services such as clean water, continuous food supply, heating, and cooling as well as several technologies supporting resilience building (e.g. access to information through early warning systems) often require a source of energy to function.[16] Therefore, disruption in access to modern energy can threaten resilience of communities to climate change.

With regards to food security, climate change is making it increasingly difficult to sustain agricultural production in water-stressed regions by reducing water availability, increasing the frequency of extreme weather events and creating conditions favourable to pests and diseases.[01,17] In particular, a global temperature rise of more than 2°C could severely limit adaptive capacity and impose higher costs, especially in regions such as the Sahel and South Asia, where high temperatures affect crops such as wheat, maize, sorghum [01.11,17]

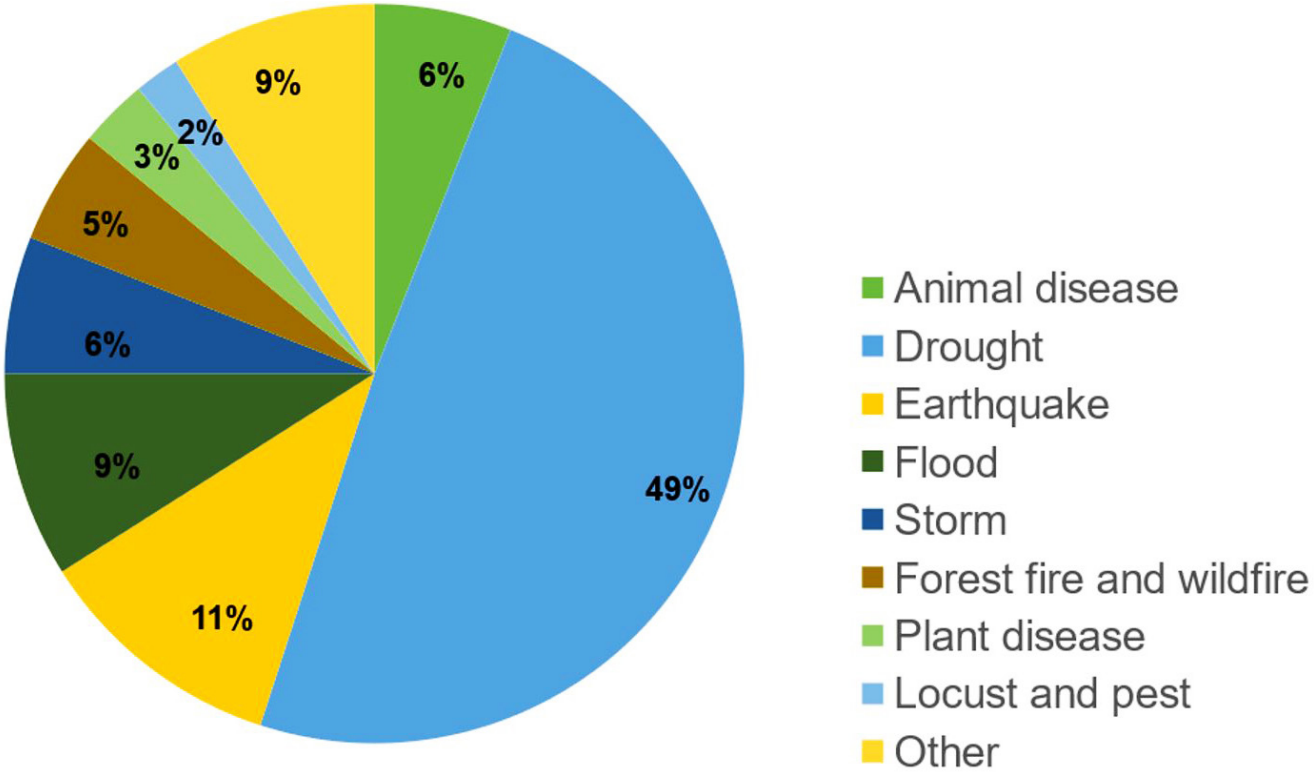
A recent assessment by FAO [18] show that crops and livestock are the two agriculture subsectors affected by disasters (Figure 2) and that droughts represent more than a half of the impacts in the agriculture sector declared under the Sendai framework indicator C2 (2015-2022) (Figure 3).

Figure 2 - Breakdown of Losses in Agriculture by Subsectors (2007-2022)



Source: FAO, 2023[18]

Figure 3 - Share of Impact by Hazard Type Declared Under Sendai Framework Indicator C2 (2007-2022)



Source: FAO, 2023[18]

In addition, climate change is altering natural and socio-economic conditions, posing a threat to water security. It disrupts the water balance within ecosystems, thereby affecting water availability[01,13] More frequent extreme droughts are likely to alter local hydrology, reduce crop productivity, increase tree mortality and disrupt water-based ecosystem services such as nutrient cycling, hydroelectric generation and flood control.[13] At the moment, approximately half of the world's population is experiencing severe water scarcity for at least one month per year due to climate and non-climate related factors and is exacerbated by inadequate water governance.[14]

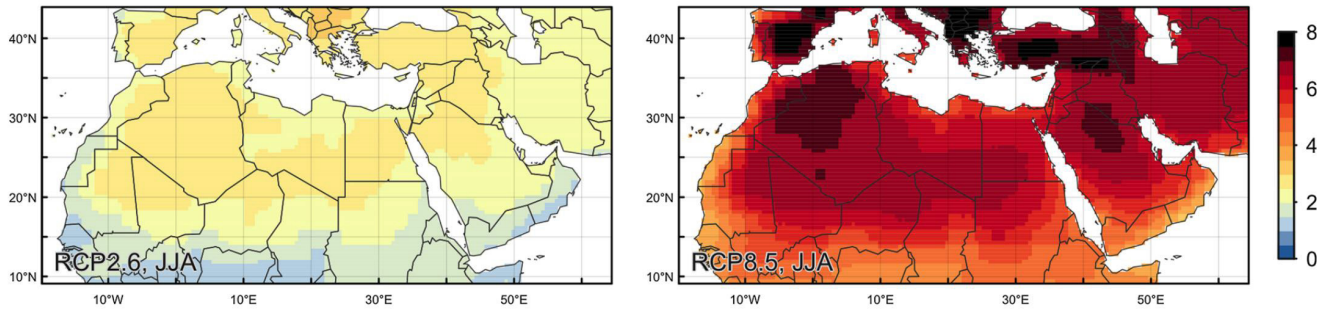
Water, food, and energy are deeply interconnected, forming a network that underscores the importance of integrated resource management.[19] Several interlinkages can be identified in this context. Firstly, agriculture is a significant consumer of water, accounting for approximately 70% of global freshwater use.[19] Secondly, there is a vital connection between water and energy. Water is essential for extracting and processing fossil fuels and generating electricity, while energy is crucial for water management, including pumping, distribution, and treatment.[10,19] Additionally, energy is indispensable in the agricultural sector, from food production and processing to transportation and distribution.[17,19] These interdependencies mean that any disruption in one area can have a ripple effect on the others.[19]

Impacts on the MENA Region

Between 1980 and 2022, the MENA region experienced a temperature increase of 0.46°C per decade, exceeding the global average of 0.18°C.[10,12] This warming trend is projected to continue, leading to higher average temperatures and more frequent heatwaves.[12] Projections also indicate that there will be varying changes in rainfall patterns, with reductions expected in North Africa and West Asia, and slight increases in the southern Arabian Peninsula.[12]

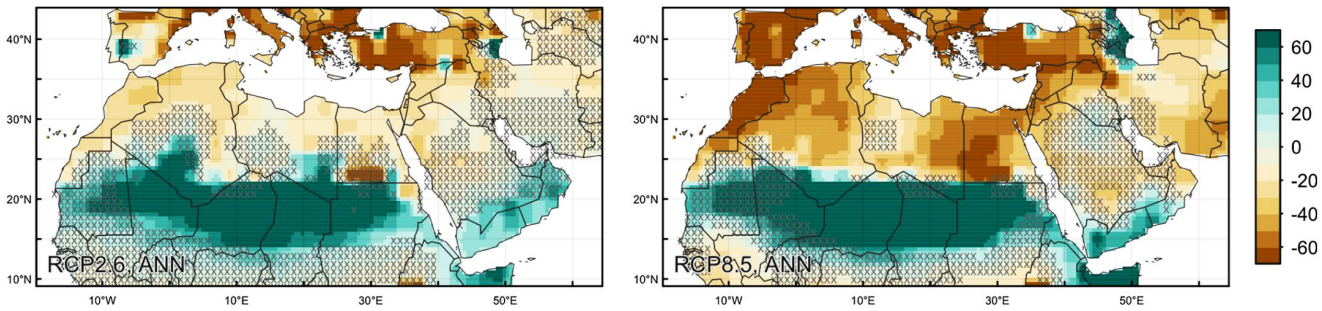
In recent years, the impacts of climate change have been evident. For instance, Morocco and Tunisia faced severe droughts in 2022 and 2023 respectively, while countries in the Arabian Peninsula were hit by significant floods in 2022.[10] Rising temperatures and changing precipitation patterns are expected to reduce water availability in the MENA region over the course of this century. In addition, the timing of peak snowmelt flows is expected to shift earlier in the year, negatively impacting water availability in the region.[12] Figures 4 and 5 depict the projected changes in average temperatures and aridity levels within the region.

Figure 4 – Mean Temperature Change (°C) for the Summer Months in the RCP 2.6 (Left) and RCP 8.5 (Right) Scenarios in 2071-2099



Source: Waha et al. (2017)[12]

Figure 5 - Percentage Change in the Aridity Index for Scenarios RCP2.6 (Left) and RCP8.5 (Right) by 2071-2099 Compared to 1951-1980



Source: Waha et al. (2017)[12]

The energy sector in the MENA region is crucial for its economic stability and growth. However, it is increasingly threatened by climate change. Changes in temperature and rainfall patterns are worsening existing water scarcity challenges, which in turn affect energy production and consumption. These climate-induced changes are putting pressure on water resources necessary for energy generation and are also changing energy demand patterns.[10] For instance, in Morocco, rising temperatures have led to a surge in electricity demand for cooling, stretching an already overburdened power grid.[10,20] Similarly, in the southern and eastern Mediterranean parts of MENA, reduced rainfall and more frequent droughts pose a critical threat to energy production.

This trend is expected to continue, reducing the availability of water crucial for cooling fossil-fuelled thermal power plants, which generate over 90% of the region's electricity.[10] Moreover, rising temperatures not only affect energy production but also reduce the efficiency of power transmission systems. Higher temperatures can cause power lines to overheat, expand, and sag, which reduces their transmission capacity and increases energy losses. These impacts pose safety risks and increase the likelihood of grid faults, further complicating power grid management resulting in additional maintenance and monitoring to ensure a reliable power supply.[10]

Agriculturally, the MENA region could experience crop yield reductions of up to 30% by mid-century due to hotter and drier conditions.[12] Key agricultural zones, especially those in low-lying coastal areas, face significant risks associated to climate hazards like flooding, erosion, and salinization, which could severely disrupt food production.[21] At the same time, while agriculture does not provide the majority of the region's food supply, it remains a crucial sector for socioeconomically vulnerable populations, including women and smallholder farmers).[22] The impacts of climate change add to the existing stresses in a region already characterized by high vulnerability and acute food insecurity. For instance, Palestine (Gaza Strip), Lebanon, and Yemen have extremely high levels of food insecurity, with significant portions of their populations experiencing emergency or catastrophic conditions.[05] This makes the agricultural sector's challenges particularly critical, as it supports those most at risk and is essential for the livelihoods of many vulnerable communities.

The MENA region is an extremely water stressed region, with around 60% of the population living under severe water stress.[23] Climate change is aggravating this crisis by altering precipitation patterns as well as snow and ice melt cycles, rising temperatures and the resulting increase in the frequency of droughts, all of which reduce water availability.[09,12] These changes are expected to affect water availability, for example by increasing evaporation losses from large dams, while also increasing water demand in various sectors.[09] Agriculture, the largest water user in the region, will require more water for crop irrigation throughout the growing season as temperatures rise.[09] Urban and domestic water use is also expected to increase due to higher temperatures, which will increase demand for drinking water, cooling systems to counteract the urban heat island effect, and irrigation to maintain urban green spaces.[9] As highlighted above, rising temperatures increase the demand for cooling, which in turn increases the demand for energy. This creates a feedback loop where more water is needed for cooling systems in fossil fuel power plants, highlighting the interdependence between water and energy production.[09,12] In addition, changing hydrological dynamics may intensify disputes over transboundary water resources, particularly in critical basins such as the Nile and Tigris-Euphrates river systems (Mahmoud, 2024). This could further hamper water management and worsen regional tensions, reinforcing the urgent need for cooperative and sustainable water resource management strategies.

11 POTENTIAL SOLUTIONS TO REDUCE VULNERABILITY AND IMPROVING RESILIENCE IN THE ENERGY, FOOD AND WATER SECTORS

A key long-term approach to improve energy security in the MENA region is to diversify the energy mix by increasing the use of renewable energy sources such as solar and wind power. This approach reduces dependence on fossil fuels, which are vulnerable to water scarcity and other climate change impacts.[10] Solar photovoltaic (PV) panels and wind turbines are particularly resilient in arid climates because they require little or no water to operate. In addition, by reducing greenhouse gas emissions, these renewable energy sources help mitigate climate change and potentially stabilise long-term climate impacts.[10] The high levels of solar radiation in the MENA region make solar power particularly viable.[10] Off-grid renewable energy systems offer additional benefits by reducing reliance on extensive infrastructure such as long-distance power lines, which can be vulnerable to severe weather events (e.g. windstorms) and energy losses due to overheating.[24]

In the short term, addressing the cooling water needs of power plants is critical.[10] One effective measure is the use of advanced cooling technologies that use less water and the promotion of seawater for cooling purposes that can significantly reduce the pressure on freshwater resources.[10]

Improving water security also requires targeted efforts. First, enhancing water infrastructures is critical, as up to 50% of water supply is lost in some countries.[09] Second, improving water use efficiency is crucial. According to the World Bank, about 82% of water in the MENA region is not used efficiently.[23] Introducing water tariffs that accurately reflect infrastructure and delivery costs can improve the efficiency of domestic water use. In the agricultural sector, efficiency can be improved by monitoring use, modernising irrigation systems and increasing water productivity on farms.[25]

For example, satellite data can be used to identify areas where water use is not optimised for agricultural production, allowing for a better adjustment of irrigation practices. In addition, improving farmers' skills in managing irrigation timing can further increase on-farm water productivity.[25] Finally, technological solutions such as desalination, a process involving distillation and reverse osmosis to convert salt water to fresh water, have been increasingly used to reduce water stress. This is especially the case in the Arabian Gulf, where some countries cover nearly 90 percent of their drinking water needs though desalination.09 While desalination contributes to improving water security it also put additional pressure on the energy demand.

Besides water-related agricultural measures, several other strategies can improve food security in the MENA region. Implementing sustainable land management practices that integrate production with ecosystem conservation is also critical.[11]

For example, agroecology and agroforestry have proven effective in minimising crop failure through diversification, improved soil management and efficient water harvesting techniques.[11] The adoption of harvest and post-harvest technologies that minimise food waste, such as cold storage and food processing techniques, is a key strategy for reducing food waste.[11] The combination of indigenous and local knowledge with modern innovations can also lead to more sustainable food production and improve food security.[11] This holistic approach ensures that agricultural practices are not only environmentally friendly, but also economically viable and socially acceptable.

In addition to technological and management innovations, a comprehensive policy approach is essential to enhance energy, food and water security. Given the interconnectedness of these sectors, policies need to be designed with an integrated perspective.

For food security, different policy interventions can stimulate systemic change. For example, developing payments for ecosystem services can incentivise farmers to adopt climate smart practices, even if they are less profitable. Policies can also stimulate markets by promoting sustainable farming standards aligned with climate smart agricultural practices (e.g. enhanced soil management practices improving soil water holding capacity). In addition, demand-side interventions, such as regulating and taxing food waste, introducing carbon pricing on specific food products, and educating the public to influence food choices, can have a significant impact on food security.[11]

Enhancing energy security will require the implementation of policies enabling the energy transition and leading for instance to the diversification of power generation technologies or the development of a robust tracking and monitoring mechanism.[26] Several policy incentives have already been considered to increase the share of renewable energy, e.g. feed-in tariffs and net metering and tax exemptions have shown potential.[27]

Several policy measures can improve water scarcity in the MENA region. First, a shift in water use from rural to urban areas and from agriculture to industry could be encouraged to meet growing urban and industrial demand. Second, a halt to the expansion of irrigated agricultural land can help prevent over-exploitation of water resources, together with improved water use efficiency in the agricultural sector.[28] Improvement of groundwater management is also crucial, for instance through the implementation of strict permitting, continuous monitoring to prevent over-exploitation and enforcement of laws to regulate groundwater use.

In addition, the reuse of treated wastewater for agricultural purposes can reduce the freshwater demand.28 Finally, ensuring equitable access to safe drinking water for poor communities is crucial to improve their living standards and health condition.[28]

Policies and initiatives should be planned at the national level and aligned with Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs) Currently, many countries have already prioritized food security in their NDCs and have identified agriculture as a critical sector for adaptation.[29] In terms of energy security, most countries include the energy sector in their climate action plans but rather with a mitigation focus; over 160 Parties plan to reduce emissions from the energy sector through actions based on renewable energy.[29] It is therefore essential to ensure that climate change impacts on energy, food and water security are well considered in NDCs and NAPs, but also that the goals and targets outlined in NDCs are translated into long-term national policies and plans, and that they are reflected in decision-making processes through clear guidelines and regulations.[30]

Increasing the production of renewable energy sources such as solar and wind and integrating them into the existing grid poses significant technical and financial challenges. This process requires significant infrastructure investment and grid upgrades, which can be both costly and complex.[31] Despite the region's high potential for renewable energy production, the sector faces several obstacles. High subsidies for fossil fuels create an uneven playing field, making it difficult for renewables to compete. Furthermore, existing institutions are often closely tied to the fossil fuel sector and lack sufficient stimulus to develop the renewable energy sector. There is also a need to increase awareness and knowledge of renewable energy at all levels of decision-making, including the banking sector, to facilitate financing and support for renewable energy projects.[31]

Improving water security in the MENA region is complex due to the existing severe water scarcity and the importance of the agricultural production in the area. Moreover, the region faces additional pressures from current developments, including population growth (1.5% in 2022), urbanisation and increased water demand, which are also linked to energy production.[07] These challenges are expected to be further exacerbated by future effects of climate change on rainfall patterns and temperatures, which are expected to further reduce water availability. These challenges are compounded by the conflicting interests of stakeholders and the inter-regional nature of water resources, which requires a high level of cooperation between governments.[09,23,28] Most countries in the MENA region have struggled to significantly reduce water scarcity. This is true even for oil-rich countries with higher income levels and greater capacity to invest in expensive desalination technologies. This situation underscores the significant challenges associated with improving water security in the region.[28]

Limitations for tackling food security in the MENA region are closely linked to the ones associated with water security; water availability being one the primary drivers for agricultural production. In addition to water scarcity, smallholder farmers face significant financial barriers that can prevent them from accessing technologies and inputs which could make them more climate resilient. They typically operate on small plots of land and have limited access to credit and financial services. Without adequate financing, smallholders cannot invest in water-efficient irrigation systems, or advanced rainwater harvesting techniques. Using substandard inputs results in lower crop yields and reduces the overall productivity and resilience of their farms.[11]

The challenges of energy, food, and water security in the MENA region are deeply interlinked and complex. Solutions must be tailored to local environmental and cultural contexts, taking into account the intricate links between these three systems.[25,31] Climate change and population growth are intensifying the demand for energy, food and water, while simultaneously constraining their supply. In addition, the cross-regional nature of these systems requires cooperation between countries, many of which are under increasing domestic tension. Political instability amplifies these challenges and limits the ability to mitigate the impacts of climate change. Conflicts in Lebanon, the ongoing Israeli-Palestinian crisis, the impact of the Arab Spring uprisings in Tunisia, Libya and Egypt, and the activities of ISIS, particularly in Iraq and Syria, have destabilised the region.[31] This instability undermines the implementation of effective policies and the adoption of new technologies, and hampers efforts to build resilience and social acceptance.

The regional turmoil not only affects the day-to-day management of resources, but also hinders long-term strategic planning, which is essential to improving sustainability and security in these critical sectors.

The MENA region is at the forefront of the global climate crisis, experiencing accelerated warming, changing rainfall patterns and an increase in extreme weather events. These changes are putting immense pressure on the region's already scarce water resources, energy systems and food production capacity. The interlinked nature of energy, food and water systems requires an integrated approach to resource management that considers the complex interdependencies between these sectors. Climate resilient solutions such as expanding renewable energy production capacity, improving water use efficiency and adopting climate-smart agricultural practices are essential.

However, as the region is confronted with a diversity of challenges like high investment costs of certain technologies and political instability, it is imperative to develop robust governance structures and policy schemes, strengthen regional cooperation and foster innovation to build resilience to the impacts of climate change.

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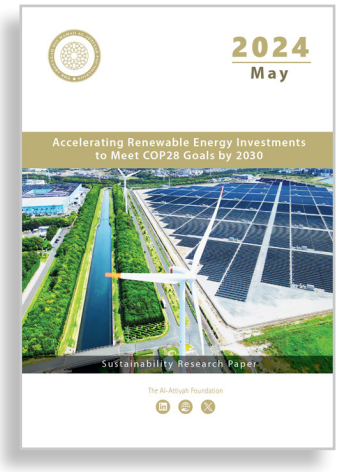

May - 2024

Accelerating Renewable Energy Investments to Meet COP28 Goals by 2030

At COP28, over 130 countries committed to tripling global installed renewable energy (RE) capacity from around 3,400 gigawatts (GW) in 2022 to 11,000 GW in 2030 or 60% of global power generation capacity.

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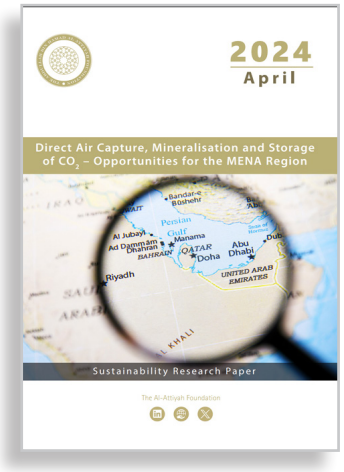

April - 2024

Direct Air Capture, Mineralisation and Storage of CO2 – Opportunities for the MENA Region

As the world grapples with the consequences of anthropogenic emissions, the Middle East, and North Africa (MENA) region stands at a critical juncture.

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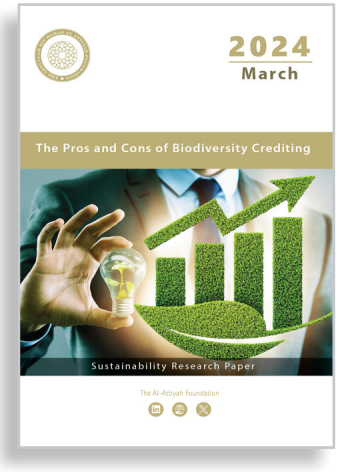

March - 2024

The Pros and Cons of Biodiversity Crediting

A significant financial gap exists between the resources currently allocated to biodiversity conserva-tion and the funding required to achieve the framework's ambitious objectives.

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