AG-WaMED | Advancing non conventional water management for innovative climate-resilient water governance in the Mediterranean Area

Grant Agreement Number: 391 del 20/10/2022

Deliverable 4.2.1.c

Watershed Management Plan - Tunisian and Algerian LL

Partnership for Research and Innovation in the Mediterranean Area Programme (PRIMA)
The AG-WaMED project has received funding from the PRIMA Programme, an Art.185 initiative supported and funded under Horizon 2020, the European Union's Framework Programme for Research and Innovation. This project also received funding from the Italian Ministry of University and Research (MUR), Science and Technological Development Fund - STDF (Egitto), Ministry of Higher Education and Scientific Research - MESRS (Tunisia), Hellenic Republic, Ministry of Development and Investments (Grecia), Agencia Estatal de Investigación (AEI) (Spagna) and General Directorate for scientific research and technological development - DGRSDT (Algeria)

This project is part of the PRIMA programme supported by the European Union. Grant Agreement Number No. [Italy: 391 del 20/10/2022, Egypt: 45878, Tunisia: 0005874-004-18-2022-3, Geece: ΓΓΡ21-0474657, Spain: PCI2022-132929, Algeria: N° 04/PRIMA_section 2/2021]

Funded by the European Union

Deliverable Identification

Deliverable No and Title	**D4.2.1.c - Watershed management plan – Tunisian and Algerian LL**		
Grant Agreement No	391 del 20/10/2022	**Acronym**	AG-WaMED
Project Full title	Advancing non conventional water management for innovative climate-resilient water governance in the Mediterranean Area		
Funding Instrument	Partnership for Research and Innovation in the Mediterranean Area Programme (PRIMA)		
Call	PRIMA CALL SECTION 2 2021 – MULTI-TOPIC		
Work-Package No and Title	Work Package 4: Governance analysis, policy creation and upscaling		
WP- Main Beneficiary	POLIMI		
WP-Leader	Maria Cristina Rulli mariacristina.rulli@polimi.it		
Task No and Title	Task 4.2 - Integrated Watershed Management Plans and NCW out-scaling		
Task Leader	Maria Cristina Rulli mariacristina.rulli@polimi.it		
Main Author	Dr. Chloe Artero & Dr. Melina Tobias		
Contributors	Mohamed Ouessar ouessar@yahoo.com, Fethi Baali fethi.baali@univ-tebessa.dz		
Status	Draft ☐ Final ☒		
Dissemination Level	Internal ☐ Public ☒		
Reviewed by			
Abstract	The present report is produced as deliverable for the task 4.2 of AG-WaMED, Integrated Watershed Management Plans and NCW out-scaling. The task builds on the scenario analysis conducted by WP2 and WP3, with the aim of formulating a new Integrated Watershed Management Plan that promotes the application of non-conventional water (NCW), taking into account each country's specific capacity and context. The plans were co-developed with each Living Lab (LL) in order to adapt the policy proposals to the suggestions and feedback of local stakeholders themselves.		
Key words			
DOCUMENT HISTORY			
Planned Release Date	30 June 2025	**Actual Release Date**	30 June 2025
Version	V1	**Released Version No**	V1

Table of Contents:

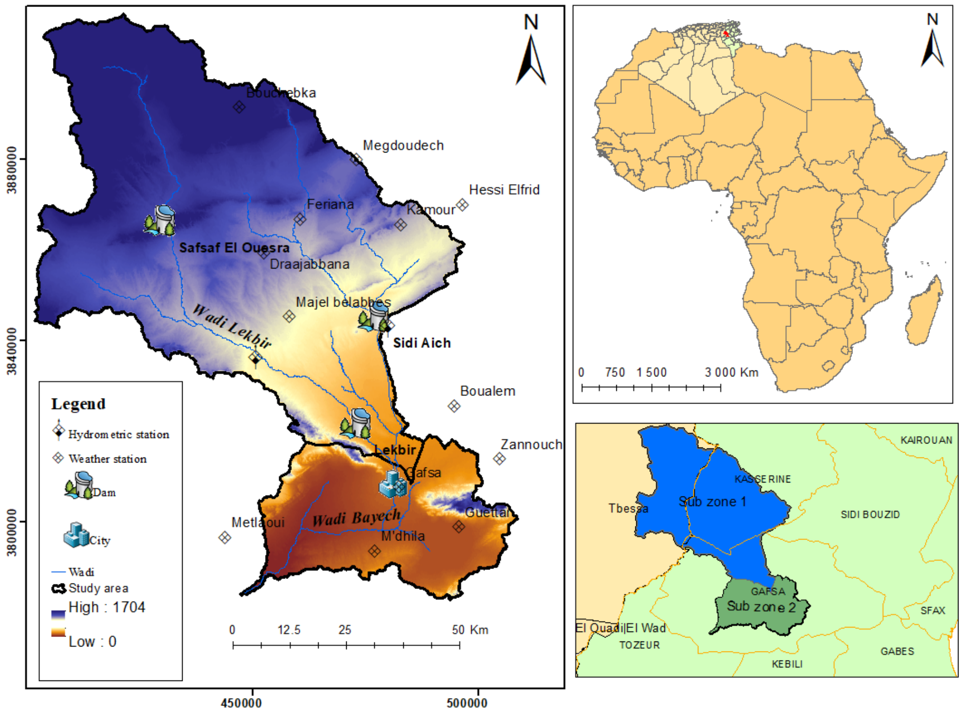
Party I Description and characteristics of the plan

1.1 Description of river basin characteristics

• *Location and boundaries of the basin*

The Wadi Lekbir Basin is shared between Algeria (Tébessa Governorate) and Tunisia (Gafsa and Kasserine Governorates). This transboundary system covers an area of 6,491 km², of which 4,508 km² (69.5%) is located in southwestern Tunisia. It originates in the wilaya of Souk Ahras, crosses the wilaya of Tébessa in Algeria, passes through the city of Gafsa, and flows into Chott El Gharsa. The study area is positioned between the High Steppes to the north and Saharan regions to the south. Consequently, it is characterised by a predominantly Mediterranean climate with arid and semi-arid variations. The basin features steep slopes and altitudes ranging from 75 to 1,711 m. The annual rainfall varies between 100 and 250 mm. In January, the minimum temperatures can drop below freezing, with occasional frosts (down to -3 °C). The months from June to August are the hottest, with temperatures reaching 45 °C. This geographical location promotes high levels of sunshine (approximately 3,000 h annually), which is favourable for agriculture. In Algeria, the basin covers six municipalities with a population of 134,210 in 2020. The largest city is Bir el Ater, with 96,182 inhabitants. In Tunisia, the basin is mainly part of the Gafsa Governorate, which has a population of 355,900. The principal city is Gafsa, which has more than 95,000 inhabitants.

Figure 1. Hydrologic map of the study area



Sources: Algeria/Tunisia LIs. n.d

• *Status of Surface Water Bodies and Aquifers*

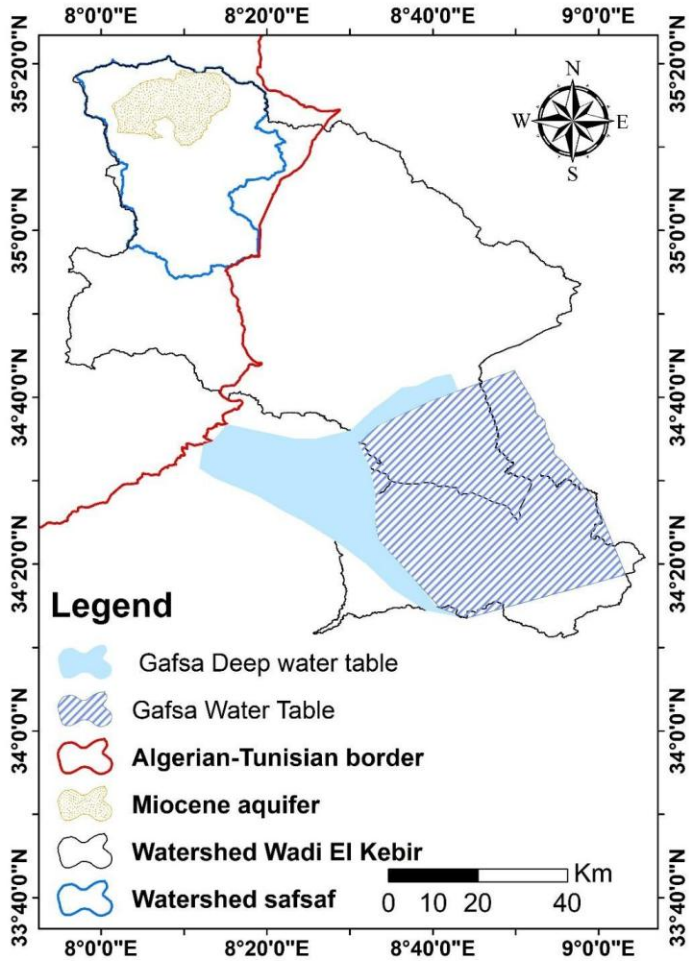
The hydrographic network of the basin is highly influenced by seasonal and interannual variations in precipitation and terrain. The wadis (seasonal watercourses) are irregular and generally dry during the summer. Violent floods often occur at the beginning and end of winter. The water from the wadis eventually disappears into large depressions known as "chotts." The estimated average annual flow rate is 107 Mm³/year (a minimum of 48 Mm³/year in dry years and a maximum of 251 Mm³/year in very wet years) (Ali, 2024).

• *Status and Quality of Groundwater*

In Tunisia, the study area includes 13 aquifers, with a renewable water potential of approximately 33.3 Mm³, divided among 4 aquifers with significant resources of 26.2 Mm³ (Gafsa Nord, Om Lagsab, Gafsa Sud El Guettar, and Moularès-Redeyef), 3 aquifers with medium resources of 3.9 Mm³ (Chott El Gharsa Nord, Garaat Sned Majoura, and Haouel el Wad), and 6 aquifers with low resources of 3.2 Mm³ (CRDA Gafsa, 2015). These reservoirs have water salinity levels ranging from 1 to 10 g/l. The basin has 33 million cubic meters of exploitable resources, and the water table receives infiltration along the foothills, primarily through wadi beds. Exploitation exceeded 115%, leading to the classification of this area as protected, including a ban on drilling and the rationalisation of water distribution for irrigated areas. The deterioration of water and soil resources due to the overexploitation of aquifers is concerning. Ecosystem degradation manifests through soil salinisation and a decline in water quality. In the medium- and long-term, not only will water become scarce owing to the inability of aquifers to recharge, but the soils will also struggle to remain arable. Thus, the entire ecosystem is degrading, and risks disappear altogether.

In Algeria, the El Malabiod plain features two distinct aquifer systems at different depths. The first is shallow and extensive, located in recent alluvial formations, consisting of reworked clays, sand, and gravel. The second, deeper aquifer is found in Miocene formations, composed of sandstone, sand, and gravel. It is tapped by around ten boreholes and approximately a hundred wells. The spatial distribution of the Miocene aquifer's thickness is based on existing boreholes that penetrate the sandstone layer down to the impermeable bedrock. The aquifer is primarily recharged from three sources. First, from the northern limestone massif (Dj. Bouroumane) near Hdjar E'safra, where the Miocene sands meet the limestone due to the southward dip of the limestone strata towards the plain. Second, from precipitation that falls directly onto exposed Miocene sands in the eastern and western zones. Lastly, from the alluvial aquifer, where the two systems are in contact, with the fault system facilitating water transfer into the Miocene aquifer. Piezometric maps show the flow direction is from the alluvial aquifer toward the Miocene aquifer, i.e., from north to south. The Miocene aquifer represents the region's principal water reserve. Since the 1970s, hydraulic services in the wilaya have been focused on exploiting this aquifer. However, the piezometric levels have been dropping due to increased extraction and reduced rainfall in the watershed over the past decade.

Figure 2. El Malabiod and Gafsa North Aquifers (wadi El Kebir Transboundary Basin, Algeria and Tunisia).



Sources: RAMDANI Rayene Sirine, FEHDI Chemseddine, KARAOULI Fatma, KHELIF Nadia, OUESSAR Mohamed. n.d.

The *Presence of Conventional and Unconventional Waters*

The primary water sources mobilised in the valley are groundwater, with rainwater and runoff playing a much smaller role. In Algeria, irrigation water mainly originates from groundwater. Drinking water is sourced from 90% of the wells, with another portion coming from the Safsaf dam, built in 1990, upstream of the border with Tunisia. This dam, with a capacity of 375,040 m³, is filled to only 30% of its maximum capacity, half of which is occupied by sediment owing to silting. Moreover, water evaporates faster than it contributes to groundwater recharge. On the Tunisian side, the basin has one dam, the Oued El Kebir (with a capacity of 23 million meters ³). In addition, runoff and rainwater are sometimes used for irrigation with an ancient hydraulic technique known as Jessour. Farmers also collect drainage water. However, as in Algeria, the use of groundwater now supports the agricultural sector, with an official count of 8,906 surface wells and 813 deep wells. Non-conventional water sources are also a growing water source. In Tunisia, a portion of treated wastewater is reused for agricultural purposes from the Gafsa wastewater treatment plant. The treatment of Gafsa's wastewater produces an average of 4 Mm³/year, of which 2 Mm³/year is used to irrigate the Gouifla perimeter in the traditional Gafsa oasis. Furthermore, still in the Gafsa region, water and soil conservation structures (water collection) contribute to the recharge of the aquifer after floods. The theoretical contribution of each structure is estimated at 0.2 Mm³/year/flood (CRDA, 2018). The Salsfa dam is also designed to temporarily retain runoff water to prevent flooding in downstream areas and ensure controlled flow. This also helps facilitate groundwater recharge.

In Algeria, traditional hydraulic techniques are increasingly abandoned. These practices can be considered a form of non-conventional water use involving the collection of rainwater or aquifer recharge. Several medium-sized structures, such as "tabias" or "foggaras", help collect and store water to support rainfed agriculture (olive trees, almond trees, etc.) or to recharge aquifers and prevent erosion. Flood diversion is also a method used, where wadi water is redirected by gravity towards neighbouring agricultural fields.

1.2 Summary of human impacts and pressure

• *Main water uses by sector*

One of the primary uses of water in the basin is irrigation. The main crops cultivated in the basin are olives (2,300 ha) and cereals (274,500 ha). The cultivation of olives and cereals is highly dependent on rainfall, which is why they are grown in shallow soils. The table below shows the different land use classes in the Lekbir Basin (Algeria an Tunisia):

Figure 3. Living lab LL Land use classes

Type of Landuse	Area (Km²)	Area (%)
Mixed Forest Land	583	8.9
Olives	23	0.35
Row Crops/ Other Agricultural Land	659	10.15
Bare Ground	2462	37.9
Pasture	2745	42.2
Mixed Urban or Built-Up Land	33	0.50

Source: Ali, 2024

These agricultural activities rely on both conventional and non-conventional water sources, as shown in the figure below. The three sources of water are aquifers, rainwater, and treated water. Water availability is significantly higher in Tunisia, where the primary sources are aquifers, followed by runoff and then treated water. In Algeria, the main sources are runoff, followed by aquifers and water reuse. In both countries, the primary use of water is for irrigation. Domestic consumption mainly comes from aquifers and a dam in Algeria.

Figure 4. Water resources and their uses (Mm3/year)

		Potential	Irrigation	Domestic
CW (aquifers)	Algeria	3.97	1.6	2.37
	Tunisia	33.1	16.55	13.09
NCW (Runoff (dams and WH)	Algeria	4	n.d	0.94

	Tunisia	8	8	0
NCW (treated wastewatet	Algeria	0.2	0	0
	Tunisia	4	1.8	0

Sources: Directorate of agricultural services, Watershed agency 2024 (Algeria side)

• *Flood Risks*

Flood risk is a complex process linked to various morphological, pedological, geological, anthropogenic, and climatic factors. In the basin, flash floods pose a significant threat, causing human casualties and damage to infrastructure such as roads, bridges, dams, reservoirs, and mudslides in populated areas and agricultural fields. Areas with high and very high susceptibility to flooding are mostly located downstream, where the city of Gafsa is located. Some upstream sites are also at risk because the slope plays a crucial role in runoff accumulation. Additionally, certain soil types exacerbate impermeability and, therefore, increase the risk of flooding.

• *Sources of Pollution*

In Tunisia and Algeria, no alarming signs of groundwater pollution have been observed. However, intensive use of pesticides and fertilisers could become a source of pollution in the coming years.

• *Drought Risks*

Drought assessment is essential for understanding the impacts of climate change, particularly in vulnerable regions. The analysis of the temporal evolution of rainfall in the whole study watershed highlights trends and anomalies that indicate periods of drought. Historical data from the basin reveal changes in rainfall patterns and allow for the evaluation of their relationship with drought episodes (Melki and Abida, 2018; Melki et al., 2017; 2022). The results show a decrease in the precipitation index (PI), indicating a shift towards a drier climate. There is a clear trend of decreasing rainfall during wet years and increasing rainfall during dry years.

1.3 Projected Water Scenarios

Water availability in the LL's territory was assessed within the framework of the AG WAMED project. The assessment integrates estimates of future supply and demand and takes into account hydroclimatic forecasts specific to the region and the river basin.

The available data produced by AG WAMED apply to the average annual flow of the Halk el Menzel Basin, next to the LL's area, which cover 15, 250 km². The results are summarised in the following table (units in km³/year).

All models (H08 and CWatM) and scenarios (ssp126, ssp370, and ssp585) predicted that the average annual flow will decrease in the Halk el Menzel basin over the years. The average annual flow, which was 0.69 km³/year from 1980–2019, is projected to range between 0.64 and 0.68 km³/year for 2020–2059 and between 0.50 and 0.63 km³/year for 2060–2099. This represents a reduction of up to 7% for the period 2020–2059 and 27% for the period 2060–2099.

Figure 5. Scenarios in Halk el Menzel Basin

Scenario	obsclim 80-19	historical 75-14	ssp126 20-59	ssp370 20-59	ssp585 20-59	ssp126 60-99	ssp370 60-99	ssp585 60-99
gswp3	0.69							
gfdl		0.75	0.69	0.73	0.57	0.66	0.53	0.67
mri		0.78	0.90	0.59	0.63	0.86	0.56	0.50
ipsl		0.79	0.46	0.54	0.58	0.51	0.53	0.34
mpi		0.73	0.66	0.58	0.61	0.53	0.61	0.42
ukesm1		0.88	0.69	0.81	0.83	0.59	0.50	0.58
mean	**0.69**	**0.79**	**0.68**	**0.65**	**0.64**	**0.63**	**0.54**	**0.50**

Sources: AG WaMED project - WP5, 2024.

For the least conservative scenario (ssp126), the average of the models shows that availability will decrease in all cases. For the other, more conservative scenarios (ssp370 and ssp585), availability shows a more significant reduction, much more pronounced for the period 2060–2099.

For the study basin, the reduction in contribution (in terms of AAF) is around 37% for the long-term ssp585 scenario, compared to the historical scenario. Under current conditions, and if they persist, the LL's will be exposed to changes in the average annual flow, which will negatively affect users who rely on rainwater, stored surface water, and groundwater. Indeed, infiltration and aquifer recharge will decrease in the long term. Non-conventional water solutions based on water and soil conservation will be limited, while the reuse of treated wastewater would reduce vulnerability. The decrease in water availability will pose even more problems as future demand estimates indicate an increase in needs for both irrigation and human consumption (see Figure 6).

Figure 6. The projected irrigated areas and water needs (irrigation, drinking) in the study watershed by 2050 (Mm3/year)

Region		Irrigation	Domestic	Irrigation water needs	Drinking water needs
Algeria side	CW	1.6	2.37	3.9	5.7
	NCW-Runoff	16.55	13.09	5.2	12
	NCW-TWW	0	0.94	0	0
Tunisia side	CW	8	0	33.1	14.399
	NCW-Runoff	0	0	7.2	1.034
	NCW-TWW	1.8	0	6	0

Source: Directorate of agricultural services, Watershed agency 2024 (Algeria side)

As part of the results of AG-WaMED project (WP3), a recent hydrogeological modelling exercise was carried out in the transboundary basin of Oued El Kebir, shared by Algeria and Tunisia, to assess groundwater dynamics under different abstraction and recharge scenarios (AG-WaMED, 2025). In Algeria, simulations for the Miocene aquifer showed that continued abstraction without recharge could lead to a 7–10 m drop in groundwater levels over 20 years. Natural recharge alone proved insufficient, while artificial recharge through infiltration basins showed potential for partial recovery in favorable zones. Geochemical modelling highlighted risks of increased salinity when treated wastewater or stormwater exceeded 30% of recharge volumes.

In Tunisia, the Gafsa North aquifer showed a rise in the exploitation rate from 79% to 115% between 1998 and 2012. Combined strategies involving treated wastewater reuse, soil and water conservation, and improved dam releases could help stabilize groundwater levels, depending on local conditions. Overall, the modelling supports the design of targeted measures for artificial recharge and improved regulation of abstraction.

1.4 Economic analysis

The territory of the El Kebir basin is gaining increasing economic importance due to the production of export crops. Although agricultural development is relatively modest compared to other regions of the countries, the trend has been towards growth, based on the use of groundwater and the expansion of irrigated crops.

Estimating the production cost of water and the price that users pay for water access is very complex, especially in the case of a transboundary basin. Figure 7 presents an estimate of water costs per year.

Figure 7. Costs (M Euros/year) of water resources

Region		Irrigation water needs	Drinking water needs
Algeria side	CW	2.17	1.55
	NCW-Runoff	2.90	3.27
	NCW-TWW		
Tunisia side	CW	18.46	3.93
	NCW-Runoff	4.01	0.28
	NCW-TWW	2.00	0.00

The calculations regarding water costs are based on several key assumptions. First, the irrigation water needs are estimated at 4,500 m³ per hectare per year. Furthermore, projections for 2050 indicate a 10% increase in water needs due to the impacts of climate change. At the same time, a 10% reduction in surface water inputs is also expected as a result of climate change. For these calculations, we have adopted the prices set by the National Water Strategy 2050 of Tunisia (2022)[1].

[1] Irrigation : 0,56 euros/m3, Drinking water : 0,27 euros/m3, TWW: 0,33 euros/m3. Sources: Water strategy 2050 Tunisia.

Party II Medium and long-term strategy

2.1 Analysis of priority problems

• *Main Issues*

1. As rainfall decreases, pressure on groundwater resources intensifies, making them the only solution to sustain agricultural activities. This is particularly the case for the most profitable and state-supported sectors, which rely on intensive water-consuming practices.

2. Local state authorities lack sufficient skills and resources to monitor the compliance of water extractions with the allocated water rights. This has led to overexploitation in many areas.

3. Water and soil conservation techniques, as well as methods to recharge aquifers, are not sufficient to compensate for declining water availability. Traditional hydraulic systems are in a state of disrepair or becoming increasingly ineffective.

4. Investments in promoting the reuse of treated wastewater remain geographically limited and pose numerous challenges for agricultural use. This prevents any significant reduction in the pressure on groundwater resources.

5. Although the watershed straddles the two countries, no framework has been implemented for the governance of transboundary waters, which is necessary to ensure the sustainable management of water resources.

• *Analysis of Priority Issues*

1. Threats to groundwater availability

Groundwater availability is a serious threat, as water extraction exceeds natural recharge capacities. This issue is exacerbated by agricultural policies in both countries. In Algeria, the government encourages the production of export-oriented intensive crops, such as horticulture (potatoes, garlic, onions), which are new to the region. These crops, cultivated in El Ma El Abiod plain, require large amounts of water, primarily drawn from shallow aquifers, now over-exploited through wells that exceed 200 metres in depth. Water demand far exceeds the aquifers' recharge capacity, and the region experiences severe droughts. On the Tunisian side of the basin, downstream farmers who persist in their activities despite the drought also rely on wells, adding further pressure to shallow aquifers. In response, the Tunisian government has halted the issuance of new water rights in the region to curb agricultural expansion. However, as in Algeria, some farmers continue to drill illegal wells.

2. Weak monitoring capacity for water extraction

Local authorities struggle to monitor groundwater extraction effectively. While both countries have introduced Water Codes and environmental laws to protect water resources and aquifers, enforcement at the local level remains limited. Monitoring illegal wells is difficult due to restricted access to private properties, the lack of measuring devices, and the fact that many wells are concealed. Additionally, local administrations responsible for water usage oversight lack the resources to inspect all plots.

3. Need to strengthen water conservation and aquifer recharge techniques
Traditional hydraulic techniques for water and soil conservation are deteriorating or have become insufficient. Some structures, such as "tabias" or "jessour," are designed to collect and store water to support rain-fed agriculture (e.g., olive, almond trees), recharge aquifers, and prevent erosion. Floodwater diversion is another ancient method that channels water from streams to nearby agricultural fields by gravity. However, states provide inadequate support for these medium and small hydraulic infrastructures, which are gradually being abandoned. This trend is due to several factors: the deterioration of the infrastructure and a lack of investment in renovation, the reduced time available for residents to maintain and operate them, and a growing preference among farmers for more accessible water sources, such as wells.

4. Insufficient wastewater reuse production
Although non-conventional water production and use are presented as future solutions in water policies of both states, investments in the basin remain limited. The wastewater treatment plant in the city of Gafsa is the only real innovation in this area, marking an important shift in water use practices. However, the number of farmers benefiting from this resource remains low. The strict regulations surrounding this practice, due to concerns over water quality and public health, make it difficult to foresee the replacement of conventional water with wastewater reuse in the agricultural sector in the short term.

5. Absence of transboundary water management
The sustainable management of transboundary aquifers is a key development challenge for Algeria and Tunisia. Although several initiatives have been launched by countries in the Saharan region to protect these aquifers, there is currently no treaty or signed agreement between the two countries to establish concrete cooperation mechanisms for coordinated and integrated watershed management. Bilateral policies could establish measures to protect these transboundary aquifers. The absence of cooperation translates into a lack of commitment from both states and local authorities to preserve the aquifers and prevent their over-exploitation. Consequently, the watershed or aquifer scale is not used as a management unit. No spontaneous collective organisation has emerged to monitor the state of the aquifers, and neither state has taken any initiative in this regard. While the Algerian government has promoted an integrated water resources management approach, this has been implemented across five major watersheds. The El Kebir basin is part of the Sahara Hydrographic Basin Agency, responsible for water resource management, but its actions have yet to result in concrete measures to curb the over-exploitation of groundwater in the upper part of the El Kebir basin.

2.2 Goals of Basin Action Plan

The objectives of the Action Plan and the main strategies to achieve them aim to increase the adoption of non-conventional water production solutions to reduce the pressure on conventional water sources. The expected outcomes will benefit both the population and the environment, contributing to long-term water security and sustainability.

To achieve this, four strategies need to be developed in tandem:

1. Support hydraulic techniques for water and soil conservation to ensure the full mobilisation of available runoff water, especially after exceptional flood events.
2. Utilise treated wastewater either for agricultural irrigation or for the recharge of groundwater aquifers.
3. Improve the efficiency of conventional water use and strengthen the control of practices that lead to the over-exploitation of aquifers.
4. Enhance cooperation mechanisms and the management of transboundary waters, ensuring joint efforts in managing shared water resources.

2.3 Main measures

Technical Measures:

On the Algerian Side:

1. Install soil conservation and water collection structures on the slopes: contour bunds, embankments, terraces, etc. These measures can help reduce runoff, soil erosion, and siltation of the Safsaf El Wesra dam.

2. Install gabion dams in the main courses of the wadi to reduce flow and ensure the recharge of groundwater aquifers.

3. Ensure better treatment of wastewater to avoid any risk of contamination of drinking water.

4. Replace as much as possible sprinkler irrigation with drip irrigation to increase water use efficiency.

On the Tunisian Side:

1. Expand the existing irrigated area (Gouifla) with treated wastewater to maximise the use of available resources.

2. Install recharge wells in the catchment areas of the two dams (Sidi Yaich and El Kebir) to allow for faster recharge of groundwater aquifers and reduce losses due to evaporation.

Political Measures:

1. Fund the installation and renovation of soil conservation, water collection, and aquifer recharge structures, as well as the reuse of wastewater.

2. Support farmers in finding solutions to improve the efficiency of conventional water use while strengthening the control of over-exploitation practices.

Legal Measures:

1. Strengthen cross-border cooperation and the exchange of best practices to establish long-term management of the transboundary basin.

2.4 Financing strategy

The main funding requirements for implementing the action plan are related to the following activities:

- Financing soil and water conservation structures, as well as aquifer recharge and their long-term maintenance.
- Investing in the reuse of treated wastewater.
- Funding infrastructure and devices to improve water use efficiency among all irrigators.
- Strengthening institutions to enhance control over extractions and management at the transboundary basin scale.

To fund these measures, it is necessary to involve all relevant administrations. There are two options for financing the plan: either integrating it fully or partially into existing national programmes, or seeking funding from bilateral or multilateral cooperation agencies.

In Tunisia, several national programmes could support these activities, such as the National Strategy for Land Management and Protection of Agricultural Soils (ACTA), the National Strategy for the Mobilisation of Water Resources, the National Action Plan to Combat Desertification, or the National Strategy for Adaptation to Climate Change. For bilateral cooperation, Tunisia could seek support from foreign partners such as AFD, GIZ, Italian Cooperation, or USAID. At another level, international aid could come from the EU, the World Bank, the African Development Bank (AfDB), or BADEA.

In Algeria, there are also several national programs that aim to combat desertification and protect agricultural land in arid and semi-arid areas, including the program of the High Commission for the Development of Steppe Zones (HCDS), as well as the program of local agricultural offices, namely the DSA, the Chamber of Agriculture and other organizations that operate in the project region. It would be important to implement new international cooperation programs, particularly with our Tunisian neighbors.

2.5 Integration into current legislation

Strengthen or Promote Laws to Support Hydraulic Conservation, Collection, and Recharge Techniques:
Hydraulic techniques for water, soil conservation, and aquifer recharge should be supported and adapted to address droughts. For example, aquifer recharge could be facilitated by constructing rainwater retention structures during heavy rainfall. Tunisia is developing a programme to protect water and soil conservation infrastructure, which could benefit from additional strengthening. Generally, in both countries, funding is more focused on large-scale production of unconventional water, such as water transfers or desalination plants. However, the needs of populations and farmers could be met by more modest investments focused on maintaining small and medium-sized infrastructure based on circularity principles. In Algeria, for example, oasis residents have gradually developed various water collection techniques suited to their environment (rainwater harvesting, drainage, aquifer recharge) to optimise water use. Adopting circular practices, focusing on water economy and recycling, in new agricultural areas could contribute to more environmentally sustainable agriculture. States could define conditions favourable to sustainable agricultural expansion by providing guidance based on the circularity principles and practices already implemented in certain oases.

Amend Water Codes to Enhance Control over Usage and Efficiency:
In Algeria, the Water Code and various decrees aim to promote sustainable development and ensure water resource conservation. However, in semi-arid regions, where groundwater is the primary source, these regulations are insufficiently enforced, and intensive agriculture could compromise future water availability. Since the 2000s, Algeria has adopted an agricultural policy aimed at improving national food security, which has led to the development of Saharan areas through agricultural activities that mobilise considerable water resources (pumps and irrigation pivots), often exploiting exceptional reserves. This creates tension between water policy and the state's agricultural policy, which must be resolved to achieve sustainable water management.

In Tunisia, according to the 1975 Water Code, groundwater belongs to the state. The government has implemented several decrees and political commitments to protect water resources. However, the state has limited means to enforce these regulations. Meanwhile, the number of wells, including illegal ones, has continuously increased, especially since the Revolution (December 2010 - January 2011), partly due to the lack of state control, although the Water Code assigns this task to the Regional Agricultural Development Commissions (CRDA). Furthermore, national strategies are primarily focused on increasing water supply, at the expense of implementing water-saving measures. Several subsidies and credits encourage the installation of wells and boreholes. Thus, subsidies for investments in water-efficient irrigation technologies could be strengthened and accompanied by additional policies, such as the introduction of water quotas – recently implemented in some basins – or the increase of tariffs.

Amend Water Quality Laws for the Reuse of Treated Wastewater:
In Algeria, most investments related to water reuse are concentrated in large cities, mainly in the extreme north of the country. Redirecting focus to medium-sized cities in arid and semi-arid regions would help reduce pressure on groundwater. Despite legislative progress, the critical water situation demands continued reinforcement of standards and laws related to the reuse of treated wastewater to prevent ecosystem contamination and minimise risks to public health. Currently, inadequate treatment of urban and industrial effluents leads to pollution not

only of surface waters but also of groundwater. Efforts made within the framework of the new water policy, which has prioritised this issue, must continue to strengthen investments in the rehabilitation of old treatment plants and the construction of new infrastructure.

In Tunisia, the treatment and reuse of treated wastewater are considered one of the main pillars of the national water strategy. However, their treatment and reuse remain limited, contributing notably to increased pollution of receiving water bodies. This pollution threatens both groundwater and surface water resources, as well as coastal areas and aquatic ecosystems. Additionally, the underutilisation of treated wastewater is explained by its poor quality. Improving this quality through advanced treatments, in line with institutionalised standards, could encourage farmers to use it. However, a noted obstacle is the lack of interest from farmers in reuse projects due to high utilisation costs and stricter controls and regulations imposed on agricultural practices.

2.6 Socialisation and implementation of Basin Action Plan

To disseminate the action plan for the basin, we will undertake the following step. First, we will send copies of the plan, once translated into Arabic or French (at least the summary), to the key stakeholders in the region, including the authorities, the Department of Agriculture, the Department of Environment, and the Farmers' Organisation. This will allow us to gather their comments and feedback. Second, we will organise a workshop to which all stakeholders will be invited. During this workshop, they will have the opportunity to present and discuss the main components of the plan.

References

Ali Z., N. Dahri, M. Vanclooster, A. Mehmandoostkotlar, A. Labbaci, M. Ben Zaied, M. Ouessar. 2023. Hybrid Fuzzy AHP and Frequency Ratio Methods for Assessing Flood Susceptibility in Bayech Basin, Southwestern Tunisia. Sustainability 15, no. 21: 15422. https://doi.org/10.3390/su152115422

Ali Z. 2024. Modeling of floods in Tunisian arid zones in a context of climate change: Case Study of the Bayech Basin (Southwestern Tunisia). PhD thesis, ISSTEG, University of Gabès, 164 pp.

Karaouli F., S. Touzi, J. Tarhouni, L. Bousselmi, 2009. Improvement potential of the integrated water resources management in the mining basin of Gafsa, Desalination, 246 (1–3), 478-484, https://doi.org/10.1016/j.desal.2008.03.069 .

Melki, Achraf, Khodayar Abdollahi, Rouhallah Fatahi, and Habib Abida. 2017. "Groundwater Recharge Estimation under Semi Arid Climate: Case of Northern Gafsa Watershed, Tunisia." Journal of African Earth Sciences 132 (August):37–46. https://doi.org/10.1016/j.jafrearsci.2017.04.020.

Melki, Achraf, and Habib Abida. 2018. "Inter-Annual Variability of Rainfall under an Arid Climate: Case of the Gafsa Region, South West of Tunisia." Arabian Journal of Geosciences 11 (18): 543. https://doi.org/10.1007/s12517-018-3868-9.

Melki, Achraf, Faten Khelifi, Mohammed Farouk Gad, and Habib Abida. 2022. "Prospective Assessment of the Water Balance of the Northern Gafsa Aquifer, South-Western Tunisia." Environment, Development and Sustainability 24 (1): 1359–75. https://doi.org/10.1007/s10668-021-01500-2.

Rouabhia A., (2006), Vulnérabilité et risques de pollution des eaux souterraines de la nappe des sables miocènes de la plaine d'El Ma El Abiod Nord-Est Algérien. Thèse de doctorat es-sciences. Université Badji Mokhtar -Annaba.

Rouabhia A., Baali F., Kherici N., Djabri L., (2004), Vulnérabilité et risque de pollution des eaux souterraines de la nappe des sables miocènes de la plaine d'El Ma EL Abiod (Algérie), Science et changements planétaires / Sécheresse, **15**, 347-52.