MADFORWATER

Contract no. **688320**

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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Introduction

It was found that in the Middle East and North Africa (MENA) region from climate-related water scarcity, greatest economic losses can be expected (World Bank 2018 in World Resources Institute 2019). Yet, here are unused opportunities to boost water security in MENA. Large amounts (about 82%) of the region's wastewater is not reclaimed; meaning using this resource would produce a new and clean water resource (World Resources Institute, 2019).

The scope of the MADFORWATER project is to develop integrated technological and management solutions to boost wastewater treatment and an efficient reuse of treated wastewater for irrigation in selected hydrological basins in Egypt, Morocco and Tunisia.

In this deliverable 6.1 integrated water & land management strategies and policy recommendations were established. This was carried out in two main approaches: i) the integration and assessment of water & land management strategies, ii) policy recommendations to promote the adoption of the proposed technologies and integrated waster & land management strategies in the target countries.

Approach

First an integration and assessment of water & land management strategies was carried out. Therefore, the different strategies were integrated based on economic, technical and stakeholder inputs. The strategies were assessed on their suitability for the different countries by experts. Additionally, a political, economic, social, water management, legal and environmental (PESTLE) assessment was carried out to investigate a more holistic influence of a strategy. On this basis a catalogue of instruments for policy recommendations was derived to facilitate implementation for integrated water & land management strategies. This catalogue of instruments includes potential barriers and the corresponding strategies to overcome the barriers. The suitability of overcoming specific barriers by the strategies was refined with stakeholder and expert interviews.

Second policy recommendations to promote the adoption of the proposed technologies and integrated waster & land management strategies in the target countries were identified. The situation in the target countries was analyzed by means of an agro-economic model. Then a Multicriteria Analysis was carried out. This led to identify barriers and opportunities. On this basis policy recommendations and conclusions were identified for each target country individually.

Results

Results of the integration and assessment of water and land management strategies

The results include for the integration and assessment of water & land management strategies 13 different strategies. Table 1 provides an overview of all proposed strategies with the corresponding technology description and associated costs.

Table 1: Overview of resulting top-ranked options from the DST application, the MADFORWATER pilots in Egypt, Morocco and Tunisia, and the agro-economic model

Egypt	***Morocco***	***Tunisia***
DST-based results	*DST-based results*	*DST-based results*
EG1: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops **Technology suggested:** No treatment necessary **Treatment costs:** No additional costs	**MO1**: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops **Technology suggested:** No treatment necessary **Treatment costs:** No additional costs	**TU1**: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops **Technology suggested:** No treatment necessary **Treatment costs:** No additional costs
EG2: Reuse of typical municipal wastewater for agriculture purposes in desert areas **Technology suggested:** Lagooning: Australia I[1] **Treatment costs:** 0.35 EUR/m^3	**MO2**: Reuse of typical municipal wastewater for irrigation of crops to be eaten raw. **Technology suggested:** Wetlands: Nicaragua[4] **Treatment costs:** 0.14 EUR/m^3	**TU2**: Reuse of municipal WWTP typical secondary effluent for irrigation (NT 106.03 standard) **Technology suggested:** Wetlands: Nicaragua[4] **Treatment costs:** 0.13 EUR/m^3
Pilot-based result	*Pilot-based result*	*Pilot-based result*
EG3: Reuse of Drainage Canal Water for irrigation **Technology suggested:** MADFORWATER Pilot (Lake Manzala, Egypt)[2] **Treatment costs:** 0.38 EUR/m^3	**MO3:** Reuse of municipal WWTP tertiary effluent for olive trees irrigation **Technology suggested:** MADFORWATER Pilot (Agadir, Morocco)[3] **Treatment costs:** 0.27 EUR/m^3	**TU3:** Reuse of municipal WWTP secondary effluent for irrigation of cereals **Technology suggested:** MADFORWATER Pilot (Chotrana, Tunisia)[5] **Treatment costs:** 0.45 EUR/m^3 **TU4:** Reuse of textile WW for non-food crops irrigation **Technology suggested:** MADFORWATER Pilot (Gwash, Tunisia)[6]

[1] See section 2.2.2 on page 29 for the technology description.
[2] This technology consists of the following components: (i) a 500 m^3 lagooning / sedimentation pond and (ii) different types of Hybrid Constructed Wetlands (e.g. Cascade Hybrid Constructed Wetland)
[3] The following technology is applied in the MADFORWATER pilot plant in Morocco: (i) a 150 000 m^3 anaerobic lagoon; (ii) 64 sand filtration unit; (iii) an UV-based disinfection unit. The treated municipal wastewater will be used for the irrigation of a field of olive trees. 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.
[4] See section 2.2.3 on page 31 for the technology description.
[5] The municipal wastewater (MWW) treatment process 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.
[6] The textile wastewater (TWW) treatment process developed applied in a pilot plant consists of the following treatment trains: (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 colour, and (vi) a drying bed for sludge dewatering.

Agro-economic model result **EG4:** Water (re)use in the technology scenario (agro-economic model) **Technology suggested:** Use of WW for irrigation with innovative gated pipes and calibrated nozzles	*Agro-economic model result* **MO4:** Water (re)use in the policy scenario (agro-economic model) **Technology suggested:** Use of WW for irrigation with innovative calibrated nozzles	**Treatment costs:** 0.64 EUR/m^3 *Agro-economic model result* **TU5:** Water (re)use in the policy scenario 1 (agro-economic model) **Technology suggested:** Use of WW for irrigation with innovative calibrated nozzles

Results of the policy recommendations to promote the adoption of the proposed technologies and integrated waster & land management strategies

The results presented in this deliverable in relation to policy recommendations to promote the adoption of the proposed technologies and integrated waster & land management strategies derive both from the agro-economic model and from the Multicriteria Analysis . Multicriteria mapping (MCM) (Stirling, 2006) is a type of Multicriteria Analysis (MCA) used to evaluate various possible solutions to a given problem, taking into account different categories of criteria (economic, social, environmental, technical and policy) by interviewing key stakeholders and evaluate the criteria individually for each solution (Bellamy *et al.*, 2013)

The policy recommendations derived from the application of the agro-economic model have been developed for all the three target countries. For Egypt, it is important to stress that, since different and conflicting objectives can be achieved, it is crucial to define the priorities among the different objectives – reduction of water demand, reduction of the reused drainage water, economic performance of the farmers and their level of satisfaction – in order to design the most effective water policies in this area. For Morocco it can be concluded that treated wastewater (TWW) reuse promotion requires to overcome the lack of social acceptance, due to inadequate information on benefits, incomplete economic analysis of TWW reuse options, misalignment between water prices and water scarcity and lack of economic incentives for re-use. Additionally, it was shown that farmers' advantage of saving fertilizer costs could be significant, but farmers should be able to assess these potential savings and to adopt optimal nutrient management strategies. However, with the current prices of 0.15 Euro/m3 and 0.23 Euro/m3 for fresh and TWW respectively, this positive effect is not sufficient to make TWW reuse an attractive option, thus confirming the low demand for treated waste water reported in the literature. For Tunisia, based on the results of the model-based simulations, it can be underlined that the implementation of the MADFORWATER technologies has a positive effect on farmer income. Additionally, the implementation of MADFORWATER technologies as well as economic instruments is likely to promote the increase in the area of productive and profitable crops such as strawberry, tomato, and citrus. However, it must be taken into account that, according to the fieldwork interviews, farmers are reluctant to accept this type of water and therefore the degree of acceptability for the adoption of the MADFORWATER technologies will need to be further considered.

The policy recommendations derived from the application of the Multicriteria Analysis in Tunisia include the ranking of the selected defined options and criteria related tosocial, economic, technical, environmental, policy aspects . It includes the results for each of the

stakeholder groups considered in this study, namely: 1) farmers, 2) policy makers, 3) water managers, 4) researchers and 5) ecologists. The Analysis has shown that in general, the order of importance of the criteria is: economic, social, environmental, policy, and technological. Efforts should be concentrated on those groups of criteria that are the most important, especially economic, and social criteria. Results of the barriers and opportunities for the integrated water & land management strategies and policy recommendations

Table 2 shows the barriers and opportunities detected from the perspective of reclaimed water production and reuse. For the reclaimed water production perspective, barriers were identified based on the PESTLE investigation and on the interviews made with stakeholders and experts. For the reclaimed water use perspective, barriers were identified based on the Multicriteria Analysis. The two perspectives have been developed independently, consequently the result differs slightly.

Table 2: Results of barriers and opportunities for the reclaimed water production and use perspectives.

Reclaimed water production perspective	Reclaimed water use perspective	
Barriers	Barriers	Opportunities
• Cheap available fresh water and missing subsidies especially at the beginning of a new technology • Lack of awareness and knowledge such as capacity building, training of to the users of reclaimed water, water quality monitoring and reporting • Legislation and enforcement on wastewater reuse and facilitation of institutional coordination • Lack of treatment facilities	• Water scarcity • Salinity of groundwater • Farmers are generally reluctant to accept treated water although it is cheaper than conventional water. • WW can only be used for fodder or permanent crop irrigation. • High cost of investment for TWW plants and irrigation technologies • Access to capital and loans appear to be difficult. • Unfavorable labor conditions in the area. • High cost of production of TWW. •	• The reuse of treated wastewater is expected to change the amount of fresh water consumed and therefore it will be an opportunity for protecting freshwater resources. • On the other side, the modernization of irrigation systems associated with the reuse of treated wastewater is an opportunity to improve the irrigation system performance in terms of efficiency, uniformity and/or adequacy. • The use of TWW can be an opportunity for increasing cropping intensity. • Existing laws for regulating the use of TWW in agriculture offer a solid base for the development of this type of water source and face the related risks. • Existing water infrastructures allow the use of water distributions systems for TWW.

Conclusions for Integrated water & land management strategies and policy recommendations

This research has shown that options are available for water reclamation, but the concept is not widely implemented in Egypt, Morocco and Tunisia. With the results of this deliverable, key barriers and drivers were identified to facilitate the implementation of water reclamation for irrigation. In particular, the considered countries show different characteristics regarding efficient water management, water pricing, subsidies and wastewater tariffs, implementation of monitoring and reporting systems or legal aspects. These were related to the use of reclaimed water for food crop irrigation. The main concerns of the experts are the high costs of the proposed technologies, quality and health concerns (missing disinfection step), training of the water users and social acceptance of the reuse of treated wastewater.

Recommendations for Integrated water & land management strategies and policy recommendations

To increase water security, and consequently economic security in all three target countries, both IWLMS and policy recommendations are needed. This means from the perspective of the MADFORWATER project, that investing in water management strategies can possibly increase water security by supporting water supply continuity by means of providing reclaimed water to the end water users (e.g. farmers). Therefore, water management actions are primarily recommended (e.g. capacity building and technological scale up). To successfully implement the water management actions, they should be accompanied by economic instruments (e.g. subsidies or/and other financial assistances). Congruently, to ensure the quality of the reclaimed water, additional environmental and legal actions are required (e.g. monitoring of water quality). These actions can only be implemented with increased social acceptance of reclaimed water use. This can be achieved by employing social instruments (e.g. building trust among farmers).

Besides the treatment of waste water, the reduction of water demand and the steady level of satisfaction of farmers should be targeted. This can be achieved by introducing new irrigation technologies (e.g. calibrated nozzles or gated pipes). Economic analysis to formulate policy recommendations has shown that the joint introduction of technological innovations and of a new policy of water supply could achieve the objective to reduce the amount of freshwater used by agriculture without affecting the level of satisfaction of farmers. In particular, the following recommendations are considered as priorities.

In terms of economic instruments, our analysis suggests introducing in all the three target countries water tariffs aimed at promoting the reuse of TWW, as well as subsidies or loans to promote the implementation of innovative WW treatment or irrigation technologies. In particular, Egypt, Tunisia and Morocco have shown country specific differentiations as follows. In Egypt financial assistance especially at the beginning of a new technology can support the farmers income, as this could decreases due to the investment and O&M costs of the gated pipe technology. In Tunisia current subsidies for wastewater have proven to be a successful instrument to encourage the use of treated wastewater for agricultural production. Alongside it has shown that the farmers' willingness to pay for an extra unit of water is higher than the actual price currently paid in the region. In Morocco subsidies are needed to enhance the use of TWW through the water pricing policy as well as through the innovation policy.

In terms of water management instruments, our analysis suggests facilitating in all the three target countries institutional coordination, regional planning and training, capacity building and technological scale up. In particular, in Egypt, Tunisia and Morocco have shown country specific differentiations as follows. In Egypt the introduction of the gated pipe contributes to reduce the quality deterioration of the water available for irrigation practices. In Tunisia training is especially important for farmers and the agency to improve the irrigation capacity. In Morocco the use of TWW allows the conservation of relevant amounts of fresh water and helps to save important amounts of fertilizing elements which results in lower production costs for farmers.

In terms of environmental and legal instruments, our analysis suggests facilitating the monitoring and regularly reporting of water quality and increase of legal enforcement and/or the adoption of new water quality regulations. In particular, Egypt, Tunisia and Morocco have shown country specific differentiations as follows. In Egypt there is more monitoring needed, since for the poor farmers monitoring does not matter, however big farms monitor for their exports. In Tunisia there is need to increase the water quality. Legal instruments are also an important issue, because currently the legislation forbids to use for all crops. In Morocco the monitoring is obligatory for treated wastewater at the WWT and end-users. The frequency in the monitoring plan for each parameter is required. The legal enforcement is a major issue. The problem is on how to enforce the law. The Moroccan would need to start to give penalties. A big problem is Moroccan have the law but do not re-enforce it.

In terms of social instruments, our analysis suggests facilitating the acceptance of reclaimed water. In particular, Egypt, Tunisia and Morocco have shown country specific differentiations as follows. In Egypt there is need to build trust among farmers with advanced water treatment in pilot plants and water quality monitoring. In Tunisia there is need to build trust among farmers with tertiary water treatment in pilot plants and water quality monitoring. Congruently, to build trust there is need to ensure the water quality with for instance a contract with three parties: farmers, producers of reclaimed water and government. In Morocco there is need to build trust among farmers with advanced water treatment in pilot plants and water quality monitoring. Congruently, the water quality needs to be ensured in order to maintain trust.

1 Introduction

1.1 Context: Target Countries and Basins

The Middle East and North Africa region is a global hotspot of unsustainable water use. This is underpinned by high baseline water stress, mostly driven by increasing human water use for agriculture and the expansion of irrigated areas (Figure 1)[7]. The situation is exacerbated by the high levels of year-to-year hydrological variability – and hence uncertainty, which in turn is leading to increased water stress in these countries. Regions with high water stress are also prone to droughts and floods, contributing to uncertainty regarding crop yields. This can put pressure on food security, primarily in North African countries whose economies are heavily dependent on agriculture.

Furthermore, the focus of water management and planning has been on blue water (liquid water in surface and groundwater systems), although it represents only around one-third of the world's available freshwater resources. Consequently, groundwater levels will decline, abstraction becomes more energy intensive, leading to higher water stress in the MENA region in the future (Figure 2). Declining groundwater can cause saltwater to intrude inland or upward into an aquifer resulting in increased salinity levels which may render the water unsuitable for human consumption. Additionally, the ongoing surface water overabstraction results in higher concentrations of pollutants in receiving bodies, hence contributing to decreasing water quality in the MENA region (World Resources Institute, 2019). Subsequently there is need for a combination of technologies and strategies that can foster the implementation of most adapted technologies and solutions. A main incentive for water reclamation[8] is the use of treated wastewater as a water resource for beneficial purposes because it can partly substitute the abstraction of fresh surface or groundwater. A sub-incentive is that contaminated wastewater is not discharged to receiving environments, thus reducing pollution of water bodies.

According to the World Resources Institute *"twelve out of the 17 most water-stressed countries are in the Middle East and North Africa (MENA). The region is hot and dry, so water supply is low to begin with, but growing demands have pushed the different countries further into extreme stress. Climate change is set to complicate matters further* (World Resources Institute, 2019). *The World Bank found that this region has the greatest expected economic losses from climate-related water scarcity, which are estimated at 6-14% of GDP by 2050 (World Bank 2018 in World Resources Institute 2019). Yet there are untapped opportunities to boost water security in MENA. About 82% of the region's wastewater is not reused; harnessing this resource would generate a new source of clean water* (World Resources Institute, 2019)*".*

[7] Water stress in the upper Nile region appears low because this calculation does not take into account seasonal variability or upstream developments that may cause water shortages. (World Bank 2018).

[8] Water or wastewater reclamation is the process of treating wastewater to turn it into water that can be used for beneficial purposes. Water reuse refers to the beneficial use of reclaimed water (the 'fit-for-purpose' concept)(WWDAP (United Nations World Water Assessment Programme), 2017).

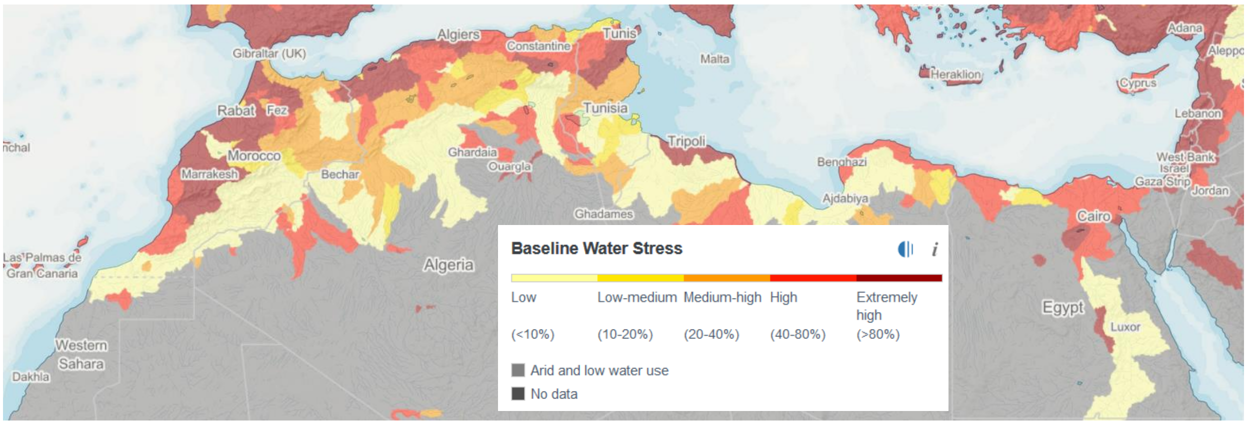


Figure 1: Baseline Water Stress. Baseline water stress measures the ratio of total water withdrawals to available renewable surface and groundwater supplies. Water withdrawals include domestic, industrial, irrigation, and livestock consumptive and non-consumptive uses. Available renewable water supplies include the impact of upstream consumptive water users and large dams on downstream water availability. Higher values indicate more competition among users (World Resources Institute, 2019)**.**

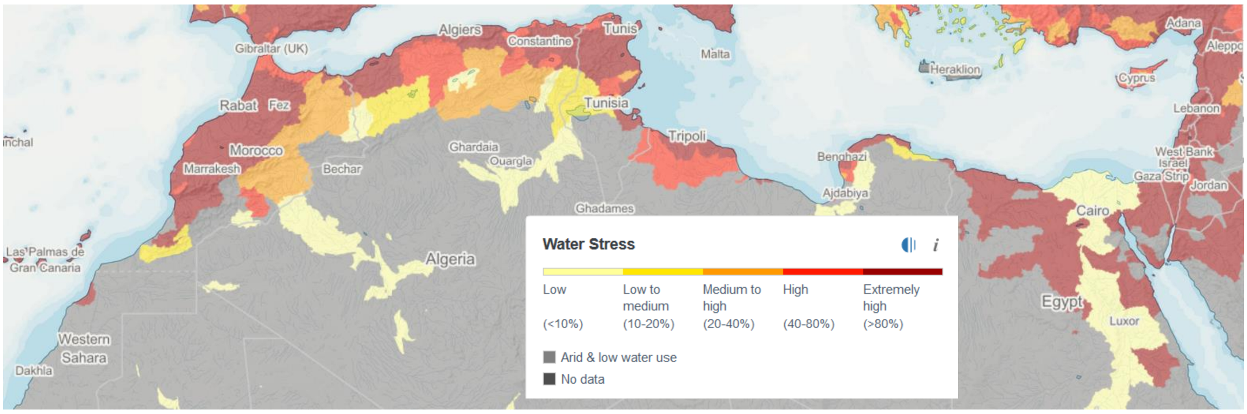


Figure 2: Water Stress in 2040 under business as usual scenario (World Resources Institute, 2019)**.**

1.1.1 Morocco

Although Morocco is far from the 'extremely high' ratio of water withdrawal to supply, as it is the case in many Middle Eastern countries, the kingdom is still among the 45 countries facing water scarcity. It is confronted with dwindling groundwater reserves and a strong dependence on rain-fed agriculture. Cultivable land is compromised, because of water shortages and soil erosion (Espace Associatif, 2012; Morocco World News, 2017; USAID, 2017). To overcome this problem, several laws and regulations were adapted to improve the availability and quality of water resources (Choukr-allah *et al.*, 2017).

1.1.2 Tunisia

In Tunisia, water resources are characterized by scarcity and pronounced seasonal and yearly variations. Furthermore, the country is subject to periodic droughts of various lengths. The most common drought years have rainfall deficits ranging from 30% to 50%. Over the last decade, Tunisia has achieved considerable success in expanding access to both water and sanitation services, but challenges remain (Ameur, 2007; World Bank, 2014).

1.1.3 Egypt

Egypt has been suffering from severe water scarcity in recent years. Renewable freshwater resources include only 20 cubic meters per person per year. As a result, the country relies heavily on the Nile River for its main source of water. Egypt is already below the United

Nations' water poverty threshold, and by 2025 the UN predicts, it will be approaching a state of "absolute water crisis". (Eco Mena, 2017; The Guardian, 2015).

1.2 Scope, aim and objectives of this deliverable

The scope of the MADFORWATER project is to develop integrated technological and management solutions to boost wastewater treatment and an efficient reuse of treated wastewater for irrigation in selected hydrological basins in Egypt, Morocco and Tunisia.

The present report is a continuation of the previous research in the MADFORWATER project. The previous research work was in Work Package (WP) 5, entitled: "Strategies and economic instruments for basin-scale water resources management''. It intended to develop strategies for wastewater management, water reuse and water & land management in agriculture, tailored to the three studied basins. This includes the task 5.1: "Review and assessment of the use of economic instruments and policies in water management in Egypt, Morocco and Tunisia"; the task 5.2: "Strategies and economic instruments for WW management" and the task 5.3: "Strategies and economic instruments for water reuse and water & land management in agriculture".

The aim of the present report is to integrate the outcome strategies of the two different decision support tools (DSTs) (Oertlé, Dietziker, *et al.*, 2020) to establish integrated water and land management strategies (IWLMS) and policy recommendations. The developed IWLMS were investigated based on different objectives, in order to:

1) Integrate and assess water and land management strategies (task 6.1); the integration has been made on three different levels:
    a. Combination of supply-based and demand-based strategies into a joint assessment framework;
    b. Consideration of a multi-level assessment beyond technical considerations, including an adapted PESTLE framework that considers policies, economic, social, technical, legal, and environmental dimensions;
    c. Conduction of surveys with local stakeholders to integrate research-based findings with local acceptance and expertise.
2) Develop policy recommendations to promote the adaption of the proposed technologies and integrated water and land management strategies in the target countries (task 6.2).

This deliverable is organized as follows (Figure 3):

Chapter 2 is devoted to the integration and assessment of water and land management strategies with the emphasis on a set of 13 strategies defined in D 5.2 that have been developed with the DST for wastewater management and water & land management in agriculture (partly published in Oertlé, Mueller, *et al.*, 2020).

Chapter 3 is devoted to policy recommendations to promote the adaption of the proposed agro-economic technologies and integrated water and land management strategies in the target countries. This deliverable provides a stakeholder assessment in addition to the work already presented in D 5.2 (Varela-Ortega et al., 2020b).

Chapter 4 is devoted to conclusions for integrated water & land management strategies and policy recommendations.

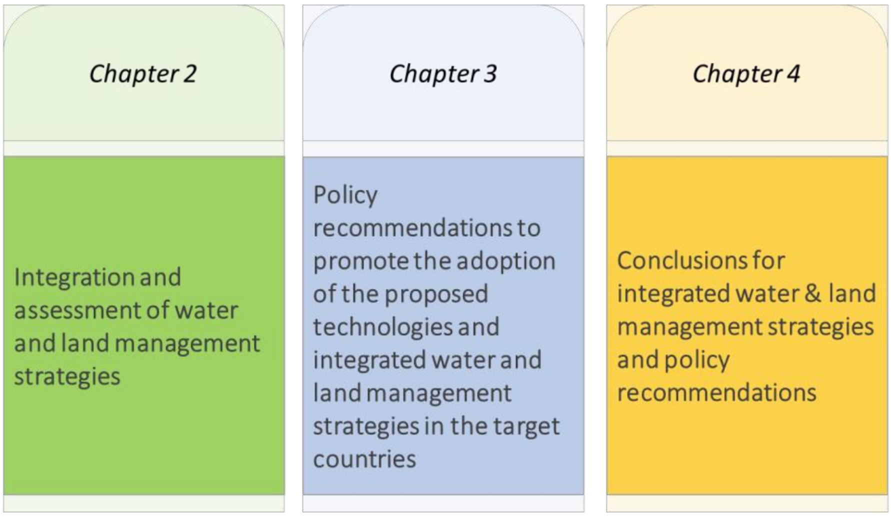


Figure 3: Architecture of the proposed framework for the development and assessment of integrated water and land management strategies.

1.3 Definitions

Vision, objective: Promote and facilitate water reclamation and efficient irrigation practices.

Scenario: A description of how demographic, socio-economic and environmental pathways might develop in the future (adapted from Oxford Dictionary 2020b).

Strategy: Plan of actions driven by technological, agro-economic, and modelling solutions to achieve integrated water & land management (adapted from Oxford Dictionary 2020c).

Integrated water & land management strategies (IWLMSs): A strategy (Plan of actions driven by technological, agro-economic, and modelling solutions) that includes both water management and land management, i.e. irrigation management to achieve integrated water & land management (adapted from Oxford Dictionary 2020c).

Actions and measures: Actions and measures to increase the feasibility of water reclamation and efficient irrigation practices regarding Political, Economic, Social, Technological, Legal, Environmental aspects (PESTLE).

For example: policy recommendation (P), water pricing policy (P, E), economic instruments (Ec), capacity building and awareness raising (S), MADFORWARER technology implementation (T), water quality standards and enforcement (L), fertilizer substitution and land use (En).

Policy: A plan of action agreed or chosen by a political party, a business, etc. (adapted from Oxford Dictionary, 2020b)

Instrument A specific strategy or policy that is used by an actor in order to achieve integrated water & land management (adapted from Oxford Dictionary, 2020a)

2 Integration and assessment of water and land management strategies (Task 6.1)

2.1 Scope, aim and objectives of integration and assessment of water and land management strategies

The wastewater (WW) management strategies and the agricultural water & land use strategies have been developed and then explained and discussed in D5.2 (Figure 4) (partly published in Oertlé, Mueller, *et al.*, 2020). In this task different modelling approaches were used to produce different decision support tools (DSTs) (Varela-Ortega *et al.*, 2020b). They include (i) the decision support tool (DST) as an early stage assessment of treated wastewater developed; and (ii) an agro-economic model to assess irrigation potential in agriculture.

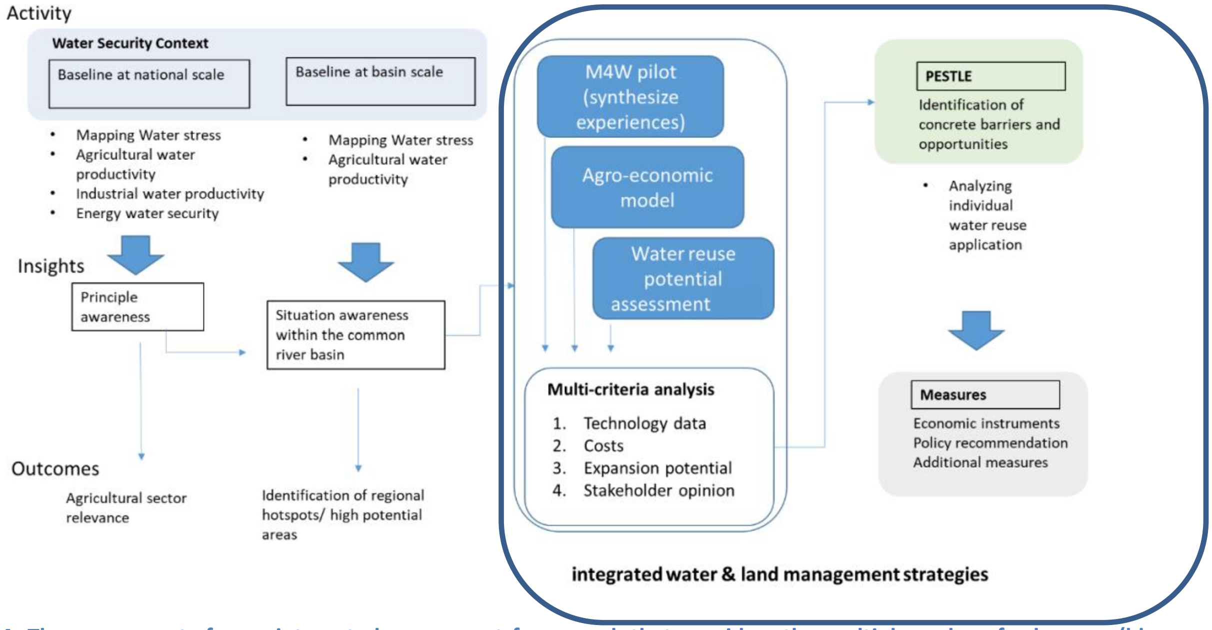


Figure 4: The components for an integrated assessment framework that considers the multiple scales of relevance (blue rectangle) from MADFORWATER pilots, agro-economic model, and water reuse potential assessment (DST-based results), multi-criteria analysis, PESTLE, and subsequent measures.

The aim of this task is to integrate the outcome strategies of the two different DSTs to establish integrated water and land management strategies (IWLMS) and policy recommendations. The developed IWLMS were investigated based on different objectives to:

1) describe the different strategies for each country with key facts that allow a comparison
2) evaluate the strategies during a workshop with different stakeholders to receive feedback from different experts on the technical and social suitability in relation to the local context
3) evaluate the strategies during interviews with different local stakeholders to receive feedback from different local experts on the technical and social suitability in relation to the local context
4) compare and evaluate the capacity of each proposed IWLMS to improve the adaptive capacity of local stakeholders to deal with PESTLE that includes the water security context. The water security includes the resource reliability, water stress and storage drought duration length index

5) develop and refine a catalogue of the economic instruments proposed for the supply and demand side and other locally relevant measures to foster the implementation of the strategies

This task is organized as follows (Figure 5): Sub-Chapter 2.2 includes the description of integrated water and land management strategies (IWLMS) for the three selected basins. The description consists of four objectives, namely A) explanation of the technology assessed for the specific strategy such as water quality and quantity that can potentially be treated, B) stating the calculated production and distribution costs for water treatment, C) provision of a wastewater treatment expansion potential of the proposed strategy, and D) in the case of the MAFORWATER pilot plants, the presentation of the results of the stakeholder opinions.

Sub-Chapter 2.3 is devoted to the comparative evaluation of sustainable water and land management strategies in agriculture for the three selected basins. The proposed strategies consider the multifaceted perspective of the water and agricultural sectors including technological, economic, social, environmental, institutional, and governance aspects. Additionally, they include the increased amount of water from improved water reuse and the implementation of efficient irrigation technologies. In this chapter, the developed IWLMS were analysed based on a survey in the last workshop with different stakeholders. In each case an analysis of the technological and economic perspective was carried out. Additionally, the national-level conditions for water reuse have been assessed with a multi-criteria decision analysis (MCA) to identify drivers and barriers. This MCA consists of six thematic subjects, namely policy and institution, economy, society, water management, legislation, and environment.

In Sub-Chapter 2.4, a catalogue of instruments for policy recommendations has been developed and refined.

In Sub-Chapter 2.5, conclusions and recommendations are presented. This includes the proposed instruments ranging from economic to social and environmental aspects.

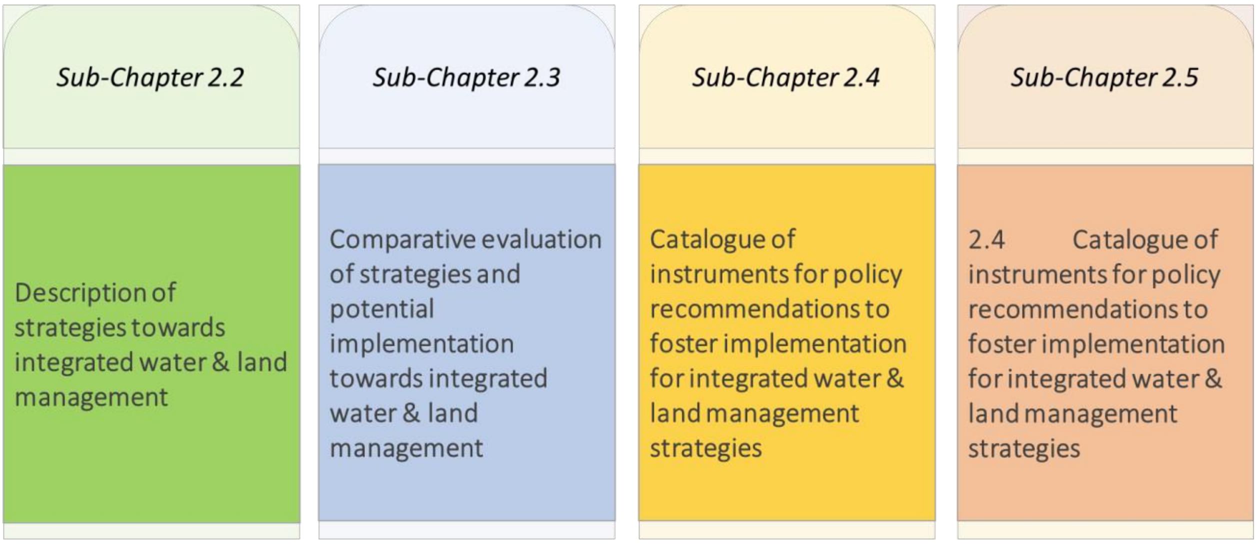


Figure 5: Architecture of the proposed task for the development and assessment of integrated water and land management strategies.

2.2 Description of strategies towards integrated water & land management – factsheets (with multi criteria analysis) and PESTLE assessment

2.2.1 Overview of combination into integrated water & land management strategies

In Table 3, an overview of the different MADFORWATER project's strategies is provided. They include a continuing number code divided by the countries. The strategies build on different elements, which include a general description, then technological data, costs, expansion potential, and, if data available, stakeholder opinion.

Table 3: Overview of the different case studies in the MADFORWATER project.

Country	*DST-based results*		*Pilot-based result*		*Agro-economic model result*
Egypt	**Strategy EG1:** Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops in Egypt	**Strategy EG2:** Reuse of typical municipal wastewater for agriculture purposes in desert areas in Egypt	**Strategy EG3:** Water reuses with drainage channels and innovative gated pipes in Egypt		**Strategy EG4:** Water (re)use in the technology scenario with innovative gated pipes and calibrated nozzles in Egypt (agro-economic model)
Morocco	**Strategy MO1:** Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops in Morocco	**Strategy MO2:** Reuse of typical municipal wastewater for agriculture purposes in desert areas in Morocco	**Strategy MO3:** Water reuse from municipalities in Morocco		**Strategy MO4:** Water (re)use in the policy scenario with innovative calibrated nozzles in Morocco (agro-economic model)
Tunisia	**Strategy TU1:** Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops in Tunisia	**Strategy TU2:** Reuse of municipal WWTP typical secondary effluent for irrigation (NT 106.03 standard[9]) in Tunisia	**Strategy TU3:** Water reuse from municipalities in Tunis	**Strategy TU4:** Water reuse from textile colouring in Tunis	**Strategy TU5:** Water (re)use in the policy scenario 1 with innovative calibrated nozzles in Tunisia (agro-economic model)

2.2.1.1 *Combination into integrated water & land management strategies (IWLMSs)*

The results of the combination of the technological and economic proposed strategies are presented in three parts. The first part comprises the description of the method used to combine

[9] At the time when the analysis of the three technological best-options to treat waste water was carried out, this was the most recent regulation in Tunisia concerning waste water treatment. However, it is noted here that at the time of finishing this report, the regulations have changed. However, since this technology was selected much earlier, the change in legislation was neglected.

the technological and economic strategies from Egypt, Tunisia, and Morocco into IWLMS. The second part provides an overview about the IWLMS combination process from Tunisia. The third part deals with the combination of technological and economic strategies from Morocco. The criteria for investigation included: (i) overall statement, (ii) technology, (iii) costs, (iv) expansion potential, and (v), if data available, stakeholder opinion.

In Del. 5.2, technological and economic strategies for reuse of treated wastewater were developed separately (partly published in Oertlé, Mueller, *et al.*, 2020). This served as an initial analysis of the technological and economic perspectives individually. In order to successfully implement the use of treated wastewater for agriculture, the technological and economic strategies are combined in this section. Different methods were used to develop the strategies. These, however, essentially pursue the same goal of water reclamation.

We applied a cost minimization approach while maintaining water quality standards. To identify the cost-minimized strategies, the DST was developed and presented in Del. 5.2. This allowed the analysis of country-specific strategies under consideration of different factors (e.g. water quality, land and energy costs, water tariffs, etc.). The selection of two DST-based strategies was based on the water outflow quality standards specified (ISO 16075 category C, or national water standards). In the DST, the treatment of municipal wastewater volumes of 10,000 m^3/d was analyzed. To select the top-ranking options, we proceeded to a ranking based on the lowest cost of treatment. This led to the identification and selection of two scenarios as a basis for basin scale strategies for water reuse in Egypt (EG1, EG2), Tunisia (TU1, TU2), and Morocco (MO1, MO2) respectively. Additionally, other included strategies were the MADFORWATER project pilot plant for the treatment and reuse of drainage canal water near Lake Manzala, Egypt (EG3), the pilot plants in Chotrana and at the Gwash industry in Tunisia (TU3, TU4), and the pilot plant in Agadir in Morocco (MO3). Even though the capacity of the pilot plant in Egypt is only 250 m^3/d, and 10 m^3/d for the two pilot plants in Tunisia, the integration of this strategy was considered essential, as it consists of locally applied treatment trains. In this way local conditions are integrated, which strongly contribute to a successful implementation of the IWLMS.

From the economic perspective, an agro-economic model (DST) was written in GAMS (General Algebraic Modeling System) language. It is based on a mathematical programming of a farm model widely applied in the economic-agricultural analysis and in the irrigated agriculture analysis. The objective of this model is to simulate farmers' behavior under different scenarios and risk situations. For each possible scenario, the proposed model allows to identify optimal farmers' choices related to cropping patterns and agro-techniques. The model also allows to estimate the effects of such choices on water consumption, water distribution among crops, land use changes and farmer income (Varela-Ortega *et al.*, 2020b). With the developed DST different scenarios (policy, water availability, technology) have been simulated and analyzed. To establish a comparison of the technological and economic perspective, strategies that combined both the reuse of treated wastewater and innovative irrigation technologies were selected.

The four selected strategies for the combination to IWLMS were then presented to stakeholders in a workshop at the last meeting of the MADFORWATER project that took place in Basel, Switzerland in February 2020 (see 2.3.1).

2.2.2 Description of strategies: Egypt

Table 4 provides an overview of the evaluated IWLMS for Egypt based on the combination of technological and economic strategies described in 2.2.1. In APPENDIX II: Catalogue of Integrated Water and Land Management Strategies, each strategy is described in detail.

Table 4: Resulting key facts for the evaluation of the proposed IWLMS for Egypt.

Item	Unit	Strategy EG1: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops in Egypt	Strategy EG2: Reuse of typical municipal wastewater for agriculture purposes in desert areas in Egypt	Strategy EG3: Water reuses with drainage channels and innovative gated pipes in Egypt	Strategy EG4: Water (re)use in the technology scenario with innovative gated pipes and calibrated nozzles in Egypt (agro-economic model)
Technology description		No additional treatment	Lagooning: Australia I[10]	Hybrid constructed wetlands (cascade, sequenced, floating bed)	Innovative irrigation technology of gated pipes and calibrated nozzles
Intended reuse		Agricultural irrigation of non-food crops	Agriculture purposes in desert areas	Irrigation of cotton and sugar beet crops	Irrigation of cotton, maize, rice, wheat, alfalfa, vegetables, and sugar beet
Flow rate of TWW produced	[m³/d]	10,000	10,000	250	10,334
Water costs	[€/m³] [11]	0	0.35	0.38	-
Expansion potential and potential economic costs	[m³/year];	Not applicable since the strategy does not include a treatment technology. However, 7,080 Mio m³ municipal WW has been produced in 2012 that could potentially be treated for reuse in different applications.	Assumed the annually produced MWW of 7,080 Mio m³ (in 2012) would be treated with this strategy, the costs would amount to EUR 2,478,000.	7,080 Mio in 2012 the pilot plant would treat 1.3% of the annual DCWW at a cost of 609,550 EGP or 34,675 EUR.	62,000 Mio m³ water was withdrawn for agricultural purpose in 2012. With the proposed innovative technology, the water use would possibly decrease to 53,568 Mio m³ per year.
	[No. of potential implementations]	could be implemented in 382 wastewater treatment plants (WWTP) (data from 2014)	could be implemented in 382 WWTP (data from 2014)	could be implemented in 382 WWTP (data from 2014)	n/a

[10] Bolivar WWTP effluents are re-used for horticultural irrigation in the Virginia area (Australia). Main irrigated crops are root and salad crops, brassicas, wine grapes and olives (=unrestricted irrigation). Sewage from the Adelaide metropolitan areas is treated in Bolivar WWTP by activated sludge process. The effluents from secondary treatment were then held in shallow aeration lagoons for a minimum of 6 weeks, before passing through a dissolved air flotation and dual media filtration process at the water reclamation plant. Here, the effluents discharge via a chlorinator into a balancing storage before being pumped into the pipeline for distribution for horticultural irrigation (AQUAREC, 2006).

[11] This has been converted from USD to Euros. The currency has been converted with the EU official currency converter. The exchange rate used was the rate at the beginning of the year 2020. https://ec.europa.eu/info/funding-tenders/how-eu-funding-works/information-contractors-and-beneficiaries/exchange-rate-inforeuro_en [accessed on 04.05.20].

2.2.3 Description of strategies: Tunisia

Table 5 provides an overview of the evaluated IWLMS for Tunisia based on the combination of technological and economic strategies described in 2.2.1. In APPENDIX II: Catalogue of Integrated Water and Land Management Strategies, each strategy is described in detail.

Table 5: Resulting key facts for the evaluation of the proposed IWLMS for Tunisia.

Item	Unit	Strategy TU1: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops	Strategy TU2: Reuse of municipal WWTP typical secondary effluent for irrigation (NT 106.03 standard)	Strategy TU3: Water reuse from municipalities in Tunisia	Strategy TU4: Water reuse from textile colouring in Tunisia	Strategy TU5: Water (re)use in the policy scenario 1 with innovative calibrated nozzles
Technology description		No treatment	Wetlands: Nicaragua[12]	**Wastewater treatment** 1. nitrifying trickling filter 2. secondary settler for sludge sedimentation 3. constructed wetland 4. chemical disinfection unit 5. excess secondary sludge dewatering system **Irrigation technology** Sprinkler, SIM-model, PGP-bacteria	**Wastewater treatment** 1. coagulation/flocculation unit 2. primary clarifier 3. aerobic Moving Bed Biological Reactor 4. secondary clarifier 5. sand filtration followed by dye adsorption 6. drying bed for sludge dewatering **Irrigation technology** Commercial calibrated nozzles	Introduction of the new technology of innovative calibrated nozzles
Intended reuse		Agricultural irrigation of non-food crops	Infiltration of groundwater for agricultural use	Irrigation of selected cereals	Irrigation of selected forage crops	Irrigation of strawberry, potato, tomato, pepper, citrus, and olive
Flow rate of TWW produced	[m^3/d]	10,000	10,000	10	10	296,809 (FW) 55,629 (TWW)
Water costs	[€/m^3]	0	0.13	0.45	0.64	0.02 (FW) 0.02 (TWW)
Expansion potential and potential economic costs	[m^3/year]	Not applicable since the strategy does not include a treatment technology.	Assumed the annually produced MWW of 27.25 Mio m^3 in the Cap Bon area (as of 2016) would be treated with this strategy, the costs would	Cap Bon area MWW: 27.25 million m^3 in 2016 the pilot plant would be capable of treating 0.01% of the wastewater annually at a total cost of TND 5,110 or EUR 1,643.	Cap Bon area: 450,000 m^3 in 2016 the pilot plant could treat 0.8% of the TWW at a cost of TND 7,264 or EUR 2,336.	221 Mio m^3 municipal wastewater was not treated in 2011 in Tunisia that could potentially be used for irrigation purposes.

[12] The system is treating the domestic wastewater (100 cubic meters per day) generated by some 1,000 people living in the city of Masaya, Nicaragua. The scheme comprises pre-treatment (screen and grit tank) and four constructed wetland beds fed in parallel. The area of each wetland bed is about 350 square meters, totalling 1,400 square meters. Effluent from the pilot plant in Masaya can be used for restricted irrigation (Gauss, 2008).

			amount to EUR 3,542,500.			
	[No. of potential implementations]	could be implemented in 109 WWTP (data from 2010)	could be implemented in 109 WWTP (data from 2010)	could be implemented in 109 WWTP (2010 figures)	could be implemented in 109 WWTP (data from 2010)	n/a

2.2.4 Description of strategies: Morocco

Table 6 provides an overview of the evaluated IWLMS for Morocco based on the combination of technological and economic strategies described in 2.2.1. In APPENDIX II: Catalogue of Integrated Water and Land Management Strategies, each strategy is described in detail.

Table 6: Resulting key facts for the evaluation of the proposed IWLMS for Morocco.

Item	Unit	Strategy MO1: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops in Morocco	Strategy MO2: Reuse of typical municipal wastewater for crops to be eaten raw in Morocco	Strategy MO3: Water reuse from municipalities in Morocco	Strategy MO4: Water (re)use in the policy scenario with innovative calibrated nozzles in Morocco (agro-economic model)
Technology description		No treatment	Wetlands: Nicaragua	**Wastewater treatment** 1. anaerobic lagoon 2. sand filtration unit 3. UV-based disinfection unit **Irrigation technology** Calibrated nozzles, SIM-model	Introduction of the new technology of innovative calibrated nozzles
Intended reuse		Agricultural irrigation of non-food crops	Irrigation of crops to be eaten raw	Irrigation of a field of olive trees	Irrigation of clementine, nadorcott, navel, maroc late, and nour.
Flow rate of TWW produced	[m³/d]	10,000	10,000	75,000	631,549 (38% reused WW)
Water costs	[€/m³]	0	0.14	0.27	0.14
Expansion potential and potential economic costs	[m³/year];	Not applicable since the strategy does not include a treatment technology.	Assumed the 325 million m³ of wastewater to be treated with this strategy and reused by 2030, the total costs would amount to EUR 45,500,000.	325 million m³ of wastewater to be reused by 2030, mainly for irrigation (142 million m³) and landscaping/golf courses (133 million m³).	670 Mio m³ wastewater (municipal and industrial) was not treated in 2012 that could potentially be used for irrigation purposes. With the proposed innovative technology, the freshwater use for agriculture would possibly decrease by

					around 3,180*106 m^3/year.
	[No. of potential implementations]	could be implemented in 73 WWTP data from 2012)	could be implemented in 73 WWTP (data from 2012)	could be implemented in 73 WWTP (data from 2012)	n/a

2.3 Comparative evaluation of strategies and potential implementation towards integrated water & land management

In this section we aim to compare and evaluate the capacity of each proposed IWLMS to improve the adaptive capacity of local stakeholders to deal with PESTLE that includes the water security. The water security includes the resource reliability, water stress and storage drought duration length index. The purpose for this comparative evaluation is to promote the water reuse in Egypt, Morocco, and Tunisia. The structure of this section includes first the method and the results of the comparative evaluation.

2.3.1 Methods for comparative evaluation

2.3.1.1 Method for the application of closed question survey

The closed question survey was used to refine and confirm the relative importance of the 13 water management and agro-industrial strategies developed in the MADFORWATER project, described in Table 4,Table 5, and Table 6. This application consisted of 2 steps: 1 preparation; 2 survey round.

Step 1: Preparation. The preparation stage consisted of data collection and aggregation from the different project partners and the development of the closed question survey. The data collection was a particularly critical step in maintaining the quality of the study due to data limitation, especially concerning the production costs. The reason for this is that in the case of the resulting DST strategies, the production costs represented an average value, and are thus not adapted to local characteristics which can possibly lead to higher production costs. However, it was clearly communicated in the survey that the proposed DST strategies should only provide a first indicator for a possible water treatment strategy.

The identification of the 13 strategies proposed has been done by narrowing down the developed strategies from the DST model in D 5.2 by selecting the two strategies with the lowest technology costs (partly published in Oertlé, Mueller, *et al.*, 2020). This resulted in six proposed strategies derived from the DST model. The remaining seven strategies consists of four pilot plant strategies described in 8.3, 8.7, and 8.11 and three agro-economic model strategies described in 8.4, 8.8, and 8.12. The agro-economic model strategies were also narrowed down to the three proposed strategies by selecting a strategy per country where the model predicted a use of treated wastewater. This approach was chosen in order to enable the integration and assessment of the technological and economic strategies in chapter 2.3.

Step 2: Closed question survey. The closed question survey aimed to identify the suitability of the proposed strategies and the necessity of instruments to support the implementation of the proposed strategies deemed suitable. For this, the meeting attendees were asked to fill two questions per strategy and given the chance to provide clarifying comments. The first question relates to the suitability of the proposed strategies. The meeting participants could choose from a four-stage ranked answer options (not, poorly, reasonably, highly suitable). In addition, it was also possible to choose "no answer" as an option if the participants had too little background knowledge about a specific strategy. However, to avoid this, the key data (technology proposed, costs, expansion potential) of each strategy were briefly explained. To prevent confusion between the strategies, participants were asked to fill in the two questions after each strategy description. Concerning the second question, the participants were asked to choose adequate instruments to support the implementation of the strategies proposed. There was the possibility to select multiple of the following instruments:

- Political (e.g. policy)
- Economic (e.g. water pricing, subsidies)
- Social (e.g. foster social acceptance)
- Water management (e.g. institutional coordination, regional planning and training of the proposed technologies)
- Legal (e.g. increase of legal enforcement, new water quality regulations)
- Environmental (e.g. monitoring and reporting of water quality)

Furthermore, the participants were given the opportunity to comment each strategy and ask clarifying questions directly after each strategy description. Finally, at the end of the questionnaire there was also an opportunity to make a comment in case that the proposed strategies were missing something in general.

2.3.1.2 Method for the statistical analysis

To identify the statistical difference of suitable or not suitable strategies, we applied a binominal test. The binominal test is highly recognised for its simplicity (O'Mahony, 1986) and small sample size (Statistics Solutions, 2020). With the binominal test the following is investigated: the frequency distribution of a dichotomic (= binary) variable with the expected distribution of 'suitable' to 'not suitable' with a five percent confidence interval (UZH, 2018). For this, from each of the 12 questions, the first two results of 'not suitable' and 'poorly suitable' were summed up to 'not suitable'. Alike, the two results of 'reasonably suitable' and 'highly suitable' were summed up to 'suitable'. Then based on the total responds, i.e. total of 'not suitable' and 'suitable' and the higher result, i.e. 'suitable', the binominal value was calculated and analysed by means of the online software STAT TREK (Stat Trek, 2020) and Microsoft Excel (Microsoft, 2020).

Since in the meeting all participants were anonymously shown all 12 different strategies, the obtained survey data are dependent between each other. Consequently, the Bonferroni correction was applied (Wolfram Research, 2020). For this the confidence interval of 0.05 was divided by 12 (which is the total number of 13 statistical tests minus one statistical test). This outcome had to be smaller or equal to each determined binominal result. The Bonferroni correction was calculated by means of the Microsoft Excel (Microsoft, 2020).

2.3.2 Comparative evaluation of strategies: Egypt

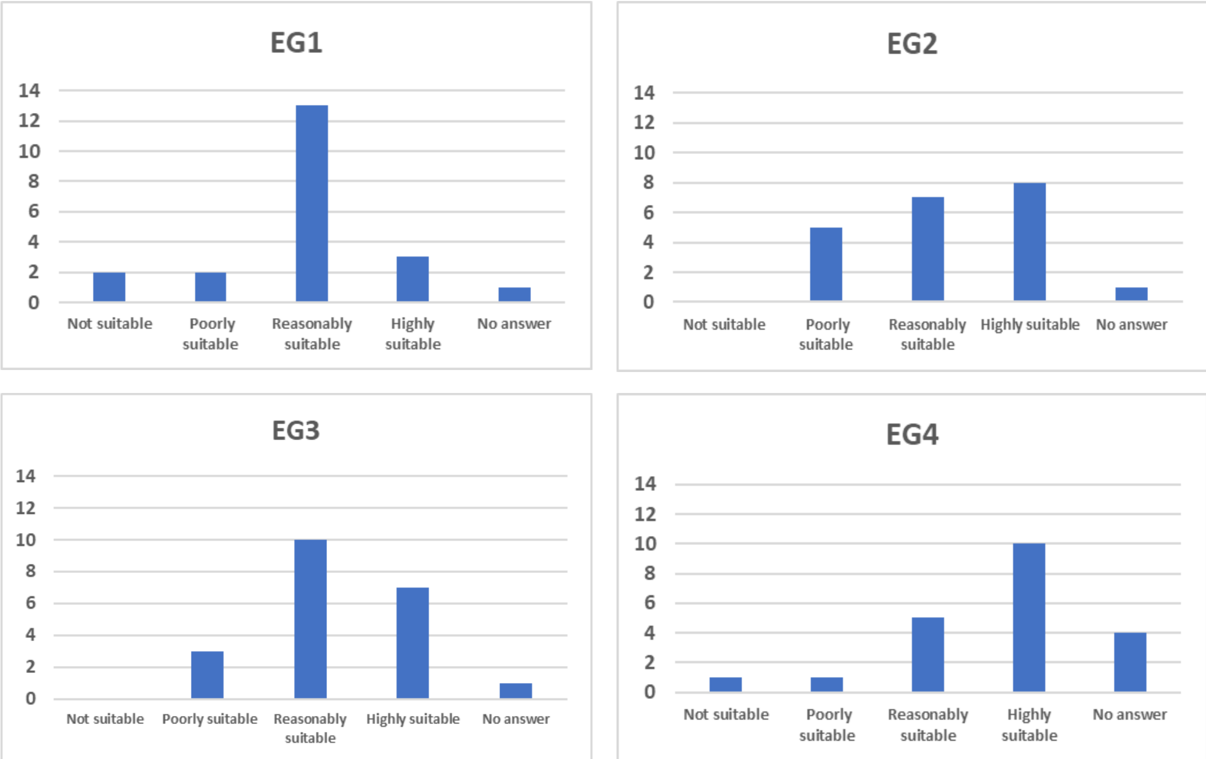


Figure 6: Egyptian MCA responses No. 1 regarding the question of suitability of the proposed strategies. EG1: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops; EG2: Reuse of typical municipal wastewater for agriculture purposes in desert areas; EG3: Water reuses with drainage channels and innovative gated pipes; EG4: Water (re)use in the technology scenario with innovative gated pipes and calibrated nozzles.

Figure 6 shows the results of the first question regarding the suitability of the proposed strategies. The results are presented in absolute figures for transparency reasons. Please note that the analysed results in the following section are only indicative, as the number of people surveyed at the last workshop with different experts was small. Nevertheless, it is possible to identify indicative trends in the suitability of the proposed strategies and suggestions/indications for possible instruments to foster the implementation of the strategies.

The first strategy, EG1, was surveyed mainly as *"reasonably suitable"*. This result of EG1 may be due to not involving any further wastewater treatment in addition to the already performed wastewater treatment in Egypt. This, therefore, will neither result in additional costs nor lead to changes in the irrigation technology. However, there were comments from the participants that for this strategy additional health assessments should be carried out to detect any coliforms at an early stage and remove or deactivate the coliforms with an additional disinfection step.

The second strategy, EG2, has surveyed the treatment train *"Lagooning: Australia I"*. This contains four process units: (a) Maturation pond, (b) Flocculation, (c) Dual media filter, and (d) Chlorine dioxide. This treatment train is already existing and applied, which reuses WWTP effluent mainly for horticultural irrigation such as root and salad crops, brassicas, wine grapes and olives. The participants considered this strategy as *"reasonably"* to *"highly suitable"* for Egypt. However, there were also critical comments that primarily consider the water loss through evaporation as a main issue of a maturation pond in Egypt. Furthermore, the costs of this proposed strategy would probably be higher than the average costs assumed in the model, because of higher land costs. As a result, this strategy would no longer be listed as the second-best DST strategy proposed. This problem was subsequently addressed in the DST model, by providing the user with the possibility to adjust the costs to their personal case.

The third strategy, EG3, concerns the MADFORWATER pilot plant near Lake Manzala which treats primary-treated and untreated municipal wastewater from drainage channels with a combination of lagooning and constructed wetlands, and reuses the treated water to irrigate cotton by means of an innovative gated pipe. The majority of the participants considered this strategy as *"reasonably"* or *"highly suitable"*. This tendency can be explained because this strategy includes technologies which have been applied locally. This made it possible to analyse and evaluate local conditions and, where necessary, allow modifications to the technologies.

The last strategy, EG4, is an agro-economic model strategy that includes the introduction of an innovative irrigation technology of gated pipes and the practice to reuse drainage channel water. The model simulated the implementation of some economic tools to evaluate their effects in terms of reduction of drainage water and hence of water quality deterioration. The results indicated that only the joint introduction of the innovation and of a new policy of water supply could achieve the objective to reduce the amount of water used by agriculture without affecting the level of satisfaction of the farmers. Therefore, this strategy has been selected to propose to the workshop attendees. The difference to EG3 is the joint introduction of the innovation of gated pipes and of a new policy of water supply. Alike for EG3, the results of the survey revealed a tendency towards a *"highly suitable"* strategy. This can be partly explained because of the new innovative irrigation technology that allows farmers to use less water for irrigation. This in turn enables cost savings.

Table 7 shows the results of the statistical investigation. The Binominal analysis enabled the identification of statistically significant suitable versus not suitable strategies. All four strategies, EG1 -EG4, were identified as suitable. Strictly speaking with the Bonferroni correction[13], the strategies EG3 and EG4 were statistically significant. This indicates the expert group did show a statistically significant suitability to all four strategies, in particularly for the strategies EG3 and EG4. In conclusion, the statistical analysis indicates that the most effective water management strategy in Egypt consists in the treatment of drainage canal water by means a combination of lagooning and constructed wetlands, and the reuse of the treated water to irrigate crops by means of an innovative gated pipe; this strategy should include a new policy of water supply (EG3, EG 4).

[13] The Bonferroni correction is a correction of multiple-comparison. It is used, because several dependent statistical tests were performed (Wolfram Research, 2020).

Table 7: Results of the statistical investigation of the suitable and not suitable strategy with a binominal investigation and Bonferroni Correction. The cells coloured in green indicate the statistically significant suitable strategy, whereas the cells coloured in orange are the statistically significant not suitable strategy. The following strategies were included EG1: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops, EG2: Reuse of typical municipal wastewater for agricultural purposes in desert areas, EG3: Reuse of drainage canal water for irrigation, EG4: Water (re)use in the technology scenario.

	Binominal investigation					Bonferroni Correction			
Strategy	**Not suitable** (no. of 'not suitable', 'poorly s.')	**Suitable** (no. of 'reasonably suitable', 'highly s.')	**Total**	**p value with 5% significance interval**	**Significant difference [yes, no]**	**Confidence interval [decimal]**	**number of questions [N]**	**Bonferroni Correction**	**Significant difference with Bonferroni correction**
EG1	4	16	20	0.00591	yes	0.05	13	0.00385	no
EG2	5	15	20	0.02069	yes	0.05	13	0.00385	no
EG3	3	17	20	0.00129	yes	0.05	13	0.00385	yes
EG4	2	15	17	0.00117	yes	0.05	13	0.00385	yes

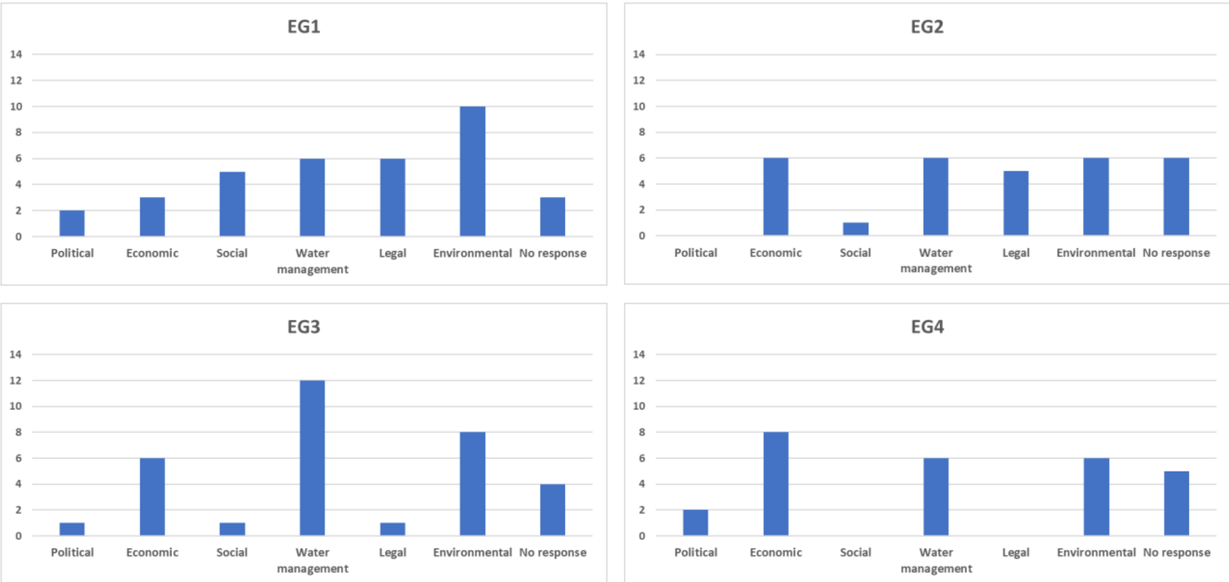


Figure 7: Egyptian MCA responses No. 2 regarding the question of supportive instruments for the proposed strategies. EG1: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops; EG2: Reuse of typical municipal wastewater for agriculture purposes in desert areas; EG3: Water reuses with drainage channels and innovative gated pipes; EG4: Water (re)use in the technology scenario with innovative gated pipes and calibrated nozzles.

Figure 7 shows the results of the second question regarding the supportive instruments for the proposed strategies. Please note, the following interpretations are indicative. Nevertheless, the responses allow an indication on which instruments should be in focus to foster water reuse.

The most frequently indicated instrument for the EG1 strategy was *"Environmental"*. This includes, for example, monitoring and reporting of the water quality after treatment. This coincides with the stated comments on the need for an additional disinfection step, as mentioned above. Furthermore, the instruments *"Legal"* and *"Water management"* were mentioned several times. This tendency can be explained because the demand for ecological measures is often accompanied by legal measures such as the increase of legal enforcement and/or the adoption of new water quality regulations. Additionally, institutional coordination, regional planning and training for the proposed strategies would also be necessary (water management instruments).

For the second strategy, EG2, no clear trend towards one or two instruments could be identified. *"Economic"* instruments such as subsidies or water pricing as well as *"Environmental"* and

"Legal" instruments, as described in the previous paragraph, are considered important to implement this strategy. In particular, the mention of economic instruments is reasonable, as the comments showed that the proposed strategy *"Lagooning: Australia I"* would lead to high land costs. Therefore, economic instruments were considered necessary to implement this strategy.

For the third strategy, EG3, a clear trend was shown towards "*Water management"* and "*Environmental"* instruments. In particular, the high number of water management instruments mentioned can be derived from the following two indications: (a) The results of response 1 showed a reasonably suitability of the strategy, which (b) is an indication that this strategy possibly should be applied in Egypt and that the application should be accompanied by water management instruments such as institutional coordination, regional planning and training for the proposed strategy.

In the last strategy, EG4, "*Economic", "Water management"* and "*Environmental"* instruments were considered of primary relevance. Economic instruments in particular are reasonable because the strategy proposes a joint introduction of innovative gated pipes and a new water supply policy. Therefore, the participants observed a need for financial support for farmers to enable them to purchase the new innovative irrigation technology. Consequently, water management instruments such as training in its use and particularly prior monitoring of the water quality for irrigation (environmental) seemed relevant.

In conclusion, this analysis indicates a tendency for supportive instruments to increase the reuse of treated wastewater and to introduce innovative irrigation technologies in combination with stable economic performances of farmers in Egypt. The choice of instruments depends strongly on the proposed strategies. However, a trend towards primarily economic, environmental and water management instruments can be observed. This is because from an economic perspective, the introduction of new technologies or the expansion of existing ones cannot solely be financed by the concerned stakeholders (WWTP, farmers). Therefore, economic instruments such as, for instance, subsidies were often considered necessary. In addition, new technologies create uncertainty regarding water quality and its management. Consequently, environmental and water management instruments were also frequently mentioned to be supportive. Finally, it should be mentioned that the selection of proposed instruments is not complete, but for reasons of time and overview, it was decided not to go into too much detail. This analysis should therefore be treated with caution, as different instruments may be more suitable for other strategies.

2.3.3 Comparative evaluation of strategies: Tunisia

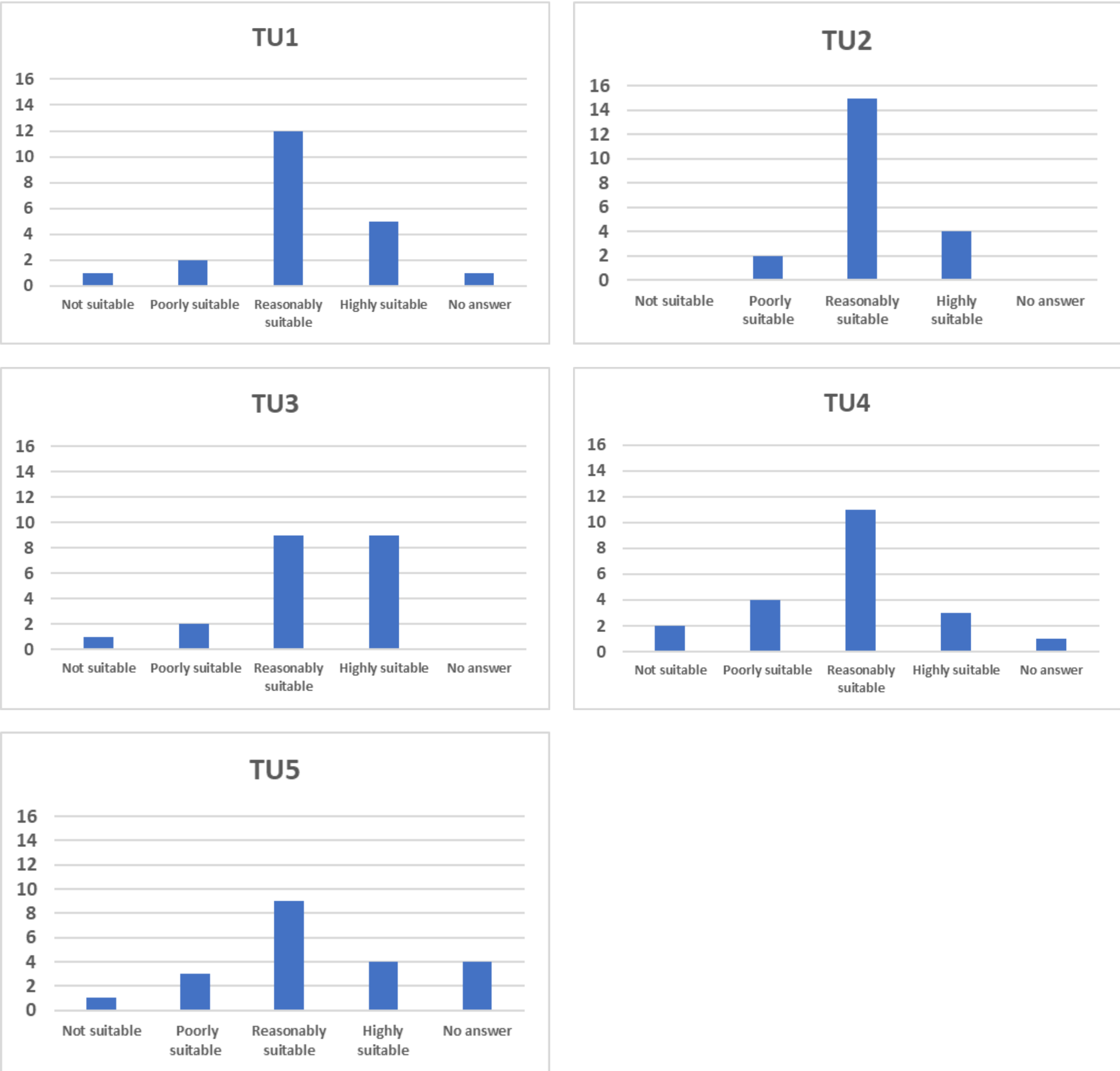


Figure 8: Tunisian MCA responses No. 1 regarding the question of suitability of the proposed strategies. TU1: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops; TU2: Reuse of municipal WWTP typical secondary effluent for irrigation (NT 106.03 standard); TU3: Water reuse from municipalities; TU4: Water reuse from textile colouring; TU5: Water (re)use in the policy scenario 1 with innovative calibrated nozzles.

Figure 8 shows the results of the first question regarding the suitability of the proposed strategies. The results are presented in absolute figures for transparency reasons. Please note that the analysed results in the following section are only indicative, as the number of people surveyed at the last workshop with different experts was small. Nevertheless, it is possible to identify indicative trends in the suitability of the proposed strategies and indications for possible instruments to foster the implementation of the strategies.

The first strategy, TU1, was mainly considered *"reasonably suitable"*. This result of TU1 may be a consequence of not involving any further wastewater treatment in addition to the already performed wastewater treatment in Tunisia. Consequently, this will neither result in additional costs nor lead to changes in the irrigation technology. However, this strategy includes the reuse of treated wastewater for irrigation of non-food crops. This led to the concerns of the participants that an additional step, consisting of disinfection to remove coliforms, should be considered to guarantee the water quality compliance.

The second strategy, TU2, has surveyed the treatment train *"Wetlands: Nicaragua"*. This contains three process units: (a) Bar screen, (b) Grit chamber, and (c) Constructed wetland. This treatment train is already existing and applied, which reuses treated domestic wastewater effluent for restricted irrigation. The participants considered this strategy as *"reasonably suitable"* for Tunisia. However, there were critical comments that mainly addressed the problem of guaranteeing a high-level disinfection efficiency. Additionally, concerns about the high temperatures in Tunisia and an associated high water evaporation rate were stated.

The third strategy, TU3, concerns the pilot plant at the Chotrana wastewater treatment plant in Ariana, which treats municipal wastewater by means of a combination of an innovative trickling filter and a constructed wetland, to irrigate selected cereals with innovative calibrated nozzles. The participants considered this strategy between *"reasonably"* and *"highly suitable"*. This tendency can be explained because this strategy includes a technology, which has been applied locally. This made it possible to analyse and evaluate local conditions and, where necessary, allow modifications to the technologies. The main concerns of the participants were the high costs of this technology and the maintenance of the disinfection efficiency. Additionally, the need to increase microbiological standards was also stated.

The fourth strategy, TU4, concerns the pilot plant at the Gwash industry in Nabeul, which treats textile wastewater to irrigate selected forage crops in an experimental field. The majority of the participants considered this strategy as *"reasonably suitable"*. This tendency can partly be explained because of following two reasons: 1) the already integrated internal wastewater treatment processes of textile companies; these treatment processes have already a positive effect on the wastewater quality; 2) because the new technology of the pilot plant could be tested locally. This made it possible to analyse and evaluate local conditions and modify the technology. However, several concerns about this strategy were noted by the participants, such as the need to monitor long term soil and groundwater pollution, when using treated textile wastewater for irrigation. Additionally, the participants expressed concerns about the excessive costs that this technology entails. Furthermore, suggestions were also made such as adding a model for irrigation scheduling to remove the human factor of not knowing how to use this technology adequately.

The last strategy, TU5, is an agro-economic model strategy that includes the joint introduction of the innovative irrigation technology of calibrated nozzles as used in TU3 and TU4, and an increase in water availability considering water supply from WW reuse. The model simulated the implementation of any type of policy intervention based on the application of wastewater management technologies and water reuse and land management technologies as well as economic instruments. The agro-economic model analysis results show that farm income has increased in all scenarios compared to the baseline scenario. As the introduction of the new technology and a higher amount of treated wastewater led to the highest use of TWW and at the same time increased the income of the farmers the most, this was chosen as the strategy and presented to the workshop attendees. The difference to TU3 and TU4 is the joint introduction of innovative irrigation technology of calibrated nozzles and increased TWW availability. The results of the survey revealed a tendency towards a *"reasonably suitable"* strategy. This can be partly explained because of the new innovative irrigation technology that allows farmers to use less water for irrigation. This in turn enables cost savings.

The results of the statistical investigation are provided in Table 8. The Binominal analysis enabled the identification of statistically significant suitable versus not suitable strategies. Four strategies

TU1, TU2, TU3, and TU5 were identified as suitable. Strictly speaking with the Bonferroni correction, the strategies TU1, TU2 and TU3 were statistically significant. This indicates the expert group did show a statistically significant suitability to the strategies TU1, TU2, TU3, and TU5, in particularly for the strategies TU1, TU2 and TU3. In conclusion, the statistical analysis indicates that the most effective water management strategy in Tunisia consists in combining different types of WW treatment for the irrigation of different type of crops by means of innovative devices such as the calibrated nozzle and the micro-sprinkler: reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops; reuse of municipal WW treated by innovative trickling filters + constructed wetlands for the irrigation of cereals and animal feed crops; reuse of municipal WW treated by traditional activated sludge process + Nicaragua wetlands for aquifer recharge (TU1, TU2, and TU3).

Table 8: Results of the statistical investigation of the suitable and not suitable strategy with a binominal investigation and Bonferroni Correction. The cells coloured in green indicate the statistically significant suitable strategy, whereas the cells coloured in orange are the statistically significant not suitable strategy. The following strategies were included TU1: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops, TU2: Reuse of municipal WWTP typical secondary effluent for irrigation (NT 106.03 standard), TU3: Reuse of municipal WWTP secondary effluent for irrigation, TU4: Reuse of textile WW for non-food crops irrigation, and TU5: Water (re)use in the policy scenario 1.

	Binominal investigation					**Bonferroni Correction**			
Strategy	**Not suitable** (no. of 'not suitable', 'poorly s.')	**Suitable** (no. of 'reasonably suitable', 'highly s.')	**Total**	**p value with 5% significance interval**	**Significant difference [yes, no]**	**Confidence interval [decimal]**	**number of questions [N]**	**Bonferroni Correction**	**Significant difference with Bonferroni correction**
TU1	3	17	20	0.00360	yes	0.05	13	0.00385	yes
TU2	2	19	21	0.00011	yes	0.05	13	0.00385	yes
TU3	3	18	21	0.00074	yes	0.05	13	0.00385	yes
TU4	6	14	20	0.05766	no	0.05	13	0.00385	no
TU5	4	13	17	0.02452	yes	0.05	13	0.00385	no

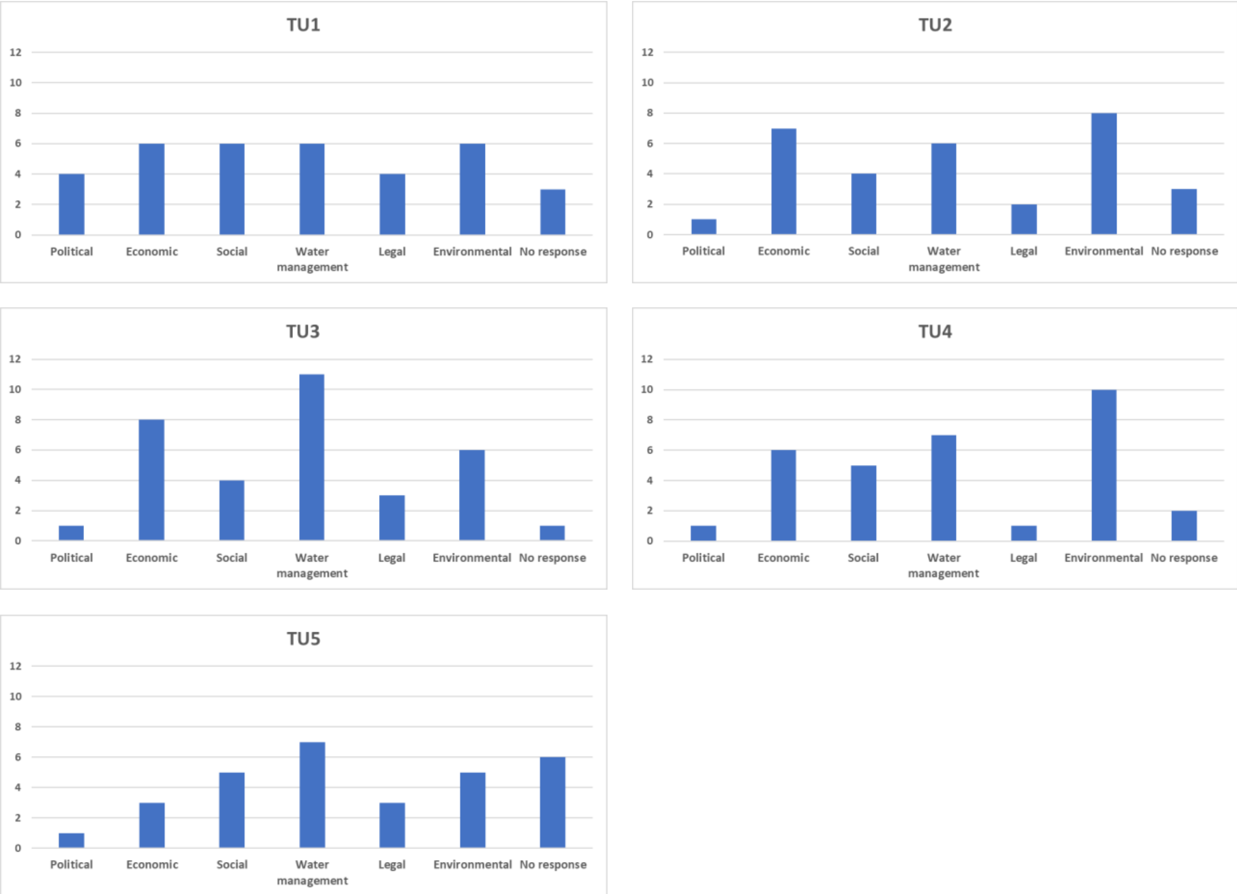


Figure 9: Tunisian MCA responses No. 2 regarding the question of supportive instruments for the proposed strategies. TU1: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops; TU2: Reuse of municipal WWTP typical secondary effluent for irrigation (NT 106.03 standard); TU3: Water reuse from municipalities; TU4: Water reuse from textile colouring; TU5: Water (re)use in the policy scenario 1 with innovative calibrated nozzles.

Figure 9 shows the results of the second question regarding the supportive measures for the proposed strategies. Please note, the following interpretations are indicative. Nevertheless, the responses allow an indication on which measures should be in focus to foster water reuse.

For the first strategy, TU1, no clear trend towards one or two instruments could be identified. "*Economic*" instruments such as subsidies or water pricing as well as "*Social*", "*Water management*", and "*Environmental*" instruments are considered important to implement this strategy. In particular, the mentioning of economic and environmental instruments is reasonable, since the comments showed concerns about the water quality compliance. Consequently, environmental instruments such as monitoring and reporting of water quality were considered necessary to assure water quality. Since additional monitoring and reporting entails additional costs, it seems reasonable that economic instruments such as subsidies seemed necessary to avoid a price increase for the technology.

For the second strategy, TU2, a clear trend was shown towards "*Water management*" and "*Economic*" instruments. In particular, the mentioning of economic instruments such as subsidies or water pricing is reasonable, as the comments showed that the proposed strategy *"Wetlands: Nicaragua"* would lead to high maintenance costs because of the high evaporation rate in Tunisia. Therefore, economic instruments were considered necessary to implement this strategy. Additionally, environmental instruments such as monitoring, and reporting of the treated wastewater quality are considered necessary to guarantee a high-level disinfection efficiency.

For the third strategy, TU3, a clear trend was shown towards "*Water management"* and "*Environmental"* instruments. In particular, the high number of mentioned water management instruments can be derived from the following two indications: (a) The results of response 1 showed a reasonable to high suitability of the strategy, which (b) is an indication that this strategy should be applied in Tunisia and that the application should be accompanied by water management instruments such as institutional coordination, regional planning and training for the proposed strategy. Furthermore, the mentioning of economic instruments can be an indication that concerns about high technology costs can be addressed by instruments such as subsidies.

For the fourth strategy, TU4, a clear trend towards *"Environmental"* instruments could be identified. This is in line with the comments on the need for long-term monitoring of soil and groundwater pollution. Environmental instruments such as periodic monitoring and reporting of water and soil quality could therefore contribute to the feasibility of this proposed strategy. Furthermore, several participants observed a need for *"Water management"* instruments. This can be taken as an indication that instruments such as institutional coordination, regional planning and training are considered crucial for a large-scale application of this proposed strategy. This is consistent with the suggestion to add a model for irrigation scheduling.

In the last strategy, TU5, *"Water management"* and "*Environmental"* instruments were considered of primary relevance. Water management instruments in particular may be an indication that the participants observed a need for coordination of trainings for farmers on the use of the new innovative irrigation technology. However, it needs to be noted that many participants have not given any response at all. One reason for this may be that the new innovative irrigation technology is already included in the two pilot plant strategies TU3 and TU4 and consequently the participants did not consider this strategy as a different strategy. Another reason may be that this was the last proposed strategy that had to be evaluated and therefore the participants were not as concentrated on the strategy as before.

In conclusion, this analysis indicates a tendency for supportive instruments to increase the reuse of treated wastewater and to introduce innovative irrigation technologies in combination with stable economic performances of farmers in Tunisia. The choice of instruments depends strongly on the proposed strategies. However, a trend towards primarily economic, environmental and water management instruments can be observed. This is because from an economic perspective, the introduction of new technologies or the expansion of existing ones cannot solely be financed by the concerned stakeholders (WWTP, farmers). Therefore, economic instruments such as subsidies were often considered necessary. In addition, new technologies create uncertainty regarding water quality and its management. Consequently, environmental and water management instruments were also frequently mentioned as supportive. Finally, it should be mentioned that the selection of proposed instruments is not complete, but for reasons of time and resources, an overview, was provided. This analysis should therefore be treated with care, as different instruments may be more suitable for other strategies.

2.3.4 Comparative evaluation of strategies: Morocco

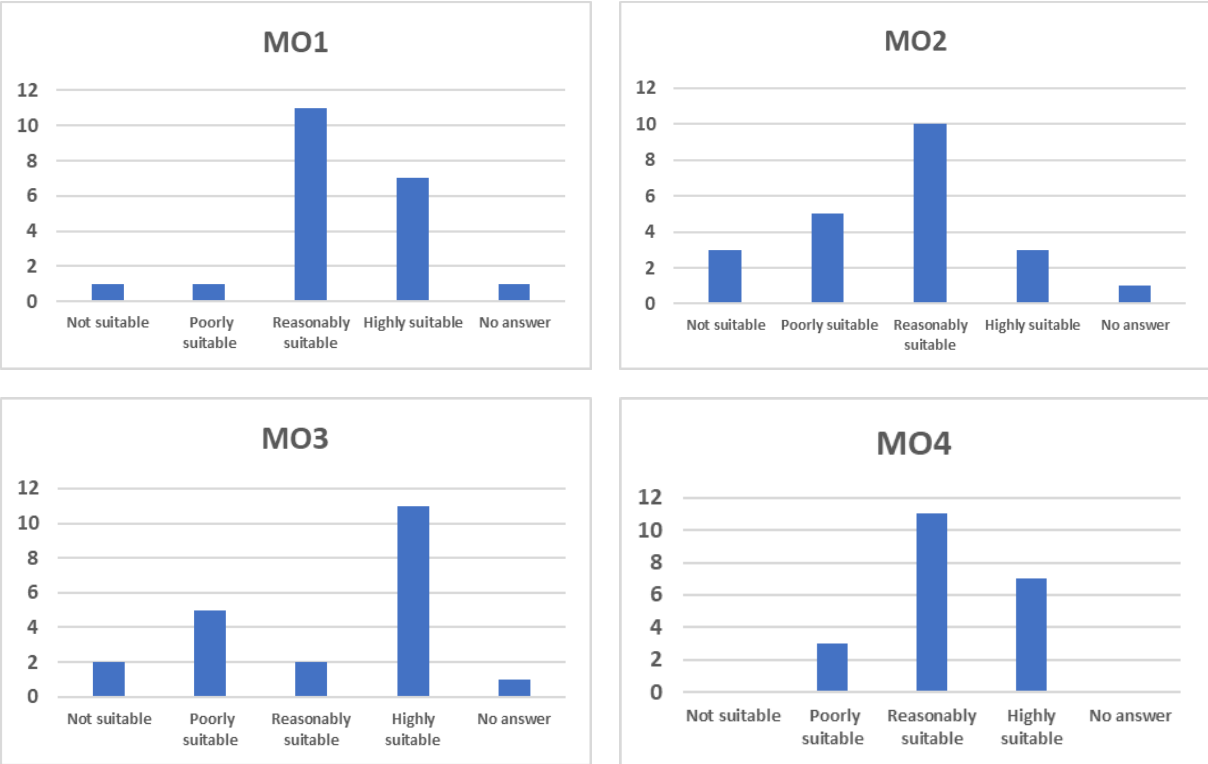


Figure 10: Moroccan MCA responses No. 1 regarding the question of suitability of the proposed strategies. MO1: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops; MO2: Reuse of typical municipal wastewater for crops to be eaten raw; MO3: Water reuse from municipalities in Morocco; MO4: Water (re)use in the policy scenario with innovative calibrated nozzles.

Figure 10 shows the results of the first question regarding the suitability of the proposed strategies. The results are presented in absolute figures for transparency reasons. Please note that the analysed results in the following section are only indicative, as the number of people surveyed at the last workshop with different experts was small. Nevertheless, it is possible to identify indicative trends in the suitability of the proposed strategies and suggestions/indications for possible instruments to foster the implementation of the strategies.

The first strategy, MO1, was considered between *"reasonably"* and *"highly suitable"*. This result of MO1 may be a consequence of not involving any further wastewater treatment in addition to the already performed wastewater treatment in Morocco. Consequently, this will neither result in additional costs nor lead to changes in the irrigation technology. However, this strategy includes (a) the reuse of treated wastewater for irrigation of non-food crops, (b) the concerns of the participants were that risk, and c) health issues regarding the irrigation method and soil composition (levels and load) could be neglected. Consequently, an additional step consisting of disinfection to remove coliforms was proposed in order to guarantee the water quality. The participants concerns were expressed regarding the social acceptance to use treated wastewater.

The second strategy, MO2, has surveyed the treatment train *"Wetlands: Nicaragua"*. This contains three process units: (a) Bar screen, (b) Grit chamber, and (c) Constructed wetland. This treatment train is already existing and applied. This process reuses treated domestic wastewater effluent for restricted irrigation. The participants considered this strategy as *"reasonably suitable"* for Morocco. Additionally, there were comments mainly addressing the problem of the social acceptance since the strategy proposes to use treated wastewater for irrigation of crops to be eaten raw.

The third strategy, MO3, concerns the pilot plant in the Souss-Mass region in Agadir which treats municipal wastewater to irrigate olive trees with innovative calibrated nozzles. The majority of the participants considered this strategy as *"highly suitable"*. This tendency can be explained, because this strategy includes a locally applied technology. This made it possible to analyse and evaluate local conditions and, where necessary, allow modifications to the technologies. However, the main concern of the participants was the high cost of this technology.

The last strategy, MO4, is an agro-economic model strategy that includes the joint introduction of the innovative irrigation technology of calibrated nozzles as used in MO3, and a water price policy. The model simulated the implementation of some economic tools to analyse alternative political scenarios and estimate the impacts of different policies in terms of parameters deemed relevant to the case study. The agro-economic model analysis results showed that farmers' decision about the use of TWW only changes when a water price policy, such as a subsidy on TWW, is introduced. Therefore, this strategy has been selected to propose to the workshop attendees. The difference to MO3 is the joint introduction of innovative irrigation technology of calibrated nozzles and a water price policy. The results of the survey revealed a tendency towards a *"reasonably suitable"* strategy. This can be partly explained because of the new innovative irrigation technology. This technology allows farmers to use less water for irrigation. This in turn enables cost savings. Furthermore, participants highlighted the usefulness of the new technology, which allows a projection of the treated wastewater reuse in agriculture.

The results of the statistical investigation are provided in Table 9. The Binominal analysis enabled the identification of statistically significant suitable versus not suitable strategies. Two strategies, MO1 and MO4, were identified as suitable. Strictly speaking with the Bonferroni correction, the same strategies MO1 and MO4 were statistically significant. This indicates the expert group did show a statistically significant suitability to two strategies MO1 and MO4. In conclusion, the statistical analysis indicates that the most effective water management strategy in Morocco consists in combining different types of WW treatment for the irrigation of different type of crops by means of innovative devices such as the calibrated nozzle: reuse of municipal WWTP typical secondary effluent for the irrigation of non-food crops; reuse of tertiary-treated municipal WW for the irrigation of citrus trees, combined to the introduction of an innovative water pricing policy (MO1 and MO4).

Table 9: Results of the statistical investigation of the suitable and not suitable strategy with a binominal investigation and Bonferroni Correction. The cells coloured in green indicate the statistically significant suitable strategy, whereas the cells coloured in orange are the statistically significant not suitable strategy. The following strategies were included MO1: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops, MO2: Reuse of typical municipal wastewater for irrigation of crops to be eaten raw, MO3: Reuse of municipal WWTP tertiary effluent for olive trees irrigation, and MO4: Water (re)use in the policy scenario.

	Binominal investigation					**Bonferroni Correction**			
Strategy	**Not suitable** (no. of 'not suitable', 'poorly s.')	**Suitable** (no. of 'reasonably suitable', 'highly s.')	**Total**	**p value with 5% significance interval**	**Significance difference [yes, no]**	**Confidence interval [decimal]**	**number of questions [N]**	**Bonferroni Correction**	**Significant difference with corr. for suitable**
MO1	2	18	20	0.00020	yes	0.05	13	0.00385	yes
MO2	8	13	21	0.19166	no	0.05	13	0.00385	no
MO3	7	13	20	0.13159	no	0.05	13	0.00385	no
MO4	3	18	21	0.00074	yes	0.05	13	0.00385	yes

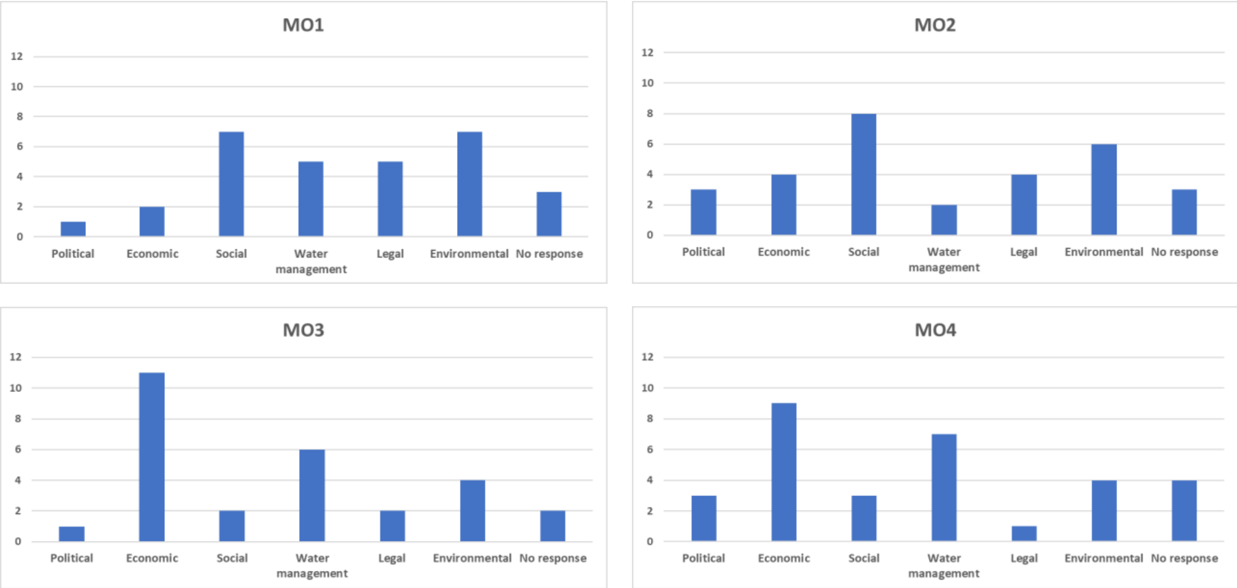


Figure 11: Moroccan MCA responses No. 2 regarding the question of supportive instruments for the proposed strategies. MO1: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops; MO2: Reuse of typical municipal wastewater for crops to be eaten raw; MO3: Water reuse from municipalities in Morocco; MO4: Water (re)use in the policy scenario with innovative calibrated nozzles.

Figure 11 shows the results of the second question regarding the supportive instruments for the proposed strategies. Please note, the following interpretations are indicative. Nevertheless, the responses allow an indication on which instruments should be in focus to foster water reuse.

For the first strategy, MO1, the most frequently indicated instruments were *"Environmental"* and *"Social"*. This includes, for example, monitoring and reporting of the water quality after treatment and to foster social acceptance of treated wastewater reuse. This coincides with the stated comments on the need for an additional disinfection step and the issue of the social acceptance. Furthermore, the instruments *"Legal"* and *"Water management"* were mentioned several times. This tendency can be explained because the demand for ecological instruments is often accompanied by legal instruments such as the increase of legal enforcement and/or the adoption of new water quality regulations. Additionally, institutional coordination, regional planning and training for the proposed strategies would also be necessary (water management instruments).

For the second strategy, MO2, a clear trend was shown towards "*Social"* instruments such as fostering social acceptance of treated wastewater reuse. The mentioning of "Social" instruments is reasonable, since the comments of the participants showed that the consumers would possibly not accept the proposed strategy. This is because the consumers perception that wastewater cannot be treated sufficiently for irrigating crops that are eaten raw. Furthermore, the measure "Environmental" was mentioned several times. This tendency can be explained because social acceptance can be fostered by environmental instruments such as monitoring and reporting of the water quality.

For the third strategy, MO3, a clear trend was shown towards "*Economic"* instruments. This can be attributed to the fact that the participants primarily considered the high costs of the new innovative technology as a potential barrier to the implementation of this strategy. With instruments such as subsidising the irrigation technology, this strategy could have potential for an implementation, since most participants considered this strategy to be *"highly suitable"*.

In the last strategy, MO4, "*Economic", and "Water management"* instruments were considered of primary relevance. Economic instruments in particular are reasonable since the strategy itself already proposed an introduction of a water price policy. This result confirmed that the participants observed a need for financial support for farmers to enable them to purchase the new innovative irrigation technology. Consequently, water management instruments such as training in its use and particularly prior monitoring of the water quality for irrigation (environmental) seemed relevant.

In conclusion, this analysis indicates a tendency for supportive instruments to increase the reuse of treated wastewater and to introduce innovative irrigation technologies in combination with stable economic performances of farmers in Morocco. The choice of instruments depends strongly on the proposed strategies. However, a trend towards primarily economic, environmental and social instruments can be observed. This is because from an economic perspective, the introduction of new technologies or the expansion of existing ones cannot solely be financed by the concerned stakeholders (WWTP, farmers). Therefore, economic instruments such as subsidies were often considered necessary. In addition, new technologies create uncertainty regarding water quality and use and consumption for the consumers. Consequently, environmental and social instruments were also frequently mentioned to be supportive. The social instruments were mentioned in particular, as there is currently a lack of consumer acceptance of use of TWW in Tunisia. Finally, it should be mentioned that the selection of proposed instruments is not complete, but for reasons of time and resources, overview was provided.. This analysis should therefore be treated with care, as different instruments may be more suitable for other strategies.

2.3.5 Potential implementation of the PESTLE approach: Egypt

Based on the research described in Deliverable 5.2 MADFORWATER developed indicative strategies for identifying barriers to an effective water management and reuse on a national level Table 10. The discussion of the identified barriers relatively to Egypt is provided in the subsequent paragraphs.

Table 10: Egypt's result of multi criteria analysis of different key questions, strategy excerpt, identified barriers. Results of the national-level conditions for water reuse assessment. 'Lower' national-level conditions for water reuse are in red and equivalent to the score '1', moderate national-level conditions for water reuse in yellow and equivalent to the score '2', 'higher' national-level conditions for water reuse in green and equivalent to the score '3'. Ts stands for Thematic subject. Ec stands for economy. WM stands for water management. P & I stands for policy and institution. L stands for legislation. S stands for society. En stands for environment. '-'stand for 'no data available' or 'not defined.

Ts	Key question	Score detailed	Strategy excerpt	Identified barrier
Ec	-What is the **official financial development assistance** (gross expenditure) for water supply and sanitation?	1	Financial support is lower	Limited growth based on financial support per WW produced
	-What is the level of **economic water security**?	2	Moderate water security	Improve water security
	-What is the **water pricing for agriculture**?	1	Higher for water pricing costs	Water is available too cheap to cover the costs
	-What are the **financial subsidies** for water use in agriculture?	1	High financial subsidies	Water is available for free, consequently no incentive to save water
WM	-What is the **transboundary water dependency ratio**?	1	Higher transboundary water dependency	High water supply dependency on neighbouring countries
	-What is the share of **produced volume** of industrial and municipal wastewater per total population in a country?	1	Higher volume of wastewater produced per total population	High volume of wastewater to be treated per population
	- What is the **share of treated to produced volume** of industrial and municipal wastewater?	2	Moderate level of treated to produce wastewater volume	Moderate share of treated WW to produced volume, meaning potentially not much water is treated in comparison to available WW
	-What is the share of **harvested irrigated crop area per cultivated area**?	2	Moderate share of harvested irrigated crop area per cultivated area	Moderate level of control irrigation per cultivated area.
P&I	-What is the **proportion of monitoring and reporting** system **in comparison to other countries**?	2	Moderate proportion of monitoring in international context	Moderate proportion of monitoring in international context
	-What is the degree of **implementation of national monitoring and reporting** system?	3	Compliance with national monitoring and reporting system	No
L	- What is the **quality of contract enforcement, property rights, and the courts** in each country?	1	In international comparison: Lower level of quality of contract enforcement, property rights, and the courts	Lower level of quality of contract enforcement, property rights, and the courts
	- What is the **regulation** for food and non-food crop irrigation with reclaimed water?	2	Partly compliance with legislation	Not allowed to irrigate non-food crop
S	-What is the degree of **implementation of equitable water and wastewater tariffs**	3	Higher degree of implementation of equitable water and wastewater tariffs	No
	-What share of population is using **improved sanitation services**?	3	Wide use of sanitation services	No, yet there is a large amount of treated WW that could be used for water reclamation
	-What is the **social acceptance** of a country towards water reuse for agriculture?	-	N/Av	N/Av
En	-What is the status of **national water reuse regulations for irrigation** in comparison with the international BS ISO 16075-2: 2015 water quality guideline?	1	Lower compliance	Stricter implementation of regulation and higher compliance with ISO 16075-2
	- What is the share of the **area equipped for irrigation that has become salinized**?	-	N/Av	N/Av

Please note that the analysed PESTLE results in the following section are indicative. Nevertheless, it is possible to identify indicative trends and possible barriers of the national-level situation regarding the thematic subjects in order to foster the implementation of the wastewater management strategies.

The PESTLE analysis of Egypt showed positive national-level circumstances for wastewater treatment in general Table 10. The main barriers have been identified primarily in the thematic subjects of *"economy"* and "*water management"*. The "economy" is because in Egypt it is rooted in the culture that there is no price for water and therefore an important economic instrument is not used in relation to water scarcity. However, it should be noted that farmers pay indirectly for their water demand. There is a levy on the farmed area and the farmers pay the electricity costs for their water distribution. Regarding the *"water management"* situation, the following main barriers have been identified in the PESTLE analysis: (i) high water supply dependency on neighboring countries, (ii) a high share of total produced wastewater before treatment in relation to the Egyptian population, (iii) and a moderate share of treated wastewater to produced wastewater volume. These barriers can partially be explained because of (i) Egypt has only 20 cubic meters per person per year of internal renewable freshwater resources, and as a result the country relies heavily on the Nile River for its main source of water (The Guardian, 2015; Eco Mena, 2017); (ii) the over exploitation of ground water resources over the last 20 years in Egypt. This has led to increased water salinization and to the inland advancing of the salt water interface (AbuZeid u.a. 2014). Additional barriers regarding the *"environment"* national-level circumstances have been identified. This means, a lower compliance with national water reuse regulation in comparison with the ISO 16075-02:2015 standard has been identified. Consequentially, the environment, and in particular in agriculture the soil, is not adequately protected to meet the ISO recommended good practices to avoid negative impacts on soil, crops, groundwater and surface water.

2.3.6 Potential implementation PESTLE: Tunisia

Based on the research described in Deliverable 5.2 MADFORWATER developed indicative strategies for identifying barriers to an effective water management and reuse on a national level Table 11. The discussion of the identified barriers relatively to Tunisia is provided in the subsequent paragraphs.

Table 11: Tunisia's result of multi criteria analysis of different key questions, strategy excerpt, identified barriers and (economic) instruments. The results of the national-level conditions for water reuse assessment. 'Lower' national-level conditions for water reuse is in red and equivalent to the score '1', moderate national-level conditions for water reuse in yellow and equivalent to the score '2', 'higher' national-level conditions for water reuse in green and equivalent to the score '3'. Ts stands for Thematic subject. Ec stands for economy. WM stands for water management. P & I stands for policy and institution. L stands for legislation. S stands for society. En stands for environment. '-'stand for 'no data available' or 'not defined.

Ts	Key question	Score detailed	Strategy excerpt	Identified barrier
Ec	-What is the **official financial development assistance** (gross expenditure) for water supply and sanitation?	2	Financial support is moderate	Restricted financial support
	-What is the level of **economic water security**?	3	High water security	No
	-What is the **water pricing for agriculture**?	1	Moderate for water pricing	Costs of water pricing is too low to cover the actual costs
	-What are the **financial subsidies** for water use in agriculture?	2	Moderate financial subsidies	50% of costs are covered by governance for irrigation currently
WM	-What is the **transboundary water dependency ratio**?	1	Higher transboundary water dependency	High water supply dependency on neighbouring countries
	-What is the share of **produced volume** of industrial and municipal wastewater per total population in a country?	2	Moderate wastewater produced per total population	Moderate volume of wastewater to be treated per population
	- What is the **share of treated to produced volume** of industrial and municipal wastewater?	2	High WW treatment potential available	Moderate share of treated WW to produced volume, meaning potentially not much water is treated in comparison to available WW
	-What is the share of **harvested irrigated crop area per cultivated area**?	2	Moderate share of harvested irrigated crop area per cultivated area	Moderate level of control irrigation per cultivated area.
P&I	-What is the **proportion of monitoring and reporting** system **in comparison to other countries**?	3	Higher proportion of monitoring in international context	No
	-What is the degree of **implementation of national monitoring and reporting** system?	3	Compliance with national monitoring and reporting system	No
L	- What is the **quality of contract enforcement, property rights, and the courts** in each country?	2	In international comparison: Moderate level of quality of contract enforcement, property rights, and the courts	Moderate level of quality of contract enforcement, property rights, and the courts
	- What is the **regulation** for food and non-food crop irrigation with reclaimed water?	2	Partly compliance with legislation	Not allowed to irrigate non-food crop
S	-What is the degree of **implementation of equitable water and wastewater tariffs**	2	Moderate degree of implementation of equitable water and wastewater tariffs	Limitations in the implementation of equitable water and wastewater tariffs
	-What share of population is using **improved sanitation services**?	3	Wide use of sanitation services	No, yet there is a large amount of treated WW that could be used for water reclamation
	-What is the **social acceptance** of a country towards water reuse for agriculture?	-	N/Av	N/Av
En	-What is the status of **national water reuse regulations for irrigation** in comparison with the international BS ISO 16075-2: 2015 water quality guideline?	3	Compliance	No
	- What is the share of the **area equipped for irrigation that has become salinized**?	3	Higher share of the area equipped for irrigation that has become salinized	No

Please note that the analysed PESTLE results in the following section are indicative. Nevertheless, it is possible to identify indicative trends and possible barriers of the national-level situation regarding the thematic subjects in order to foster the implementation of the wastewater management strategies.

The PESTLE analysis of Tunisia showed positive national-level circumstances for wastewater treatment in general. The main barriers have been identified primarily in the thematic subjects:

"economy" and *"water management"*. Regarding the "economy" situation the water costs for treated wastewater of 0.02 €/m^3 are too low to cover the actual treatment costs to meet the required regulation standards for irrigation. It is important to highlight that treated wastewater in Tunisia is subsidized and its price is half the price of conventional water. This explains the low score regarding the water pricing for agriculture. Therefore, the price is skewed because the costs are not internalized, leading to an inefficient market equilibrium. This in turn, decreases incentives to invest in new water treatment technologies which could mitigate the problem of groundwater salination and its subsequent water scarcity (AbuZeid u.a. 2014). Regarding the *"water management"* situation, the following main barriers have been identified: (i) high water supply dependency on neighboring countries, and (ii) a moderate share of treated wastewater to produced wastewater volume. The high water supply dependency on neighboring countries can partially be explained because of the salinity of the groundwater and the general reluctancy to accept treated water (MADFORWATER D3.4 - 2019)

2.3.7 Potential implementation PESTLE: Morocco

Based on the research described in Deliverable 5.2 MADFORWATER developed indicative strategies for identifying barriers to an effective water management and reuse on a national level Table 12. The discussion of the identified barriers relatively to Morocco is provided in the subsequent paragraphs.

Table 12: Morocco's result of multi criteria analysis of different key questions, strategy excerpt, identified barriers and (economic) instruments. The results of the national-level conditions for water reuse assessment. 'Lower' national-level conditions for water reuse is in red and equivalent to the score '1', moderate national-level conditions for water reuse in yellow and equivalent to the score '2', 'higher' national-level conditions for water reuse in green and equivalent to the score '3'. Ts stands for Thematic subject. Ec stands for economy. WM stands for water management. P & I stand for policy and institution. L stands for legislation. S stands for society. En stands for environment. '-'stand for 'no data available' or 'not defined

Ts	Key question	Score detailed	Strategy excerpt	Identified barrier
Ec	-What is the **official financial development assistance** (gross expenditure) for water supply and sanitation?	1	Financial support is lower	Limited growth based on financial support per WW produced
	-What is the level of **economic water security**?	2	Moderate water security	Improve water security
	-What is the **water pricing for agriculture**?	1	Higher for water pricing costs	Costs of water pricing is too low to cover the actual costs
	-What are the **financial subsidies** for water use in agriculture?	-	N/Av	N/Av
WM	-What is the **transboundary water dependency ratio**?	3	Lower transboundary water dependency	No
	-What is the share of **produced volume** of industrial and municipal wastewater per total population in a country?	3	Lower volume of wastewater produced per total population	No
	- What is the **share of treated to produced volume** of industrial and municipal wastewater?	1	High WW treatment potential available	Lower share of treated WW to produced volume, meaning potentially not much water is treated in comparison to available WW
	-What is the share of **harvested irrigated crop area per cultivated area**?	1	Lower share of harvested irrigated crop area per cultivated area	Lower share of harvested irrigated crop area per cultivated area
P&I	-What is the **proportion of monitoring and reporting** system **in comparison to other countries**?	-	N/Av	N/Av
	-What is the degree of **implementation of**	-	N/Av	N/Av

Ts	Key question	Score detailed	Strategy excerpt	Identified barrier
	national monitoring and reporting system?			
L	- What is the **quality of contract enforcement, property rights, and the courts** in each country?	2	In international comparison: Moderate level of quality of contract enforcement, property rights, and the courts	Moderate level of quality of contract enforcement, property rights, and the courts
	- What is the **regulation** for food and non-food crop irrigation with reclaimed water?	3	Compliance with legislation	No
S	-What is the degree of **implementation of equitable water and wastewater tariffs**	-	N/Av	N/Av
	-What share of population is using **improved sanitation services**?	3	Wide use of sanitation services	No, yet there is a large amount of treated WW that could be used for water reclamation
	-What is the **social acceptance** of a country towards water reuse for agriculture?	-	N/Av	N/Av
En	-What is the status of **national water reuse regulations for irrigation** in comparison with the international BS ISO 16075-2: 2015 water quality guideline?	1	Lower compliance	Stricter implementation of regulation and higher compliance with ISO 16075-2
	- What is the share of the **area equipped for irrigation that has become salinized**?	3	Higher share of the area equipped for irrigation that has become salinized	No

Please note that the analysed PESTLE results in the following section are indicative. Nevertheless, it is possible to identify indicative trends and possible barriers of the national-level situation regarding the thematic subjects in order to foster the implementation of the wastewater management strategies.

The PESTLE analysis of Tunisia showed a positive national-level circumstances for wastewater treatment in general. The main barriers have been identified primarily in the thematic subjects of *"economy"* and "*water management"*. From an "economy" perspective, the water costs for treated wastewater of 0.15 €/m^3 are too low to cover the actual treatment costs to meet the required regulation standards for irrigation. This tariff does not vary according to the volume of water consumed, and there is no fixed tariff applied for each unit of cultivated land (MADFORWATER, 2019b). No data on subsidies were available at the time of writing this report. Nonetheless, the treated wastewater price is still too low to cover treatment costs. This prevents the incentive for wastewater treatment companies to invest in a new technology that would treat the wastewater according to the irrigation regulation for food crops. Regarding the *"water management"* situation, the following main barriers have been identified: (i) a moderate share of treated wastewater to produced wastewater volume, and (ii) a lower share of harvested irrigated crop area per cultivated area. According to the PESTLE analysis, around 30% of total produced wastewater (industrial and municipal) are treated (FAO, 2011; AbuZeid *et al.*, 2014). Consequently, there is still potential to achieve a higher proportion of treated wastewater. To achieve this, investments in existing and new wastewater treatment plants must be expected. The lower share of harvested irrigated crop area per cultivated area is explained by a share of around 18%. This result is supported by FAO (2018), which also estimated that nearly 20 percent of Morocco's arable land is currently equipped for irrigation. Therefore, the potential to increase the amount of irrigated land is high.

2.4 Catalogue of instruments for policy recommendations to foster implementation for integrated water & land management strategies

In this section, we aim to develop a catalogue of economic instruments proposed for the supply and demand side and other locally relevant measures to promote the implementation of the proposed strategies. The purpose of the catalogue of instruments is to facilitate water reuse in Egypt, Morocco and Tunisia. The structure of this section includes first the method and the results in the catalogue of instruments.

2.4.1 Methods for developing a catalogue of instruments

2.4.1.1 Method for identification of instruments

To identify the most promising instruments to facilitate water reuse, different instruments were considered in the research related to the MADFORWATER project. Economic instruments are used to add economic value to water in order to justify the need for the rational allocation of water as a scarce resource. There exist a variety of economic instruments that can be used in water management. In this section, we present a brief overview of the most usually applied instruments. In general, two different types of instruments can be distinguished. Firstly, the quantity-based instruments, where the quantity of water is limited and thus, if trade is permitted, a price is established through the trade market. Secondly, the price-based instruments, where the price is directly or indirectly influenced by instruments (e.g. increase through taxes or decrease through subsidies). Another not-classifiable instrument related to water management is the insurance instrument. Table 13 gives an overview about the main types of instruments and their differences, supplemented by examples. The source of this economic instruments is based on the Deliverable 5.1 from the H2020 MADFORWATER project (MADFORWATER Project, 2018). The detailed description of the different type of instruments can be found in Deliverable 5.2.

Table 13: Economic instrument overview (MADFORWATER Project, 2018).

Type of instrument	Examples
Price-based instruments	**P1**: Pricing/ water tariffs **P2**: Subsidies or other financial assistance (e.g. assisted loans) **P3**: Taxes
Quantity-based instruments	**Q1:** Quotas (command-and-control) **Q2:** Water markets/ water trading
Non-classified instruments	**N1:** Insurance

To facilitate a comprehensive development of the water reuse, the economic instruments were complemented with non-economic instruments. These instruments include the following sections and instruments:

<u>Water management:</u>

- Capacity building
- Technology scale up and further development
- Increase of enforcement
- Institutional coordination, regional planning and

- Training for the proposed strategy and in the use of the new innovative irrigation technology
- Introducing a model for irrigation scheduling to remove the human factor

Legislation:

- Increase of legal enforcement and/or the adoption of new water quality regulations

Society

- Fostering social acceptance of treated wastewater reuse

Environment

- Monitoring and reporting of the water quality after treatment (e.g. with additional disinfection step)

2.4.1.2 Method for closed question survey with experts and stakeholders

The closed question survey was used to refine and confirm the identified measures on how to overcome specific barriers. The identified barriers and their measures are described in Table 15. This application consisted of 2 steps: 1 preparation; 2 Closed question survey.

Step 1: Preparation. The preparation stage consists of data preparation of our previous survey (chapter 2.3) and the development of the closed question survey. The identification of the measures and barriers has been completed by transferring the results from Table 15 to the individual countries. This led to 8 barriers for Egypt, 10 for Tunisia, and 8 for Morocco. Of which one to four measures were identified. This approach was chosen to refine and confirm the measures with local experts and stakeholders. This in turn strengthens the practical applicability of the developed catalogue of instruments for policy recommendations.

Per country five to six experts and stakeholders were contacted with subject knowledge in wastewater treatment. Two to three experts and stakeholders were willing to share their knowledge in phone call interviews. For this we used the phone but also Skype.

Step 2: Closed question survey. The closed question survey intended to identify the suitability of the proposed measures to overcome country specific barriers to support the implementation of the proposed strategies. For this, in the first questions the experts and stakeholders were asked to evaluate the suitability of different measures on how to overcome barrier and to provide clarifying comments. The suitability was divided as not suitable, poorly suitable, reasonably suitable, and highly suitable; as well as no answer was possible if the participants had too little background knowledge about the strategies. Then the experts and stakeholders were asked about their professional background and their number of years of experience. The professional background was divided in the categories "Local governance", "National governance", "Manager of a company", "Plant operator", "Engineer / technician", "Farmer", and "Other, please state:". The years of experience were divided in the years: "0-5", "5-10", "10-20", and ">20".

2.4.2 Catalogue of instruments with expert and stakeholder inputs

Based on the results of the comparative evaluation of the IWLM strategies in section 2.3 we identified indicative strategy specific barriers and instruments. The discussion of the proposed measures and instruments is provided in the subsequent paragraphs. Table 14 provides an overview of all proposed strategies with the corresponding technology description and associated costs. Based on these 13 proposed strategies we identified a catalogue of instruments for policy recommendations to address the barriers identified in the comparative evaluation of the IWLM strategies (see Table 15).

Table 14: Overview of resulting top-ranked options from the DST application, the MADFORWATER pilots in Egypt, Morocco and Tunisia, and the agro-economic model

Egypt	*Morocco*	*Tunisia*
DST-based results	*DST-based results*	*DST-based results*
EG1: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops **Technology suggested:** No treatment necessary **Treatment costs:** No additional costs	**MO1**: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops **Technology suggested:** No treatment necessary **Treatment costs:** No additional costs	**TU1**: Reuse of municipal WWTP typical secondary effluent for irrigation of non-food crops **Technology suggested:** No treatment necessary **Treatment costs:** No additional costs
EG2: Reuse of typical municipal wastewater for agriculture purposes in desert areas **Technology suggested:** Lagooning: Australia I **Treatment costs:** 0.35 EUR/m^3	**MO2**: Reuse of typical municipal wastewater for irrigation of crops to be eaten raw. **Technology suggested:** Wetlands: Nicaragua **Treatment costs:** 0.14 EUR/m^3	**TU2**: Reuse of municipal WWTP typical secondary effluent for irrigation (NT 106.03 standard) **Technology suggested:** Wetlands: Nicaragua **Treatment costs:** 0.13 EUR/m^3
Pilot-based result	*Pilot-based result*	*Pilot-based result*
EG3: Reuse of drainage Canal Water for irrigation **Technology suggested:** MADFORWATER Pilot (Lake Manzala, Egypt) **Treatment costs:** 0.38 EUR/m^3	**MO3:** Reuse of municipal WWTP tertiary effluent for olive trees irrigation **Technology suggested:** MADFORWATER Pilot (Agadir, Morocco) **Treatment costs:** 0.27 EUR/m^3	**TU3:** Reuse of municipal WWTP secondary effluent for irrigation **Technology suggested:** MADFORWATER Pilot (Chotrana, Tunisia) **Treatment costs:** 0.45 EUR/m^3 **TU4:** Reuse of textile WW for non-food crops irrigation **Technology suggested:** MADFORWATER Pilot (Gwash, Tunisia) **Treatment costs:** 0.64 EUR/m^3
Agro-economic model result	*Agro-economic model result*	*Agro-economic model result*
EG4: Water (re)use in the technology scenario (agro-economic model) **Technology suggested:** Use of WW for irrigation with innovative gated pipes and calibrated nozzles	**MO4:** Water (re)use in the policy scenario (agro-economic model) **Technology suggested:** Use of WW for irrigation with innovative calibrated nozzles	**TU5:** Water (re)use in the policy scenario 1 (agro-economic model) **Technology suggested:** Use of WW for irrigation with innovative calibrated nozzles

Table 15: Catalogue of instruments of IWLM strategies from a technological perspective. Barriers I-III are national-level barriers identified by the PESTLE analysis, and barriers IV-XI are barriers identified by the February 2020 survey in the workshop with different stakeholders . P & I stand for policy and institution. WM stands for water management. L stands for legislation. S stands for society. En stands for environment. '-'stands for 'no data available' or 'not defined.

Identified barriers and suggested instruments to foster implementation				Refinement of suitability of strategy			Comments		
Barrier I:	Freshwater is too cheap to incentivize treatment plants to produce and sell TWW at production costs								
Strategies concerned:	Egypt: EG1, EG3	Tunisia: TU1, TU2, TU3, TU4	Morocco: MO1, MO2, MO3, MO4	Egypt:	Tunisia:	Morocco:	Egypt: Farmers already are paying for the price of energy. Also, not feasible based on the Egyptian culture.	Tunisia: - Difficult to manage water pricing in Tunisia. If increased/removed the water pricing and then people cannot pay price of either water or the treatment. This is a national security problem. - First, it is not about the Tariffs. It is because of the quality. - Second, it is about the tariffs. - Wastewater treatment plant does not have enough subsidies to produce water. Give it away for almost free. - The removal of subsides or other financial assistance can help that the farmer can understand that the water has a price.	Morocco: - Water pricing not so much for small village sell it to cover the costs - No law on this, every region does it differently. The response depends from region to region.
Instruments I:	P1: Pricing/ water tariffs P2: Remove subsidies or other financial assistance (e.g. assisted loans) P3: Taxes			P1: Not suitable P2: Not suitable P3: Not suitable	P1: reasonably suitable P2: reasonably suitable P3: reasonably suitable	P1: Poorly suitable P2: Poorly suitable P3: Poorly suitable			
Barrier II:	Only a fraction of the total WW produced is actually treated. In comparison to available WW, not much water is treated.								
Strategies concerned:	Egypt: **EG1, EG2, EG3, EG4**	Tunisia: **TU1, TU2, TU3, TU4**	Morocco: **MO1, MO2, MO3, MO4**	Egypt:	Tunisia:	Morocco:	Egypt: Farmers will be willing to use reclaimed water if it is treated.	Tunisia: - There is need to rethink the entire water management system in the country	Morocco: - Subsidies are good at the beginning, because of problems such
Instruments II:	P1: Pricing/ water tariffs for fresh water			P1: Highly suitable	P1: Highly suitable	P1: Not suitable			

	P2: Subsidies or other financial assistance (e.g. assisted loans) at the beginning of new technology	P2: Highly suitable	P2: Highly suitable	P2: Highly suitable		- Only for the beginning - First, it is not about the tariffs. It is because of the quality. - Second, it is about the tariffs. - Wastewater treatment plant does not have enough subsidies to produce water. Give it away for almost free. - The removal of subsides or other financial assistance can help that the farmer can understand that the water has a price.	as clogging or ages '- Cannot compete with the price of conventional water
Barrier III:	Lack of awareness and knowledge on wastewater reuse. Further treatment facilities are required.						
Strategies concerned: **Instruments III:**	Egypt: **EG1**, **EG2**, **EG3**, **EG4** Tunisia: **TU1**, **TU2**, **TU3**, **TU4** Morocco: **MO1**, **MO2**, **MO3**, **MO4** WM: Capacity building WM: Technology scale up WM: Institutional coordination, regional planning and training for the proposed strategy	Egypt: WM: Reasonably suitable WM : Reasonably suitable WM: Reasonably suitable	Tunisia: WM : Highly suitable WM : Highly suitable WM : Highly suitable	Morocco: WM : Highly suitable WM : Highly suitable WM : Highly suitable	Egypt: - Inter governmental coordination is difficult and trained on inter disciplinary work	Tunisia: - There are good options but currently the practical implemental solutions are missing, consequently, only after they have been implemented the awareness and knowledge is recommended - Currently the situations are working for themselves, consequently there is much potential. .	Morocco: First, water management is important with awareness campaign, especially form the government. Second, train the operators for a good management Third, train the users of treated waste water: clogging, against algae's, schedule the irrigation, amount of fertilizers that is in the reused water. - They do water reuse and irrigate

									golf course from M'Zar WWTP.
Barrier IV:	Some users do not trust the quality of reclaimed water								
Strategies concerned:	Egypt: **EG1**	Tunisia: **TU1**	Morocco: **MO1**	Egypt:	Tunisia:	Morocco:	Egypt: - Environmental instrument: more monitoring: for poor farmers, does not matter, big farms for exporting sure - Water management instrument, more training: Because people do not know the type of pollution, e.g. industrial and pesticides → engineers do not know the - Especially across different sectors of industry or governance - It is really about investment	Tunisia: - The government is revising the water code and legislation. Currently they have the drafts are in the parliament. - Legal instruments are important, because the legislation forbids to use for all crops. - Training is especially important for farmers and the agency to improve the irrigation capacity	Morocco: - The monitoring is obligatory for treated wastewater at the WWT and end-users. The frequency in the monitoring plan for each parameter is required. '- The legal enforcement is a major issue. The problem is, how to enforce the law. Need to start to give penalties. Problem have the law but do not re-enforce it. '- Regarding institutional coordination, Morocco does not have a person that is responsible person who is responsible have for the reuse. It has to be clearly stated. '- Measurements already being done.
Instruments IV:	En: Monitoring and reporting of the water quality after treatment (e.g. with additional disinfection step) L: Increase of legal enforcement and/or the adoption of new water quality regulations WM: Institutional coordination, regional planning WM: Training for the proposed strategies			En: Highly suitable L: Reasonably suitable WM: Highly suitable WM: Highly suitable	En: Highly suitable L: Highly suitable WM: Highly suitable WM: Highly suitable	En: Reasonably suitable L: Highly suitable WM: Highly suitable WM: Highly suitable			
Barrier V:	Water loss through evaporation as a main issue of water ponds								
Strategies concerned:	Egypt: **EG2**			Egypt:			Egypt: -		

Instruments V:	WM: Cover the maturation pond to decrease water evaporation from direct sunlight WM: Water management instruments: Build natural based system to reduce water evaporation (natural based systems such as hedgehogs, dew and fog collection)		WM: Not suitable WM: Reasonably suitable			
Barrier VI:	Higher land costs because of maturation ponds					
Strategies concerned:	Egypt: **EG2**		Egypt:		Egypt: - Yet one of three interviewees stated this was not implementable because of the current high loans in Egypt.	
Instruments VI:	P2: Subsidies or other financial assistance (e.g. assisted loans) at the beginning of new technology		WM: Highly suitable			
Barrier VII:	Innovative irrigation technologies (for farmers) often require high investment costs					
Strategies concerned:	Egypt: **EG4**	Morocco: **MO3**, **MO4**	Egypt:	Morocco:	Egypt:	Morocco:
Instruments VII:	P2: Subsidies or other financial assistance (e.g. assisted loans) at the beginning of new technology WM: Training in the use of the new innovative irrigation technology		P2: Highly suitable WM: Highly suitable	P2: Highly suitable WM: Highly suitable	- Maintenance and training are very important	- Regarding subsidies in drip irrigation, the government gives up to 60% subsidies for large farms and the farms with less than 5ha receive 100% subsidies.
Barrier VIII:	Water loss through evaporation as a main issue of a constructed wetland					
Strategies concerned:	Tunisia: **TU2**		Tunisia:		Tunisia:	
Instruments VIII:	WM: Construct subsurface wetlands to tackle the issue of a high evaporation rate *Consequently:* P2: Subsidies or other financial assistance (e.g. assisted loans) at the beginning of new technology		WM: Reasonably suitable P2: Reasonably suitable		- In some areas 30-70% of water is lost, especially in deserted areas.	
Barrier IX:	High costs to construct wetlands					
Strategies concerned:	Tunisia: **TU3**		Tunisia:		Tunisia:	
Instruments IX:	P2: Subsidies or other financial assistance (e.g. assisted loans) at the beginning of new technology		P2: Highly suitable WM: Reasonably suitable		- The investment would need to be very high.	

	WM: Institutional coordination, regional planning and training for the proposed strategy		
Barrier X:	• Soil and groundwater pollution stemming from irrigation with treated textile wastewater • Excessive costs of the proposed technology to reuse textile WW for non-food crops irrigation		
Strategies concerned: **Instruments X:**	Tunisia: **TU4** EN: Periodic monitoring and reporting of water and soil quality WM: Institutional coordination, regional planning WM: Training for the proposed strategy P2: Subsidies or other financial assistance (e.g. assisted loans) at the beginning of new technology	Tunisia: EN: Highly suitable WM: Highly suitable WM: Highly suitable P2: Highly suitable	Tunisia: -
Barrier XI:	Human factor as a possible risk of not knowing how to use new technologies		
Strategies concerned: **Instruments XI:**	Tunisia: **TU4** / Morocco: **MO3** WM: Introducing a model for irrigation scheduling to remove the human factor WM: Institutional coordination, regional planning WM: Training for the proposed strategy	Tunisia: WM: Highly suitable WM: Highly suitable WM: Highly suitable Morocco: WM: Reasonably suitable WM: Highly suitable WM: Highly suitable	Tunisia: - Additionally, there is need to revise the agricultural mapping of Tunisia regarding less water required fruits and vegetables. Morocco: - Model irrigation is good for large farms only and not small farms.
Barrier XII:	Reluctancy of farmers to use treated wastewater		
Strategies concerned: **Instruments XI:**	Egypt: **EG1**, **EG2**, **EG3**, **EG4** Tunisia: **TU1**, **TU2**, **TU3**, **TU4** Morocco: **MO1**, **MO2**, **MO3**, **MO4** SO: Fostering social acceptance of treated wastewater reuse EN: Monitoring and reporting of the water quality	Egypt: SO: Highly suitable EN: Reasonably suitable Tunisia: SO: Highly suitable EN: Highly suitable Morocco: SO: Highly suitable EN: Reasonably suitable	Egypt: - Water use association do encourage farmers to change from surface to modern techniques. And in the same way, use gated pipes is very easy and make demonstration farms. '- Egyptian farms feel jealousy, then the farmer wants to be better. Consequently, a Tunisia: - Water quality monitoring and training to farmers and operators of waste water treatment plant. '- There is need to increase to tertiary treatment '- Farmers would need to have trust the quality. For this it is suggested to have a good pilot plant and really engagement to Morocco: - To have good treatment and monitoring. - Not a problem

				natural competition to be the best. '- This is only accepted, if good and trustful data is available. '- First improve the water quality also the operation of the secondary treatment plants. Forrest for wood productions - Farmers must get confidence	produce good quality for reuse. E.g. if there is a contract with 3 parties: farmers, producers and government in a contract to ensure the quality. Maybe then the trust of the farmers can be increased.	

2.5 Conclusions and recommendations for integrated water & land management strategies

2.5.1 Conclusions for integrated water & land management strategies

For all the case studies, the adapted treatment trains that could treat wastewater to the desired quality at reasonable costs were presented and combined with the economic case studies into IWLMS in this deliverable. Note that with this evaluation a preliminary assessment was implemented, thus the presented results are to be considered as indicative. The results show that technological options are available for water reuse, but the concept is not widely implemented in Egypt, Morocco and Tunisia. With the results of this deliverable, key barriers and drivers were identified to facilitate the implementation of water reclamation for irrigation. In particular, the considered countries show different characteristics regarding efficient water management, water pricing, subsidies and wastewater tariffs, implementation of monitoring and reporting systems or legal aspects. These were related to the use of reclaimed water for food crop irrigation. However, further exploration of the case studies regarding high potential water reuse and financially affordable wastewater reclamation is required.

Based on the developed IWLMS, we established a workshop with a survey to assess the strategies' suitability in terms of technology and costs. All proposed strategies have been evaluated between reasonably and highly suitable for the implementation in the corresponding countries. However, main concerns of the workshop participants have been the high costs of the proposed technologies, health concerns (missing disinfection step), and social acceptance of the reuse of treated wastewater. Note that the distribution costs were not considered for the IWLMS, but it can be stated that a judicious combination between the location of the wastewater source and the end-user location is crucial. Ideally, the potential reusers should be situated at a lower elevation than the source and the distance should be minimized. If reclaimed water has to be transported uphill after treatment for a long distance, the transportation costs outreach greatly the treatment costs. Considering this and the responses of the stakeholder participants regarding most adequate instruments to foster the implementation of the proposed IWLMS, we propose the following instruments:

- economic instruments such as subsidies, water tariffs, or/and other financial assistances
- water management instruments such as institutional coordination, regional planning and training
- environmental instruments such as monitoring and regularly reporting of water quality
- social instruments such as facilitating the acceptance through environmental instruments

Based on the PESTLE analysis we identified country-specific barriers and drivers. The main underlying identified barriers are:

- fresh water is available at a cheap price
- lack of awareness and knowledge such as capacity building and monitoring
- lack of legislation on wastewater reuse and facilitation of institutional coordination
- lack of WW treatment facilities.

Based on the catalogue of instruments, we established phone interviews with experts and stakeholders to refine the strategies' suitability in relation to the established barriers. More than half of the strategies have been evaluated as highly suitable for the implementation in the corresponding countries to overcome the corresponding barriers. Main inputs of the experts and stakeholders were missing monitoring of the water quality, training to the users of reclaimed water and subsidies, especially at the beginning of a new technology. Note that for the in-depth interviews a highly knowledgeable but limited number of 7 experts and stakeholder could be included. Considering this and the responses of the experts and stakeholder regarding most adequate instruments to foster the implementation of the proposed IWLMS, we propose the following instruments:

- economic instruments such as subsidies, water tariffs, or/and other financial assistances
- water management instrument such as institutional coordination, regional planning and training, capacity building and technological scale up
- environmental instruments such as monitoring and regularly reporting of water quality
- social instruments such as facilitating the acceptance of reclaimed water.

2.5.2 Recommendations for integrated water & land management strategies

To increase the water security, and consequently economic security in all three target countries, both IWLMS and policy recommendations are needed. This means from the perspective from the MADFORWATER project, that investing in water management strategies can possibly increase water security by supporting water supply continuity by means of providing reclaimed water to the end water users (e.g. farmers). Therefore, water management actions are primarily recommended (e.g. capacity building and technological scale up). To successfully implement the water management actions, they should be accompanied by economic instruments (e.g. subsidies or/and other financial assistances). Congruently, to ensure the water quality of the reclaimed water, additional environmental and legal actions are required (e.g. monitoring of water quality). These actions can only be implemented with increased social acceptance of reclaimed water use. This can be achieved by employing social instruments (e.g. building trust among farmers). Detailed country-specific recommendations are presented in the following:

2.5.2.1 Egypt

Since Egypt relies heavily on the Nile River as its main source of water and has been suffering from severe water scarcity in recent years, the need for a combination of technologies and strategies that can facilitate the implementation of water reclamation for irrigation is apparent. Currently, Egyptian laws prohibit local wastewater reuse options. However, by law the drainage systems must comply with a certain water quality standard (as listed under the Law 48), which can often not be met. Furthermore, the PESTLE analysis identified main barriers in the thematic subjects of *"economy"* and *"water management"*, for instance, the lack of use of the pricing instrument for a scarce good in the form of water tariffs (due to cultural traditions), as well as a moderate share of treated wastewater to produced wastewater volume. This in turn was refined with experts and stakeholder in-depth interviews.

Considering this and the favourable conditions for wastewater reuse in Egypt, we recommend the following instruments to support the proposed IWLMS for Egypt:

a) Economic instruments to reflect the scarcity of water accordingly

   i. Water pricing/tariffs (P1)

   ii. Subsidies or other financial assistance (e.g. assisted loans) especially at the beginning of a new technology

b) Wastewater management instruments to build knowledge about and foster awareness of wastewater reuse

   i. Capacity building to obtain, improve, and retain the skills, knowledge, tools, equipment, and other resources to foster the awareness of wastewater reuse

  - ii. *Institutional coordination, regional planning and training for the proposed strategies to support knowledge building about wastewater reuse*

c) **Environmental and legal instruments to comply with water quality standards for drainage canals**

  - i. *Monitoring and reporting of the water quality after treatment (e.g. with an additional disinfection step)*
  - ii. *Increase of legal enforcement and/or the adoption of new water quality regulations*

d) **Social instruments to foster the social acceptance of reclaimed water**

  - i. *Building trust among farmers with advanced water treatment in pilot plants and water quality monitoring*
  - ii. *Ensure trustful data of water quality monitoring is available.*

2.5.2.2 Tunisia

Since Tunisia has large deserted areas and limited fresh water sources, it has been suffering from severe water scarcity in recent years. Consequently, the need for a combination of technologies and strategies that can facilitate the implementation of water reclamation for irrigation is apparent. Currently, the limited subsidies and lack of quality guarantee of reclaimed water. Furthermore, the PESTLE analysis identified main barriers in the thematic subjects of *"economy"* and *"water management"*, for instance, the lack of wide subsidies and control of water quality monitoring. This in turn was refined with experts and stakeholder in-depth interviews.

Considering this and the favourable conditions for the wastewater reuse in Tunisia, we recommend the following instruments to support the proposed IWLMS for Tunisia:

a) **Economic instruments to reflect the scarcity of water accordingly**
  - i. *Water pricing/tariffs*
  - ii. *Subsidies or other financial assistance (e.g. assisted loans) especially at the beginning of a new technology*

b) **Wastewater management instruments to build knowledge about and foster awareness of wastewater reuse**
  - i. *Capacity building to obtain, improve, and retain the skills, knowledge, tools, equipment, and other resources to foster the awareness of wastewater reuse*
  - ii. *Institutional coordination, regional planning and training for the proposed strategies to support knowledge building about wastewater reuse*

c) **Environmental and legal instruments to comply with water quality standards**

  - i. *Monitoring and reporting of the water quality after treatment (e.g. with an additional disinfection step)*
  - ii. *Increase of legal enforcement and/or the adoption of new water quality regulations*

d) **Social instruments to foster the social acceptance of reclaimed water**

  - i. *Building trust among farmers with tertiary water treatment in pilot plants and water quality monitoring*
  - ii. *Ensuring water quality with for instance a contract with three parties: farmers, producers of reclaimed water and government.*

2.5.2.3 Morocco

Since Morocco has large deserted areas and limited fresh water sources, it has been suffering from severe water scarcity in recent years. Consequently, the need for a combination of technologies and strategies that can facilitate the implementation of water reclamation for irrigation is apparent. Currently, the lack of knowledge and legal enforcement of wastewater treatment are main issues. Furthermore, the PESTLE analysis identified main barriers in the thematic subjects of *"economy"* and *"water management"*, for instance, there is need for further subsidies at the beginning of a technology, because of a lack of wide subsidies and a responsible person for the reclamation of water. This in turn was refined with experts and stakeholder in-depth interviews.

Considering this and the favourable conditions for the water reclamation in Morocco, we recommend the following instruments to support the proposed IWLMS for Tunisia:

e) Economic instruments to reflect the scarcity of the water accordingly

i. *Water pricing/tariffs especially in small villages*
ii. *Subsidies or other financial assistance (e.g. assisted loans) especially at the beginning of a new technology*

f) Wastewater management instruments to build knowledge about and foster awareness of wastewater reuse

i. *Capacity building to obtain, improve, and retain the skills, knowledge, tools, equipment, and other resources to foster the awareness of wastewater reuse*
ii. *Institutional coordination, regional planning and training for the proposed strategies to support knowledge building about wastewater reuse*

g) Environmental and legal instruments to comply with water quality standards for

i. *Monitoring and reporting of the water quality after treatment (e.g. with an additional disinfection step)*
ii. *Increase of legal enforcement and/or the adoption of new water quality regulations*

h) Social instruments to foster the social acceptance of reclaimed water

i. *Building trust among farmers with advanced water treatment in pilot plants and water quality monitoring*
ii. *Ensuring water quality.*

3 Policy recommendations to promote the adoption of the proposed technologies and integrated water and land management strategies in the target countries (Task 6.2: UPM)

3.1 Scope, aim and objectives to identify policy recommendations

The main aim of this task is ‘to identify potential policy measures aimed at facilitating the implementation and social acceptance of the proposed Integrated Water & Land Management Strategies (IWLMSs), with particular emphasis on the associated economic instruments. Note that this section is subject to different methodologies. Therefore, the analysis and the underlying results are independent from Chapter 2. To perform this analysis, we have used two specific and complementary approaches, with distinct methodological content. These are, namely, the agro-economic model (specified in DEL. 5.2) and a Multicriteria analysis. Both approaches are integrated and are meant to identify policy recommendations for the implementation of economic and other regulatory instruments to support the adaptation of MADFORWATER technologies to achieve IWLMSs. These policy recommendations were developed considering socio-economic and environmental impacts, analysis of barriers and opportunities and feasibility of application.

This section is organized in 4 sub-chapters (Figure 12): in sub-chapter 3.2, we present the methodology applied to identify policy recommendations. In sub-chapter3.3, the results obtained from the application of the two selected methodologies are presented. Sub-chapter 3.4 is devoted to evaluating potential barriers and opportunities to the adoption of the proposed IWLMSs. Finally, sub-chapter 3.5, contains the final policy recommendations based on the two types of methods used, the agro-economic model and the Multicriteria analysis.

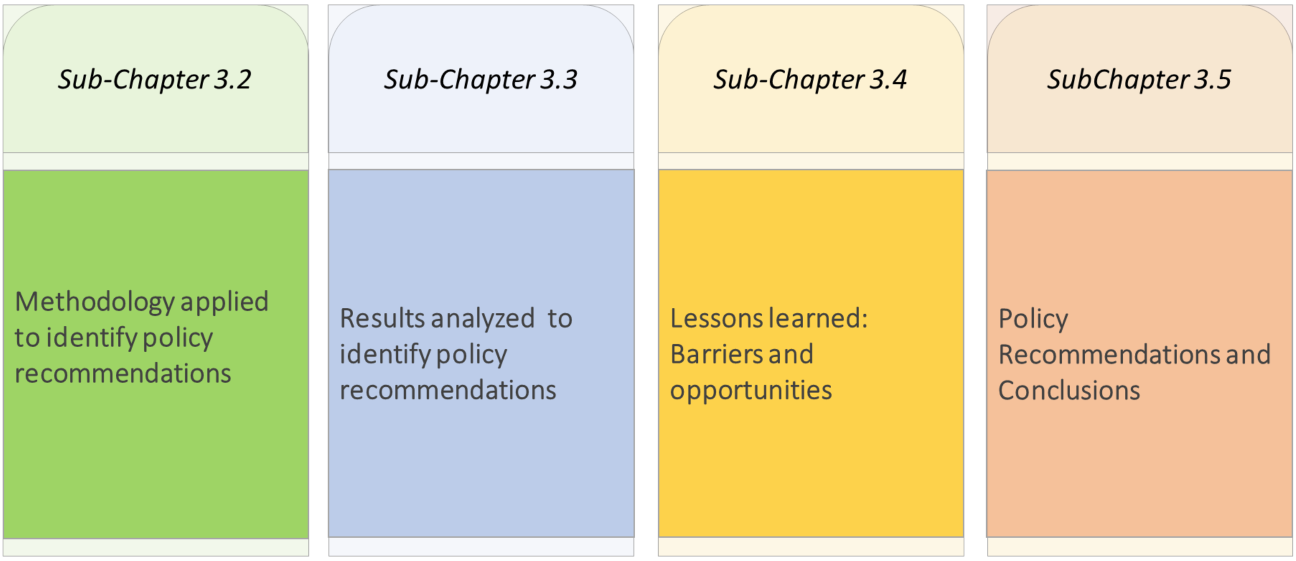


Figure 12: Architecture of the proposed task for the policy recommendations to promote the adoption of the proposed technologies and integrated water and land management strategies in the target countries.

3.2 Methodology applied to identify policy recommendations

3.2.1 General structure

As indicated in the previous section, one of the methodological approaches used in MADFORWATER is a DST farm-based agro-economic model that was developed and calibrates for the three MADFORWATER case studies. These are: the irrigated farming system in the Kafr-El-Sheikh Region in Egypt, the citrus farming system in Souss-Mass region in Morocco and the annual and permanent irrigated farming system in the Nabeul governorate in Tunisia. The models in the three regions were developed and calibrated to simulate the farmers' response to different water management and WW treatment technology scenarios. In parallel, we developed only for the Tunisia case study a Multi Criteria Analysis (MCA), whose objective is to rank the technologies and strategies simulated in the agro-economic model by interviewing a wide array of representative stakeholders, and ultimately to identify potential policy recommendations. The MCA was supported by multiple-stakeholder engagement actions. Specifically, the MCA used, on the one hand, the results of the Tunisia agro-economic model (backed by successive fieldwork missions) and , on the other hand, explicit stakeholder consultation activities.

Figure 13 shows the integrated methodological framework to provide policy recommendations for promoting the adoption of WWT technologies and IWMSs. This framework integrates two analytical methods: (1) the agro-economic model (developed in tasks T3.3 and T5.3), and the derived results of the application of selected technological, economic and policy scenarios; and, (2) the Multicriteria Analysis (MCA), developed in Task 6.2.

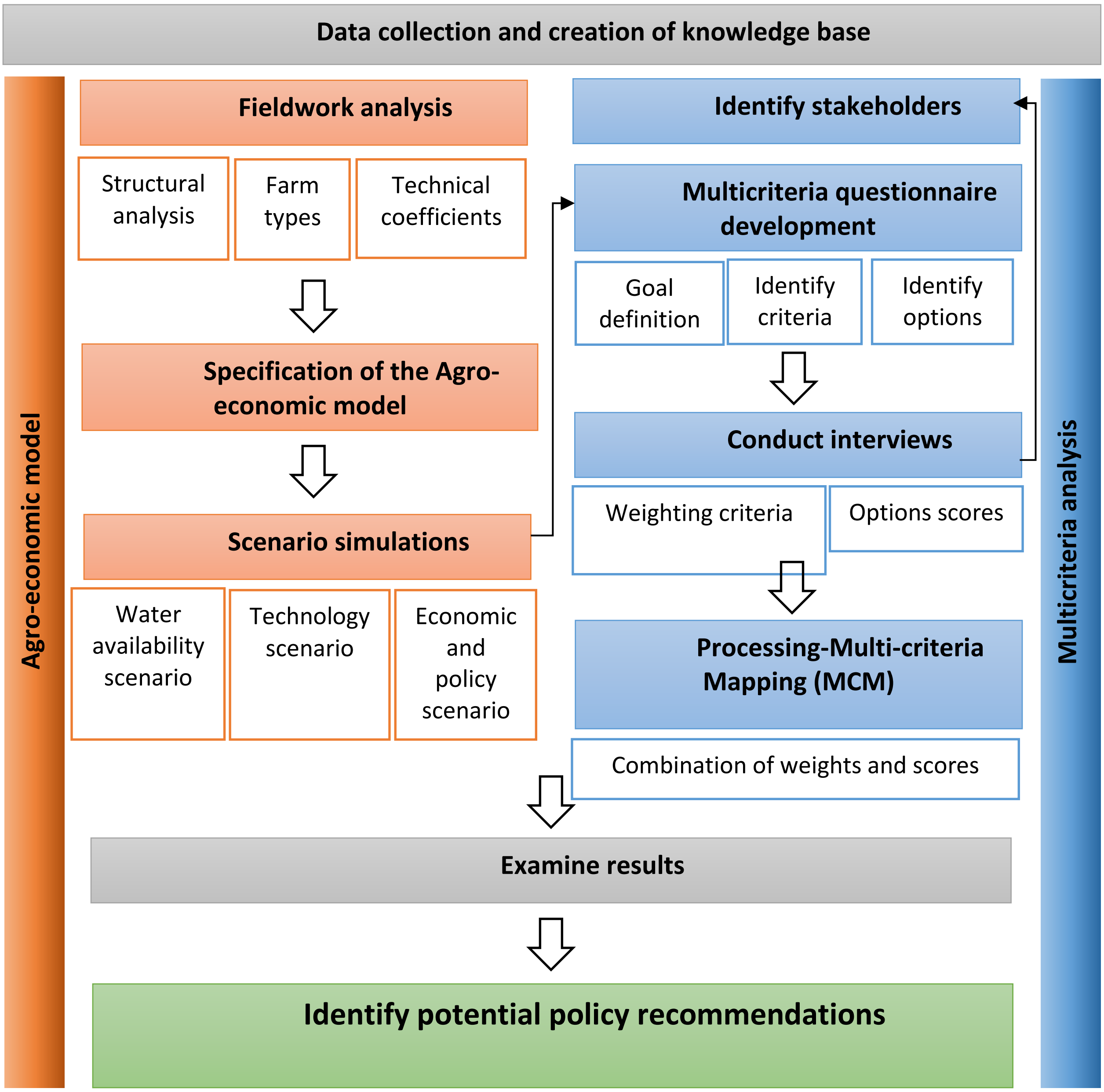


Figure 13: General structure of the methodology applied to identify policy recommendations

Source: Own elaboration

In the agro-economic model (shown on the left hand side of Figure 13), the proposed scenarios consider the multifaceted perspective of the water and agricultural sectors including technological, economic, social, environmental, and institutional aspects. The final goal of all scenarios is to reduce water vulnerability in the three MADFORWATER case studies. Key parameters are the increased amount of water obtained from improved water reuse and the implementation of efficient irrigation technologies for the enhancement of wastewater treatment, and the reuse of treated wastewater for irrigation. The scenarios are characterized by different parameters, and can be summarized as follows: (1) the water availability scenario that refers to an increase in water availability obtained from treated wastewater reuse and a decrease in fertilizer requirement (due to high levels of organic matter in treated WW); (2) the technology scenario, which includes the MADFORWATER new irrigation technologies; and (3) the policy scenario, where different economic instruments for water management are considered, such as water pricing, water quotas and subsidies. Based on the results of the scenarios' simulations, some policy recommendations are identified (see section 6.4.1).

As mentioned in the previous section, we developed in parallel to the agro-economic model, a participatory Multicriteria Analysis (MCA) (shown on the right hand side of Figure 13). The main objective of the MCA is to contrast the opinions of different stakeholders (that represent distinct interest groups) regarding the various solutions identified in the agro-economic model. These options take into account a series of criteria grouped in economic, social, environmental, policy and technological issues (Coburn and Stirling, 2016). The MCA provides a systematic, transparent approach that increases objectivity and can generate reproducible' results (Janssen, 2001). In this analysis, we identified various solutions (or options) from the fieldwork missions and from the results of the scenario simulations. These were then evaluated with the Multicriteria approach, considering the different types of criteria by interviewing selected stakeholders that represent the key interest groups in the area of study.

3.2.2 The Agro-economic model approach

The agro-economic mathematical programming model of constrained optimization, written in GAMS (General Algebraic Modelling System) language, is summarized in Figure 14. The model is extensively described in Del. 5.2 and it is defined at farm level and at aggregated level using the structural parameters of the Nabeul region in Tunisia. This type of farm-based model has been widely used in agricultural economic analysis and specifically for irrigated agriculture. The model optimizes farm income, subject to several constraints: physical (water availability, types of water use, land use), technical (tillage operations, fertilizer use), socio-economic (production costs, labour, prices) and water policy (pricing, subsidies, quotas). Results of the model are the optimal cropping pattern and water allocation strategies followed by the farmers confronted to different types of scenarios.

For the Tunisian case study, the development of the model is based on three fieldwork missions carried out in the region of Nabeul during 2018-2019, that have provided relevant structural, technical, agronomic, economic and social data on the agricultural sector in the region. The model was used to simulate scenarios for an optimal exploitation of the MADFORWATER irrigation technologies (developed in WP3), and for the assessment of the impact of economic instruments. The objective of the model was to improve irrigation efficiency and to enhance wastewater reuse in agriculture. The results of the scenarios simulations can be found in Del. 5.2. They are key to identify policy recommendations to promote the implementation of the proposed MADFORWATER technologies and IWLMSs.

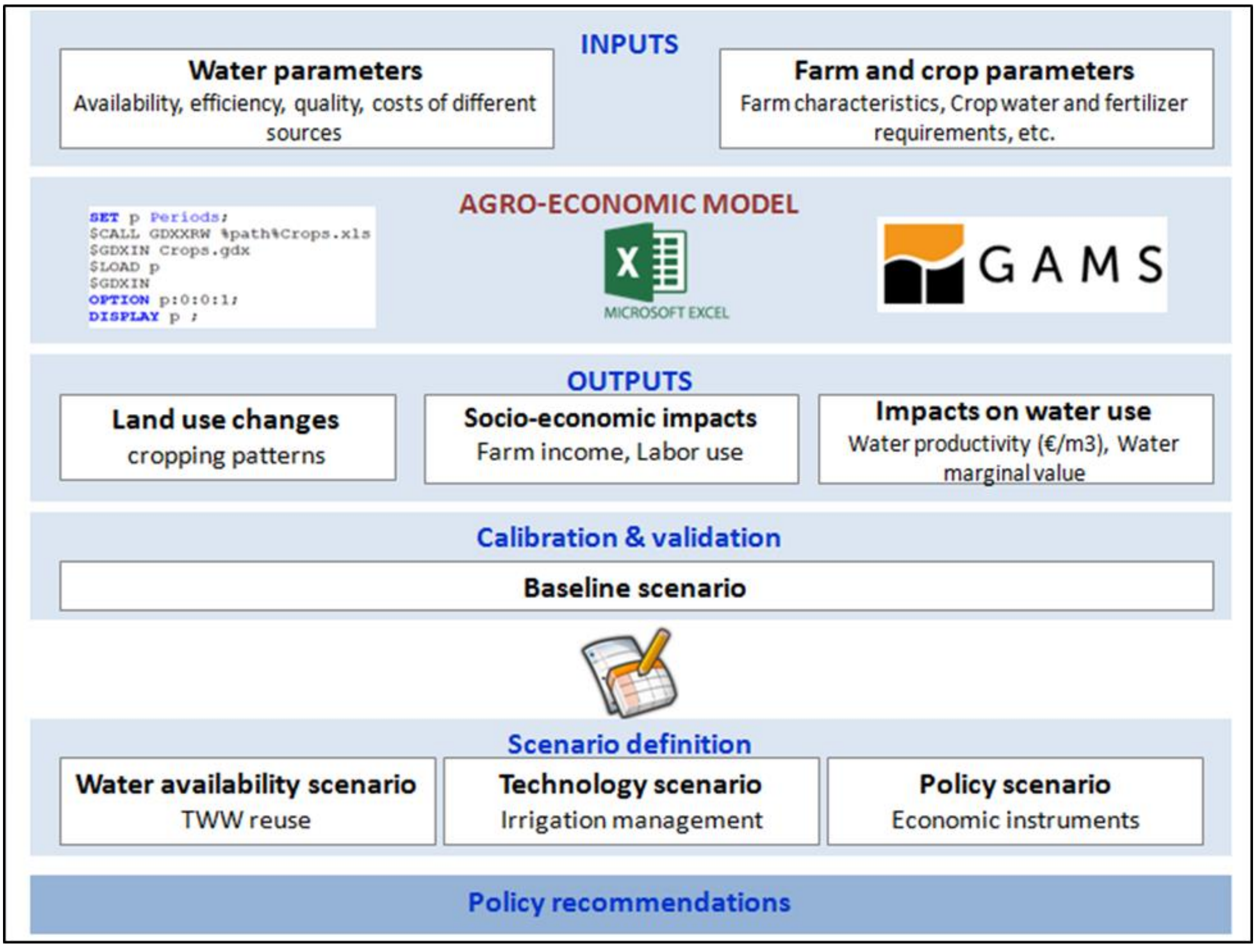


Figure 14: The agro-economic model approach to identify policy recommendations

Source: own elaboration (reproduced from MADFORWATER Newsletter nº 4)

3.2.3 Multi Criteria Analysis (MCA) approach

Multicriteria mapping (MCM) (Stirling, 2006) is a type of Multicriteria Analysis (MCA) used to evaluate various possible solutions (options) to a given problem, taking into account different categories of criteria (economic, social, environmental, technical and policy) by interviewing key stakeholders and evaluate the criteria individually for each solution (Bellamy *et al.*, 2013). In this study, we followed a similar process for the development of the MCM, shown in Figure 15.

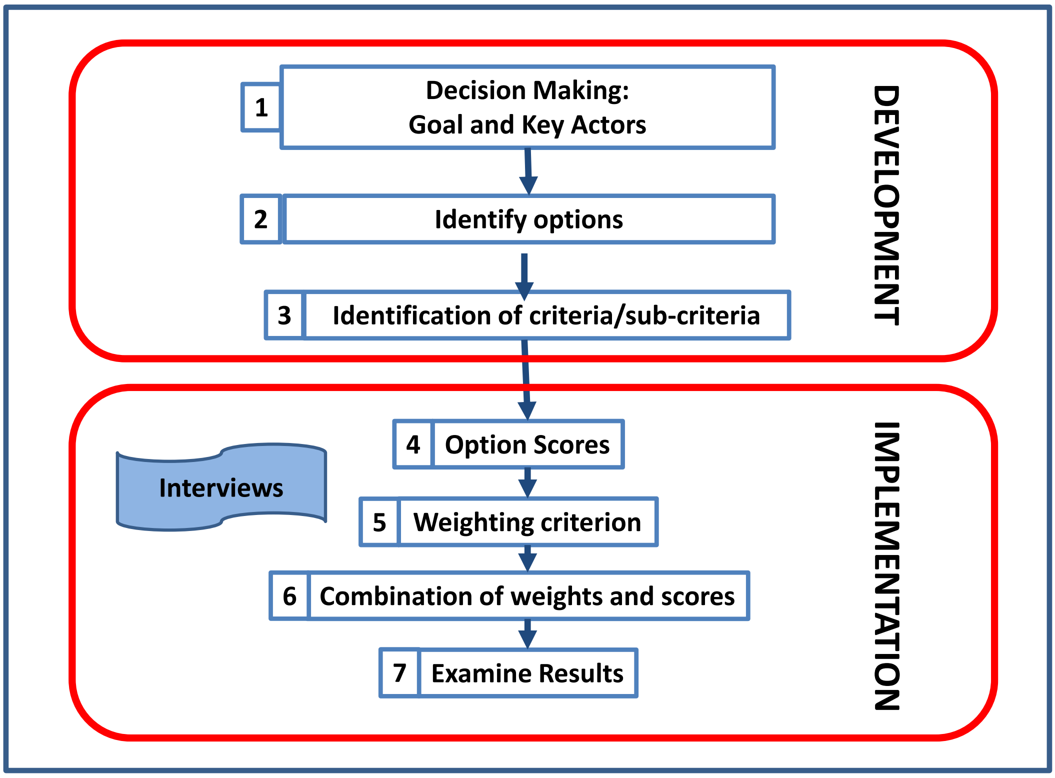


Figure 15: Multicriteria analysis approach to identify policy recommendations

Source: Own elaboration

The process comprises 7 steps, divided into two stages, development and implementation

(A) The stage of development

It includes three steps:

1st step: Identifying objectives and key actors (groups of stakeholders).

2nd step: Once the objectives are defined, the next step is identifying options or solutions to achieving the objectives.

3rd step: Identifying the criteria to be used to compare the options.

In our research, these steps are the following:

First step: The main goal was defined as 'increasing the use of treated wastewater (TWW) in agriculture in Mediterranean African Countries (MAC) region and coping with water scarcity and food security'.

The groups of stakeholders considered in this study are farmers, water managers, policy makers, ecologists and researchers.

Second step: Based on the results of scenario simulation and the fieldwork carried out in the region, a set of solutions (options) were defined to achieve the goal. These options are:

- New plants for treated wastewater to increase the water availability
- New treatment technologies to secure water quality

- New irrigation technologies to increase efficiency in TWW use
- Improve water management (such as water distribution, human health, etc.)
- Economic incentives (such as subsidies, water tariffs, etc.)
- Increasing awareness and education

Third step: A set of criteria groups were chosen: 1 Economic, 2 Social, 3 Environmental, 4 Technical, and 5 Policy. For each group of criteria, a series of sub-criteria were selected (see Figure 16). Then, each criterion was related to a question that was posed to the person interviewed.

The economic criteria group includes two sub-criteria: increase in farm income and public financial feasibility. The social criteria group contains, also, two sub-criteria: capacity to generate employment and social acceptance of the options. In the environmental criteria group, we have considered only one sub-criteria: the protection of environmental resources. The technical criteria group is represented by the speed of implementation of the solutions. Finally, the policy criteria group includes one sub-criteria: the legal and policy implementation feasibility.

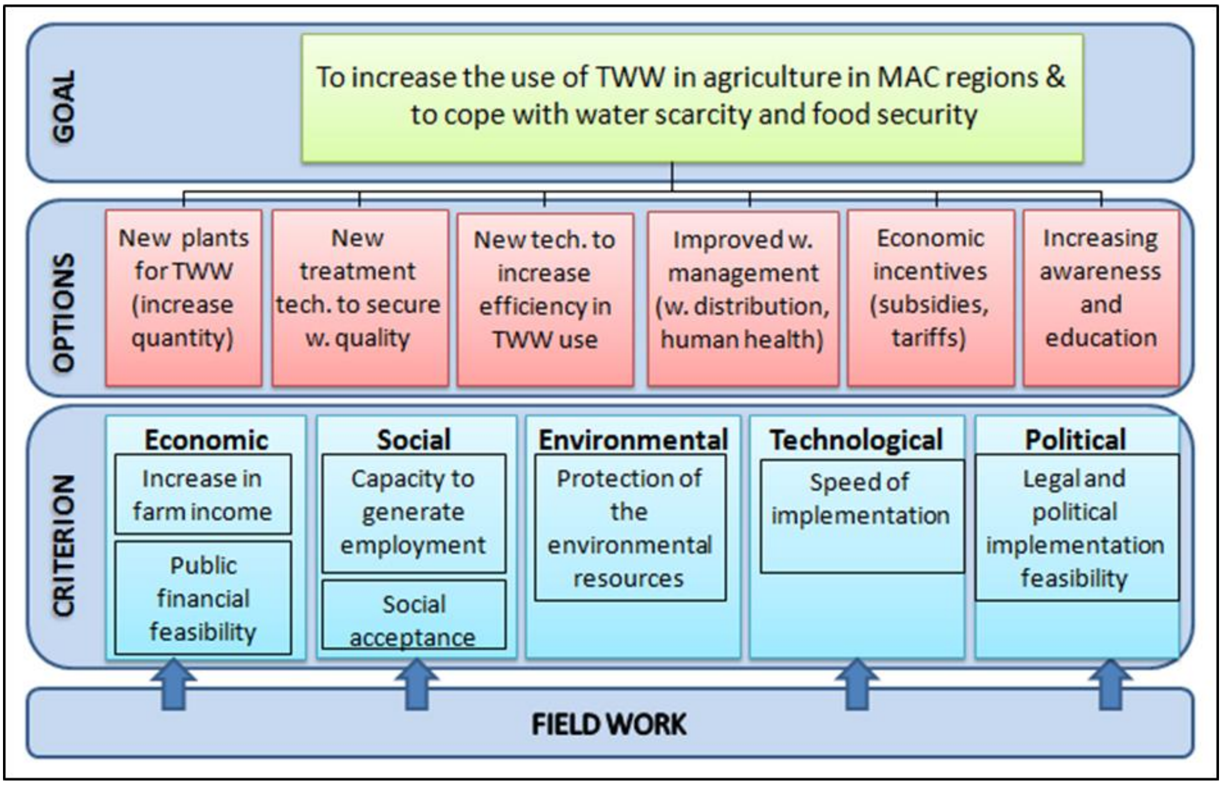


Figure 16: Structure of the Multicriteria Analysis in the Tunisia case study

(B) The implementation stage,

It includes the other steps of the process and are defined as follows:

4th step and 5th step: Interviewing key stakeholders. In this stage, the interviewee must give a range note (from 0 to 100) for each option based on each criterion. The lower part of the range represents the most pessimistic situation according to the interviewee, and the higher part of the range represents the most optimistic situation according to the interviewee. Then, the interviewee must give a weight for the criteria groups.

In total, 25 stakeholders from different groups were interviewed (Table 16). Specifically, the stakeholder groups covered in this analysis are listed as follows (in parenthesis , the number of participants within each group):

- Farmers (11): several farmers from different regions were interviewed with the aim of covering the different areas represented by 3 types of farms and different water sources. The aim was to capture the heterogeneity of the farming systems in Nabeul (Tunisia) based on the different opinions provided by farmers. This is necessary because the MCM analysis has to be consistent with the agro-economic model simulations that cover all three farm types in the region.
- Water manager (2)
- Policy makers (3)
- Ecologists (1)
- Researchers (8)

Table 16: Multicriteria analysis : stakeholders groups

SH Group	Description	Contact and institution
Farmers	End-users of TWW	Farmers from the region
		Agricultural cooperatives
		Agricultural associations
W. managers	Water management institutions	Groupements de développement Agricole (GDAs)
		Direction générale des ressources en eau (DGRE)
		Office National de l'assainissement (ONAS)
Policy makers	Regional and national governments, and other political authorities	Commissariat Régional de Développement Agricole (CRDA)
		Ministry of Agriculture & Ministry of Health
		Agence Nationale de Contrôle Sanitaire et Environnemental des produits (ANCSEP)
		Direction General du Genie Rural et de l'Exploitation de l'Eau (DGGREE)
		Direction de l'Hygiène du Milieu et de la protection de l'Environnement (DHMPE)
Ecologists	Environmental NGOs and others	Agence Nationale de Protection de l'Environnement (ANPE)
Researchers	Researchers and research centre related with the MADFORWARER field	Institut National de Recherche en Genie Rural, Eaux et Forets (INRGREF)
		Centre International des Technologies de l'Environnement de Tunis (CITET)
		MADFORWARER partners (UMA, UTM)

The processing of the questionnaires (see Appendix I) was done by the MCM tool software.

6th step: Combining weights and scores. In this step, scores and weights were combined in order to calculate the overall weighted scores at each level in the hierarchy. In this case, the combination of weights and scores was automatically done by the MCM tool software that is a web-based software tool to enable collection and analysis of data (Stirling, 2006).

7th step: The last step is the analysis of results obtained from the MCM tool such as the ranking of options considering all involved stakeholders or a specific stakeholder's perspective. Also, the overall weights of criteria that is indented to analyse relative magnitudes of weightings assigned to different issues under a selected perspective.

As an example, the results of the MCM software are shown in Figure 17.

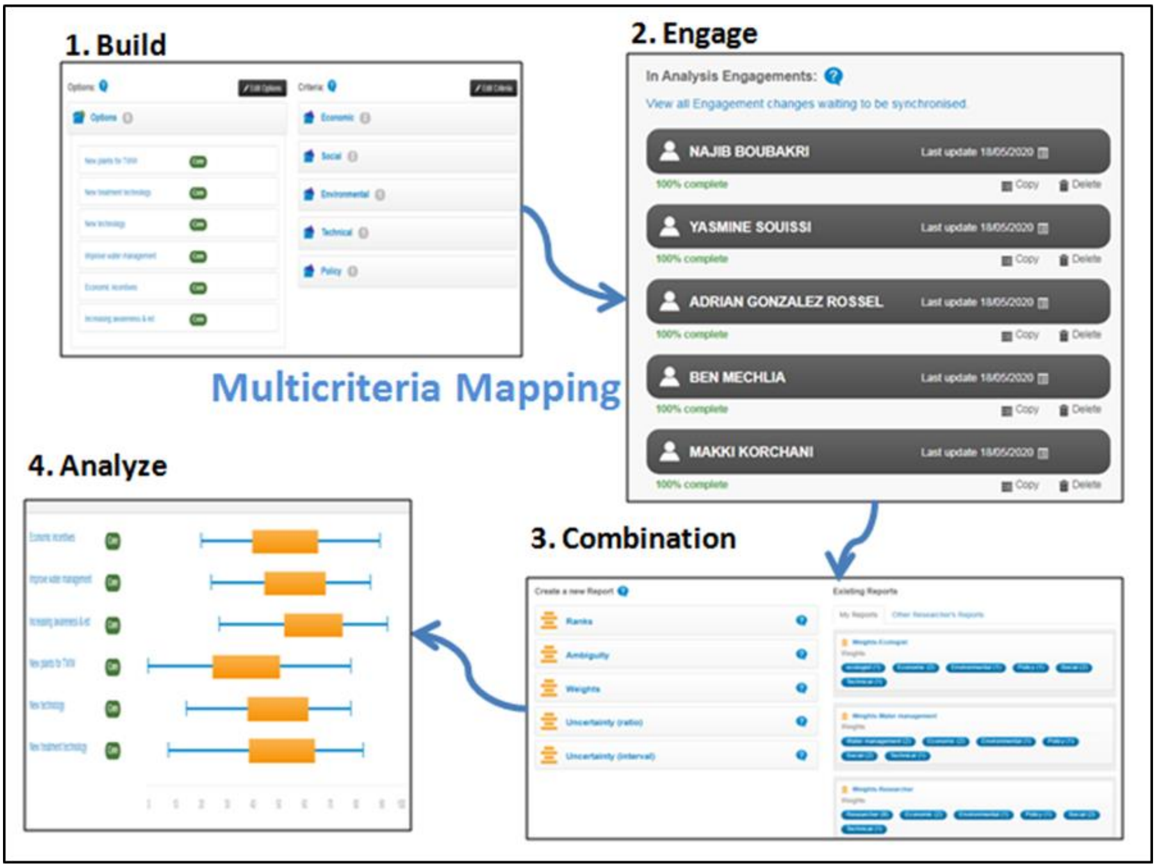


Figure 17: Multicriteria Mapping software results

Source: Elaborated based on MCM software (Stirling, 2006)

3.3 Results analyzed to identify policy recommendations

3.3.1 Results from the agro-economic model (Egypt, Morocco, and Tunisia)

This section corresponds to section 3.2 of MADFORWATER deliverable 5.2 “Wastewater management strategies and water & land management strategies in agriculture”. It contains a summary of the scenarios simulated and of the derived results.25 in the target countries (Egypt, Morocco and Tunisia).

3.3.1.1 Egypt

For the Egypt case study, the scenarios are defined as follow:

<u>The baseline scenario</u>

The baseline scenario corresponds to the current situation in the studied region. In this scenario, 17,787 m^3/year/ha of water are provided as an average where 19,310 m^3/year/ha, 18,670 m^3/year/ha and 15,100 m^3/year/ha are the amount of water provided in the different sections of the mesqa. Water distribution and application efficiency changes, for each different irrigation method, along the sub-branch canal according to the position of the mesqa – head, middle, and tail section - as given in the following: Paddy.Head 55%, Paddy.Middle 50%, Paddy. Tail 45%, Furrow.Head 65%, Furrow.Middle 60%, Furrow. Tail 55%. The price of the energy used by the farmers to pump the drained water into the system is equal to 0.061 Euro/kWh.

By changing one or more factor, different scenarios can be obtained:

The technology scenario

In this scenario, a new irrigation technology - the gated pipe - is proposed.

Gate pipe is a new type of high flow calibrated nozzle able to provide constant discharges as pressure decreases: self-compensating gated outlets minimizes each pressure variation and maintain constant outlet discharges within a certain operating range. The main objective to develop such technology is to increase the distribution uniformity of water applied at farm level and, therefore, to reduce the amount of water going to the drainage system in favor of more clean water available at the upstream irrigation canals.

Figure 18: Egypt: Self-compensating gated pipe system

The annualized cost of the equipment is estimated to 232 Euro for each hectare of irrigated land equipped with the new technology while an additional cost of 145 Euro/year for the O&M is estimated compared to the traditional irrigation system currently used. Both the costs of investment and operation & maintenance have to be paid by the farmers. The effect of the new technology appears in the efficiency of the irrigation system: a uniform efficiency of 0.75% is considered along all the sub-branch canal for the furrow irrigation; nothing changes for the paddy method. The price of the energy is set equal to 0.061 Euro/kWh. In combination with the 'water availability scenario' (see below), decreasing quantities of water supplied to farmers are also simulated.

The water availability scenario

In this scenario, the quantity of water supplied to farmers can be gradually reduced in combination with the efficiency gains achieved in the 'technology scenario' thanks to the introduction of the gated pipes. A uniform reduction of 10% along all the mesqa has been simulated and price of the energy is set equal to 0.061 Euro/Kwh.

The policy scenarios

In this scenario, given both the introduction of the innovative gated pipe (with the associated costs and efficiency gains) and the reduction in the water supply: an innovation subsidy policy is simulated to cover all or part of the gated pipe equipment and O&M costs. Further, an energy pricing policy is also simulated by increasing the current price for electricity.

Results of the simulated scenarios provide with some useful elements to draft water resources management strategies in the area. Given the availability of a technology able to improve the traditional irrigation widely used in Egypt into an innovative and more efficient system, the implementation of some economic tools is simulated in order to evaluate their effects in terms of reduction of drainage water and hence of water quality deterioration.

Obtained results demonstrate that the introduction of the gated pipe allows to achieve two relevant positive impacts: i) to reduce the drained water re-pumped into the system and, consequently, reduce the quality deterioration of the water available for irrigation practices (MADFORWATER, 2019b), and ii) to improve the equity of the system measured as the difference among the ratio between the water supply and the gross irrigation requirement of the cultivated crops in the different sections of the mesqa.

However, the adoption of the gated pipe technology could be not accepted by the farmers since, 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 O&M costs of the gated pipe technology (Figure 19).

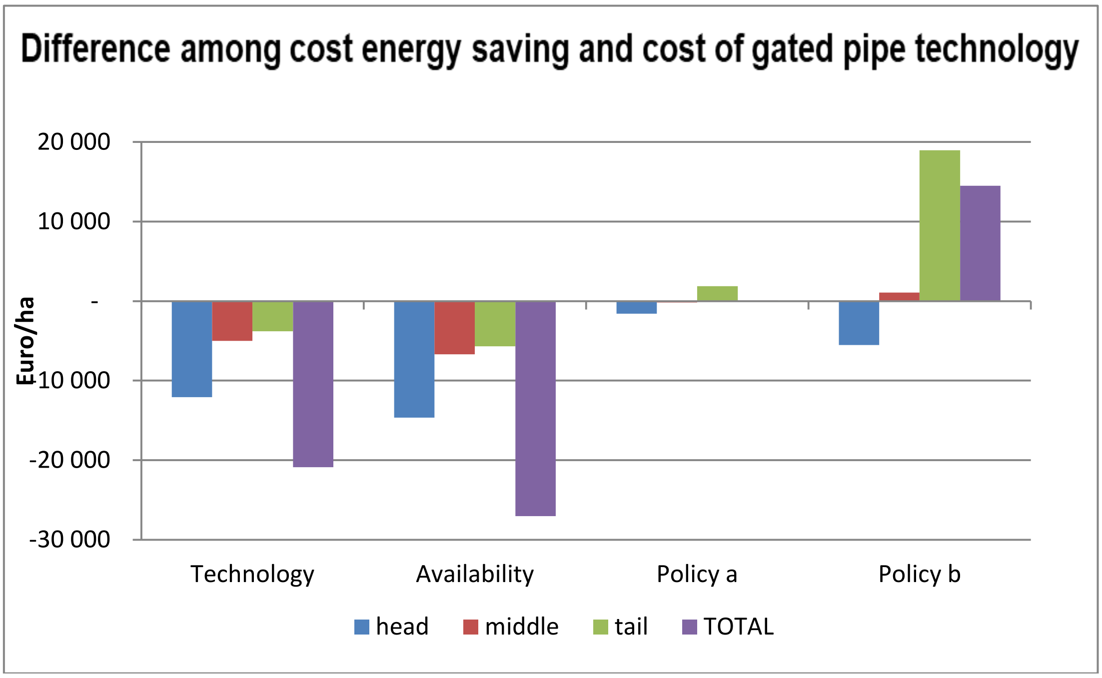


Figure 19: Egypt: Difference between cost of energy saving and cost of gated pipe technology

Source: reproduced from Del. 5.2

As shown in Figure 19, only by fully covering the total cost of the investment and O&M, the energy savings in terms of costs exceed the cost of the gated pipe with a positive impact on farmers' income and a consequent favourable attitude of farmers towards the adoption of innovation.

Obtained results also show that the mere introduction of gated pipe is not able to contribute to reduce the weight of the agricultural sector on the country's total water consumption if the efficiency gains are not "transferred" into the water policy. The "transmission" of the efficiency gains into a new water policy is crucial to determine the effects of the measures simulated. Our results indicate that only the joint introduction of the innovation and of a new policy of water supply could achieve the objective to reduce the amount of water used by agriculture without affecting the level of satisfaction of the farmers. On the other side, the combined implementation of the gated pipe and of a new policy of water supply partially reduces the effects on the drained water.

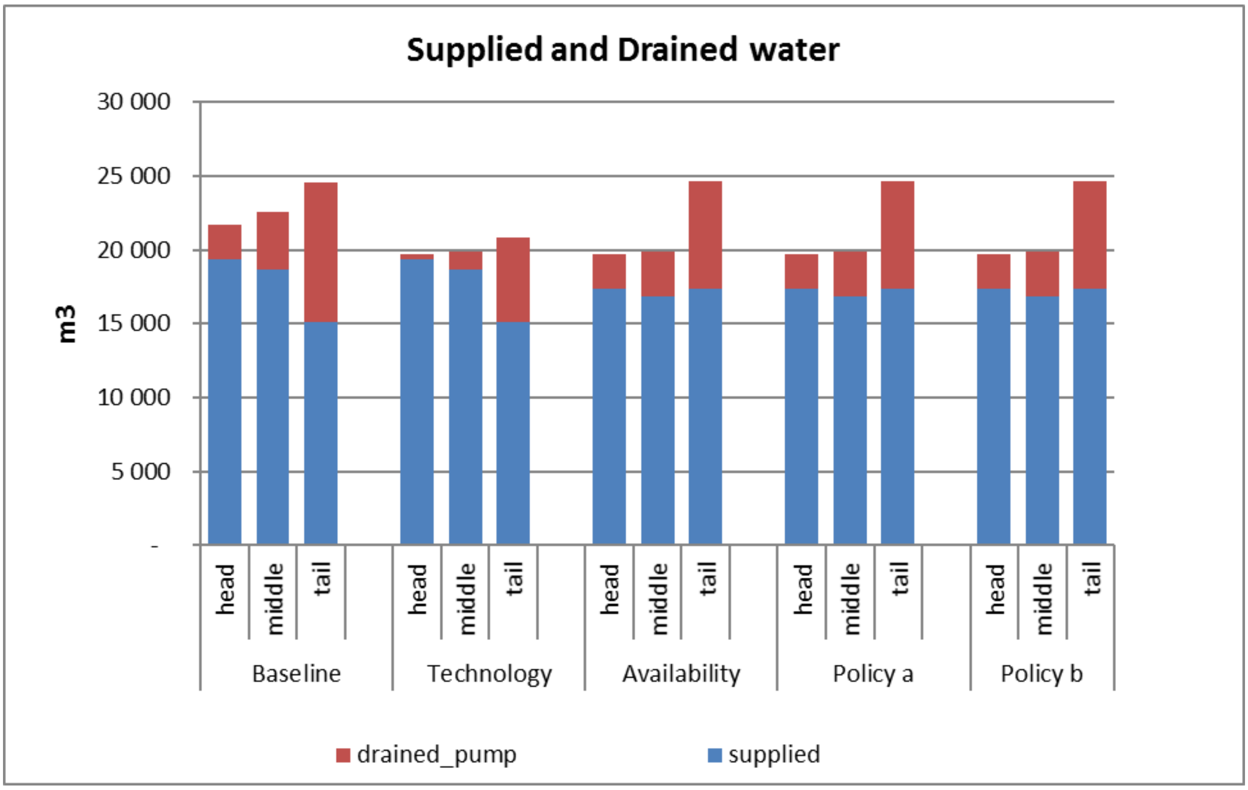


Figure 20: Egypt: Supplied and drained water in the different scenarios and in the three sections along the mesqua.

Source: reproduced from Del. 5.2

From the simulated scenarios, it also emerges that the costs to achieve these important results can be distributed differently between farmers and the community. However, a partial coverage of the costs seems to be a condition for the adoption of the technology by farmers: with a coverage of 30% of the only O&M costs it is possible to preserve the starting income levels and obtain significant results in terms of reduction in water consumption and total drainage.

Furthermore, it could be useful to evaluate the possible effects on crop yields deriving from the use of variable percentages of reused water.

To conclude it is important to stress that, since different and conflicting objectives can be achieved, it is crucial to define the priorities among the different objectives – reduction of water demand, reduction of the reused drainage, economic performance of the farmers and their level of satisfaction – in order to design the most effective water policies in this area.

3.3.1.2 Morocco

With respect to the Morocco case study, the scenarios are defined as follow:

The baseline scenario

The baseline scenario corresponds to the current situation in the study region. In this scenario, only fresh water is available for farmers in a sufficient amount (8000 m^3/year/ha). The price of fresh water is equal to 0.15 Euro/m^3 with an efficiency of the drip irrigation system equal to 95%. (from Del. 5.2)

By changing one or more factor, different scenarios can be obtained:

The water availability scenario

In this scenario, the treated wastewater is an additional irrigation water source made available by the innovative technologies proposed and tested by the MADFORWATER project

(MADFORWATER, 2019a). Both fresh water and wastewater, with their current prices are considered: price of wastewater 0.23 Euro/m^3 and price of fresh water 0.15 Euro/m^3. The efficiency for the system is equal to 0.85 for wastewater, and 0.95 for fresh water. The efficiency is considered lower in the case of wastewater, due to the lower quality of this resource. Such lower quality affects the functioning of the system by clogging and salts accumulation on pipes. The Safe Irrigation Management (SIM) model was used in order assess irrigation and nutrient requirements, crops' yields and soil quality in terms of soil salinity under treated wastewater irrigation (Miguel *et al.*, 2020).
Given the characteristics of the TWW and their nutrient content, crops fertilizer requirements are totally satisfied by using this additional irrigation water source. However, the strict use of TWW induces an average yield decrease of 8%, mainly due to the negative impact of the increase of salinity level in the root zone.

The policy scenarios

In this scenario, given the availability of both fresh and treated water and their associated levels of efficiency, 0.95% and 0.85%, respectively, a water pricing policy is simulated by taking constant the price for freshwater (0.15 Euro/m^3) and decreasing more and more the price of treated wastewater starting from its current level of 0.23 Euro/m^3 to 0.08 Euro/m^3.
Also, in combination with the 'technology scenarios' (see below), a public subsidy to the farmer to cover the cost of the innovative calibrated nozzle is also simulated.

The technology scenario

In this scenario, given the availability of both fresh and treated water and their prices, 0.15 Euro/m^3 and 0.23 Euro/m^3, respectively, a new technology – the innovative calibrated nozzle adapted to the irrigation with treated wastewater - was proposed with an annualized cost (including investment costs for nozzle, pumps and pipes and O&M costs such as cleaning solvent and electricity) estimated in 350 Euro/ha. The effect of the new technology appears in the efficiency of the irrigation system: an application efficiency of 0.95% is considered.

Results of the simulated scenarios provide some useful elements to draft water resources management strategies in the area. Farmers' decision about the use of TWW only changes in the water price policy scenarios, when the price of TWW is subject to a certain level of subsidies. Compared with the baseline scenario, 40% of the total land switches to TWW as a source for irrigation. On the contrary, in the water availability and technology scenarios, the cultivated land is totally irrigated with fresh water. We can also deduce that the switch from fresh water to TWW happens to varieties with the least annual water requirements, which is due to the difference between fresh water and TWW in terms of application efficiency. Therefore, the least water demanding crops will be less affected by this loss.

The substitution of fresh water with TWW allows the conservation of an average amount of 2414 m^3 of fresh water per hectare. This important amount has a great socio-economic value, since it can be used for other crucial activities, such as drinking water.

The simulations carried out also reveal that the reuse of TWW helps to save important amounts of fertilizing elements. This results in lower production costs for the farmer, thus confirming impressive results on cereals, forage and vegetable already documented in the literature (Hamdy and Choukr-Allah, 2003).

As for the average annual water costs, in the water availability and technology scenarios it is identical to the baseline scenario since the total land is irrigated with fresh water. In the policy scenario, where the price of TWW (0.1 Euro/m^3) is lower than that of freshwater, the annual water cost has decreased compared to the baseline scenario. These results indicate that subsidies through the water pricing policy are needed to cover the difference in water consumption due to the loss of application efficiency and to the negative effects on crops' yields.

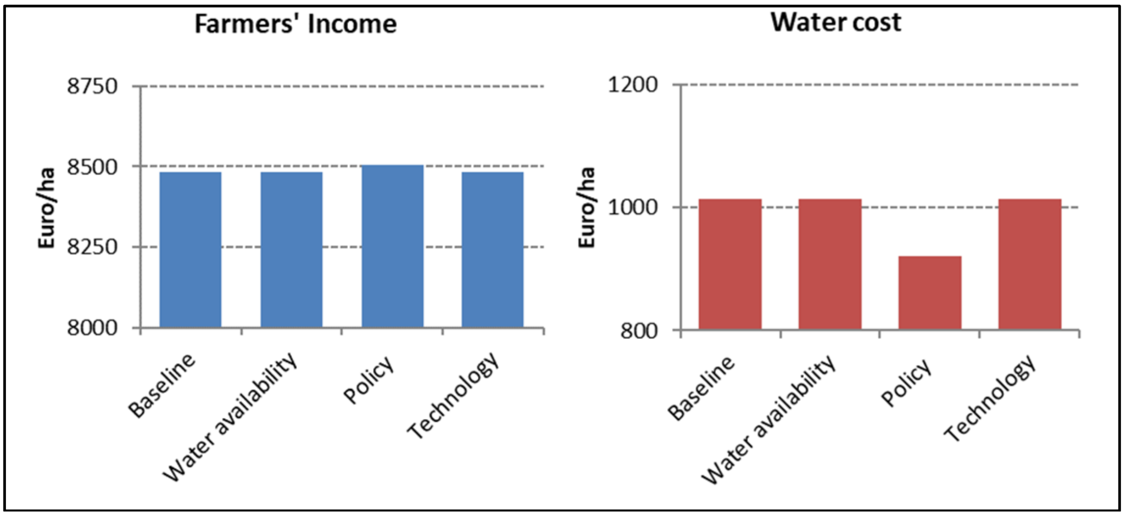


Figure 21: Morocco: Water Cost and Farmers' Income for the different scenarios

Source: reproduced from Del. 5.2

The comparison between the amount of subsidies per unit area and of average income per unit area shows that, in order to achieve a gain of 20 Euro/ha in the farmers' income, 350 Euro/ha of public subsidies are needed. This analysis demonstrates that subsidizing the price of TWW to a level where its cost is lower than fresh water is not justified from a pure economic point of view. However, a more holistic evaluation should also take into account the economic value of the environmental benefits that TWW reuse can generate.

In the case of the technology scenario, the micro-sprinkler technology adapted to low-quality water was introduced and simulations were carried out assuming that the additional cost for the implementation of this technology is subsidized, keeping the cost of TWW at its actual level. As shown in the results of the Technology scenario (Deliverable Del. 5.2), TWW is not suggested as an optimal solution for irrigation, even when the technology cost is totally subsidized. This signifies that the gain in efficiency allowed by the technology does not help to account for the difference in water cost.

Combining the obtained results, it can be concluded that the TWW reuse promotion require to overcome the lack of social acceptance due to inadequate information on benefits (Massoud, Terkawi and Nakkash, 2019), incomplete economic analysis of TWW reuse options, misalignment between water prices and water scarcity and lack of economic incentives for re-use (Frascari *et al.*, 2018).

The results obtained show that the farmers' advantage of saving fertilizer costs could be significant, but farmers should be able to assess these potential savings and to adopt optimal nutrient management strategies. However, with the current price level for the two water sources (0.15 Euro/m^3 and 0.23 Euro/m^3 for fresh and TWW respectively), this positive effect is not sufficient to make TWW reuse an attractive option, thus confirming the low demand for treated waste water reported in the literature (Jeuland, 2015).

The economics of reuse will not be favorable as long as the price of conventional water remains so far below the actual cost of water if, as in this case study, users do not suffer acute shortage of water and have a choice between conventional water and TWW.

The increase in TWW supply must be associated with a good water resource design policy that fills the widespread lack of effective price signals (El Yacoubi and Belghiti, 2002) and restructures the reuse funding.

In fact, with subsidies equal to 0.13 Euro/m^3 for the TWW used by farmers - equal to the difference between the actual cost and the price paid by farmers -, about 40% of the cultivated land is irrigated with TWW and 2414 m^3/ha of fresh water are saved.

It was also found that decreases in wastewater treatment costs – which will vary depending on the extent to which wastewater processing is developed – could contribute to its reuse. In addition, the evaluation of saved fresh water could help to raise public awareness on the effectiveness and opportunities for reuse, emphasizing the "social benefit" generated by this reuse.

It is also to be mentioned that conditions and assumptions on the basis of which the above results have been obtained could change in the future: increasing water scarcity for the agricultural sector could eliminate the choice between the sources that is still preserved in the Moroccan irrigation sector, and the total or partial substitution of fresh water with different sources of non-uniform quality irrigation water will become one of the main future research lines to be explored (Reca *et al.*, 2018).

3.3.1.3 Tunisia

Three fieldwork missions were carried out in the region of Nabeul during 2018-2019, in order to provide relevant structural data on the agricultural sector in the region. During the fieldwork rounds, several sites and institutions were visited such as the Ministry of Agriculture of Tunisia, the Regional Commissariat for Agricultural Development (CRDA) and Agricultural Development Group (GDA). In addition, several farmers from different delegations were surveyed to collect specific farm information. The results of the fieldwork also enabled us to refine the structural analysis of the region and to identify three region-based representative farms: F1 (3ha, vegetables), F2 (2ha, citrus), and F3 (1.5 ha, citrus+olives). Sources of water for irrigation have been considered. Specifically, farm F1 and F2 use conventional water sources (groundwater and surface water respectively) and F3 uses only treated wastewater. Furthermore, they represent typical farms, with the most common crops present in the region of Nabeul. These are horticultural crops such as tomato, potato, pepper, and strawberry, and permanent crops such as olive trees for oil and citrus. Also, the fieldwork missions enabled us to build the simulation scenarios.

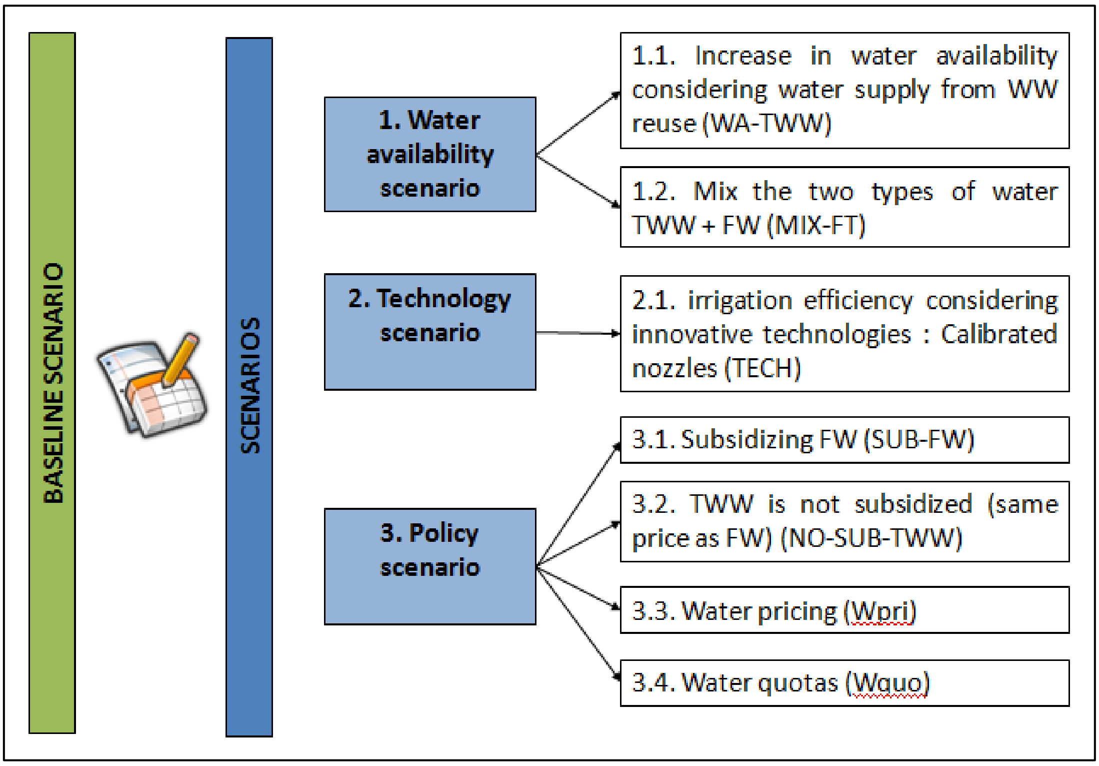


Figure 22: Scenario definition for the Tunisia case study

Source: own elaboration based on Del. 5.2

The baseline scenario

The baseline scenario represents the current situation of the case study, i.e. the starting point for scenario simulations. In this scenario, water availability varies according to the type of farm, type of water (freshwater, treated wastewater), period of the year. The price of water is set at 0.04 €/m^3 for freshwater and 0.02 €/m^3 for treated wastewater, according to official data and official invoices (GDA and farmers). The irrigation system used in all farms is drip irrigation with an irrigation efficiency equal 85% (DGA).

The water availability scenario (TWW reuse)

In this scenario, we are considering an increase in water availability obtained from treated wastewater reuse, particularly in summer to simulate a continuous flow of water throughout all the irrigation period. Two simulations were defined (Figure 22): In the first simulation (1.1), all freshwater availability is replaced by treated wastewater in both periods (summer and winter); In the second simulation (1.2), farmers can mix the two types of water (freshwater and treated wastewater), which applies only to farm F1 (annual crops) and farm F2 (citrus) because farm F3 (citrus + olive) already uses treated wastewater. In both cases (F1 and F2), the assigned amount of treated wastewater varies according to periods and farms types. In this scenario, the price of water is set at 0.02 €/m^3 for treated wastewater and 0.04 €/m^3 for freshwater.

The technology scenario (Irrigation management)

In this scenario, a new irrigation technology (calibrated nozzles) is considered, assuming that irrigation efficiency is enhanced up to 95% and the cost of calibrated nozzles is the same as traditional nozzles. The rest of the parameters (water price, etc.) are the same as used in the baseline scenario.

The policy scenarios (Economic instruments for water management)

In this scenario, we consider that the price of freshwater is subsidized (Figure 22: 3.1) and equal to the price of treated wastewater (0.02 €/m^3), and that the price of treated wastewater is no longer subsidized (Figure 22: 3.2) and equal to the price of freshwater (0.04 €/m^3). Also, different economic instruments are included: Water pricing (Figure 22: 3.3), simulated as a gradual increase of 0.02 €/m^3 in freshwater or treated wastewater price for twenty price levels, to analyse the capacity to adapt of the different representative farms; and Water quotas (Figure 22: 3.4), simulated as a gradual decrease in freshwater or treated wastewater availability, to examine the hypothetical application of a more restrictive environmental policy in the region.

The results of the scenarios simulations (Varela-Ortega *et al.*, 2020a) of the Tunisia case study are at two different levels of aggregation, at the level of the farm and at basin level. Farm level results have been obtained by applying the DST model specified for each of the three selected representative farms and are largely based on the extended fieldwork that has been conducted in the area of study along three different periods. These results capture the way the farmers develop their cropping strategies when they are confronted to different types of technologies as well as socio-economic scenarios. The aggregated results have been developed taking into account a detailed structural analysis based on the surface weight that each type of representative farm has on the overall area of the basin. The results at basin level illustrate the impact of the same type of simulated scenarios in the whole Cap-Bon basin. Both levels of aggregation have proven to be of great importance for analyzing any type of policy intervention based on the application of wastewater management technologies and water reuse and land management technologies as well as economic instruments.

Figure 23 shows the basin scale results on farm income under different scenarios.

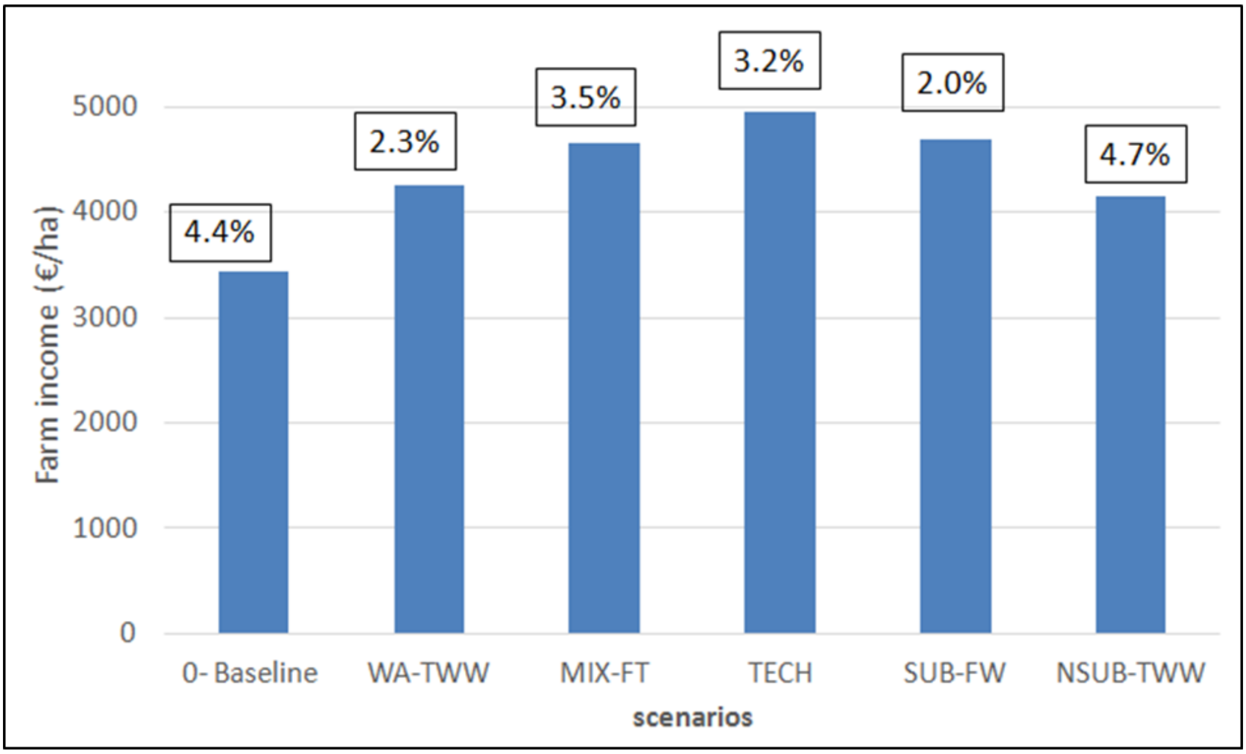


Figure 23: Tunisia: Effects on farm income (basin aggregate) under different scenarios and % ratio (water cost)/(farm income)

Source: own elaboration reproduced from Del. 5.2

Note:

0-Baseline: Current situation of the case study

WA-TWW: Increase in water availability considering water supply from treated wastewater reuse

MIX-FT: Mix the two types of water (treated wastewater and fresh water)

TECH: Irrigation efficiency is enhanced due to the implementation of innovative technologies (Calibrated nozzles)

SUB-FW: The price of freshwater is subsidized and equal to the price of treated wastewater

NSUB-TWW: The price of treated wastewater is no longer subsidized and equal to the price of freshwater

Results show that farm income has increased in all scenarios compared to the baseline scenario, explained by the fact that, with an additional quantity of water, farmers cultivate more profitable crops such as strawberry, citrus and tomato in comparison with the baseline scenario. These results are in line with the fieldwork results.

Scenario TECH (Figure 23) that combines the water availability scenario and the technology scenario is suggested as the optimal scenario with an income gain of 1506 €/ha in comparison with the baseline scenario. Comparing scenario NSUB-TWW (TWW is not subsidizes) with scenario WA-TWW, farm income decreases by 99 €/ha. Based on these scenario simulation results, it can be underlined that the implementation of the MADFORWATER technologies has a positive effect on farm income.

Values in boxes refer to the proportion of water costs over farm income. As Figure 23 shows, there is no much difference on the impact of water costs over farm income across scenarios. Subsidizing Fresh water is the scenario that has a lower impact of water costs over farm income (2.0%), which is reasonable because all types of water are subsidized. On the contrary, when subsidies are eliminated, scenario 6, the cost of water take a higher proportion of farm income (4.7%).

Figure 24 shows the effects on water public costs under different scenarios, that blue boxes represent water public costs without treatment cost and red boxes reflect water public costs with treatment cost. The scenario that requires the highest public expenditure is the water availability scenario (WA-TWW), all the water delivered is Treated waste water, that is subsidized and requires a high treatment cost of a large volume of water. The technology scenario (TECH) is cost-effective in public terms.

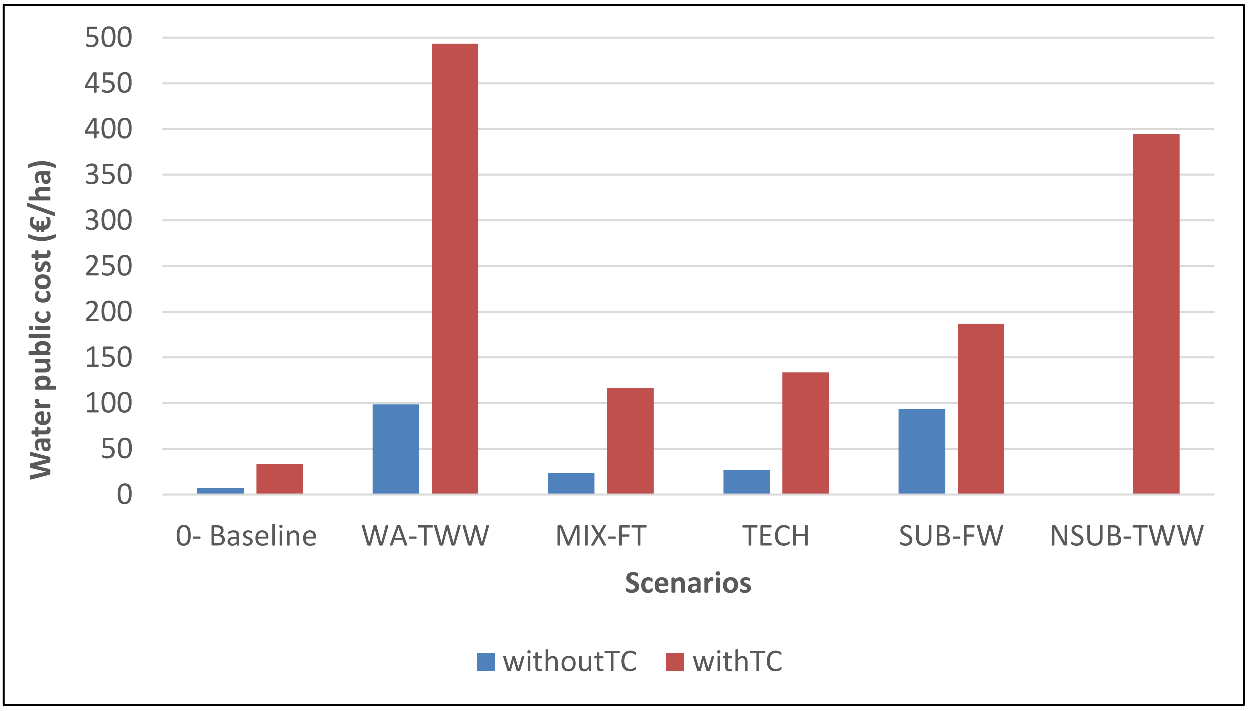


Figure 24: Tunisia: Effects on water public cost (subsidies and cost of water treatment)

Source: own elaboration reproduced from Del. 5.2

Note:

0-Baseline: Current situation of the case study

WA-TWW: Increase in water availability considering water supply from treated wastewater reuse

MIX-FT: Mix the two types of water (treated wastewater and fresh water)

TECH: Irrigation efficiency is enhanced due to the implementation of innovative technologies (Calibrated nozzles)

SUB-FW: The price of freshwater is subsidized and equal to the price of treated wastewater

NSUB-TWW: The price of treated wastewater is no longer subsidized and equal to the price of freshwater

Blue boxes represent water public costs without treatment cost and red boxes reflect water public costs with treatment cost.

Figure 25 depicts the basin-scale results of the farmers' cropping strategies under different scenarios. In comparison with the baseline scenario, we can see an increase in in the area dedicated to more profitable crops (strawberry, tomato and citrus), and, in turn, a decrease in the area cultivated with less profitable crops such as potato. This increase in profitable crops can be explained by several factors. The most important factor is the additional amount of water that permit to cultivate the more water-demanding profitable crops. In fact, the Cap-Bon region is known for being a large producer of profitable crops such as citrus, strawberry and tomato that represent the highest proportion in the region in terms of area and production. In particular, Cap-Bon is considered an important producer of citrus accounting for 85% of the overall national production in 2016 (CRDA, 2016). In addition, the Cap-Bon region concentrated 63% of the national production of tomato in 2016, due to the growth of the number of industrial enterprises for the transformation of agricultural products such as tomato. According to the results of the scenarios simulations and in line with the fieldwork results, the implementation of MADFORWATER technologies as well as economic instruments is likely to promote the increase in the area of these productive and profitable crops.

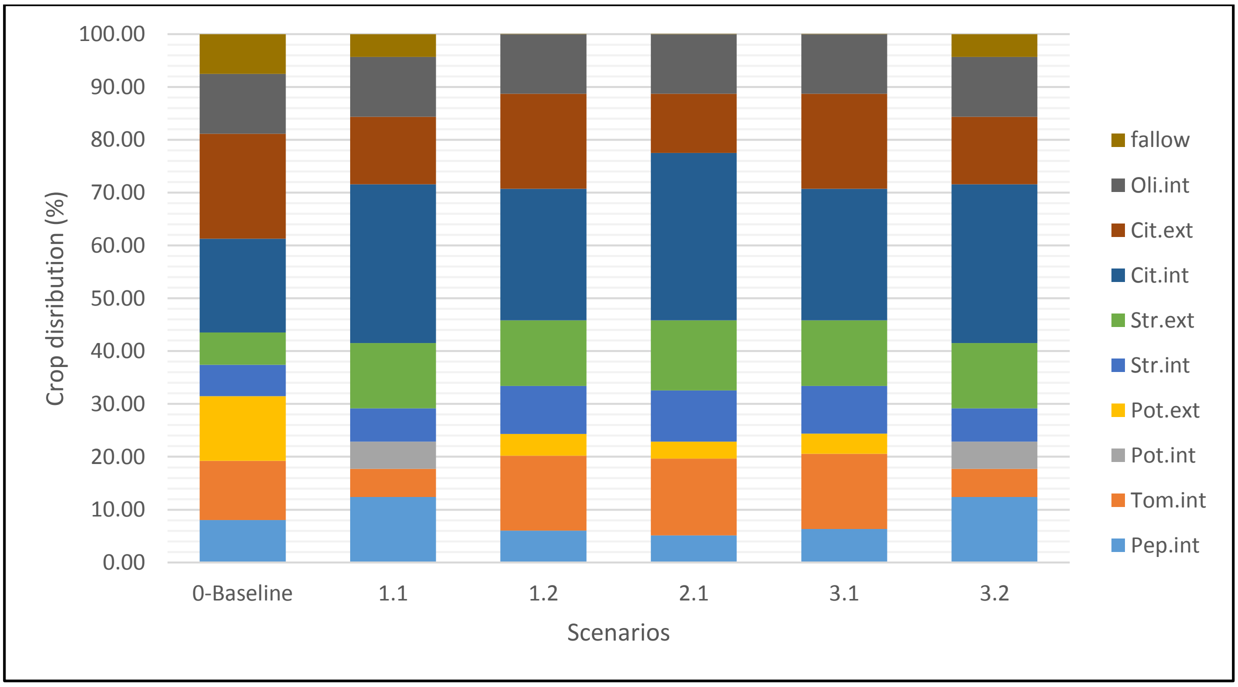


Figure 25: Tunisia: Aggregate results on farmers' cropping strategies under different scenarios

Source: own elaboration reproduced from Del. 5.2

Note:

1.1: The water availability scenario (WA-TWW use): Increase in water availability considering water supply from WW reuse

1.2: The water availability scenario (MIX-FT): Mix the two types of water TWW + FW

2.1: The technology scenario (TECH: Irrigation management): Irrigation efficiency considering innovative technologies (Calibrated nozzles).

3.1: The policy scenario (Economic instruments for water management): Subsidizing FW (SUB-FW)

3.2: The policy scenario (Economic instruments for water management): TWW is not subsidized (same Price as FW) (NSUB-TWW)

Figure 26 shows the aggregated results on water consumption under different scenarios. Regarding treated wastewater, results indicate that crops consume all the available water and an additional volume in comparison with the baseline. However, it must be taken into account that according to the fieldwork interviews farmers are reluctant to accept this type of water and therefore the degree acceptability for the adoption of this type of technologies will need to be further considered. In fact, the reluctancy to accept reused wastewater for agricultural production was identified during the fieldwork series as one of the main barriers for using TWW mainly due to its appearance (colour and smell). Accordingly, it will be necessary to develop ad-hoc incentives to promote the acceptance and adaptation of wastewater reuse in agriculture.

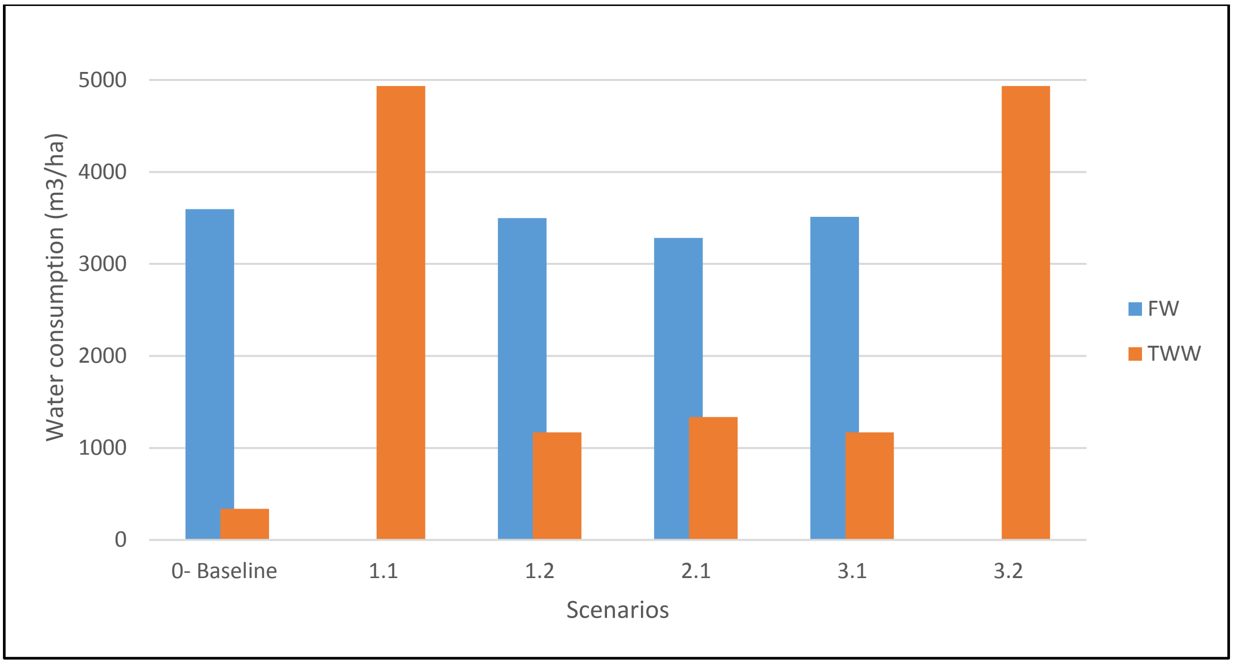


Figure 26: Tunisia: Aggregated results on water consumption under different scenarios

Source: own elaboration reproduced from Del. 5.2

3.3.2 Results from the MCA (only for the Tunisia case study)

This section contains the results of the MCA on the ranking of the selected criteria (social, economic, technical, environmental, policy) and the ranking of the defined options. It includes the results for all the stakeholders and for each of the stakeholder groups considered in this study, namely: 1) farmers, 2) policy makers, 3) water managers, 4) researchers and 5) ecologists.

3.3.2.1 Ranking of criteria

Figure 27 depicts the weighting of criteria for all stakeholders interviewed. On the vertical axis, the chart displays all the criteria groups chosen to evaluate the options (economic, environmental, policy, social and technical). On the horizontal axis, the chart uses a scale from 0 to 100 to express (in percentage terms) the overall value of the weights attached to each criteria group. The blue horizontal lines show the ranges between the lowest and highest weights attached to a specific criteria group. The orange crossline shows the mean value of the weightings on this criteria group.

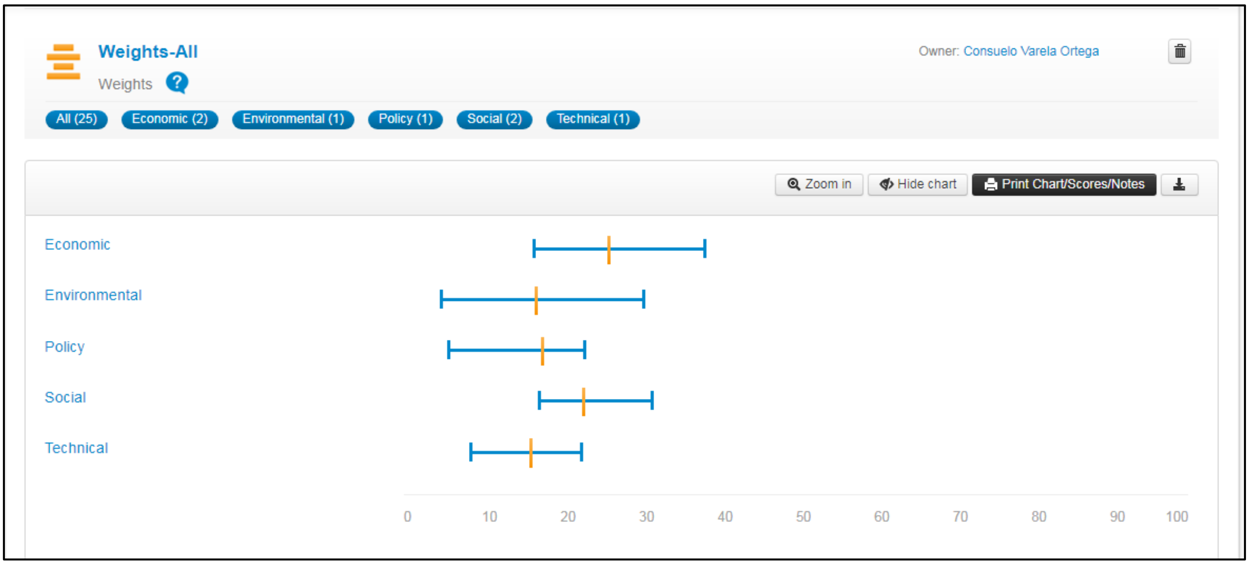
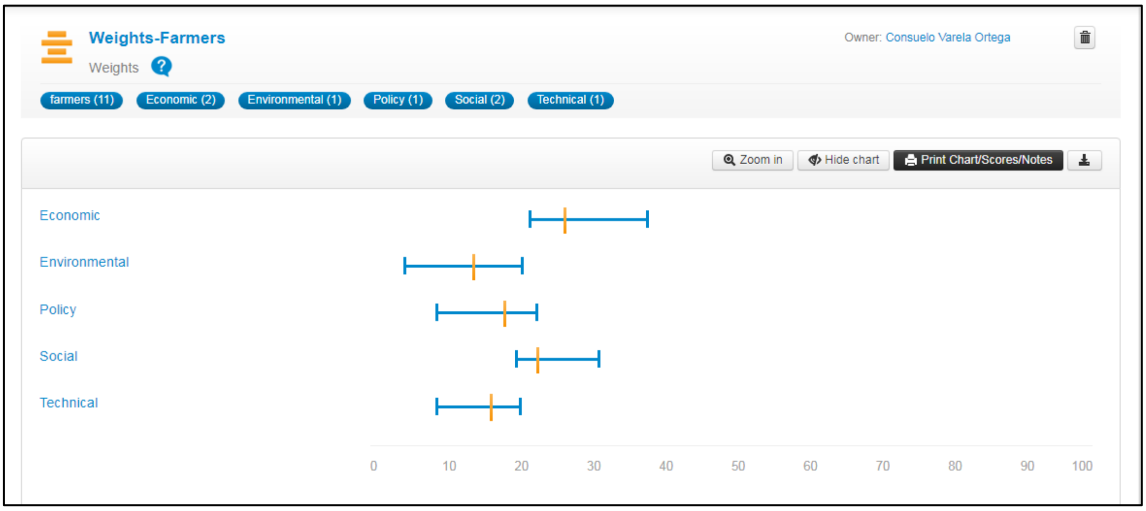


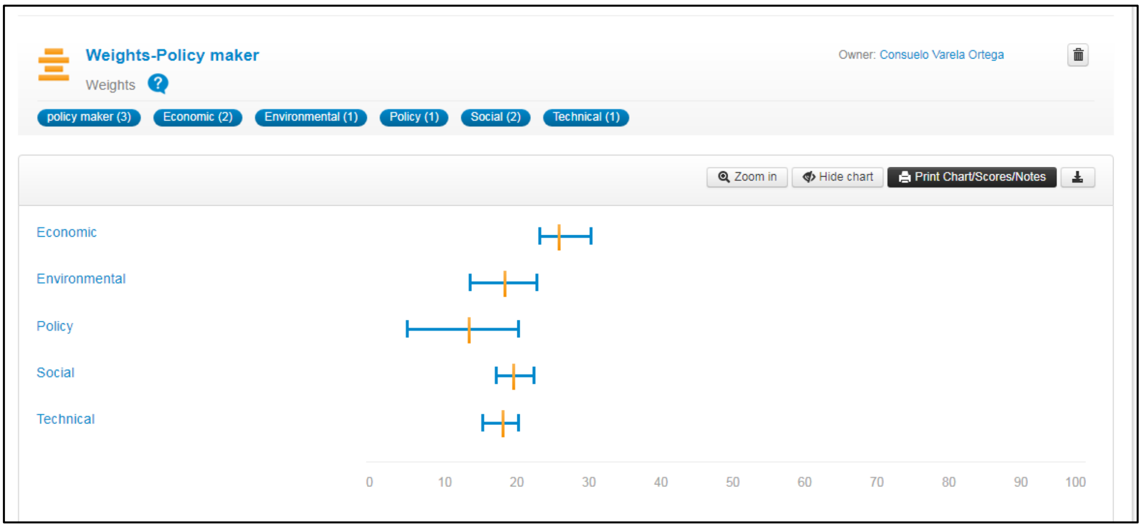
Figure 27: Weighting of criteria according to all stakeholders

As we can see, economic is the most important criteria group according to all stakeholders interviewed. Social and environmental criteria groups have medium importance and technical and policy are the least important.

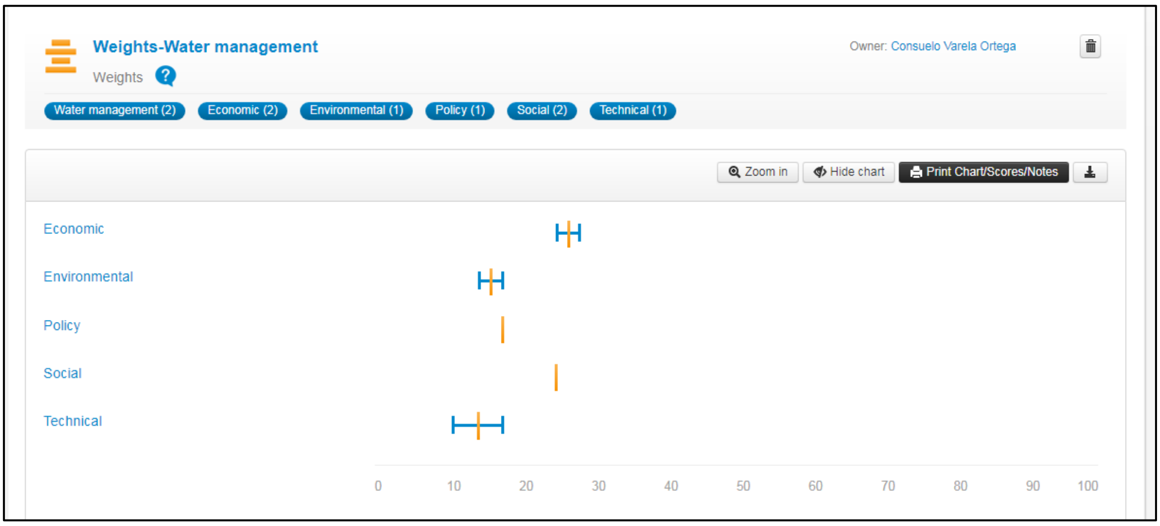
Figure 28 shows the weighting of criteria by stakeholder groups (a- farmers, b- policy makers, c- water managers, d- researchers and e- ecologists).



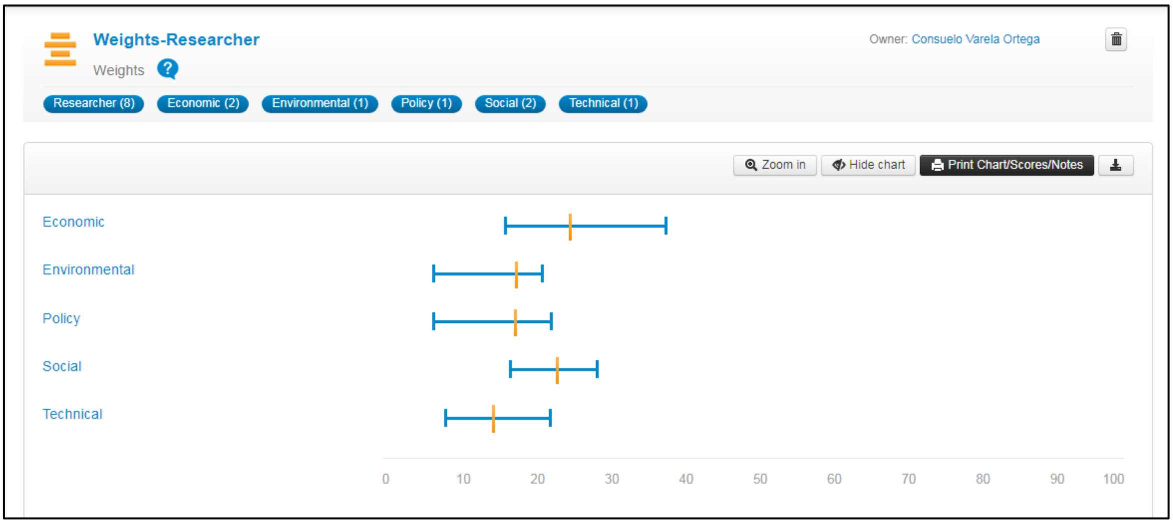
a- Farmers



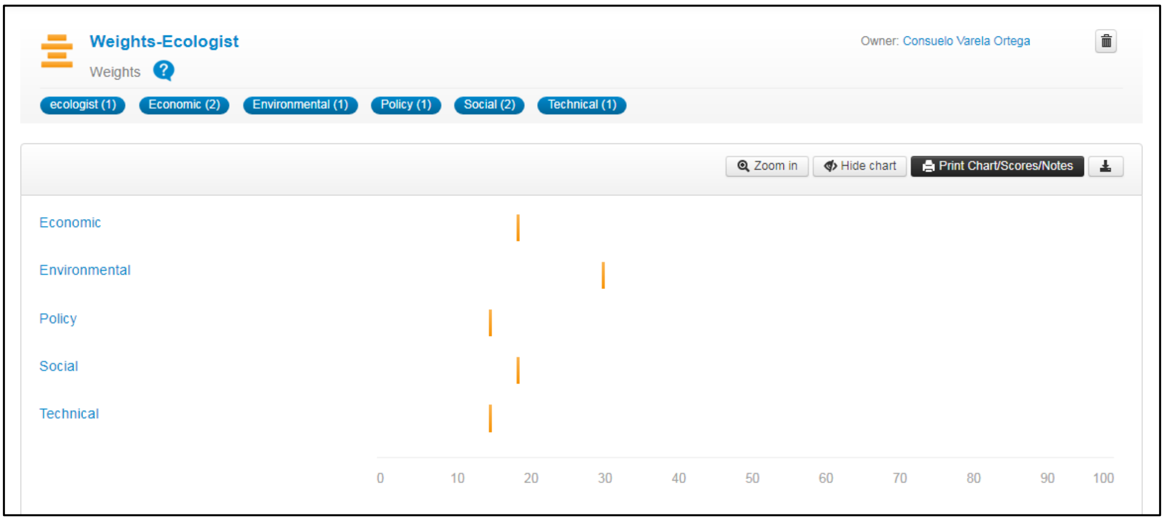
b- Policy makers



c- Water managers



d- Researchers



e- Ecologists

Figure 28: weighting criteria by group of stakeholders

For farmers (a), economic and social criteria are the most important criteria. These results are in line with the results of the fieldwork missions that showed that the main objective of the farmers was to increase the farm's profit and improve some social aspects such as the generation of employment. The environmental criteria are the least important, which could be explained by the lack of information about the environmental sector since most of the farmers in the region have a basic educational level.

For policy makers (b), economic is the most important group of criteria. Social, technical, environmental and policy criteria are less important and similarly weighted by policy makers.

Water managers (c) and researchers (d) show similar visions. For them, the economic is the most important group of criteria and technical is the least important. Environmental, social and policy criteria have medium importance.

For ecologists (e), the environmental criteria are the most important criteria and the rest of criteria (economic, social, technical and policy) are less important and similarly weighted. It clearly shows the environmental concerns that this group of stakeholders has regarding the use and conservation of water resources, especially in a water-scarce region.

Figure 29 depicts the average of criteria weights by stakeholders' groups.

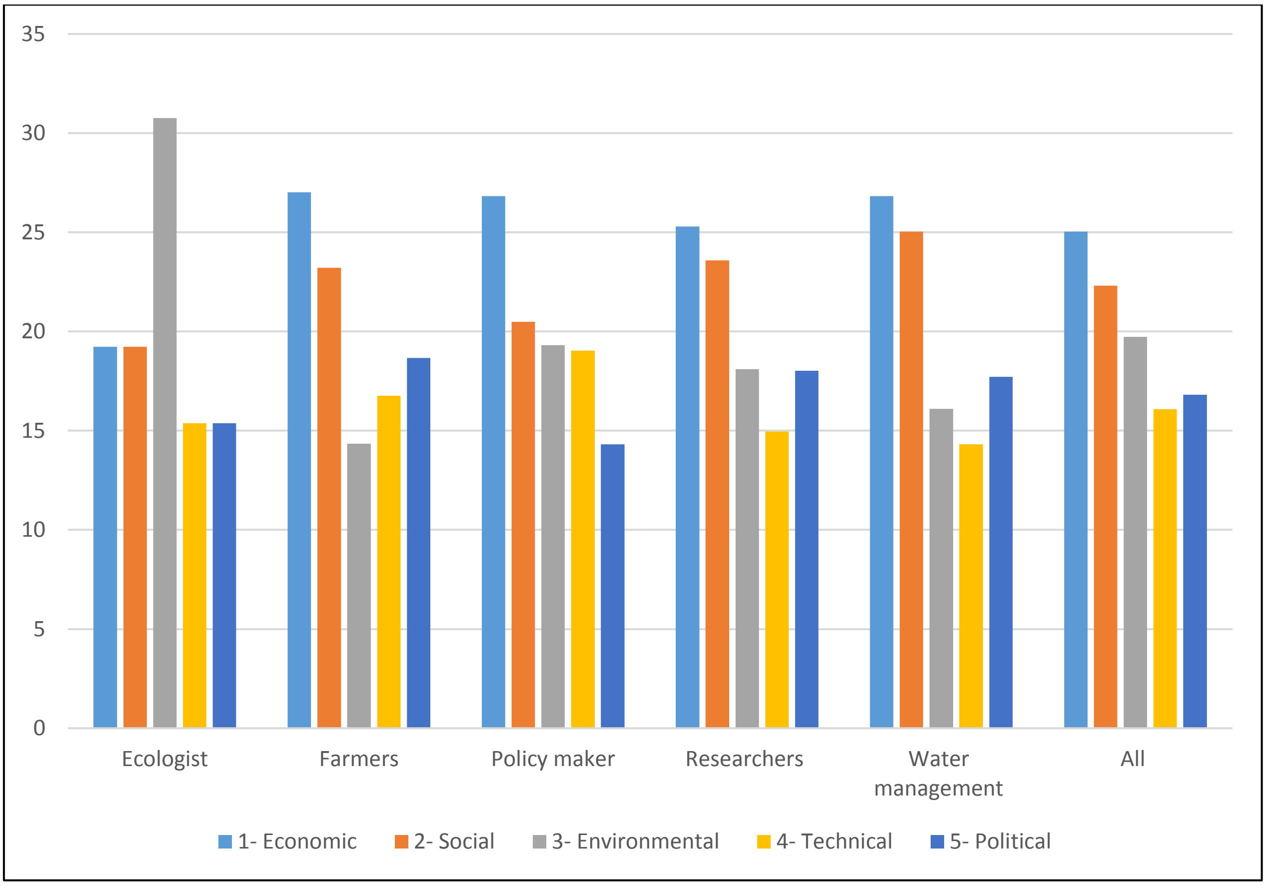


Figure 29: Average of criteria weights by stakeholders' groups

For all stakeholders' groups, economic and social criteria are the most important group of criteria, except for ecologists that have weighted the environmental criteria the highest. Technical is the less important criteria for all stakeholder groups, except for farmers, which value more technical issues than environmental issues.

To conclude, in general, the criteria group in order of importance is economic, social, environmental, policy, and technological. Efforts should be concentrated on those groups of criteria that are the most important, especially economic, and social criteria.

3.3.2.2 Ranking of options

Figure 30 shows the ranking of options for all stakeholders. On the vertical axis, the chart displays all the predefined options to be assessed by all stakeholders in the MCM analysis. On the horizontal axis, the chart displays a scale from 0 to 100 expressing the ranks assessed for each option by the stakeholders involved. The colored bars in the chart indicate the rank assessed for each option. The higher value of the bar indicates the rank assessed under the most optimistic assumptions; the lower value of the bar indicates the rank assessed under the most pessimistic assumptions. The length of the bar indicates the degree of uncertainty associated with the ranking of each option.

Thin blue lines represent the rank interval that gives a full picture of the variability in the ranks assigned by different participants. The left end of the blue line indicates the lowest rank assigned to each option by any participant involved. The right end of the blue line indicates the highest rank assigned to each option. The solid orange bars represent the rank averages (means) that gives an indication of the distribution of the participants' ranks within the ranges defined by the extremes. The left ends of the orange bars indicate the means of the pessimistic (low) ranks assigned by each participant and the right ends of the range indicate the means of the optimistic (high) ranks.

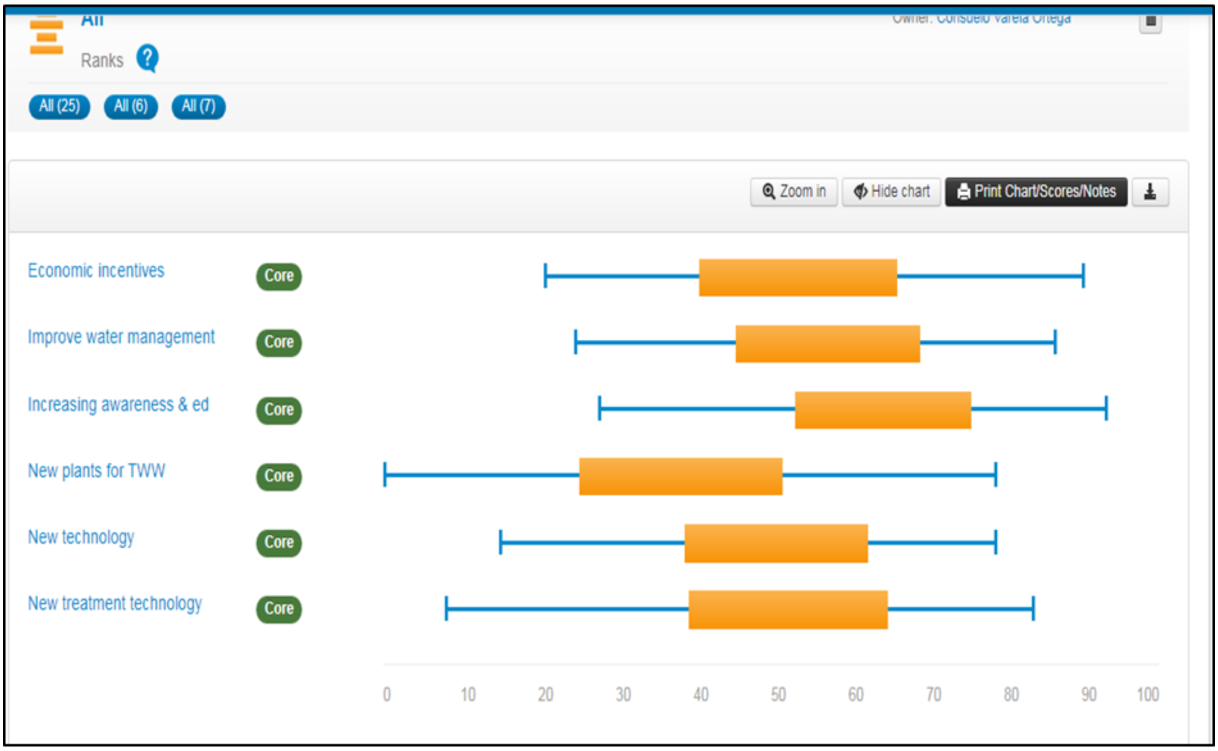


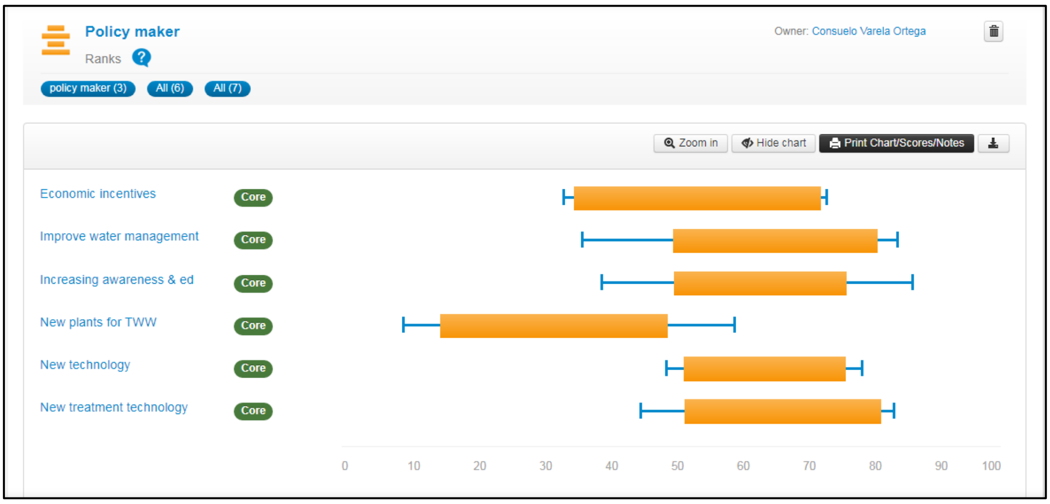
Figure 30: Ranking of options for all the interviewees

Figure 31 shows that 'Increasing awareness and education' is the most preferred option by all stakeholders, which may be explained by its feasible technical implementation. The development of new plants for treated wastewater is the less preferred option due to many reasons such as the difficult technical and political implementation, based on the stakeholders' opinions.

The extrema rank (min-max) is higher for new plants for treated wastewater showing that there is more variability regarding stakeholders' opinions.

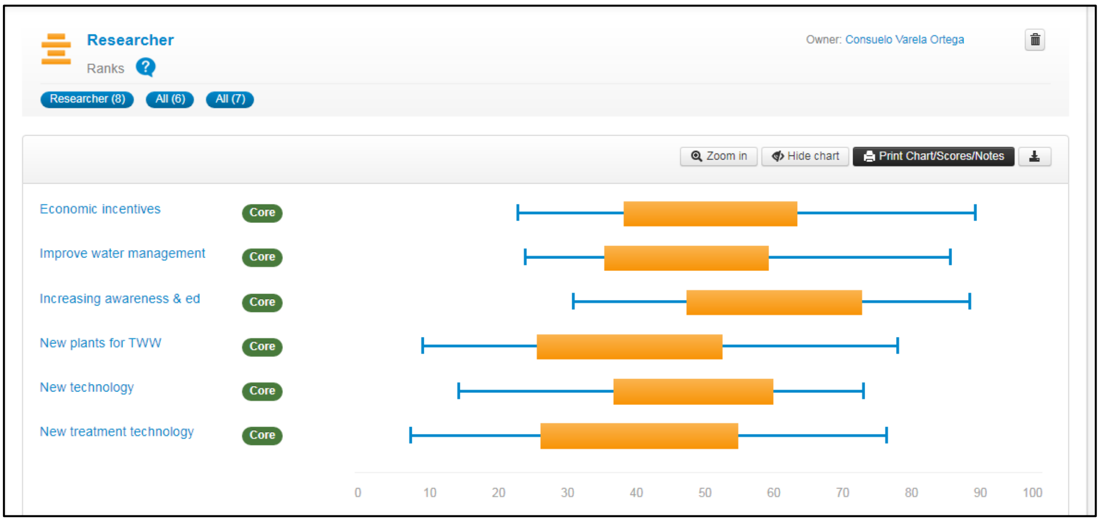
Figure 31 depicts the ranking of options by groups of stakeholders (a- farmers, b- policy makers, c- water managers, d- researchers and e- ecologists).

a- Farmers



b- Policy makers

c- Water managers



d- Researchers

e- Ecologists

Figure 31: Ranking of options by stakeholders' groups

Results show that for farmers (a), the best option is 'increasing awareness and education' followed by the improvement of water management. The option of the new plants of treated wastewater was ranked last.

For policy makers (b), improving water management is the most important option followed by the new treatment technologies to secure water quality. The extrema rank (min-max) is lower for all options showing that there is no much variability regarding the opinions of policy makers

For water managers (c) and ecologists (e), the best options are improving water management, increasing awareness and education, new treatment technologies and new irrigation technologies.

For researcher (d), the best option is increasing awareness and education.

According to the extrema, rank (blue line) is higher for all options for farmers and researchers showing that there is more variability regarding their opinions.

Figure 32 depicts the means of options ranking by stakeholders' groups.

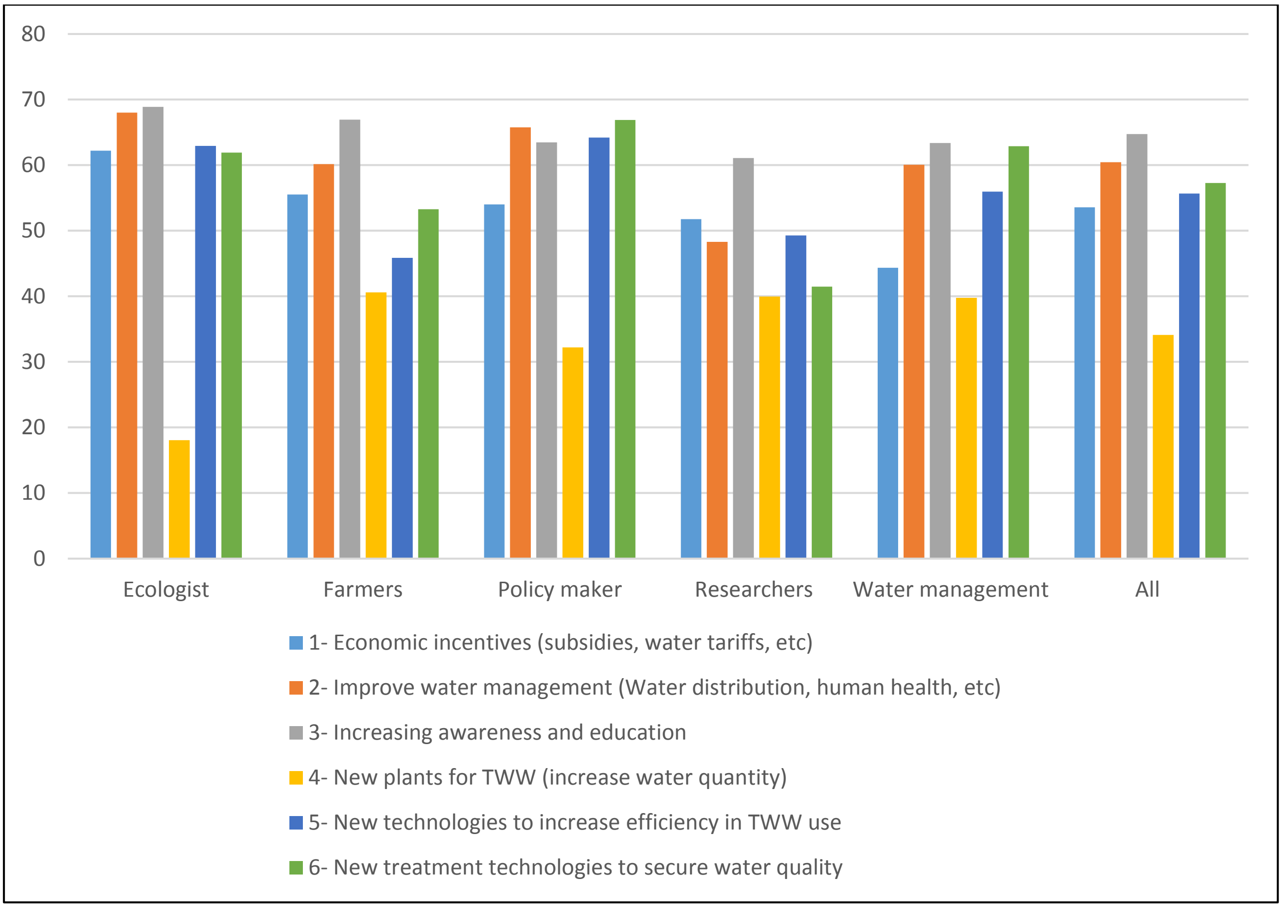


Figure 32: Means of options' ranking by stakeholders' groups

We can see that the best option for all stakeholders is improving awareness and education and the last ranked option is the construction of new plants for wastewater treatment. Only policy makers have a different vision. For them, the development of new treatment technologies to secure water quality is the best option.

3.4 Lesson learned: Barriers and opportunities

Based on the results of fieldwork conducted in the region, the results of the agro-economic model and the results of the MCM, we identified potential barriers, and opportunities stemming from the adoption of the proposed IWLMSs.

The main **barriers** identified are:

- Water scarcity: Surveyed farmers said that they are facing a severe water scarcity, considering surface and groundwater together. In fact, farmers only cultivate part of the land in some of the plots due to the lack of water. Then, given this barrier, it is important to look for solutions for the adaptation of the Nabeul agricultural sector to cope with water scarcity and to provide recommendations on how to reduce its effects.
- Salinity of groundwater: Due to the salinity of the groundwater, which reaches up to 8 g/l in many regions, most of the farmers use surface water, which is not enough.
- Farmers are generally reluctant to accept treated water although it is cheaper than conventional water. They said that treated water reduces the product's

quality due to the low water quality. Also, they added that this type of water has a higher risk of causing bacteria and parasite infections.

- WW can only be used for fodder or permanent crop irrigation. But the number of livestock farms is decreasing due to robbery and costs to shift from fodder cultivation to permanent crops are high making WW less attractive.
- High cost of investment for TWW plants and irrigation technologies. Most farmers do not receive subsidies, grants nor other type of financial support that enables the acquisition of the TWW equipment.
- Access to capital and loans appear to be difficult.
- Unfavourable labour conditions in the area. A large number of workers in the agricultural sector do not benefit from social security, as the workforce in the Cap Bon is mostly feminine with more stringent labour conditions.
- High cost of production of TWW.

On the other hand, the main **opportunities** stemming from the implementation of the proposed IWLMSs are:

- The reuse of treated wastewater is expected to change the amount of fresh water consumed and therefore it will be an opportunity for protecting freshwater resources. This will produce positive environmental effects. In addition, it will also produce a reduction in the fertilizer requirements of the crops and hence a decline in fertilizer use. This will in turn provoke a reduction in the cost of cultivation and a positive environmental effect.

- On the other side, the modernization of irrigation systems associated with the reuse of treated wastewater is an opportunity to improve the irrigation system performance in terms of efficiency, uniformity and/or adequacy.

- The use of TWW can be an opportunity for increasing cropping intensity. In fact, most of the surveyed farms have an area that varies between 2 and 5 ha, but farmers cultivate a larger surface as they grow more than 2 crops in the same plot.

- Existing laws for regulating the use of TWW in agriculture offer a solid base for the development of this type of water source and face the related risks.
- Existing water infrastructures allow the use of water distributions systems for TWW.

3.5 Policy recommendations and conclusions

3.5.1 Policy recommendations obtained from the agro-economic model approach (Egypt, Morocco and Tunisia)

3.5.1.1 Egypt

The introduction of the gated pipe contributes to reduce the quality deterioration of the water available for irrigation practices – by reducing the drained water re-pumped into the system - and to improve the equity of the system.

Specific incentives should be introduced in order to enhance the adoption of the proposed innovative technology since, notwithstanding the energy cost saving due to the reduce amount of drained water re-pumped into the system, farmers' income decreases due to the investment and O&M costs of the gated pipe technology.

The joint introduction of the technological innovation and of a new policy of water supply could achieve the objective to reduce the amount of water used by agriculture without affecting the level of satisfaction of farmers.

Since different and conflicting objectives can be achieved, it is crucial to define the priorities among the different objectives – reduction of water demand, reduction of the reused drainage, economic performance of the farmers and their level of satisfaction – in order to design the most effective water policies in the area.

3.5.1.2 Morocco

The use of TWW allows the conservation of relevant amounts of fresh water and helps to save important amounts of fertilizing elements which results in lower production costs for farmers.

The increase in TWW supply must be associated with a sound water resource design policy that fills the widespread lack of effective price signals (El Yacoubi and Belghiti, 2002) and restructures the reuse funding.

Subsidies - through the water pricing policy as well as through the innovation policy - are needed to enhance the use of TWW. Although they are not justified from a pure economic point of view, a more holistic evaluation should also take into account the economic value of the environmental benefits that TWW reuse can generate.

It is important to stress that local conditions could change in the future: while decreases in the treatment cost of wastewater reuse could contribute to its reuse, an increasing water scarcity for the agricultural sector could eliminate the choice between the sources that is still preserved in the Moroccan irrigation sector; in this scenario, the total or partial substitution of fresh water with different sources of non-uniform quality irrigation water will become one of the main future research lines to be explored.

3.5.1.3 Tunisia

In relation to the different scenarios simulated, we can conclude that there is a trade-off between the environmental consequences (e.g. use of water) and the socio-economic consequences (e.g farm income) when a given technology or economic instrument is applied. In all scenarios, we can observe that positive environmental consequences, such as less water being used, can be off-set by negative socio-economic effects, such as farm-income loss. Specifically, the environmentally preferred scenario (not subsidized treated wastewater) that results in substantial water savings inflicts a serious income loss to the farmers. In general terms, the most balanced scenario is the technology scenario that can combine effectively positive environmental and socioeconomic effects, by reducing water use and preserving farm income. An increase in irrigation technical efficiency reduces water consumption while maintaining farm income across all farm types and in the whole basin. Combining water sources, fresh and treated wastewater, is also proven to be effective to attain well-balanced environmental and socioeconomic consequences. A policy that will encourage mixing fresh and treated waters can lead to positive outcomes for conserving water resources and maintaining rural livelihoods.

From our analysis, we can also conclude that there is not a unique policy that could lead to positive ecological and social consequences across all farm types and in the basin as a whole. Different types of farms in the area could have different responses to a given technological or socio-economic policy and thus different consequences can be expected. Farms that cultivate annual crops are more flexible to adapt their cropping patterns when a given technology or pricing system is applied. In contrast, farms that grow permanent crops have less capacity to adapt their cropping pattern.

In relation to the current subsidies applied in Tunisia for wastewater, we can conclude from our study, that it has proven to be a successful instrument to encourage the use of treated wastewater for agricultural production. This opens the way, in the context of the MADFORWATER project, to support the use of this type of water and thus the development of related technologies and pricing schemes.

Alongside, we can also conclude from our study that the farmers' willingness to pay for an extra unit of water is higher than the actual price currently paid in the region. This holds both at farm level and for the basin as a whole and shows that it will be possible to develop a sound water tariffs and water quotas policy in the area of study.

In sum, we can conclude that encouraging well-balanced water policies based on an efficient combination of technology and economic instruments will lead to positive effects in the area of study in Tunisia. In addition, engaging stockholders is key for fostering the adoption of new technologies and for analyzing the consequences of the application of these policies. In general, this study contributes to support and enhance the water policies that Tunisia is already applying. It intends to encourage water policy making with the development of new water technologies and socio-economic instruments that will be environmentally proof, economically sound and socially acceptable.

3.5.2 Policy recommendations obtained from the MCM approach (Tunisia case study)

From our analysis, we can identify potential policy measures aimed at facilitating the adoption and social acceptance of the proposed IWLMSs. The appropriate management of wastewater reuse policies should be under a well-established legal and regulatory framework. For the implementation of these policies, it is important to take into account socio-economic and environmental aspects, barriers and opportunities and feasibility of application. Due to water shortages, it is important to install treatment plants to increase availability to meet agricultural water requirements. In addition, wastewater treatment must be ensured with new treatment technologies to secure water quality and to avoid the health harms associated with low-level quality. Some degree of treatment must normally be provided to raw wastewater before it can be used for agriculture.

Farmers and consumers often show a great reluctance to the reuse of treated wastewater. Therefore, it is important to create incentives that support the sector, such as providing necessary investments, subsidies, and financial support to farmers.

For a better irrigation management, it is important to use new irrigation technologies (e.g calibrated nozzles to enhance irrigation efficiency). This measure contributes to reduce water consumption and hence the conservation of water resources and nature protection.

The actions to promote the use of TWW have to consider the location of the treatment plants as an important issue. The majority of farmers do not want that the treatment plants will be located near their farms. This reluctancy is often due to bad smells or insects living around the treatment system. These problems are usually due to poor treatment and can be avoided by ensuring efficient treatment system

Water users, particularly farmers, are reluctant to use treated wastewater as it affects the selling of their products due to health harms associated with low-level water quality. This may need the establishment of focused educational activities to counterbalance the misunderstanding by farmers and consumers. Increasing awareness and education is essential to ensure appropriate treatment and reuse of wastewater and to change public attitudes and behaviour. In addition, selling treated wastewater, even at a considerable subsidy level, may need campaigning to convince water users to accept this type of water. The objective of awareness campaigns is to educate and orient farmers on the precautions of wastewater reuse, and to inform the consumers about the safety of agricultural products irrigated with well-managed reclaimed wastewater. In sum, monitoring of treated wastewater before its reuse is important to assess its suitability for irrigation, and it should also be extended to crops, soils and environment.

4 Conclusions and recommendations for integrated water & land management

This research has shown that options are available for water reclamation, but the concept is not widely implemented in Egypt, Morocco and Tunisia. With the results of this deliverable, key barriers and drivers were identified to facilitate the implementation of water reclamation for irrigation. In particular, the considered countries show different characteristics regarding efficient water management, water pricing, subsidies and wastewater tariffs, implementation of monitoring, reporting systems and legal aspects. These were related to the use of reclaimed water for food crop irrigation. Concerns of the experts were the high costs of the proposed technologies, quality and health concerns (missing disinfection step), training of the water users and social acceptance of the reuse of treated wastewater.

Recommendations for Integrated water & land management strategies and policy recommendations

To increase water security, and consequently economic security in all three target countries, both IWLMS and policy recommendations are needed. This means from the perspective of the MADFORWATER project, that investing in water management strategies can possibly increase water security by supporting water supply continuity by means of providing reclaimed water to the end water users (e.g. farmers). Therefore, water management actions are primarily recommended (e.g. capacity building and technological scale up). To successfully implement the water management actions, they should be accompanied by economic instruments (e.g. subsidies or/and other financial assistances). Congruently, to ensure the quality of the reclaimed water, additional environmental and legal actions are required (e.g. monitoring of water quality). These actions can only be implemented with increased social acceptance of reclaimed water use. This can be achieved by employing social instruments (e.g. building trust among farmers).

Besides the treatment of waste water, the reduction of water demand and the steady level of satisfaction of farmers should be targeted. This can be achieved by introducing new irrigation technologies (e.g. calibrated nozzles or gated pipes). Economic analysis to formulate policy recommendations has shown that the joint introduction of technological innovations and of a new policy of water supply could achieve the objective to reduce the amount of freshwater used by agriculture without affecting the level of satisfaction of farmers. In particular, the following recommendations are considered as priorities.

In terms of economic instruments, our analysis suggests introducing in all the three target countries water tariffs aimed at promoting the reuse of TWW, as well as subsidies or loans to promote the implementation of innovative WW treatment or irrigation technologies. In particular, Egypt, Tunisia and Morocco have shown country specific differentiations as follows. In Egypt financial assistance especially at the beginning of a new technology can support the farmers income, as this could decreases due to the investment and O&M costs of the gated pipe technology. In Tunisia current subsidies for wastewater have proven to be a successful instrument to encourage the use of treated wastewater for agricultural production. Alongside it has shown that the farmers' willingness to pay for an extra unit of water is higher than the actual price currently paid in the region. In Morocco subsidies are needed to enhance the use of TWW through the water pricing policy as well as through the innovation policy.

In terms of water management instruments, our analysis suggests facilitating in all the three target countries institutional coordination, regional planning and training, capacity building and technological scale up. In particular, in Egypt, Tunisia and Morocco have shown country specific differentiations as follows. In Egypt the introduction of the gated pipe contributes to reduce the quality deterioration of the water available for irrigation practices. In Tunisia training is especially important for farmers and the agency to improve the irrigation capacity. In Morocco the use of TWW allows the conservation of relevant amounts of fresh water and helps to save important amounts of fertilizing elements which results in lower production costs for farmers.

In terms of environmental and legal instruments, our analysis suggests facilitating the monitoring and regularly reporting of water quality and increase of legal enforcement and/or the adoption of new water quality regulations. In particular, Egypt, Tunisia and Morocco have shown country specific differentiations as follows. In Egypt there is more monitoring needed, since for the poor farmers monitoring does not matter, however big farms monitor for their exports. In Tunisia there is need to increase the water quality. Legal instruments are also an important issue, because currently the legislation forbids to use for all crops. In Morocco the monitoring is obligatory for treated wastewater at the WWT and end-users. The frequency in the monitoring plan for each parameter is required. The legal enforcement is a major issue. The problem is on how to enforce the law. The Moroccan would need to start to give penalties. A big problem is Moroccan have the law but do not re-enforce it.

In terms of social instruments, our analysis suggests facilitating the acceptance of reclaimed water. In particular, Egypt, Tunisia and Morocco have shown country specific differentiations as follows. In Egypt there is need to build trust among farmers with advanced water treatment in pilot plants and water quality monitoring. In Tunisia there is need to build trust among farmers with tertiary water treatment in pilot plants and water quality monitoring. Congruently, to build trust there is need to ensure the water quality with for instance a contract with three parties: farmers, producers of reclaimed water and government. In Morocco there is need to build trust among farmers with advanced water treatment in pilot plants and water quality monitoring. Congruently, the water quality needs to be ensured in order to maintain trust.

5 Symbols and Abbreviations

ANCSEP	Agence Nationale de Contrôle Sanitaire et Environnemental des produits
ANPE	Agence Nationale de Protection de l'Environnement
CITET	Centre International des Technologies de l'Environnement deTunis
CRDA	Commissariat Régional de Développement Agricole
CRDA	Regional Commissariat for Agricultural Development (Commissariat Régional de Développement Agricole)
DCWW	Drainage Canal WasteWater
DGGREE	Direction General du Genie Rural et de l'Eploitation de l'Eau
DGRE	Direction général des ressources en eau
DHMPE	Direction de l'Hygiene du Milieu et de la protection de l'Environnement
DST	Decision support tool
DST	Decision Support Tool
F_1, F_2 and F_3	Farm types
FAO	Food and Agriculture Organisation
FHNW	FachHochschule NordWestschweiz
FW	Fresh water
FW	Freshwater
FWS	Free Water Surface
GAMS	General Algebraic Modelling System
GAMS	General Algebraic Modeling System
GDA	Groupements de developpement Agricole
GDA	Agricultural Development Groups (Groupement Développement Agricole)
GDP	Gross Domestic Product
IAMB	Centro Internazionale di Alti Studi Agronomici Mediterranei- Istituto Agronomico Mediterraneo di Bari
INRGREF	Institut National de Recherche en Genie Rural, Eaux et Forets
IWLMS	Integrated Water & Land Management Strategies
MAC	Mediterranean Africain Countries
MAC	Mediterranean African Countries
MAP	MonoAmmonium Phosphate
MCA	Multicriteria Analysis
MCA	Multi-Criteria Analysis
MCM	Multicriteria Mapping
MENA	Middle East and North African
MWW	Municipal WasteWater

NWRC	National Water Research Centre
O&M	Operation and Maintenance
ONAS	Office National de l'assainissement
SIM	Safe Irrigation Management
TWW	Treated Wastewater
TWW	Treated Wastewater
UMA	Université Mannouba
UN	United Nations
UPM	Universidad Politecnica de Madrid
UPM	Universidad Politecnica de Madrid
UTM	University of Tunis El Manar
WUA	Water Users Associations
WW	Wastewater
WWTP	WasteWater Treatment Plant

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7 APPENDIX I : Policy recommendations (T6.2): Multicriteria analysis : questionnaire & interviewee list

Multicriteria Analysis (MCA) questionnaire

Project:..

Interview N°: .... Name of interviewer: .... Date: .... Place: ....

Participant's name: .... Position:..Email: ....

GOAL: To increase the use of TWW in agriculture in order to cope with water scarcity and food security

Criteria	Weight [score from 0 to 100]	Sub-criteria	Sub-crit-Weight	Options [range from 0 to 100]											
				New plants for TWW (increase quantity)		New treatment tech. to secure water quality		New tech. to increase efficiency in TWW use		Improve water management (w. distribution, human health)		Economic incentives (subsidies, tariffs, etc)		Increasing awareness and education	
				Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Economic		Increase in farm income													
		Public Financial feasibility													
Social		Capacity to generate employment													
		Social acceptance													
Environmental		Protection of envr. Resources													
Technical		Speed of implementation													
Policy		Legal and political implementation feasibility													

Table 17: interviewee list

Nº	Sex	Nationality	SH group	Institution
1	M	Tunisian	Researcher	UPM
2	F	Tunisian	Researcher	UTM
3	F	Spanish	Researcher	UPM
4	M	Peruvian	Researcher	UPM
5	F	Tunisian	Researcher	UPM
6	M	Tunisian	Policy maker	CRDA NABEUL
7	M	Tunisian	Farmer	KASSERINE (TUNISIA)
8	M	Tunisian	Water management	GDA SOMAA (NABEUL)
9	M	Tunisian	Farmer	NABEUL (TUNISIA)
10	M	Tunisian	Researcher	IAMZ
11	F	Moroccan	Researcher	IAV (MOROCCO)
12	F	Moroccan	Researcher	IVIA (VALENCIA)
13	M	Tunisian	Ecologist	INAT (TUNISIA)
14	F	Tunisian	Water management	GDA SOUHIL (NABEUL)
15	M	Tunisian	Farmer	NABEUL (TUNISIA)
16	F	Tunisian	Policy maker	MINISTRY OF AGRICULTURE (TUNISIA)
17	M	Tunisian	Farmer	NABEUL (TUNISIA)
18	F	Tunisian	Policy maker	MINISTRY OF AGRICULTURE (TUNISIA)
19	M	Tunisian	Farmer	NABEUL (TUNISIA)
20	M	Tunisian	Farmer	NABEUL (TUNISIA)
21	F	Tunisian	Farmer	NABEUL (TUNISIA)
22	M	Tunisian	Farmer	NABEUL (TUNISIA)
23	M	Tunisian	Farmer	NABEUL (TUNISIA)
24	M	Tunisian	Farmer	NABEUL (TUNISIA)
25	F	Tunisian	Farmer	NABEUL (TUNISIA)

8 APPENDIX II: Catalogue of Integrated Water and Land Management Strategies

8.1 EG1: Strategy description from decision support tool

Technology data (EG1)

The Nile valley, Egypt, with its concentration of large population and the abundance of several oasis offers in principle very favourable conditions for the wastewater reuse. Clear focus areas could be instead all cities such as Qena (230,000 inh.), Asyut (400,000 inh.). El Fayoum (440,000 inh.), or the outskirts of Cairo with areas such as Benha (196,000 inh.). Being concentrated in the Nile valley, traditionally the distance to irrigated areas is short.

The developed decision support tool (DST), which identifies technology options that can treat wastewater to the desired quality, was used to evaluate basin-scale and national level wastewater treatment strategies (WWTS). We analysed the reuse potential of typical effluent of municipal wastewater in order to comply with the ISO regulation category C – agricultural irrigation of non-food crops. The technological parameters include the following (Varela-Ortega *et al.*, 2020b):

- Water quantity (availability) [m^3/d] — The analysis has been conducted with a water capacity of 10,000 m^3/d.
- Water quality [e.g. total coliform CFU /ml] — The typical effluent municipal wastewater quality consists of the following quality parameters:

  25 mg/L for TSS, 31 mg/L for BOD, 56 mg/L for COD, 40 mg/L for total nitrogen, 10,000 No/100ml for total coliforms, 500 mg/L for TDS, and 10 mg/L for total organic carbon.

Costs (EG1)

In the following the costs facts are summarized (Varela-Ortega *et al.*, 2020b):

- Production costs [€/m^3] — Since the DST resulted in a “no treatment” strategy, there would be no production costs at all.
- Selling price of treated WW [€/m^3] — N/Av

Expansion potential (EG1)

In the following the expansion potential is summarized (Varela-Ortega *et al.*, 2020b):

• Average WW quantity per WWTP/industry [m³/d]	This is not applicable since no treatment technology would be applied.
• Maximal potential amount of reusable WW with M4W tech. [m³/d]	See sentence above.
• Number of potential WWTP or industries that could apply the M4W tech. [no.]	382 wastewater treatment plants in Egypt in 2014 to considered for applying the MADFORWATER technology (Food and Agriculture Organization of the United Nations, 2016)

8.2 EG2: Strategy description from decision support tool

Technology data (EG2)

The Nile valley, Egypt, with its concentration of large population and the abundance of several oasis offers in principle very favourable conditions for the wastewater reuse. Clear focus areas could be instead all cities such as Qena (230,000 inh.), Asyut (400,000 inh.). El Fayoum (440,000 inh.), or the outskirts of Cairo with areas such as Benha (196,000 inh.). Being concentrated in the Nile valley, traditionally the distance to irrigated areas is short.

The developed decision support tool (DST), which identifies technology options that can treat wastewater to the desired quality, was used to evaluate basin-scale and national level wastewater treatment strategies (WWTS). We analysed the reuse potential of typical municipal wastewater (MWW) in order to comply with the local Egyptian wastewater reuse regulation level B – agriculture purposes in desert areas regulation. The treatment strategy *Lagooning: Australia I* is the top ranked strategy according to the cost criterion with the following technological parameters (Varela-Ortega *et al.*, 2020b):

• Water quantity (availability) [m³/d]	The analysis has been conducted with a water capacity of 10,000 m³/d.
• Water quality [e.g. total coliform CFU /ml]	The typical effluent municipal wastewater quality consists of the following quality parameters: 25 mg/L for TSS, 31 mg/L for BOD, 56 mg/L for COD, 40 mg/L for total nitrogen, 10,000 No/100ml for total coliforms, 500 mg/L for TDS, and 10 mg/L for total organic carbon.

Costs (EG2)

In the following the costs facts are summarized (Varela-Ortega *et al.*, 2020b):

• Production costs [€/m³]	According to the new decision support tool, the costs of this technology amount to 6.20 EGP/m³ or 0.35 EUR/m³. With the annually treated waste water of 3,650,000 m³ (Varela-Ortega *et al.*, 2020b) annual costs of 1,277,500 EUR would occur.

- Selling price of treated WW [€/m^3] N/Av

Expansion potential (EG2)

In the following the expansion potential is summarized (Varela-Ortega *et al.*, 2020b):

- Average WW quantity per WWTP/industry [m^3/d] Considering the produced MWW in Egypt (Food and Agriculture Organization of the United Nations, 2016) of around 7,080 Mio m^3/year in 2012 (Food and Agriculture Organization of the United Nations, 2016) and the cost of the technology, the annual costs would amount to EUR 2,478,000.
- Maximal potential amount of reusable WW with M4W tech. [m^3/d] See sentence above.
- Number of potential WWTP or industries that could apply the M4W tech. [no.] 382 wastewater treatment plants in Egypt in 2014 to considered for applying the MADFORWATER technology (Food and Agriculture Organization of the United Nations, 2016)

8.3 EG3: Strategy description from the MADFORWATER pilots

Technology data (EG3)

The Nile valley, Egypt, with its concentration of large population and the abundance of several oasis offers in principle very favourable conditions for the wastewater reuse. Clear focus areas could be instead all cities such as Qena (230,000 inh.), Asyut (400,000 inh.). El Fayoum (440,000 inh.), or the outskirts of Cairo with areas such as Benha (196,000 inh.). Being concentrated in the Nile valley, traditionally the distance to irrigated areas is short.

The pilot plant operates with the following treatment sections: 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 technological parameters include the following (Varela-Ortega *et al.*, 2020b):

- Water quantity (availability) [m^3/d] The pilot plant, with a capacity of 250 m^3/d, consists of the following components: (i) a 500 m^3 lagooning / sedimentation pond and (ii) different types of Hybrid Constructed Wetlands (HCW).
- Water quality [e.g. total coliform CFU /ml] 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.

Costs (EG3)

In the following the costs facts are summarized (Varela-Ortega *et al.*, 2020b):

- Production costs [€/m³] — According to the new decision support tool, the costs of this technology amount to 6.68 EGP/m^3 or 0.38 EUR/m^3. With the annually treated waste water of 91,250 m^3 (Varela-Ortega *et al.*, 2020b), the annual costs of 34,675 EUR would occur.
- Selling price of treated WW [€/m^3] — N/Av

Expansion potential (EG3)

In the following the expansion potential is summarized (Varela-Ortega *et al.*, 2020b):

- Average WW quantity per WWTP/industry [m^3/d] — Considering the produced MWW in Egypt (Food and Agriculture Organization of the United Nations, 2016) of around 7,080 Mio m^3/year in 2012 (Food and Agriculture Organization of the United Nations, 2016) and the cost of the technology, the pilot plant would be able to treat 1.3% of the annual DCWW at a cost of 609,550 EGP or 34,675 EUR.
- Maximal potential amount of reusable WW with M4W tech. [m^3/d] — See sentence above.
- Number of potential WWTP or industries that could apply the M4W tech. [no.] — 382 wastewater treatment plants in Egypt in 2014 to considered for applying the MADFORWATER technology (Food and Agriculture Organization of the United Nations, 2016)

Stakeholder opinion (EG3)

In the following the stakeholder opinion is summarized (Souissi, 2019) :

- How do you evaluate this wastewater treatment in general?

  Summary:

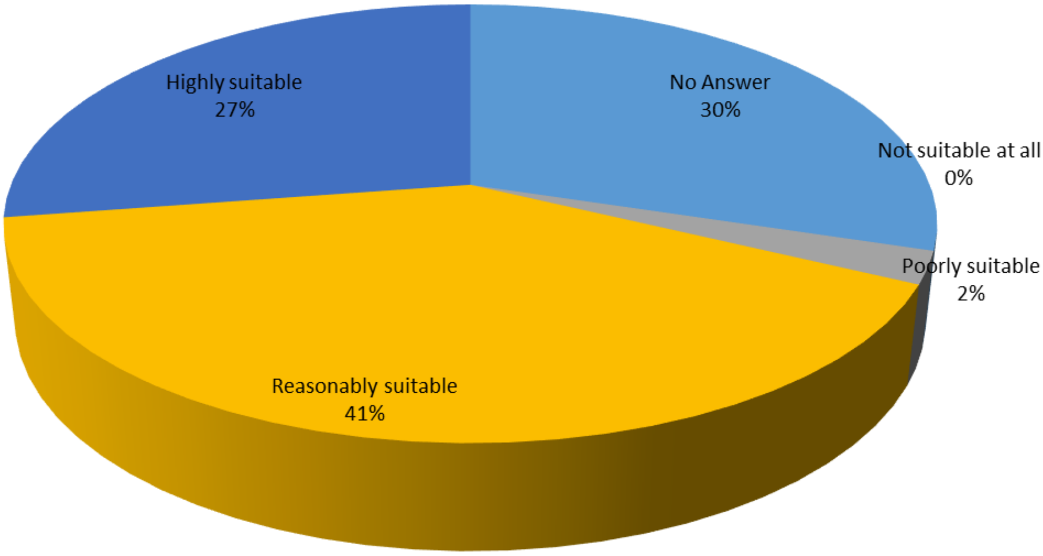


Figure 33: MWW Stakeholder opinion on the suitability of constructed wetlands

- How do you evaluate this wastewater treatment according to the specific needs and characteristics of this wastewater and your country / governorate / basin ?

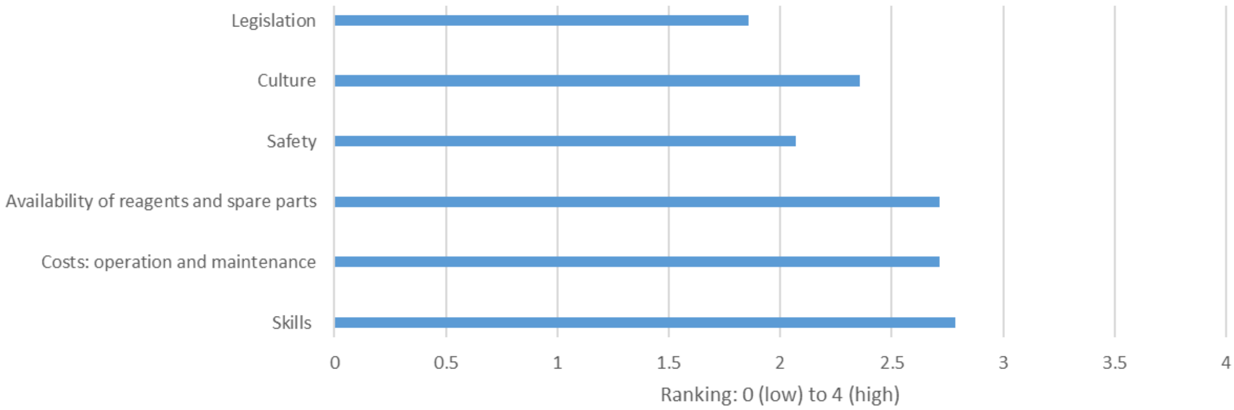


Figure 34: MWW Stakeholder opinion on the specific needs and characteristics of constructed wetlands.

- Is this irrigation technology suitable for your country, governorate or basin?

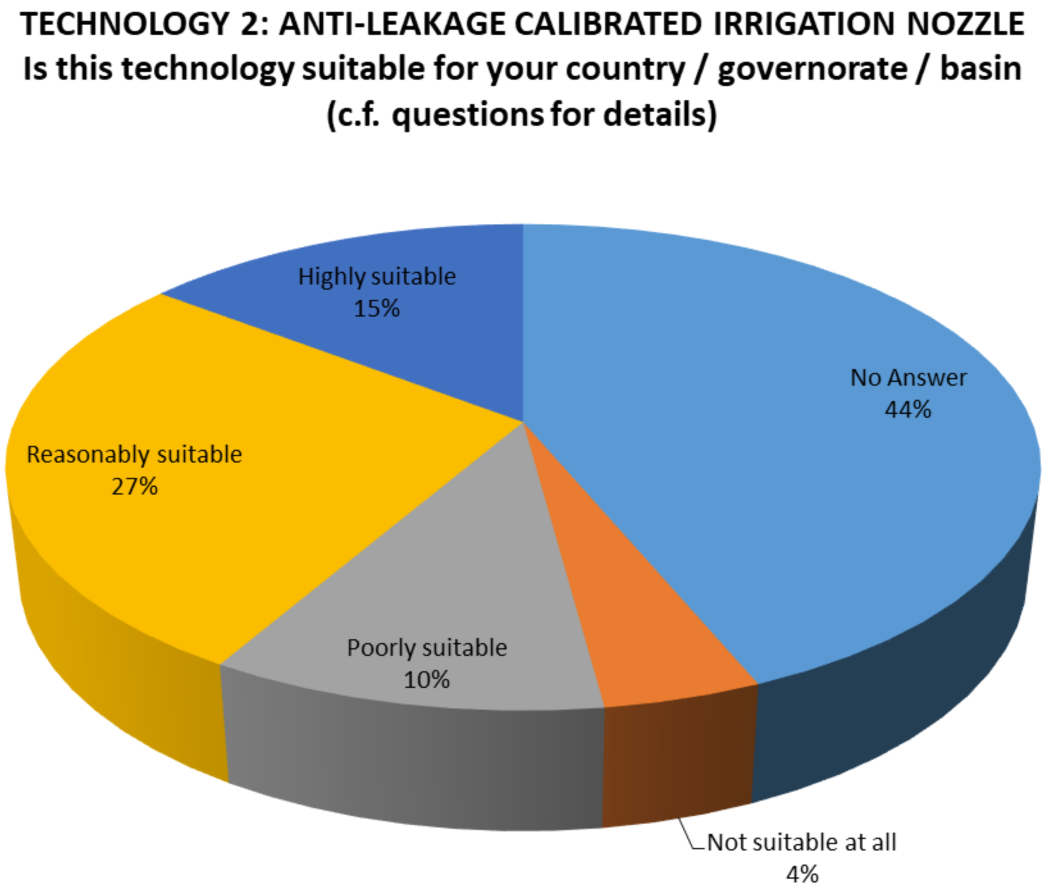


Figure 35: General suitability of irrigation technology "anti-leakage calibrated irrigation nozzles" in stakeholder country, governorate or basin

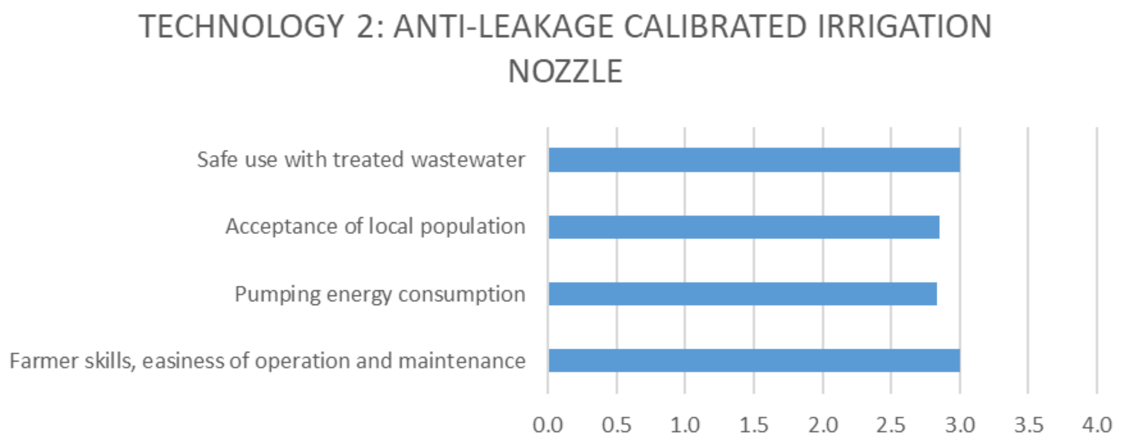


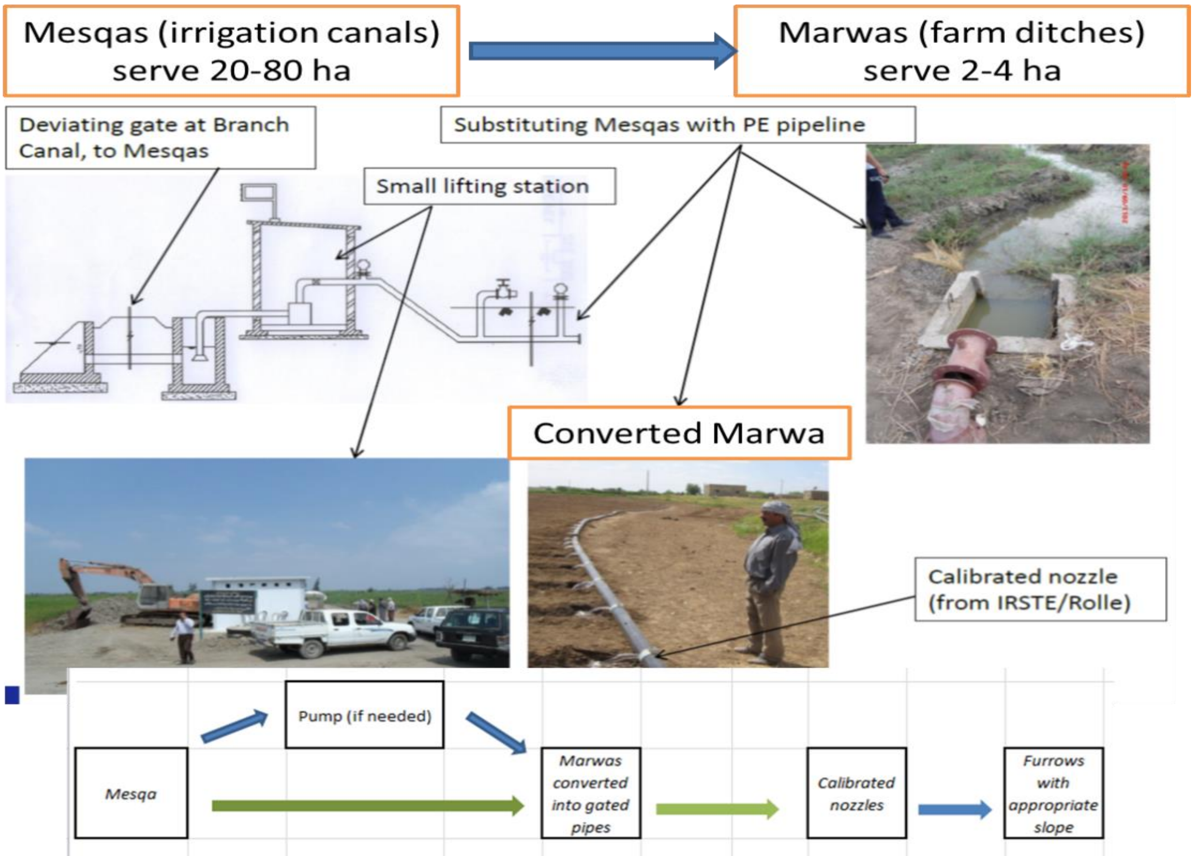
Figure 36: Suitability of different aspects of irrigation technology "anti-leakage calibrated irrigation nozzles" in stakeholder country, governorate or basin

8.4 EG4: Strategy description from the WP5 agro-economic model from a technological perspective

Technology data (EG4)

The Irrigation Improvement Project (IIP) enabled the operation of Daqalt canal on a continuous flow through **automatic downstream control gates** with the aim to guarantee greater flexibility in the timing of irrigation applications. The flow is in the branch canal is determined by regulation of the discharge at the head of the canal and accounts for the area served by the canal and the cropping area. Despite the improvements, the problem of inequity between head and tail areas along the branch canals could not be solved. The developed agro-economic decision support tool (DST) (see Del. 5.2 for a detailed description) helps to evaluate the **introduction of an innovative irrigation technology of gated pipes (EG-TS and EG-WAS)** and the **practice to reuse drained water.** Additionally, alternative political scenarios are analyzed and impacts of different policies in terms of parameters deemed relevant are estimated by the agro-economic model (EG-PS1 and EG-PS2).

Figure 37: Flow chart of the current and proposed irrigation technology - MADFORWATER WP3.



- Water availability:

Table 18: Water availability data. Retrieved from the MADFORWATER Del. 5.2 report (2020).

	Water supply			Water demand		
Strategies	Average provided water (m^3/year/ha)	Daily average provided water for 185 ha (m^3/d)	Average provided water for 185 ha (m^3/year)	Water used for 185 ha (m^3)	Drained water (m^3)	System performance index
EG-BS	17,787	9,141	3,290,595	4,226,196	936,818	0.78
EG-TS	17,780	9,137	3,289,377	3,720,227*	430,850	0.88
EG-WAS	16,002	8,223	2,960,430	3,720,227*	759,797	0.80
EG-PS	16,002	8,223	2,960,430	3,720,227*	759,797	0.80

* Water demand decreased due to the new technology

- Distance from WWTP to irrigation [km] 11.42km long Yazeed (62km) branch canal+
- Land and crop data [ha] 185 ha (six selected Mesqas [private channels])
- Irrigation method Innovative calibrated nozzles

+ Study area covered six tertiary canals of the Daqalt sub-branch canal

Costs (EG4)

The cost and revenue data are stated in the following:

Table 19: Cost and revenue data. Retrieved from the MADFORWATER Del. 5.2 report (2020).

	Costs				Revenue
Strategies	Average production costs [€]	Distribution costs [€/kWh]*	Annualized cost of new technology [€]	Additional O&M cost [€/year]	Average farmer income [€/ha/y]
EG-BS	170,173	0.061	-	-	3,481
EG-TS	170,173	0.061**	42,893	145	3,368
EG-WAS	< 170,173	0.061	42,893	145	3,335
EG-PS1	< 170,173	0.061			3,481
EG-PS2	< 170,173	> 0.061***	42,893	145	3,481

* Energy costs cannot be calculated based on the data available in the Del. 5.2
** Energy/cost savings due to a positive effect on the irrigation system (only furrow irrigation)
*** Energy/cost savings due to a positive effect on the irrigation system (only furrow irrigation) but simultaneously a higher energy price due to an introduced energy pricing policy

- Selling price of products [€/ha] and average crop yields [ton/ha]

Table 20: Average crop yields in Egypt - Source: Agricultural Statics in Kafr El Sheikh, Economic Affairs Sector, MALR, various years

	2007-'12	2013

Table 21: Selling price of agricultural products in Egypt - Source: MALR

Price, Euro/ha	
Cotton	971
Maize	157
Rice	240
Wheat	209
Alfalfa	512
Vegetables (Potatoes)	209
Sugarbeet*	34

Cotton	14.2	11.6
Maize	8.6	8.7
Rice	9.5	8.9
Wheat	6.4	6.3
Alfalfa	n.a.	n.a.
Vegetable	33.8	34.3
Sugarbeet	48.6	47.8

Expansion potential (EG4)

The data in Table 6 for an expansion potential in Egypt bases on the assumption that the water supply and use would decrease approximately about the same percentage (-10% and -13%, respectively) as calculated with the agro-economic model. The water supply for agriculture would possibly decrease by around **$7{,}230*10^6$ m^3/year**. The water use reduction would possibly decrease by around **$8{,}432*10^6$ m^3/year.**

Table 22: Estimated figures based on FAO. 2016. AQUASTAT Main Database, Food and Agriculture Organization of the United

	Water supply		Water demand
Strategies	Average provided water for 185 ha (10^6 m^3/year)	Average provided water for Egypt (10^6 m^3/year)	Water used for Egypt (10^6 m^3/year)
EG-BS	3.29	72,300	62,000
EG-TS	3.29	72,300	53,568
EG-WAS	3.29	65,070	53,568
EG-PS	3.29	65,070	53,568

8.5 TU1: Strategy description from decision support tool

Technology data (TU1)

Overall, the situation in Tunisia appears diverse in the possible combination of production potentials and agronomic centres that are more wide spread in Tunisia. Touristic centres and to irrigate high valuable crops in a highly intensive and surface minimizing way, whereas the seasonality of the wastewater availability according to the touristic peak seasons should be considered. From the logistic perspective the priority areas to intensify the production of high value crops should be the area of Nebeul (73 100 inhabitants) at the south of the Cap Bon peninsula.

The developed decision support tool (DST), which identifies technology options that can treat wastewater to the desired quality, was used to evaluate basin-scale and national level wastewater treatment strategies (WWTS). We analysed the reuse potential of typical effluent of municipal wastewater in order to comply with the ISO regulation category C – agricultural irrigation of non-food crops. The top ranked treatment strategy according to the cost criterion is *no treatment* with the following technological parameters (Varela-Ortega *et al.*, 2020b):

• Water quantity (availability) [m^3/d]	The analysis has been conducted with a water capacity of 10,000 m^3/d.
• Water quality [e.g. total coliform CFU /ml]	The typical effluent municipal wastewater quality consists of the following quality parameters: 25 mg/L for TSS, 31 mg/L for BOD, 56 mg/L for COD, 40 mg/L for total nitrogen, 10,000 No/100ml for total coliforms, 500 mg/L for TDS, and 10 mg/L for total organic carbon.

Costs (TU1)

In the following the costs facts are summarized (Varela-Ortega *et al.*, 2020b):

• Production costs [€/m^3]	Since the DST resulted in a “no treatment” strategy, there would be no production costs at all.
• Selling price of treated WW [€/m^3]	N/Av

Expansion potential (TU1)

In the following the expansion potential is summarized (Varela-Ortega *et al.*, 2020b):

• Average WW quantity per WWTP/industry [m^3/d]	This is not applicable since no treatment technology would be applied.
• Maximal potential amount of reusable WW with M4W tech. [m^3/d]	See sentence above.
• Number of potential WWTP or industries that could apply the M4W tech. [no.]	MWW & TWW: 122 wastewater treatment plants in Tunisia in 2018 to considered for applying the MADFORWATER technology (Office National de l'Assainissement, 2018)

8.6 TU2: Strategy description from decision support tool

Technology data (TU2)

Overall, the situation in Tunisia appears diverse in the possible combination of production potentials and agronomic centres that are more wide spread in Tunisia. Touristic centres and to irrigate high valuable crops in a highly intensive and surface minimizing way, whereas the seasonality of the wastewater availability according to the touristic peak seasons should be considered. From the logistic perspective the priority areas to intensify the production of high value crops should be the area of Nebeul (73 100 inhabitants) at the south of the Cap Bon peninsula.

The developed decision support tool (DST), which identifies technology options that can treat wastewater to the desired quality, was used to evaluate basin-scale and national level wastewater treatment strategies (WWTS). We analysed the reuse potential of typical municipal wastewater (MWW) in order to comply with the local Tunisian wastewater reuse regulation – NT 106.03 standard irrigation. The treatment strategy *Wetlands: Nicaragua* is the top ranked strategy according to the cost and regulation criteria with the following technological parameters (Varela-Ortega *et al.*, 2020b):

• Water quantity (availability) [m^3/d]	The analysis has been conducted with a water capacity of 10,000 m^3/d.
• Water quality [e.g. total coliform CFU /ml]	The typical effluent municipal wastewater quality consists of the following quality parameters: 25 mg/L for TSS, 31 mg/L for BOD, 56 mg/L for COD, 40 mg/L for total nitrogen, 10,000 No/100ml for total coliforms, 500 mg/L for TDS, and 10 mg/L for total organic carbon.

Costs (TU2)

In the following the costs facts are summarized (Varela-Ortega *et al.*, 2020b):

• Production costs [€/m^3]	According to the analysis carried out by the decision support tool, the costs for the treatment of MWW amount to 0.42 TND/m^3 or 0.13 EUR/m^3. With the annually treated

	waste water of 3,650,000 m³ (Ref D 5.2), the annual costs would amount to EUR 474,500.
• Selling price of treated WW [€/m³]	N/Av

Expansion potential (TU2)

In the following the expansion potential is summarized (Varela-Ortega *et al.*, 2020b):

• Average WW quantity per WWTP/industry [m³/d]	To treat the annually produced MWW of 27.25 Mio m³ in the Cap Bon area (measured in 2016) with the technology proposed would lead to total annual treatment costs of EUR 3,542,500.
• Maximal potential amount of reusable WW with M4W tech. [m³/d]	See sentence above.
• Number of potential WWTP or industries that could apply the M4W tech. [no.]	MWW & TWW: 122 wastewater treatment plants in Tunisia in 2018 to considered for applying the MADFORWATER technology (Office National de l'Assainissement, 2018)

8.7 TU3 & TU4: Strategy description from the MADFORWATER pilots

Technology data (TU3 & TU4)

Overall, the situation in Tunisia appears diverse in the possible combination of production potentials and agronomic centres that are more wide spread in Tunisia. Touristic centres and to irrigate high valuable crops in a highly intensive and surface minimizing way, whereas the seasonality of the wastewater availability according to the touristic peak seasons should be considered. From the logistic perspective the priority areas to intensify the production of high value crops should be the area of Nebeul (73 100 inhabitants) at the south of the Cap Bon peninsula.

The pilot plant operates with the following treatment sections:

The municipal wastewater (MWW) treatment process 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.

The textile wastewater (TWW) treatment process developed applied in a pilot plant consists of the following treatment trains: (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.

The technological parameters include the following (Varela-Ortega *et al.*, 2020b):

• Water quantity (availability) [m³/d]	• **MWW:** The pilot plant, with a capacity of 10 m³/d with a potential volume of treating up to 3,650 m³ per year.

	• **TWW:** The pilot plant, with a capacity of 10 m^3/day with a potential volume of treating up to 3,650 m^3 per year.
• Water quality [e.g. total coliform CFU /ml]	• **MWW:** 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. • **TWW:** N/Ava

Costs (TU3 & TU4)

In the following the costs facts are summarized (Varela-Ortega *et al.*, 2020b):

• Production costs [€/m^3]	• **MWW:** According to the analysis carried out by the decision support tool, the costs for the treatment of MWW amount to 1.40 TND/m^3 or 0.45 EUR/m^3. With the annually treated waste water of 3,650 m^3 (Varela-Ortega *et al.*, 2020b), the annual costs of 1,643 EUR would occur. • **TWW:** The MADFORWATER pilot plant has been installed in the textile industry Gwash, located in the governorate of Korba (Nabeul, Tunisia), with a capacity of 10 m^3/day. According to the developed DST, the TWW treatment costs amount to 1.99 TND/m^3 or 0.64 EUR/m^3. With the annually treated waste water of 3,650 m^3 (Varela-Ortega *et al.*, 2020b), the annual costs of 2,336 EUR would occur.
• Selling price of treated WW [€/m^3]	**MWW & TWW:** < 0.5 EUR/m^3

Expansion potential (TU3 & TU4)

In the following the expansion potential is summarized (Varela-Ortega *et al.*, 2020b):

• Average WW quantity per WWTP/industry [m^3/d]	• **MWW:** The total annual MWW collected in the Cap-Bon Basin in 2016, where the pilot plant is located, amounts to 27.25 million m^3 (Office National de l'Assainissement, 2016). Consequently, the pilot plant would be capable of treating 0.01% of the wastewater annually at a total cost of 5,110 TND or 1,643 EUR. • **TWW:** Extrapolated, the pilot plant is capable of treating up to 3,650 m^3 per year. In the Cap-Bon basin where the pilot plant

	is located, a TWW volume of 450,000 m^3 has been collected in the year 2016 (http://www.nabeul.gov.tn/fr/les-industries-manufacturieres/). Consequently, the pilot plant could treat 0.8% of the TWW at a cost of 7,264 TND or 2,336 EUR.
• Maximal potential amount of reusable WW with M4W tech. [m^3/d]	See sentence above
• Number of potential WWTP or industries that could apply the M4W tech. [no.]	• **MWW & TWW:** 122 wastewater treatment plants in Egypt in 2018 to considered for applying the MADFORWATER technology (Office National de l'Assainissement, 2018)

Stakeholder opinion (TU3 & TU4)

In the following the stakeholder opinion is summarized (Souissi, 2019):

- How do you evaluate this treatment in general?

MWW:

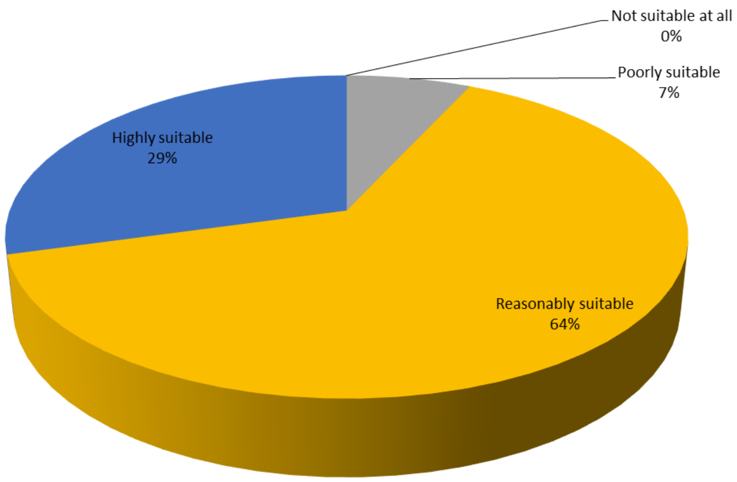


Figure 38: MWW Stakeholder opinion on the suitability of nitrifying trickling filters with innovative high specific-surface carriers.

TWW:

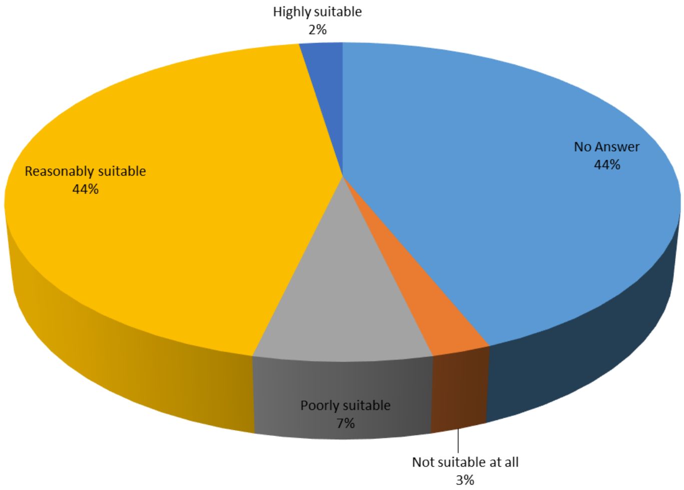


Figure 39: TWW Stakeholder opinion on the suitability of moving bed biological reactor.

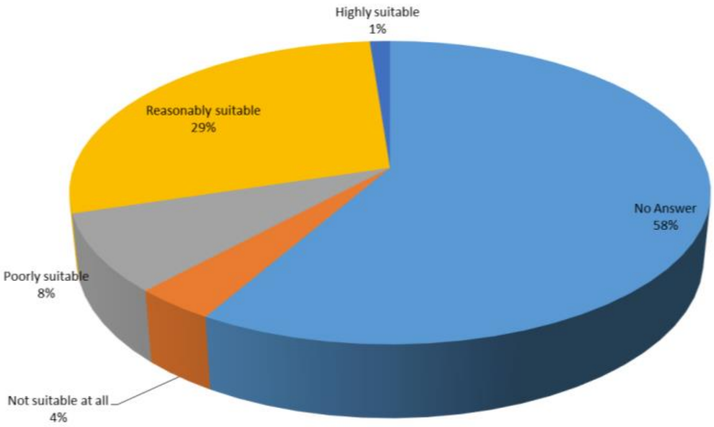


Figure 40: TWW Stakeholder opinion on the suitability of adsorption on innovative resins.

MWW:

- How do you evaluate this treatment according to the specific needs and characteristics of this wastewater and your country / governorate / basin? with possible answers as follows:

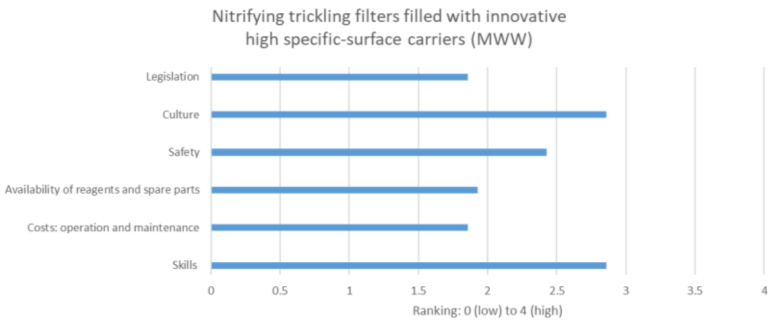


Figure 41: MWW Stakeholder opinion on the specific needs and characteristics of nitrifying trickling filters with innovative high specific-surface carriers.

TWW:

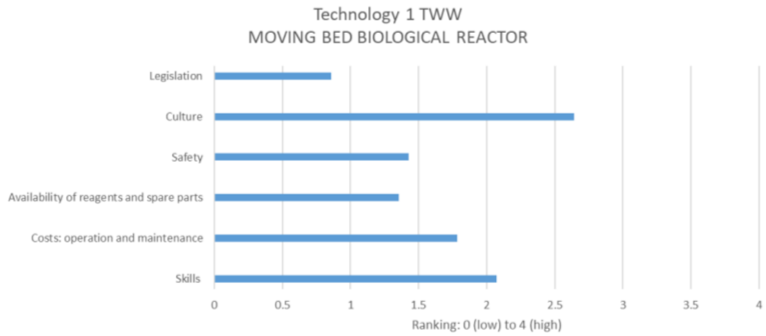


Figure 42: TWW Stakeholder opinion on the specific needs and characteristics of moving bed biological reactor.

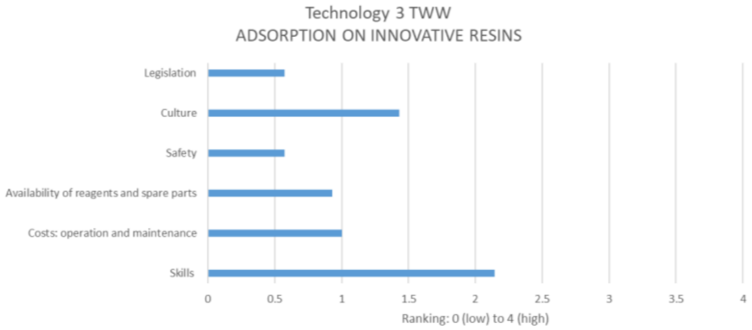


Figure 43: TWW Stakeholder opinion on the specific needs and characteristics of adsorption on innovative resins.

Irrigation

MWW and TWW

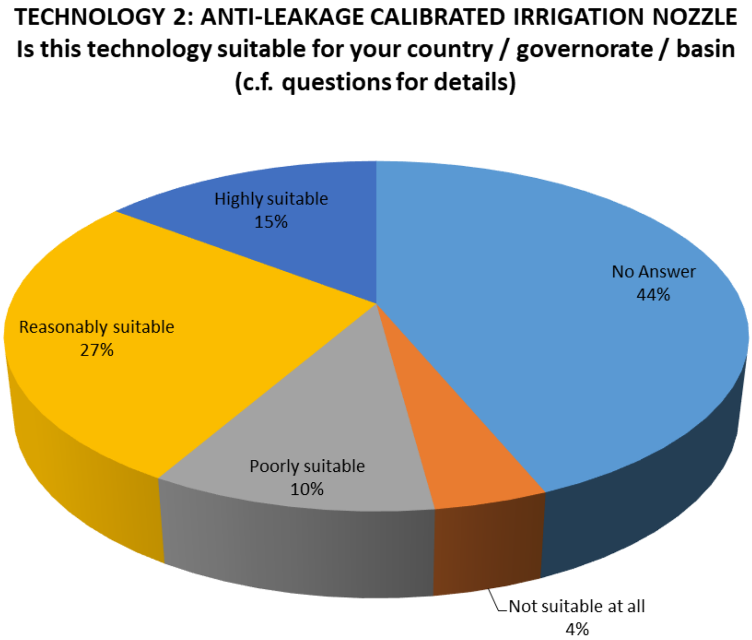


Figure 44: MWW & TWW general suitability of irrigation technology “anti-leakage calibrated irrigation nozzles” in stakeholder country, governorate or basin

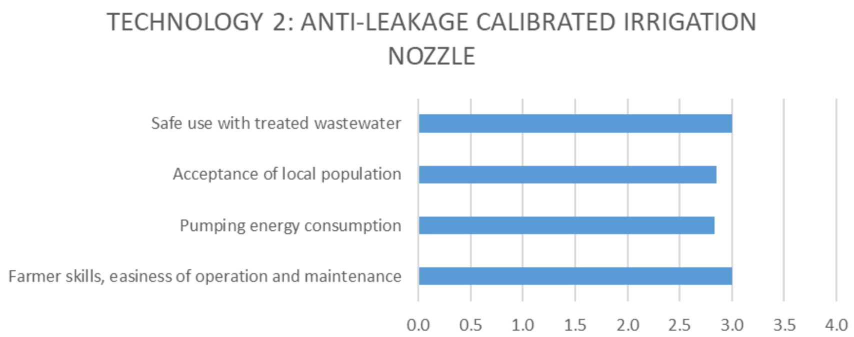


Figure 45: MWW & TWW suitability of different aspects of irrigation technology "anti-leakage calibrated irrigation nozzles" in stakeholder country, governorate or basin

MWW only

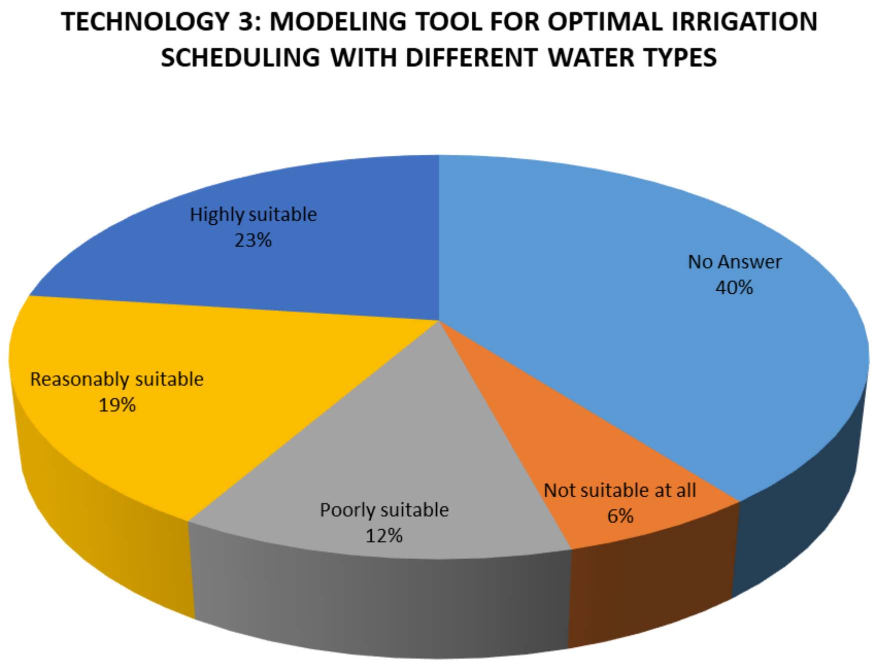


Figure 46: MWW general suitability of irrigation technology "modelling tool for optimal irrigation scheduling with different water types" in stakeholder country, governorate or basin

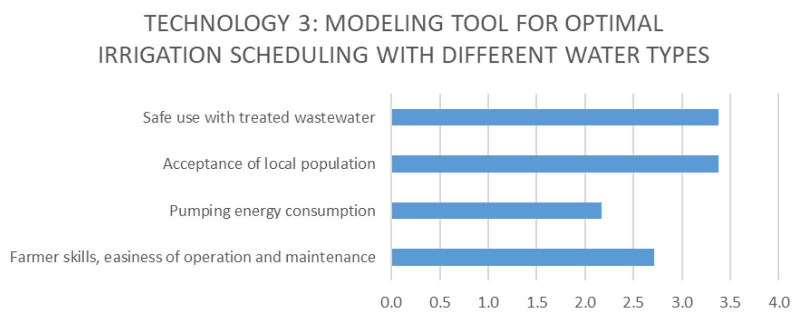


Figure 47: MWW suitability of different aspects of irrigation technology "modelling tool for optimal irrigation scheduling with different water types" in stakeholder country, governorate or basin

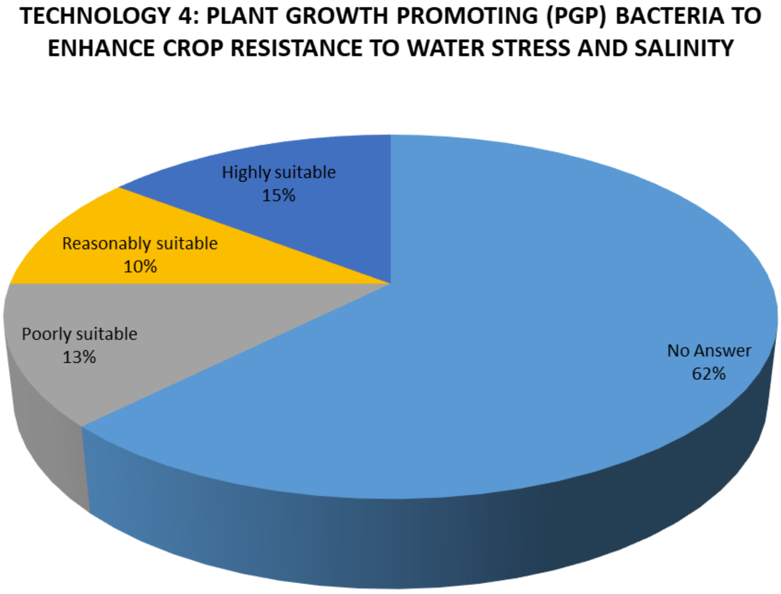


Figure 48: MWW general suitability of irrigation technology "modelling tool for optimal irrigation scheduling with different water types" in stakeholder country, governorate or basin

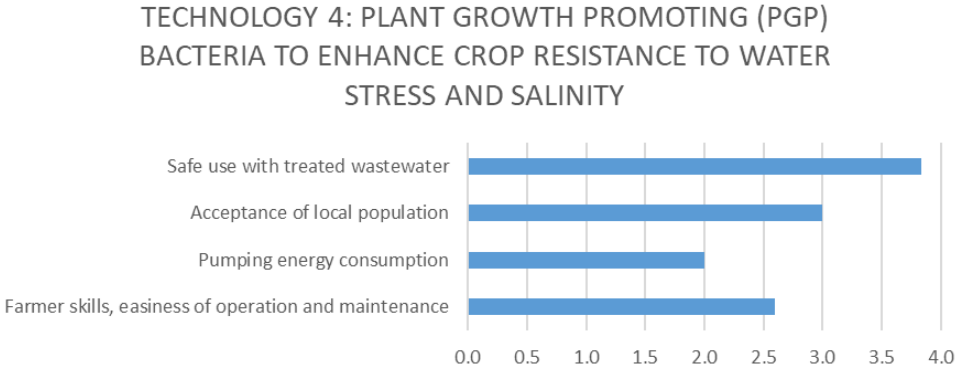


Figure 49: MWW suitability of different aspects of irrigation technology "Plant growth promoting bacteria" in stakeholder country, governorate or basin

8.8 TU5: Strategy description from the WP5 agro-economic model from a technological perspective

Technology data (TU5)

Nabeul is known by several crop cultivation, in fact, the region accounts for 85% of the national citrus production, 63% of the national tomato production, 97% of the national strawberry production and 40% of the vine production. Water scarcity is considered the main problem faced by farmers in Nabeul. Then, it is important to search for solutions to adapt the Nabeul agricultural sector in order to cope with water scarcity. This then can lead to recommendations on how to reduce the effects of water scarcity. These recommendations base on scenarios development. These scenarios are introduced in the following. The **baseline scenario (TU-BS)** represents the **current situation** of the case study, where water availability varies according to the type of farm, type of water (freshwater, treated wastewater) and period of the year. The **water availability scenario** considers an increase in water availability obtained from treated wastewater reuse. Two simulations were defined: (i) **(TU-WAS1),** all freshwater availability is **replaced by treated wastewater**; (ii) **(TU-WAS2),** farmers can **mix the two types of water.** The next scenario considers a **new technology** (calibrated nozzles; see Figure 50) **(TU-TS),** assuming that the irrigation efficiency increases by 10 percentage points. Lastly, the **policy scenario** considers two simulations: (i) **(TU-PS1),** the **price of freshwater is subsidized** and equal to the price of treated wastewater, and (ii) **(TU-PS2),** the **price of freshwater is no longer subsidized.** The following sections give a short overview about the technological and cost data of all technologies (Varela-Ortega *et al.*, 2020b).

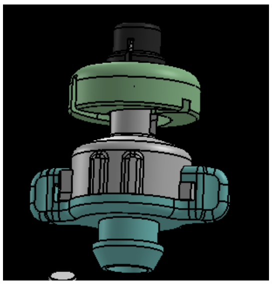


Figure 50: A low-cost innovative mini-sprinkler suitable for treated WW - Source: MADFORWATER WP3.

- Water availability:

Table 23: Water availability data. Retrieved from the MADFORWATER Del. 5.2 report (2020).

Strategies	Total freshwater used [m³/year]	Total treated wastewater used [m³/year]	Total water used [m³/year]	Average water used [m³/ha/year]
TU-BS	140,159,821	2,651,662	142,811,483	3,596 (freshwater) 336 (wastewater)
TU-TS	104,075,703	23,944,475*	128,020,177	3,596 (freshwater) 1,336 (wastewater)
TU-WAS1	-	231,126,641	231,126,641	- (freshwater) 4,932 (wastewater)
TU-WAS2	106,691,427	20,080,892*	126,772,319	3,596 (freshwater) 1,168 (wastewater)
TU-PS1	106,851,386	20,026,579*	126,877,965	3,596 (freshwater) 1,168 (wastewater)
TU-PS2	-	231,126,641	231,126,641	- (freshwater) 4,932 (wastewater)

* This amount has been calculated the following:

$$Total\ aggregated\ TWW\ used = aggregated\ TWW\ consumption * \Big(total\ aggregated\ F3\ farm\ area + total\ aggregated\ F1\ farm\ area * \frac{F1\ TWW\ consumption}{F1\ FW\ consumption} + total\ aggregated\ F3\ farm\ area * \frac{F2\ TWW\ consumption}{F2\ FW\ consumption}\Big)$$

- Distance from WWTP to irrigation [km] -
- Land and crop data [ha] 46,860 (approx. 470 km²)
- Irrigation method drip irrigation systems

Costs (TU5)

The cost and revenue data are stated in the following (Varela-Ortega *et al.*, 2020b):

Table 24: Cost and revenue data. Retrieved from the MADFORWATER Del. 5.2 report (2020).

	Costs		Revenue
Strategies	Total water cost [€/year]	Average water cost [€/ha/year]*	Average farmer income [€/ha/year]
TU-BS	6,793,132	145	3,444
TU-TS	4,641,918	99	4,950

	Costs		Revenue
Strategies	**Total water cost [€/year]**	**Average water cost [€/ha/year]***	**Average farmer income [€/ha/year]**
TU-WAS1	4,622,533	99	4,257
TU-WAS2	4,669,275	100	4,660
TU-PS1	2,537,559	54	4,694
TU-PS2	9,245,066	197	4,158

* Average water cost = Total water cost / 46,860 ha [total aggregated area in Nabeul]

Conclusion: Results show that farm income has increased in all scenarios compared to the baseline scenario, explained by the fact that, with an additional quantity of water, farmers cultivate more profitable crops such as strawberry, citrus and tomato. Furthermore, the water availability scenario and the technology scenario are suggested as the optimal scenario with an income gain of 1,506 €/ha in comparison with the baseline scenario. Based on these scenario simulation results, it can be underlined that the implementation of the MADFORWATER technologies has a positive effect on farm income in Tunisia. However, the reluctancy to accept reused wastewater for agricultural production was identified during the fieldwork series as one of the main barriers for using TWW mainly due to its appearance (color and smell). Accordingly, it will be necessary to develop ad-hoc incentives to promote the acceptance and adaptation of wastewater reuse in agriculture.

Expansion potential (TU5)

The data

Table 11 shows the expansion potential in Tunisia based on the assumption that the freshwater and wastewater use, and subsequently the water costs would decrease approximately about the same percentage as calculated in the agro-economic model. Consequently, the freshwater use for agriculture could possibly decrease from **889*10^{6} m^{3}/year** to **971*10^{6} m^{3}/year** and there is a great potential for wastewater reuse (municipal) in Tunisia, which is about **221*10^{6} m^{3}/year.** The extrapolated water cost saving would amount to an average for all scenarios of **302 Mio €/year.** For the last scenario, the water cost would increase about **268 Mio €/year,** due to discontinuing of the wastewater subsidization.

Table 25: Estimated figures based on FAO. 2010. AQUASTAT Main Database, Food and Agriculture Organization of the United.

Strategies	Total freshwater use for agriculture in the Nabeul region [10^6 m^{3}/year]	Total extrapolated freshwater use for agriculture in Tunisia [10^6 m^{3}/year]	Total TWW used in the Nabeul region [10^6 m^{3}/year]	Total potential for wastewater treatment in Tunisia [10^6 m^{3}/year]	Total water cost in the Nabeul region [in Mio €/year]	Total extrapolated water cost in Tunisia [in Mio €/year]*
TU-BS	140	3,773**	2.7	221***	6.8	759.2
TU-TS	104	2,802	23.9	221***	4.6	513.6
TU-WAS1	-	-	231.1	221***	4.6	513.6
TU-WAS2	107	2,884	20.1	221***	4.7	524.7
TU-PS1	107	2,884	20.0	221***	2.5	279.1
TU-PS2	-	-	231.1	221***	9.2	1,027.2

* This is a simple extrapolated calculation based on the following figures:
*Extrapolated water costs = (Water cost in Nabeul / Land and crop data in Nabeul) * Cultivated area in Tunisia*
*759.2 = (6.8*10^{6} € / 46,860 ha) * 5,232,000 ha*

** This figure has been calculated based on the "total freshwater withdrawal in 2017" multiplied with "the percentage of water withdrawal in agriculture of the total water withdrawal in 2017". Consequently, this figure must be treated with caution since this is only an approximative calculation of the true value.

*** This figure was calculated based on the "Not treated municipal wastewater discharged in 2010" and the "Not treated municipal wastewater in 2009" in Tunisia. This number should be treated with caution as more recent data are not yet available.

8.9 MO1: Strategy description from decision support tool

Technology data (MO1)

In the Souss Massa region, especially the smaller towns in the region east of Agadir with the areas around Taroudant or Oulad Berhil offer a very interesting opportunity. The high business potential is furthermore characterized by a nearby located clustering of agri-enterprises south of Agadir and along the motorway N1 in the surrounding of Tin Mansour (2 hrs drive to Oulad Berhil). The reasonable travel distances would allow investors to engage in new upcoming endeavours in the East of Agadir.

The developed decision support tool (DST), which identifies technology options that can treat wastewater to the desired quality, was used to evaluate basin-scale and national level wastewater treatment strategies (WWTS). We analysed the reuse potential of typical effluent of municipal wastewater in order to comply with the ISO regulation category C – agricultural irrigation of non-food crops. The technological parameters include the following (Varela-Ortega *et al.*, 2020b):

• Water quantity (availability) [m³/d]	The analysis has been conducted with a water capacity of 10,000 m³/d.
• Water quality [e.g. total coliform CFU /ml]	The typical effluent municipal wastewater quality consists of the following quality parameters: 25 mg/L for TSS, 31 mg/L for BOD, 56 mg/L for COD, 40 mg/L for total nitrogen, 10,000 No/100ml for total coliforms, 500 mg/L for TDS, and 10 mg/L for total organic carbon.

Costs (MO1)

In the following the costs facts are summarized (Varela-Ortega *et al.*, 2020b):

• Production costs [€/m³]	Since the DST resulted in a "no treatment" strategy, there would be no production costs at all.
• Selling price of treated WW [€/m³]	N/Av

Expansion potential (MO1)

In the following the expansion potential is summarized (Varela-Ortega *et al.*, 2020b):

• Average WW quantity per WWTP/industry [m³/d]	This is not applicable since no treatment technology would be applied.
• Maximal potential amount of reusable WW with M4W tech. [m³/d]	See sentence above.
• Number of potential WWTP or industries that could apply the M4W tech. [no.]	73 wastewater treatment plants in 2012 in Morocco to considered for applying the MADFORWATER technology (Food and Agriculture Organization of the United Nations, 2016).

8.10 MO2: Strategy description from decision support tool

Technology data (MO2)

In the Souss Massa region, especially the smaller towns in the region east of Agadir with the areas around Taroudant or Oulad Berhil offer a very interesting opportunity. The high business potential is furthermore characterized by a nearby located clustering of agri-enterprises south of Agadir and along the motorway N1 in the surrounding of Tin Mansour (2 hrs drive to Oulad Berhil). The reasonable travel distances would allow investors to engage in new upcoming endeavours in the East of Agadir.

The developed decision support tool (DST), which identifies technology options that can treat wastewater to the desired quality, was used to evaluate basin-scale and national level wastewater treatment strategies (WWTS). We analysed the reuse potential of typical municipal wastewater (MWW) in order to comply with the local Moroccan irrigation regulation category A

– irrigation of crops to be eaten raw. The resulting treatment strategy *Wetlands: Nicaragua* includes the following technological parameters (Varela-Ortega *et al.*, 2020b):

• Water quantity (availability) [m^3/d]	The analysis has been conducted with a water capacity of 10,000 m^3/d.
• Water quality [e.g. total coliform CFU /ml]	The typical effluent municipal wastewater quality consists of the following quality parameters: 25 mg/L for TSS, 31 mg/L for BOD, 56 mg/L for COD, 40 mg/L for total nitrogen, 10,000 No/100ml for total coliforms, 500 mg/L for TDS, and 10 mg/L for total organic carbon.

Costs (MO2)

In the following the costs facts are summarized (Varela-Ortega *et al.*, 2020b):

• Production costs [€/m^3]	According to the new decision support tool, the costs of this technology amount to 1.53 MAD/m^3 or 0.14 EUR/m^3. With the annually treated waste water of 3,650,000 m^3 (Varela-Ortega *et al.*, 2020b), annual costs of 511,000 EUR would occur.
• Selling price of treated WW [€/m^3]	N/Av

Expansion potential (MO2)

In the following the expansion potential is summarized (Varela-Ortega *et al.*, 2020b):

• Average WW quantity per WWTP/industry [m^3/d]	The produced MWW in Morocco was around 700 Mio m^3/year in 2012 (Food and Agriculture Organization of the United Nations, 2016). According to the National Water Resources Plan (PNA), it is expected that by 2030 the generated wastewater will grow to 900 million m^3. The PNA establishes an annual target of 325 million m^3 of wastewater to be reused by 2030, mainly for irrigation (142 million m^3) and landscaping/golf courses (133 million m^3). Other uses such as reuse for industry and groundwater recharge are also considered in the plan. Assuming the treatment of the 325 million m^3 of WW with the proposed strategy, the costs would amount to EUR 45,500,000.
• Maximal potential amount of reusable WW with M4W tech. [m^3/d]	See sentence above.
• Number of potential WWTP or industries that could apply the M4W tech. [no.]	73 wastewater treatment plants in 2012 in Morocco to considered for applying the MADFORWATER technology (Food and Agriculture Organization of the United Nations, 2016).

8.11 MO3: Strategy description from the MADFORWATER pilots

Technology data (MO3)

In the Souss Massa region, especially the smaller towns in the region east of Agadir with the areas around Taroudant or Oulad Berhil offer a very interesting opportunity. The high business potential is furthermore characterized by a nearby located clustering of agri-enterprises south of Agadir and along the motorway N1 in the surrounding of Tin Mansour (2 hrs drive to Oulad Berhil). The reasonable travel distances would allow investors to engage in new upcoming endeavours in the East of Agadir.

The pilot plant operates with the following treatment sections: (i) a 150 000 m^3 anaerobic lagoon, (ii) 64 sand filtration unit, and (iii) an UV-based disinfection unit. This treatment scheme allows the production of a high-quality effluent. The technological parameters include the following (Varela-Ortega *et al.*, 2020b):

• Water quantity (availability) [m^3/d]	WWTP has an average flow of 75,000 [m^3/d]
• Water quality [e.g. total coliform CFU /ml]	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

Costs (MO3)

In the following the costs facts are summarized (Varela-Ortega *et al.*, 2020b):

• Production costs [€/m^3]	According to the new decision support tool, the treatment costs 2.87 MAD/m^3 or 0.27 EUR/m^3. With the annual treatment volume of 27.4 Mio m^3 (Ref D 5.2), the annual costs of 7,398,000 EUR would occur.
• Selling price of treated WW [€/m^3]	2.6 €/m^3 (0.28 €/m^3 for operation and maintenance)

Expansion potential (MO3)

In the following the expansion potential is summarized (Varela-Ortega *et al.*, 2020b):

• Average WW quantity per WWTP/industry [m^3/d]	Considering the produced MWW in Morocco is around 700 Mio m^3/year in 2012 (Food and Agriculture Organization of the United Nations, 2016). According to the National Water Resources Plan (PNA), it is expected that by 2030 the generated wastewater will grow to 900 million m^3. The PNA establishes an annual target of 325 million m^3 of wastewater to be reused by 2030, mainly for irrigation (142 million m^3) and landscaping/golf courses (133 million m^3). Other uses such as reuse for industry and groundwater recharge are also considered in the plan.
• Maximal potential amount of reusable WW with M4W tech. [m^3/d]	See sentence above.
• Number of potential WWTP or industries that could apply the M4W tech. [no.]	73 wastewater treatment plants in 2012 in Morocco to considered for applying the MADFORWATER technology (Food and Agriculture Organization of the United Nations, 2016).

Stakeholder opinion (MO3)

In the following the stakeholder opinion is summarized (Souissi, 2019):

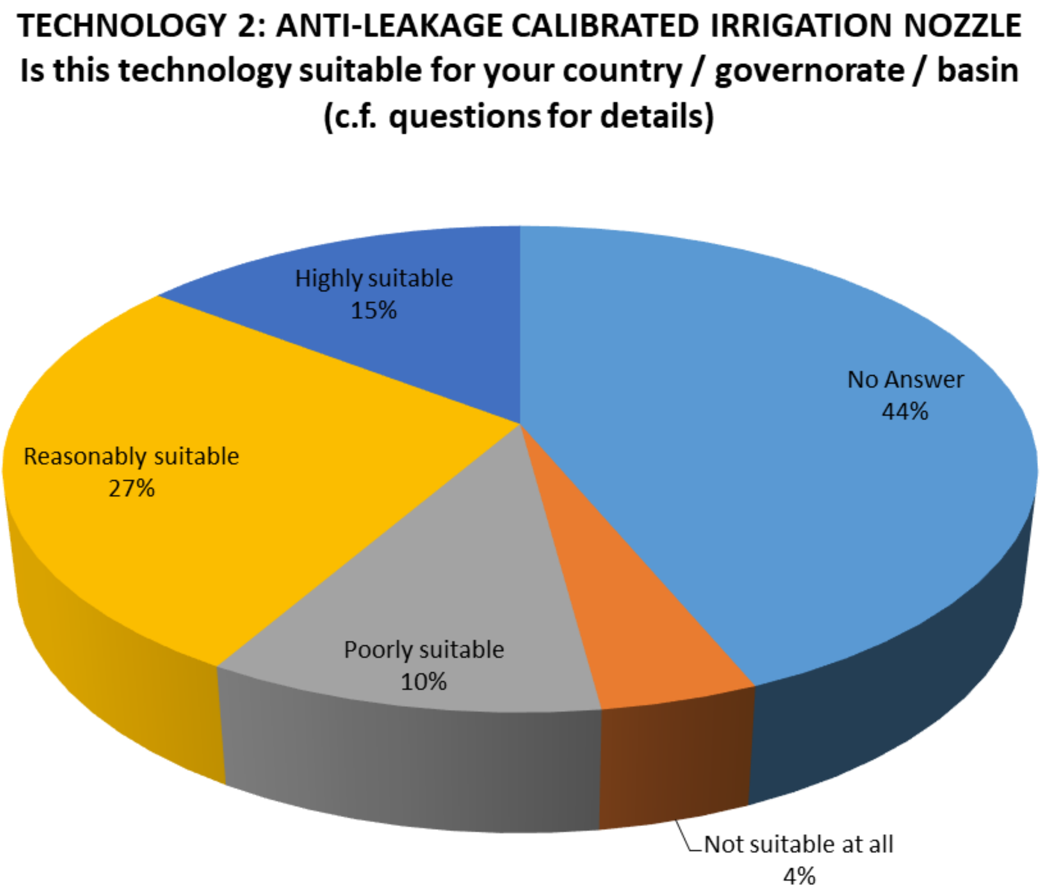


Figure 51: General suitability of irrigation technology "anti-leakage calibrated irrigation nozzles" in stakeholder country, governorate or basin

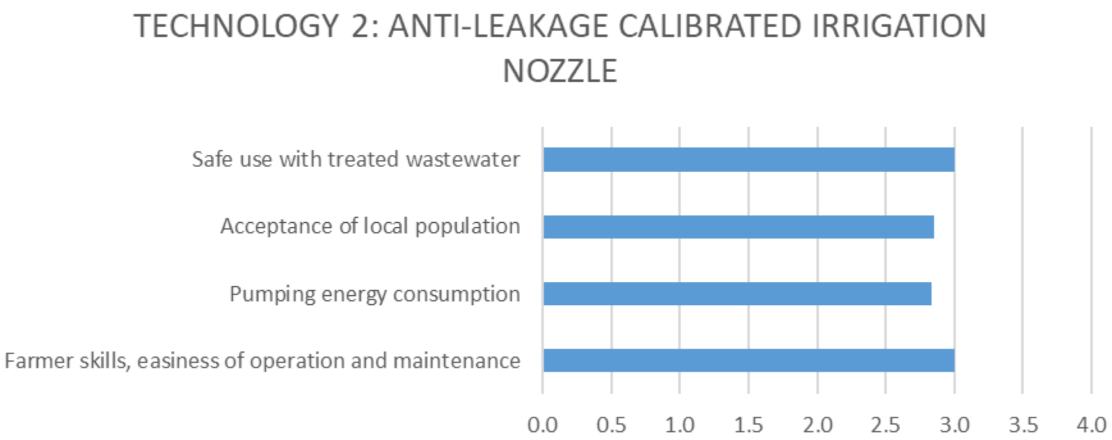


Figure 52: Suitability of different aspects of irrigation technology "anti-leakage calibrated irrigation nozzles" in stakeholder country, governorate or basin

8.12 MO4: Strategy description from the WP5 agro-economic model from a technological perspective

Technology data (MO4)

Agriculture is the most important economic activity in the region of Souss Massa, and it is in fact considered a leading region in the production of several fruit and vegetable crops such as tomato and citrus. Citrus production in the Souss Massa region occupies an area of 40,343 ha, which represents one third of the total citrus area in Morocco. The agro-economic model, integrated and modified, was applied to the Moroccan case study to analyze alternative political scenarios and estimate the impacts of different policies such as the **optimal allocation of land and of different irrigation water quality among crops, economic performance of the farmers,** as well as the **convenience and the effectiveness to adopt treatment and irrigation technologies** developed in MADFORWATER. Four different scenarios were considered. The baseline scenario (MO-BS) corresponds to the current situation in the study region, where only fresh water is available for farmers in a sufficient amount. The water availability scenario (MO-WAS) considers treated wastewater as an additional irrigation water source, which was made available by the innovative technologies proposed and tested by the MADFORWATER project (MADFORWATER, 2019a). The first policy scenario (MO-PS1), given the availability of both fresh and treated water, simulates a water pricing policy by taking the price for freshwater as constant and a gradually decreasing price of treated wastewater whereas the second policy scenario (MO-PS2) assumes a full cost cover of the new technology by a subsidy. Lastly, the technology scenario (MO-TS) simulates the introduction of the new technology of innovative calibrated nozzles (see Figure 53), adapted to the irrigation with treated wastewater (Varela-Ortega *et al.*, 2020b).

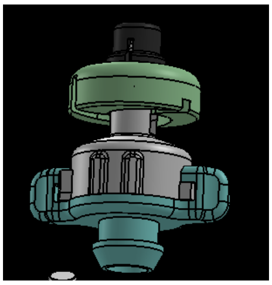


Figure 53: A low-cost innovative mini-sprinkler suitable for treated WW - Source: MADFORWATER WP3.

- Water availability:

Table 26: Water availability data. Retrieved from the MADFORWATER Del. 5.2 report (2020).

Strategies	Total freshwater used [m^3]	Total treated textile wastewater (TWW) used [m^3]	Total water used [m^3]	Average water used [m^3/ha]	Availability of new irrigation technology	Use of treated TWW
MO-BS	218,449,511	-	218,449,511	6,764	No	No
MO-TS*	218,449,511	-	218,449,511	6,764	Yes	No
MO-WAS*	218,449,511	-	218,449,511	6,764	No	No
MO-PS1**	140,507,230	86,850,330	227,357,560	7,040	No	Yes
MO-PS2	218,449,511	-	218,449,511	6,764	Yes	No

* The results have shown that TWW reuse does not appear in the optimal solution as an irrigation water source
** Farmers only decide to substitute fresh water with TWW when the price that they have to pay is equal and/or lower than the price of freshwater

- Distance from WWTP to irrigation [km] NOT SPECIFIED
- Land and crop data [ha] 40,343 ha (approx. 400 km^2)
- Irrigation method drip irrigation systems

Costs (MO4)

The cost and revenue data are stated in the following (Varela-Ortega *et al.*, 2020b):

Table 27: Cost and revenue data. Retrieved from the MADFORWATER Del. 5.2 report (2020).

	Costs			Revenue
Strategies	Total water cost [€]	Average water cost [€/ha]	Annualized cost of new technology [€/ha]	Average farmer income [€/ha/year]
MO-BS	32,767,427	1,014	-	8,485
MO-TS	32,767,427	1,014	350*	8,485
MO-WAS	32,767,427	1,014	-	8,485
MO-PS1	29,761,118	921	-	8,505***
MO-PS2	32,767,427	1,014	0**	8,485

* These are the implementation costs, however, the results showed that the farmer do not consider the TWW as an adequate source for irrigation. Consequently, the average farmer's income remains the same as in MO-BS.

** Assumption that the full cost of the technology is covered by a subsidy granted to farmers.

*** Higher average farmer income under the assumption that TWW allows the saving of important amounts of fertilizers

Expansion potential (MO4)

The data in Table 28 shows the expansion potential in Morocco based on the assumption that the freshwater use and the water costs would decrease approximately about the same percentage (-36% and -9%, respectively) (Varela-Ortega *et al.*, 2020b). Consequently, the freshwater use for agriculture could possibly decrease by around **3,180*10^6 m^3/year.** There is a great potential for wastewater treatment (municipal, industrial, and textile) in Morocco, which is about **680*10^6 m^3/year.** However, it must be noted that water users, i.e. farmers', decision about the use of treated wastewater only changes in the price water policy scenarios when the price of treated wastewater is subject to a certain level of subsidies. The extrapolated water cost saving would amount to around **168 Mio €/year** under the assumption of the average water cost as calculated in the agro-economic model (see Table 27) and the "total harvested irrigated crop area (full control irrigation) in 2011" (FAO, 2011).

Table 28: Estimated figures based on FAO. 2010. AQUASTAT Main Database, Food and Agriculture Organization of the United.

Strategies	Total freshwater use for agriculture in the Souss Massa region [10^6 m^3/year]	Total extrapolated freshwater use for agriculture in Morocco [10^6 m^3/year]	Total treated textile wastewater (TWW) used in the Souss Massa region [106 m^3/year]	Total potential for wastewater treatment in Morocco [10^6 m^3/year]	Total water cost in the Souss Massa region [in Mio €]	Total extrapolated water cost in Morocco [in Mio €/year]
MO-BS	218.5	9,080	-	670*	32.8	1,735
MO-TS	218.5	9,080	-	670*	32.8	1,735
MO-WAS	218.5	9,080	-	670*	32.8	1,735
MO-PS1	140.5	5,900	86.5	670*	29.8	1,567
MO-PS2	218.5	9,080	-	670*	32.8	1,735

* This figure was calculated based on the estimation of the "total produced industrial wastewater in 2010" (around 170 Mio m^3/year) and the "total not treated municipal wastewater in 2011" (around 500 Mio m^3/year) in Morocco. This number should be treated with caution as more recent data are not yet available.