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

Watershed Management Plan – Egyptian LL

Partnership for Research and Innovation in the Mediterranean Area Programme (PRIMA)
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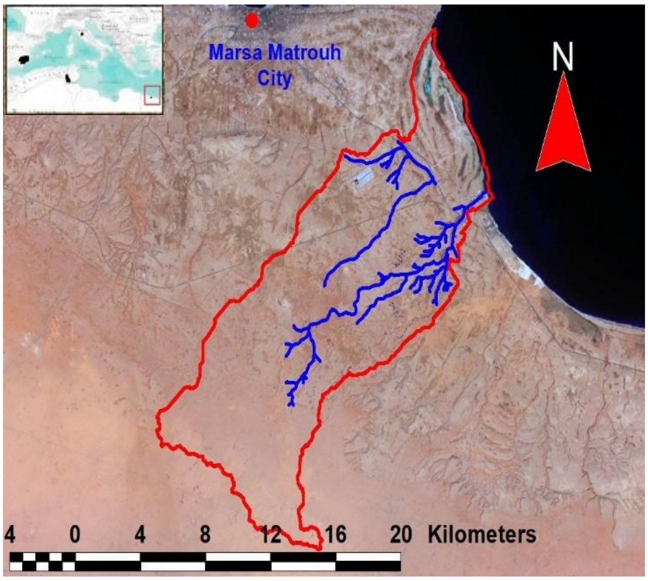
1.1 Description of river basin characteristics

• *Location and boundaries of the basin*

The Naghamish and El-Kheir wadi catchment is located on Egypt's north-western coast. It lies within Ras Alam El-Rum Bay, about 15 km east of the city of Marsa Matrouh, with elevations ranging from sea level to 125 m (in the southern part). The average rainfall is approximately 130 mm/year, equating to around 30 million m³/year. There are seventeen villages in the region, with a population of about 2,600 people (Daoud, 2015), spread across three major tribes. The climate is Mediterranean, with hot, dry summers (temperatures reaching 35°C in August) and mild, rainy winters (with temperatures around 10°C in December and January). The basin covers a total area of 199 km² and includes 374 farms, which are family-owned properties passed down to children according to a traditional inheritance pattern. The average farm size is between 4 and 12 hectares.

Figure 1. Location of Egyptian Living Lab



Sources: AG-WaMED Project data, 2024.

• *Status of surface water bodies and aquifers*

In the studied basin, rainfall is the main source of water used. It is concentrated between October and March, with approximately 100 mm. This water is collected by constructing dikes (made of earth, dry stone, and cement) in the wadi bed for irrigation. Access to water for human consumption and livestock relies on another rainwater collection technique: the use of cisterns. In Wadi Naghamish, the total number of cisterns is 448 (Daoud, 2015). These cisterns are the main system for storing rainwater for human consumption. The quality of surface water is threatened due to the heavy use of chemical fertilisers for agricultural purposes.

• *Status and quality of groundwater*

Groundwater wells are not a viable solution due to low water availability, high salinity, their deterioration caused by the use of chemical fertilisers, and high prices for digging and maintaining the well.

• *Presence of conventional and unconventional waters*

The basin benefits from three types of non-conventional water solutions: desalination, reuse, and rainwater collection. The levels of water production are as follows:

First, desalinated water is produced at El-Rumaila, with a capacity of 48,000 m³/day, amounting to 17.5 million m³/year. The cost of 1 m³ of desalinated water is 10 Egyptian pounds (LE). Currently, the Bedouin population does not use desalinated water due to the need for additional purification stages to achieve high purity levels and its high cost (over 10 LE/m³). Additionally, cultural practices regard this water as impure.

Second, the domestic wastewater treatment plant (WWTP) produces 60,000 m³/day (7.6 million m³) during the summer months (June to September) and 25,000 m³/day (6 million m³) for the rest of the year, totaling 13.2 million m³/year. Treated domestic wastewater is not used for agricultural activities, except for planting timber trees under the Ministry of Agriculture, as local customs and traditions consider it impure. As with desalinated water, there is little demand for this product.

Lastly, rainfall runoff is utilized. The average annual rainfall is approximately 130 mm, equating to about 30 million m³/year, with an estimated runoff volume of 10% of the total rainfall (around 2 to 3 million m³/year).

1.2 Summary of human impacts and pressure

• *Main water uses by sector*

Water use in the basin is distributed across various activities. However, we do not have official data on the quantity of water allocated for each use.

The primary use of water is for crop irrigation. The main crops in this basin are olives (406 ha), figs (1818 ha), and cereals (332 ha), and it has been noted that these crops have remained largely the same over recent years. The cultivation of cereals depends on the amount of rainfall, which is why they are planted in shallow soils. Changes in land use are limited. When a fig tree dies, it is replaced by an olive tree. Furthermore, Bedouins now prefer planting olive trees for oil production, as the price of a kilogram of olive oil reaches 500 to 600 Egyptian pounds, which is considered highly profitable. Production systems are not very mechanised, particularly with minimal use of machines for ploughing. Value chains are not well developed. The produce is sold by the farm owner at the Cairo wholesale market, with very little involvement from actors other than the producer and the final consumer.

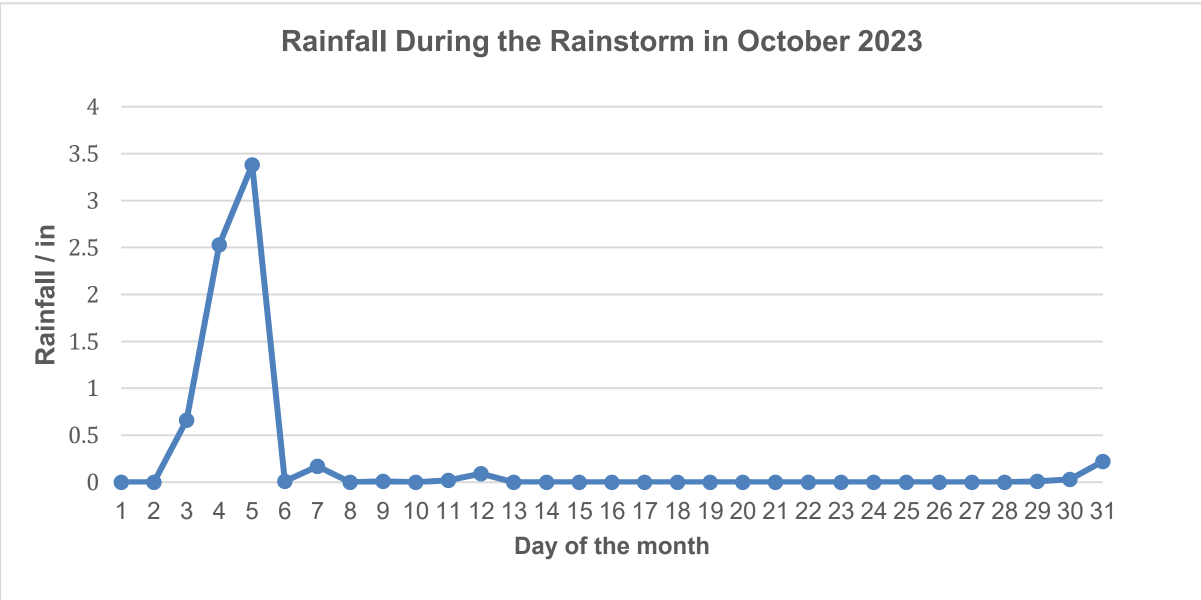
The second use is domestic water consumption by households. This is met by runoff water, which is then stored in cisterns. The priority order for the use of cistern water is as follows: potable water consumption, then watering livestock, and finally irrigating young trees (in case of drought). In the northern part of the region, residents supplement their water supply through the main freshwater pipeline from Alexandria Governorate. This water is managed by the Marsa Matrouh Water and Sanitation Company. This water source primarily serves the northern part of the region, near the location of the pipeline along the coast.

It is worth noting that there is no industrial water use in the basin.

• *Flood risks*

The vulnerability to flooding is very high. The basin experienced a flash flood in October 2023, which led to the destruction of water collection structures, primarily earthen and stone dikes, as well as damage to the railway (see Appendix 1 and rainfall data in Appendix 2). Additionally, several young trees were swept away by the floodwaters. No damage assessment has been conducted. Weather data from the NASA repository clearly shows the flood, with the highest rainfall recorded between October 3rd and October 5th (Figure 2). This extreme event, linked to the effects of climate change, has had a significant impact on local communities. The risk remains, and it is likely that such an event will happen again.

Figure 2. Rainfall in October 2023.



Sources: NASA/POWER CERES/MERRA2, 2023. https://power.larc.nasa.gov/data-access-viewer/

• *Sources of pollution*

One source of pollution is linked to the use of agrochemicals and pesticides in plantations. This affects environmental quality as well as irrigation water quality (via runoff). Nevertheless, there is no data available on the amount used or its effects.

• *Drought risks*
The basin has experienced severe heat-waves, with temperatures reaching 40°C during May-June. The number of heatwave days has not been determined. The effects of drought have been more pronounced in the south, where, after 1995, the absence of rainfall and dry winds led to rapid desertification and land degradation (Daoud, 2015).

During drought years (1995-2005), residents are forced to transport water to their cisterns from the city of Matrouh. This dependence increases as rainfall decreases, particularly in the southern region. The company responsible for potable water and sanitation in the city of Matrouh sells water volumes, which it delivers by truck to several residents. Thus, the Matrouh Sanitary Authority and the Matrouh Drinking Water Authority play an important role in delivering water for domestic use in the rural areas of the basin. Freshwater comes from the Alexandria pipeline and is transported by truck from the main station located on the international coastal road. The cost of transportation increases significantly for areas further south (Daoud, 2015).

1.3 Projected water scenarios

Climate change will result in higher temperatures and unpredictable rainfall patterns in northwest Egypt. Although average annual temperatures have increased at a global rate of 0.1°C per decade between 1901 and 2013, a gradual decline in rainfall has also been observed, which will lead to water shortages and desertification (Al-Mailam and Hamzawy, 2023).

The available data produced by AG WAMED apply to the average annual flow of the Abou Haggag Basin, next to the Naghamish basin. This LL's area covers 200 km², while the total basin of the Abou Hagga cover 3,640 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 Abou Haggag basin over the years. The average annual flow, which was 0.130 km³/year from 1980–2019, is projected to range between 0.12 and 0.13 km³/year for 2020–2059 and between 0.10 and 0.12 km³/year for 2060–2099. This represents a reduction of jusqu'à 7% pour la période 2020-2059 and 23% pour la période 2060-2099.

Figure 3. Scenarios in Abou Haggag 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	0.13							
gfdl		0.13	0.13	0.12	0.12	0.12	0.12	0.12
mri		0.12	0.12	0.14	0.14	0.12	0.12	0.10
ipsl		0.13	0.12	0.11	0.14	0.12	0.10	0.09
mpi		0.12	0.12	0.13	0.13	0.13	0.12	0.09
ukesm1		0.13	0.13	0.11	0.12	0.12	0.12	0.11
mean	**0.13**	**0.13**	**0.13**	**0.12**	**0.13**	**0.12**	**0.12**	**0.10**

xf

Sources: WP5 - AG WaMED project, 2024.

For the least conservative scenario (SSP126), the model averages show that water availability will either remain stable or decrease. For the more conservative scenarios (SSP370 and SSP585), water availability shows a more significant reduction, particularly marked for the 2060–2099 period.

For the study basin, the reduction in contribution (in terms of DAM) is approximately 23% for the long-term SSP585 scenario, compared to the historical scenario. Under current conditions, and if they persist, the Living Labs (LLs) will be exposed to changes in the average annual flow, negatively impacting users. In fact, water used for irrigation comes exclusively from rainwater and its storage in dams and cisterns. At present, the only non-conventional water solutions are focused on increasing storage capacity or, in the long term, delivering regenerated or desalinated wastewater.

According to the most recent scenarios developed within the AG-WaMED project in Wadi-Nagamish, the simulated annual average of rainfall over the 41-year period analyzed (1986–2000) was 172 mm, and the model showed that this precipitation is overwhelmingly consumed by evapotranspiration processes. Specifically, the model estimated that 167.83 mm/year (98%) of rainfall is lost through actual evapotranspiration (AET), while only 5.83 mm/year (3.41%) is transformed into surface runoff. The simulation recorded no percolation to deeper layers, confirming that groundwater recharge is negligible in this context. This means that nearly all incoming precipitation is immediately returned to the atmosphere, with extremely limited runoff to be captured or stored. The ET/P ratio (evapotranspiration over precipitation) was calculated at 0.98, and the streamflow/precipitation ratio at 0.03, values that confirm the high hydrological losses characteristic of hyper-arid environments (AG-WaMED, 2025).

The watershed is dominated by rangelands (over 83%), with only 6.3–7.6% under agricultural use (mainly olives, figs, barley, and wheat), concentrated along the wadis. These agricultural zones are especially sensitive to water availability fluctuations, and the model confirms their dependency on very limited and irregular surface runoff.

An assessment of future water demand by productive sectors has not yet been conducted, as fig and olive trees remain the primary agricultural crops, relying mainly on winter rainfall. New olive varieties, such as the Shamlaley olive, which require little water, more tolerant to drought, and good for oil production are also being considered (Fayed, 2010). The reduction in rainfall is likely to result in the decline of wheat and barley cultivation. Consequently, drought periods will affect the economy and social life of the Bedouins, causing disruptions to their way of life.

Water-related development scenarios include the introduction of rainwater harvesting techniques, such as rooftop water collection and contour trenching techniques. New irrigation methods, such as nano-technology irrigation, are being considered. The application of treated wastewater reuse for the cultivation of aromatic and medicinal plants is also under study.

1.4 Economic analysis

The basin's productive activities rely mainly on agriculture, with water primarily sourced from rainfall. As a result, it is difficult to estimate the price of water in the basin. Supplemental irrigation is carried out by adding extra buckets of water at the base of the trees. Additionally, the dikes and cisterns used have been in place on this land for many years. Local organizations provided financial aid for digging cisterns and building underground water tanks, based on inhabitants' contributions. Initially, these infrastructures were dug using financial aid from international organizations like the World Bank and World Food Program (WFP) of the FAO.

According to LL sources, the current prices of non-conventional water are as follows:

1 m^3 of fresh water from the Alexandria water pipeline = 20 Egyptian pounds
1 m^3 of desalinated water = 10 Egyptian pounds, but there is no estimate of consumption
1 m^3 of domestic wastewater = no price set yet (it is not sold and nobody is using it for the time being).

Party II Medium and long-term strategy

2.1 Analysis of priority problems

• *Main Issues*

1) The dykes are insufficient to collect rainwater and runoff, which affects water availability for agriculture in the context of climate change.

2) The number of cisterns to store runoff water for domestic consumption and agriculture is poorly maintained and insufficient to meet the needs of Bedouin families.

3) The use of treated wastewater is not sufficiently developed due to regulatory and cultural barriers.

4) The limited integration of women in the agricultural workforce and care systems significantly reduces their development capacity and living conditions.

• *Analysis of Priority Issues*

1. The decrease in rainfall and water availability in the basin has increased pressure on hydraulic infrastructures such as the dykes installed on the wadis. The basin lacks investment in the installation and maintenance of these dykes, which are used to collect rainwater and provide water to plantations. These dykes are often in poor condition, and local populations have limited income to maintain them. Moreover, financial support from the state and local authorities is limited. Currently, no specific measures or large-scale interventions are planned to increase water availability or improve its sustainable use in the basin. In the past, farmers received subsidies from agricultural cooperatives and previous development projects (MRMP), or international institutions (World Bank, World Food Programme), but these aids are now non-existent or insufficient.

2. Another issue in the region is the condition and functioning of cisterns used for domestic purposes. According to Douad (2015), only 79% are operational, and no other alternatives have been promoted by the state to ensure the population's access to water. Additionally, there are inequalities in terms of water availability and access between the north and the south. The vegetation cover has gradually disappeared in some southern territories. The proximity of the northern region to Marsa Matrouh facilitates the transportation of water by truck. However, this solution becomes more expensive as one moves south, where prices can be up to four times higher.

3. The reuse of treated wastewater could eventually be an alternative to guarantee water access in the region. In urban areas of the country, water and sanitation services are provided by the Holding Company for Water and Sanitation and its 23 affiliated companies, which are responsible for purifying, distilling, transporting, distributing, and selling potable water, as well as collecting, treating, and safely disposing of wastewater. However, there are obstacles to its use in rural areas due to the implementation of decrees 135/1999 and 334/2002, which aim to

establish local wastewater treatment systems in remote areas. Indeed, decree 603/2002 (AbuZeid and Elrawady, 2014) prohibits the use of treated or untreated wastewater for irrigating conventional plants, and decree 1038/2009 (Nasr and Negm, 2023) prohibits the use of treated or untreated wastewater for irrigating all food crops (Souli, 2013 ; FAOLex, 2024; Ministry of Water Resources and Irrigation, 2017).

4. Bedouin society is characterised by the preservation of its traditions, particularly patriarchy, although customs and traditions are gradually evolving. Nevertheless, the role of women in Bedouin society is limited to domestic life and household chores. Their education level often stops at primary school, and few Bedouin women hold higher education degrees. They do not participate in agricultural activities (planting, harvesting, or marketing) or decision-making concerning water distribution. However, as they are responsible for household duties, they manage water within households. It should be noted that the lack of quality water and healthcare facilities in these regions has a particularly harmful impact on women's health.

2.2 Goals of Basin Action Plan

The action plan for Wadi Naghamish-ElKheir aims to utilise non-conventional water resources for innovative and climate-resilient governance while increasing community awareness regarding these resources. The plan seeks to address various challenges facing the region, particularly increasing food production to enhance per capita income while reinforcing the importance of women's engagement in local decision-making. In this regard, emphasis will be placed on preventing land and water degradation and raising awareness of the use of non-conventional water sources, such as the reuse of treated wastewater.

To achieve this, four strategies must develop concurrently:

1. Restore the existing dykes and cisterns.
2. Install new dykes and cisterns.
3. Promote the reuse of treated wastewater.
4. Ensure women's participation in local economic and political life.

2.3 Main measures

Legal measures:

1.Intervene on legislation regarding the reuse of treated wastewater to reduce regulatory barriers that hinder the use of this water for agricultural purposes, while also considering health risks.

Political measures:

1.Secure sustainable funding for the installation, rehabilitation, and maintenance of dykes for agricultural use and cisterns for domestic use.
2.Fund the capacity for collecting and treating wastewater to sufficient levels to allow for its reuse for agricultural purposes.

3.Encourage a transition towards the gradual phasing out of harmful pesticide use to preserve the quality of water and soil, as well as the health of local populations.
4.Promote the introduction of new crop varieties to address the decreasing water availability such as the Shamlaley olive.

Practical and cultural measures:

1.Encourage a shift in mindsets and practices to promote the inclusion of women in economic (farming, agriculture) and political activities, while ensuring their access to education and healthcare.

2.Raise awareness among communities about the use of non-conventional water resources, such as the reuse of treated wastewater.

2.4 Financing strategy

To finance the measures, it is necessary to involve all relevant administrations. Several potential sources of funding have been identified, such as international development projects, the state's financial plan, or the budget of the Ministry of Agriculture. Furthermore, private sector companies and certain banks could be involved in financing the necessary policies and infrastructures. Finally, the intervention of NGOs or State initiatives such as "Hayah Karima" (Decent Life Initiative) could also support the necessary changes in the region. In 2019, the president, in collaboration with civil society, launched a program aimed at improving the quality of life and developing the most vulnerable rural villages.

2.5 Integration into current legislation

- **Implement the non-conventional water component of the National Water Plan 2037, the National Water Resources Development and Management Strategy 2050, and the 2030 Sustainable Development Strategy Vision.**

The state has committed, through three public policy programming plans (the National Water Plan 2037, the National Water Resources Development and Management Strategy 2050, and the 2030 Sustainable Development Strategy Vision), to ensure water security by promoting sustainable water resource management and the development of non-conventional water sources. The 2050 National Strategy notably plans to promote rainwater and floodwater harvesting to recharge coastal reservoirs, construct dams to harness rainwater, expand wastewater treatment facilities, and gradually transition to desalination through the widespread use of desalinated water in coastal and remote areas. However, these policies and measures are not yet implemented in the region.

- **Direct the actions of the National Climate Change Strategy towards 2050 in the northwest.**

The national climate change strategy towards 2050 aims to improve the efficiency of water resource use by developing rainwater harvesting systems, promoting reforestation, and increasing green spaces. However, currently, water investments seem to favour the Nile basin and the development of new cultivated lands, neglecting the northwestern regions of the country. Most laws concern cultivation in the Nile Valley and the Nile Delta, which rely entirely on irrigation methods (drip, sprinkler, etc.). More coherent legislation tailored to the social and environmental conditions of the northwestern coast of Egypt should be developed. The lack of investment is also partly explained by administrative centralisation and decision-making difficulties, as well as coordination problems between different ministries.

- **Amend decrees 135/1999 and 334/2002 regarding the reuse of treated wastewater.**

The government has proposed a strategic plan for the reuse of water that would allow for nearly complete treatment of wastewater in Egypt by 2030. However, the treatment and reuse of wastewater are unresolved challenges, both in urban and rural areas. A future task is to examine the technical and human resources necessary to implement existing regulations, such as the wastewater reuse code. This code was amended in 2015 to promote the improvement of the quality of reclaimed water and encourage its use in food crops; however, it has not yet been fully implemented. For now, the reuse of wastewater is not deployed. The transportation cost of this water and the standards regarding the quality of treated water permitted for irrigation (decrees 603/2022 and 1038/2009) pose

2.6 Socialisation and implementation of Basin Action Plan

The Action Plan could be socialised through a workshop involving all identified stakeholders concerned with the issue (Appendix 3). The goal is to share the main recommendations and conclusions from scientific research conducted under the Ag-Wamed project.

Debate forums and workshops, such as those developed in this project, are effective measures for sharing issues and outlining possible solutions. In the long term, the forum provided by the negotiation and decision-making committee itself would serve as an appropriate means for continuing the process of socialisation.

Stakeholders will be kept informed through regular meetings with them, telephone communication with key person (local leader and local influencers), other communication methods.

Appendix 1

Photos for rainstorm in October 2023

Damage to railway

Damage to Dykes

Appendix 2

Weather data for Wadi Naghmish and El-kheir downloaded from the internet

https://power.larc.nasa.gov/data-access-viewer/

NASA/POWER CERES/MERRA2 Native Resolution Daily Data
Dates (month/day/year): 10/01/2023 through 10/31/2023
Location: Latitude 31.2362 Longitude 27.3972
Elevation from MERRA-2: Average for 0.5 x 0.625 degree lat/lon region = 131.4 meters

Date	Rainfall/mm
01-10-23	0
02-10-23	0
03-10-23	0.66
04-10-23	2.53
05-10-23	3.38
06-10-23	0.01
07-10-23	0.17
08-10-23	0
09-10-23	0.01
10-10-23	0
11-10-23	0.02
12-10-23	0.09
13-10-23	0
14-10-23	0
15-10-23	0
16-10-23	0
17-10-23	0
18-10-23	0
19-10-23	0
20-10-23	0
21-10-23	0
22-10-23	0
23-10-23	0
24-10-23	0
25-10-23	0
26-10-23	0
27-10-23	0
28-10-23	0
29-10-23	0.01
30-10-23	0.03
31-10-23	0.22

Appendix 3

List of authorities to whom this Water Management Plan will be sent:

- Garawla Agricultural Society – NGO
- The local People (Bedouins)
- Ministry of Agriculture
- Ministry of Environment
- Ministry of Water Resources and Irrigation
- Agricultural Research Center
- Egyptian Environmental Affairs Agency
- National Water Research Center
- Municipality of Matrouh
- Matrouh University
- Water Desalination Plant
- Farmer Associations
- Information and documentation center, Matrouh Governorate
- GI Unit, Matrouh Governorate
- Urban Planning Administration, Matrouh Governorate

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