Integrated Water Resources Management in the Lower Jordan Rift Valley

Sustainable Management of Available Water Resources with Innovative Technologies

SMART

Workpackage 7, Deliverables D711

Assessing the socio-economic aspects related to irrigation with water of different qualities

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INTRODUCTION

1.1. Preface

1.1.1. Reclaimed wastewater as an additional water source

Agriculture is by far the largest water consumer, accounting for 80% of the annual water demand in many countries. Under arid and semi-arid environmental conditions, irrigation is a prerequisite for agricultural development. Reclaimed wastewater as an additional water source becomes exceptionally valuable where other water sources are scarce, and its utilization for irrigation frees high quality water for other uses. Another important issue is that reclaimed wastewater is available through all year long, which is significant to cultivation mainly at peak demand days (water demands vary with the crop types and season), though it requires seasonal storage. Furthermore, the importance of effluent as a source of irrigation water is as great as the need for its disposal. An unsustainable approach was to consider sewage disposal through land treatment, and in this manner to prevent potential health and environmental hazards caused by the uncontrolled flow of wastewater.

Wastewater treatment processes are conventionally classified into primary, secondary, tertiary and quaternary treatments. The higher of wastewater treatment level, the higher wastewater quality and its costs. The level of treatment required depends mainly upon the intended use or the environmental regulations for discharge of the wastewater. Moreover, Chemical characteristics of reclaimed wastewater vary with the source of the potable water supply, the sewage system, the season and the nature of industrial discharge into the system. Sewage water intended for irrigation is treated mainly in order to protect the public both from consuming contaminated crops and from direct exposure to the applied wastewater. Additional reasons for treatment are the prevention of nuisance conditions, operational problems in the irrigation system and adverse effects on soil and crops. Quality standards are usually designed to obtain maximum benefit from irrigation water (Feigin et al, 1991).

1.1.2. The quality of irrigation water

The quality of irrigation water, particularly in the case of reclaimed wastewater, affects crop yield and its quality, soil fertility, groundwater properties and environmental quality. The water quality refers to the concentration of dissolved and particulate, which have direct or indirect influence on its use. Reclaimed wastewater is generally of lower quality than conventional irrigation water due to its higher salinity level, accumulation of Boron, sodification, damage to soil structure (SAR/ESP) and flow regime (soil hydraulic characteristics), potential N and P accumulation in the soil and water, undesired effects of organic constituents and health risk by pathogens

(Shaviv et al, 2009). Reclaimed wastewater as a source of irrigation water differs from fresh water supply in the following aspects:

- Most of the biodegradable **organic matter** (as expressed in the BOD and COD indices) is eliminated during the biological treatment processes and disinfection of the reclaimed wastewater (methods used in primary treatment remove Coliform, grease and oils, grit and settleable solids). Therefore, removal of these hazardous constituents from the sewage effluents makes the water acceptable for irrigation.
- The **suspended solids** content is an important parameter in evaluating the suitability of sewage effluent for irrigating, since these solids may clog both the soil pores and components of the water distribution system.
- Effluents contain different levels of plant macro-**nutrients**, especially nitrogen and phosphorus. These elements should be taken into consideration as a source of plant nutrients as well as groundwater contaminants.
- A major concern in using sewage effluent for irrigation is the presence of high concentrations of hazardous constituents, such as **trace elements**, stable organics and complex synthetic micro-pollutants (for example: zinc, copper, and nickel are harmful to plants; cadmium, chromium and lead pollute groundwater and surface water).
- Although very small quantities of **Boron** are required for plant growth, yet its presence in sewage water as a result of soap and detergent use becomes toxic to many plants at slightly higher levels.
- The principle criteria for assessing the suitability of sewage effluent for irrigation are the Total Dissolved Salt (**TDS**) content and the Sodium, Bicarbonate and Chloride concentrations. The salt concentration of water, measured by the Electrical Conductivity (EC) of water at 25°C, in dS/m, is an indicator of salinity hazard.

These values are higher in sewage water than in fresh water.

1.2. The Israeli experience

Valuable information on effluent irrigation has been gained in Israel, where shortage of water stimulated research on different aspects of the subject, including social, environmental, and economic aspects. The Israeli experience gained better understanding of interaction with soil-plant-water, so as to allow improved irrigation management practices that assure sustainable agricultural production as well as consideration of concerns related to human health and environmental protection. The Israeli government encourages improvements and innovations in wastewater treatment technologies (Shaviv et al, 2009).

1.2.1. Israel's water allocation policy

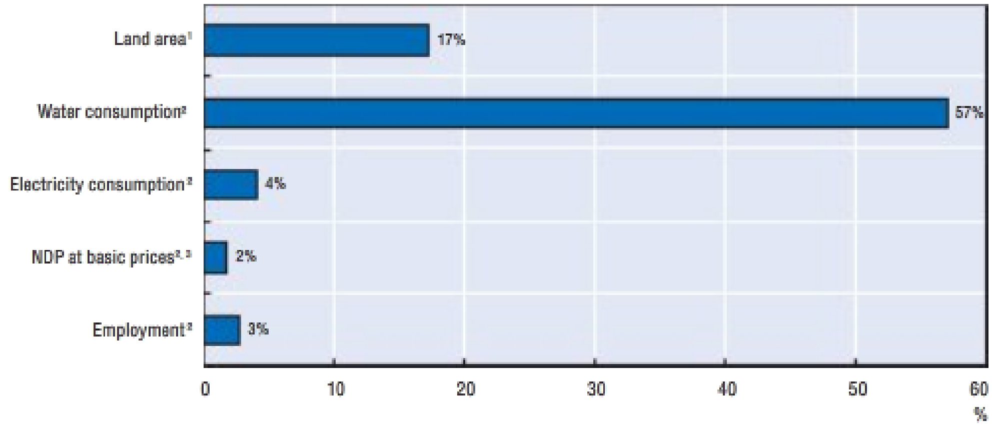
Water in Israel is considered as a national resource of utmost importance, and the concentration of all water resources management is in the hands of the governmental **Water Authority**. The water supplied to agriculture is mainly provided by the National Water Company “Mekorot”, and Agricultural Association. Three primary directives implement water planning in Israel: agriculture development, population dispersal, and development of arid regions. According to the **Water Law** (1959), each and every water use requires a license. This includes well drilling, extraction (production), supplying, consumption, sub-surface recharging, and water treatment. The license lists conditions that relate to quantities, qualities, procedures and arrangements of production and supply of water, increasing the efficiency of water use, preventing pollution, etc. The Water Law also established an administrative annual **quotaallocation** mechanism. The Water Regulations prescribe that in Rationing Areas (i.e. geographic areas in which the demand exceeds the supply), water allocations will be granted. Most of the country has been declared as a Rationing Area. Water allocations to **domestic** users are channeled to the users via the Municipalities. The quota allocation for domestic water use solely regulated through a strict differential pricing mechanism. **Industrial** uses are subject to quotas that are based on water use tables for the various industrial uses and annexed to the Regulations. There are specific provisions relating to small consumers (i.e. up to 5000-10000 CM per year). The water is supplied through the municipalities. Water allocations for **agricultural** localities are based on the water needs as defined in the agricultural plan for the locality, and the allocation makes a distinction between private agriculture and planned agriculture (kibbutzim and moshavim). Water allocation is also based on the type of agricultural growth, the growth stage of the tree and the geographical location of the plants/trees. The allocations are based on the water needs in the various regions of the country and normally water will not be allotted to regions where a particular growth is not considered economical (Arlosoroff, 2001).

1.2.2. Israeli Agricultural water use

Over the years the composition of water used by agriculture has changed. While the share of agriculture in overall **water use** tends to decline, it is still 57% in recent years (Figure 1). As it is shown in Figure 2, agricultural water use descends as agricultural freshwater price ascends. In 1990 fresh and surface water accounted for 95% of water used by agriculture. This has decreased to 55% by 2001and to 45% by 2008 (OECD, 2010). During the same period the yield of agricultural production also rose as the area farmed remained virtually unchanged up to 2000. From 2000 up to present, the area farmed has decreased under further pressure from rapid population growth and urbanization (Tal, 2007). It is important to mention that agriculture contribution to the Israel economy is small (low share in NDP - 2%, and employment 3%), though production has grown substantially contributing to expansion of agri-food chain and growth in agri-technology exports. The growth in agriculture production since 1990s has been achieved by improving the productivity of fixed and variable inputs, including water (Feitelson, 1999).

Agriculture’s embrace of technological innovation has given rise to more technically efficient use of water, pesticides and fertilizers per unit of output, for example recycling of effluent, but on the other hand pollution of water and air, land degradation and pressure on biodiversity (Tal, 2007). Since 2000 environmental issues have become more important in agricultural policy making and sustainable principles guide the nationwide multi-year agricultural development plan. The main objectives in the context of waterare: efficient use of runoff water and collection of rainwater; utilization of recycled effluent and marginal water resources (OECD, 2010).

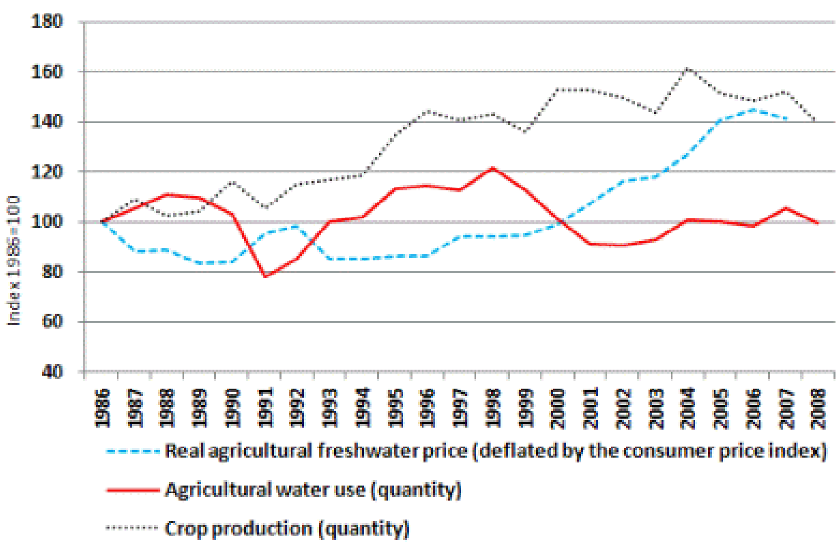
Figure 1: Natural resource & agricultural profile: share of primary agriculture in national total (2006-2008)



1. Average 2006-08 (OECD estimate).
2. Average 2006-08.
3. Net Domestic Product at basic prices equals GDP at market prices after deduction for consumption of fixed capital and net taxes on products.

Data source: OECD, 2010

Figure 2: Real agricultural freshwater price, agricultural water use and crop production (1986-2008)

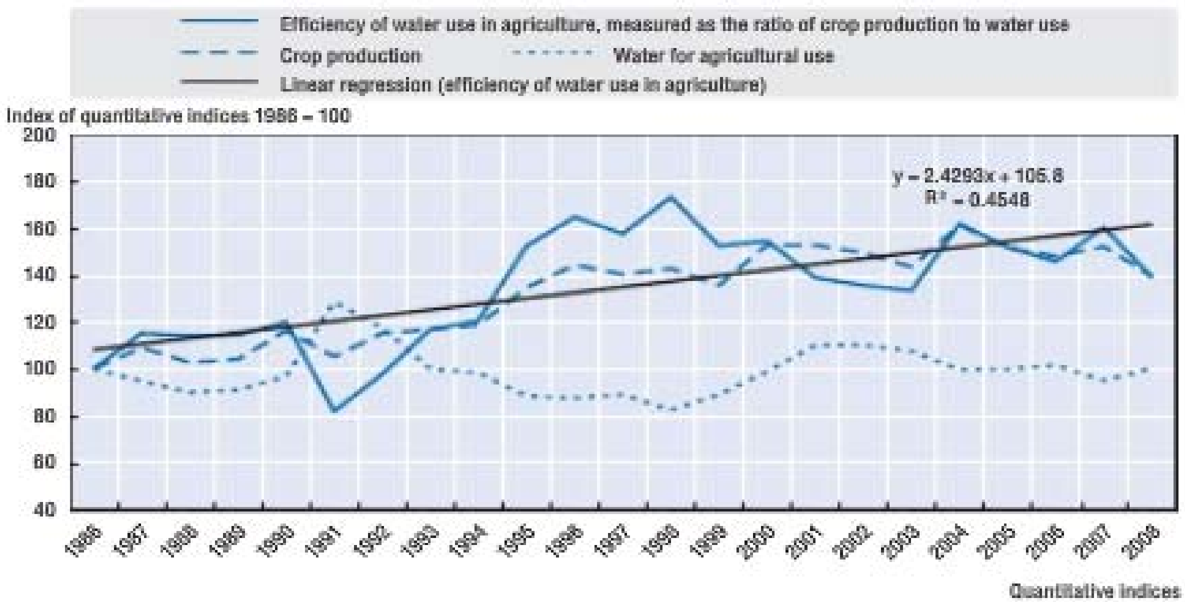


Data source: OECD, 2010

Efficiency of water use in agriculture has been improved in **physical** (technical) terms of water use per ton of output or hectare irrigated (Figure 3), mainly due to new irrigation technologies and computerized systems, utilizing drip irrigation systems and changing crop patterns which require less water; in terms of **economic** water use efficiency (value of output per unit of water used), mainly by investing in research projects and improving management practices; through reducing the sector's use of fresh water while increasing use of reclaimed wastewater; and by improving the quality of effluents.

Figure 3: Technical efficiency of agriculture's water use

Quantitative indices: crop production and water use



Data source: OECD, 2010

1.2.3. Exchanging freshwater by agriculture for reclaimed wastewater

Israel has already reached the stage when conventional groundwater and surface water resources are fully utilized. Therefore it is clear that wastewater is viewed as an agricultural resource, and its utilization is long recognized as economically beneficial. Freshwater for irrigation is limited, and a choice between using freshwater or reclaimed wastewater does not exist (Feigin et al, 1991). National policy calls for the gradual replacement of freshwater quota allocations to agriculture by reclaimed wastewater.

In 2000, treated wastewater constituted about 17% of consumption by the agricultural sector. By 2008, in the wake of several years of drought, effluents constituted about half of the water supplied to agriculture (Chen and Tarchitzki, 2010), which together with brackish water resources increased from 350 MCM (in the mid-nineties) to approximately 630 MCM (Shaviv et al, 2009). Since 2008 the water allocated for agriculture use is 46% from freshwater sources, and farmers must show evidence that they have made investments in water saving and efficient technologies and practices (OECD, 2010). Today, the reclaimed wastewater used in agriculture is approximately 75% of the treated wastewater country wide (Weinberg, 2010), compared to less than 5% in the USA (OECD, 2010). Other countries that utilize a significant proportion of their reclaimed wastewater for irrigation are Oman, Kuwait, Mexico,California, Florida (Hamilton et al, 2007), and Cyprus, Greece, Italy,Spain,Iran, Pakistan and China (O'Connor et al, 2008).

Effluents are the most readily available and cheapest source of additional water and provide a partial solution to the water scarcity problem. Water quota allocation cutbackand the relatively low cost of reclaimed wastewater (Table 1), are the main driving forces behind the high percentage of irrigation use. Furthermore, Israel's Water Law includes sewage water in its definition of "water resources".

Agriculture water demands vary with the crop types and season, whereas wastewater supply is continuous, thus seasonal storage or some alternative means of disposal of excess effluent must also be considered. **Storage** may be necessary for effluents during periods of low water demand for their use during peak irrigation demand in excess of supply, and for operational basis. Starting in the 1980s a network of almost 200 **reservoirs** has been established, providing nearly 7% of the total water in Israel, mainly located in drier southern regions. Initially these reservoirs were mainly supplied by sporadic flood water diverted from rivers, with the aim to replenish groundwater, although often reservoirs have been directly connected to irrigation systems. Recently, reservoirs have been constructed to store treated wastewater before its use in agriculture, requiring operational management to avoid pollutant discharges from reservoirs to irrigated land (OECD, 2010).

Another storage method is percolation of effluents through the soil and dilution into the aquifer. The Dan Region Wastewater Treatment Plant (**Shafdan**) is a complex inter-regional system that collect, treats and reclaims municipal and industrialwastewater by mechanical-biological wastewater treatment facility. The Shafdan produces high-quality irrigation water, which is very close to drinking water quality. Total of 130mcm/y are injected into the aquifer for final filtration, pumped from it after a period of about six months and are sent to the Negev Desert (southern of the state) for irrigating farms.

Approximately 70% of agricultural activity in the Negev is irrigated using these effluents, thereby saving millions of cubic meters of drinking water in Israel.

Reclaimed wastewater frequently is transported for agricultural use from nearby towns or for longer distances from large municipal facilities (OECD, 2010).

Exchanging freshwater by agriculture for reclaimed wastewater encouraged Israel to augment its water supplies through small to medium size **desalinization** plants in order to process brackish groundwater and seawater. The large scale desalinization plant together with the other plants provides capacity 10% of the country's total freshwater resources. Desalination of seawater has raised environmental concerns, including agronomic problems, as the desalinization process removes ions that are essential to plant growth (e.g. calcium, magnesium) while concentration of boron is highly toxic to many crops (OECD, 2010).

1.2.4. Upgraded Effluent Quality Standards

The rate of effluent reuse in Israel is among the highest in the world, but it does not encompass the total quantity of wastewater produced in Israel nor does it comply with sufficiently high quality standards (http://www.water.gov.il). Sewage water must be treated before disposal in accordance with water pollution and environmental laws and regulations. Permits for irrigators using reclaimed wastewater and the control of freshwater quality are the responsibility of the Ministry of Health. Israel's 1992 public health regulations on wastewater treatment set a minimal standard of 20/30 BOD/TSS. The Ministry of Health maintains a permit system designed to ensure that irrigation with effluents is limited to crops such as cotton, fodder, etc. Only highly treated effluents, after chlorination, are used for irrigation of citrus groves and other crops. In 2001, 46% of the effluents produced in the country (200 MCM) complied with the standards, growing to 92% of the total (500 MCM) in 2008. Nevertheless, the organic load in Israel's municipal wastewater is much higher than that in the western world. Furthermore, due to the high rate of effluent reuse for irrigation purposes, environmental sensitivity to the salt content of sewage is especially high. The high rate of effluent reuse in Israel made it imperative to set more stringent standards (http://www.sviva.gov.il).

A government decision taken in 2000 set the basis for the promulgation of stringent regulations on effluent quality at 2010. According to the decision, the government called on the Ministry of Environmental Protection to set up an inter-ministerial committee (known as the "Inbar Committee") with the participation of all relevant stakeholders including representatives of government ministries, local government, the private sector, experts, academics and scientists.

The "**Inbar committee**" recommended upgrading the effluent standards, which internalize externalities, while assuring economic viability. The committee was required to relate to health, soil, crop and hydrological considerations to ensure that effluent use would not cause environmental hazards, on the one hand, and would be economically feasible, on the other hand. The standard was reviewed both in terms of its technological feasibility under Israeli conditions and economic feasibility to assess the cost/benefit to the national economy which would result from applying the standard.

The Public Health Regulations (Effluent Quality Standards), 2010 include maximum levels for dissolved and suspended elements and compounds and for 37 different parameters in effluents for unrestricted irrigation and discharge for rivers. The objective is to treat 100% of the country's wastewater to a level enabling unrestricted irrigation in accordance with soil sensitivity and without risk to soil and water sources. The maximum levels for dissolved and suspended elements and compounds and for different parameters in effluents for unrestricted irrigation and discharge to rivers that were set by Inbar committee are listed in Appendix 1.

1.2.5. Water Pricing

The water price is the price charged for water consumption as established between the production supplier and the consumer. As mentioned before, the water is allocated to each sector (domestic, industry and agriculture) by administrative water quota, correspondingly to the consumption. The water consumption rates are progressive including a **three tier block price structure** (increasing-block tariffs) and rise considerably for water used above quota. The first rate is for consuming initial 50% of the water quota. The second rate is for consuming the next 30% of the quota, the third price is for the next 20%, and for each additional cubic meter the consumer pays a fine. The consumers have an incentive not to exceed the water quota due to the rising water price.

The rates are categorized by the water type and quality (Freshwater, Effluent, Brackish water), by different uses (industry, agriculture, domestic consumption and services), and by suppliers (Mekorot, water corporation or private company) each rate differing from each other (Table 1). The differences in water prices reflect not only the quality and cost of water supply, but also the government's goal to encourage use of different water types. The prices for reclaimed wastewater used by agriculture are lower than freshwater to encourage farmers to increase the substitution of freshwater for effluent.

The bulk water tariff for a specific use is the same throughout the country, irrespective of the difference in costs of supplying water to a specific locality or despite the seasonal variations in the water price. The absence of a regional water pricing system has been justified by the government to: achieve social equity through a one nation tariff structure for water; encourage the relocation of population and capital in the more peripheral areas of the country; and support agriculture in the arid southern region. To reflect the scarcity value of freshwater, and not just the cost of supply, the government imposed a water extraction levy on water consumers. The levy rate is determined on the basis of location and hydrological status, and it is lower for agriculture compared to other sectors (this provides an implicit subsidy to agriculture.

Table 1: Water Sale Price (NIS* per CM, Valid for 2011).

Sector	Freshwater	Effluent	Brackish water
Agriculture	1.628-5.003	0.721-1.881	0.664-0.995
Domestic	2.811	--	--
Industry	2.031-4.762	1.523	1.320-1.523

* 1 Euro ~ 5.5 NIS

Data Source: http://www.water.gov.il

Although water for the agricultural sector is allocated by the government, consumption of water in all three primary sectors (agriculture, industrial, and domestic) is a function of price. For all sectors, however, the price of water is determined by regulatory bodies, and thus, is not reflective of its true market value or shadow price. There has been a long run increase in real water price paid by consumers.

Irrigation water is subsidized, while water for domestic and industrial sectors is not. The farmers are supported through rates lower than the real cost of water (OECD 2010). The rates for industrial and agriculture uses are lower than those for domestic consumption and services for two major reasons: 1) Water for agriculture and industry is designated for production. 2) Water for agriculture is supplied on a less reliable basis and is of poorer quality (http://www.water.gov.il).

Since 2008 the government agreed to allow holders of water allocations to sell up to 30% of their quota allocation to other farmers by transferring the actual transaction via the National Water Carrier. This action enables some water trading and might also help toward reducing illegal sales of unused agricultural water quota, which are estimated as 20 MCM per year.

JUSTIFICATION & OBJECTIVES

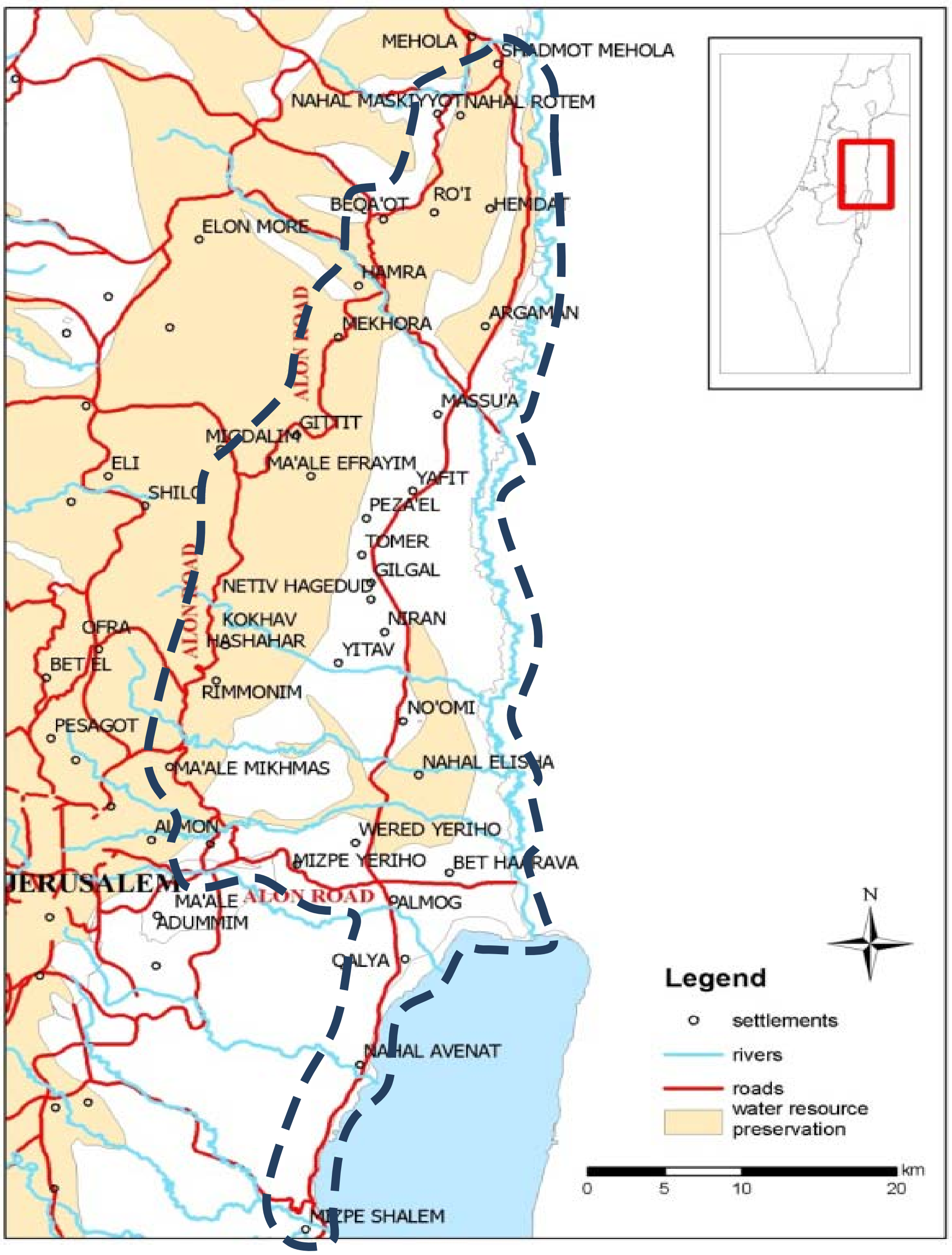
In the selected study area (LJRV) there are substantial sources of residual waters such as brackish water of various degrees of salinity and treated effluent. A proper mixing of these waters can be channeled for the irrigation of different crops, thus releasing the available freshwater for other more restrictive uses (domestic, tourism, industry and water sensitive crops). While this approach is being deployed in the area, its socio-economic implications remain to be quantified. The purpose is to fill this gap and the suggested work includes:

- Gathering relevant data (water quantities and qualities, mixing ratios between different waters, irrigated crops, the income they produce, the degree of acceptance by the farmers and by the market, the environmental impact, dedicated technologies);
- Analysis of the data production of trade-off matrices (the benefits versus the short-comings of the approach for various key criteria to be defined);
- Conduct a multi-criteria analysis (MCA), i.e., using with the AHP method, involving technical experts, the farmers, the decision makers and other stakeholders in order to identify the acceptable practices;
- Suggest a framework compatible with all constraints from the various sectors;
- Suggest guidelines that could be applicable to the other basins of the LJV (in the Palestinian Authority and Jordan).

THE STUDY AREA

The Lower Jordan River Valley (LJRV) is an elongated valley and is located in the extreme east of Israel state. The eastern strip includes the Jordan Valley and the northern shores of the Dead Sea. The Eastern strip lay between two longitudinal axes, one along the west side of the River Jordan and the Dead Sea and the other, along the eastern slopes of the Samarian Hills. This section also marks most of the border between Israel, the west bank and Kingdom of Jordan.

Figure 4: The study area and the Israeli settlements in the LJRV



3.1. Israeli settlements in the Jordan Valley

The Israeli localities in the LJRV were established after the 1967 war, at two main areas: along Biqua Road (road no. 90) and along the eastern slopes of the Samarian Hills / Alon Road (road no. 458) (Figure 4). The area generally follows a rural settlement pattern, and the 32 localities are classified as agricultural rural ones (Kibbtz, Moshav, and Communal locality). The localities in the study area are unionized into three separate Regional Councils (Northern, Southern, and Eastern Regional Councils). Regional Council refers to a number of rural localities, which provides various municipal services for the villages within its jurisdiction boundaries. Only one urban Local Council was found in the study area.

The Israeli CBS classified all the localities by their socio-economic characterization of the population residing in the localities, according to different demographic and socio-economic variables (such as education, standard of living, labor force, health, etc.). The localities in the study area are socio-economic ranked according to the regional councils which they belong to. The socio-economic level of the population living in LJRV is medium-low.

The settlements pattern is a combination of farming and industry wherever this has been found to be necessary, and they will continue to rely on agriculture as main employment sector in the future. The northern part of the study area is more suitable for cultivation than the southern part due to combined conditions. Therefore, more localities were established there. The potential amount of land and water available determined the number of agricultural units (agricultural estate) and settlements. The Jordan Rift Valley was estimated to comprise 66,000 Dunam (1 hectare = 10 dunam) of cultivable land, unevenly distributed along the Valley. The special geographic-climatic conditions of the JRV are what make agriculture the leading economic sector of the region.

- The high temperature yields early ripening in the spring and late ripening in autumn, allowing for high financial gains.
- The strong sun radiation favourably affects the fruits and vegetables and encourages their growth.
- The below average rainfall and moisture contribute to low infestation resulting in high quality crops.

On the other hand, some of these conditions create burdensome difficulties for the farmers:

- Salt content- below most of the Jordan Valley's soil is lime-rich marlstone, sediment left from salt water that covered the Jordan Valley in the past. This makes it difficult for vegetables and vineyards to grow and requires sluicing the soil and using large amounts of irrigation.
- Climate- the high temperatures are an advantage in the winter (18-20°C), but become a serious disadvantage in the summer (37-38°C). The harsh climate causes strong winds to blow from the western hills, increases the amount of evaporation and dryness (2000 mm a year), and limiting possibilities in the summer.
- Water- agriculture depends entirely on artificial irrigation, and this sector is the main water consumer, consuming more than 95% of the freshwater supplied to the

LJRV region. The farmers have four sources of water: freshwater, floodwater, treated wastewater and brackish water – all suffer from availability and reliability problems in water supply.

Figure 5: Yafit Locality and the Jordan Valley Regional Council center

3.2. Agriculture in the Jordan Valley

The idea was that with the aid of large scale capital investment in the development of water resources and the use of agro-technical knowledge, it would be possible to raise large crops of winter vegetables and fruits, which can be sold at high prices in the European markets. Though, many changes occurred to the LJRV agriculture through the years, and varied crops were implanted or removed, sometimes causing economic crises. At the beginning, the farmers relied on experimental agriculture, until they could gather enough data on the crops that are most suitable to grow in the LJRV conditions. Eventually, the water scarcity dictated the crops type, and along the years, the farmers changed to crops more suitable (and efficient) growing at the LJV harsh conditions. In the mid-1970s, an agricultural R&D unit was established in the study area to assist and escort the farmers. In addition to the special experimental cultivated fields at the R&D unit, research is also implemented at the farmers cultivated fields, which provide tight surveillance from the R&D guides.

Approximately 30% of the households are occupied directly in agriculture (727 Agricultural estates), and additionally30% are occupied in industries and craft which supplement the agriculture sector (related services such as packing houses, refrigeration, transport, office services etc.). The total cultivated area is approximately 36,000 Dunam (1 Dunam = 1,000m^2). The LJRV agriculture production value is estimated as 460 million NIS in 2011. Approximately 61% of the households are occupied in orchards cultivations, 34% in field crops and 5% in animal barns. The data is valid for the northern part of the JRV only.

The cultivated fields are distant from the some of the agricultural settlements, and without proper roads and suitable infrastructure, such as electricity for computerized irrigation system or high-tech greenhouse. Despite the harsh conditions, the agriculture sector in the LJRV is prosperous due to un-standard solutions and agro-technical technologies. The rapid development of the agro-technical technologies, high quality professional guidance and an independent R&D unit, have brought stability in the past five years to many of the major crops and allowed them to expand each year, especially palms and peppers. Therefore, the area allocated for palms and peppers cultivations had expanded respectively (http://www.mop-bika.org.il). Strict standards and high investments are required from the farmers in order to sell the crops at the European markets. Reclaimed waste water in agriculture is used mostly to irrigate non-edible crops, and it is used to irrigate palms trees. Nevertheless, continuous research is conducted on its use for food crops. Vegetables and spices grow in high-tech greenhouses with computerized drip irrigation systems, isolated from the local soil (on tufa platform) to overcome the soils quality problems, protect frompests and to control the climate and water quality. Special brand of cherry tomatoes and edible grapes was developed in the LJRV that are suitable for the harsh conditions and come to fruition early before other crops sold at European markets. The main types of agricultural cultivations that exist in the study area are detailed as fallow and are listed at Table 2:

Palms – The Jordan Valley is the major producer of dates and 80% of the yield is exported. At the northern part of the JRV thereare approximately 16,000 dunam, and 4,000 Dunam at the southern part, mostly of the Medjoul variety. The water demand for this brand at the northern part of the JRV at the first 6 years is 300-400 CM/Y per Dunam, while mature trees demand 1,600-1,800 CM/Y per Dunam. At the southern part of the LJV, mature trees demand 2,200 CM/Y per Dunam. Only palms are irrigated with reclaimed wastewater and they can tolerate high salinity and 60/90 mg/l BOD/TSS. The major water demand period for this cultivation is in March-April.

Edible grapes – There are 4,600 dunam of table grapes in the Jordan Valley. In the past, this crop suffered from ongoing crises, but is now expanding from year to year. 70% of the yield is exported and is half of the grape export of the State of Israel. The SBS (Early Sweet) brand was developed in the local R&D. The crops are grown under unique nets that were developed by the LJRV R&D agriculture center.

Pepper is the main cultivation grown at winter and spring seasons, with variety of species. The long season of growth makes it possible for a long period of marketing (8 months a year), for exporting and for the local Israeli market.

The fresh spices grown in the LJRV are all designated for exportation, and they are half of Israel's exported spices. 3,000 Dunam of basil, peppermint, tarragon, arugula and asphodel are yield during all seasons due to special crop system which was developed by the LJRV R&D agriculture center.

Other agricultural crops include; cherry tomatoes, eggplants, flowers, citrus fruits, olives, pomegranates, chicken, turkey, dairy, goats and sheep barns.

Table 1: main types of agricultural cultivations and their economic value*

Cultivation	Area (Dunam**)	Product value (Million NIS)
palm	20,000	281
edible grapes	4,642	70.5
Pepper	3,180	21
Herbs & spices	2,320	33
Vegetables & field crops	6,699	13
Citrus & orchards	2,589	5
Flowers	550	--
Dairy farming + goat/sheep Pen	3,715 (heads)	35
Livestock + Turkey	10,140 (Ton)	
sheep and goat barns	1,785 (heads)	--
Fish farming	15	--

*northern part of the JRV only
**1 Dunam = 1,000m^2
Data Source: http://www.jordanvalley.org.il

3.3. Water consumption & supply in the Jordan Valley

Mekorot (a governmental authority) is the main **freshwater** supplier for the LJRV consumers, and it supplies the water by a local distribution network, mainly from drilling water from the mountain aquifer. This system is isolated from the main Israeli national water systems, and therefore water can't be transferred from other sources of freshwater available in the state. The LJRV population is solely dependent on this local freshwater distribution network. The water is drilled from 23 wells and pumping units from the aquifer reservoir,approximately 400-700m depth with salinity of 50-400mg Cl^-per liter (the drinking water regulation are 600mg Cl^-per liter). This underground reservoir is located underneath the Judea and Samarian Mountains. The annual water drilled from the mountain aquifer at the LJRV wells (approximately 33 MCM valid for 2010) is shown in Table 3. The drilling wells are located along the mountain bed (eastern slopes of the Samarian Hills) and the water is transferred gravitationally from the wells closer to population centers and to the agricultural consumers by pipe lines. Drilling water demands significant energy.Furthermore, freshwater from drilling wells are inadequate during the demanding season. In addition, the water level drops from year to year due to intense pumping and causes saline water and stops the pumping. For instance, the salinity of the water damaged the greenhouse flower yield, which led the farmers to abandon this cultivation for other crops.

Figure 6: Mekorot's mountain aquifer drilling well – Fatzael Basin

As it is shown in Table 3, the main water consumption region is Fazael-Naaran because it is the largest cultivation area, consuming approximately 37% of the water in the LJRV. Furthermore, it is important to mention that additional of 300-500 CM per Dunam of freshwater is needed for soil rinsing, each time before renewing plantation (solar soil disinfection is also implemented.

Table 2: Annual pumping from the mountain aquifer separated into regions (Thousands of CM / Y)

Regions	Average	2010	2009	2008	2007	2006	2005
Mitzpe Jerico	4398.70	4292.9	4185.0	4434.4	4716.7	4343.4	4419.8
Fazael-Naaran	12054.03	12204.3	11498.8	12279.4	12489.6	11727.3	12124.8
Wadi Faraa	4429.28	4669.6	4139.1	4633.3	4544.6	4215.0	4374.1
Bekaot	1522.98	1622.3	1587.2	1538.9	1623.3	1364.6	1401.6
Argaman	301.42	297.1	356.7	305.0	338.9	208.7	302.1
Bardale	7871.27	8091.8	7291.5	8295.6	8265.2	7601.5	7682.0
Sum	**32585.18**	**33188**	**31067.3**	**33494.6**	**33985.3**	**31466.5**	**32309.4**

Data Source: Guttman, 2011

Figure 7: Agriculture at Fazael-Naaran region

According to senior persons from Mekorot, 90 thousand CM of drilled freshwater are supplied each day for the Israeli and Palastinian localities (15 thousand CM for drinking and the rest for agriculture).The total quantity of freshwater resource is limited to 90 thousand CM per dayand is finite, and additional drilling wells will not increase the total freshwater inventory. On the contrary, additional drillig wells will lower the water level at the exisisting drilling wells. There is no future master water plan for this area. The LJRV main water peak demand season is between April utill October, as opposed to the Israeli characteristic water demand,and all users need the water at the same time.

In the northern part of the LJRV, **brackish** water for agriculture use is provided from the Jordan River, which has a high saline level (1,200-3,200mg Cl- per liter) and is appropriate only to irrigate date palms. Along the Dead Sea shore there are two spring clusters (Feshkha springs). Their salinity varies between 600-6000mg/l Cl- (Hötzl et al., 2008: chapter 3.3.2) and the total discharge is approximately 90-95 MCM per year. most of the spring's water flows to the Dead Sea without utilization.

Two Water Associations exist in LJRV, which supply water to agricultural use, and each operate a water reservoir: Tirza at the northern part of the LJRV, and Og at the south.

- The Tirza reservoirs (5 different reservoirs containing total of 5-9 MCM) collects winter **floodwater** flowing downstream from the Nablus region to Triza stream. It is designated to collect 1.5-4.5 MCM from a single floodwater event. The water source has inferior quality. This water source is mixed with different types such as brackish water from the Jordan River, and treated wastewater, but dilution is executed solely by the water supplier before supplied to the farmers. Untreated **wastewater** flowing from eastern Jerusalem neighbourhoodsand Ma'aleAdumim locality direct toOg and Kidron streams is collected and transformed by pipelines to Tirza reservoirs. The treated wastewater (primary and secondary treatment processes) after dilution is being used for irrigating palm trees,containing 200-250 mg/l Cl^-, and approximately 10/5 BOD/TSS.The water sale price is 1.07NIS per CM, due to the Water Association's primary investmentsin infrastructure and pipe lines (more than 80km of pipeline transferring wastewater from Og and Kidron streams to Tirza reservoir).

- Og reservoir (2 reservoirs with volume of 1.5 MCM each) also collects **wastewater** from theOg andKidron streams. The water quality after secondary treatment processes has approximately 20/30 BOD/TSS.The water sale price (increasing-block tariffs) is determined according to its chemical quality (see paragraph 1.2.5. Water Pricing).

Table 4 shows the water demand for the different crops growing in the LJRV.

Table 3: Cultivation water demand in the LJRV

Cultivation	Average Water consumption (CM per Dunam* per month)	Average Water consumption (CM per Dunam* per season)	Season duration (month)
palm	--	300-1,800	--
Pepper	150-180	1,600	10
cherry tomatoes	180-200	1,700	9
basil	150-180	1,500	9
arugula	--	400	4
asphodel	150	1,350	9

*1 Dunam = 1,000m^2

Figure 8: Tirza reservoirs


Figure 9: Og reservoirs

In order to study the socioeconomic aspects of different water resources and irrigation management that are used, an integrated context is needed. Integrated water resources management (IWRM) in the context of this study means that all the water of different qualities for irrigation used in the LJRV should be considered together. Additionally, the IWRM concept should take into account both the benefits and the negative impacts. When there is competition for water resources it brings into the open the need to justify the water allocation to one user rather than to another. Problems and constraints arise in each water use, and decisions must be made.

Decisions are typically characterized by a large set of alternatives and multiple, conflicting and incommensurate evaluation criteria. Multi Criteria Decision Making (MCDM) is a discipline aimed at supporting decision makers who are faced with making numerous and conflicting evaluations (criteria). This methodology aims at highlighting these conflicts and deriving a way to come to a compromise in a transparent process, mainly lead by the decision maker. MCDM is the study of methods and procedures by which concerns about multiple conflicting criteria can be formally incorporated into the management planning process. The diversity of MCDM models makes it difficult to gain a clear understanding of which methodologies are appropriate to a particular context. Therefore, the choice of which model is most appropriate depends on the problem at hand and may be to some extent dependent on which model the decision maker is most comfortable with.

In order to make decisions in the complex environment of multiple criteria, we need to know the problem, the need and purpose of the decision (the goal), the criteria with which we screen the decisions, to define a set of sub-criteria, consult the stakeholders and other affected groups and finally to define a set of alternatives or scenarios that can meet the stated goal.

We then try to determine the best alternative, or in the case of resource allocation, we need priorities for the alternatives to allocate their appropriate share of the resources. The goals of a certain project or action have to be defined by decision variables and need to be maximized subject to constraints.

MCDM problems involve a number of criteria that may not be of equal importance to the decision maker. The decisions involve many intangibles that need to be traded off. Through tradeoffs it clarifies the advantages and disadvantages of policy options under circumstances of risks and uncertainty. Therefore, each criterion is assigned a weight that represents the preference of the decision maker with regard to the objectives. This represents the main core of the Analytical Hierarchy Process (**AHP**), which was developed by Thomas L. Saaty in the 1970’s and has been extensively studied and refined since then.

4.1. The Analytical Hierarchy Process (AHP)

The AHP is a mathematical theory of value, reason, and judgment, based on ratio scales for the analysis of multiple-criteria decision-making problems (Saaty, 2008). The AHP method is designated to assist the decision maker to rank predefined alternatives according to a set of predefined criteria (Saaty 2001; Saaty 2005; Saaty 2006; Saaty and Hu 1998; Barzilai and Golany 1994). It is important to note that some combinations of alternatives are contrary to the others and these tools are aiming in defining and selecting the proper alternative (combination).

The AHP is a systematic procedure to construct and represent the elements of a problem in a hierarchy formant. The basic rational of AHP is organized by the breakdown of the problem into smaller constituent parts at different levels. An AHP model typically consists of an overall goal, a set of criteria to specify the overall goal decomposed to sub-criteria, and finally, at the lowest level of the hierarchy, the decision alternatives to be evaluated. In AHP, each element in the hierarchy is considered to be independent of all the others.

Beyond the decomposition principle, the AHP is based on pair-wise comparisons of elements in a decision hierarchy with respect to the parent element at the next higher hierarchical level (i.e., among criteria and lower level elements). The pair-wise comparison is aimed in providing a cardinal scale to evaluate objects according to some subjective preference criteria. Pair-wise comparisons are made on a scale of relative importance (see Table 5) where the decision maker has the option to express the preferences between two elements on a ratio scale from equally important (i.e., equivalent to a numeric value of one) to absolute preference (i.e., equivalent to a numeric value of nine) of one element over another.

Table 4: A nine point scale for pair-wise comparison

Intensity of Importance	Definition	Explanation
1	Equal Important	Two elements contribute equally to the objective.
3	Weak Importance	Experience and judgment slightly favor one element over another.
5	Strong Importance	Experience and judgment strongly favor one element over another.
7	Very Strong Importance	One element is favored over another; its dominance is demonstrated in practice.
9	Absolute Importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intermediate values used to interpolate between adjacent scale values		

Ratings of decision makers are arranged as numerical numbers in a comparison matrix. Based on this, relative weights for all elements of the hierarchy are calculated with the eigenvalue method (EM), indicating the priority level for each element in the hierarchy (Saaty, 2001). Accordingly, priorities for the alternatives are gained by judgments with respect to each above-level element of the hierarchy. Their performances are weighted with the relative weights of criteria and sub-criteria, and added to an overall priority for each alternative (i.e. how they contribute to the goal), which allows a cardinal ranking of the alternatives (Saaty, 2006).

The combination of the social-economic-environmental benefits versus the short-comings from implementing water of different qualities for irrigation is defined as IWRM practices.In this phase we conducted an analysis of the data collected and defined IWRM practices for the study area in order to specify various key criteria.It is significant to conclude the conflicting and incommensurate evaluation criteria to the IWRM practices. By conducting a multi-criteria analysis (MCA), using the AHP method we identified the acceptable IWRM practices.

5.1. Costs and benefits from using reclaimed wastewater in agriculture

Using reclaimed wastewater for irrigation introduces the valuable advantage of conserving a precious and scarce resource in regions where it is critically needed, with the added benefit of reclaimed wastewater containing a substantial amount of nutrients needed by plants. On the other hand, reclaimed wastewater, particularly when poorly treated, poses several critical threats and disadvantages (Shaviv et al, 2009). The following chapter summarizes the main advantages and disadvantages, and Costs and benefits from using reclaimed wastewater in agriculture.

5.1.1. Governmental Intending

Israel's government has developed a policy framework to: provide financial support for treating, storing and supplying reclaimed wastewater to agriculture; establish regulatory arrangements to address human health and environmental concerns associated with reclaimed wastewater; develop research to improve the quality and framing practices in using reclaimed wastewater; and organize farmers education and advisory services in the use of reclaimed wastewater. The government also provides funding to establish a national network of reservoirs to hold reclaimed wastewater.

The use of reclaimed wastewater in agriculture is supported by: lowering the reclaimed wastewater price relative to freshwater in order to encourage substitution on farm; offering grants that cover 40-60% of the investment costs of treating, storing and supplying reclaimed wastewater to agriculture; supporting for the on-farm costs associated with adapting irrigation systems to use reclaimed wastewater; offering grants for installing drip irrigation and other water efficient technologies; and also supporting research and development on new irrigation technologies and enhanced water management systems.

5.1.2. Advantages from Irrigating with reclaimed wastewater

Supplying reclaimed wastewater for agriculture is viewed by the government as a low cost and beneficial way of disposing sewage or else it would be treated to a lower standard that would lead to environmental pollution. Improvements in effluent quality lead also to technology improvements. Additionally, it is viewed as lowering the freshwater demand and converting it to the domestic and industrial sector. Reclaimed wastewater is also viewed as a way of ”greening” the desert and helping to establish agriculture in marginal and national border regions.

In addition to the cutback of freshwater quota allocation for irrigation, water sale price of effluent is the main incentive for the farmers to utilize reclaimed wastewater. The cost of reclaimed wastewater is cheaper than freshwater, so the farmers can lower their expenses on irrigation. Additional economic benefits can occur due to the availability of reclaimed wastewater through all year long; especially in peak demanddays (Heinz et al. 2011).

Irrigation with reclaimed waste water from Og and Tirza reservoirs (classified as primary-secondary effluent treatment) results in the addition of considerable amount of Nitrogen and Phosphorus to the soil. Potassium is another essential nutrient element, and irrigation with this type of water often does not satisfy plant needs and therefore, fertilizers and organic materials are added (Shaviv, 2009). In order to maximize the economic benefits of using such water, appropriate irrigation and fertilization management should be imposed.

In conclusion, farmers see reclaimed wastewater beneficial in terms of: overcoming limited freshwater allocations and increasing the water supply availability; providing a lower cost source of water compared to freshwater; and improving crop yield and reducing fertilizers costs due to the high levels of nutrients in reclaimed wastewater.

5.1.3. Disadvantages from reclaimed wastewater

The use of reclaimed wastewater in agriculture raised economic, agronomic, environmental and human health costs: the support provided for reclaimed wastewater raises **economic** issues as to whom should bear the full costs of recycling, the urban / industrial producers of the effluent or agricultural users the beneficiaries of effluent treatment, which result in savings if these costs were not financed by the government. Additional costs are bound with the separated pipeline network required, as a result of using reclaimed wastewater for irrigation and the need of avoidingintersections. The economic issue raised is who should bear the full costs, the farmers or the private water associations.

The costs of adapting irrigation systems of using reclaimed effluent are not negligible, including upgrading sewage treatment plants; pumping and transporting the water to the farms so that it is not mixed with drinking water; and storing the water from winter to summer. Therefore, the cost of upgrading the Og and Tirza plant in order to improve the treatment of the current effluents quality, that it would be suitable for irrigating different crops, and the cost of the pipelines network to flow the reclaimed effluents to the fields, should be economically efficient, in order to motivate the investment of theprivate water associations.

The **agronomic** difficulties are concerned with the high concentration of pollutants in reclaimed wastewater, high levels of salinity and excess boron, damaging soils and crop growth. Salinity accumulation in the soil increases the use of freshwater by the farmers in order to rinse the soil before plantation.

High levels of salinity led also to **environmental** costs, especially reclaimed wastewater leaching from irrigated agriculture leading to growing salinity of aquifers and high concentration levels of nutrients. Pathogens, micro-organisms and different chemicals (from industrial sewage) in reclaimed wastewater can be passed throw the soil into plant root systems and contaminate crops, and leaching into aquifers used for drinking water eventually causing **human** health hazards.

5.2. Problem formulation – Criteria and Alternative

In order to construct an comprehensive and integrated water resources management supply plan for the LJRV, it is important to identify all the water resources, their potential and the locations for utilization, the customers and their needs (drinking, agriculture), the agricultural planning (types of crops, irrigation periods etc.).

5.2.1. Criteria definition

The main decision criteria to be evaluated are:

- Criteria 1: Aquifer Vulnerability - preserving water levels and its quality in order to minimize the impact on the fresh water resource (Aquifer sustainability).
- Criteria 2: Natural environment preservation
- Criteria 3: maximizing the economical profit (client's economical profit).
- Criteria 4: Reliability of water supply including minimizing the gap between water demand and supply especially on peak demands.

5.2.2. Alternatives definition

The farmers in the study area can integrate between four sources of water–freshwater, floodwater, saline water from the Jordan River and reclaimedwastewater:

Freshwaterpumped out of the wells from the regional mountain aquifer (Judea Group aquifer) by "Mekorot" Company, are inadequate during the demanding season. In addition, the water level drops from year to year due to intense pumping and causes saline water and stops the pumping. The total of 90 thousand CM is supplied per day.

Previous studies (Flexer et al., 2001; Flexer et al., 2002) show that by drilling **new wells** additional freshwater of approximately 25 MCM/year can be produced. This additional amount adds to the current water abstraction from Israeli and Palestinian wells of approximately 25 MCM/year. The water from the wells in the western and central parts can be supplied to Ramallah, Jerusalem, Bet Lehem area and Male Edumim, while the water in the eastern part can be supplied to the Lower Jordan Valley.

The other water source -"marginal water" is a mixure of different types andhas inferior waterquality (it is appropriate only to irrigate date palms): winter **floodwater** that flows from the Nablus region to the Tirza reservoir,saline water from the **Jordan River**, and**reclaimedwastewater** from Og and Kidron stream.

as a result of continued populationgrowth,the wastewater quantity is espected to increase. Therefore, addition of "**marginal water**" can beprovided from Tirza and Og reservoirs, in terms of maximizing the reservoir capacity.

saline water can be supplied to the study area from Feshaha and Kane-Smar **springs**, which are the outlet of the mountain aquifer. The total discharge is approximatlly 95 MCM per year and they are brackish to saline (600-6000 mg/lit Cl^-). Today, the water isn't used and flow to the Dead Sea and lost there(Hötzl et al., 2008). Usage of the springs water requires building a desalination plant and pipeline system.

The uses of different water resources that are accessible in this region and the water mixing between them are defined as alternatives as listed at Table 6.

Table 5: Alternatives

Alternative	Water Sources	Water Use
A1	Freshwater	Traditional and high precision agriculture
	marginal water	Palm Trees Irrigation
A2	Freshwater	Traditional and high precision agriculture
	marginal water	Palm Trees Irrigation
	Additional freshwater from new wells	Traditional and high precision agriculture
A3	Freshwater	Traditional and high precision agriculture
	marginal water	Palm Trees Irrigation
	Additionalmarginal water	Palm Trees Irrigation
A4	Freshwater	Traditional and high precision agriculture
	marginal water	Palm Trees Irrigation
	Spring saline water	Palm Trees Irrigation

In the prioritization process and the pair-wise comparison between the criterionssolely, relative weights for all elements of the criteria hierarchy were given. According to the criteria rating results, the criteria hierarchy is: C1>C4>C3>C2. These results indicate thataquifer vulnerability has the highest priority in order to preserve the only fresh water source in the study area. Criteria 1 isviewed as more important than the other criteria due to the highly significance of the mountian aquifer.

Table 6: The outcome comparison of water resources alternatives for all policy criteria

AHP - AHPSocioEco

File

Settings | Criteria Weighting | Judjement | Results

Calculation Method :

	Weight	A1	A2	A3	A4
C1	0.553	0.129	0.020	0.367	0.037
C2	0.120	0.030	0.007	0.079	0.004
C3	0.220	0.008	0.021	0.053	0.137
C4	0.107	0.003	0.008	0.071	0.025
	0.100	0.170	0.056	0.570	0.203

Prioritization process was held through comparison of all four alternatives for each criterion. The pair-wise comparison between all four alternatives of water resources enabled to give an overall priority for each alternative. The results are presented in the following table. The results (Table 7) show the overall alternative hierarchy: A3>A4>A1>A2. These results indicate that the alternative of maximizing the reservoirs capacity and adding marginal water to the LJRV water inventory has significantly higher preference than adding new wells or desalinatingthe brackish water from the springs. Reclaimed effluents is much more favorable than addional fresh water or spring water alternatives.

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http://www.jordanvalley.org.il

http://www.mop-bika.org.il

http://www.sviva.gov.il

http://www.water.gov.il

Appendix 1: Maximum Levels for Dissolved and Suspended Elements and Compounds and for Different Parameters in Effluents for Unrestricted Irrigation and Discharge to Rivers

Parameter	Units	Unrestricted Irrigation*	Rivers
Electric Conductivity	dS/m	1.4	
BOD	mg/l	10	10
TSS	mg/l	10	10
COD	mg/l	100	70
Ammonia	mg/l	20	1.5
Total nitrogen	mg/l	25	10
Total phosphorus	mg/l	5	1
Chloride	mg/l	250	400
Fluoride	mg/l	2	
Sodium	mg/l	150	200
Fecal coliforms	Unit per 100 ml	10	200
Dissolved oxygen	mg/l	<0.5	<3
pH	mg/l	6.5-8.5	7.0-8.5
Hydrocarbons	mg/l		1
Residual chlorine	mg/l	1	0.05
Anionic detergent	mg/l	2	0.5
Total oil	mg/l		1
SAR	(mmol/L)0.5	5	
Boron	mg/l	0.4	
Arsenic	mg/l	0.1	0.1
Barium	mg/l		50
Mercury	mg/l	0.002	0.0005
Chromium	mg/l	0.1	0.05
Nickel	mg/l	0.2	0.05
Selenium	mg/l	0.02	
Lead	mg/l	0.1	0.008
Cadmium	mg/l	0.01	0.005
Zinc	mg/l	2	0.2
Iron	mg/l	2	
Copper	mg/l	0.2	0.02
Manganese	mg/l	0.2	

Aluminum	mg/l	5	
Molybdenum	mg/l	0.01	
Vanadium	mg/l	0.1	
Beryllium	mg/l	0.1	
Cobalt	mg/l	0.05	
Lithium	mg/l	2.5	
Cyanide	mg/l	0.1	0.005

* From soil, flora, hydrological and public health considerations

Data source: http://www.sviva.gov.il

Appendix 2: irrigation water analysis guidelines

IRRIGATION WATER ANALYSIS GUIDELINES

DISCLAIMER: No warranty is made, expressed or implied, concerning crop performance as a result of following these guidelines.

TERMINOLOGY: part per million = ppm = mg/L = 1,000 ug/L = lb per million lb water. ppm x 2.72 = lbs/acre-foot of water. e.g. 10 ppm = 10 x 2.72 = 27.2 lb per acre-foot of water.
ppm or mg/L = milliequivalents per liter (meq/L) x EW of analyte < = less than > = greater than 325,851 gals per acre-foot of water.

POTENTIAL PROBLEM MAY BE...	SODIUM meq/L (sprinkler)	SODIUM meq/L (surface)	CALCIUM meq/L	MAGNESIUM meq/L	CARBONATE meq/L	BICARBONATE meq/L	CHLORIDE meq/L (sprinkler)	CHLORIDE meq/L (surface)	E.C. mmhos/cm or dS/m	pH	COPPER ppm (toxicity)	IRON ppm (clogging)	MAN-GANESE ppm (clogging)	ZINC ppm (toxicity)
SEVERE ★★★	?	>9	>8	>8	?	>8.5	?	>10	>3.0	>8.0	>0.2	>1.5	>1.5	>2.0
INCREASING ★★	>3	3-9	3-8	3-8	>0.1	1.5-8.5	>3	4-10	0.7-3.0	7.0-8.0		0.1-1.5	0.1-1.5	
LOW ★	<3	<3	<3	<3	<0.1	<1.5	<3	<4	<0.7	<7.0		<0.1	<0.1	
CONV. TO ppm	x 23.00	x 23.00	x 20.04	x 12.15	x 30.00	x 61.02	x 35.46	x 35.46	~x 640=TDS		x 1	x 1	x 1	x 1
COMMENTS AND ACTION	Avoid irrigating when hot and windy. Maximize rotation speed and droplet size.	Irrigate heavily prior to rainy season to facilitate leaching by better quality rain-water.	Require at least 1 meq/L to avoid restricted water infiltration. Clogging problems increase above a combined Ca+Mg level of 3 meq/L.	See comments below.	Levels found only above a pH of about 8.3 and related to high sodium.	1 meq/L equates to 200 lb of lime (83% neutralizing value) per ac-ft of water. Unsightly deposits may be left on crop.		1 meq/L = approx 100 lb Cl per ac-ft of water.	mmhos/cm divided by 1.15 = approx tons of "salt" per ac-ft of water.	High pH may reduce pesticide activity or increase precipitation.	*May become toxic if more than 0.2 ppm.	Not toxic in aerated soils, but may leave unsightly deposits.	*May become toxic if more than 0.2 ppm. Usually, only in acidic soils.	*May become toxic if more than 2.0 ppm Usually, only in acidic coarse-textured soils.
	Trees and vines are the most sensitive to salt burn.	Gypsum may be required beforehand.	Approx 250 lb of gypsum/ac-ft of water will raise Ca by 1 meq/L... depending on purity.	High Mg may result in an inverse Ca:Mg ratio, leading to poor water infiltration.		Acidify to pH 6.5 to decompose 50% of bicarbonates. Ask lab to do a titration with a selected acid.		Maintain close to field capacity.	If too low, see adj SAR. If too high, see Chloride.	Low pH may be corrosive below 4.5.				

* Assuming about 3 ac-ft of water is applied annually.

POTENTIAL PROBLEM MAY BE...	PHOSPHORUS ppm	POTASSIUM ppm	NITRATE ppm	SULFATE ppm	BORON ppm	TDS ppm	ADJ. SAR ratio	LANGELIER SAT INDEX
SEVERE ★★★	?	?	?	?	>8.0	>2000	>9.0	>2.0
INCREASING ★★	2 -10	10-50	45-150	100-1000	0.5-8.0	450-2000	6.0-9.0	0.2-2.0
LOW ★	<2	<10	<45	<100	<0.5	<450	<6.0	<0.2
CONVERSIONS	x 6.22 = lb P_2O_5 /ac-ft water	x 3.26 = lb K_2O /ac-ft water	x 0.61 = lb N /ac-ft water	x 0.90 = lb SO_4-S /ac-ft water	x 2.72 = lb B /ac-ft water	/ 640 = approx ECw of water	Adjusted for CO_3, HCO_3	An indication of alkalinity or corrosivity of water.
COMMENTS AND ACTION	Excessive P may lead to precipitation in high-Ca water. Restrict fertigation to <200 ppm P_2O_5 (~500 lb/ac-ft).	Excessive K may lead to soil surface sealing. Restrict to crop requirements.	Excessive NO_3 will contaminate ground water. Test wastewater also for TKN. Restrict to crop requirements.	Excessive SO_4 combined with Ca may lead to unsightly deposits on foliage and fruit. Sulfur burners may be used for both acidification and biocidal effect.	Excessive B tends to be crop-specific, but generally unsatisfactory for all crops if above 4 ppm and applied annually.	Maintain soils close to field capacity to minimize plant stress. 735 ppm = 1 ton of "salt" per ac-ft of water.	Soil permeability more of a problem with low salinity water.	plus value = potential problem of precipitation of $CaCO_3$, minus value = potential problem of corrosivity.

OTHER CLOGGING FACTORS IN DRIP IRRIGATION

	TSS mg/L	SULFIDE mg/L	BACTERIA maximum number per mL (CFU/mL)
SEVERE	>100	>2.0	>50,000 (5×10^4)
INCREASING	50-100	0.5-2.0	10,000-50,000 (1×10^4 - 5×10^4)
LOW	<50	<0.5	<10,000 (1×10^4)

Chlorination of irrigation water susceptible to clogging by the above may often provide sufficient maintenance. Ensure at least 1 ppm residual chlorine at the end of the line, and inject at each irrigation.
Where bacterial slimes are severe, a continuous injection of 5-10 ppm may be necessary. Certainly, 10-20 ppm for the last hour of the irrigation cycle. Repeat as necessary.

Acidifying water to pH 6.5 will both increase effect of chlorine and help dissociate high bicarbonates. Inject separately from chlorine and upstream of filter station. Seek further advice on all of the above.

SOME USEFUL CONVERSIONS

CHLORIDE: Approximately 75 lb chloride accompanies every 100 lb potash applied through potassium chloride, and 50 lb accompanies every 30 lb calcium with every 20 gallons of calcium chloride.

CHLORINE: Approximately 13 lb chloride accompanies every acre-foot of water treated with 10 ppm chlorine, due to traces of sodium chloride in sodium hypochlorite ("chlorine bleach").

1. Sodium Hypochlorite (chlorine bleach):

Chlorine injection rate/hr = <u>0.008 x desired ppm chlorine x flow rate</u> / % strength of sodium hypochlorite

e.g. 2 gallons per hour = <u>0.008 x desired 17.5 ppm chlorine x flow rate of 100 gph</u> / 5.25% chlorine

2. Calcium Hypochlorite (12.8 lb/100 gal water = 1% chlorine solution):

e.g. 10.5 gallons per hour = <u>0.008 x desired 17.5 ppm chlorine x flow rate of 100 gph</u> / 1.00% chlorine

3. Chlorine gas, although less expensive, is hazardous to apply. Illegal in some areas.

e.g. 21 lb chlorine gas per day = 0.012 x 17.5 ppm chlorine x flow rate of 100 gph

Other methods of water treatment include sulfur burners, ozone and a variety of other products. Seek further advice.

05/02

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