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In 2020, El-Mahsama wastewater treatment plant (WWTP) was constructed in Sinai, Egypt to treat 1.0 million m³daily of agricultural drainage water. This research aims to identify the economic valuation of the favorable safe and sustainable WWT management in agriculture. The highest cost was construction of agriculture schemes including the installation of the modern irrigation systems, land management services, pumps, pipes, nozzles, valves, civil and other auxiliary works. Benefits accrued from agriculture schemes was on the top benefit. In three years, the project recovers its full costs, then it starts to accrue benefits. The cost-benefit ratio was doubled in 10 year of operation. It was proven that expansion in constructing WWTPs and use of the treated wastewater safely and sustainably for irrigating agriculture schemes as well as wood trees is a successful practice in the future. This justifies the potentiality of investments in wastewater treatment domain.

Kyewords: cost-benefit analysis (CBA), economic valuation, use of treated wastewater, sustainable agriculture management, Sinai development, El-Mahsama wastewater treatment plant.

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I. INTRODUCTION

Mismanagement of wastewater irrigation would create health, economic and environmental impacts (Mohammad and Ayadi, 2005). Among the consequences, unfavourable effects on crops productivity and soil pollution (Vazquez-Montiel *et al.,* 1996). The available fresh water resources in Egypt from the River Nile, few coastal precipitations and small non-renewable deep groundwater collectively are significantly less than the quantity needed to produce the adequate food demand of the increasing population of Egypt. The deficit is about 54 billion m³ per year (MWRI, 2018). In Egypt, multiple reuse of agricultural drainage water is widely practiced. It contributes to filling the gap between the available freshwater resources and water demands for all sectors. Reusing the agricultural drainage water several times fills about 20 billion m³ per year of that deficit gap. Importing virtual water (key commodities are wheat, meat and oils) closes the remaining deficit of about 34 billion m³ per year (NWRP, 2018). According to the National Water Resources Strategy of Egypt till year 2030, safe utilization of treated wastewater should be expanded in irrigating newly reclaimed agricultural schemes. In addition, Khairy *et al.*, (2020) stated that the wastewater treatment of the agricultural drains leads to less carbon emission to the atmosphere.

The National Water Resources Strategy of Egypt focuses more on the effective sustainable development of the Sinai Peninsula (MWRI, 2018). One of the agriculture development projects in middle Sinai is designed to depend mainly on the treated wastewater from El-Mahsama wastewater treatment plant (WWTP) that could add about 265 million m³/year for irrigating large agricultural schemes (Allam, 2020). The Egyptian Wastewater Treatment Code (ECP 501) issued on 2015, permits the use of

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treated wastewater in irrigating crops such as cotton, maize, wheat, oil crops, fiber crops, and animal fodder taking into consideration the required health safety measures stated by the World Health Organization, (MHUUC, 2015). That Egyptian Code is flexible yet the health safeguards of the humans and environment are strictly maintained. The ECP 501 classifies treated wastewater into four grades (A, B, C, and D) depending on the level of treatment, and prohibits the use of treated wastewater for any edible vegetable crops without cooking such as cucumber or tomatoes.

Khairy and Abdel Ghany in 2021 proved that the "favorable safe and sustainable agricultural management" for using El-Mahsama WWTP water using modern drip and sprinkler irrigation systems could be a 1st scheme (about 30,000 ha) cultivated with wheat, barley, beans, and maize, and then a 2nd scheme (about 22,300 ha) cultivated with cotton, flax, kenaf, oil crops as jojoba, jatropha, canola and sunflower. In addition, the Egyptian environmental laws strictly forbid the disposal of any low quality waters into Suez Canal, being an international navigational route. The disposal of agricultural drainage water from those schemes is planned to be diverted to irrigate wooden trees forest "mahogany" for high-quality wood production. The risk of shortage of water in El-Mahsama Drain (or temporary stopping El-Mahsama WWTP) shall be compensated by developing a number of groundwater wells (with reasonable quality) to be readily standby for irrigating the agricultural schemes in such unlikely water shortage situations. The sludge waste of El-Mahsama WWTP could be used after anaerobic digestive processes to produce compost used as animal fodder and could further be processed to produce biofuel. That biofuel could be considered a source of energy for the nearby isolated communities' daily life activities. The remaining harmful effluent sludge waste from El-Mahsama WWTP should be disposed into secured and impervious evaporation ponds or depressions. The dried accumulated harmful sludge in those evaporation ponds should be removed periodically and cautiously, then carried in closed trucks to remote safe dumping sites/depressions in the deserts according to the safeguards procedure stated in the international dumping manuals of hazardous materials (Mercer *et al.,* 2004; Environment Agency, 2004; Nawrocki, 1976).

The climate change risks on crop productivity should be minimal due to crop high resilience to climate change. Furthermore, less carbon emission should occur due to removal of pollutants during water treatment. All types of human health risks and environmental quality risks are not expected when the "favorable alternative sustainable manage- ment" is applied. Safeguards associated with treated wastewater handling, management, and use shall be strictly met. The socio-economic benefits associated with the application of that favorable sustainable agricultural management is high (Khairy and Abdel Ghany, 2021).

There are numerous socio-economic costs associated with the deterioration of water quality, including costs related to water treatment and health care, impacts on economic activities such as agriculture, fisheries, industrial manufacturing and tourism, degradation of ecosystem services, reduced property values, and opportunity costs of further development. Further economic, social, and environmental benefits can arise if WWT management practiced wisely (WWAP, 2012). Comparison between the estimated cost of no action (benefits lost) with the cost of action versus the significant benefits is also possible to provide essential information for decision-making processes (Molinos-Senante *et al.*, 2013; Bateman *et al.*, 2006).

The research problem is the inadequacy of socio-economic evaluation studies and cost-benefit analysis of large wastewater treatment projects including the use of such treated water sustainably in irrigating agriculture crops and wood trees. Wastewater treatment could be a safe and sustainable non-conventional water resource is a key solution that must be tapped in countries located in arid or semi-arid climatic zones and countries with severe water scarcity like Egypt.

II. RESEARCH OBJECTIVES

Objectives of this research paper are as follows:

1. To develop a simple cost-benefit analysis model (in spreadsheet Microsoft Excel) for using treated wastewater in agriculture with no risks to human health nor environmental quality.
2. To conduct economic valuation analysis for ten years, as a planning guide to avail proper informative development decisions to support the water policy makers in Egypt.
3. To draw reasonable and reliable conclusion and recommendations leading to successful replication in other treated wastewater sites with similar conditions.

III. MATERIALS AND METHODS

3.1 Case study: agricultural schemes irrigated through El-Mahsama wastewater treatment plant

Year 2020 witnessed the completion of the first drainage wastewater treatment plant in Egypt (El-Mahsama WWTP) for safe use of treated wastewater in irrigating new agricultural schemes (Grade "A" treatment according to the Egyptian code, ECP 501). That project is one of the promising non-conventional solutions to overcome water scarcity challenge Egypt. Figure (1) shows the location of El-Mahsama WWTP and the study area (agricultural schemes). El-Mahsama WWTP is a mega drainage wastewater treatment facility in Sinai Peninsula east of Suez Canal (total area of 42,000 m^2, infrastructure cost is 100 million US dollars). It aims to treat the whole El-Mahsama Drain waters rather than letting it run in raw-condition into Lake El-Timsah causing significant negative environmental impacts in the lake's ecosystem (Abd El Samie *et al.*, 2008). El-Mahsama WWTP is currently in experimental and testing phase up to end of 2021. It is planned to treat a blend of domestic wastewater and agricultural drainage water from El-Mahsama Drain and other small nearly agricultural drains. It has a capacity of 1.0 million m^3 of treated water per day sufficient to irrigate several agricultural schemes in Sinai. The 1st scheme (70,000 feddans eq. to 30,000 ha) to be cultivated with wheat, barley, beans, and maize, and then a 2nd scheme (about 52,000 feddans eq. to 22,300 ha) to be cultivated with cotton, flax, kenaf, oil crops as jojoba, jatropha, canola and sunflower (Khairy and Abdel Ghany, 2021).

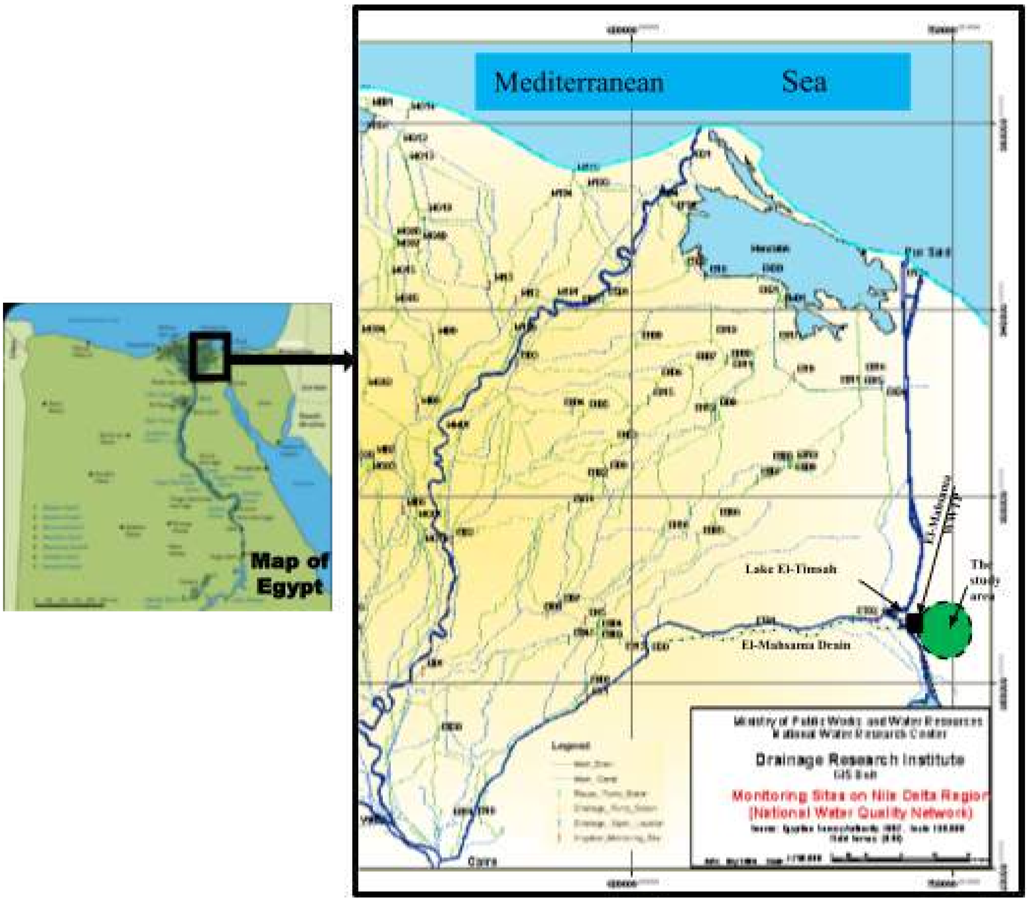

Figure (1): Location of New El-Mahsama wastewater treatment plant and the agriculture schemes (the study area) in Sinai *(source: DRI database, 2021)*

IV. METHODOLOGY

The approach used in this research paper is developing and applying a simple cost-benefit analysis (CBA) model (using spreadsheet in Microsoft Excel) that capable of simulating the annual operation, management, and production of agricultural crops for ten years using the treated wastewater of El-Mahsama WWTP. The favorable safe management should have sufficient precautions to maintain the good environmental quality and to create economic value to the society. Figure (2) articulates the conceptual model used (Anthony E. Boardman *et al.*, 2018). The annual benefits (B) and costs (C) estimated on the vertical axis while time in years (representing the level of construction, operation, management with safeguard precautions applied, and production) is on the horizontal axis. The slope of curve (B) indicates that the increase in safe management and production is an increasing function. The slope of curve (C) indicates that the cost of operation, management and precautions measures are initially increasing but turns to be a function with decreasing rate. The economic efficiency is achieved at certain year of operation where the difference between curve (B) and curve (C) is zero (at point E). The net gain starts to accrue after point E and continues to increase according to the level of management and safe crop production. The breakpoint E should be exceeded in a smallest number of years so as to achieve a real benefit of such WWTP.

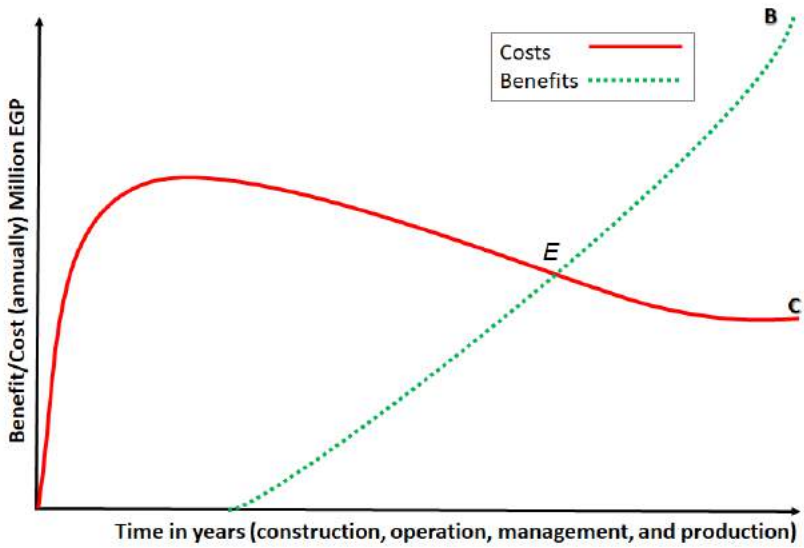

Figure (2): Conceptual CBA model used for safe and sustainable management of the treated wastewater of El-Mahsama WWTP in irrigating agricultural crops

CBA compares the costs of the project with its benefits, to determine if the project is economically viable and worthwhile. The span of this research is 10 years starting from the year of operation of El-Mahsama WWTP. A simple CBA includes in the cost side of the analysis both capital expenditures (CAPEX; i.e. the upfront costs of constructing the infrastructure) and operational expenditures (OPEX; the ongoing operational and maintenance costs of the project). For instance, the CAPEX of a water treatment plant includes costs of designing and constructing the plant itself. It also includes construction of the agricultural scheme/s with its irrigation infrastructure. The OPEX includes costs of paying salaries and materials to operate and maintain both the plant as well as the agricultural scheme/s over its expected lifetime. Other costs that are conceptually accounted-for include social costs, such as impacts on human health, and environmental costs like land conservation/degradation, non-renewable groundwater depletion, or contamination prevention works. Techniques for estimating those costs are similar to those for estimating social and environmental benefits, depending on logic and reasonable assumptions (Go, 1988).

With El-Mahsama WWTP operation, various economic, social and environmental benefits will accrue. For instance, it will create profits by selling the agricultural crops, reducing the costs of obtaining irrigation water from remote sources (economic), and creating jobs. In addition, it will reduce illnesses such as diarrheal diseases leading to general health benefits (social) and improve water quality through minimizing contamination in water (environmental). A critical factor for determining economic benefits of such project is comparing it to what would happen if the project was not undertaken (Markandya, 2016; UNWWDR, 2021). Aggregating those benefits to estimate its monetary values can be difficult, as those benefits are with various nature (Molinos-Senante *et al.*, 2013; Bateman *et al.*, 2006).

Net Present Value (NPV) approach is considered in this research. The typical equation used is $NPV=\sum_{t=1}^{T}\frac{NPt}{(1+r)t}$, where NPV is the cumulative net present monetary value, NP_t is incremental present monetary value of (all benefits – all costs) in each year, t ranges from zero to 10 years, r is the discount rate used, and T is the project lifespan which is considered 10 years. NPV is the result of calculations used to find today's value of a future values (costs and benefits). It accounts for the time value of money and can be used to compare similar economic conditions for various future years. The NPV relies on a discount rate that may be derived from the cost of the infrastructure, operation as well as from the benefits accrue from the agriculture schemes. The discount rate considered in this research was 8.75% p.a. (per annum), (CBE, 2020).

3.2 Assumptions and data sets used

Since El-Mahsama WWTP is under experimental and testing operation phase. Also the associated agriculture schemes are not fully operational. The actual detailed data sets required to conduct an economic research and analysis were not available. The monitoring of systems performance is not even operational yet to relay on concerning data acquisition (Karczmarczyk *et al.*, 2021). Therefore, field visits, questionnaires, previous experience, and related literature studies were ruled out because of the difficulty in resolving breaking down costs and benefits in the details required (Logan *et al.*, 1962).

3.2.1 Costs considerations

Some logic and reasonable assumptions and considerations were adopted and used for monetizing the costs and benefits, as follows:

- Infrastructure costs (CAPEX) of El-Mahsama WWTP include cost of all civil, electrical, mechanical and electronic works in El-Mahsama WWTP, but not the land cost. The Government of Egypt availed the land (total area of 42,000 m^2) for free because El-Mahsama WWTP is a public good facility run by governmental institutions.
- Irrigation water is free (no volumetric water charges applied for irrigation).
- Annual operation costs (OPEX) of El-Mahsama WWTP (Grade "A" treatment facility according to the Egyptian code, ECP 501) includes cost of fuel, utilities, site utilities, chemical materials, sludge extraction, administration fees, salaries and membranes/consumable/disposable materials. Figure (3) shows typical breakdown of OPEX ratio among the above components.
- Annual maintenance costs of the WWTP (additional part to OPEX) includes cost of spare parts for machines and vehicles as well as fees for technical services providers.
- Infrastructure costs of agriculture schemes (additional part to CAPEX) covering construction cost of modern irrigation systems and land management includes cost of infrastructure of the modern irrigation systems, pumps, pipes, nozzles and valves.
- Annual operation costs of agriculture schemes (additional part to OPEX) include cost of machinery fuel, workers' salaries, farming utilities, seeds, materials (fertilizers and environmentally- degradable pesticides) and other crops services and handling.
- The actual cultivated area is only 0.9 of the total agriculture schemes, the rest left for roads, handling and services facilitation.
- Other costs considered in the CBA were cost due to risk of shortage of water in El-Mahsama Drain, cost due to risk of stopping El-Mahsama WWTP, cost due to risk of disposal of remaining harmful sludge waste of the WWTP, and cost due to risk of climate change.

3.3.2 Benefits considerations

- The seasonal crop production of the 1st agricultural scheme (area of 70,000 feddans) with crops: wheat, barley, beans and maize.
- The seasonal crop production of the 2nd agricultural scheme (area of 52,000 feddans) with crops: cotton, flax, kenaf and oil crops (peanuts, sesame, soya beans, jojoba, canola and sunflower).
- Human health improvements (in three Governorates: Port Said, Ismailia and Suez).
- Environmental quality of Lake Timsah and other sparse benefiting surrounding ponds.
- Socio-economic benefits such as jobs creation and improved livelihood.
- Products-chain beneficiaries including agro-industrial crops processing and marketing, animal meat manufacturing, dairy productions, and trade.

- Disposal of agricultural drainage water from the agricultural schemes in irrigating Mahogany Trees forests (good cash for local markets and export).

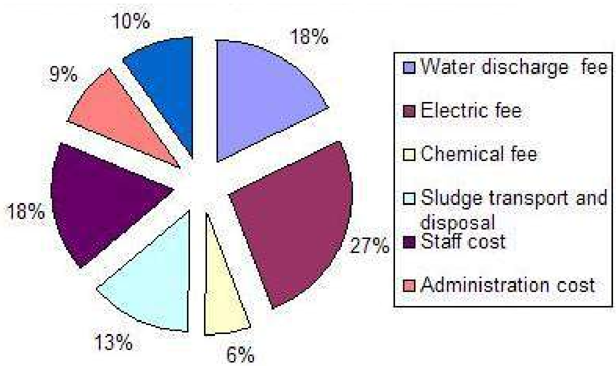

Figure (3): Typical breakdown of operation/running (OPEX) costs of a wastewater treatment plant - source: *(COST Water, 2021)*

There are clusters of assumptions and hypothesis adopted and used in this research paper, those were cited from authenticated and relevant references that suit the Egyptian conditions, as shown in Table (1). Costs estimation were based on the net present value (NPV). Quantification of environmental and social impacts and benefits in the study area were based on approaches and methodologies adopted by the World Health Organization and the World Bank (WB, 2002).

Table (1): Costs and benefits data, assumptions, and justifications of the used CBA model for El-Mahsama WWTP operation and use *(sources are authenticated references, otherwise values are assumed by the authors)*

Elements/sub-elements of CBA	Assumptions/justifications/ references/sources	
	Costs	
Land tenure: Government of Egypt availed the land of El-Mahsama WWTP for free	El-Mahsama WWTP is a public good facility owned & operated by the Ministry of Housing, Utilities and Urban Communities similar to all Egyptian WWTPs *(MHUUC - Wikipedia, 2021)*	
Infra-structure costs in El-Mahsama WWTP (CAPEX) include all civil, electrical, mechanical, and electronic works as well as transportation tools.	1.0 million USD	*(Allam, 2020; Rewater, 2019)*
Type and area of El-Mahsama WWTP (Grade “A” treatment facility)_	Total area is 42,000 m²	*Masr Consultants, 2019*
Operation costs (OPEX) of WWTP: - *Cost of electricity, gas and fuel* - *Utilities and materials* - *Administration fees and salaries (100 technicians+12 managers+500 workers)* - *Consumable/disposable materials*	*200,000 EGP per month* *100,000 EGP per month* *1,580,000 EGP per month* *1,500,000 EGP per month*	for all machineries *(COS T Water, 2021; (Molinos-Senante et al., 2013)*

Maintenance costs (OPEX) of WWTP: - *Cost of spare parts for machines* - *Cost of spare parts for vehicles and trucks* - *Fees for technical services providers*	*100,000 EGP per month* *50,000 EGP per month* *25,000 EGP per month*	*(Puja Mondal, 2021; Molinos-Senante et al., 2013)*
Infrastructure costs (CAPEX) of agriculture schemes: modern irrigation systems and land management service includes cost of infrastructure: pumps, pipes, nozzles, valves, and the auxiliary works (0.9 of area only, the rest are for services)	*50,000 EGP/feddan*	*(Rawlins et al., 2020)*
Operation costs (OPEX) of agriculture schemes: fuel, workers' salaries, utilities, seeds, materials (fertilizers and environmentally-degradable pesticides), periodical maintenance and handling (0.9 of area only, the rest are for services)	*9,000 EGP/feddan/year*	Crop season using modern irrigation system costs between (8,000-12,000 EGP/feddan/year) without fees for irrigation water (free)
Cost due to risk of shortage of water in El-Mahsama Drain	*215,063,908 EGP*	10% loss of crop production in both Schemes 1 and 2 *(WB, 2002)*
Cost due to risk of stopping El-Mahsama WWTP	*537,659,769 EGP*	25% loss of crop production in both Schemes 1 and 2 *(WB, 2002)*
Cost due to risk of disposal of remaining harmful sludge waste from WWTP	*948,357 EGP*	5% loss of environmental quality of Lake Timsah and other scattered benefiting ponds *(Abd El Samie et al., 2009)*
Cost due to risk of climate change	*1,709,803 EGP*	5% loss of crop production in both Schemes 1 and 2, environmental quality of Lake Timsah, other scattered benefiting ponds, and the related socio-economic benefits
Benefits		
1st agricultural scheme (area of 70,000 feddans eq. to 30,000 ha) with crops (wheat, barley, beans and maize)	*60,000 feddans (net area)*	90% of the area is cultivated and 10% are fallow lands for services
Area covered by each crop: - *Wheat* - *Barley* - *Beans* - *Maize*	 *40000 feddans* *10000 feddans* *10000 feddans* *60000 feddans*	 Winter crop Winter crop Winter crop Summer crop
- Net yields of each crop	0.9 of the estimated yield	Handling of wastes and loss of yield is ~ 10%
Average yield of crop (*<u>in Sinai</u>*): - *Wheat* - *Barley*	 *6 ardab/ feddan* *5 ardab/ feddan*	 (5-8) ardab/feddan (4-6) ardab/feddan

- *Beans* - *Maize*	*4 ardab/ feddan* *3.3 ton/ feddan*	(3-5) ardab/feddan (3.0-3.5) ton/feddan *(MALR, 2020)*
Average selling price of crop: - *Wheat (including secondary animal fodder)* - *Barley (including secondary animal fodder)* - *Beans* - *Maize*	*892 EGP/ardab* *1112 EGP/ardab* *2032 EGP/ardab* *2450 EGP/ton*	(820-970) EGP/ardab (1000-1200) EGP/ardab (2000-2150) EGP/ardab (2200-2600) EGP/ton *(MALR, 2020)*
2nd agricultural scheme (area of 52,000 feddans eq. to 22,300 ha) with cotton, flax, kenaf, and oil crops (peanuts, sesame & soya beans, jojoba, canola and sunflower)	*46,800 feddans (net seasonal area)*	90% of the area is cultivated and 10% are fallow lands for services *(MALR, 2020)*
Area covered by each crop: - *Cotton* - *Flax* - *Kenaf* - *Peanuts, sesame & soya beans (equal areas)* - *Jojoba* - *Canola* - *Sunflower*	*31200 feddans* *11700 feddans* *11700 feddans* *7800 feddans* *11700 feddans* *11700 feddans* *7800 feddans*	Summer crop Winter crop Winter crops Summer crops Winter crops Winter crops Summer crops
Average yield of crop (***in Sinai***): - *Cotton* - *Flax* - *Kenaf* - *Peanuts, sesame & soya beans (equal areas)* - *Jojoba* - *Canola* - *Sunflower*	*7.0 kantar/feddan* *4.0 ton/feddan* *7.0 kantar/feddan* *(~1.39, 0.52, and 1.23) ton/feddan* *0.9 ton/feddan* *0.7 ton/feddan* *1.0 ton/feddan*	(5-8) kantar/feddan (3.5-5) ton/feddan (5-9) kantar/feddan Average respectively ~0.9 ton/feddan (0.5-0.8) ton/feddan ~1.0 ton/feddan *(MALR, 2020)*
Average selling price of crop: - *Cotton* - *Flax* - *Kenaf* - *Peanuts, sesame & soya beans* - *Jojoba* - *Canola* - *Sunflower*	*2737 EGP/kantar* *4000 EGP/feddan* *1250 EGP/kantar* *(9462, 12634, and 4431) EGP/ton* *8000 EGP/ton* *58500 EGP/ton* *4795 EGP/ton*	(1900-3200) EGP/kantar (2500-5000) EGP/feddan (600-1800) EGP/kantar Average respectively (4680-10920) EGP/ton (55000-60000) EGP/ton (4000-5385) EGP/ton *(MALR, 2020)*
Human health improvements: - *Population of Port Said Governorate* - *Population of Ismailia Governorate* - *Population of Suez Governorate*	*779,587 capita* *1,404,557 capita*	Census of year 2020, Central Agency for Public Mobilization and Statistics (CAPMAS) *(CAPMS, 2021)*

	771,481 capita	
Human health improvements & risk prevented	*10% sick*	2500 EGP/sick person
	1% dead	20000 EGP/died person
Costs of human health improvements (no sicknesses)	*738,906,250 EGP*	(194,896,750+351,139,250 +192,870,250) EGP
Costs of human health improvements (no deaths)	*591,125,000 EGP*	(155917400+280911400+1 54296200) EGP
Environmental quality: - *Area of Lake Timsah* - *Area of other scattered benefiting surrounding ponds*	*14 km²* *3 km²*	*(Gasiorowski, 2019; ISO, 2019)*
Environmental quality: Restoration gain of 17.0 km² of water bodies (1 km² = ~238 feddans)	*18,967,143 EGP*	300 USD/feddan = 4,686 EGP/feddan *(Khairy, 2004)*
Socio-economic benefits: - *Jobs creation and improved livelihood (assumed that annual benefits package for each person is equivalent to about 500 EGP)* - *Products-chain such as (agro-industrial crops processing and marketing, animal meat & dairy productions and trade). Beneficiaries, each receives annual benefits package of 1000 EGP*	*250,000,000 EGP* *1,000,000,000 EGP*	100,000 jobs created + their families (4 persons in average) = 500,000 beneficiaries Assumed that 1,000,000 beneficiaries from that WWTP and associated agricultural schemes *(Stefea and Circa, 2010; Bateman et al., 2006)*
Disposal of agricultural drainage water from the agricultural schemes in irrigating Mahogany Trees (wood forests) *(assumption: 100 tons of Mahogany wood after five years shall be produced, and so on in the following years)*	*188,000,000 EGP* *(starting: Year #5)*	Price of one tone of Mahogany wood is 1,880,000 EGP *(Indiamart, 2021)*

The CBA was conducted over a time-span of ten consecutive years. Construction and equipping work (CAPEX) of El-Mahsama WWTP is completed already at Year (zero), and it is currently in experimental operation and testing phase. The (OPEX) are considered valid from Year (1) of the analysis whereas, benefits start to accrue one year after, according to agricultural schemes' harvesting, production, processing, and marketing. An annual inflation rate of (9.8% or 10%) was used for equipment and commodities (CBE, 2021). It affected all costs and benefits associated with the operation of El-Mahsama WWTP as well as the agriculture schemes starting from Year 2 up to Year 10.

V. RESULTS ANALYSIS

A simple cost-benefit model was developed using Micro-soft Excel and populated by the presented calculated and derived data sets shown in Table (1). An economic valuation analysis was conducted for ten years to determine the CBA of applying such WWTP project in Sinai, and to estimate the value of reusing such treated wastewater in agriculture with no risks to the human health nor the environmental quality. Figure (4) shows the estimated costs of all components related to the construction and operation of El-Mahsama WWTP Project as well as the agriculture schemes during 10 years' time-span, in Egyptian Pound.

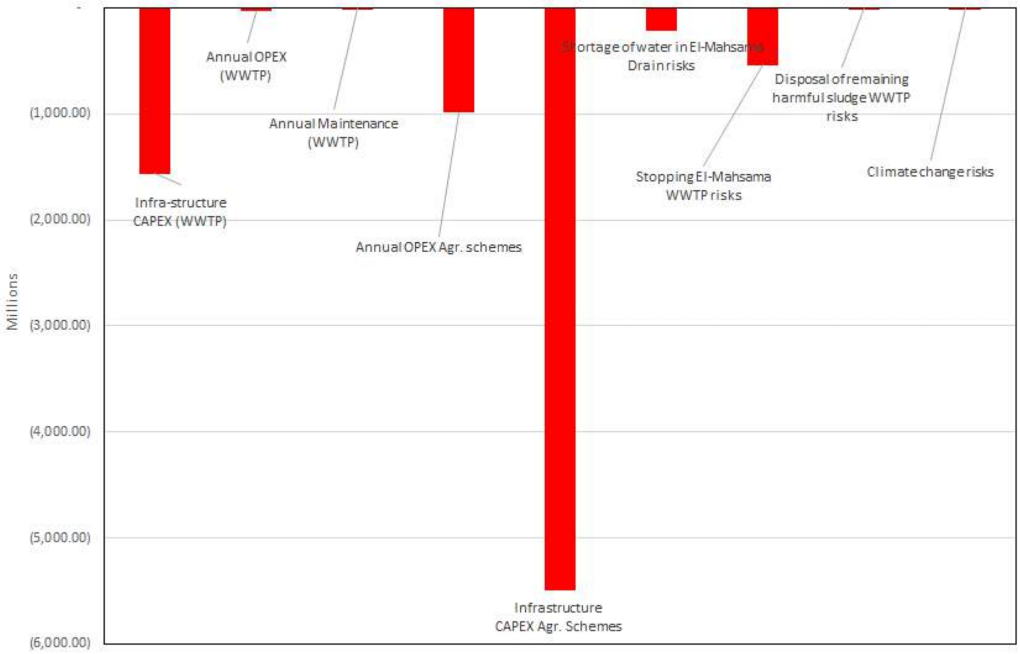

Figure (4): Estimated cost components of El-Mahsama WWTP project (EGP)

It is obvious that the highest cost is that associated with the construction of the agriculture schemes (CAPEX) including the installation of the modern irrigation systems, land management services, pumps, pipes, nozzles, valves, civil works, and the other auxiliary works. This is considered reasonable because the area of agriculture schemes exceeds 122,000 feddans, which is equivalent to more than 50,833 hectares. The cost of constructing El-Mahsama WWTP (CAPEX) includes all civil, electrical, mechanical, and electronic works as well as transportation tools comes second as high-cost component. The order of costs from third place to ninth is as follows: annual operation costs (OPEX) for the agriculture schemes, stopping El-Mahsama WWTP risks, shortage of water in El-Mahsama Drain risks, annual operation costs (OPEX) of El-Mahsama WWTP, Annual maintenance cost of El-Mahsama WWTP, Climate change risks, and disposal of remaining harmful sludge WWTP risks, respectively. The cumulative NPV of costs during the ten years of analysis El-Mahsama WWTP Project was estimated at about 23.5 Billion EGP.

On the other hand, Figure (5) shows the estimated benefits of all components related to the operation of El-Mahsama WWTP Project as well as the agriculture schemes during 10 years' time-span, in Egyptian Pounds. Benefits accrued from the 2nd agriculture scheme (cotton, flax, kenaf, peanuts, sesame & soya beans, jojoba, canola, and sunflower), which are cash crops, came on the top with the highest monetary value. Human health benefits came second in order with respect to monetary value, followed by socio-economic benefits, benefits accrued from 1st agriculture scheme (wheat, barley, beans, and maize), mahogany trees production, and environmental quality benefits, respectively. The cumulative NPV of benefits during the ten years of analysis of El-Mahsama WWTP Project was estimated at 44.8 Billion EGP.

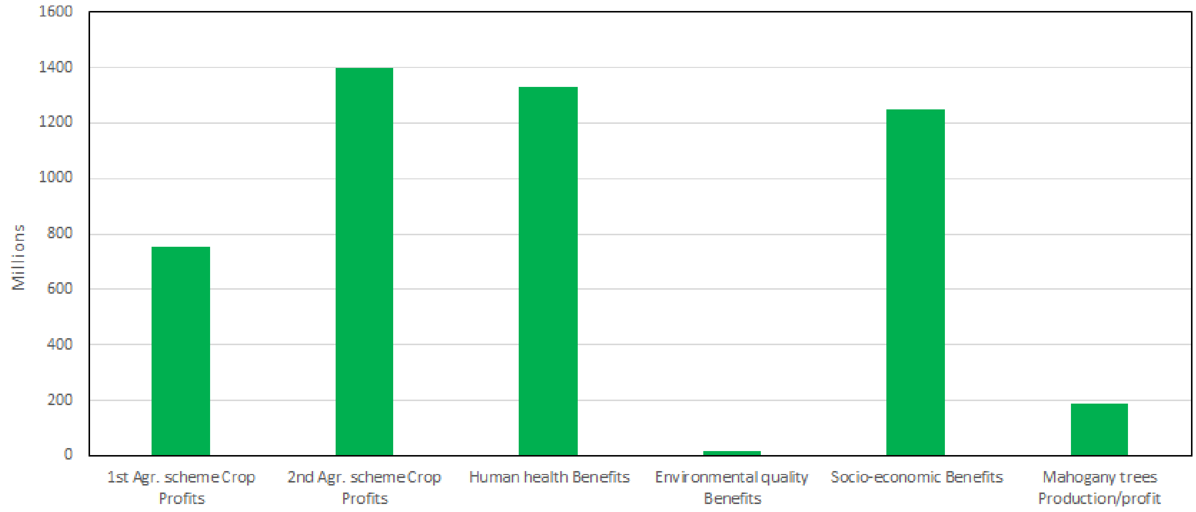

Figure (5): Estimated benefits components of El-Mahsama WWTP project *(EGP)*

Figure (6) illustrates the cumulative NPV curves of costs versus benefits of El-Mahsama WWTP Project along ten years of operation. This was associated with safe and sustainable management of the resulting treated wastewater in agriculture purposes, provided that no risks to human health nor environmental quality shall occur. It is important to highlight that in less than three years of operating El-Mahsama WWTP Project; it pays back its full costs and starts to accrue benefits. Furthermore, Figure (7) demonstrates the CBA curve of El-Mahsama WWTP Project operation for ten years. The cost-benefit ration increases with logarithmic rate scoring close to 2.0 in ten years. The relationship between costs and benefits of El-Mahsama WWTP Project could be simulated by a logarithmic trend line with a regression (R^2) close to 0.99, as shown in (Figure 7).

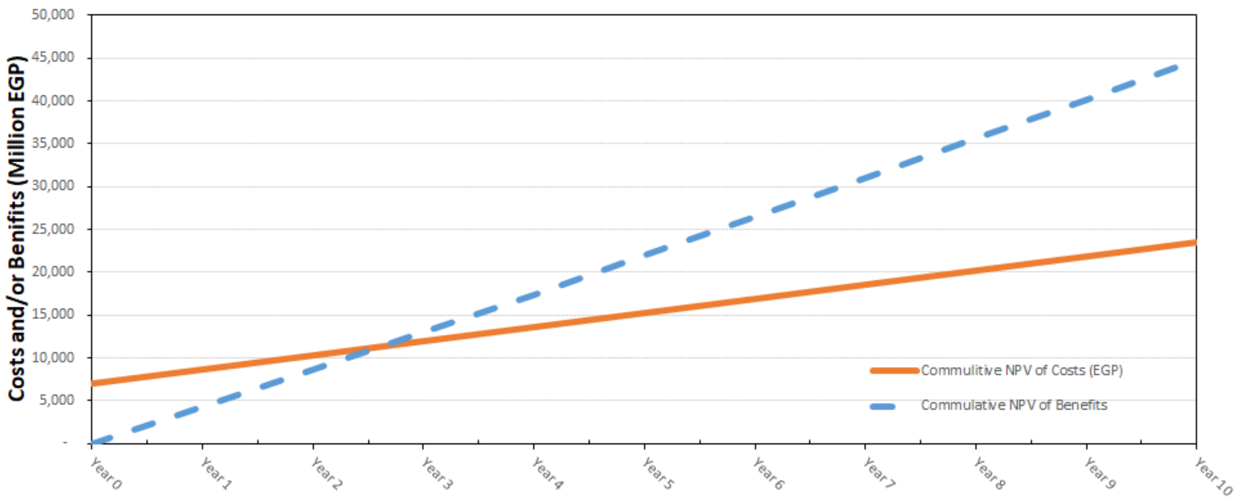

Figure (6): Cumulative NPV of costs vs. benefits of El-Mahsama WWTP project (EGP)

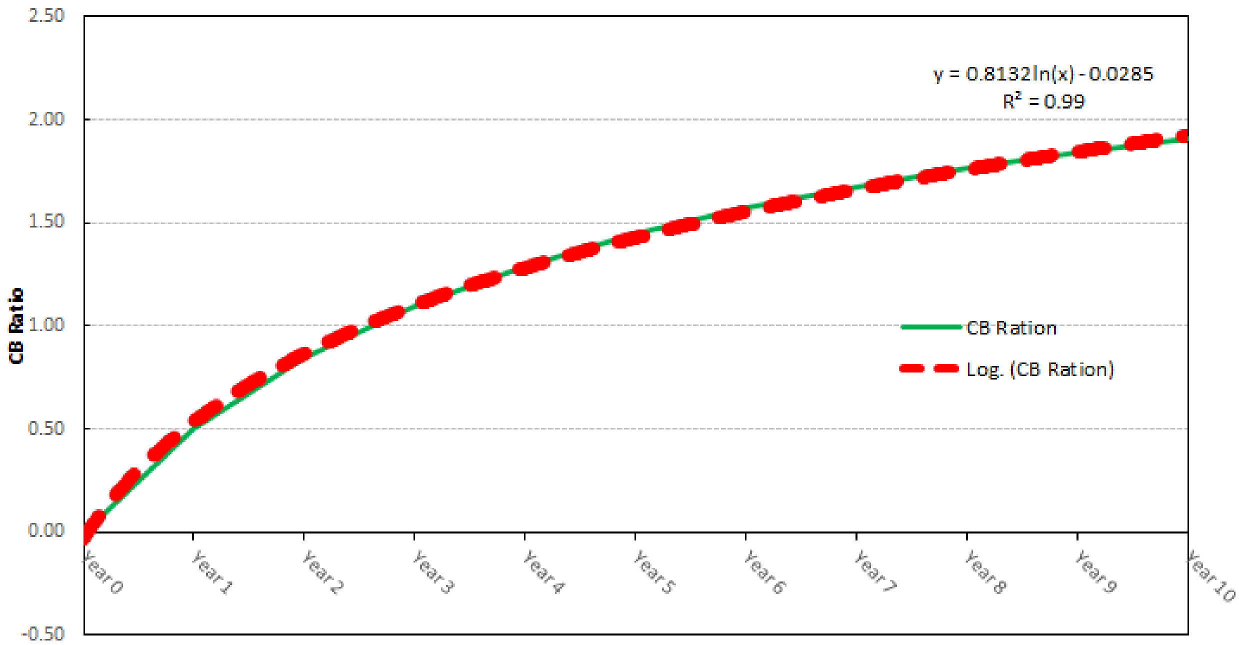

Figure (7): CBA curve of El-Mahsama WWTP project with trend-line of logarithmic scale, regression (R^2=0.99)

VI. DISCUSSION

Following the Sustainable Development Goals (SDGs), which include a goal to ensure sustainable water and sanitation for all. Economic valuation of wastewater therefore identifies economic benefits for municipalities associated with wastewater treatment. In addition, Hernández-Sancho *et at.*, (2015) agree with the results of this research paper that wastewater treatment inherits key benefits (environmental and health) that generate positive results and that wastewater management is economically feasible, and produces benefits of higher value than non-action.

This research proved that El-Mahsama WWTP and its associated agricultural schemes accrue benefits of using treated wastewater in agriculture. This benefits were estimated by economic valuation analysis and found almost double the costs in 10 years. This finding is evaluated as "significantly good" by the United States Environmental Program (UNEP), (Hernández-Sancho *et at.*, 2015). Accordingly, this research work encourages and gives confidence to the private sector to invest in wastewater treatment projects, provided that lands can be availed by the government to the investors through concession leases with free utilization for fifty years.

CBA methodology used in this research allows the valuation of costs and benefits of wastewater treatment, safe use, and sustainable management. The findings and detailed results of this research support informed development decision by the policy makers concerning national and regional non-conventional water resources planning and management, particularly in countries suffering from water scarcity.

VII. CONCLUSION AND RECOMMENDATIONS

This research focused on conducting a cost benefit analysis (CBA) of El-Mahsama WWTP's operation as a good model for wastewater treatment and use in safe and sustainable agriculture purposes, provided that no risks to human health nor environmental quality shall occur. It developed a simple spreadsheet model that simulates costs and benefits associated with the operation of El-Mahsama WWTP. The CBA of operating El-Mahsama WWTP Project for ten years proved that it increases with logarithmic rate scoring close to 2.0 in ten years. Those results support the decision makers concerning water resources planning and management in Egypt and encourage the private sector as well to invest in wastewater treatment projects. It was proved that expansion in constructing WWTPs in order to utilize its treated wastewater safely and sustainably for irrigating agriculture schemes as well as wood trees is a successful practice. It is evident that wastewater treatment, production and utilization in crop irrigation is viable, cost effective, and has a high positive financial, social and environmental rewards. This practice brings benefits and scores no risks to human health nor environmental quality. The approach and results of this research paper is recommended to be used as a planning guide that can be replicated in other WWTP projects with similar conditions.

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