Treatment and reuse of water: Economic feasibility and assessment of water pricing policies in Ouardanine irrigation district (Tunisia)

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Abstract

Treated wastewater reuse is a valuable water source in water scarcity conditions. If its technical feasibility is largely demonstrated, less attention is paid to the economic assessment. By applying an ex-post Cost-Benefit Analysis to Ouardanine irrigation district, in eastern Tunisia, the economic feasibility of wastewater treatment and reuse in irrigation was assessed. Data on costs and benefits were evaluated throughout the lifespan of the project and four scenarios - no treatment, treatment, treatment with reuse, and treatment with reuse without considering the environmental benefits – were considered. The results prove that: the project is economically profitable for all scenarios except the first; it is still profitable with an increase in costs or a decrease of benefits up to 30%; farmers are the main beneficiaries of the project which is financially not viable for both the treatment plant company and the public body charged of the distribution of water; the affordability of the treated wastewater price depends on the cropping pattern: with increased water pricing peach growers will still have substantial benefit while olive growers will reduce significantly their benefits.

Keywords: *Cost-Benefit Analysis, Wastewater reuse, Wastewater treatment plan, Economic feasibility, Irrigation water pricing, Irrigation system.*

1. Introduction

Reusing water is a valuable solution to stop the loop between water supply and wastewater disposal, turning what was formerly deemed trash into a resource after the necessary treatment (Urkiaga *et al.*, 2008). Reusing water for irrigation has the benefit of providing water and the needed nutrients associated with crop development, and it may replace the usage of fertilizers, which is quite expensive (Alobaidy *et al.*, 2010). Wastewater irrigation can therefore help to lessen environmental carbon emissions while also reducing water shortages and saving money on disposal and pumping expenses (Hanjra *et al.*, 2012). Reusing recovered wastewater is a particularly enticing alternative in these ecolog-

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ically conscious times (Mujeriego *et al.*, 2008) and, to develop strategies to meet the regulatory criteria for direct reuse of recovered wastewater in agricultural, industrial, or urban uses, several wastewater treatment systems have been examined (Meneses *et al.*, 2010).

However, wastewater treatment and management are costly and present challenges in terms of funding (Fernandez *et al.*, 2009) mainly because the benefits of wastewater treatment are less evident to individuals and more difficult to assess in monetary terms. Identifying and evaluating external advantages, which are typically immeasurable, is quite complex. Although several practical approaches and frameworks have been proposed, none are complete or accurate (Kihila *et al.*, 2014). The economic value of these projects is sometimes underestimated due to a failure to adequately account for and quantify the various non-monetary advantages of water reuse (e.g., watershed conservation, local economic growth, and public health improvement) (Godfrey *et al.*, 2009). With the aim of economically evaluating wastewater treatment, this paper will present a scheme to assess the economic feasibility of the "Ouardanine wastewater treatment and irrigation district project" taking both internal and external impacts into consideration. The specific objectives of the present work are to evaluate the economic viability of the wastewater Treatment Plant and irrigation system of Ouardanine under different assumptions and to learn lessons for similar cases in Tunisia.

Estimating the profitability of a public project, such as wastewater treatment plants and water reuse, should be addressed to determine whether the country makes a profit with the planned investment. Therefore, the economic analysis takes a broader view of the project's profitability where external effects such as environmental and health impacts are included, and international prices are applied. For this purpose, by applying the Cost Benefit Analysis (CBA) methodology, we will determine the economic value of the environmental benefits and search for water pricing policies that contribute to a more efficient O&M of the irrigation system and the Waste Water Treatment Plant (WWTP). Although the literature on CBAs of planned or existing reuse project is rather sparse, CBA is now recognized by many researchers as the most suitable appraisal tool of reuse projects (Acampa *et al.*, 2019; Arena *et al.*, 2020).

Of course, since wastewater treatment and reuse projects are either implemented to increase water availability and its use and to enhance the environment or both an improved and extended CBA have recently been intensified by explicitly including environmental costs and benefits.

The technical solutions for those projects are available and well developed, but they come with a huge financial demand since they are very expensive to implement (Fernandez *et al.*, 2009). In general terms, the costs of the investments are well known but not so much the benefits, particularly in the case of environmental benefits where different approaches prevail (Chen and Wang, 2009; Godfrey *et al.*, 2009; Hernández *et al.*, 2006; Molinos-Senante *et al.*, 2010; Ćetković *et al.*, 2022). Previous research focus on water reuse for environmental purposes (Birol *et al.*, 2010; Chen et Wang, 2009; Kihila *et al.*, 2014; Molinos-Senante *et al.*, 2010; Verlicchi *et al.*, 2012) while economic and financial feasibility evaluations are often missing especially when the reuse in irrigation is the main option.

The project's overall performance is mainly evaluated by (European Commission, 2015) three indicators: the Net Present Value (NPV), the Internal Rate of Return (IRR) and the Cost-Benefit Ratio (BCR). The CBA's greatest aspect is that it makes it easier to compare different types of costs and benefits, giving evidence for decision-makers to choose the water reuse plan that is most likely to generate the largest net benefits. In this approach, all costs and benefits must be stated in monetary terms, allowing for comparing cost and benefit items of changeable nature (for example, project market and nonmarket benefits) (Winpenny *et al.*, 2010).

2. Treated wastewater in Tunisia

With an area of 16.361 million hectares, Tunisia is in a semi-arid to an arid climate zone (ONAS, 2017) and is increasingly facing years of drought caused or exacerbated by climate change with both years of heavy rains causing violent floods, and droughts (Benabdallah, 2007).

The long-term average annual rainfall is 207 mm, with inter-annual variance ranging from 70 to 620 mm. Rainfall varies widely across the country, with 600 mm in the north, 300 mm in the middle, 150 mm in the south, and less than 100 mm in the extreme southwest. Tunisia's water resources are projected to be 4700 Mm^3, with 650 Mm^3 of non-renewable resources accounting for 13.8% of total water resources. As a result, in 2015 the annual endowment per capita is around 450 m^3 which is below the absolute water shortage criterion (Drechsel and Hanjra, 2018) and will be 315 m^3 per capita per year in 2030. Annual water consumption in Tunisia is distributed between irrigated agriculture 2,080 Mm^3, drinking water 365 Mm^3, industry 130 Mm^3 and tourism 25 Mm^3. The country will shortly be confronted with a water deficit between its consumptive uses and its water productivity which is pushing the government to turn to non-conventional waters.

The main responsible for WWTP development is the Office National de l'Assainissement, (ONAS). It operates about 115 wastewater treatment plants, only 66 are active. There are essentially (2/3) activated sludge treatment plants with low load and prolonged aeration, 7% use activated sludge with medium load, 12% use lagoons, as well as small rural plants and two wastewater treatment plants for industrial discharges. The flow of wastewater treated, is approximately 905,000 m^3/d, or nearly 330 Mm^3/year.

The reuse of treated water started in Tunisia in 1965 with the project of the irrigated perimeter (IP) of Soukra and Oued Souhil where surface wells were no longer able to satisfy farmers' water needs, causing overexploitation and salinization. New IPs emerged between the 80s and 90s in greater Tunis, the governorate of Sousse, and Sfax. Subsequently, other projects were created in the interior areas and the country's south. Between the 70s and 80s treated wastewater reuse (TWWR) projects also emerged for watering golf courses and green spaces. TWWR in irrigation is considered a necessity and is an integral part of the National Strategy for the Rationalization of the Use of Hydraulic Resources initiated simultaneously with the first Ten-Year Water Mobilization Strategy (1990-2000).

The treated water is allocated by 53% indirect or ecological use (wetlands, groundwater recharge, etc.), 33% in irrigated area, 12% for golf courses and 2% green spaces. 20,3 Mm^3 of treated wastewater is reused for irrigation which only meets 1% of the needs of irrigated agriculture (ONAS, 2017). The Irrigated area has continuously increased since 1965 (ONAS, 2017) and during the 2015-2016 campaign the irrigable area using treated wastewater was 8,474 of which 32% was irrigated. The most significant areas are: Borj Touil and Mornag in the North and Dhraa Tamar in Kairouan, in the Center and El Hajeb in Sfax in the South. The crops grown are mainly fruit trees (45% of the total area), especially olive trees, and fodder (51%), field crops represent only 4% of the surface (ONAS, 2017). Water reuse in the irrigation of green spaces and golf courses remains very limited. In the tourism sector, there are a few cases of TWWR to water the green spaces of hotels in the touristic area of Sousse and Djerba. The reuse of treated wastewater in the industry is minimal.

The governance of the TWWR involves state institutions, with a central role in the decision-making process, regardless of its use i.e. agricultural, green space (tourist and municipal), golf, and groundwater recharge, research, donors, industrialists, user groups as well as civil society associations established at the regional level complete the panorama (ONAS, 2017). The Ministry of Public Health and the National Agency for Sanitary and Environmental Control of Products (ANCSEP) are responsible for the sanitary control of water (drinking water, mineral water, raw and treated wastewater and bathing water). The Ministry of Agriculture, Water Resources and Fisheries, – the institution responsible for administering the hydraulic public domain and plans the mobilization and allocation of water resources – through several directorates-general and supervisory structures have specific attributions to the TWWR (ONAS, 2017): in particular, the Regional Commissariats for Agricultural Development (CRDA), are responsible for the implementation of the agricultural policy adopted by the government. They carry out water and soil conservation missions, distribution of agricultural water, management of hydraulic equipment. In the irrigated perimeters, the CRDA is responsible for the distribution of the wastewater to irrigated agricultural areas, the monitoring and maintenance of all hydraulic equipment, the application of the water code, the collection of fees, operation of public irrigated areas and the quality control of TWWs. Finally, the National Sanitation Office (ONAS), an industrial and commercial public establishment endowed with legal personality and financial autonomy created in 1974 to ensure the management of the sanitation sector in Tunisia. In 1993, ONAS's mission has shifted from a sanitation network manager to that of the leading player in water environment protection and the fight against all sources of pollution. ONAS carries out self-monitoring of its water's microbiological and chemical quality throughout the purification process. This regular monitoring targets both environmental discharge standards and TWWR standards. ONAS can rely on regional sanitation offices to carry out these missions in the governorates. In 1975 the use of treated wastewater was regulated with the publication of the Water Code (Law No. 75-16 of March 31, 1975) that reaffirms the hydraulic public domain, provides measures regarding the pollution of surface and underground waters, prescribes general provisions for the treatment of wastewater and the regulation of discharges into the environment and prohibits the use of raw wastewater and the irrigation of market garden crops with treated wastewater (ONAS, 2017). In 1985, wastewater discharges into the receiving environment were regulated and in 1989, a decree (No. 89-1047 of July 28, 1989) set the conditions for the use of treated wastewater for agricultural purposes and the decision-making process between the various ministries in charge of hydraulic production, health control, and environmental. The use of treated wastewater for agricultural purposes must be authorized by the Minister of Agriculture, issued after approval by the Minister of Public Health, and advice from the National Environmental Protection Agency. Two standards developed based on FAO and WHO recommendations were also published that same year on environmental protection and effluent discharges into the water environment and the quality of TWWs reused for agricultural purposes with physicochemical and biological specifications (ONAS, 2017). From 1991, irrigation projects using treated wastewater must comply with decree no. 91-362 of March 1, 1991, regulating the procedures for drawing up an impact study which must be approved by ANPE. In 1993, ONAS passed from the role of manager of the sanitation network to that of the leading player in protecting the water environment and the fight against all sources of pollution. To this end, it is responsible for promoting the distribution and sale of treated water, sludge from treatment plants, and all other by-products. Decree No. 93 R 2447 of December 13, 1993**,** extends the powers of distributing organizations that are now responsible for part of the analyses (ONAS, 2017). In 1994, a decree of the Minister of Agriculture fixed the list of crops that can be irrigated by treated wastewater, including industrial crops (cotton, tobacco, flax, jojoba, castor oil), cereals (wheat, barley, oats), fodder (maize, sorghum), fruit trees (date, lemon, vine), fodder trees, forest trees, floral and aromatic crops. In 1995**,** the terms and conditions for using treated wastewater were set providing a series of prevention and control measures for farmers, with analyses to be carried out by public or private laboratories. In 2002, a new standard (NT 106.20) was drawn up to regulate the use of sewage sludge from urban wastewater treatment works as fertilizer. There is currently no legal framework for other benefits of TWW (aquifer recharge, golf courses, green spaces, industry, etc.). Tunisia is in the process of revising its reuse standards to reflect the broader applications of treated wastewater.

3. Materials and methods

3.1. *The study case of OUARDANINE TWWR system*

Ouardanine WWTP is one of the Tunisian WWTP dedicated to irrigation systems. The city of Ouardanine belongs to the governorate of Monastir located about 160 km south of the capital and lim-

Figure 1 - Location of Tunisia, Monastir governorate, district of Ouardanine.

ited to the northeast by the Mediterranean, to the northwest by the governorate of Sousse, to the west by the governorate of Kairouan, and to the south by the governorate of Mahdia (Figure 1). Currently, the population of Ouardanine totals 21,814 people, divided into 6,312 homes. Because the region has a semi-arid environment, it has a water deficit of 1,000 mm per year. The salty (4.3 g/L) and overexploited (110 percent) Sahline-Ouardadine aquifer underneath the area is no longer usable for irrigation (Mahjoub *et al.*, 2016) and, although agricultural activity is centred on dry farming, wastewater reuse is the best alternative water supply for supporting the development of a more intensive and productive irrigated agriculture (Vally Puddu, 2003).

Ouardanine has long experienced the negative impacts of discharging untreated sewage into the Oued Guelta stream, resulting in the rural area's degradation (CRDA, 2014). The lack of economic possibility combined with the environmental deterioration encouraged many locals to leave the area. Based on the farmers' request, the ONAS and the Ministry of Agriculture and Water Resources subcontracted a study to treat the used water and then use it in an irrigation scheme as part of the national water reuse program. The CRDA of Ouardanine developed the irrigation scheme with the farmers regrouping in a formal water user organization the *Groupement de Développement Agricole* (GDA) responsible for site selection, land rights decisions, and plant culture selection, while ONAS built the treatment system. This has made it possible to lower farmers's resistance to use recycled water.

The WWTP was completed in 1993 and gathered 17,000 people's effluents with a treatment capacity of 1000 m^3/d and 600kg of Biological oxygen demand (BOD) per day (ONAS, 2022). It uses an oxidation pond treatment technology to function. Currently, the plant treats 17500m^3/year (GDA, 2022).

The WWTP is composed of (ONAS, 2022) a lifting station at the head of the treatment plant, a pre-treatment structure consists of two non-aerated static grit channels followed by two automatic fine screening channels, a static de-oiling, a contact well, a "carousel" design oxidation channel equipped with a surface aerator, a circular clarifier, a lifting station, with an Archimedean screw, returns the sludge to the contact well, a station for removing excess sludge to the thickening stage, an harrowed static thickener, a set of natural drying beds for thickened sludge. In addition, the existing wastewater treatment plant in the city of Ouardanine is equipped with

Table 1 - Evolution of treated wastewater and irrigated land.

Year	*2002*	*2006*	*2014*	*2022*
Treated water (m^3/day)	200	500	500-1,500	1,000-1,500
Irrigated area (ha)	23	48	74	72.99
Total treated water (m^3)	6,968,000			

Source: CRDA, 2014 and GDA, 2022.

a gauging channel for measuring flow rates, a drainage network for internal water, a closing service building of transformer station, offices, store, workshop, room for workers, changing rooms, showers, and toilets. The irrigated area of Ouardanine, established in 1994, is currently of 74 ha of which 72.99 ha are used and the number of beneficiaries increased to 42. Table 1 provides an overview of the time evolution of the treated wastewater and the irrigated land.

The irrigation scheme is composed of one pumping station, one reservoir with a capacity of 1000 m^3, the water distribution network, 21 hydrants and the control and monitoring system. In 2007, a 500 m^3 storage basin was built upstream the perimeter, about 5 m high, to ensure gravity distribution of TWW to the irrigated land. The quality of TWW transferred into the basin caused sediment to settle and irrigation systems to block and difficulties in cleaning up the basin have produced environmental problems (CRDA, 2014).

In 2007, the CRDA built a 1,000 m^3 storage basin to control the quantity of TWW released to the irrigated area, to adjust the daily irrigation demand to the 16-18 hours functioning of the WWTP and to improve the TWW's quality by enabling suspended material to settle and microbes to die off. CRDA of Monastir manages the irrigated perimeter IP where they are responsible for the distribution of wastewater to irrigated land, maintenance and monitoring of hydraulic equipment, operation of irrigation channels and their rehabilitation, care of the pumping station and filtration station; quality control of TWW, collection of water fees from the GDA, training to the farmers.

The GDA of Ouardanine, is composed of 42 farmers, and charged with the collection of water fees, small maintenance of water facilities, coordination between the farmers and the authorities.

The Ouardanine WWTP is managed by the Regional Direction of Monastir of the ONAS. The main missions of the office are the collection of waste water, monitoring the quality of the TWW, the management, operation, maintenance, renewal and construction of any for urban sanitation work, the collection of water disposal fees from the inhabitants of the region, the treatment of waste water, the management, operation, maintenance, rehabilitation and construction of any work intended for the WWTP, the free distribution of purified water to the CRDA, the free supply of sludge to farmers.

Planted crops consist mainly of fruit trees covering about 70 ha, 34 ha of peaches, 10 ha of pomegranates, figs, apples, and medlars, 11 ha of olive trees, 15 ha for supplementary irrigation for olive seedlings, forage crops like alfalfa and barley are grown as well only 2 ha (GDA, 2022).

A 2.3-kilometer irrigation network has been installed to irrigate cereal and fodder crops with furrow irrigation while for permanent crops farmers adopted drip irrigation techniques more than 15 years ago with a discharge of 4L/h to ensure optimum quality and output of peaches (Mahjoub *et al.*, 2008). Irrigation systems are seen as an effective approach to protect soil, crops, and end-users from chemical and biological pollution, as well as a health precaution. Notwithstanding these efforts to use irrigation water efficiently, most of the crops suffer from a moderate water stress since available resources are not sufficient to fully meet crop water requirements.

The government provides incentives to farmers who adopt water-saving practices. When transitioning from classic irrigation techniques like furrow irrigation to more water-saving technologies (sprinklers or drip), up to 60% of the irrigation system's investment cost are subsidized (GDA, 2022).

Together with incentives several constraints also act over the development and appropriate functioning of the project. They are economic, such as the high expense of wastewater treatment and the limited availability of funding for the maintenance; technical, such as droplet blockage due to high suspended matter, poor utilization of available water resources, poor storage capacity; deteriorating water quality from the purification station, need to expand the irrigated area, failure to respond to the water needs of crops when there are damages in the disinfection station; social, such as the reluctancy to buy fruits and vegetables irrigated by treated wastewater (Saliba *et al.*, 2018). Also, the inhabitants of the region demand those products to be less expensive than those irrigated with conventional water. Another important factor is the lack of coordination between the CRDA and ONAS resulting in the water not being provided according to the need of the farmers.

3.2. *The Cost-Benefit Analysis*

Wastewater treatment projects are implemented to both increase water availability and to improve and protect the environment. For this reason, both an economic analysis and a financial analysis will be performed to evaluate both the national budget and that of the different stakeholders.

A comparison between a reference scenario – without the project – and the project alternative is performed using the CBA approach. The study covers the entire duration of the project considering that the WWTP was built in 1993 while the IS was constructed in 1997 and assuming that the construction of the WWTP and the IS has been completed in one year and that Operation and Maintenance costs (O&M) begin in the second year.

Therefore, this economic analysis is an "ex-post evaluation" to assess the economic results of the operation of the WWTP after 29 years of service. This type of analysis has the advantage that uses real data and therefore the results are more reliable than when assessing the current value of future developments. "In principle ex-post CBA shall be performed exactly as an ex-ante but using historical rather than forecasted data. However, far from being as straightforward as apparently it would look like, performing an ex-post CBA raises several interesting methodological issues" like, for example, the choice of an appropriate reference scenario (Florio and Vignetti, 2013) which have been taken into account in this paper. All the benefits and costs have been converted from the Tunisian Dinars (TDN) into USD using the average conversion rate of each year of the project life.

Economic analysis and financial evaluation of the projects both involve identifying project benefits and costs in the years in which they occur and converting all future cash flows to their present value using the technique of discounting. However, the perspectives and objectives of the two analyses differ.

The financial evaluation is carried out from the perspective of the project investor and considers incremental cash flows (both revenues and costs) generated by the project. The purpose of financial evaluation is to assess the ability of the project to generate adequate cash flows to recover its financial costs (capital and recurrent costs) without external support. On the other hand, economic analysis is carried out from the perspective of the entire country's economy, and it assesses overall impact of a project on the welfare of all the citizens of the country concerned. Indirect effects and externalities – both positive and negative - should be identified, evaluated, and included in the analysis since the purpose of project economic analysis is to assess whether a project is economically viable for the country.

3.2.1. *Determination of costs and benefits*

Relevant data were collected throughout multiple meetings with CRDA, ONAS, and GDA and local farmers in the region of Ouardanine, Monastir, Tunisia during a field data collection campaign which lasted one month (from 26 February 2022 to 26 Mars 2022) aimed at describing all the events that happened during the lifespan of the project and the costs and benefits associated to them (Table 2). These data were used to calculate the costs and benefits of the main physical structures or organizations involved in the process.

3.2.1.1. Environmental benefits

Environmental benefits are calculated using the shadow price approach developed "to assess internal (which is easy to monetize) but also external economic impacts" (Ćetković *et al.*, 2022; Molinos-Senante *et al.*, 2011 and 2012). The shadow price is the monetary value assigned to an abstract or intangible commodity which, not traded in the market, must be included in an economic evaluation (Sartori *et al.*, 2014). They are mainly used to take into account the numerous market distortions while their use for determining the environmental benefits is a relatively new approach that still has been used little.

Shadow prices can be used to quantify the environmental benefits and costs of wastewater treatment (Molinos-Senante *et al.*, 2011 and

Table 2 - Costs and benefits associated to the main components of the project.

Main components	*Costs*	
	Investments costs	*Annual recurrent costs*
WWTP	Investments in physical works, land, and administrative Major improvements	Fix and variable annual costs
Irrigation system	Investment in irrigation network. Pumping station, reservoir, hydrants	O&M costs of the irrigation system
On-farm Cost	All investments considered depreciated since farm investments are older than 10 years	The total cost of production are calculated according to standard practices based on local information
Main components	*Benefits*	
WWTP	Subscription fee paid by the inhabitants of the Ouardanine region. Environmental Benefits	
CRDA	Annual subscription + Fee collection (The CRDA collects water for free from the WWTP and sells it to the GDA)	
CDA	Annual subscription + Fee collection resulting from selling the water to farmers	
On farm benefits	The benefits are calculated based on the production quantity and crop prices	

2012), thus reflecting actual values of inputs and products that may differ from market values. In some studies (Molinos-Senante *et al.*, 2011), calculated as the costs of not removing basic wastewater pollutants such as nitrogen (N), phosphorus (P), suspended particles (SP), Biological oxygen demand (BOD) and chemical oxygen demand (COD) – shadow prices "actually represent the avoided damages/costs, i.e. the benefit/income realized for the environment as a result of the removal of pollutants during treatment in the sewage treatment plant. The difference between pollution costs for wastewater and pollution costs for treated water represents the savings achieved in the cost of pollution, i.e., the environmental benefits" (Ćetković *et al.*, 2022).

To our knowledge there is no studies that investigate the monetary value of water treatment environmental benefits in Tunisia, but also in many of more developed countries. For the computation of the environmental benefits this paper takes the recommendations from relevant studies (Ćetković *et al.*, 2022) using shadow prices developed by (Hernández-Sancho *et al.*, 2015) and those based on previous studies (Molinos-Senante *et al.*, 2011). The shadow prices used in this study are reflected in Table 3.

The original values in EURO were converted to USD on 7/18/2022.

To compute the environmental benefits, the quantity of removed pollutants will be first calculated and then, using the value of shadow prices of the main pollutants in water presented in the Table 3, we will attribute a monetary value to them.

3.2.2. *Choice of the discount rate*

In CBA, future cash flows are discounted at the chosen discount rate to obtain the present value (PV) of a future sum of money or stream of cash flows: the higher the discount rate,

Table 3 - Shadow prices of the main pollutants in water.

	Phosphorus	*Nitrogen*	*COD*	*Suspended Particles*	*BOD*
Shadow prices USD/kg	83.75	35.73	0.21	0.01	0.03

Source: Ćetković et al., 2022.

the lower the present value of the future cash flows. Determining the appropriate discount rate is the key to properly valuing future cash flows. The discount rate can refer to both the interest rate that national and international financial institution's set for short-term loans or to most complex evaluation that tries to reflect the social view on how future benefits and costs should be valued against present ones (Sartori *et al.*, 2014). For example, in the context of climate change policymaking, the choice of the discount rate is considered very important for working out how much today's society should invest in trying to limit the impacts of climate change in the future; it is usually considered between 2% and 3%. To discount a monetary flow, the following formula is used.

$$V_i = \sum_{j=0}^{n} (F_j * (\frac{1}{(1+r)_j})$$

where: Vi = current value of the project; Fj = monetary flows at the nth year; r = discount rate; n = time frame of the project.

In this paper, we will use actualization which mean that we will use the present value of payment that have been made in the past to help us understand the importance of the costs and benefits and for that we will use the following formula:

$$V_i = \sum_{j=0}^{n} (F_j * (1+r)^j)$$

where r, is given by the annual discount rate selected.

Given the difficulties in finding the trend of official discount rates in Tunisia, we decided to consider the inflation rate of the currency adopted as a proxy for the discount rate (Table 4).

3.2.3. *CBA indicators*

Two indicators are evaluated: the NPV and the BCR. The first one determines the potential profitability of projects It is the difference between the present value of cash inflows and the present value of cash outflows over a period.

$$NPV = B_i - C_i$$

where: $C_i = IC_i + AOM_i$; $B_i = R_i + E_i$; B_i = initial accumulation of benefits (benefit present value); C_i = initial accumulation of costs (cost present value); IC_i = Investment cost; AOM_i = accumulation of annual O&M costs; R_i = accumulation of annual revenue; E_i = accumulation of environmental benefits expressed in monetary terms.

The investment is cost-effective when:

$$NPV > 0$$

The second one, the benefit cost ratio (BCR), is a dimensionless number that reflects the importance of the benefits compared to the costs.

$$BCR = B_0/C_0$$

where: B_0 = initial accumulation of benefits (benefit present value); C_0 = initial accumulation of costs (cost present value).

The investment is cost-effective when:

$$BCR > 1$$

All the items considered have been discounted to be expressed as present monetary values.

3.2.4. *The simulated scenarios*

To better highlight the different benefits and costs generated by the project, the economic feasibility has been assessed in four different scenarios.

- Scenario 1: no-action situation. Without any

Table 4 - Inflation rate, 1994-2020.

Year	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
(%)	4.73	6.24	3.72	3.65	3.12	2.69	2.96	1.98	2.72	2.71	3.63	2.01	3.22	2.96
Year	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
(%)	4.34	3.66	3.33	3.24	4.61	5.31	4.62	4.43	3.62	5.30	7.30	6.72	5.63	5.73

Source: International Monetary Fund, International Financial Statistics and data files.

Table 5 – Benefits and costs for each scenario.

Scenario	*Cost*	*Benefits*
Scenario 1	Environmental	Opportunity cost
Scenario 2	Investment, O&M of the WWTP	Environmental; Subscriptions fees
Scenario 3	Investment, O&M of the WWTP Investment, O&M of the IS Farm-level costs	Environmental; Subscription fees; Farm benefits; Irrigation system benefits
Scenario 4	Investment, O&M of the WWTP Investment, O&M of the IS Farm-level costs	Subscription fees; Farm benefits; Irrigation system benefits

project the used water would be released directly to Wed El Gelta without any treatment.

- Scenario 2: only water treatment situation. In this case, we assume that the used water would be treated and then released to Wed El Gelta without any direct uses.
- Scenario 3: water treatment plus reuse in irrigation. In this case, after the wastewater treatment, a part of it is be used in irrigation of a nearby irrigation scheme.
- Scenario 4: the environmental benefits will not be considered.

Table 5 reflects the main benefits and costs considered for each of the above scenarios.

3.2.4.1. Water pricing alternatives

Several scenarios have been considered to evaluate impact of different water tariffs on the net benefit of the different stakeholders. The water pricing policy depends on several factors, some of which are purely political, and therefore it goes beyond the scope of the present paper, but we intend to analyze the possible financial effect of the different scenarios proposed on farmers' budget to provide a first assessment of their possible application.

We will analyze the following water pricing scenarios:

WP1. Present tariff (used as the reference): 0.025 USD/m^3

WP2. Present tariff with the addition of electricity costs: 0.038 USD/ m^3

WP3. A tariff covering the full O&M costs of the CRDA: 0.036 USD/ m^3

WP4. A tariff covering 20% of the total costs (O&M + Recovery of investments): 0.449 USD/m^3

WP5. A tariff covering the cost of water used by farmers (44% of the treated wastewater):0.749 USD/m^3

WP6. A tariff covering the full costs (O&M + Recovery of investments), as the EU recommends in the Water Directive (2000/60/EC): 1.675 USD/m^3.

The present tariff – WP1 – is set to encourage farmers to use the treated water from the WWTPs and is lower that the tariff applied for conventional water resources. The rest of the scenarios reflect a progressive increase in the recovery of costs starting by the O&M cost of electricity and up to the last scenario where all investments and O&M costs are recovered. Even though the full recovery of cost is far to be applied in practice, we try to understand if the system would be capable of paying for it.

3.2.5. *Sensitivity analysis*

In an ex-post CBA, sensitivity analysis can serve two different purposes: i) assessing the impact of unlikely but possible omissions or inaccuracies in the collected data and ii) performing a risk analysis of the projects to get useful indications for the cost and benefits evaluation of similar future projects. The sensitivity analysis will be conducted for an increase in costs of 10%, 20%, and 30% and a decrease in benefits of 10%, 20%, and 30%.

Table 6 - Investment costs.

	Investments cost in USD (year)	*Actualization to year 2021 (USD)*
WWTP	1,200,000 (1993)	3,665,874
IS	337,000 (1997)	860,667
Improvement of IS	130,407 (2007)	252,711
Improvements of WWTP	778,627 (2019)	869,591
	4,306,049 (2021)	4,306,049
Actualised Total Investments		9,954,892

Source: CRDA, 2014; Drechsel and Hanjra, 2018.

Table 7 - Production costs for the year 2021.

Production Costs	*Olive (new)*	*Olive (old)*	*Peach*
Materials (USD/ha)	106.18	68.07	1,494.91
Labour (USD/ha)	308.70	197.88	4,346
Total Costs=M+L (USD/ha)	414.88	265.95	5,840.91
Planted area (ha)	15	11	34
Total crop production costs (USD)	6,233.17	2,925.42	198,590.87

4. Results

4.1. *Costs calculation*

The costs of different components of the project – investment, O&M, and major improvement – have been calculated.

4.1.1. Investment costs

The investment costs for the WWTP and the IS have been made respectively in 1993 and 1997. Also, improvements were made in 2007 for the IS and in years 2019 and 2021 for the WWTP. All the costs incurred in Tunisian dinars have been converted in USD and actualised according to the methodology illustrated. Table 6 illustrates the cost of investments made and their actualized value.

The total actualized investment costs are 9,954,892 USD and the investment of the WWTP represents the biggest share (80%) of the total investment costs while the IS only account for 20% of the total.

4.1.2. *O&M costs*

O&M costs vary from year to year based on the level of operation of the system: for the irrigation system, they depend on the irrigated area and for the WWTP they depend on the treatment capacity. Based on the available data for 2013, we estimate the costs for the other years, calculating the O&M costs per cubic meter for WWTP and the O&M costs per hectare for IS. From the presented data we can calculate the O&M/ha and the O&M/m^3.

$$O\&M(TND/ha) = Total\ IS_{O\&M}\ cost / Area = 19{,}434/75 = 259.12\ TND/ha$$

Considering that the WWTP works five days a week and fifty-two weeks a year, the average O&M costs of the irrigated area in the different periods, and the exchange rate of TND/USD the actualized value of the total IS O&M cost is: 382,485 USD.

$$O\&M(TND/m^3) = Total\ WWTP_{O\&M}\ cost/ Treated\ water\ year = 50{,}660.5/1500*(5*52) = 0.13\ TND/m^3.$$

Considering the volume of the water treated in the different period, the average O&M cost value of the m^3 and the exchange rate of TND/USD the total actualized WWTP O&M cost is 908,124 USD. Like with the WWTP investment costs, the WWTP O&M costs are much higher than those of the IS.

4.1.3. *Farm costs*

Following the procedure indicated in section 3.2.1, the farm costs of the major crops have been calculated and reported in Table 7.

Water price is not included in the production costs, but it is considered in a separate way as it's a cost for the farmer but a benefit for the managers of the irrigation scheme, in particular for the CRDA and GDA.

4.2. *Benefits calculation*

4.2.1. *Wastewater treatment plant benefits*

Benefits for WWTP are generated from two pillars: subscription fees and environmental benefits. The subscription fees are paid by households of Ouardanine village: they are fixed at 5 USD per household per year (Drechsel and Hanjra, 2018) regardless of the collected or treated water. The total collection of the subscription fee for the year 2013 was17,000 USD/year which is 53% of what potentially should have been collected. Then, using the yearly exchange rate from TDN to USD, we determine the yearly paid fee in USD. After the actualisation process of this benefit, we found that the present value of the subscription fees paid was:

SB = 1,092,244.89 USD

4.2.2. *Environmental benefits*

The environmental benefits come from removing the pollutants from the used water and will be calculated using the next three steps:

I. Quantity of treated water per year

The WWTP works 5 days a week, 52 weeks a year for a total of 260 days per year. The amount of treated water per day has been changing throw out the years. Mainly, the treatment capacity remained the same, but the actual treated water changed according to the demand of the farmers as shown in the Table 1.

Table 8 - Quantity of removed pollutants.

Parameter	*Removed*	*Benefit (USD/m³)*
TSS (Kg/m³)	358 10^{-3}	0.004
COD (Kg/m³)	1051 10^{-3}	0.221
BOD (Kg/m³)	441 10^{-3}	0.013
Global nitrogen NGL (Kg/m³)	80 10^{-3}	2.858
Phosphorus Pt (Kg/m³)	2 10^{-3}	0.168

II. Amount of removed pollutants and benefits per m³ treated

Table 8 shows the total quantity of removed pollutants considering the amounts of water treated for the different periods mentioned above and the benefits per m³ treated.

III. Environmental benefits

After calculating the removed pollutants per cubic meter of water, we can estimate the benefit of the treatment per cubic meter using the total volume of treated water. Total benefit per treated m³ = 3.26 USD and therefore the total environmental benefits are:

B_E = 6,968,000 ∗ 3.26 =22,739,510.56 USD

4.2.3. *Irrigation scheme benefits*

Farmers use the irrigation system that it is managed by the GDA which is responsible for the small maintenance and the collection of water fees. At the same time, the GDA pays CRDA for the water provision. The beneficiaries of the irrigation scheme are both the CRDA and the GDA.

4.2.4. *CRDA benefits*

The CRDA's only benefit comes from providing water to the GDA. The water sales, varying from year to year, were calculated as an average per hectare for those years in which it was available and used to interpolate the missing data. Once the yearly benefit was calculated we change the values to USD and then actualized them to 2021 (Table 9).

4.2.5. *GDA level benefits*

The GDA sells the treated wastewater to farmers against payment of a fee composed of two parts: a fixed fee per hectare and a variable one depending on the water consumption. The same steps that were used to calculate the CRDA benefits are used in this section for year with missing data.

Table 9. CRDA benefits.

Start year	1998	2003	2007
End year	2002	2006	2021
Distributed water (m^3)	23,333	58,333	175,000
Price (TDN/m^3)	0.02	0.02	0.02
Subscription fees (TDN/farmer)	50	50	50
CRDA benefits (USD)	*99,242*		

Table 10 - GDA benefits.

Start year	1998	2003	2007
End year	2002	2006	2021
Used water (m^3)	23,333	58,333	175,000
Water price (TDN/m^3)	0.035	0.035	0.035
Subscription fees (TDN/farmer)	50	140	275
GDA benefits (USD)	*275,633*		

4.2.6. *Farm benefits*

The revenue of the farmers comes from the value of crop production obtained. In this part, we will treat the entire irrigated area as a big farm and compute the total production for the year 2021.

The main components of the total crop production costs are reflected in Table 11 and the total revenue for the year 2021 is 732,843 USD and the average revenue per hectare is 10,470 USD.

The Table 12 represents the evolution of the farmer's revenues from the start of the project until 2021: data from 1996 to 2001 were provided by the CRDA and those for the years 2013 and 2021 were taken from the literature. It should be noted that the farmers' revenue is largely influenced by the variable market prices.

Before the project, most of the land was planted with olive trees and was not irrigated which explains the low income in the year 1996. After the installation of the irrigation scheme, the farmer's income starts to increase from year to year and reaches a maximum in 2001. For the other years, we used interpolation to estimate the revenue. The calculated total revenue since the start of the project is 26,149,647 USD.

Table 11 - Crop production.

	Production (kg/tree)	*Planted area(ha)*	*Trees per ha*	*Total production (kg)*	*Price (USD/Kg)*	*Total income (USD)*
Olive (new)	25	15	156	58,500	0.414	24,219
Olive (old)	25	11	100	27,500	0.414	11,358
Peach	40	34	494	671,840	0.889	597,266
Others	40	10	500	200,000	0.5	100,000

Table 12 - Farmer's revenue per year.

Year	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2013*	*2021*
Revenue (TND)	1,000	0	2,500	6,000	10,000	30,000	17,000	17000
Revenue (USD)	947	0	2,199	5,474	7,974	21,023	10,900	10,470

Table 13 - Financial CBA results.

	WWTP	*CRDA*	*GDA*	*FARMERS*
Costs (USD)	8,841,513	1,495,862	246,008	8,874,418
Benefits (USD)	1,092,245	99,242	275,633	26,149,647
NPV (USD)	-7,749,269	-1,396,620	29,626	17,275,229
BCR	0.12	0.07	1.12	2.95

Table 14 - Economic CBA results.

	Scenario 1	*Scenario 2*	*Scenario 3*	*Scenario 4*
Costs	22,739,511	9,749,638	19,844,285	19,844,285
Benefits	0	23,831,755	50,257,035	27,517,525
NPV	-22,739,511	14,082,117	30,412,750	7,673,239
BCR	0.00	2.44	2.53	1.39

4.3. *CBA results*

After the calculation of the different costs and benefits, we performed the financial CBA for every stakeholder of the project and then the economic analysis under each scenario.

4.3.1. *Financial Cost Benefits Analysis*

The evaluation of the financial costs and benefits for each stakeholder of the project leads to a negative NPV for both WWTP and CRDA and positive for the GDA and the farmers (Table 13). WWTP only recovers 12% of its expenditure and the rest is subsidized. The current pricing policies need to be changed to increase the financial benefits, especially since wastewater treatment proved to be the most expensive part of the project.

As for the CRDA, despite receiving the treated water for free, the result is highly negative. The benefit of the CRDA represents only 7% of the costs. Again, this evidences that the water pricing applied is unsustainable from a financial point of view and the need for upgrading it. On the other side, despite being a non-profitable organization, the GDA shows a positive NPV and a BCR of more than 1, but this is compatible with their non-profit nature since the small benefit of every year is used to reduce the planned costs for the following year. Finally, for the farmer's the results are highly positive with almost three times the return on their investment. Nevertheless, the project shows a large benefit when considered as a unit but when the different types of farms are taken into account there are large differences between the peach growers and the rest of the farms as it will be demonstrated later.

4.3.2. *Economic Cost Benefits Analysis*

The results of the economic analysis are summarized in table 14 for the four scenarios considered. In Scenario 1, the Economic CBA's results reflect the cost of the effect of placing the untreated sewage water of Ouardanine on the environment. In other words, if the project was not implemented the environmental damages will cost the society 22,139,510.56 USD and no significant benefits. Strictly speaking, the old existing olives under rainfed conditions would have generated some small benefits but they are negligeable compared to the large environmental costs. The results of Scenario 2 are the opposite: the wastewater treatment feasibility is proven by the high BCR obtained where benefits are nearly 2,5 times higher than the costs. The results of Scenario 3 after the introduction of water reuse in irrigation are slightly better than the Scenario 2 but still highly positive. The NPV is double but, with the increase in costs, the BCR increased a little compared with Scenario 2. On the other hand, this scenario has improved greatly the wellbeing of the benefiting farmers and contributed to the development of subsidiary activities in the agriculture sector like transport, markets, agriculture machinery and

Table 15 - Sensitivity analysis of the economic CBA.

Scenario 1				
Decrease benefit		*10%*	*20%*	*30%*
NPV	-22,739,511	-22,739,511	-22,739,511	-22,739,511
BCR	0	0	0	0
Increase Cost		*10%*	*20%*	*30%*
NPV	-22,739,511	-25,013,462	-27,287,413	-29,561,364
BCR	0	0	0	0
Scenario 2				
Decrease benefit		*10%*	*20%*	*30%*
NPV	14,082,117	11,698,942	9,315,766	6,932,591
BCR	2.44	2.20	1.96	1.71
Increase Cost		*10%*	*20%*	*30%*
NPV	14,082,117	13,107,153	12,132,190	11,157,226
BCR	2.44	2.22	2.04	1.88
Scenario 3				
Decrease benefit		*10%*	*20%*	*30%*
NPV	30,412,750	25,387,046	20,361,343	15,335,639
BCR	2.53	2.28	2.03	1.77
Increase Cost		*10%*	*20%*	*30%*
NPV	30,412,749.77	28,428,321	26,443,893	24,459,464
BCR	2.53	2.30	2.11	1.95
Scenario 4				
Decrease benefit		*10%*	*20%*	*30%*
NPV	7,673,239.21	4,921,486.75	2,169,734.30	-582,018.15
BCR	1.39	1.25	1.11	0.97
Increase cost		*10%*	*20%*	*30%*
NPV	7,673,239.21	5,688,810.67	3,704,382.14	1,719,953.61
BCR	1.39	1.26	1.16	1.07

others. Even without considering the environmental benefits, the project is profitable in Scenario 4: the results show that the irrigation reuse of treated wastewater can cover the expensive cost of wastewater treatment plus those of the irrigation system which is quite remarkable.

4.4. *Sensitivity analysis*

The sensitivity analysis shows that the project is economically feasible even under extreme assumptions of increasing costs and decreasing benefits up to 30%.

Obtained results (Table 15) mainly reflect the importance of the environmental benefits: the NPV is positive for all the scenarios and the BCR is bigger than one for all of them and higher than those of Scenario 2. These results confirm the robustness of the results obtained for the economic evaluation and prove once again the feasibility of the project.

The fourth Scenario shows that only the scenario of a 30% decrease in the benefits gives a negative result. For the others the results were positive, and this shows that the project is sensitive to the reduction of benefits of more than 20%

The sensitivity analysis of the financial CBA for the farmers (Table 16), who are the main

Table 16 - Sensitivity analysis for the farmer's financial CBA.

	FARMERS			
Decrease benefit		*10%*	*20%*	*30%*
NPV	17,275,229	14,660,264	12,045,300	9,430,335
BCR	2.95	2.65	2.36	2.06
Increase cost		*10%*	*20%*	*30%*
NPV	17,275,229	16,387,787	15,500,346	14,612,904
BCR	2.95	2.68	2.46	2.27

Table 17 - CBA under water pricing scenarios for farm typology.

Olive Farmer	*WP1*	*WP2*	*WP3*	*WP4*	*WP5*	*WP6*
C	465.48	487.52	490.48	1,311.93	1,913.57	3,765.20
B	1,614.60	1,614.60	1,614.60	1,614.60	1,614.60	1,614.60
NPV	1,149.12	1,127.08	1,124.12	302.37	-298.97	-2,150.60
BCR	3.47	3.31	3.29	1.23	0.84	0.43
Peach farmer	*WP1*	*WP2*	*WP3*	*WP4*	*WP5*	*WP6*
C	5,942.12	5,986.19	5,992.12	7,635.01	8,838.30	12,541.55
B	17,566.64	17,566.64	17,566.64	17,566.64	17,566.64	17,566.64
NPV	11,624.52	11,580.45	11,574.52	9,931.63	8,728.34	5,025.09
BCR	2.96	2.93	2.93	2.30	1.99	1.40

beneficiaries of the project, shows for all scenarios that the CBA is positive even when we consider extreme cases with cost higher than 30%. For all the other stakeholders – GDA, GCDA and WWTP – any increase in costs will lead to increases in the water pricing (benefits) with negligible impact of their CBA financial results.

4.5. *Water pricing scenarios*

The financial effect on farmers' budget of the different water pricing scenarios have been estimated to provide a first assessment of the possible application of different water pricing policies. Scenarios have been evaluated separately for the two main type of farmers, i.e. peach and olive growers (Table 17).

The present tariff – WP1 – is set to encourage farmers to use the treated water from the WWTPs and is lower that the tariff applied for conventional water resources. The rest of the scenarios reflect a progressive increase in the recovery of costs starting by the O&M cost of electricity and up to the last scenario where all investments and O&M costs are recovered. Even though the full recovery of cost is far to be applied in practice, we try to understand if the system would be capable of paying for it.

We conclude that a higher price in scenarios WP2 and WP3 will have positive effects on the CRDA since they reduce their current financial deficits. On the other hand, the recovery of the investments (scenarios WP4, WP5 and WP6) that could affect the balance of the WWTP, only appears feasible for the peach growers but with significant losses in their benefits and for olive growers, only scenario WP4 would be marginally possible. For olive farmers, the WP5 and WP6 are not economically feasible while even the WP4 gives a positive but insignificant NPV. The WP2 and WP3 give better results furthermore they are not far away from the current scenario.

Peach farmers can pay the prices in each scenario and still have a positive NPV but the difference in the NPV between the WP1 and WP6 is quite high, and the farmer's benefit will be reduced by more than half. Scenarios WP5 and WP4 are economically feasible but involve a still high reduction in the benefit (25% and 15% respectively) and their practical application

Figure 3 - NPV for the two main types of farms.

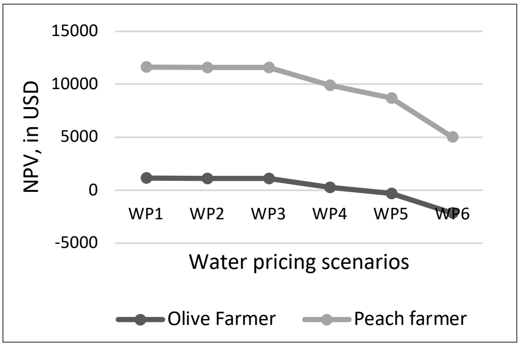
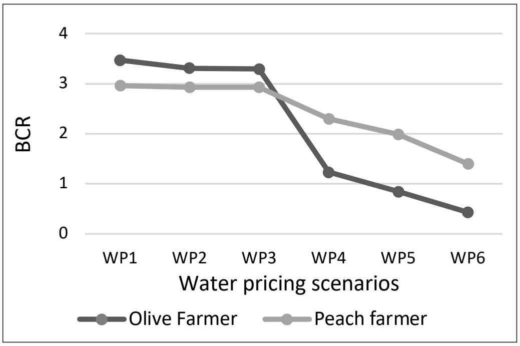


Figure 4 - BCR for the two main types of farms.



does not appear feasible because of the logical resistance of the farmers. On the other side, the olive growers could not afford their payment in scenarios WP5 and WP6 and only marginally for scenario WP4. In general, the recovery of the investments of the irrigation system appears highly questionable while the impact of water price changes on different type of farmers being olive farmers more vulnerable to water fees then peach farmers.

Figures 3 and 4 illustrate the difference between the current situation and other scenarios but also the large difference between the scenarios that only recover partly or totally the O&M costs (scenarios WP1, WP2 and WP3) and those that recover also partly or totally the investments (scenarios WP4, WP5 and WP6) made in the construction of the main works. Great differences also exist between the NPV of peach and olive growers being the later much more sensitive to reduction of the NPV when water pricing increases.

In conclusion, only scenarios WP2 and WP3 have a real potential for their implementation. A gradual approach whereby the scenario WP2 is applied for a short number of years followed by the scenario WP3 should deserve a more detailed consideration by the concerned stakeholders.

5. Conclusions and policy implications

This paper presents an ex-post CBA of Ouardanine wastewater treatment plant and of the irrigation project for the reuse of the TWW implemented in 1993 and 1997, respectively.

Firstly, the financial feasibility of the project for the different stakeholders – WWTP, CRDA, GDA and the farmers – was assessed. Given the current business model, for both the WWTP and the CRDA, the project is unfeasible: after 27 years of operating for the WWTP and 24 for the CRDA they were able to recover respectively 12% and 7% of their costs. Contrarily, the GDA despite being a non-profitable organization had a small positive financial analysis. For the farmers, the obtained results show that they are by far the bigger beneficiary of the project.

Secondly, we performed an extended CBA including both the economic and the environmental costs and benefits of treating and reusing wastewater. The benefits of removing the main pollutants - suspended particles, phosphorus, nitrogen, COD and BOD - from the water used were evaluated by applying the shadow process approach. The evaluation was carried out under four different scenarios followed by a sensitivity analysis and a study of the effect of different water pricing scenarios on the farmers' net benefit.

The results obtained indicate positive and significant benefits from water treatment, especially if we look at the costs on non-treatment for a country like Tunisia that, in recent decades, has been facing severe water shortage and water quality degradation. With only the treatment, the economic impact shifted from a loss of approximately 22 million USD for the non-treatment to a gain of more than 14 million USD. These results, although refer to our study case, confirm those of by Molinos Senante *et al.*, 2011 who demonstrated the economic feasibility of wastewater treatment when non-use option is considered.

The results of the third and fourth scenarios shows that the development of the treatment and reuse in irrigation is a highly profitable investment both economically and financially. The CBA indicators (NPV and BCR) were positive with and without considering environmental benefits while the NPV doubled when we considered both the environmental benefits and the benefit of wastewater reuse in irrigation, and this demonstrates the importance of the treated water reuse.

The sensitivity analysis, useful to understand the level of stability and sustainability of the analyzed project as well as to generalize the result to similar projects, showed that the project, even under extreme considerations of 30% drop in benefits and 30% increase in costs, still provides positive results.

This ex-post CBA evaluation shows fundamentally that the investments made in the WWTP of Ouardanine are economically advantageous for Tunisia independently of the construction or not of the irrigation system (Scenario 2). This important statement – based on the estimation of the environmental benefits which largely compensates all the investment and operational costs in economic terms – leads to conclude that Tunisia should develop similar WWTPs provided that technologies used are comparable and the level of removal of contaminants is about the same or greater than for the case of Ouardanine the unit costs are kept below those of Ouardanine.

The second important policy issue is the relevance of constructing irrigations systems to reuse the treated water. Hence the question is to be seeing from the perspective of the potential increments of social and economic benefits that the beneficiaries may obtain out of the new irrigation system. The results obtained confirmed that the opportunities to develop reuse projects exist and depend on the possibility of increasing overall social well-being since if social welfare is actually increased, then forms of compensation/incentives/subsidies to support the projects can be devised (Arena *et al.*, 2020).

In this case, the economic and financial analysis are not only strictly necessary but not sufficient since the capacity of the beneficiaries to use a new intensive agricultural production system under irrigated conditions needs to be evaluated and complemented with the learning and financial facilities that may render this objective achievable.

The third policy issue is related to the of water pricing for the beneficiaries of the WWTP and the irrigation system. In the case of Ouardanine, both farmers and house dwellers pay a very small fraction of the currents costs of the IS and the WWTP. The analysis undertaken here show that famers could pay much higher fees than those actually paid. This also applies to the dwellers of Ouardanine since only 50% of the dwellers pay the annual contribution to the O&M costs of sewage system and nothing for the O&M costs of the WWTP. Considering the predominantly positive economic returns of the beneficiaries in Scenarios 2, 3 and 4 the pertinence of revising present water prices policies appears fully justified. This does not necessarily mean that strong increases in water tariffs should be promoted compared to the current situation, but a progressive adaptation to a more realistic recovery of recurring costs could be studied and discussed with stakeholders.

6. Method caveats and future research and development pathways

The main limitation of this analysis concerns the availability and adequacy of data, in particular relating to costs and revenues at the farm level and the actual quantity of water treated in the treatment plant. If we consider the sensitivity analysis where the results do not change much, we believe that this limitation does not fundamentally question the results obtained. However, to increase the reliability of the evaluation, it would be advisable to replicate the ex-post feasibility analysis of this project and other similar ones in the wastewater treatment and reuse sector in order to extrapolate simple and scalable indicators, to establish fully reliable benchmarks and to inform the decision-makers in the allocation of public and private budget funds. Considering that Tunisia is a leading country in the use of the reuse of treated water the development of such indicators could be of relevance to other countries of the Mediterranean Region.

It should be noted that the economic evaluation is not the only criteria to evaluate the feasibility of a project and that multicriteria approaches should be used to have a more complete assessment. However, in this case the analysis focuses on the economic analysis since is the one that is more commonly absent. Furthermore, the social acceptance of the system is largely proved by the fact that the present number of farmers has been increasing since 2002 until reaching the maximum possible in 2014 and at present the cultivated area exceeds the technical capacity of the irrigation system and farmers suffer from critical water shortages.

The Ouardanine system is generally considered as one of the most successful experiences in Tunisia in the development of treatment of reused water and has a consolidated experience of more than 30 years making out of it an excellent laboratory for further learning in these complex undertakings. Future research lines mainly could include:

- Improving a more traditional approach to CBA in WWTP, complementing the environmental benefits with social benefits and costs.
- The determination of the environmental benefits in this paper has been done based on shadow prices determined outside Tunisia and therefore the definition of more accurate shadow prices for Tunisia and the rural area of the Mediterranean is necessary.
- The environmental impact of the treated water placed in the riverbed during the winter season, when water is not used by the irrigation system, is unknown but could have significant effect in improving the quality of deteriorated underlying aquifers.
- The evolution of the present cropping pattern needs to be understood clearly.
- The environmental effects of the solid waste as a fertilizing practice needs to be evaluated.
- The existing governance systems is shared among several organizations with limited communication among them and economic consequences that affect their functioning. For instance, the financial benefit of the CRDA depends on the level of fees imposed to the GDA but they are low and insufficient to undertake a proper maintenance of the irrigation system. Similarly, the WWTP often interrupts the service due to maintenance problems which may deserve review of the fees paid by all beneficiaries of the treatment plant (for instance, by using part the land use tax for this purpose).
- The present WWTP meets only a part of the crop water requirements of the present cropping area and surrounding farmers are anxious to have access to the irrigation water. Furthermore, the WWTP was constructed in 1993 for an estimated population of 17,000 inhabitants while the present population exceeds 23,000 inhabitants and it is obvious that it is under designed for the present needs of the population. Therefore, the need for a substantial enlargement is urgent and the design of a new plant is under consideration by ONAS. In this later case, a significant improvement of the irrigation system should go in parallel.

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