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# Socio-Economic Aspects of Wastewater Reuse in the Gaza Strip

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**Abstract:** The main concern of the current research is to investigate the socio-economical aspects of reuse which rarely discussed in Gaza Strip. Questionnaire to farmers in three areas in Gaza Strip have been conducted and analysis and two sites irrigated with treated effluent was monitored. The study indicates an economical improvement for farmers switching from groundwater to effluent irrigation, even though full yield potential of citrus and olive.

**Key words:** Wastewater reuse, socio-economic, agriculture, irrigation, benefits, groundwater

## INTRODUCTION

The Gaza Strip is a plain coastal strip of 365 km² located in a semi-arid area (Khalaf *et al.*, 2006). The annual average rainfall varies from 400 mm at the North to about 200 mm at South of the strip (Al-Najart and Adeloye, 2005). The entire population depends totally upon groundwater. The total abstraction of groundwater in Gaza Governorates exceeds 155 $Mm^3$ $year^{-1}$ (Hamdan *et al*., 2007; Melad, 2001). The agriculture consumes around two thirds of groundwater pumped through more than 4000 wells located overall Gaza Strip (Afifi, 2006). The reminder is used for industrial and domestic water supplies. The aquifer is being over-exploited. The gap between water demand and water supply increases with time as a result of rapid population growth in this small area. The water balance record reveals a deficit of about 55-60 Mcm $year^{-1}$ (Hamdan *et al*., 2007). Reconciliation relies in the strategy of ensuring additional water supply and wastewater reuse schemes.

The Gaza Strip is divided geographically into five Governorates: Northern, Gaza, Middle Area, Khan Younis and Rafah (Fig. 1). Most of the Governorates are served by sewerage system ended to three central wastewater treatment plants (Nassar *et al*., 2006). Currently, partially treated waste water is discharged to the sea without any significant re-use (Naciri, 2001). The treated effluent is enough to irrigate more than 100 km² of permanent trees, equivalent to more than 50 million $m^3$ of potable water. Agriculture is the prevalent sector Gaza's economy and contributes to 32% of its economic production (Al-Najar, 2007).

Wastewater reuse will provide an alternative to groundwater for irrigation when well treated wastewater can be used for irrigation as it is planned in the National Water Plan by year 2020. Reuse of treated wastewater in irrigation is considered a priority in the Gaza Strip due to a number of factors including the depletion of groundwater resources and the fact that reuse would increase the availability of freshwater resources for domestic and industrial use (Al-Agha, 1995).

In many countries in the Middle East, including the Gaza Strip, groundwater is used for agriculture. Due to the limited availability and overexploitation of groundwater, many

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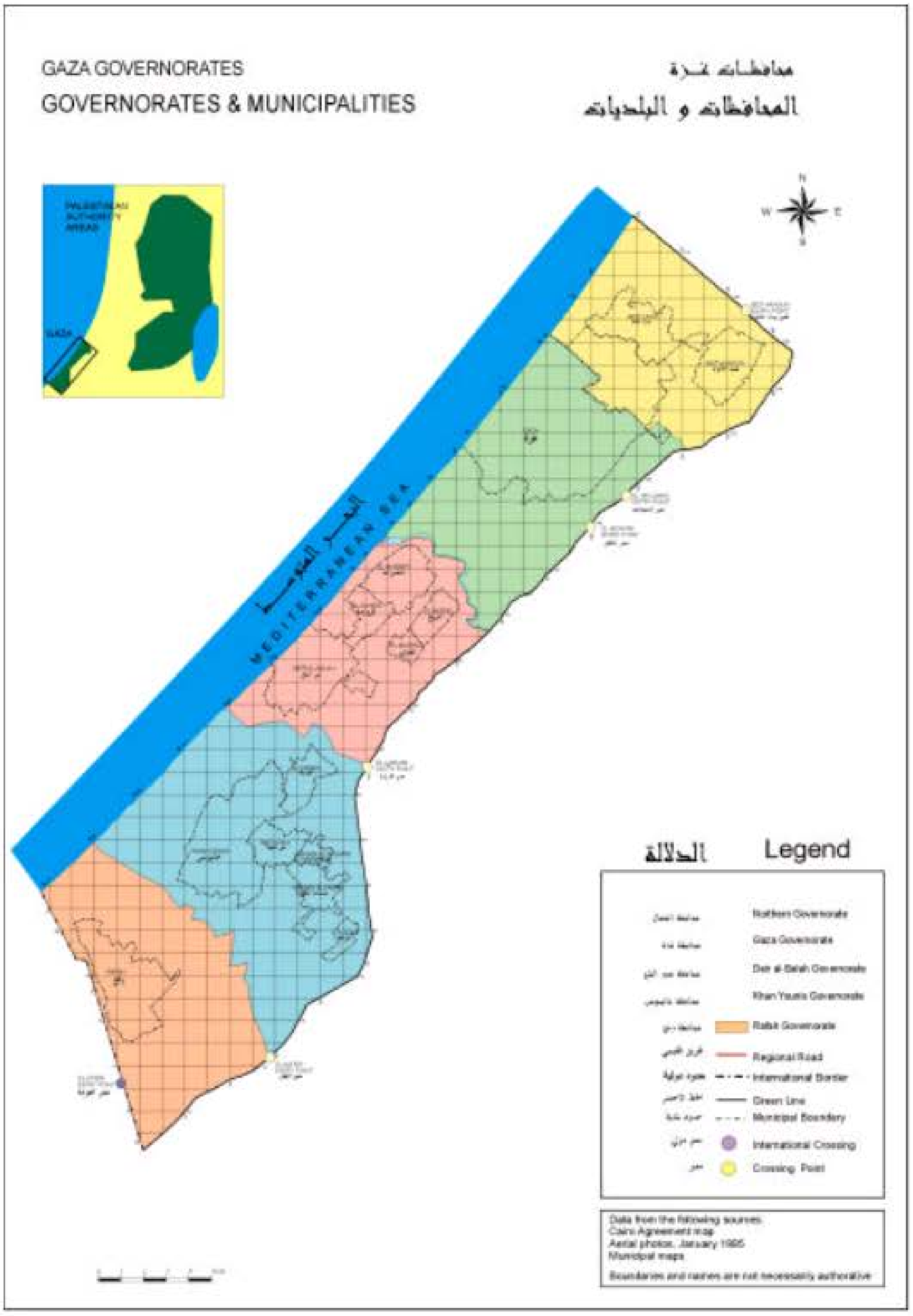


Fig. 1: Map of the Gaza Strip

countries are looking for alternative resources for irrigation in order to preserve the amount of groundwater available for domestic purposes (Tubail *et al*., 2004). However, the use of treated wastewater for irrigation is subject to major concerns because of the probable escalating of social and environmental problems. Using treated wastewater could be one of the main options to develop the water resources in the Gaza Strip as it represents an additional renewable and reliable water source (Afifi, 2000). Using treated effluent for agricultural purposes would minimize the deficit and would reduce the degradation of the groundwater quality.

Future reuse projects in the different activity sectors will depend on a better planning and management of reuse operations based on real water demand. This means a better institutional, regulatory and organizational setting (Afifi, 1998).

Economic and financial feasibility of water reuse applications need to be better assessed (Tubail *et al*., 2004).

In this research more concern will be given to the socio-economical aspects rather than environmental concerns.

## MATERIALS AND METHODS

In this research two approaches were followed; field investigations and questionnaire analysis. The field investigations concerns about the potential lands for reuse and models to identify the quality of irrigated water. Two agriculture areas one in Gaza Governorate and the other in the North were irrigated with treated wastewater from 2002 until 2006. The two pilot projects financed by the Agricultural Mission in the French Embassy in Amman (MREA). Moreover, regulations and reuse criteria of similar circumstances were cited. While, the questionnaire venture the social aspect of the research. The questionnaire was designed to address the following:

- Socioeconomic information on farming households
- Land ownership and tenancy
- Crop types
- Irrigation quantities, cost, quality, irrigation methods and irrigation schedule
- Previous experience of wastewater reuse
- Perceptions and willingness to use and pay for treated effluent

The questionnaire was conducted in the North, Middle and South of the Gaza Strip in 2006. The questionnaire was discussed with local experts in order to make sure that local conditions and all possible answers were captured. A pre-test was carried out with a sample of 6 farmers and some adjustments were included in the final version of the questionnaire. SPSS software was used to analysis the questionnaire (SPSS Inc., 2003).

## RESULTS AND DISCUSSION

### Social Consideration

The agricultural activity in the Palestinian lands is an important productive activity. The agricultural sector has an important and fundamental role in the national economy since agricultural products contribute with a noticeable portion in the foreign trade and providing foreign currency. The Palestinian Central Bureau of Statistics (PCBS) (2007) indicated that agriculture accounted 34.4% of the Gaza Strip's Gross Domestic Product (GDP) in 1998, but its contribution to GDP has decreased from 34% in the 1970s to 25 and 8% in the 1990s and 2001, respectively.

The main water consumer crop is citrus in Gaza Strip. The importance of citrus has diminished from 63% of the agriculture output value in 1970 to less than 25% at present days. Citrus and olives, fodder crops are highly recommended to be irrigated by treated wastewater in Gaza Strip. Selection of citrus and olive trees to be irrigated with treated wastewater is a function of many factors due to the crop pattern predominated in the Gaza Strip, level of water salinity and the safety measures recommended by WHO and FAO. Furthermore, shifting old irrigation techniques to modern ones in the traditional farms will save more than 25-30% of the irrigation water (Afifi, 2006). The reuse of wastewater effluent for irrigation will definitely save potable water for human usage in addition to introducing solutions for some environment problems. The public acceptance of wastewater reuse is a key factor in reuse policy success.

The main reasons behind the high level of agreement of interviewed farmers to use wastewater for irrigation includes increasing salinity level in the local agricultural wells, increasing fuel price and maintenance cost. This is obvious in the acceptance of most farmers to pay for wastewater. On the other hand the health and religious aspects are major concern of people. A great effort should be made to introduce safe wastewater as a water resource and to increase public awareness, although, the reluctance of using treated wastewater due to the religious concerns recorded a minor ratio (Tubail *et al*., 2004). This was explored through conducting a questionnaire among the farmers of the rural area in Beit Hanoun (North Gaza) which still characterized with reasonable fresh water. It is obvious that the majority of the interviewed farmers (68%) agreed directly to use the treated wastewater for irrigation purposes. In the Southern area, where the cubic of fresh water purchased with more than USD 0.45 and the quality of groundwater is increasingly deteriorated qualitatively and qualitatively, more than 91% of farmers accepted direct wastewater reuse schemes, while the reminder expressed their hesitation and conservative attitude towards the idea. The educational level, living background and the environment played a remarkable role in convincing the farmers about the feasibility of using treated wastewater, obviously observed in the two pilot projects financed by the Agricultural Mission in the French Embassy in Amman (MREA), as at the beginning, almost all people were hardly convinced of the safety of feeding their animals with the plants irrigated by the treated water. In the second pilot project site in Gaza City, no difficulties to get the farmer acceptance about irrigating their farms with treated waste water was observed. Furthermore, gradual time and incentives are important factors to promote wastewater reuse to generalize treated waster in the Palestinian areas. Lately of June 2006, a new questionnaire was conducted in the Eastern parts of Khan Yonis area showed that more than 96% of farmers interviewed accepted unrestrictedly using of wastewater due to the severe shortage of fresh water, poor water quality, educational programs and high cost of purchased water. Increasing the proper treatment and reuse of wastewater will bring significant social and environmental benefits. In general, farmers will be willing to use treated water if provided with enough information of reusing treated wastewater with crop restrictions and if proper mechanisms are in place for water quality monitoring and enforcement of compliance with effluent quality standards.

## Economic Consideration

Palestine faces the situation where not only is it in a region suffering from water shortage, but its lawful water allocation has not been made available.

It is stated in the National Water Plan (NWP) that wastewater investment costs represents about 37% of the overall Palestinian investment plan for Gaza Strip overall the period time to achieve the strategies and targets outlined in the National Water Plan. The

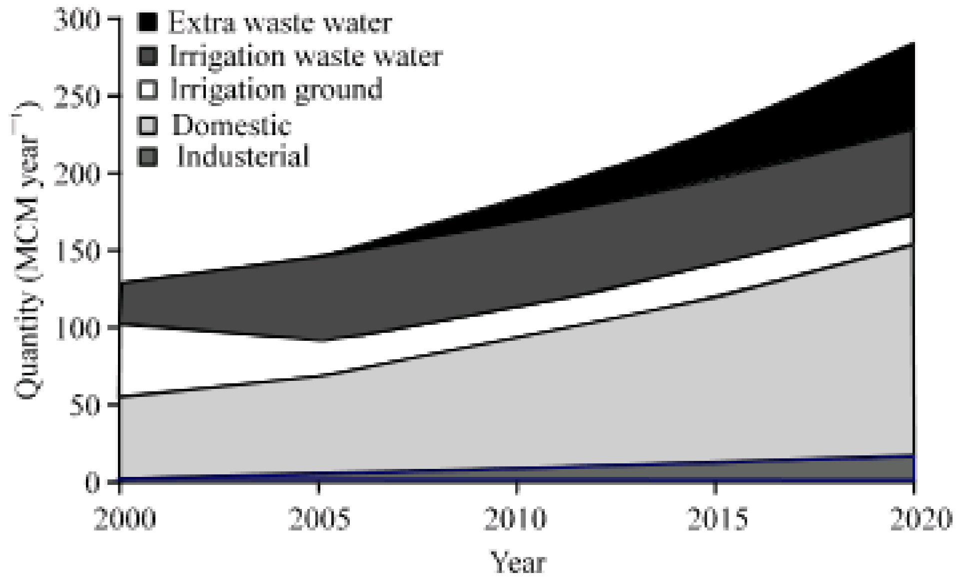


Fig. 2: Utilization of wastewater in Gaza Strip

national investment target for wastewater production was set for from a careful consideration of the extent of the sewerage works and the construction of the wastewater treatment plants. Wastewater reuse schemes are indispensable option for Palestine in general and Gaza in particular. It is relatively lower cost than other options like importing water or desalination of brackish water, which estimated roughly by the Palestinian Water Authority (PWA) and the World Bank at USD 0.55 $m^{-3}$ for production purposes only. For example, farmers in the South of Gaza buy water from Israeli Water Utility at USD 0.5 $m^{-3}$. By comparison, the cost of safely effluent used for irrigation or groundwater recharge has been recently estimated at USD 0.1 $m^{-3}$ (for capital costs) which has led to significant financial savings (World Bank, 2004).

The population concentrations, heavy dependence on the groundwater aquifers for water supply and their susceptibility to pollution means that if sewerage treatment and safe disposal in not carried out, the aquifers would not be available as a reliable supply. From hydrological point view, it should be recalled that the main objective of the wastewater treatment program is to lighten draw off from the groundwater table by proposing an alternative source of water to farmers for irrigating their crops. The treated water supplied will not allow for irrigating all categories of plants, however because of environmental and sanitary restrictions. The Integrated Aquifer Management Program (IAMP) aims to reduce the agricultural pumping from 90 MCM per year to about 60 MCM per year. The difference between these two volumes could be supplied by reclaimed water directly from the three regional treatment plants and a small quantity may be extracted from recovery wells in the vicinity of proposed infiltration basins as shown in Fig. 2.

In this context, adequate water pricing (tariff) is important for cost recovery to encourage water conservation by the users and to generate proportional revenues to develop the sector (Afifi, 2006). Finding an adequate policy for water pricing can control the feasibility of the wastewater reuse schemes. The aspect although important for all water resources, is of particular importance for managing wastewater reuse. The pollution that expected from wastewater reuse would be much higher when irrigation efficiency is low. Even effluents of acceptable quality could be adversely affect health and environment if the application efficiency is low. It is important to remember that each increase in standards also increase the capital costs of the project as well as the long term operating costs.

**Cost/Benefits of Wastewater Reuse Schemes**

An important step in the investment program of the strategic planning process was to prioritize projects based on a cost benefit analysis and other socio-economic factors. When

Table 1: Input/output costs of citrus and olive (NIS/dunum, farm gate prices)

| Parameters | Full yield (EC ≤ 1.7 dS $m^{-1}$) Olive[3] | Citrus | Effluent[1] (Yield at EC = 2 dS $m^{-1}$) | Groundwater[2] (Yield at EC = 3.2 dS $m^{-1}$) |
|---|---|---|---|---|
| Yield (kg $dunum^{-1}$) | 350 | 3000 | 2,400 | 1,500 |
| Selling price (NIS $kg^{-1}$) | 5 | 0.5 | 0.5 | 0.5 |
| Gross profit (NIS) | 1,750 | 1,500 | 1,200 | 750 |
| **Expenses** | | | | |
| Fertilizer (NIS) | 52 | 172 | 172 | 172 |
| Chemicals (NIS) | 65 | 35 | 35 | 35 |
| Water (0.5 NIS $m^{-3}$) | 188 | 450 | 450 | 450 |
| Hired machinery (NIS) | 40 | 30 | 30 | 30 |
| Labour costs[4] (NIS) | 300 | 480 | 480 | 480 |
| Total Var. Costs (NIS) | 645 | 1,167 | 1,167 | 1,167 |
| Gross Matgin (NIS) | 1,105 | 333 | 33 | -417 |
| Depreciation | 200 | 147 | 147 | 147 |
| Interest on capital | 63 | 135 | 135 | 135 |
| Total Cost[5] (NIS) | 908 | 1,449 | 1,449 | 1,449 |
| Net Profit (NIS) | 842 | 51 | -249 | -699 |
| **Results of the agricultural development program** | | | | |
| Lowered cost of water[6] (NIS) | 131.75 | 281.25 | 281.25 | |
| Lowered cost of fertilizer[7] (NIS) | 26 | 86 | 86 | |
| Gross Margin (NIS) | 1,262.75 | 700.25 | 400.25 | -417 |
| Net Profit (NIS) | 999.75 | 418.25 | 118.25 | -699 |

[1]For EC = 2 dS $m^{-1}$, yield reduction of 20%. [2]For EC = 3.2 dS $m^{-1}$, yield reduction of 50%. Groundwater expected to be more saline than effluent. [3]No yield reduction expected due to salinity. [4]Including hired and family labor. [5]Land rent not included. [6]Cost of effluent assumed at 0.15 NIS $m^{-3}$. [7]Fertilizer value of the effluent, sludge replacing imported manure

evaluating wastewater reuse projects, the initial approach is to categorize all benefits into two groups, directs and indirect benefits:

- Direct benefits are related to the use of wastewater in agriculture, aquaculture, industrial or potable water supply, or for other purposes such as: increase crop production, saving in fertilizer costs, saving in water supply and job creation
- Indirect benefit are related to minimize environmental damages, control soil erosion, protection of groundwater, reduces wastes and enhance water conservation

An estimate of the economic benefits and potential of using treated effluent in irrigation has been made by different models. The purpose of this is to show the impact of the use of treated effluent for irrigation at the farm level. The economic parameters of the market, such as product selling price and other factors have been taken as being constant. The reference standards for this computation have been taken from the FAO studies with application of information obtained during the present study. The computation method employed is an input/output analysis applied to crops. To show the potential financial benefit to farmers, a simple input/output calculation is shown in Table 1 based on citrus and olive as being the principal crops that are likely to be irrigated with the effluent.

Areas with groundwater EC of 3.2 dS $m^{-1}$ would in theory experience yield reductions in citrus of about 50%, at which level citrus production would make a loss on gross margin of 417 NIS (USD 93.7) per dunum. Areas with high salinity have lead many farmers to abandon their citrus plantations. By replacing well water of this quality for effluent at a future projected salinity of 2 dS $m^{-1}$ and by using sludge, the gross margin would become positive and is estimated at 400 NIS/dunum (USD 90.1). Olive is more tolerant of salinity and significant yield reductions are not expected within the range of concentrations in the area. By irrigating with effluent and using sludge, the gross margin may be expected to increase by 14%. This indicates an economical improvement for farmers switching from groundwater to effluent irrigation, even though full yield potential of citrus will not necessarily be achieved. For this example, a low tariff for effluent was assumed in comparison with well pumping cost which exceeds 2NIS (USD 0.45).

It is assumed that the installation costs of the effluent supply system from the Waste Water Treatment Plant (WWTP) would be covered by donor funding and the O and M costs of the system would be recovered through a tariff paid by the farmers. The costs of on-farm irrigation systems are not included as it is assumed that farmers would initially use their existing systems, although in the future, it is expected that all farmers would eventually convert to drip irrigation. The following factors have been taken into account for the calculation:

- The economic parameters are constant
- Lower water cost: selling price of treated effluent is estimated at 0.15 NIS $m^{-3}$ (USD 0.035) compared with 0.5 NIS $m^{-3}$ (USD 0.11) for well water (current pumping cost)
- Lower fertilizer costs: effluent and sludge will substitute part of imported costs of chemical fertilizers and manures

Substantial revenues can also be derived from cultivated certain crops with treated wastewater. For example, assuming a farmer can afford to cover the initial costs, growing mango, guava or avocado has a net present value (NPV, 10 years, 10% discount rate) of USD 5000, USD 3500 and USD 850 $dunam^{-1}$, respectively. Reusing wastewater to grow Rhoads Grass begins by providing USD 270 $dunam^{-1}$ net income in the first year, rising to $ 370 $duamm^{-1}$ afterwards (World Bank, 2004).

Concerning the nutrients load in the treated effluent, wastewater contains nutrients and trace elements necessary for plant growth. The value of nutrients for an assumed added water volume of 800 $m^3$ $dunam^{-1}$ is about USD 70. The average cost of fertilizers needed for one dunum is approximately USD 100, or 13% of the total production running costs. This indicates that nearly 70% of the cost of fertilizers can be excluded from the total production cost, which would result in a clear increase in the profits. In addition, treated sludge could represent a significant source of income. Treated sludge for soil conditioning and fertilization has a nutrient value equivalent to between USD 0.125 to USD 0.5 $year^{-1}$ while manure or chemical fertilizers can cost more (Nassar *et al*., 2009).

In this context, comparing the cost for the control block irrigated with fresh water and the blocks irrigated with treated waste water in the North Governorate which funded by MREA, where alfalfa is irrigated by the effluent, the production allow a benefit of 1100 NIS $dunum^{-1}$ (250 USD $dunum^{-1}$) under drip irrigation techniques. This result is really interesting, as it showed the potential sustainability of the waste water reuse in agriculture for producing alfalfa as well as the pilot areas in Gaza City which cultivated with citrus and olive trees, as 30-40% increasing in the production was observed in the last two years, in addition to the previous advantages of water and fertilizers savings.

The benefits of wastewater reuse schemes for job creation programs, as a special case of Palestinian people and due to the severe and tense circumstances in the region, is worthy estimated and evaluated. Most of the farmers depend on agriculture as the main income (Tubail *et al*., 2004) and many of children, women and younger also participate in the working activities in the various farms. Furthermore, such wastewater reuse projects will create many other supported jobs (World Bank, 2004), e.g., transport, packing of citrus, crushing of olives and marketing jobs. In terms of employment generation, newly irrigated land and quarrying industries create at least 5 new jobs for every 1000 $m^3$ $year^{-1}$ of treated wastewater used (World Bank, 2004).

The indirect benefits prominently represented in the environmental benefits can also be gained from the use of wastewater. The factors that may lead to the improvement of the environment when wastewater is used rather than being disposed of in other ways are:

- Avoiding the discharge of wastewater into surface waters
- Preserving groundwater resources in areas where over-use of these resources in agriculture is causing salt intrusion into the aquifers
- The possibility of soil conservation by humus build-up and by the prevention of land erosion

Despite these benefits, some potential negative environmental effects may arise in association with the use of wastewater. One negative impact is groundwater contamination by high level of salinity nitrate and other detergents in the effluent reuse (Afifi, 2006). The quantity and kind of salts present in wastewater is probably the most important single parameter for evaluating the suitability of treated effluent for irrigation. Data on the increase in the salt content of wastewater resulting from wastewater use and the variations of the increase within a sewage system are especially important in evaluating the reuse potential of wastewater in irrigation projects. Increase in the salt content of wastewater from domestic use and from private wells must be considered in designing treated wastewater irrigation projects and their economic feasibility. According to Afifi (2006), the expected increase in salt concentration ranges from 150-380 mg $L^{-1}$ as TDS. Groundwater contamination by agricultural chemicals, particularly nitrate ($NO_3$), is one of the major problems facing agriculture in the next century. Increases in groundwater $NO_3$ levels have been associated with major increases in nitrogen (N) fertilization and the leaching of nitrates from soils is recognized as a serious problem for water authorities, farmers and the general public.

## CONCLUSION

The obvious conclusion and all the socio-economic indicators of the relevant studies and the results of the pilot projects carried out in GS emphasized that a high degree of effluent reuse must be achieved in Gaza in order to reduce the current levels of groundwater withdrawal by the agricultural sector and mitigate the negative environmentally sound impacts. All future collection and treatment strategies should integrate reuse possibilities wherever practical. Reuse of wastewater effluent offers the release of complementary resources, sustaining the existing and expanding irrigated areas, in addition to the treated wastewater provides a renewable and valuable source for agriculture and free limited water supplies for domestic and industrial purposes. This indicates an economical improvement for farmers switching from groundwater to effluent irrigation, even though full yield potential of citrus and olive will not necessarily be achieved and all the precautionary and safety measures should be considered and enhanced regularly and systemically.

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