Sahara and Sahel Observatory

AFD Agence Française de Développement

Enhancing unconventional and fossil water in a context of climate change in North Africa:

Challenges and solutions

December 2023

Sahara and Sahel Observatory

Regional initiative
"Water stress and climate change in North Africa"

Enhancing unconventional and fossil water in a context of climate change in North Africa: Challenges and solutions

Guidance Document

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Summary

North Africa has a naturally predominantly arid climate, characterized by a scarcity of renewable water resources, compromising the sub-region's sustainable development. The sub-region is also experiencing a strong drying-up trend and a reduction of available renewable water resources. At the same time, the total population of the area and the rate of urbanization are rapidly increasing, leading to high demand for water. For all the countries in the sub-region, this situation represents a serious threat to their already scarce water resources, and a common and urgent challenge for meeting water needs in the short, medium and long term. Aware of these challenges, the countries of the sub-region have been making substantial investments for several decades to implement policies and strategies through projects and programs aimed at reinforcing the rational management and availability of water. Sustainable water resources management and development best practices have been capitalized on through these initiatives. The mobilization of water resources and alternatives such as unconventional water (treated wastewater, drainage water, etc.) and fossil water are top measures to think of. This capitalization integrates the information and data required for the exchange of best practices and experiences between North African countries, as well as with other water-stressed African countries.

The document provides the means to facilitate interaction and strategic dialogue between the research community and decision-makers in the formulation of public policies for the mobilization and sustainable management of water resources. It is also intended as a decision-making tool for the effective implementation of these policies.

Keys words

Water resources, Water stress, North Africa, climate change, Unconventional water, Fossil water, good practices.

Acknowledgements

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Highlights

- **Poorly supplied Renewable water resources:** In North Africa, groundwater is better supplied compared to surface water but it largely takes the form of reserves contained in so-called fossil aquifers whose exploitation can be compared to that of a mining deposit, i.e. with a risk of irreversible exhaustion. All sustainability precautions must then be observed regarding their operation.
- **Fragility of water resources:** The data and information available in the five North-African countries highlight the fragility of water resources, particularly renewable ones, due to worsening aridity and rainfall (barely 200 mm/year on average). This fragility will be further exacerbated by the very remarkable global changes in the region (climate change, demographic change, urbanization, etc.).
- **Compromised current and future quantitative and qualitative availability of water resources:** The simulations indicate that with the aforementioned trends, all countries living under water stress[1] will inevitably experience persistent water shortages[2] in the coming decades. Similarly, the region's water resources quality will be affected, impacting a good part of the available potential due to (i) drainage water containing high amounts of residual agricultural inputs (salts, pesticides, herbicides) particularly in areas of large-scale irrigated agricultural production, (ii) problems of saline intrusion in coastal communities, etc.
- **Implementation of adapted governance options but also mobilization of alternative resources such as unconventional water to alleviate growing water stress:** Policies and strategies for securing and managing water resources have been adopted to improve the availability of water resources. Likewise, countries have engaged in the mobilization of unconventional water through large projects/programs to strengthen the availability of water resources. However, strengthening the governance conditions of these resource and adopting practices guaranteeing better efficiency in the use of this resource seem are becoming a must.

[1] Water stress: According to the FAO, water stress is reached if the availability of renewable water ranges between 500 m^3/inhabitant/year and 1,000 m^3/inhabitant/yea

[2] Water shortage: It occurs when there is not enough water to meet all demands, including environmental needs. According to the FAO, the water shortage threshold for a country is reached if the availability of renewable water is less than 500 m^3/inhabitant/year

Scope and limitations

This Policy Paper, which results from a regional report, provides a regional summary on the current and future situation of water resources in the five countries of North Africa and presents the opportunities offered by unconventional and fossil water to support the water deficit. The impacts of climate change on water resources are taken into account in the analyses. The summary is essentially based on the collection and analysis of existing data and information at the country level within the framework of national investigations carried out in the relevant countries. Documentary resources available on the theme in the region[3][4][5] were also used to consolidate the data and information collected during national investigations. The initial version of the summary made it possible to enrich the debates during a regional consultation workshop, organized in Tunis, on June 10, 2022. The regional workshop helped collect additional data and information to produce an improved version of the regional report.

[3] OSS, 2020. Water in our regions, ISBN: 978-9938-933-29-1

[4] OSS, 2018. State of play in the Water sector (Algeria, Morocco, Tunisia). Regional summary. 12p.

[5] Mr. Abdourahman Maki (FAO) and Mr. Faycel Chenini (FAO). 2022. Analysis of the situation and prospects for the use of treated wastewater in the countries.

I- Introduction

Algeria, Egypt, Libya, Morocco and Tunisia (Figure 1) are the five North African countries covered by this summary and extend over a vast territory of approximately 6 million km^2, generally characterized by a predominantly arid climate with great variability and irregularity of rainfall (less than 300 mm/year on average). The region has less than 1% of the continent's renewable resources while it represents 20% of its surface area, leading to a sharp quantitative and qualitative scarcity of water resources. Most countries are in a situation of water shortage (less than 500 m^3/inhabitant/year) if we look at the availability of internal renewable water resources.

Despite the situation of stress or shortage, the levels of access to water and sanitation services are the highest for all countries in this region, compared to other regions of Africa. Indeed, since 2015, a significant effort has been made by these countries to achieve and consolidate access to water (Algeria, 94%; Egypt, 99%; Libya, 100%; Morocco 90%; Tunisia, 98%) of the population) and more than 95% for access to sanitation (Algeria, 86%; Egypt, 97%; Libya, 92%; Morocco, 87%; Tunisia, 97%). To maintain this dynamic towards universal access to water and sanitation and above all to properly and regularly satisfy the water needs of the different economic sectors (agriculture and industry in particular), some of the countries have already almost completely exhausted their renewable water resources, which results in exploitation indices beyond 100% (Figure 2). This applies to Egypt, Libya and Tunisia. The situation in the two other countries is also critical: more than 80% rate for Algeria and around 40% for Morocco. These levels of demand for water and demand for renewable resources will continue to increase due to demographics coupled with the modernization of lifestyles as well as the exacerbation of the negative effects of climate change in the region. In order to find the appropriate solutions to these shortages or avoid them in the long term, it is absolutely indispensable to adopt rigorous management strategies for water resources. The aforementioned countries could adopt strict water management, use alternative resources (unconventional water resources and, for those who have them, fossil water), with all the sustainability measures.

Here is why, these countries have already been mobilizing unconventional water: the reuse of treated wastewater (REUT/RTWW), the desalination of seawater and/or the demineralization of brackish and fossil water. Despite these efforts, there are still major challenges to overcome in order to achieve appreciable performance and use technologies that limit environmental impacts and the carbon footprint, given the available potential.

From this perspective, it would be quite appropriate to provide support to these countries. Such a support can take the form of scientific, technical, institutional, political assistance, etc.) in order to effectively respond to these challenges. Strengthening the dynamic of exchange and cooperation between the countries of the region on water resources management issues in a climate change context seems to be highly important to achieve the objective. The proposal of this paper, which addresses the main elements described below, is part of this perspective:

- General data, information, current and future situation of water resources in North African countries;
- Best practices in the sustainable management of water resources;
- Prospects for complementary responses provided by unconventional and fossil water in the sub-region;
- Proposed recommendations for additional studies and work to fill the gaps in scientific information and/or existing and reliable data.

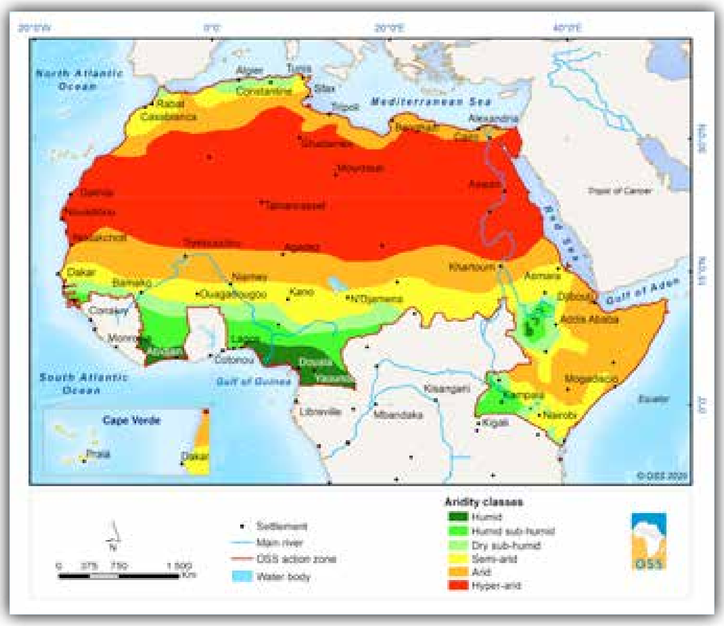


Figure 1 - Location map of the region and spatial variation of the aridity index (Source: OSS, 2020)

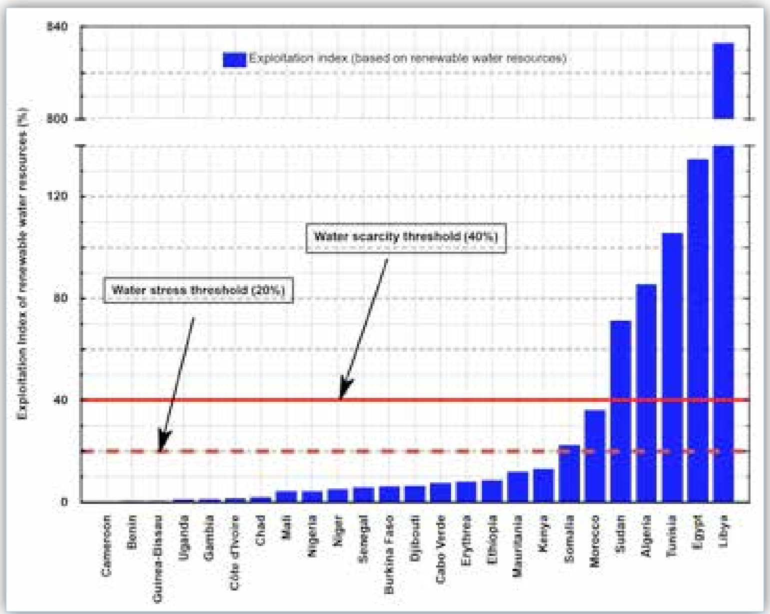


Figure 2 - Water resources exploitation indices in North African countries

II- North Africa, a climate change hotspot with a significant impact on natural resources requiring significant means of adaptation and resilience strengthening

North Africa is located between the Mediterranean Sea and the Sahara Desert (the driest in the world) and is considered one of the climate change[6] hotspots. The North African region has a naturally arid or semi-arid climate and is already bearing the effects of climate change: exacerbated water stress, drop in agricultural yields, increase in the pace and intensity of extreme events. Despite a spatial and temporal disparity, the projections of the different climate models expect an amplification of the main hazards (increase in temperatures, drop in rainfall or increase in their interannual variability, increase in the pace and/or intensity of extreme events such as droughts and floods and sea level rise). According to climate models, the region should experience a strong drying trend due to a rise in temperatures (which leads to an increase in evaporation) combined with a relative drop in rainfall. Maps generated by the Aqueduct Water Atlas (WRI) in 2019 show a 40% reduction in renewable water resources available by 2040 due to climate change.

Specifically, the forecasts established by the SMHI with the Cordex Middle East North Africa Model, High Scenario (RCP 8.5), indicate that there will be an overall drop in rainfall by 2040 throughout the region.

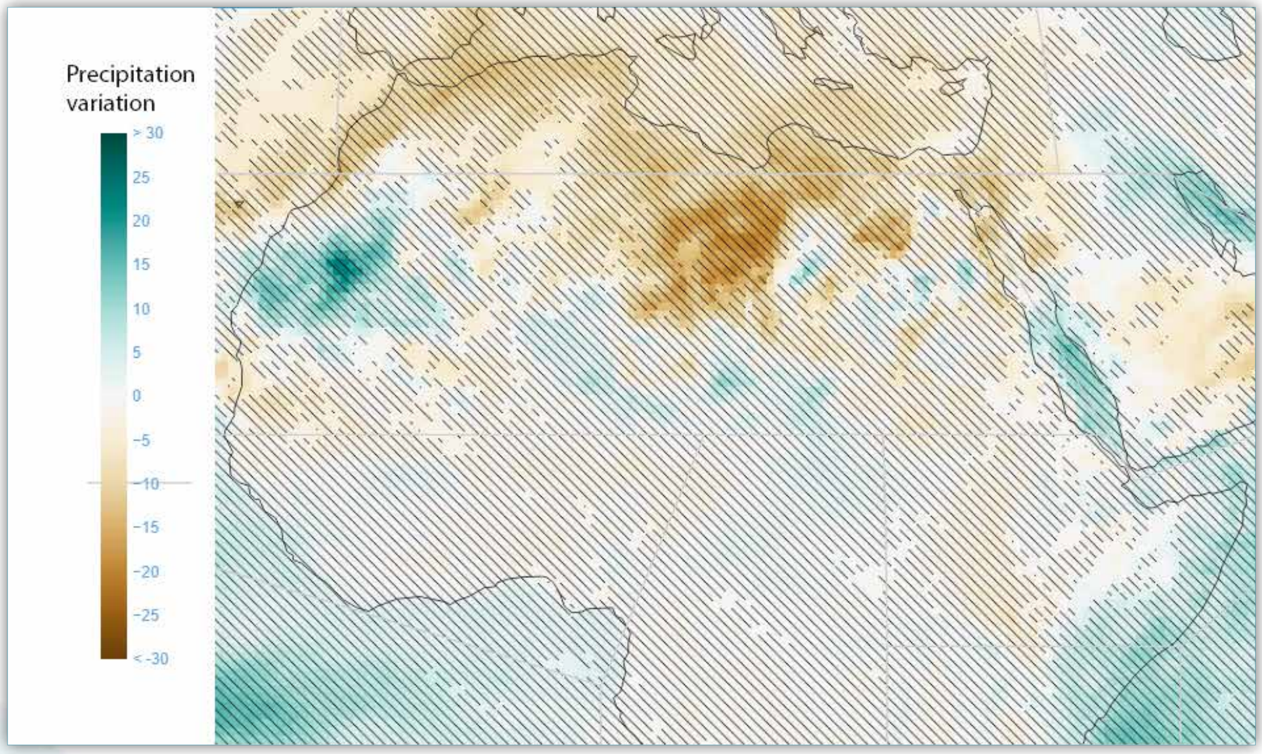
These changes are also confirmed in the sixth report of the IPCC[7] which emphasizes a possible drop in rainfall of up to 40% by 2040 compared to the reference period (1986-2005). Conversely, we will witness an increase in temperatures as well as the pace of exceptional rainfall in the region (Figures 3 and 4).

6 Diffenbaugh NS, Giorgi F (2012) Climate change hotspots in the CMIP5 global climate model ensemble. Clim Chang 114:813–822 https://doi. org/10.1007/s10584-012-0570-x

7 IPCC, 2021. Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In press

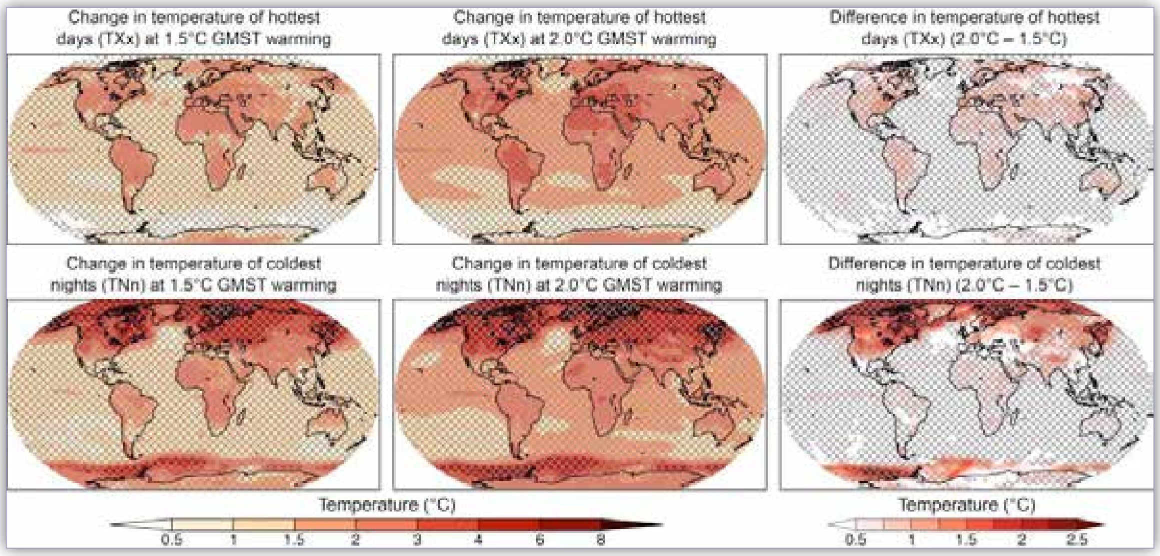
Future climate changes will have negative impacts on the amount and quality of the water resources. Reduced inputs and therefore resources are, in fact, foreseen by the different models even if the amplitudes of these changes vary depending on the models and methods used. Reduced inputs coupled with rising temperatures will result in reduced flow rates in rivers and reduced groundwater recharge. As an illustration, in the region, the last three decades have been characterized by a clear reduction in river flows, particularly during low water periods. Deficits reached record levels for certain years and during periods covering several successive years impacting the recharge of the dams. Also, it has been noted that periods of intense and long drought are becoming more and more frequent. Likewise, frequent and violent floods have been recorded in several points of the region and will be more so, due to the intensification of exceptional rains. The impacts will affect all economic sectors, particularly agriculture, on which people's livelihoods and food security in the region largely depend.

Figure 3 - Variation (%) in projected total rainfall (2021-2040) compared to the period 1986-2005 following the RCP2.6 scenario – CORDEX Africa Model



Source: IPCC WGI Interactive Atlas: Regional information (Advanced) (https://interactive-atlas.ipcc.ch/regional-information)

Figure 4 - Projected changes in mean temperature (top) and mean rainfall (bottom) at 1.5°C (left) and 2°C (middle) of global warming relative to the pre-industrial period (1861-1880)), and the difference between 1.5°C



Source: https://www.ipcc.ch/site/assets/uploads/sites/2/2018/11/figure-3.4-2-e1550133398489.jpg

III- Water resources in the region and expected evolution by 2050

III.1- Current availability (quantity and quality) of water resources in the countries: overall and resource-based assessment

In North Africa, the water potential is mainly made up of renewable and fossil water, called conventional, and to a lesser extent by so-called unconventional water (purified wastewater, desalinated water and demineralized water)[8,9]. An overview of the potential of each of these types of resources will be presented here. The data and information used come mainly from the national reports and a regional summary report. These national reports can be viewed for more detailed information. Additional documentary resources were also exploited, namely, the national studies carried out as part of the CREM project (CREM-GIZ, 2017), the national reports of the FAO REUSE initiative (2021), the recent edition of the water monograph in the OSS countries (2020), data and online platforms such as Aquastat-FAO.

- **Surface Water: Unfavourable Hydrography and prone to severe aridity**

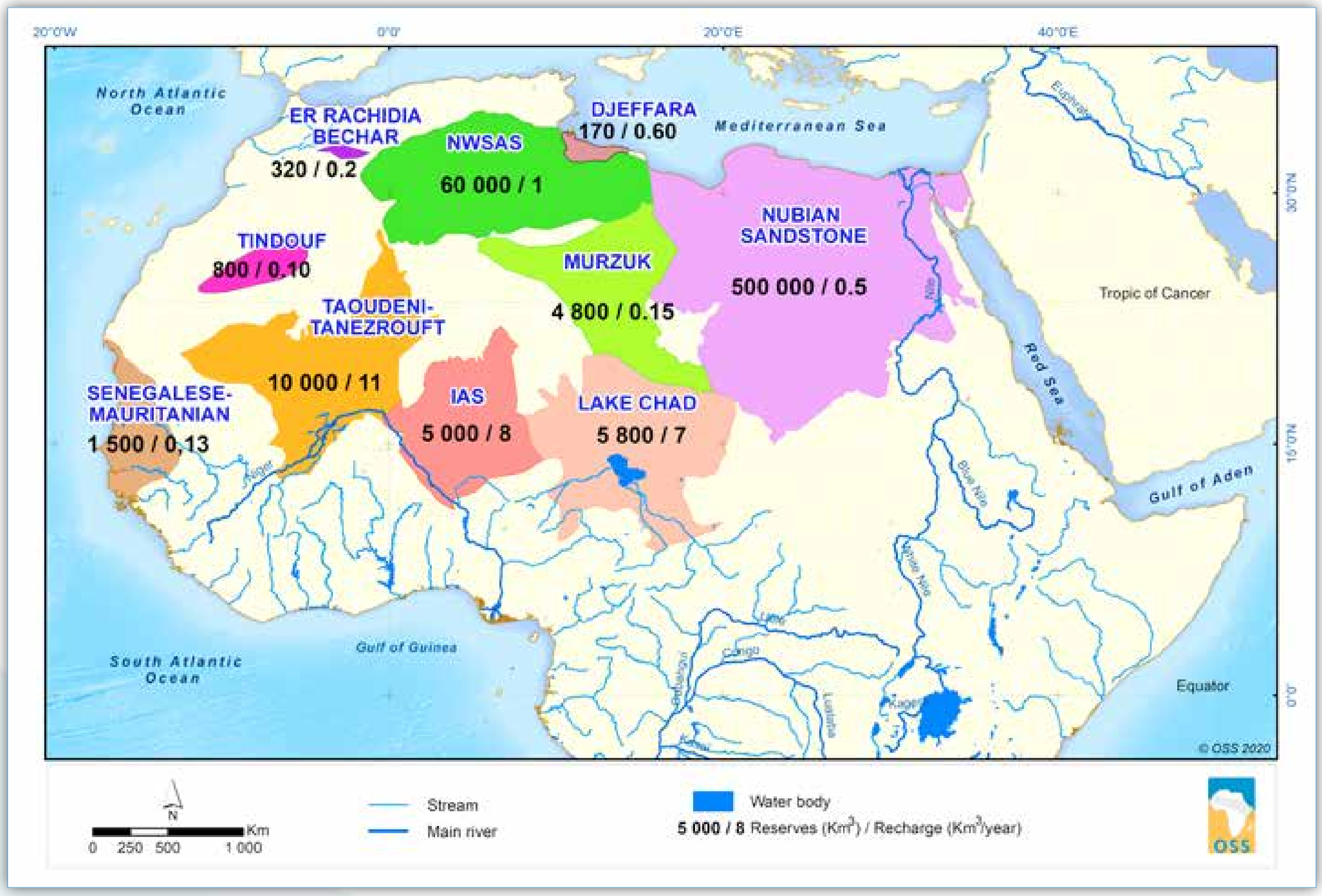
In the region, surface water is scarce due to the arid climate and therefore to the very low rainfall in the region. These are mainly located in the trans-boundary river basins of the Nile (Egypt for the North Africa part)[10] and the Medjerda (shared by Algeria and Tunisia) and to a lesser extent, those of Niger (South of Algeria) and Lake Chad (Southern Libya). There are also small national coastal basins like[11]: Moulouya, Loukkos, Oum Er Rbia, El Abid, Sejnane, Joumine, Melah, Maaden, Ichkeul, El Abid, etc. These renewable water resources in the region have been estimated at approximately 92 billion m^3 (Algeria: 10.2 billion m^3, Egypt: 56 billion m^3; Libya: 0.2 billion m^3; Morocco: 22 billion m^3 & Tunisia: 3.4 billion m^3). The numerous dams and hillside water reservoirs built in the region can retain nearly 198 billion m^3/year[12]. Although these resources are limited, Egypt for example depends mainly on the surface water of the Nile[13].

[8] OSS, 2020.Water in our regions, ISBN: 978-9938-933-29-1
[9] OSS, 2018. State of the water sector; Regional summary reports
[10] NBI, 2012. State of the river Nile basin. 32p.http://sob.nilebasin.org/pdf/Chapter_2_Water%20resources.pdf
[11] Detailed information is found in the national reports of this initiative
[12] AO-AQUASTAT, 2019. Database, https://table.apps.fao.org/views/ReviewDashboard-v1/country_dashboard?:embed=y&:sGuestRedirectFromVizportal=y&:display_count=n&:showVizHome=n&:origin=viz_share_link
[13] WorldBank, 2010. Brief on water in the Middle East and North Africa.11

- ### Groundwater: Appreciable availability but in the form of reserves[14]

Groundwater is better supplied compared to surface water. But these are largely in the form of reserves and contained in so-called fossil aquifers whose exploitation can be compared to that of a mining deposit, that is to say with a risk of irreversible exhaustion. These resources are estimated at nearly 600,000 billion m^3 and contained mainly in (i) the Nubian Sandstone Aquifer System (NSAS) with nearly 500,000 billion m^3 of reserves and shared by Egypt, Libya, Sudan and Chad and (ii) the North Western Sahara Aquifer System (NWSAS) shared by Algeria, Libya and Tunisia with nearly 60,000 billion m^3. Other shared aquifer systems which also contribute to the availability of groundwater in the region are: **the Taoudéni/ Tanezrouft Aquifer (Southern Algeria), the Lake Chad Basin Aquifer (Southern Algeria and Libya), the Mourzouk Aquifer (Southern Algeria and Libya), the Tindouf Aquifer System (Southern Algeria and Morocco). Figure 5 presents the geographical location of these different aquifers.**

Figure 5 - The main trans-boundary aquifer systems in the region: reserves and refills



Data source: OSS, 2020

[14] As for groundwater, it will be necessary to distinguish the "reserve" from the "resource (properly so called)": The resource, constituted by the recharge of aquifers by infiltration of current rainfall, is linked to flows maintained by the water cycle and is therefore, to a large extent, renewable. Groundwater reserves correspond, for their part, to stocks, not replenished under the current climate and therefore not very renewable (Source: Seguin JJ et al. 2014. Water resources of the African continent: scarcity and abundance. Geoscience Review, AFRICA, LAND OF KNOWLEDGE, N° 21)

- ## Conventional water resources: low quantitative availability compared to the needs

Table 1 presents the quantitative state of renewable water resources for each of the five countries. In total, the average volumes of rainfall in all countries are estimated at 818.10 billion m³/year, 88% of which is taken up by evapotranspiration linked to the region aridity. In addition, the renewable water potential of the five countries amounts to approximately 103.5 billion m³/year distributed as follows: approximately 92 billion m³ for surface water and 15 billion m³ of groundwater, of which a common share for both types of resources[15], estimated at 3.5 billion m³. However, some disparities exist in the spatial distribution of these resources as illustrated in **Table 1** and **Figures 6** and **7**.

Regarding the availability of renewable water per capita, the average value for the five countries is estimated at 438.64 m³/inhabitant/year. This average rate across the region is below the threshold of 500 m³/inhabitant/year, commonly accepted for water stress, even if there are some disparities between the countries.

Tableau 1 - Availability of the resources in renewable water In countries

Country	Contribution of rainfall		Total renewable surface water	Total renewable groundwater	Part commune : aux eaux superficielles et aux eaux souterraines	Ressources en eau renouvelables totales**	Ressources en eau renouvelables totales par habitant (m³/hab/an)
	Height mm/year	Volume Billion m³/year	Billion m³/year	Billion m³/year	Billion m³/year	Billion m³/year	m³/inhabitant/year
Algeria	89,00	211	10,15	1,517	0	11,67	282,4
Egypt	120,10	18,13	56	1,5	0	57,5	589,4
Libya	56,00	98,53	0,2	0,6	0,1	0,7	109,8
Morocco	346,00	154.5	22	10	3	29	811,4
Tunisia	207,00	38,87	3,42	1,60	0,4	4,62	400,2
Total/ Average	**163,62****	**103,40**	**91,77**	**15,21**	**3,5**	**103,49**	**438,64****

** Average parameter values for the five countries

Source: CREM-GIZ (2017)[16]; CEDARE (2014)[17], FAO-Aquastat (2019)

[15] According to the FAO estimation method, the total renewable water resource corresponds to: Renewable surface water + Renewable groundwater - the common share between the two types of resources

[16] OSS (2017): State of the art of the water sector; National reports

[17] CEDARE (2014): Monitoring and Evaluation for Water in North Africa (MEWINA)

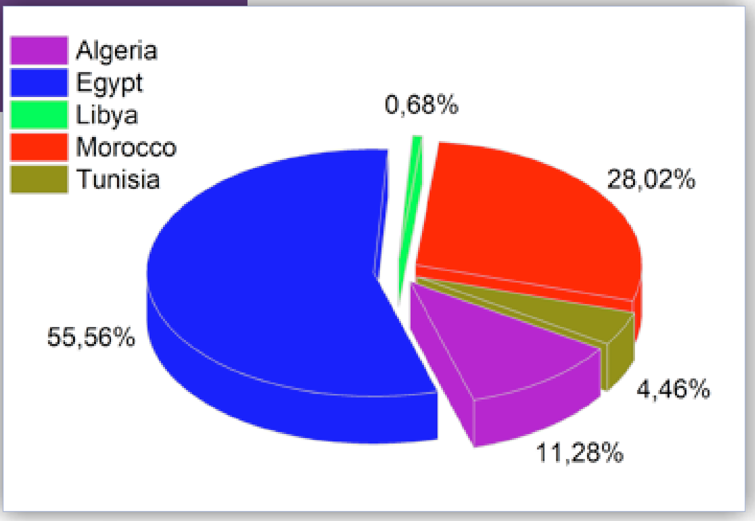


Figure 6 - Proportion of renewable water resources by country compared to the availability at the regional level

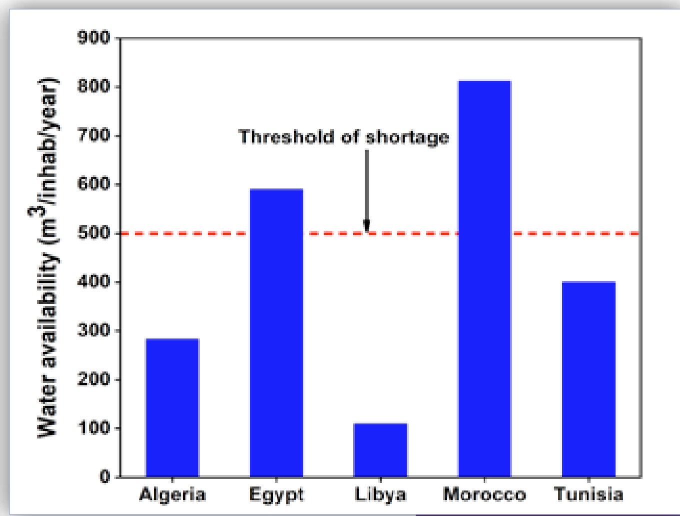


Figure 7 - Water availability by inhabitant by country

- **Conventional water resources: quality problems affecting their exploitation**

The region's water resources quality is affected, impacting a good part of the available potential. In Tunisia, for example, the quality of the available potential is relatively poor, especially since the large part of this potential (more than 50%) has a salinity greater than 1.5 mg/l. The water quality problems in the region can be summarized as follows:

- Surface water is generally affected by drainage water containing high amounts of salts, pesticides, herbicides, particularly in areas of large irrigated agricultural operations. Likewise, in areas of large cities, failures in hygiene and sanitation systems are the basis for the discharge of industrial and municipal effluents into adjacent water courses and bodies. In Egypt, for example, around 1.3 billion m^3/year of untreated wastewater from industrial effluents is discharged into surface water.
- As for groundwater, there are two sources of the quality degradation: anthropogenic and natural. The anthropogenic sources are the same as those mentioned above for surface water. In addition to saline intrusions in coastal communities. This applies to the Souss Massa basin (Morocco), whose groundwater is largely affected by saline intrusion due to the overexploitation of the aquifer[18]. The natural causes of groundwater degradation are due to the nature of the surrounding area and the age of the water (fossil water are brackish for example) which lead to significant salinization of this water. Most of the water in the NWSAS is brackish and requires demineralization for efficient exploitation. Likewise, in the southern parts of the countries, it is easy to detect water with high fluoride contents, impacting on the high prevalence of dental fluorosis among the populations.

[18] Moreno-Dodson, Blanca; Gasmi, Ines; Gouraud, Cyril; Tsakas, Constantin, 2022. "The Water Security Nexus in North Africa: Catalyzing Regional Coordination Around Climate Change, Resilience and Migration", Centre for Mediterranean Integration and UK Government, April

III.2- Situation of current uses/withdrawals and needs by sector (agriculture, domestic use, industries, other sectors) and type of the resource

Table 2 and Figures 8 a and b present data and information on the water use situation in each of the five countries.

Considering the types of the resources, we note that in Morocco and Egypt, surface water is the most exploited while in the three other countries (Algeria, Libya and Tunisia), the groundwater exploitation dominates. This situation is mainly linked to the type of water. For example, Libya has almost no surface water, the only alternative being groundwater. In Egypt, the majority of samples come from the Nile.

Regarding withdrawals by sector of use, withdrawals for agriculture largely dominate for all countries (more than 70% of withdrawals), followed by withdrawals for domestic water consumption (around 20%) and are on the rise. Indeed, a clear increase in the supply of drinking water has been recorded in the region in recent years. The current average value is around 120 l/d/inhabitant in the region.

Withdrawals for industry purposes are still low, less than 10% of uses in each of the five countries.

Tableau 2 - Situation of the Specimens by kind of resource and by sector in each of the five countries

Country	Dam capacity	Withdrawals by type of the resource			Specimens by sector of use			
		Surface Water	Groundwater	Total by type	Agriculture	Industry	Domestic Consumption	Total by sector
	Billion m³	Billion m³/year	Billion m³/year	Billion m³/year	Billion m³/year	Billion m³/year	Billion m³/year	Billion m³/year
Algeria	8,62	1,70	8,10	9,80	6,67	0,19	3,60	10,46
Egypt	168,20	71	6,50	77,50	61,35	5,40	10,75	77,50
Libya	0,39	0,17	5,55	5,72	4,85	0,28	0,70	5,83
Morocco	17,96	8,25	2,32,00	10,57	9,16	0,21	1,06	10,43
Tunisia	3,60	1,05	2,73	3,78	2,93	0,05	0,87	3,84
Total	198,77	**11,17**	**25,21**	**107,38**	**84,96**	**6,13**	**16,98**	**108,07**

Data sources: FAO-Aquastat, 2019; Reports of the national summaries of the AFD Water Stress Initiative

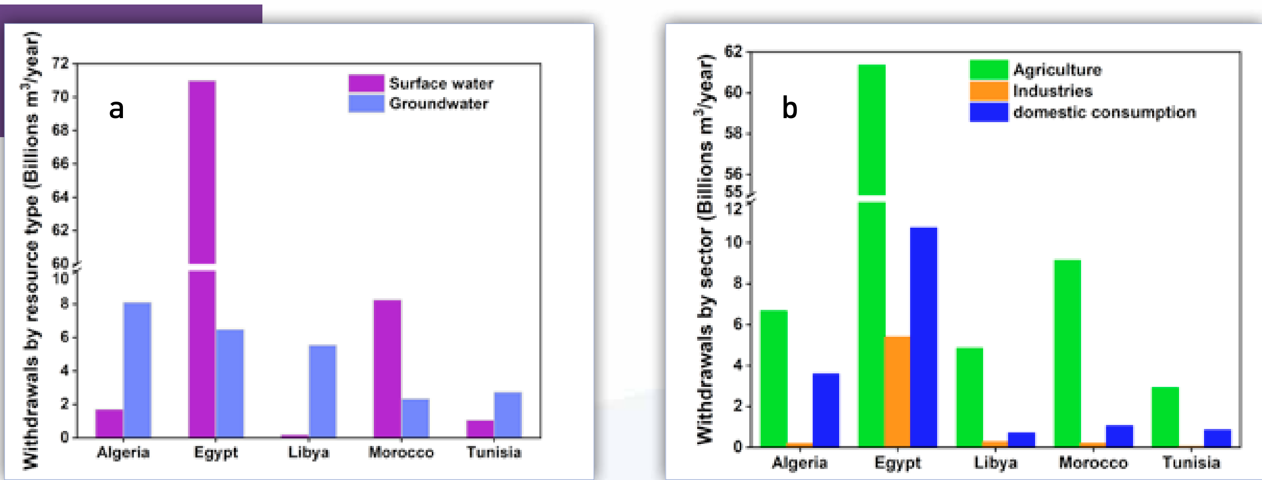


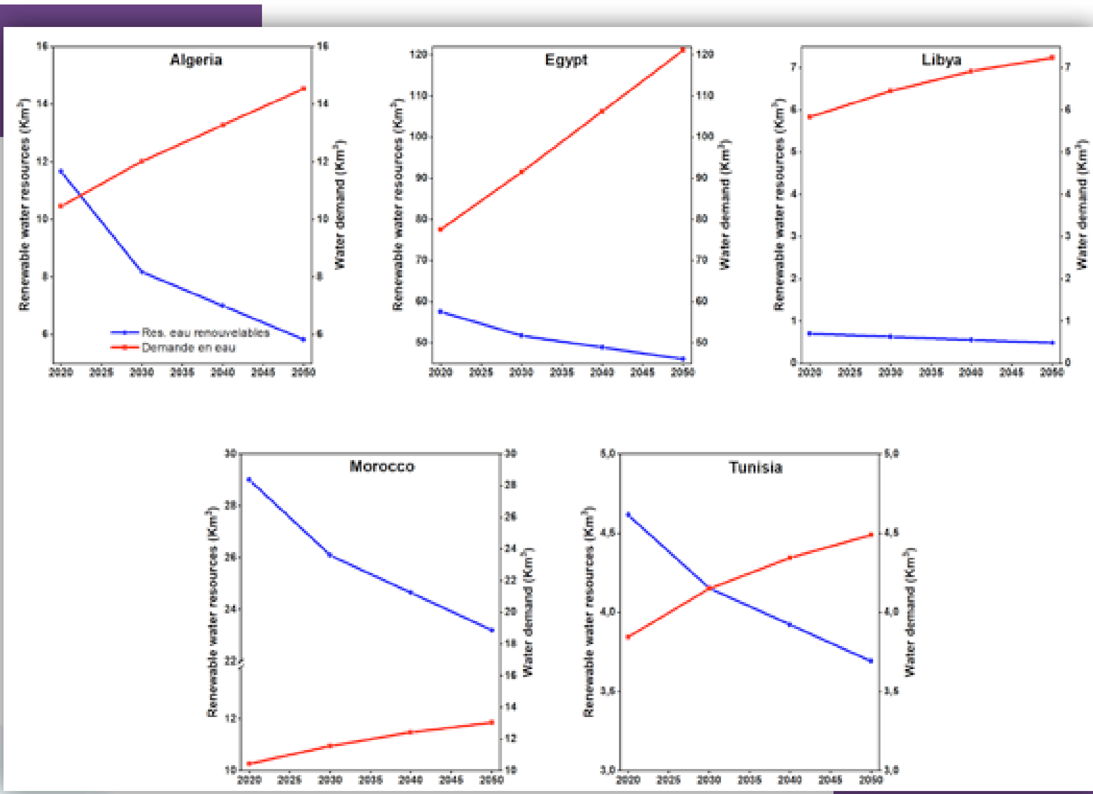
Figure 8 - a. Situation of withdrawals in countries by type of resources and by sector

III.3- Analysis of the expected evolution of water resources and adequacy with global needs over various horizons taking into account the impact of climate change

The information provided is based on summary analyses carried out using FAO-Aquastat[19] data for each of the five countries as well as the results of the scenarios provided by the different climate models. As indicated in Section II.1, all results concluded on a 10 to 20% (on average) reduction of water supplies by 2040 in the region. The combined exploitation of these climate trends coupled with demographic change and urbanization made it possible to estimate, for 2030, 2040 and 2050, the evolution of available renewable water resources as well as that of water needs. (Figure 9) and cross these two parameters. Likewise, water resources per capita were estimated at different horizons for each country (Table 3). These data analyses may be the subject of in-depth research depending on the availability and accessibility of more detailed data (like the work underway in Tunisia as part of the Water 2050 study).

The results obtained are fairly consistent with the overall trends available and can be useful for guidance and informed decision-making. As the graphs in Figure 10 indicate, available renewable water resources will gradually decrease while the needs will continue to increase drastically over time. The graphs already show a gap between the supply (referring to renewable water resources) and the needs (needs greater than demand) for Libya and Egypt and this gap will increase over time for all countries except Morocco which will be able to continue to meet its needs, even if the risks of exhaustion exist elsewhere.

Figure 9 - Evolution des ressources en eau disponibles et des besoins aux horizons 2030, 2040 et 2050



This phenomenon will result in a progressive reduction in water availability per capita (Table 3) implying a situation of persistent shortage for all countries by 2040.

This situation will have a very negative impact on all economic sectors which suffer the adverse effects of water stress and climate change in the region.

[19] FAO-Aquastat, 2020.https://www.fao.org/aquastat/statistics/query/index.html?lang=en

Tableau 3 - Estimation of the available renewable resources by inhabitant at various horizons

Country	Total renewable water resources per capita (m³/inhabitant/year)			
	2020	2030	2040	2050
Algeria	276,28	162,17	125,81	95,75
Egypt	584,21	428,28	348,24	287,58
Libya	104,81	82,82	68,70	57,48
Morocco	804,91	638,34	560,57	502,54
Tunisia	399,04	325,62	293,77	267,60

Summary of the water resource situation in North Africa

The data and information available in the five countries highlight the fragility of renewable water resources, which are already very poorly supplied due to worsening aridity and rainfall (barely 200 mm/year on average). This fragility will be further exacerbated by the very remarkable global changes in the region (climate change, demographic change, urbanization, etc.). This will severely compromise the current and future availability of water resources: the simulations indicate that with this dynamic, all countries (already under water stress) will inevitably experience persistent shortages in the coming decades. Even if the use of fossil waters (available in large aquifers such as the Nubian Sandstone and the NWSAS) cannot be a sustainable solution for these resources are not renewable. In these conditions, it will be necessary to strengthen the governance of the resources and adopt practices that guarantee a better efficiency in its use. Likewise, the use of alternative resources, namely unconventional waters, constitutes an appropriate means of strengthening the availability of this resource.

With this in mind, this work focused on (i) the identification and summary of good practices in the management and development of water resources in the sub-region, and (ii) the state of mobilization and enhancement of unconventional water and an analysis of their possible contribution to the availability of conventional water resources.

IV- Management of the water resources demand in North Africa: Policies, strategies and examples of good practices

The countries of Africa, particularly in northern Africa, benefited from numerous local projects and initiatives and adopted policies to secure and manage water resources to improve their availability for socio-economic activities in a context of water stress linked to climate change. The summary, capitalization and sharing of good practices in water resources management, resulting from its projects and initiatives, are crucial for the successful implementation of future projects and initiatives and international commitments.

All countries have agreed on the need for institutional and regulatory reforms as a key element to facilitating the implementation of new strategies aimed at more balanced exploitation and demand management. Other preliminary support actions for successful WDM can include capacity building for the various stakeholders.

Examples of good practices have been identified through various national and cooperation documents, scientific articles, local initiatives and projects/programs implemented or currently being implemented in the five countries. The information relating to these initiatives, projects/programs was completed by the author institutions on the basis of the sheets provided and interviews. These good practices in Water Demand Management (WDM) have been classified according to several related themes. The good practices selected in the different countries can be viewed in the national reports and the regional summary report.

Water Demand Management in National Policies and Strategies in North Africa

All countries have planning and management tools (laws, policies, strategies) governing the management of water demand. The mobilization of alternative resources, particularly unconventional water, is also encouraged to increase availability and thereby relieve pressure on conventional resources.

All countries have agreed on the need for institutional and regulatory reforms as a key element to facilitating the implementation of new strategies aimed at reaching a more balanced exploitation and management of the resources. Other preliminary support actions for successful GDE can include subsidies, PPPs and pricing.

V- Unconventional and fossil water in North Africa: Quantitatively significant alternative resources

V.1- Potential and current situation of mobilization, enhancement and prospects

The five countries are committed to mobilizing unconventional water to secure the availability of water resources and make up for the increasing shortage. These are mainly desalinated seawater, demineralized brackish water, treated wastewater and drainage water, considered strategic alternatives to strengthen the availability of water for irrigation (small and medium hydraulics) and the supply of drinking water to (particularly coastal) towns.

V.1.1- Treated wastewater

With demographics and progressive urbanization in recent decades, the volumes of wastewater have increased significantly with no signs of any improvement anytime soon, particularly in urban centres. These represent potential resources that can be reused through purification, provided that they meet internationally recognized health standards

According to national data on the state of sanitation in the different countries and presented in Table 6 and Figure 10, the rate of wastewater purification amounts to approximately 95% in Tunisia, 72% in Algeria, 60% in Egypt, 43% in Morocco, and 4% in Libya. Common uses of treated wastewater in the region are irrigation, watering of green spaces in municipalities and cooling in industries and artificial groundwater recharge. These figures indicate a poor level of re-used treated wastewater (Figure 11) in the different countries (an average of 13% of treated water).

Table 6 - Situation of collected and purified wastewater in North Africa

Country	Quantity of wastewater produced (x 10^6 m^3/ year)	Quantity of wastewater collected (x $10^6 m^3$/ year)	Quantity of wastewater treated (x $10^6 m^3$/ year)	Quantity of rejected wastewater collected (%)	Number of treatment plants	Fraction of treated water exploited (%)[b]	Year of reference	Comments
Algeria	1 300	1 062	935	12	187	15	2020	
Egypt	7 078	6 494	4 282	34	384	12	2017	
Libya	537	100	21	78	79	13	2020	National report estimates
Morocco	700	542	301	44	113	12	2018	Prediction to reach 160 stations in 2023
Tunisia	287	277	274	1	122	14	2020	

Source: OSS, 2017. State of the water sector - National reports; OSS, 2020. Water in our regions; Reports of the national summaries of the AFD initiative

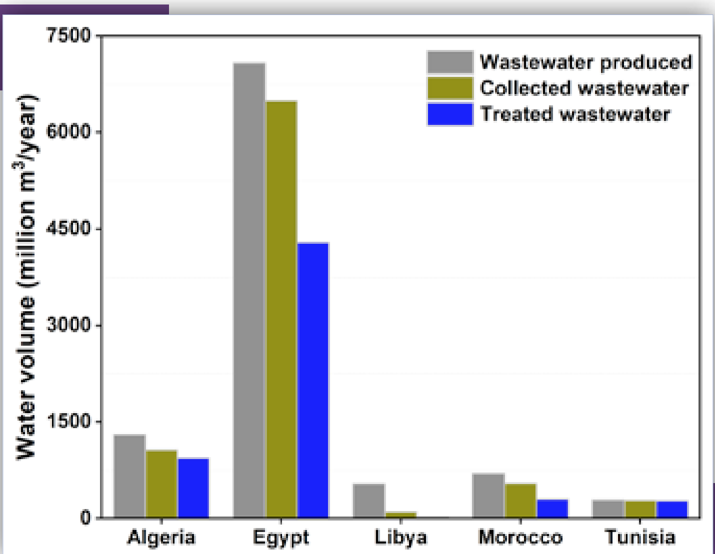


Figure 10 - State of Wastewater collection and purification

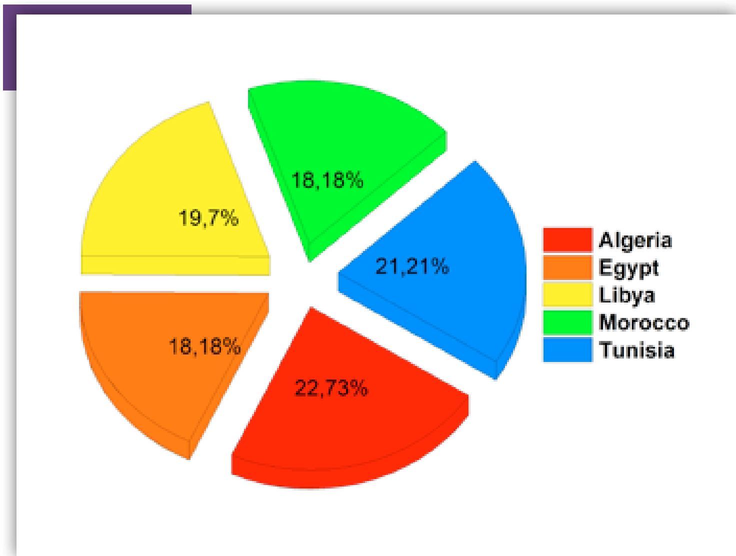


Figure 11 - State of re-used treated wastewater

V.1.2- Desalination of sea water and demineralization of brackish water

The five North African countries open onto the Mediterranean Sea and the Atlantic Ocean (for Morocco) which provides them with great opportunities for developing seawater desalination. These are the countries that have the longest experience in this area in Africa.

Algeria had launched a vast program to build desalination stations, the largest station being that of Oran (500,000 m³ of water per day). Morocco, Libya, Egypt and Tunisia did the same, particularly for the supply of drinking water to coastal towns.

Figures 12 and 13 provide an overview of the desalination situation in the different countries.

Sources: OSS, 2020. The water in our regions; Reports of the national summaries of the AFD initiative (2022)

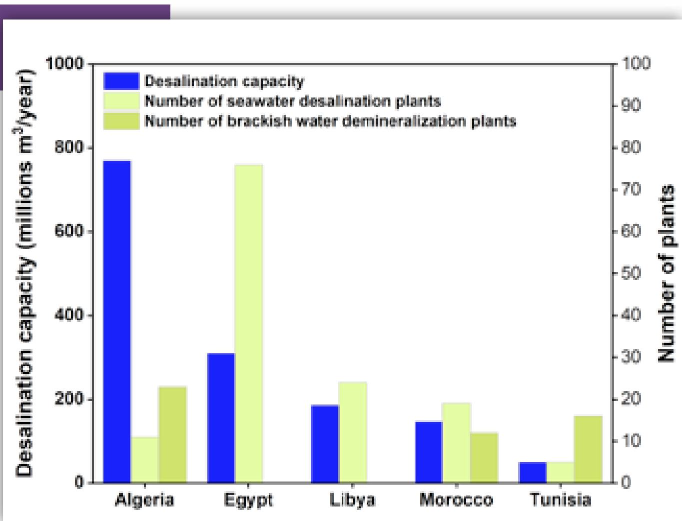


Figure 12 - State of sea water desalination

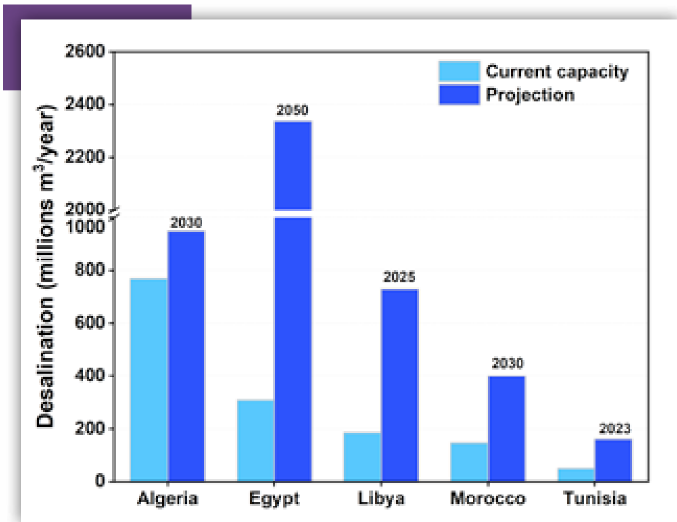


Figure 13 - Capacités actuelles et futures du dessalement de l'eau de mer

V.1.3- Drainage water

Egypt: Agricultural drainage water is an important water resource. Their annual average is around 12 billion m³/year. The Central Agency for Public Mobilization and Statistics announced that the total amount of reused agricultural drainage water in agriculture reached 6.5 billion m³ during the year (2019-2020). This volume is expected to increase each year to reach around 20 billion m³ by 2050.

Libya: Initially, the process of using treated wastewater for irrigation continued successfully in Libya, starting in 1967. The maximum volume reported was in 2005, for the treated wastewater used for irrigation in the Al Hadbah Al Khadrah project.

However, the use of drainage water for irrigation recently began to undergo problems and difficulties that caused it to stop and not expand its use, especially due to the latest political and social instability since 2011; most of the treatment plants have been damaged.

Morocco: The total volume of mobilizable EUT/TWW was estimated at nearly 20 million m³/year in 2019. The developed irrigable area was 1,100 ha. The projects are equipped with fairly comprehensive purification systems to be able to secure reuse[20].

Tunisia: The study of the sustainable development strategy for oases in Tunisia drawn up in 2015[21] estimates that the drainage water after irrigation in the oases in the 4 governorates whose consumption of irrigation water (from deep aquifers) is nearly 600 million m³/year. The exploitable potential from drainage water is estimated at nearly 120 million m³/year.

Algeria: The list of STEPs/WWTP selected for the development of planning for projects for the reuse of purified wastewater is finalized at 101 STEPs/WWTP, with a cumulative nominal capacity of 752.39 million m³/year. The volume available for irrigation is 626.8 million m³/year, which would allow the initial irrigation of 94,987 hectares[22].

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[20] FAO (2021) Reuse of treated wastewater in agriculture - Analysis of the current situation and prospects - Case of Morocco

[21] Ministry of the Environment and World Bank, 2015. Sustainable Development Strategy for Oases in Tunisia

[22] FAO (2021) Reuse of treated wastewater in agriculture - Analysis of the current situation and prospects - Case of Algeria

V.1.4- Fossil Water

Algeria: Fossil groundwater used in Algeria comes mainly from the aquifer of the North Western Sahara Aquifer System. They are currently estimated at around 2 billion m³/year.

Egypt: More than approximately 2.4 billion m³/year of fossil water are withdrawn for various uses. According to estimates, this volume will increase to reach 15 billion m³/year in 2050.

Libya: Libya depends on groundwater sources. About 98% of the water available for use is groundwater, of which more than 80% is non-renewable (fossil water), and most of the resources are economically available in some areas (especially northern aquifers) have been exploited to the maximum for many years.

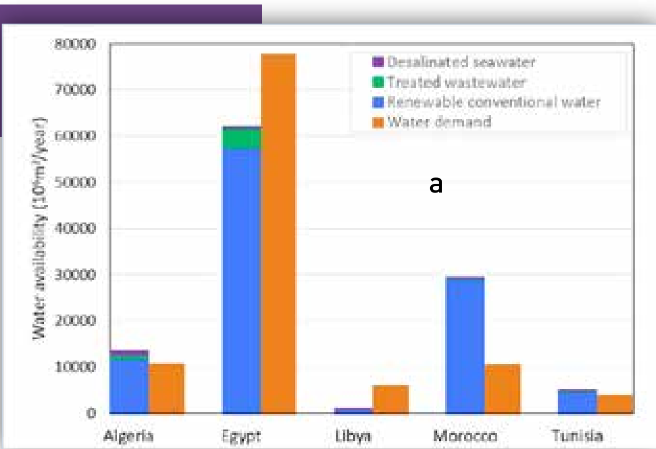
The volume of fossil water taken from groundwater amounts to 4.99 billion m³/year, particularly in the aquifers of the Nubian Sandstone and Murzuk SASS.

Tunisia: Tunisia shares with its neighbours two trans-boundary aquifers where current withdrawals total approximately 0.7 billion m³/year.

Morocco: Groundwater used in Morocco is almost all renewable water.

Unconventional and fossil water can contribute to increased supply

Unconventional water can contribute to strengthening the supply as indicated in the graphs in Figure 14. However, available data indicates that they are not filling current demand gaps in the countries. Increasing the capacity for purification and reuse of wastewater and especially drainage water in these countries would constitute a way to overcome the situation. The use of fossil water will also increase supply and reduce the deficit but requires precautions that guarantee their sustainable exploitation.



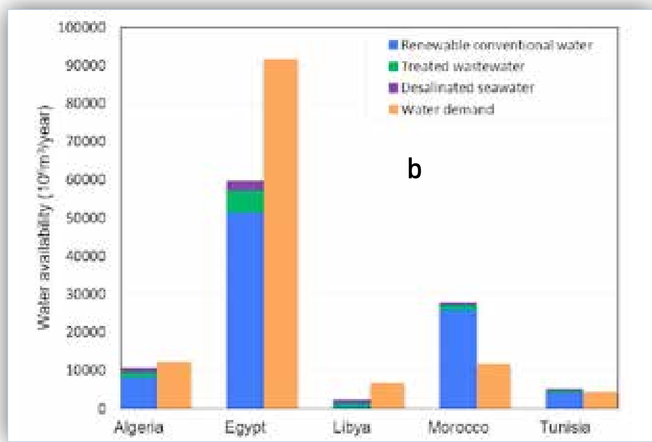


Figure 14 - Water balance: Estimated current (a) and future (b) deficit (by 2030) and the contribution of unconventional water

V.2- Socio-economic and environmental issues associated with the mobilization of unconventional water and innovative solutions

V.2.1- Cost-benefit Analysis

The main results obtained from the financial analysis of cost-benefits at the scale of certain REUT/ TWWR -irrigation projects in the region (FAO[23], 2021, Raouda, 2022) highlighted overall high costs of complementary tertiary treatment, reuse drainage water for agricultural and desalination purposes. This also means that cost recovery requires both the imposition of a significant water fee for farmers and a significant subsidy rate. Regarding financial viability, financial profitability can be achieved, but highly depend on the rate of the royalty and the weight of public subsidies.

The example of Tunisia shows that the desalination of sea water costs 3 dinars per m^3 on average, 60% of which relates to energy and constitutes a major challenge for SONEDE. The use of renewable energies and energy management are part of SONEDE's policy, but this will only slightly reduce the costs if support from the State or the private sector is not provided. In addition, the desalination of seawater involves discharging brines into the seabed which has harmful long-term consequences on marine biodiversity. The solutions recommended to date (diffusion of brine at a specific depth, etc.) have not proved to be efficient. The use of innovative solutions such as the production of desalinated water with zero discharge into the sea and therefore the recovery of all discharges is an alternative, especially that the technology exists.

The demineralization of brackish water for the needs of irrigated areas will increase water costs, thus penalizing the most vulnerable farmers by intensifying socio-economic conflicts.

The symbolic sale price of EUTs /TWWs to irrigators (20 millimes/m^3) is very low to ensure the economic balance of the system and leads to systematic coverage of considerable deficits by the budget of the Ministry of Agriculture. For example, it does not cover the cost of pumping energy which varies between 33 and 209 millimes/m^3, respectively in the PPIs of El Aguila and Borj Touil[24]

V.2.2- Environmental Impacts of desalination

The desalination process is used to make up for the lack of fresh water from natural sources. However, this process requires large amounts of energy, leading to pollution. Discharge of brines into the natural environment will have harmful consequences on the environment, ecosystems and water in particular. The main problem with desalination plants is the return of water from desalination processes, which is characterized by high salinity and temperature.

[23] FAO (2021): Reuse of treated wastewater and drainage water in agriculture - Cost benefit analysis - cases of Algeria, Morocco and Tunisia

[24] Pricing of EUTs/TWW at the PPI/PIP level, diagnostic report and pricing proposals - Part 1: diagnosis", AHT Group / SCET-Tunisia, final version, January 2018

They affect sensitive marine communities, such as coral reefs and seagrass beds. The risk depends on the environmental and geological characteristics of the area, such as the movement of ocean currents, waves, water depth, and the physical and chemical properties of the water. These factors determine the intensity of the mixing that occurs with seawater, and therefore the geographic extent of the impact, which changes from one place to another depending on its nature (coral reefs, rocks, sand...). The negative impacts of desalination plants are as follows:

- The high salinity wastewater poisoning marine life if the discharged water was dumped into the sea;
- Increased salinity of groundwater through infiltration of high salinity water which may be drained into the aquifer;
- The threat to marine life by: i) the discharge of brine waste directly into the sea increasing the salt content of already very salty seawater, reducing its ability to retain oxygen and posing a clear danger for marine life, and ii) treatment chemicals contained in wastewater;
- Noise pollution that occurs around desalination plants due to the use of high-pressure pumps and power generators, such as turbines whose noise might exceed 90 dB;
- The desalination process consumes a lot of energy, which is obtained by burning fuel or oil, or by using electric or nuclear energy, and thus increases the percentage of carbon dioxide or fears the complications of a radioactive nuclear leak.

It is therefore necessary, for the various desalination projects, to resort to environmental and social impact studies.

V.3- Limitations and difficulties linked to the implementation of policies and programs

V.3.1- Political Challenges

The difficulties linked to the implementation of policies and programs for the use of unconventional water arise essentially from the inadequacy/insufficiency of national water resources management policies in terms of governance, pricing policy, knowledge and understanding the sources of real water management problems or rather the water cycle.

Water policy is almost focused on blue surface and groundwater as well as that from desalination and REUT/TWWR as new resources in terms of mobilization and not for demand management. The main challenges are:

- Limited water resources: There is a significant water deficit between the resources and uses.
- Water losses: losses linked to resource management (in irrigation or drinking water) can vary according to Expert reports between 35 and 52%[25].
- Deterioration of water quality: The main reasons for deterioration of water quality are:
  - Water pollution from household waste and factory waste,
  - Fertilizer and pesticide residues,
  - Wastewater.
- Pricing: the reuse of EUT/TWW faces a major and essential difficulty which is the pricing method for sanitation fees. Pricing is generally poorly adapted and well below actual production costs.

V.3.2- Possible solutions to face water-related challenges

In order to address this forecast of water shortage, and with a view to efficient implementation of Integrated Water Resources Management, the five countries have developed strategies[26] aimed at sectoral objectives and in accordance with the Sustainable Development Goals as well as water policies and strategies. These strategies are based in particular on:

- The implementation of water-saving irrigation techniques;
- The improvement of water quality and its preservation against pollution;
- The development of alternative water resources, mainly unconventional water resources;
- The rationalization of water use;
- Adaptation to climate change;
- Governance of the water resources sector.

[25] (35% on average for Morocco:www.econostrum.info/Les-leaks-sont-le-principal-probleme-des-reseaux-d-eau-potable-au-Maroc_a2154.html).(52% on average for Algeria including leaks and unbilled illegal. connections). www.algeriemondeinfos.com/2018/02/02/water-resources-leaks-illicit-connections-pricing/ (50% for Tunisia) www.webmanagercenter.com/2018/05/14/419929/tunisie-une-etude-de-lites-preconise-un-recours-aux-eaux-intelligent-in-the-face-of-water-scarcity/

[26] Such as: the National Water Resources Plan (2017/2037) in Egypt, Water 2050 in Tunisia, the National Water Security Strategy in Libya (2015-2050). etc.

VI- Recommendations and future prospects

The common and shared challenges and recommendations at the regional level are presented in two categories below:

Improving the quality of relevant data for better reliability, sharing them and facilitating their access

- Generally speaking, there is a very limited availability of up-to-date data and information; this results in gaps in the various national summary reports with regard to information on the evolution of the resources and their uses. The same applies to information for the mobilization and exploitation of unconventional water.
- In some cases, the situation is not necessarily linked to the non-existence of data but rather due to the difficult access to existing data. To overcome this, open access data and information sources such as the FAO Aquastat platform are real alternatives.

Taking the necessary measures to fill the gaps in scientific information and/or reliable data

- Strengthening the monitoring and evaluation of the temporal evolution of water resources and actual withdrawals/needs by taking into account the main influencing factors such as climate change and population growth;
- Establishing/strengthening surveillance and monitoring systems for extreme climate phenomena by taking into account the monitoring of climate change indicators in the countries;
- Defining relevant and reproducible data processing methods for calculating losses in the different networks;
- Strengthening the use of unconventional water resources through communication and awareness-raising actions because these constitute valuable and sustainable alternative sources and can help reduce the water deficit;
- Carrying out a thorough and accurate assessment of unconventional water resources as well as the potential products in the different countries in order to have complete, accurate and detailed information on REUSE;
- Developing reference studies based on the analysis of local, regional and international experiences on the use of treated wastewater and agricultural drainage water in irrigation;
- Strengthening investments in the sanitation sector in order to optimize the use of wastewater and the performance of existing treatment plants.

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List of acronyms and abbreviations

ADGs: Agricultural development groups
AFD: French Development Agency
AnGed: National Waste Management Agency
ANPE: National Environmental Protection Agency
APAL: Coastal Protection and Development Agency
APP: Annual Performance Project
ARP: Assembly of People's Representatives
AWEDAM: Autonomous Water and Electricity Distribution Authority of Marrakech
BMO: Budget management by objective
BOD5: Biochemical Oxygen Demand at 5 days
BSPWS: Budget Support Program for the Water Sector
CI: Continental Interlayer
CC: Climate change
CO: Cereals Office
COD: Chemical Oxygen Demand
COSTEA: Scientific and Technical Committee for Agricultural Water:
CT: Terminal Complex
DEHP: Directorate of Environmental Hygiene and Protection
DR: Dry Residue
DUH: Department of Urban Hydraulics
DWS: Drinking water supply
DWSS: Drinking Water Supply System
EIS: Environmental Impact Studies
FAO: Food and Agriculture Organization of the United Nations
GBPPP: General Body of Public Private Partnerships
GDALDC: General Directorate of Agricultural Land Development and Conservation
GDDMHW: General Directorate of Dams and Major Hydraulic Works
GDEQL: General Directorate of the Environment and Quality of Life

GDREWE: General Directorate of Rural Engineering and Water Exploitation
GDF: General Directorate of Forests
GDP: Gross domestic product
GDSAD: General Directorate of Studies and Agricultural Development
GDSD: General Directorate of Sustainable Development
GDWR: General Directorate of Water Resources
GIZ: German Development Cooperation Agency
GRDA: Regional Commissioner for Agricultural Development
GWP: Global Water Partnership
Ha: Hectare
HBPO: Hydraulic Balance Planning Office
IHD: Index of human development
Inh: Inhabitant
INSSQPA: Authority for the health safety and quality of food products
JICA: Japanese International Cooperation Agency
LAC: Local authorities code
LIPP: Large Irrigated Public Perimeter
MAWRF: Ministry of Agriculture, Water Resources and Fisheries
ME: Minister of the Environment
MEHTP: Ministry of Equipment, Housing and Territorial Planning
MH: Ministry of Health
Mm^3: Million cubic meters
MTD: Million Tunisian Dinar
NCI: National Consumer Institute
NIM: National Institute of Meteorology
NIS: National Institute of Statistics
NONED: National Observatory of New and Emerging Diseases
NOO: National Oil Office
NOTH: National Office of Thermalism and Hydrotherapy

NQIP: National Quality Improvement Program
NWSAS: North Western Sahara Aquifer System
OHRI: Office of Hydraulic Resources Inventories
ONAGRI: National Agricultural Observatory
OSS: Sahara and Sahel Observatory
PDH: Public Domain Hydraulics
PIP: Private Irrigated Perimeter
PIP: Public Irrigated Perimeter
PPPs: Private public partnership
RG: Rural Genius
RLV: Rejection Limit Values
RMC: Restricted Ministerial Council
RTW: Reuse of Treated Wastewater
SCP: Company of the Canal de Provence and development of the Provence region
SD: Sustainable development
SECADENORD: National Company for the Exploitation of the Canal and Northern Waters
SM: Suspended matter
SMHI: Swedish Meteorological and Hydrological Institute
SNO: Sanitation National Office
SONEDE: National Water Exploitation and Distribution Company
STEG: Tunisian Electricity and Gas Company
TCG: Tunisian Chemical Group
TFPs: Technical and Financial Partners
TICQS: Tunisian Institute of Competitiveness and Quantitative Studies
TISS: Tunisian Institute of Strategic Studies
JORT: Official Journal of the Tunisian Republic
Kfw: German Development Bank
ToRS: Terms of Reference
TS: Tunisian Standard
TWW: Treated wastewater
UE: European Union
UGTT: Tunisian General Labour Union

UN: United Nations

UTAP: Tunisian Union of Agriculture and Fisheries

VAT: Value added tax

WB: World Bank

WC: Water Code

WDM: Water Demand Management

WHO: World Health Organization

WIS: Water Information System

WSC: Water and Soil Conservation

WWTP: Wastewater treatment plant

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