MADFORWATER Newsletter | Issue n°3 | July 2019

MADFORWATER

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

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Dear Reader,

welcome to the third newsletter of MADFORWATER, an Horizon 2020 Research and Innovation Action project financed under topic WATER-5c-2015 "Development of water supply and sanitation technology, systems and tools, and/or methodologies" and coordinated by the University of Bologna (Italy). The general goal of MADFORWATER is 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 is focusing 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 is 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 reached its 36th month of activity. During the 3rd year of activity, the identification of the best-performing MADFORWATER technologies for wastewater treatment and irrigation was performed, and the four pilot plants dedicated to the scale-up and testing of these technologies in field conditions were designed and constructed. One of these plants is already in operation, whereas for the others the shipment and installation is in progress. These technological activities have been integrated by the development of water management models, that will be used for the development of water management strategies during the last year of activity.

In this newsletter you will find:
- a description of the four MADFORWATER pilot plants;
- the results of the analysis of water security in Egypt, Morocco and Tunisia, and of its impact on food security and socio-economic development.
- the illustration of the MADFORWATER model-based approach for the development of water & land management strategies in agriculture;

The next newsletter will be released in May 2020.

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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Scale-up and validation of the MADFORWATER technologies in four 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 – is 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 will be 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) in 2017 and 2018. Different wastewater types will be 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.

PILOT PLANT FOR THE TREATMENT AND REUSE OF MUNICIPAL WASTEWATER IN CHOTRANA, ARIANA, TUNISIA

Faced with increasing water scarcity, policy makers in Mediterranean African Countries (MACs) are increasingly interested in non-conventional water resources, such as treated municipal wastewaters. Despite their perceived advantages, few countries have succeeded in developing extensive, successful, and safe wastewater reuse in agriculture. Actually, a small amount of the treated wastewaters generated in MACs is currently reused. In the Tunisian case, only 23% of the treated wastewaters are recycled, while this amount is somewhat lower in Egyptian and Moroccan cases (18% and 10%, respectively). This is mainly due to the quality of treated wastewaters, that does not meet the limits imposed by the National and ISO standards for their reuse in irrigation. Indeed, municipal wastewater treatment in MACs is mainly limited to the secondary process, using mostly the conventional aerobic activated sludge process, while tertiary treatment is missing in most cases.

Figure 2. The Chotrana municipal wastewater treatment plant (Ariana, Tunisia): the site for the MADFORWATER municipal wastewater pilot plant

The wastewater treatment section of the municipal wastewater treatment pilot will be installed at the Chotrana wastewater treatment plant, in Ariana, Tunisia (Figure 2). The pilot plant, with a capacity of about 10 m3/d, consists of a train of multiple integrated treatment technologies, namely: (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 3). The installation and start-up of this pilot plant is currently in progress.

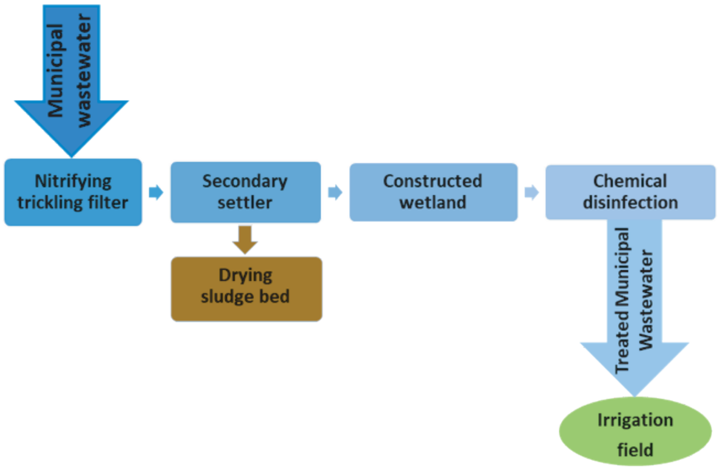


Figure 3. The municipal wastewater treatment process developed by MADFORWATER

The quality of the treated wastewater produced by the pilot plant will be compared with the Tunisian national permission limits (NT106.03) before it will be reused for the irrigation of selected cereals. The experimental field for the agricultural reuse of treated wastewater is located in the Institut Supérieur de Biotechnologie de Sidi Thabet, University of Manouba (ISBST-UMA), Sidi Thabet, Tunisia (Figure 4). The treated wastewater will be transferred from the Chotrana plant to the irrigation pilot on a regular basis. MADFORWATER partners made a relevant effort in order to improve irrigation efficiency and to develop irrigation technologies suitable for the use with treated wastewater. Several irrigation technologies will be tested in the Sidi Thabet pilot: an innovative calibrated nozzle; a model for irrigation scheduling that takes into account the specific characteristics of the treated wastewater; the supply of plant growth-promoting bacteria. The irrigation and crop growth performances obtained with treated municipal wastewater will be compared to the corresponding values obtained with freshwater.

Figure 4. Aerial photo of the site for irrigation with treated municipal wastewater (ISBST-UMA)

PILOT PLANT FOR THE TREATMENT AND REUSE OF TEXTILE WASTEWATER AT THE GWASH INDUSTRY (NABEUL, TUNISIA)

Figure 5. Gwash industry (Korba, Nabeul, Tunisia): the site for the pilot plant of textile wastewater treatment and reuse

The current situation of textile wastewater treatment in Mediterranean African Countries is quite diverse. In Tunisia, some textile companies have already integrated internal wastewater treatment processes into their process sequences, aiming to reach up to 60% reuse of the treated sewage into the production processes. The remaining treated wastewater is discharged into the municipal sewage network. Coagulation is a widely applied process as a pre-treatment prior to principal treatment by activated sludge, oxidation or membranes. Coagulation aims to remove colloidal particles and organic substances. The efficiency of the current processes is generally instable in relation to the important daily and seasonal variation of effluent flow rate and of organic and mineral load. An adequate process able to tolerate occasional peaks of effluent volume and organic load must be used. In some cases, textile effluents are discharged directly into the municipal sewage network without any pre-treatment.

The MADFORWATER pilot plant for the treatment and reuse of textile wastewater will be installed in the textile industry Gwash, located in the governorate of Korba (Nabeul, Tunisia) (Figure 5).

The wastewater treatment section of the pilot plant (10 m3/d) consists of the following treatment train: (i) a coagulation / flocculation pre-treatment unit, (ii) a primary clarifier, (iii) an aerobic Moving Bed Biological Reactor (MBBR), (iv) a secondary clarifier, (v) a filter followed by dye adsorption on resins to further remove the remaining color, and (vi) a drying bed for sludge dewatering (Figure 6). The installation and start-up of this pilot plant is currently in progress.

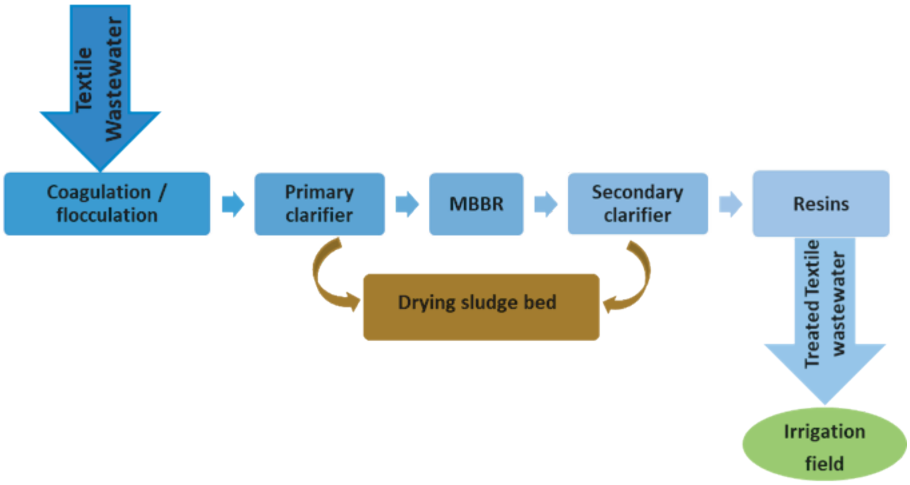


Figure 6. The textile wastewater treatment process developed by MADFORWATER

The quality of the treated textile wastewater will be compared with Tunisian national permission limits (NT106.03) before it will be reused as irrigation water to evaluate the growth and development of selected forage crops. Irrigation experiments will be conducted in an experimental field close to Gwash industry using an innovative calibrated nozzle developed by MADFORWATER partners. The irrigation and crop growth performances obtained with treated textile wastewater will be compared to the corresponding values obtained with freshwater.

PILOT PLANT FOR THE TREATMENT AND REUSE OF MUNICIPAL WASTEWATER IN AGADIR, MOROCCO

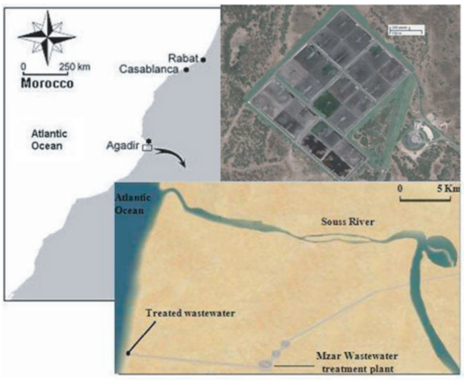


Figure 7. The M'zar municipal wastewater treatment plant (Agadir, Morocco): the site for the municipal wastewater pilot plant

In the Souss-Massa region in Morocco the pilot plant for municipal wastewater treatment and agricultural reuse will rely on an existing wastewater treatment plant within the station M'zar in Agadir, with a capacity of 75 000 m3/day. The plant is articulated on the following treatment sections: (i) a 150 000 m3 anaerobic lagoon; (ii) 64 sand filtration unit (Surface area of each filter is 5000 m2); (iii) an UV-based disinfection unit. This treatment scheme allows the production of a high-quality effluent, with a BOD equal to 17 mg/L, a total nitrogen concentration of 22 mg/L and an average level of fecal coliforms equal to 80 MPN/100 mL. An aerial view of the M'zar wastewater treatment plant is provided in Figure 7.

In the framework of MADFORWATER, the municipal wastewater treated by the Agadir plant will be used for the irrigation of a field of olive trees located at the Ocean Golf (Agadir, Morocco) (Figure 8).

In this pilot test, the crop growth and irrigation performances obtained with an innovative calibrated nozzle will be compared to the performances obtained with the traditional drip irrigation system largely used by Moroccan farmers.

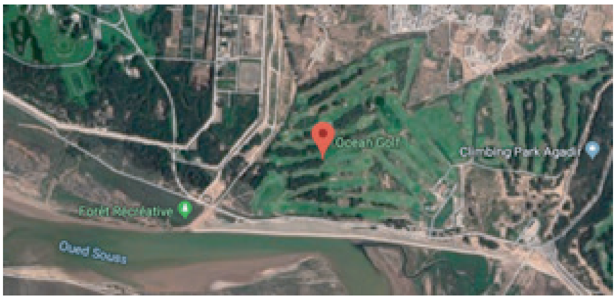


Figure 8. Aerial photo of the site for irrigation with treated municipal wastewater (Ocean Golf, Agadir, Morocco)

A PILOT PLANT FOR THE TREATMENT AND REUSE OF DRAINAGE CANAL WATER NEAR LAKE MANZALA (EGYPT)

In Egypt, agricultural drainage water is considered as a valuable water source that is collected and re-used for irrigation through a well-developed irrigation and drainage canal system. However, primary-treated and untreated municipal wastewater is discharged into the drainage canals, which in turn convey organic contaminants, nitrogen and pathogens to the main drains. No treatment is actually performed on drainage canal water before it is used for irrigation.

The MADFORWATER pilot plant for drainage canal water treatment has been installed in December 2018 in an experimental station operated by the National Water Research Center (NWRC) of Egypt near Lake Manzala, Egypt (Figure 9). The pilot plant, with a capacity of 250 m3/d, consists of the following components: (i) a 500 m3 lagooning / sedimentation pond and (ii) different types of Hybrid Constructed Wetlands (HCW). Three types of HCW are tested in parallel and compared: a Cascade Hybrid Constructed Wetland, a Sequenced Hybrid Constructed Wetland and Floating Bed Constructed Wetland. The first result indicate that the Cascade Hybrid Constructed Wetland is the most effective one. Indeed the combination of lagooning and Cascade Hybrid Constructed Wetland leads to a very high quality effluent, with effluent concentrations equal to 18 mg/L for BOD, 3 mg/L for ammoniacal nitrogen, 2 mg/L for phosphate and 460 MPN/100 mL for fecal coliforms. The HCW model may be applied on a wide scale to reduce pollution loads before entering Lake Manzala as a tool to protect the Mediterranean Sea. The treated water can be safely recycled for either cash crops cultivation and fish production.

Figure 9. Aerial photo of the site for the DCW pilot and treatment process developed by MADFORWATER project

In the framework of MADFORWATER, the treated effluent is reused to irrigate cotton and sugar beet crops in the NWRC experimental station at Lake Manzala, Egypt by means of an innovative gated pipe. The irrigation and crop growth performances obtained with treated drainage canal water will be compared to the corresponding values obtained with untreated drainage canal water.

CONCLUSION AND PERSPECTIVES

The MADFORWATER results allowed the development and the selection of wastewater treatment and irrigation technologies based on their high performances, reduced capital, operation and maintenance costs as well as social acceptance. The integration and extrapolation at field pilots of the successful technologies is essential to provide a good insight on their actual potential. In the next newsletter released on May 2020 you will receive more details about the reliability and validity of the innovative treatment trains and irrigation systems at field scale.

Effects of water stress on food security and socioeconomic development

A specific MADFORWATER activity was devoted to the analysis of the effects that water stress and vulnerability may have on food security and socioeconomic development in Morocco, Egypt and Tunisia. The analysis demonstrated that the activities developed in MADFORWATER could have a very positive impact on food security and socioeconomic development in the region through different channels:

- First, because improvements in the levels of irrigation efficiency and treated wastewater reuse are expected to lead to improvements in food security, partially offsetting the negative impact of climate change by 2050.
- Secondly, because one of the MADFORWATER objectives is to increase the level of treated wastewater reuse, with the improvements in the availability of water resources and a reduction of water stress levels in the targeted countries. The resulting socioeconomic growth in the region is expected to partially offset the projected negative effects of climate change on food security.

However, unless additional efforts are made to reduce food insecurity, the 2nd target of the Sustainable Development Goals (SDG 2) of ending world hunger by 2030 may not be met. Indeed, demographic pressures and an uncertain evolution of climate may put additional pressure on food security and limit access to water resources, endangering the achievement of the food security goals.

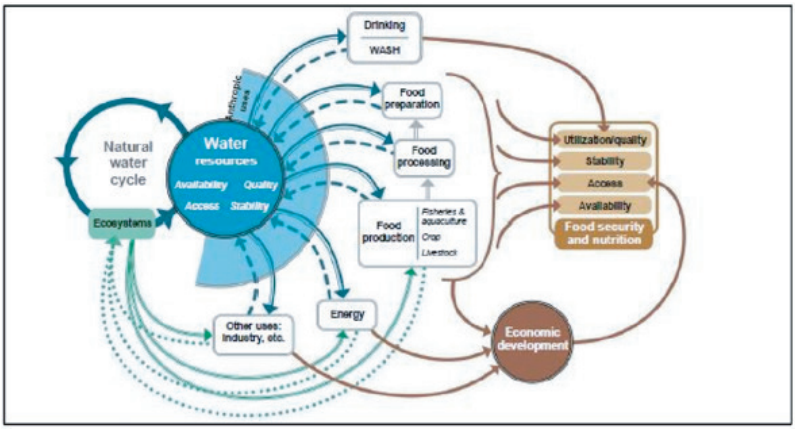
An empirical approach was employed in MADFORWATER, focusing on the four dimensions expected to impact differently on food security: resources (i.e. physical availability and endowment of water resources), access (i.e. disposability of the available resources for the population), capacity (i.e. intra-allocation of water resources depending mainly on education, health and affordability) and use (i.e. adequate management of water resources in the domestic, industrial and agricultural sectors of the economy). Additionally, an econometric modelling approach was implemented by means of panel data models including both country and year fixed effects for the period 2000-2015, and employing an extensive database covering up to 60 preliminary variables and 29 finally selected variables, for all countries in the Mediterranean.

The study positions Morocco as the country among the MADFORWATER target countries that shows the best evolution up to 2015 and the lowest levels of undernourishment, with data for the 2000-2015 period showing a salient progress on food security indicators. Besides policy efforts to improve agricultural competitiveness and rural development, positive trends in key aspects of water management and use may have underpinned food security improvements. In the case of Egypt, a significant decrease of undernourishment levels has been sustained by positive economic growth in the 2000-2015 period. While with respect of Tunisia, food security indicators show irregular trends along the considered period that may be explained by economic and political instability in recent years.

Food security levels in the Mediterranean seem to be influenced mainly by access to water resources by the population, the capacity to use those resources properly, and an adequate management and use of water resources. Particularly, access to at least basic drinking water resources by the population seems to be the most relevant dimension in ensuring food security. Capacity is found to be second in importance, with affordability and health being highly related to food security, and education found only of slight less importance.

Regarding socioeconomic development, the study found that higher levels of water availability as well as an improved allocation and capacity of the population to use those resources properly seem to have a positive influence on economic growth. In addition, water stress seems to be an important factor in explaining socioeconomic development.

Finally, the study found that climate change will lead to a worsening in the situation of food security in Mediterranean African countries by 2050. However, the effects of the likely improvements experienced in socioeconomic development during this period seem to be enough as to compensate the negative impacts of climate change.



The multidimensional relationship between water stress, food security and socioeconomic development.

An integrated agro-economic model for land and water use optimization

A specific MADFORWATER task was dedicated to the development and implementation of an integrated agro-economic model that can be used to optimize land and water use in agriculture.

Built and calibrated in the three case studies area of MADFORWATER - the irrigated farming system in the Kafr-El- Sheikh Region in Egypt, the citrus farming system in the Souss-Massa region in Morocco and the Nabeul Governorate in Tunisia - the developed decision support tool has been structured **to simulate treatment and irrigation technological solutions as well as related economic and regulatory instruments identified and tested in MADFORWATER**. Given the representativeness of the case studies and the generality of the model, the developed tool **can be up-scaled and replicated** in order to support the definition of **strategies and the identification of economic instruments for basin-scale water resource management in agriculture**.

Indeed, it can include different types of crops, intensification levels, use of fertilizers, chemicals, labor use, tillage operations, water delivery periods, as well as different types of water sources. Further, the possibility to input the data and to export the results through a data sheet **will make easier the use of the model** in other case studies and **by non-expert decision makers**.

The developed model allows to identify the optimal allocation of water of different qualities that can be made available to agriculture by treating a larger amount of wastewater. Ultimately, **the model is capable to assess the convenience to adopt in each specific context the wastewater treatment and irrigation technologies developed by MADFORWATER**.

The reuse of treated wastewater is expected to reduce the amount of freshwater consumed as well as fertilizer crop requirements, with a positive impact on the cost of cultivation. On the other side, the modernization of irrigation systems that in some cases can be associated with the reuse of treated wastewater can affect the irrigation system performance in terms of efficiency, uniformity and/or adequacy. The impact of the adoption of innovative treatment and irrigation technologies as well as of water policies and economic instruments is analysed, by assessing their impact on the most relevant parameters:

- Land use, cropping pattern, crop production
- Water use: consumption from different sources, water productivity, water marginal value, water price
- Fertilizer use
- Drained water
- System performance index, defined as the ratio between water supplied and water demand
- Socio-economic variables: farm income, labor use, public subsidies for innovation.

In the first step of model application, for each case studies area of MADFORWATER, the set of model parameters associated to an optimized cropping pattern as close as possible to the current one has been identified. As an example, some representative model parameters relative to the current situation are reported below for the three study areas.

Tunisian case study (Nabeul Governorate): water use in the current scenario in three representative farms

Farm	Water cost (€/ha) (% income)	Water productivity (€/m3)	Water marginal value (€/m3)	Water Price (€/m3)
1	224.1 (10.3%)	0.43	0.11	0.04
2	306.9 (7.6%)	0.55	0	0.04
3	100.5 (3.7%)	0.70	0	0.02

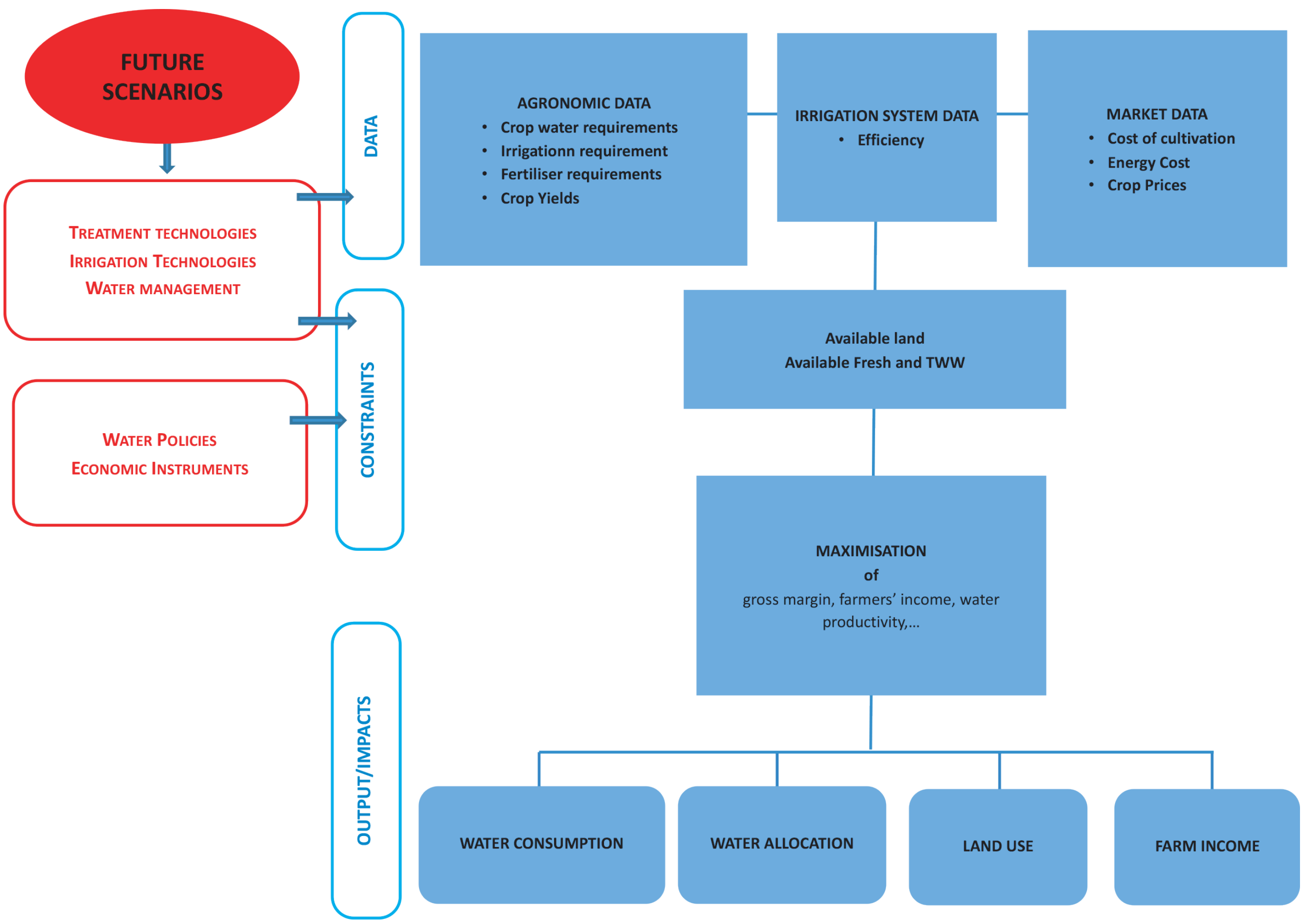
Egyptian case study (irrigated farming system in the Kafr-El- Sheikh Region): drained and used water in the current scenario

Water used (m^3)		Drained Water (m3)	
Total	4 226 196	Total	90 509
Per ha	22 851	Per ha	4 892

Moroccan case study (citrus farming system in the Souss-Massa region): fertilizer use in the current scenario

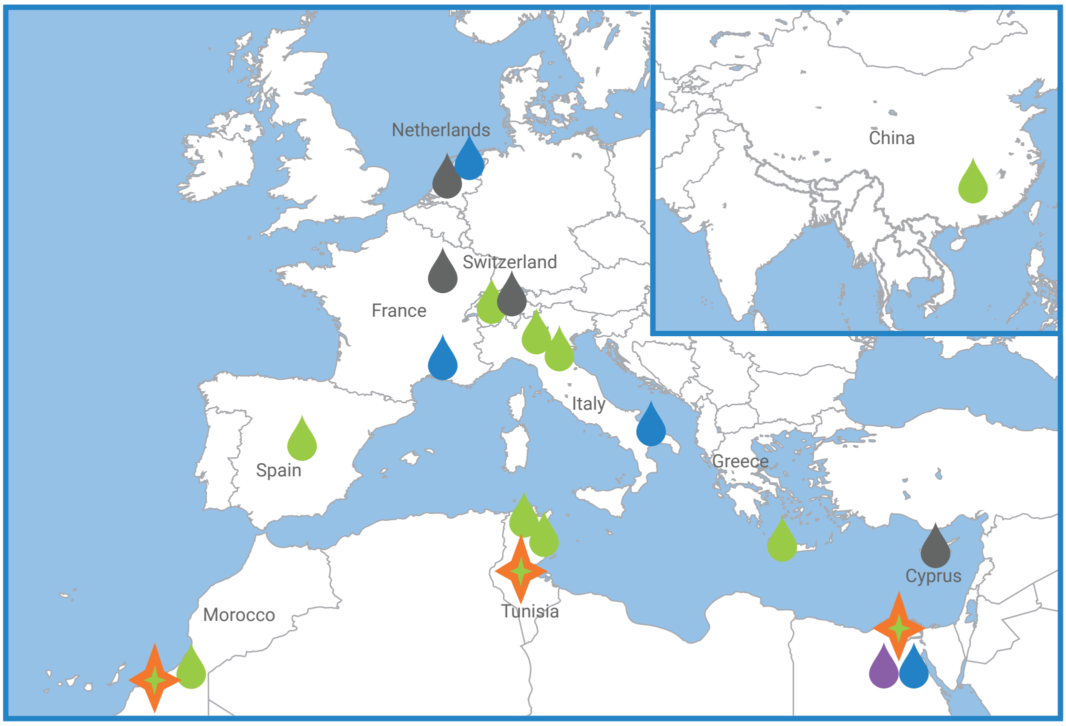
Fertilizers used	
Nitrogen (Kg)	6 057 836
Nitrogen (Kg/ha)	188
Phosphorus (kg)	2 064 593
Phosphorus (kg/ha)	64

In the second step of model application, that will be implemented during the last year of MADFORWATER, **the current values of the relevant parameters will be compared to the corresponding values relative to several future scenarios**, characterized by the inclusion in the model of several factors, such as a higher availability of treated wastewater, more efficient irrigation technologies, different cropping patterns or economic instruments. Thus, the upgraded version of the model will allow to evaluate the impact of the different policies and strategies aimed at enhancing the reuse of treated wastewater in agriculture **in the framework of broader water and land management strategies** that countries could implement to ensure the long-term sustainability of the water resource.



The MADFORWATER consortium

The MADFORWATER consortium consists of 18 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 3 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.



University | Research Institute | SME | International Organization | Location hosting pilot plants

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