MADFORWATER Newsletter | Issue n°4 | November 2020

MADFORWATER

MADFORWATER focused on the development and application of integrated technological and management solutions for wastewater treatment and efficient reuse in agriculture tailored to the needs of Mediterranean African Countries.

www.madforwater.eu

Dear Reader,

welcome to the forth newsletter of MADFORWATER, an Horizon 2020 Research and Innovation Action financed by the European Union and coordinated by the University of Bologna (Italy). The general goal of MADFORWATER was to develop a set of integrated technological and management solutions to enhance wastewater treatment, treated water reuse for irrigation and water efficiency in agriculture in Egypt, Morocco and Tunisia. MADFORWATER focused on municipal, agro-industrial and industrial wastewaters, as well as on the drainage canal waters of the Nile Delta. The development and validation of technologies was combined to the definition of integrated water management strategies, tailored to the local context of selected hydrological basins in Egypt, Morocco and Tunisia.

MADFORWATER, started on June 1 2016, has completed its activities after 4.5 years of intense collaboration between European and North African partners. During the last 1.5 years of activity, we focused in the first place on the installation and operation in Egypt, Morocco and Tunisia of four pilot plants in which wastewater treatment and wastewater reuse for irrigation were tightly integrated. In addition, model-based water management strategies tailored to 3 selected hydrological basins in Egypt, Morocco and Tunisia were developed, and a wide range of dissemination, capacity building and exploitation activities took place. Even though the Covid crisis forced us to stop all the experimental activities during the Spring of 2020, MADFORWATER partners quickly resumed the operation of all pilot plants during June-July 2020, in order to deliver all the expected results by the end of the project, in November 2020.

In this newsletter you will find:

- the presentation of the MADFORWATER approach for the analysis of water security in the North African context;

- an illustration of the FAO Water Scarcity Initiative;

- the description of the MADFORWATER Decision Support Tools for the development of strategies for wastewater management and for water management in agriculture;

- the presentations of the main results delivered by the four pilot plants of wastewater treatment and wastewater reuse for irrigation.

Enjoy the reading! If you would like to receive further information or to set up collaborations, feel free to contact us:

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An innovative approach for the assessment of water security in North African countries

Agricultural development plays an important role in the economies of the Mediterranean African Countries (MACs). Food demand is increasing and consumption patterns are changing. The countries face common challenges in their strategy to improve food security, such as a rapid population growth, urbanisation, dependency on rainfed agriculture with fluctuating yields, water scarcity, increased water demands, and challenges in water quality. However, MACs are characterized by interesting opportunities for agricultural development: availability of arable land, a temperate Mediterranean climate with year-round production possibilities, and a growing consumer market. To better understand the current and future water-related issues and the capacity of society to cope with them, a Water Security assessment has been developed for the three North African countries involved in MADFORWATER: Morocco, Tunisia and Egypt.

According to UN-Water, Water Security is defined as "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" (https://www.unwater.org/publications/water-security-infographic/).

Usually, Water Security is indistinctly used from other similar terms such as Water Stress and Water Vulnerability to highlight risks and problems of the water challenge "too much – too little - too dirty"! Still today the literature offers a vast diversity of definitions, approaches and assessment frameworks, and a unified approach for the analysis of water security is missing. Thus, the intention of MADFORWATER was not to create another water assessment framework, but to seek ways to link the project results to the current international debate. That is why the 2016 AWDO assessment framework has been selected (Asian Water Development Outlook 2016. Strengthening Water Security in Asia and the Pacific. Asian Development Bank). This framework provides a comprehensive national overview for five key dimensions related to water security: household, economic, urban, environmental, and resilience to water-related disasters.

MADFORWATER focused on the key economic dimension. This dimension is based on the performance of four indexes: a general one to assess the water-related boundary conditions (Water Resources Index) and three sector-specific indexes (Agriculture, Energy and Industry Indexes). Each of these indexes is subsequently composed by several sub-indicators, whose results are transformed into AWDO scores. A detailed description of the methodology can be found in the public Deliverable 1.2 "Water stress and Water Vulnerability indicators and maps", available on the MADFORWATER website (www.madforwater.eu). The final total score of each sub indicator is subsequently aggregated into the final Economic Water Security dimension to a maximum of 20 points. The Economic Water Security follows a nested approach, combining both the elaboration of spatial explicit Water Stress related indicators with indicators developed at national level.

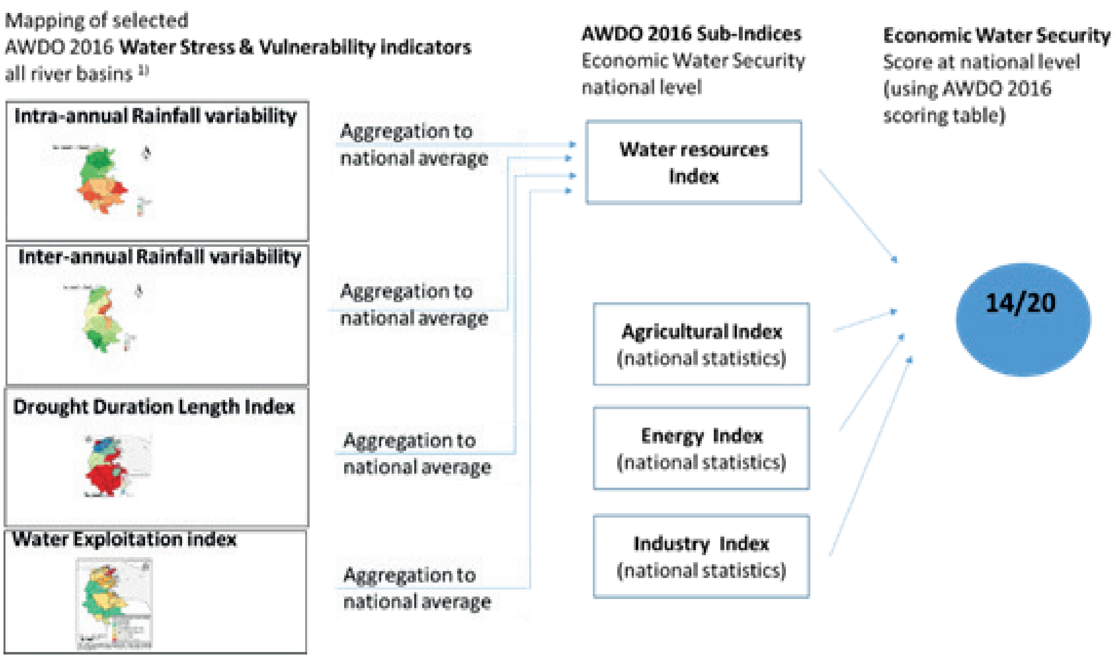
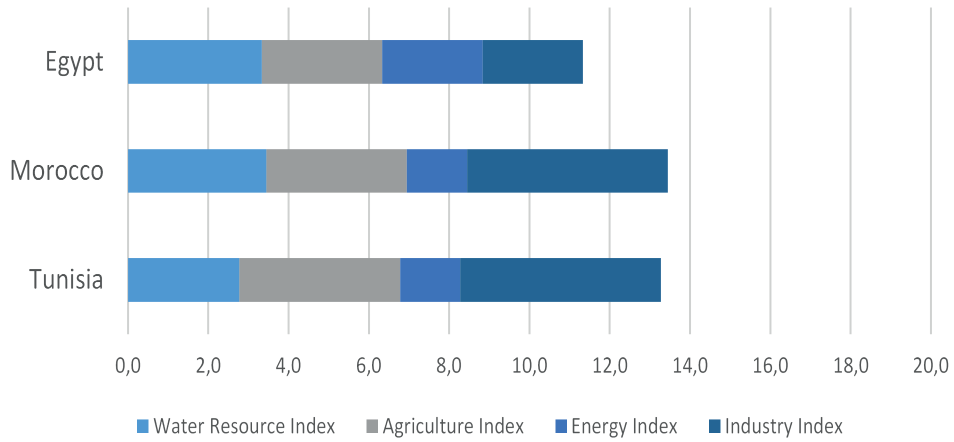


Figure 1. Structure and calculation of the 2016 AWDO Economic Water Security

This analysis resulted in a relatively low Economic Water Security for the three countries assessed. Egypt is the country with the lowest value (about 11), indicating a higher vulnerability, due to the low agricultural water productivity and the low self-sufficiency of its economy related to agricultural products. In Morocco and Tunisia the Economic Water Security resulted equal to about 13, with a low value of the Energy Index since energy production per capita is far below the regional average production for MENA countries.

A more detailed analysis of the Water Resource Index reveals that as a result of the high storage capacity of surface water in these regions, the risk of water shortage related with rainfall variability and droughts is limited in the three studied countries. However, the large inter and intra-annual rainfall variability, coupled to a high-water exploitation, could hamper the future Water Security of these countries. The assessment indicates a potential increase in vulnerability for the near future, as the expected reduction of water availability could jeopardize the satisfaction of the future water necessities.



Water security of Morocco, Egypt and Tunisia following the 2016 AWDO Economic Water Security approach. Aggregated values over a maximum score of 20.

In conclusion, a water security assessment is a powerful tool to understand the water related issues and hazards of a specific area. It combines the information provided by several sources into a grouped and standardised value. This approach, that could be used for awareness raising at different levels, from citizens to policy makers, represents the key to initiate measures and to derive policy instruments to improve water security. When this approach is applied on a broader geographic scope, is also allows to compare the water related situation of various regions. Similarly, when a water security assessment is developed on a regular basis, the effect of different policies on the evolution of water security can be assessed. In this way, countries can secure their future food supply.

The Regional Initiative on Water Scarcity (WSI)

The Near East and North Africa (NENA) region has the lowest per-capita fresh-water resource availability of any region in the world. In the last 40 years, available fresh water has decreased by two-thirds. By 2050, it is expected to decline a further 50 percent due to rising populations, food security policies, socio-economic development, and climate change. Irrigated agriculture consumes over 85 percent of the region's available fresh-water resources, meaning it will face strong competition from other water using sectors and must therefore become more efficient, while continue to contribute to food security and to the rural economy.

In response to this situation, FAO and partners launched the Water Scarcity Initiative (WSI) to support the countries of the Near East and North Africa region to cope with one of their most striking challenges: the pursuit of food and water securities within sustainable social and economic development and under unprecedented severe escalation of water scarcity. The WSI supports countries of the region to strategically plan their water resource management and allocation, review their water, food security and energy policies, formulate effective investment plans, modernize governance and institutions, account for transboundary surface and ground water and adopt good agricultural practices.

The WSI is a regional mechanism that will help implement the FAO's Strategic Objective 2 "Make agriculture, forestry and fisheries more productive and sustainable". In this context, a "Regional Collaborative Strategy" was formulated on "Sustainable Agricultural Water Management in the Near East and North Africa Region" which, among other objectives, aims at supporting and complementing existing Regional Initiatives such as the Arab Water Security Strategy 2030. In fact, the WSI has been endorsed by the Water Ministerial Council of the League of Arab States as a mechanism to support the Arab Water Security Strategy 2030.

The major focus areas of the initiative include: (i) adopting global standards for water-accounting systems; (ii) expanding the knowledge base for irrigation efficiency and water productivity; (iii) improving groundwater governance; (iv) using nonconventional water; (v) adapting to climate change; (vi) managing drought; and (vii) implementing scenario analysis, including the water-food-energy nexus approach, to identify safe operational boundaries for water consumption within which achieving SDGs targets.

MADFORWATER, of which FAO is an active partner, is one of the projects that contribute to the goals of the WSI. Indeed, nonconventional water resources, and treated wastewater in particular, have the potential to positively influence water availability, as it is probably the only growing renewable water resource in many countries of the Arab region. Appropriate and cost effective concepts and decision support tools like those being developed in the MADFORWATER project can support sustainable water management. Tailored wastewater treatment units coupled with innovative clogging resistant devises for the different irrigation systems have direct applications in many of the Arab countries. The project outputs, in terms of tools, strategies and devises, have the potential to provide additional safe water supplies and thus help integrate wastewater within water resources planning and management and at the same time contribute to food security through higher agricultural production.

Development of a Decision Support Tool (DST) for the establishment of wastewater management strategies

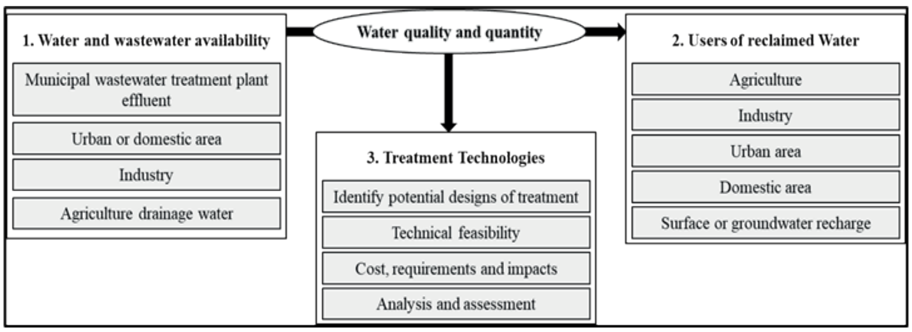
Based on the 2019 World Resources Institute data, twelve out of the seventeen most water-stressed countries are in the Middle East and North Africa (MENA) and 82% of the region's wastewater is not reused. The Institute for Ecopreneuship (IEC) at the University of Applied Sciences and Arts Northwestern Switzerland (FHNW) developed a robust decision-support tool (DST) to pre-assess water reuse feasibility for various cases with high potential for water reuse. The DST is based on Microsoft Excel, it is open-access and it can be downloaded from the MADFORWATER project website (www.madforwater.eu).

The DST allows a non-expert user to obtain top-ranking technology options, including cost of treatment and quality compliance. The main application is to conduct pre-feasibility studies and assessments, but the DST can also be applied for capacity building at universities and for practitioners.

The DST's purpose is to identify technology options that can treat wastewater to the desired quality for several representative case studies. The user has to provide information about (1) the wastewater to be reclaimed (quantity and quality from a selection of pre-defined classes), (2) the desired reclaimed water quality (from a set of national regulations and international guidelines), and (3) local cost information (i.e., electricity cost, land cost).

The DST automatically proposes top ranking technology options from a database of benchmark treatment trains (series of unit processes) based on lifecycle treatment costs and/or based on a weighting profile defined by the user. It currently encompasses 37 units processes combined into 70 benchmark treatment trains. The DST focuses on the pre-feasibility stage and considers potential water reuse schemes in a systemic approach. This allows determining if an identified area with potential for water reuse could lead to a feasible reclamation scheme with current resources, technologies and available information.

In the frame of MADFORWATER project, the DST has been adapted to the specific cases of Egypt, Morocco, and Tunisia, by including country-specific data and information in the tool. The added data include typical wastewater qualities, national regulations on water quality requirements for the compliance with different types of reuse, ISO 16075 guidelines for treated wastewater reuse in agriculture and local cost factors.



Water reuse for pre-feasibility in a systemic approach: (1) wastewater for reuse, (2) type of intended reuse, (3) identification and assessment of technology.

The DST goes beyond technical considerations and includes a multi-criteria analysis consisting in six thematic subjects, namely economy, water management, policy and institution, legislation and environment. Each thematic subject is described by two to four key questions. These in turn are underpinned by one quantitative or semi-quantitative indicator. Collectively, these indicators provide an indicative general understanding of the current situation of water reuse in Egypt, Tunisia, and Morocco. These indicators are selected on the basis of existing indicators, which were scanned from major water reuse studies and databases.

The objective of the DST application to Egypt, Morocco and Tunisia was to identify adapted treatment trains for the reclamation of municipal wastewater or secondary effluents from existing wastewater treatment plants for agricultural applications. For all defined case studies, adapted treatment trains that could treat wastewater to the desired quality at reasonable costs were identified. The assessment indicated a high potential for water reuse in Egypt, Morocco, and Tunisia. In particular, Tunisia resulted with high water reuse level, followed by Egypt and Morocco. It showed that the policy context and social acceptance is favorable to the implementation of water reuse. The main barriers hampering implementation of water reuse resulted to be of economic, management and environmental nature.

The wastewater management DST is freely available to any interested stakeholder through the Zenodo repository: http://doi.org/10.5281/zenodo.3755380

Development of a decision support tool for the production of water and land management strategies in agriculture

A specific MADFORWATER task was dedicated to build up and implement an integrated agro-economic model useful to basin authorities and water management agencies to develop strategies for water reuse and water & land management in agriculture

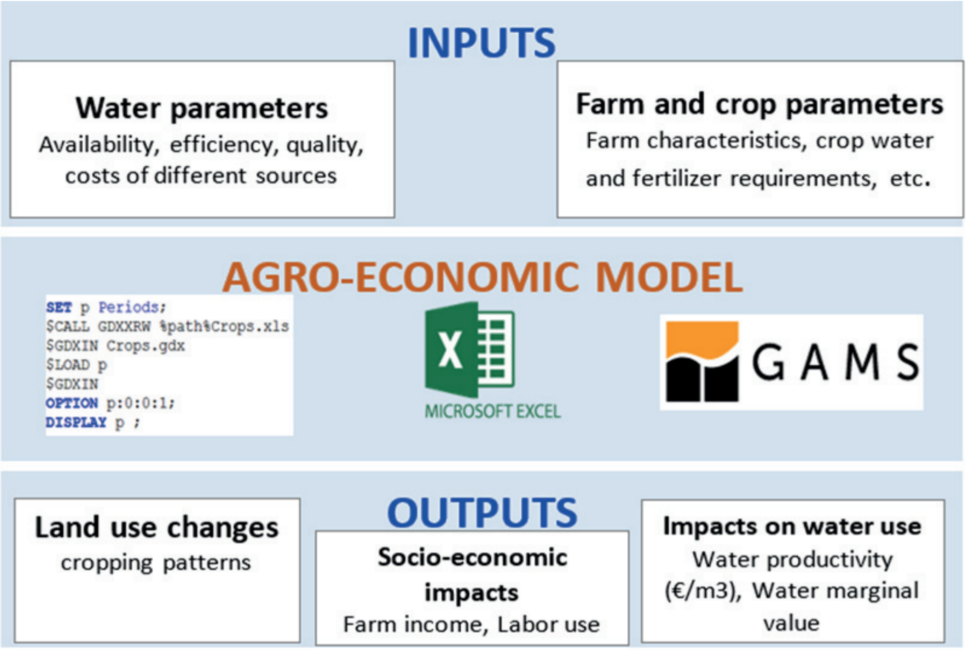
The general objective of the model-based decision support tool (DST) is to develop water and land management strategies aimed at (i) an optimal exploitation of the irrigation technologies, and (ii) identifying economic instruments for improving irrigation efficiency and for enhancing treated WW reuse in agriculture.

A general and flexible structure of the DST has been framed, in order to include all the specificities of the three case studies on which MADFORWATER focuses its activities: the Souss-Massa basin in Morocco, the Nabeul region in Tunisia and the North-Eastern Nile Delta in Egypt. The general DST was framed in order to incorporate different types of crops, intensification levels, use of fertilizers, as well as different types of water sources. The general structure of the agro-economic model can be illustrated as follows:

By identifying the optimal choices of farmers in relation to cultivation and agro-technical models, the model allows to estimate the impact of the adoption of technological innovations and economic and regulatory tools that can be put in place to encourage the reuse of treated wastewater. Several technological scenarios were combined with technological and political scenarios, such as an increased amount of water availability thanks to an improved water reuse and to more efficient irrigation technologies, as well as the decrease in fertilizer requirement due to high levels of organic matter in treated WW. For each possible scenario, the proposed DST allows to identify the most efficient scenario for farmers and water managers, in terms of land allocation to different crops, mix of different water types and level of adoption of the different water reuse and irrigation technologies developed in MADFORWATER. The decisions of the managers of the basin authorities and of the water resource planning and management agencies can therefore be based on an evaluation of the measures taken in terms of consumption of fresh and treated water, the need for fertilizers, changes in land use and necessary subsidies for the implementation of the proposed policies.

A water pricing policy to enhance wastewater reuse in the Moroccan citrus sector

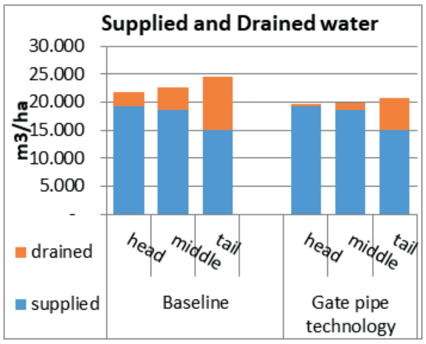
For the Souss-Massa region in Morocco, intensively cultivated with citrus, a water pricing policy was simulated by decreasing the price of treated wastewater (TWW) from the actual level - 0.23 €/m3 - to 0.10 €/m3. As a result of this policy, according to the DST 40% of the total irrigated area results to be irrigated with TWW, the total freshwater required by the citrus sector decreases by 64% compared to the current level and the total water cost decreases by 10%. Clementine, the citrus variety that switched to TWW, is the one characterized by the lowest water requirement as well as the highest consumption of fertilizers, so that the switch to TWW can be offset by savings in fertilizers.



The use of TWW allows to save 38% of the current fertilizer consumption in the Moroccan citrus sector, which determines an additional economic saving for the farmer and a contribution to the environment. The combined effects of the proposed water pricing policy on crop yield, water cost and fertilizer cost translates into a significant increase of farmer income, equal to 8500 Euro/ha.

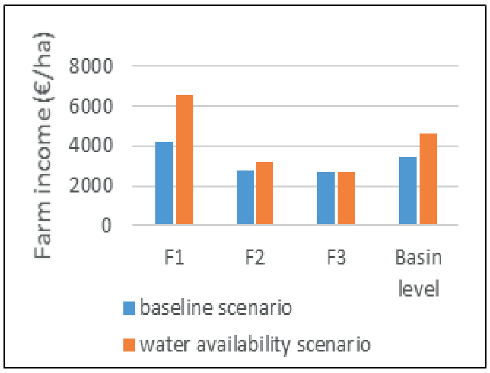
An innovative technology to increase efficiency and equity of the traditional surface irrigation in Egypt

In the Nile Delta region in Egypt, all the agricultural surface is irrigated with freshwater ultimately provided by the Nile River through a complex network of canals. Surface irrigation is widely applied, and the excess irrigation water, contaminated with fertilizers and pesticides, is collected by means of an intricate network of drainage water canals. The main scenario proposed for this region by means of the DST consists in the introduction of an innovative irrigation technology, the gated pipe, a new type of high-flow calibrated nozzle. Providing constant discharges as pressure decreases it is expected to have two relevant positive impacts on the traditional surface irrigation system of Egypt: i) to reduce the drained water re-pumped into the system and, consequently, the deterioration of the water available for irrigation practices, and ii) to improve the equity of the system measured as the difference among the system performance index in the different sections of the tertiary canal.



By increasing the irrigation efficiency, the introduction of the gated pipe is expected to reduce the irrigation requirements by 9%, 12% and 15 % for the head, middle and tail section of each irrigation canal, respectively. Further, the system performance index - i.e. the ratio between supply and demand of water – is expected to increase, inducing farmers to reduce the amount of drained reused water re-pumped into the network of irrigation canals.

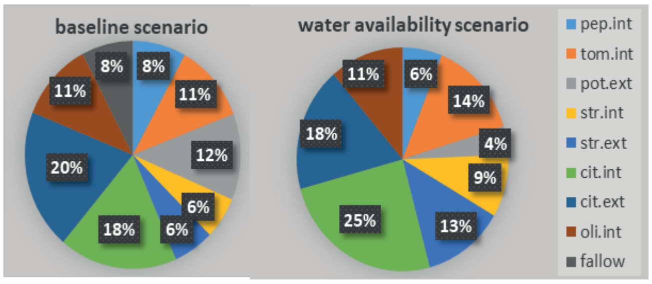
On the other hand, the model-based scenario indicates that, notwithstanding the energy cost saving due to the reduced amount of drained water re-pumped into the system, farmers' income decreases slightly, due to the investment and operation & maintenance (O&M) costs of the gated pipe technology. Thus, only if public subsidies fully cover the total gated pipe cost (investment + O&M), the farmers' energy savings will determine a positive impact on farmers' income and a consequently favorable attitude of farmers towards the adoption of the proposed innovative technology.



An intense field work conducted in the study area indicated that the most realistic scenario is that farmers mix freshwater and treated wastewater. Therefore, the DST was used to simulate a scenario consisting in an increase in water availability for F1 and F2, obtained from treated wastewater reuse. The price of water is set at the Tunisian official rates: 0.02 €/m3 for treated wastewater and 0.04 €/m3 for freshwater. The results are presented at two different levels of aggregation, i.e. farm and basin level. The simulation indicates that farmers' income is expected to increase by 55% and 14% for F1 and F2 respectively, in comparison with the baseline scenario. At the aggregated level, farm income increases by 35%. Regarding the crop distribution, the simulation indicates that farmers cultivate more profitable annual crops such as strawberry and tomato (farm F1) and permanent crops such as intensive citrus (farm F2).

Conclusion

The DST developed by partners IAMB and UPM has proven to be essential for the production of water and land management strategies in agriculture for the three case studies (Tunisia, Morocco and Egypt) and has permitted to analyze the impact of irrigation technologies and economic instruments at different levels of aggregation, from farm to basin scale. Built and calibrated on the three case study areas, the model can be utilized in similar agro-ecological and socio-economic contexts. In the presence of conflicting objectives and a multiplicity of stakeholders, this DST is particularly useful in complex decisions in the framework of broader water and land management strategies that countries could implement to ensure the long-term sustainability of the water resource.



pep.int:pepper intensive; tom.int:tomato intensive; pot.ext:potato extensive; str.int:strawberry intensive; str.ext:strawberry extensive; cit.int:citrus intensive; cit.ext:citrus extensive; oli.int:olive intensive

Scale-up and validation of the MADFORWATER technologies: the pilot plants of integrated wastewater treatment and agricultural reuse

In the MADFORWATER project, the lab-scale development and adaptation of technologies for wastewater treatment and irrigation – performed during the first two years of activity – was completed during the last two years by the scale-up and validation of selected technologies by means of four pilot plants in which wastewater treatment and agricultural reuse of the treated water were effectively integrated. The selection of the technologies to be scaled up in each pilot was based on their technical performances, cost-benefit analysis (CBA), life cycle assessment (LCA) and on the feedbacks collected during several stakeholder consultation workshops that took place in Agadir (Morocco), Cairo (Egypt) and Tunis (Tunisia). Different wastewater types were treated and reused in the MADFORWATER pilots: municipal wastewater, textile wastewater and drainage canal water. The geographical location of the 4 pilot plants is shown in Figure 1.

Figure 1. Location and main characteristics of the 4 MADFORWATER pilot plants. P1: municipal wastewater; location: Chotrana Municipal wastewater treatment plant, Ariana, Tunisia. P2: textile wastewater; location: Gwash industry, Nabeul, Tunisia. P3: municipal wastewater; location: Agadir, Morocco. P4: drainage canal water; location: Lake Manzala, Egypt.

Integrated pilot plants for municipal wastewater treatment and reuse in irrigation (P1 and P3)

Two pilot plants were constructed and run for the purpose of municipal wastewater (MWW) treatment and reuse in Tunisia and Morocco. Pilot plant P1 (10 m3/d), installed at the Chotrana wastewater treatment plant in Ariana (Tunisia), consists of a train of (i) a nitrifying trickling filter that provides secondary treatment of organics and ammonia, (ii) a secondary settler for sludge sedimentation, (iii) a constructed wetland for heavy metals and remaining nutrients removal, (iv) a chemical disinfection unit and (v) an excess secondary sludge dewatering system (Figure 2). A satisfying removal efficiency was recorded during the experimental period: 90% for COD, 92% for BOD, 93% for TSS and NTK, 61% for TP and 3-log reduction for E. coli. The average outlet concentrations were found to be within the safe limits set by the Tunisian standard NT106.03 for wastewater reuse in agriculture and the Tunisian Decree n°2018-315 for wastewater discharge in the public domain.

Treated MWW generated from the pilot plant was used for the irrigation of wheat crops. MADFORWATER partners made a relevant effort in order to develop irrigation technologies suitable for TMWW reuse, with the aim to reduce water consumption and increase crop production. Several irrigation technologies were tested in the Sidi Thabet pilot: a model for irrigation scheduling that takes into account the specific characteristics of the treated wastewater, innovative mini-sprinklers suitable for treated MWW and hot climates and the supply of plant growth-promoting bacteria (PGPB). Promising results on wheat agronomic parameters were obtained by combining irrigation with treated MWW and the supply of PGPB. PGPB inoculants can be prepared in a way that can be easily used by farmers. However, the social and legal acceptance of this technology still represents a major barrier to its large-scale implementation.

Figure 2- a) Municipal wastewater treatment process in Chotrana wastewater treatment plant (Ariana, Tunisia), b) Wheat irrigated with treated municipal wastewater using micro-sprinklers

In the Souss-Massa region in Morocco, pilot plant P3 relied on an existing wastewater treatment plant within the station M'zar in Agadir, with a capacity of 75 000 m3/day (Figure 3). The MWW treatment process includes an anaerobic lagoon, biodegradation and infiltration on a sand layer, and UV disinfection. The monitoring activity showed an average 97-98% removal of BOD5, COD, TSS, 99% removal of NTK and turbidity, 100% removal of helminth eggs and fecal coliforms and 60% phosphorus removal. The final effluent complies with the Moroccan standards for irrigation with treated wastewater, except for electrical conductivity (3 - 4.5 mS/cm) that slightly exceeds such standard. The high electrical conductivity can be explained by the huge amount of saline wastewater produced from fish processing plants. To overcome this concern, the Moroccan company in charge of MWW treatment (RAMSA) has forced fish canneries to separate the internal sanitation network.

Treated MWW produced by the M'Zar plant was used for the irrigation of young olive trees by means of innovative calibrated nozzles. The irrigation water scheduling was performed using an innovative soil water balance simulation model (SIM). After one year of experiments, irrigation using TMWW allowed fertilizers and water savings of 570 €/ha, when the SIM model was applied. The crop yields obtained with MWW and freshwater resulted similar.

In conclusion, both the MWW treatment trains tested in the MADFORWATER pilot plants led to the production of high-quality treated wastewater that was successfully utilized for the irrigation of wheat and olive trees. For both treatment trains, the overall cost of wastewater treatment (0.6-0.7 €/m3) resulted acceptable in the Tunisian and Moroccan context. In particular, the trickling filter / constructed wetland combination appears to be highly suitable for small rural communities (1000-10000 people) actually characterized by a complete lack of MWW treatment and by a lack of irrigation-quality freshwater. On the other hand, further research is needed to assess the effectiveness of such treatment sequence for the removal of viruses, pathogen bacteria and emerging pollutants.

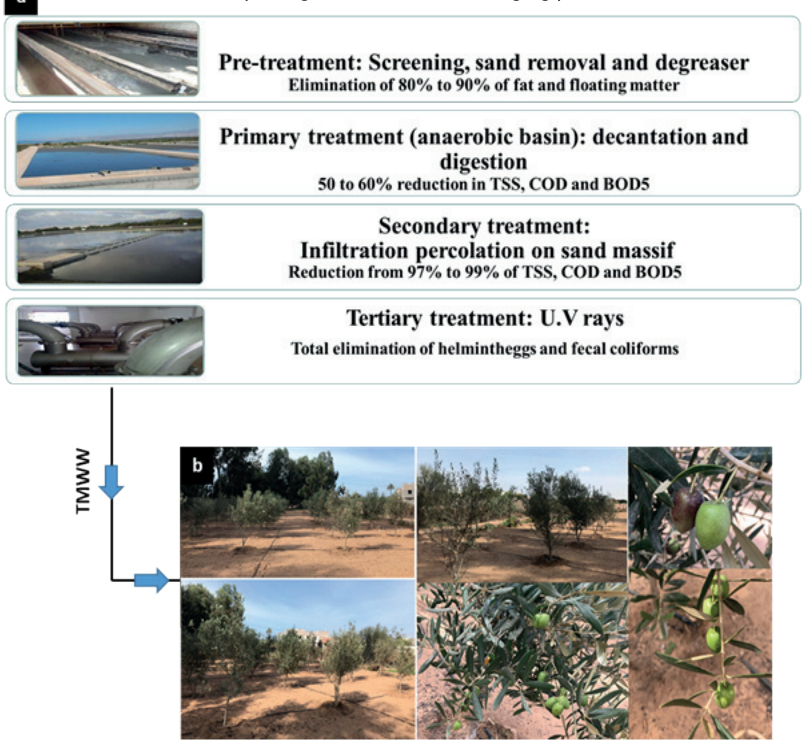


Figure 3- a) Municipal wastewater treatment process in L'Mzar (Souss-Massa, Morocco), b) olive trees irrigated with treated municipal wastewater using calibrated nozzles

Integrated pilot plant of textile wastewater treatment and reuse for irrigation

A textile wastewater pilot plant (Fiugre 1, P2) with a capacity of 10 m3/d was installed in the GWash textile industry (Nabeul, Tunisia) and consisted of a coagulation/flocculation unit, a primary clarifier tank, an aerobic Moving Bed Biological Reactor (MBBR), a secondary clarifier tank, a sand filter and an adsorption column (Figure 4). During preliminary runs of the pilot plant, the MBBR stage resulted not suitable for this type of wastewater, as high salinity and recalcitrant pollutants play an inhibitory role on biomass growth. In light of these results, the developed pilot plant was readapted and coagulation flocculation was applied as a principal treatment prior to the refining processes of adsorption and filtration. The pilot plant led to the production of a high-quality effluent, with average removals equal to 96% for color, 63% for COD, 66% for BOD, 95% for TSS and 100% for NH4, PO4, total and fecal coliforms. All effluent values except EC (in average around 18 mS/cm) were within the Tunisian limits for wastewater reuse in agriculture NT106.03 and the national acceptable wastewater discharge in the public domain (Decree n° 2018-315). The developed technology is characterized by a treatment cost of € 0.15 per m3 wastewater, which is within the range of discharge prices paid in Tunisia.

The treated textile wastewater was reused for the irrigation of sorghum. The results were encouraging in terms of morphological, physiological and yield parameters. Growth and crop yields were similar between the plots irrigated with treated textile wastewater and those irrigated with freshwater. In both plots, sorghum grain yields were equal to about 1500 kg/ha, in the range of the average values reported for Tunisia in 2017.

Textile industries in Tunisia produce about 3 million m3/year of wastewater, that gets typically discharged in the public sewer determining a significant additional load of non-biodegradable organic matter and colour to municipal wastewater treatment plants. The low-cost treatment process successfully tested in pilot plant P3 could potentially be implemented at large scale in the North African context, leading to a marked decrease of such pollutant load. The treated textile wastewater can be reused for the irrigation of non-food crops, as effectively demonstrated in the MADFORWATER pilot. An alternative option consists in internal reuse within the textile industry, with a consequent decrease of freshwater consumption and ultimately of the entity of water stress in regions characterized by a high density of textile industries.

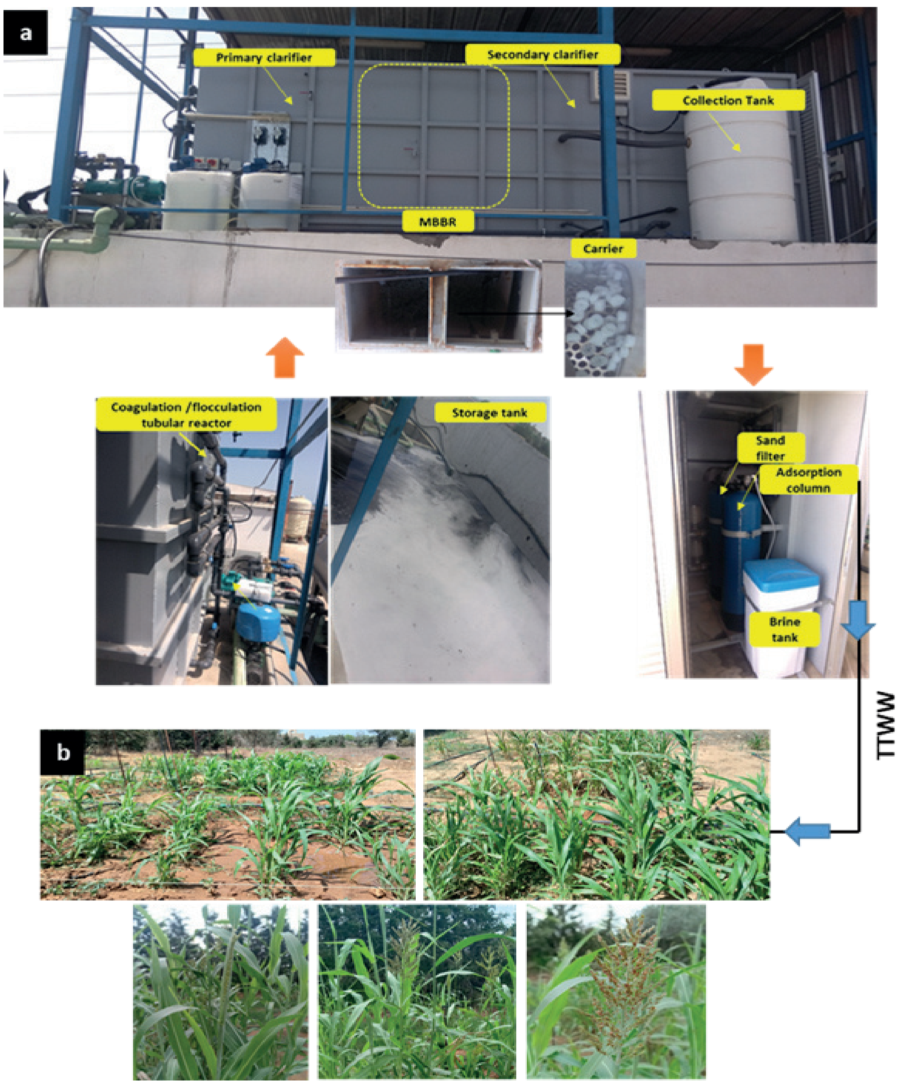


Figure 4- a) Textile wastewater treatment process in the textile industry Gwash (Nabeul, Tunisia), b) Sorghum plants at different growth stages irrigated with treated textile wastewater using micro- sprinklers

Integrated pilot plant for drainage canal water treatment and reuse

The MADFORWATER pilot plant P4, dedicated to drainage canal water (DCW) treatment and reuse, has been installed near Lake Manzala in Egypt, with a capacity of 250 m3/d (Figure 5). The pilot plant, consisting of a facultative lagoon and three types of constructed wetlands tested in parallel (Cascade Hybrid Constructed Wetland-CHCW, Sequent Hybrid Constructed Wetland-SHCW and Floating Bed Constructed Wetland- FBCW), was conducted for more than one year at two different retention times. The combination of lagooning and cascade hybrid constructed wetland led to the highest removal efficiencies, i.e. 70% for BOD, 66% for COD, 90% for TSS, 83% for total nitrogen, 81% for PO4, 1.9-log reduction for total coliforms and 2.2-log reduction for fecal coliforms, at 2.1-day retention time in the constructed wetland and 2-day retention time in the lagoon. The average effluent concentrations (39 mg/L for COD, 16 mg/L for BOD, 13 mg/L for TSS, 3 mg/L for total nitrogen, 1.1 mg/L for PO4, 220 MPN/100 mL for fecal coliforms) were compliant with the Egyptian standards for the irrigation of cereals and non-food crops, such as cotton.

Treated and semi-treated drainage canal water (sampled after the lagooning treatment and before the constructed wetlands) were reused for the irrigation of cotton plants, using gated pipes in a section of the pilot plant and traditional furrow irrigation in another section. In comparison to the surface irrigation system traditionally implemented in the Nile Delta, the calibrated nozzle gated pipe technology was tested. It allowed to save between 14 and 23% of irrigation water – depending on the type of water used – without any decrease in cotton yield. Irrigation with semi-treated drainage water led to the highest cotton yield, for both gated pipe and surface irrigation (1780 and 1690 Kg/ha, respectively). These experimental yields were significantly higher than the yields provided by the index mundi site, equal to 762 Kg/ha in Egypt for 2019. The water productivities obtained with both treated and semi-treated drainage water were quite high, without any significant difference between the two irrigation techniques.

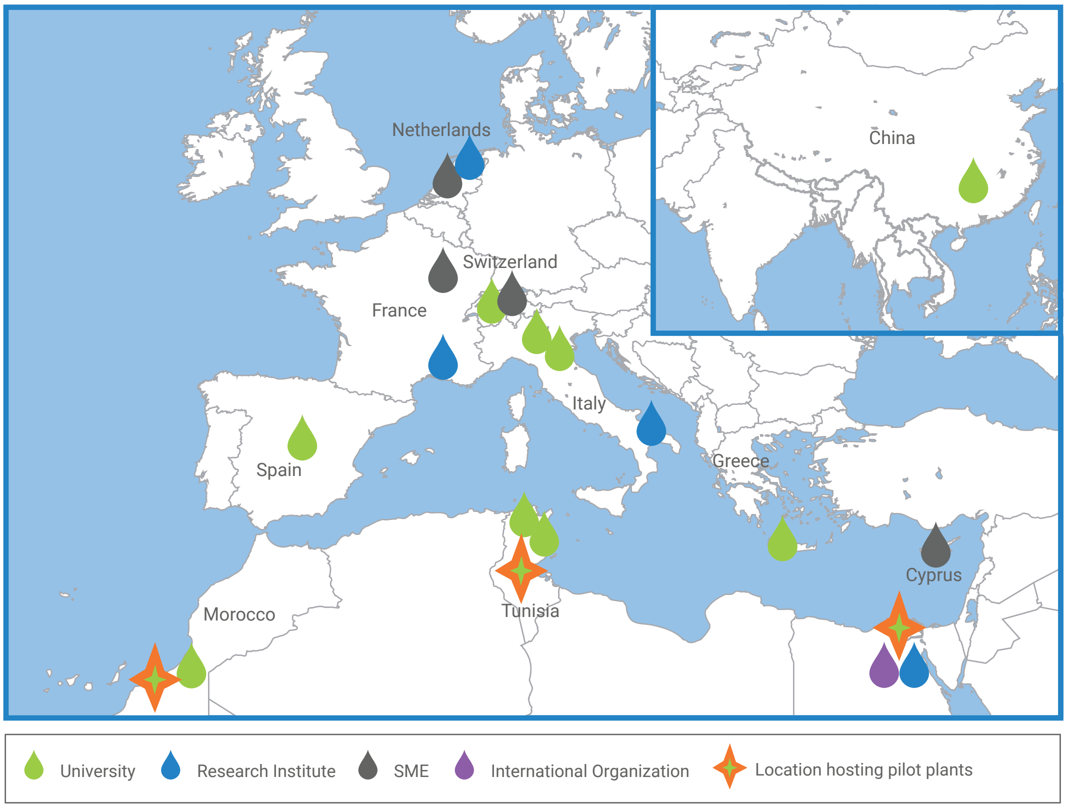
In conclusion, the combination of facultative lagoons and constructed wetlands showed a great potential for drainage canal water treatment in the Nile Delta. With careful design and planning, they can treat drainage canal water leading to the production of an irrigation-quality effluent, with an extremely low energy consumption and a null consumption of chemicals. Also the use of calibrated nozzle gated pipe systems could significantly reduce the amount of water supplied at field level, thus reducing the amount of drainage water, without reducing the crop yield. The large-scale implementation of these technologies in the Nile Delta could lead to a marked improvement of the quality of irrigation water, a significant saving in the consumption of freshwater derived from the Nile river and a relevant decrease in the pollutant load ultimately discharged into the Mediterranean sea.

Figure 5- a) Drainage canal water treatment process in Lake Manzala in Egypt,
b) Cotton plants irrigated with treated drainage canal water using gated pipes

The MADFORWATER consortium

The MADFORWATER consortium consists of 17 partners geographically distributed mainly around the Mediterranean Sea in 7 European countries, 3 MACs and China. It comprises 9 universities, 4 research centers, 1 international non-profit organization (FAO), 1 consultant and SME expert of marketing, business plan development and innovation management and 2 SMEs in the fields of WW treatment and irrigation.

The MADFORWATER partners have a multi-disciplinary expertise that includes wastewater treatment, irrigation, life cycle analysis of technologies, cost benefit analysis of technologies, water vulnerability analysis, stakeholder involvement, integrated water management, capacity building, business plan development.



For more info about the project visit the MADFORWATER website at: www.madforwater.eu

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 688320