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Land Use and Water Management in Israel- Economic and Environmental Analysis of Sustainable Reuse of Wastewater in Agriculture

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ABSTRACT

We will analyze land use and water management issues in Israel by focusing on wastewater irrigation. Irrigation with treated effluents has become an important water source in Israel due to scarcity of natural water resources. Treated wastewater serve as source of water and nutrients and assist with wastewater discard. Wastewater also carries pollutants including micro and macro organic and inorganic matter and its treatment and use should adapt to sustainability criteria. Wastewater treatment processes can decrease pollutants levels, while salinity is not influenced unless combining relatively expensive desalination processes.

Advantages of using wastewater in irrigation include: supporting agricultural production, highly reliable supply, low cost, solution for effluent disposal and fewer chemical fertilizers. Disadvantages include groundwater contamination and potential damage to human health, crops and irrigation systems, increased water requirement and need for continuous follow up and control. The higher is the treatment level, the higher are the treatment costs but the potential environmental hazards are lower. We will assess advantages and disadvantages of irrigating with treated effluents, focusing on the economic and environmental analysis of sustainable wastewater reuse in agriculture and its impact on groundwater, soil and society.

Keywords: wastewater, groundwater salinity, agriculture, cost, cost-benefit
JEL codes: Q1, Q2, Q5

1. Background

Israel has been experiencing a rapid urban growth rate. Israel's freshwater resources per capita are already among the lowest in the world (Lawrence et al.) and as the urban population increases, the demand on freshwater resources increases leaving less fresh water sources for agricultural use. While domestic water consumption increases so is the production of wastewater which needs treatment and discard. In developing countries the situation is more complicated; urban drainage and sanitation has not been developed in proportion to the increase in fresh water use, leading to major health problems (Rose, 1999).

The urban wastewater contains chemical and microbiological content that may deteriorate groundwater quality. These include biodegradable organics chemicals such as suspended solids and nutrients, toxic chemicals (chlorine, ammonium, trace organics, trace metals), and chemicals related to health care (pharmaceutical products, antibiotics), that can cause health damage. The microorganisms may include bacteria and viruses of fecal origin and others. In addition, stormwater in urban areas that flows to the sewage collection system may contain chemicals such as persistent organic pollutants (POPs) and hydrocarbons (Marsalek et al., 2002, Chambers et al., 1997). Also salinity level in effluents is higher than in influents due to domestic use.

Of the fresh water supplies in Israel, 65% is used by the agricultural sector. The amount available for agriculture is reduced as the demand for freshwater for urban consumption increases. In the Middle East, in particular, this has been an increasing concern, leading to suggestions to exploit the increasing urban wastewater supply to replace fresh water for irrigation in Middle Eastern countries (Faruqui, 2002).

The advantages of using wastewater in irrigation include supporting agricultural production, highly reliable supply, low cost, solution for effluent disposal and fewer chemical fertilizers. Wastewater treatment enables to provide water for agriculture as well as to mitigate the environmental damage from untreated wastewater. In India, for example, using urban wastewater has enabled the urban poor to develop agriculture and fisheries (Gupta, 2002). Reusing organic wastewater from urban areas enables to exploit a large resource of water with nutrients for food production rather than filling the rivers with polluted water (Niemczynowicz, 1996). The production of urban wastewater in large and continuous quantity assures a highly reliable supply source of water for irrigation.

Faruqui (2002) lists the benefits in using treated wastewater to solve the water shortage for agriculture in the Middle East. First, is enables to conserve the freshwater for domestic use - the cost of secondary-level treatment for domestic wastewater is cheaper than developing new drinking water supplies in the region. Since urban wastewater needs to be treated before disposal to rivers, wastewater irrigation offers a low-cost alternative to treatment and disposal (Haruvy, 1997a; Haruvy, 1997b; Haruvy, 1998; Haruvy, 2000). Second, treated wastewater may be more suitable for irrigation than fresh water sources because its high nutrient content can reduce the need for fertilizer use.

The disadvantages of reusing treated wastewater in agriculture include groundwater contamination and potential damage to human health, crops and irrigation systems. Irrigation with wastewater increases soil salinity, causing a reduction in crop yields. This requires an increase in water use for leaching to reduce the damage from soil salinity. Wastewater irrigation also requires continuous follow up and control to maintain the required quality standards.

In the long run, the quality of the aquifer water can deteriorate due to some pollutants remaining in treated effluents. At lower treatment levels, the nitrogen leaching is greater, causing increased environmental damage (Haruvy et al., 1997). Cost-benefit analysis adapted to a specific region in Israel concluded that secondary treatment is preferable over tertiary treatment despite the increased salinity and damage to the aquifer (Haruvy, 1998).

Another problem that may be caused by low water quality is pathogenic microorganisms. Since 1990 there have been three major outbreaks of illness as a result of contaminated drinking water, including hospitalization of over 4,000 Milwaukee residents; about 200 residents in Ontario; and another outbreak which claimed seven lives and caused illness in 2300 residents. It is generally believed that these disease outbreaks are not were caused by agricultural sources (International Association for Great Lakes Research, 2002). Pathogenic organisms can be the reduced by appropriate disinfection.

Using wastewater may also cause damage the irrigation systems, increase the water requirement for leaching, and requires continuous follow up and quality control.

Several concerns relate to the desired treatment level. Many researchers have recommended treating wastewater to the level of drinking water quality. However, this method is expensive and if the farmers will have to pay the full cost of treatment will cause the agricultural sector to become uneconomic. In addition, as the nutrients removed from the wastewater through treatment are then added through fertilizers, this method is inefficient.. New methods of treating wastewater to remove nutrients are in the process being developed (for example, Fukumoto and Haga, 2004), thereby increasing the technical and economic feasibility of reusing urban wastewater for agriculture.

While most of the constituents can be reduced using advanced treatment processes (Feigin et al., 1990), salinity level in treated wastewater will remain higher than the level recommended for drinking water, unless more expensive desalination processes are used (EPA, 1992; Cecen and Gonenc, 1995). This may affect soil structure as well as groundwater quality. The increased water salinity affects crop yields (Maas and Hoffman, 1977), and other wastewater constituents may cause damage as well (Paranichianakis et al, 1999; Reboll et al., 2000).

The potential hazards of wastewater reuse can be diminished by appropriate treatment while salinity level can be decreased by additional desalination processes. Membrane desalination systems can be applied to the effluent from wastewater treatment plants to produce water that is clean enough for human consumption (Reuther, 2000). Desalination can be applied also to seawater diluted with other water supply sources or to saline groundwater to reduce salinity level. Higher treatment levels increase the costs of treatment, but reduce the potential environmental potential hazards.

Irrigation with wastewater also has an important impact on society. Farmers are usually among the low-wage earners in society, and their income is unstable, depending on drought and other varying outside conditions. In Israel, the cost of water is an important factor in determining the farmers' net income. Irrigation with wastewater provides a stable source of low cost water, increasing the farmers' profits and the stability of their income levels. In Israel, this is especially important in the peripheral areas of the country, where there are few alternatives available to employment in agriculture. Therefore the cost of water for irrigation has an important impact on the level of employment in remote rural areas.

This paper discusses focuses on comparing alternative water supply and treatment processes by estimating the supply costs and the resulting salinity/chlorides level and their effect on groundwater pollution. This is demonstrated in a case study of a two hydrological cells in the Coastal aquifer, each composed of 4 hydrological cells combining wastewater treatment processes and agricultural reuse.

2. Methodology

A hydrological model was constructed to simulate the flow of chlorides through the unsaturated zone of the soil into the groundwater. The concentration of chlorides in groundwater thus changes gradually over time. Groundwater is desalinated when the concentration of chlorides reaches the threshold value allowed for domestic water consumption and/or irrigation. The water is than desalinated to a given salinity level, and diluted with other water sources until reaching the threshold value.

Irrigation with treated wastewater gradually increases the concentration of chlorides in groundwater. Therefore, desalination will be initiated earlier than under conditions of irrigation with freshwater. The economic value of the damage to groundwater caused by effluent irrigation can be estimated as the costs of earlier desalination The total supply costs include the cost of wastewater treatment and water pumping and transporting as well as the cost of desalination.

We will compared alternative water supply and treatment processes by estimating the flow of chlorides into the groundwater using an hydrological model, the resulting effect on the timing of desalination and the financial costs associated with earlier desalination. The water supply alternatives included supply from local groundwater, national carrier's water and wastewater.

This model was applied on a case in two regions of the Coastal aquifer in Israel. Coastal region 1 included 4 hydraulic cells with groundwater salinity levels higher than 230 mgl Cl. Coastal region 2 included 4 hydraulic cells with groundwater salinity levels of less than 164 mgl Cl. It includes a wastewater treatment plant, whose effluents are conveyed to Coastal region 2; The total area includes an urban area of 7,988 ha and an agricultural area of 16,530 ha (Table 1).

The total water demand is for the chosen region 86.63 MCM, of which 27.29 MCM is demanded by Coastal region 1 and 59.34 MCM- by Coastal region 2. Ninety percent of Coastal 1's water demand is for agriculture- 24/46 MCM, while only 59% of Region A's water demand is for agriculture- 34.88 MCM, and the rest is urban demand (Table 1).

Table 1: Land and Water Use in the Coastal Region

	Coastal 1		Coastal 2		Total Region	
	Land Use Total ha or % of total	**Water Use Total MCM or % of total**	**Land Use Total ha or % of total**	**Water Use Total MCM or % of total**	**Land Use Total ha or % of total**	**Water Use Total MCM or % of total**
Agriculture: total	99%	**24.46**	51%	**34.88**	67%	**59.34**
National carrier		0.9%		34.3%		20.5%
Local aquifer		38.5%		55.6%		48.6%
Wastewater		60.6%	49%	10.1%	33%	30.9%
Urban: total	1%	**2.57**		**24.71**		**27.29**
National carrier		0.8%		88.1%		79.8%
Local aquifer		99.2%		11.9%		20.2%
Total	**8,354**	**27.03**	**16,164**	**59.59**	**24,518**	**86.63**

Several scenarios were compared, differing by Chloride thresholds for town and agriculture (Scenarios 1-4) and by type of water used for irrigation (with or without wastewater irrigation). These scenarios are presented in more detail in Haruvy (2004).

In scenarios 1-2 the threshold for town water salinity is 250 Mgl Cl, in scenario 3 this level decreases to 150 and in scenario 4 to 50 mgl cl. The threshold for agricultural water salinity is the same as the town salinity in scenarios 2-4, and unrestricted in all other scenarios. Irrigation includes wastewater, at a salinity level of 250 mgl Cl, and the town has priority of pumped water.

In scenarios 5-8 the threshold for town water salinity is 250 Mgl Cl. In Scenarios 5-6 wastewater irrigation is not included; in scenarios 7-8 wastewater irrigation is included and the wastewater salinity level is 350 mgl Cl. In scenarios 5 and 8 the town has priority of pumped water, and in scenarios 6 and 7 agriculture has priority of pumped water.

3. Results

The hydrological model estimated the aquifer salinity levels over time. These levels increase gradually for most cells (the exception is the hydrological cells near the sea that are not pumped). The results of the hydrological model's prediction of salinity levels for Coastal Regions 1 and 2 are presented in Figure 1 and Figure 2, respectively. When the threshold levels of allowed chlorides are lower, the groundwater salinity is lower (scenarios 1-4). The salinity levels are higher when irrigation with wastewater is allowed under scenarios 5-8.

Figure 1. Derived salinity levels for Coastal 1 area for scenarios 1 - 8

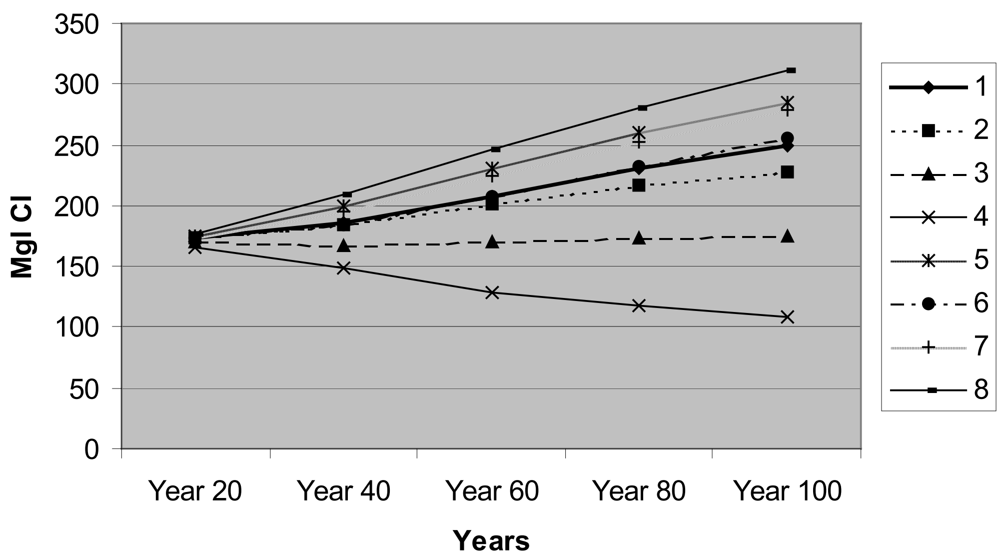
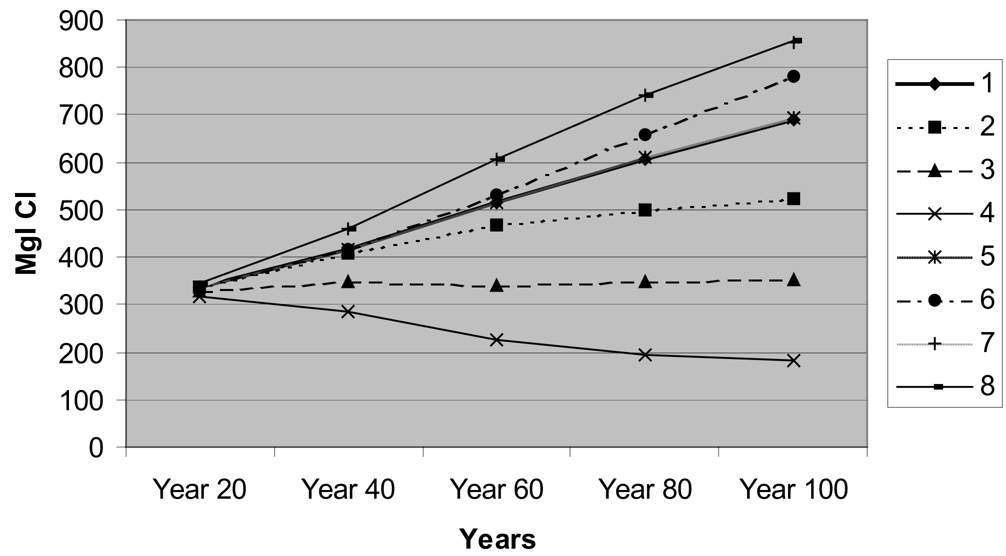


Figure 2. Derived salinity levels for Coastal 2 area for scenarios 1 - 8



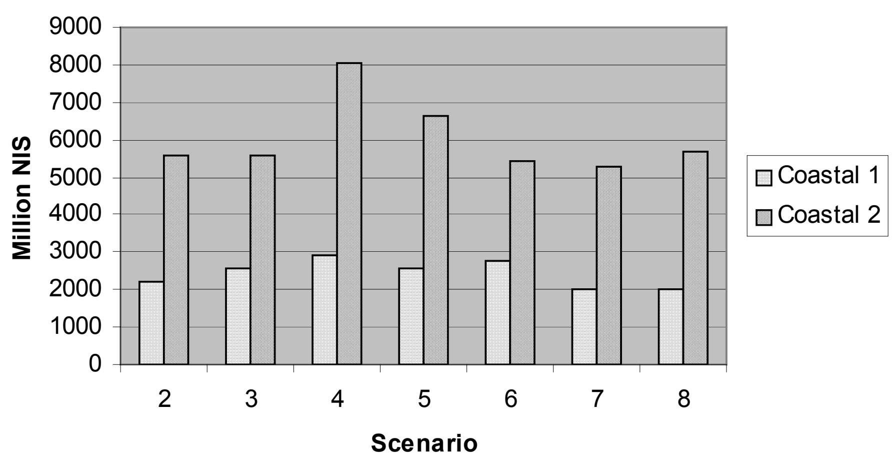
Costs of water supply, including desalination, for each scenario are presented in Table 2 and Figure 3. As the required threshold level for Chlorides is lower (that is, stricter restrictions on water quality are placed) in scenarios 1-4, the water costs gradually increase from 2227 million NIS in the case of 250 mgl cl to 2933 million NIS in the case of a restriction to 50 mgl cl. (an increase of 32% in the cost of water supply). When irrigation with wastewater is allowed, desalination costs increase but the total cost of water supply decreases (scenario 5 is compared to 6 and scenario 8 is compared to 7). This is because the cost of wastewater to the farmers is lower than the cost of freshwater for irrigation. However, the result is increased groundwater salinity, which causes environmental damages that should be accounted for in the decision making process.

High levels of salinity in wastewater also cause an increase in soil salinity, which can sodify the soil surface and deep soil layers, reduce soil infiltration to water and drainage of the root zone through lower layers. An earlier model (Haruvy et al., 2002) estimated the variation of soil moisture and salinity with wastewater irrigation, the resulting crop yield losses in the major crops of the region, and the costs associated with different levels of soil salinity.

Table 2: Computed water supply and treatment costs for the various scenarios (million NIS)

	Coastal 1		Coastal 2	
Scenario	Total cost	Desalination	Total cost	Desalination
	Million NIS	%	Million NIS	%
2	2226	28.1%	5562	14.1%
3	2581	40.1%	5596	15.6%
4	2932	51.6%	8021	84.3%
5	2572	11.1%	6612	11.6%
6	2756	0.0%	5426	0.0%
7	2028	14.8%	5286	0.0%
8	2028	14.8%	5674	8.5%

Figure 3. Total water supply costs



4. Summary and conclusions

The rise in development and the growth of the urban population causes an increased demand for freshwater, reducing the supply available for agriculture. It also creates an increased supply of wastewater, which should be discarded and may be used for irrigation. Wastewater is already a major source of irrigation water in Israel, but it may increase groundwater pollution. This research estimated the economic value of the environmental effects of irrigation with wastewater. This was done using a hydrological model to evaluate the groundwater salinity levels under different scenarios of chloride restrictions and irrigation with or without wastewater, and evaluating the treatment costs in different scenarios of groundwater salinity.

Development has economic advantages but has also environmental impacts which may be decreased through appropriate reuse and treatment of effluents. The costs of the treatment processes reflect the environmental costs of aquifer pollution. The results show that costs increase with stricter restrictions on domestic water salinity. Although the desalination costs increase, the total costs decrease under the scenarios that include wastewater irrigation, because of the lower costs of wastewater to farmers. The derived environmental damage should include the higher salinity levels in the soil and groundwater.

Although the scenarios with lower restrictions have a higher negative environmental impact, this should be balanced against the benefits to society from supplying water at lower cost to the farmers, which increases the employment rates and income levels of the lower-level earners in the country.

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