ISRAEL

Yehuda SHEVAH*
TAHAL Consulting Eng. Ltd., Tel-Aviv, Israel, E-mail : tahalcmp@netvision.net.il

1. Physiography

Israel lies on the eastern shore of the Mediterranean Sea between latitudes 29o 20'N and 33o 15'N, and longitudes 34o 15'E and 35o 40 E. The country is about 420 km long form north to south, 19 km wide near Tel Aviv and 112 km wide near Beer-sheba. The north-western boundary follows the Mediterranean for a distance of 188 km; the country is bordered by Egypt in the south-west, by Jordan and Syria in the east, and by Lebanon in the north. To the extreme south lies the Gulf of Eilat, and in the south-east the boundary runs for 56 km along the middle of the Dead Sea. In the north-east the territory of Israel is bordered by the east banks of the upper course of the Jordan River and Lake Tiberias. The area of Israel is 20,770 km2.

The terrain of Israel shows considerable diversity is altitude within short distances, and the topography is largely determined by the Great Rift which extends from northern Syria across the Red Sea and southwards. The Jordan Valley (including lake Tiberias) forms part of this rift; the rift crosses the boundary of Israel in the north-eastern corner of the country at an elevation of 400 m above mean sea-level (M.S.L) and descends to 800 m below mean sea-level to form the bottom of the Dead Sea. The water surface level of the Dead Sea is at -400 m below mean sea-level; this is the lowest place on earth. South of the Dead Sea, the rift forms the Ha'arava Plain and further south it becomes the bed of the Gulf of Eilat in the Red Sea.

Topographical Zones

The land is divisible into three longitudinal strips running from north to south : the Costal Plain, the Hilly Zone, and the Rift Valley. The Coastal Plain lies between the Mediterranean and the Hilly Zone. Its width varies from 5 km at the Carmel promontory to 30 km at Ashkelon and further south, and is crossed by several small rivers and wadis, the more important of which are the Na'aman, the Qishon, and the Yarkon. The sand dunes along the shores have now largely been reclaimed. The Hilly Zones from north to south consist of the Galilee, the Shomron, the Yehuda and the Negev hills. The highest peak in Israel lies in the Galilee hills. The hill ranges are broken between the Galilee and the Shomron hills by the Jezreel Valley, which opens on to the Coastal Plain in the west and to the Jordan Valley in the east, forming a chain of the more e proximity to the sea or to the desert and also to a large extent on topographical features.

2. Climate

The average annual rainfall in the Coastal Plain varies from 600 mm in the north to 150 mm in the south.In the lower elevations of the Hilly Zone (150 m to 600 m above mean sea-level) the average annual rainfall varies from 700 mm in the north near Safad to 500 mm near Hebron and declines sharply towards the Negev. In the Rift Valley the rainfall varies from 600 mm in the Hula Plain to 30 mm at the southern end of the Dead Sea. Arid conditions prevail in the Negev and aridity increases from north to south and from west to east. The annual average rainfall in the Negev varies from 400 mm at Ashkelon (near the shore) to 200 mm at Beersheba, and 60 mm at Eilat. (see Figure 1, Rainfall contour map). The climatic conditions of Israel, especially the lack of rain during the long summer, make irrigation imperative for the development of intensive agriculture.

3. Population

Israel’s population increased from 0.87 million in 1948 to about 4.0 million in 1980 and 6.0 million in 1999. About 90% lives in urban areas and about 10% in rural areas. The population is concentrated to a considerable degree in and around the three cities of Jerusalem, Tel Aviv-Yaffo and Haifa. In 1999 about 70 per cent of the urban population (60 per cent of the total population) lived in the conurbation of these three centers.

Rural and farming Population. The rural population amounts to about 0.5 million of which the number of farming households is 25,000, or about 100,000. The rural population has decreased from about 28% in the fifties to the current 9%. The number of farming households was also reduced from about 75,000 in the sixties to the current 25,000. The farmers were replaced by hired labour, which contributes about 50,000 of the total employment in agriculture. 3.7 per cent, or approximately 75,000 persons, were engaged in agricultural activities in 1995.

Land Ownership. The major part of the land in Israel is owned by the State and the Jewish National Fund. The land is given on lease for 49 years to groups or individuals able and willing to cultivate it.

Farm Settlements. Most of the arable land is controlled by collective (Kibbutzim) and co-operative (Moshavei Ovdim) settlements, totalling about 25,000 farm units.. A small part of the agricultural land belongs to small private farmers who reside in rural villages. There are also a few larger commercial farms.

The Kibbutz is a collective settlement engaged in agriculture and often also in industry. The means of production belong to the collective which manages the agricultural production on the basis of large-scale mixed farming. Hired labour is usually not allowed. In return for their work, members are given housing, food, clothing, education and cultural and social services; the dining rooms and kitchens are communal. The Kibbutz is governed by the general assembly of all members, and varies in size from 60 to 1,000 members. The oldest Kibbutz, Degania, was founded in 1909. In 1996 there were about 302 Kibbutzim, combining about 9,500 farm units and a total population of about 115,000.

The Moshav-Ovdim is an agricultural settlement of small holders run on cooperative principles. The produce and the inputs for each single farm unit is sold and supplied trough the cooperative. The population ranges from 100 to 1,000. The first Moshav- Ovdim was Nahalal established in 1921. In 1996 the number of Moshavei- Ovdim was about 411, combining about 15,500 farm units and a total population of 140,000.

Size of Holdings. The holdings allotted to a farming unit in the collective and cooperative settlements vary in size according to the soil and climatic conditions. The average holding is 7 ha. The land holdings allotted to a farm unit, in a collective settlement, are integrated in a single large-scale farm. In the south region, the size of holding per unit is 4 to 5 ha of which 3 ha are irrigated. In the western Galilee-Kishon, 6 ha are allotted to a unit, and in the Hula Plain 3 to 4 ha.

The average annual turnover per unit is $100,000, ranging between $300,000 in the Arava Valley and about $80,000 in the Western Galille.

4. Land Resources

Out of the total area of Israel 2,077,000 ha, the land area is 2,032,000 ha. The basic land use statistics are :

Arable land	652,000 ha
Forest and Grazing land	240,000 ha
Other land*	1,140,000 ha

* Includes built up areas, sand dunes, nature reserves and desert pastures.

(Source: Ministry of Agriculture, Dept. of Soil Conservation and Drainage Israel).

The area actually irrigated in 1995 was 230,000 ha or approximately 35 per cent of the arable land.

Soils. The major soil types in the Coastal Plain are sand dune, Pleistocene sand and sandstone. The soils in the north of the country are alluvial loamy and clayey, and in the Northern Negev, light rendzina, coastal dunes sand, sandstone and sandy loam, calcareous soils with loess deposits, loess and rocky "hamada".

5. Water Resources

Water Potential. The total average annual precipitation is estimated at about 10,000 MCM of which 70-80 per cent evaporates, and 5 per cent flows down the dry river beds and the few perennial rivers to discharge into the Mediterranean in the west, or into the Jordan River and the Dead Sea in the east. Part of the remaining quantity that percolates into the ground is also lost due to underground drainage into the sea. The total average annual renewable potential amount to some 1,600 MCM, of which about 95% are already exploited and used for domestic consumption and irrigation. About 80% of the water potential lies in the northern parts and only 20% in the south, while most of the population and arable land are found in the central and southern regions, hence, large quantities of water have to be conveyed over 200 km to supply the water needs. Other sources include intermittent water runoff and reclaimed wastewater. The inventory of potential mean safe yields is shown in Table I .

Major sources of water:

Surface water - The Kinneret Basin. The Kinneret Basin which covers 2,730 km2 is situated in the north east of Israel. 70 per cent of the water reaching the Lake is the discharge of the Upper Jordan River; the remaining is the contribution of the tributaries flowing into the Kineret from the east and west sides. The Kineret has a surface area of about 170 sq.km and a total volume of 4,300 MCM. The Water level at the lake is regulated by the Deganya Gates maintaining an operational volume of 590 MCM, between -209 and - 213 m. Of the annual yield about 380 MCM on average are pumped out of the watershed, while the remaining is used by consumers within the watershed. The Kineret watershed contributes about 33% and water from the Kineret has to be lifted over 400 m from an elevation of -212 m below sea level.

Groundwater. Groundwater are available from two major aquifers: the Coastal Aquifer - a relatively shallow sand aquifer, lying along a deep limestone - Dolomite Aquifer, named Yarkon-Taninim Aquifer or the Mountain quifer.

The Mountain Aquifer main water body is a 150 km long between Taninim in the north and Beer Sheva in the south, underlying the Judea and the Summaria highlands. Natural outlets are the Yarkon and the Taninim springs with a possible outlet to the Mediterranean Sea. More than 300 deep boreholes are used to abstract about 340 MCM/year, including 40 MCM of brackish water, maintaining a water table level at +16.5 m. Artificial recharge using excess supply from the Kineret is practiced through single and dual purpose deep wells connected to the National Water Carrier.

The Coastal Aquifer. The aquifer extends over some 120 kms, along the Mediterranean cost from the Carmel in the North to Gaza Strip in the south, having a total area of aabout 1,800 sq.km. Rainfall, stormwater and return flow from irrigation. Also artificial recharge of storm water and excess supply from the NC is practiced through several spreadung basins and boreholes. The safe yield which is fully utilised is estimated at about 300 MCM/year. A certain level of sea water intrusion is allowed for optimal exploitation of the aquifer. The interface was stabilised at about 1500 m from the coast.

Being a sand aquifer with a large holding capacity, the aquifer is used for short and long term storage, allowing a normal supply in drought years. However, due to frequent droughts, the trend was for excess pumpage and depletion of reserves, endangering the sustainability and the long term functioning and conservation of the aquifer. To counter balance these trends, artificial recharge has been intensified and pumpage is carefully monitored, while consumers reliance on local supply has been reduced.

Other Aquifers. In addition to the two major aquifers, there are several smaller and localised aquifers in various parts of the country. The most significant is the Wester Galile Aquifer, having a safe yield of about 60 MCM/year.

Intercepted runoff and artificial recharge. Surface runoff is sporadic and infrequent and observed only for a few days in a good rainy year. Despite the low occurrence, several regional and local schemes were established. The schemes divert storm flows from the rivers into surface reservoirs from where they are pumped into the supply system, or spread on spreading grounds and left to percolate into the underground aquifer (mainly along the coastal plain). At present, approximately 40 MCM are intercepted out of a potential of 135 MCM/year of storm water.

The main intercepting installations operating today are Kefar Baruch, Dalya, Menashe, Shikma, Bsor and Arava river interception projects for surface detention and groundwater recharge. Other small schemes include more than a hundred of small runoff interception projects. The aggregate capacity of the small reservoirs is about 130 MCM which include treated effluents from local sewage treatment plants. Another major recharge scheme is the Dan Region Scheme in which secondary effluents of the Tel-Aviv Metropolitan are recharged into the local aquifer.

Reclaimed wastewater. The use of reclaimed and treated municipal wastewater is becoming an increasingly important source of water for agricultural and industrial purposes as the other conventional sources are far reaching a complete exploitation. It is estimated that by the end of the decade (2000) about 15 per cent of the total amount of water supplied will be in the from of reclaimed sewage effluents. Currently, about 220 MCM of effluents, treated to varying degrees, are already utilsed for irrigation, about 65% of the generated wastewater. This amount will increase to about 425 MCM in the year 2020.

Artificially-Induced Rainfall - Cloud Seeding. Cloud seeding has been practiced in Israel for last 30 years on a countrywide basis. Originally, seeding with the aid of silver iodide began with the use of ground incinerators. The process has been improved and special air-crafts are used for this purpose, including the use of brine as the seeding material. Controlled experiments that were conducted between 1960 and 1975 provided the scientific justification for the routine seeding since. The results point to a positive significant effect of seeding on increasing rainfall in a number of regions, especially in the Kinneret Basin. It is assumed that a significant increase of 10 - 15% in rainfall in the northern part of the country has been materialised. However, it is to be noted, that the limited clouds occurrence in drought years limit the benefits of cloud seeding when most needed.

Desalination. During the last decades several small and medium desalination plants have been installed, for desalination of brackish and sea water, mostly for domestic water supply in the Arava Valley and the Gulf of Eilat.

Reverse osmosis has been adopted as the leading technique for brackish and sea water desalination. The first sea water desalination plant, with a capacity of 10,000 cum/day was commissioned in 1997 and a much larger plant of 150,000 cum/day, the first of a series, is planned for the early years of the next millenium. Sea water desalination is expected to make a significant mark on the Israeli water balance by 2010.

Water Supply and Demand. Annual renewable water resources amount to about 1.7 billion cum, compared to an annual water demand of about 2000 MCM/year, of which about one half is used for agriculture and the remaining is used by the urban and industrial sectors. Currently, the urban sector consumes about 700 MCM and the annual increase is about 20 MCM per year, about 4 %. Israel population is projected to increase to about 8.5 million by the year 2020 and urban water consumption to about 1 billion cum, as shown in Table 1.

Total Water Production. Water production has increased by more than 70 per cent during the first decade, mainly due to the construction of the National Water Carrier. Water is supplied from all sources including: groundwater, storm water, treated effluents and desalinated water. Groundwater constitutes between 55-70 per cent of the total amount supplied according to climatic and hydrological conditions in each year.

All the Israeli settlements are served by public waterworks supplying an average of about 250 litres/capita /day. Similarly, about 95% of the return flow is collected and about 80% is adequately treated and in many cases (42%) reused for irrigation. Drinking water quality conforms with WHO standards and further improvements to meet prevailing E.U. and USA standards are planned.

Water Quality

Water quality is equally important to water scarcity and water quality degradation is a considerable issue in water management. The quality of supplied water in Israel varies from very low salinity water (10 mg/l of chlorides) of the Upper Jordan River, 200 mg/l of the Kineret and more than 1500 mg/l of groundwater sources in the south. Groundwater exploitation is controlled to prevent sea water intrusion to the Coastal Aquifer and movement of saline water bodies within the Karstic Limestone Aquifer.

However, despite the limits on water withdrawal, due to global warming and frequent droughts, the regime of the natural flows are decreasing while the influxes of pollutants, due to man made activity above the aquifers, are increasing, resulting in the increase in the mineral and other pollutants contents in groundwater.

Due to unbalanced exploitation against long-term safe yield level and return flow from irrigation, a subsequent increase in the salinity of the groundwater has occurred in many wells. Based on past trends, groundwater with chlorides contents of more than 250 mg/l was 16% in 1973, reaching about 20% in 1990 and is expected to increase to 25% within 10 years.

Crops sensitive to salinity, such as citrus and avocado are first to be affected and various measures are being adopted including :

- Change of cropping patterns and irrigation and fertiliser control
- Introduction of salt tolerance rootstocks, replacing salinity sensitive crops
- Advanced dilution systems in multiple and single distribution networks

The National Water Carrier. To overcome regional imbalances in water availability, most of the country's fresh water resources were inter-connected into the National Water Carrier. The Carrier, the backbone of the national system conveys an annual amount of about 1,100 MCM, of which 400 MCM from the Kineret. The Carrier connects regional surface and groundwater sources to bridge spatial and temporal gaps between supply and demand, over 180 km from north to south. The system is characterised by heavy investments in pumping, pipes and treatment plants An integrated network of pumping stations, reservoirs, canals and pipelines is used to supply water under pressure for all the domestic, industrial and irrigation consumers.

Conjunctive use, scarcity and water use efficiency. To maintain a balanced supply, a mix of water from the various resources is supplied in order to avoid over exploitation of relatively cheap resources. During the winter months, excess supply is used for artificial recharge of the aquifers, recharge of ground water depressions, and
establishment of hydraulic barriers.

Demand Management. The traditional management of the supply or the "top-down" approach is being replaced by Demand Management, in which a greater public participation is introduced right from the planning stage, followed by implementation and operation. Functions previously performed by the government are also transferred to the private sector. Economic, financial and ability to pay issues are included as part of the technical solutions, to institutionalise sustainable use of water.

Water Quality Protection. Best technology and best practices are being applied to protect and minimise the pollution of water resources. Water conservation maps, restricting land use activities above groundwater resources, were produced to protect the underlying resources. Regular monitoring of water resources, including: replenishment and recharge, water table levels, abstraction, salinity (chlorides) and pollution (nitrates) data are regularly monitored and reported. The data provide an effective tool to influence the planning, the development process and permissible emission of pollutants to the environment.

Water Conservation. Public water conservation campaigns coupled with technical and economic measures are being applied to reduce consumption and to increase awareness to the water scarcity conditions. Water saving measures include :

- Controlled exploitation, spatial distribution of new boreholes, replacing old boreholes
- Water metering is compulsory for all type of consumption and consumers
- Abstraction licensing is on a yearly basis and the annual and peak month abstraction rights are adjusted to water resources replenishment
- A three block rate pricing system and a penalty for exceeding allocation rights are applied
- Use of on-farm advanced micro-irrigation systems
- Household pressure reducer devices, pull handle taps and cisterns with double quantity dispensers
- Regular operation and maintenance of all networks, at the regional and state levels
- Public awareness and media campaigns

Financial, Institutional and Management Programme. The Government through the relevant ministries provides grants and low interest loans for the improvement and expansion of water supply and wastewater treatment plants. Local governments and NGOs such as the Nature Protection societies, Green Peace and other are also strongly active in water resources conservation and related aspects.

Investment capital is channelled through :

- Water Networks Rehabilitation Fund
- National Sewerage Programme
- Irrigation systems Improvement Fund
- Wastewater Renovation and reuse Programme.

6. Brief History of Irrigation and Drainage

With the turn of the century, the early settlers in the Coastal Plain introduced oil-plunger pumps of 20 m3 per hour capacity sufficient to irrigate 2-3 ha. By the World War I, the first pumping plant of 300 m3/hour was installed on the Yarkon River. Later, electric pumps and new methods of boring, pipe laying and reservoir construction, were introduced by Mekorot - the National Water Company which was founded in 1937, in its first regional irrigation scheme in the Jezreel Valley. The new technologies allowed the expansion of the irrigated area to about 28,000 ha, in 1948, the establishment of the State of Israel (May 1948). By then, water development has reached 350 MCM/year.

The first "Master Plan for Irrigation in Israel" was drafted in 1950 and approved by a Board of Consultants (of the U.S.A) on March 8, 1956. The main features of the Master Plan were the construction of the National Water Carrier (NWC), and the integration of all major regional projects into a national grid. Tahal - Water Planning for Israel Ltd., a public corporate body, was established in 1952, being largely responsible for planning of water development, drainage, etc., at the national level, including the National Water Carrier (NWC) which was commissioned in 1965. Subsequent development have been mainly aimed at enlarging the main distribution systems, runoff interception, reclamation of wastewater, and increasing the operational efficiency of water distribution networks. Over the year, the irrigated area has increased from 28,000 ha in 1948 to some 220,000 ha today.

Israel Water Law. In 1959, a comprehensive water law was passed making water resources a public property and regulating water resources exploitation, allocation and prevention of pollution and water conservation. Under the law all available water resources are under public domain and made available for use by the consumers as directed by the water Commissioner. The Water Commissioner is the sole statutory body responsible for executing the State's water policy, regarding exploitation, allocation and conservation of water.

Water Allocation. Water is allocated by the Water Commissioner, empowered by the water Law 1959. The Water Commissioner is responsible for safeguarding water quantity and quality, issuing abstraction license and allocations to consumers.

Agricultural Production. Israel's agricultural sector is characterised by an intensive production systems, stemming from the need to overcome the scarcity of natural resources, particularly water and arable land. Despite a continuous decrease in the number of farmers, agriculture still plays a significant role in the national economy, contributing, in 1996, about 1.9 % of the GDP, 7% of exports and 3.1 % of the total work force (66,500). Agriculture is particularly important for the outlying areas where agriculture provides the sole means of livelihood for the population.

Israel produces 92 % of its own requirements, supplemented by imports of grains, oil seeds, meat, coffee and sugar. The monetary value of the import is offset by the large export of a wide range of agricultural products. Agricultural export amount to US $ 1.42 billion (7% of the total export), of which about $808 million (57 %) is the export of fresh produce and about $610 million is processed food.

The production of agricultural inputs stands at over $2 billion, of which 70% is exported.

Major characteristics of the Israeli agriculture (1996) are shown in the following :

Total Population (000)	Of which Rural Population (000)	Employment in agriculture (000)	Total Cultivated Area (000ha)	Of which Irrigated Area (000 ha)	Irrigation Water Use (MCM/yr)
5,759	513	66.5	342	183	1297

Improved production systems have led to almost self sufficiency in food supply (92%) in monetary terms, while reducing the number of producers to 1:90 in 1996, as compared to 1:17 in 1950s.

Current production is faced with the following challenges :

- transition and shifting of agriculture production to the arid south
- substitution of fresh water for brackish and wastewater effluents for irrigation
- adaptation to open markets and free competitive trade, requiring further R&D to strengthen the Israeli advantages and identify new ones.
- development of water and salinity tolerant crops and further diversification
- expansion of IPM
- environmental protection\recycling of agricultural waste
- protection of intellectual and property rights

Further development of the agricultural sector derives from the need to adjust to new trends in the world trade agreements GATT and the outcome of the peace process, in terms of development of new and improved products, allowing competition in the local and external markets. Market forces at home and abroad, and a scarcity of land, labour and water are forcing major changes. Increasingly, there is a shift from extensively farmed mass produced crops to intensive growing of products based on advanced technology, like hybrid tomatoes or genetically engineered banana tree saplings. To enable the growth of crops under a wide range of climatic conditions, advanced growing methods are used including ultra-low flow rate emitters and greenhouses with climatic control systems and soil-less culture.

7. Irrigation and Drainage Technology

Irrigation Water Use

The agricultural sector consumes about 1200 MCM/year (65%) and this amount will not changed, although the amount of fresh water will be drastically reduced, as shown below:

Year	**Fresh Water**	**Tertiary Effluents**	**Secondary Effluents**	**Brackish Water**	**Total**
1995	910	100	120	100	1230
2020	600	180	400	100	1280

This quantity has not changed significantly over the last 20 years, despite the significant increase in agricultural production. Agricultural output has increased over a period of 30 years almost five folds with hardly any increase in the amount of water used (Table 5).

Irrigation and Drought Management. The National Carrier met in a single system, the requirements of the domestic, industrial and agricultural sectors. In a drought years, the requirements of the urban sector are met to a certain extent, while the supply for irrigation is drastically reduced and legal and compensation measures are employed to ensure the water cut throughout, including self-supplied consumers.

Due to population growth and the associated water demand, the supply of the agricultural sector from fresh water resources has been decreasing from about 77% in the sixties, to about 60% at present. The reduced allocation is substituted with non - potable resources, including brackish and reclaimed sewage effluents.

The importance of treated effluents for irrigation is markedly emphasised in drought years, when fresh water supply is drastically reduced to the farmers and available effluents became a major and a stable source of water for irrigation, enabling the authorities to implement flexible allocation system.

Irrigation and Drainage Methods. Pressure irrigation systems have been generally adopted leading to the development of a wide range of irrigation systems. Sprinkler irrigation is still used to a lesser extent for the irrigation of crops which require irrigation of the entire area.

Micro-irrigation. Drip Irrigation. Line drippers, regulated fixed drippers and integrated drippers pre-cast onto the wall of the irrigation lines were developed, delivering between 1 litre and less to 20 litres per hour. Also low flow emitters that deliver 200 cc per hour and a uniform spread of moisture through the soilless media were also developed together with irrigation drippers suitable for use with effluents.

The drippers allow regulated water distribution and are clog resistant. Filter traps installed along the drip line sweep away any dirt and suspended particles, preventing the blockage of the dripper outlet. Also herbicides and air injection systems are used to sprouting around the drippers and suction of external dirt into the drippers are used to protect buried irrigation systems. Spray irrigation systems suitable for orchards and delivering 30 to 300 litres per hour, reaching an efficiency of 85% were developed

Ultra-Low-Rate Micro-Irrigation (ULR). This novel irrigation methods apply water at rates lower than 1 mm/hr, using micro-spitters or drippers, activated by an intermediary pulsator. The device transform a steady, low-rate water supply into minute and frequent timed short-duration surges. Functioning as a heart pump, the pulsator delivers to the attached emitter 0.5 ml of water per pulse. The pulsator also serves as a non-leakage device, keeping the system full of water between irrigations.

Drip ULR irrigation rates are as low as 0.15 - 0.4 litre/hr, compared to 2 - 10 litre/hr. A 2 litre/hr. mother dripper can supply 4 - 8 secondary drippers with of 0.5 - 0.25 litre/hr. ULR irrigation can also be achieved by short irrigation pulses with relatively long intervals in between. Intermittent controlled discharge of a 4 litre/hr dripper can discharge at a rate of 0.16 litre/hr, when activated for one minute every 25 minutes.

Using ULR irrigation, a breakthrough was achieved in the irrigation of ornamental plants grown in containers, providing uniform wetting of the growth medium and reduced drainage water and production cost. This method has great potential, especially in super-intensive production on detached growth media, offering better water and fertilizer application control, while lowering drainage flow.

Fertigation. Approximately, 80% of the irrigated land uses the fertigation method, combining irrigation and fertilisation

Irrigation Water control

Computers and Automation. Computers were introduced to allow real-time operation of the irrigation systems. The use of computers improves the performance of operation and monitoring through pre-programming of the irrigation quantity and interval and continued operation throughout, providing precision, reliability and savings in manpower. Recently, satellite linked valve control was implemented to to control distant water systems. The same controller relays back operational data to the control center.

Moisture Sensors. Soil and plant moisture sensors are also used to provide information on moisture, allowing automatic operation of the system when needed.

Irrigation Efficiency. Due to scarce water resources, there has been continuous endeavour to improve irrigation efficiencies and reduce unit application of water by improving the efficiency of irrigation methods and using advanced techniques for system management. The wide scale adoption of low volume irrigation systems (e.g., drip, micro-sprinklers) and automation has increased the average efficiency to 90% as compared to 64% for furrow irrigation. Other factors include:

- water metering

- water pricing policy,
- change to high value crops
- computerisation and remote control of irrigation
- expansion of greenhouse production
- fertigation - fertiliser application via the irrigation systems

As a result, the average requirement of water per unit of land area has decreased form 8,700 m3/ha in 1975 to 5,500 m3/ha in 1995. At the same time agricultural output has increased twelve fold, while total water consumption by the sector has remained almost constant.

Despite the marked achievements, irrigated agriculture still consume smore than 60% of available water resources, while contributing only 5 % of the GDP. Irrigated agriculture must therefore compete for water with other sectors of the economy use less than seven percent of the available resources.

Pricing of water for irrigation

Water Cost. The Israeli water system is characterised by heavy investments in water elevation, large conveyance systems and treatment plants. The average water cost indicated by the National Water Co. - Mekorot which supply about 60% of the total consumption. is US C 31/cum. The cost includes: capital costs (41%), fixed costs (26%) and variable costs (33%). The marginal cost of water supplied to distant and elevated areas are much higher.

The Cost Plus method used by Mekorot to calculate water cost was replaced in 1994 with a business oriented method in which the fixed cost (capital and labour) and variable costs (energy and materials) were defined and a 2.5% efficiency factor was imposed on Company's performance. A substantial increase in water prices coupled with improved performance (saving in energy cost and other variable and fixed costs) have resulted in a significant reduction in Government subsidy from 40 to 20% over the last four years. Current tariffs have totally eliminated the subsidy for water supplied to the urban and industrial sectors and in fact a slight cross subsidy is apparent.

Water tariff. Water tariffs and water allocation are based on a quantitative allocation to groups of consumers, namely: towns, local councils, and water users associations. water prices for the various consumers are fixed by a parliamentary committee based on recommendation made by the Ministry of Finance and the Water Commission. Recently, an Increasing Block Rate Prices system is applied for payment for the first 50, 80 and 100% of the allocation, leading to 10 - 15 % savings in water used for irrigation. Different block rates are fixed by the various authorities and differ in the various zones, as shown in Table 8.

A discount of 10 to 40% is applied on the ongoing rates for brackish water with chlorides content ranging between 600 and 1500 mg/l and above, while a penalty is levied on consumers exceeding their allocation. A single tier level is imposed on all crops, although this could distort farm level cropping pattern decisions in favour of crops with relatively low water requirements, but sensible when the ultimate goal is water conservation. The current charges are still subsidised and the average tariff for irrigation covers only 82% of the average cost. The current tariffs are however on an increasing scale, as shown in Table 9.

Drainage and flood control. Until the late 1930's there were many malaria bearing swamps and marshes in the northern and central plains of the country and large areas were inundated by flood waters in the winter. In the 1920's and 1930's much effort was invested by the early settlers to drain these swamps, control malaria and redeem land for agricultural use. These efforts which were carried out in the Jezreel, Zevulun Beth Shean and Emek Hefer plains, the Carmel Coast area, and the Hula plain, restored agricultural lands that were the basis for the many settlements established during that period.

The early work was followed by large scale regional operations, enabling control of whole river courses or drainage basins. The emphasis in these drainage works has been on :

(a) Improvement of poorly drained soils
(b) Flood protection

(c) Diversion of runoff water from agricultural lands
(d) Swamp drainage
(e) Concentration of the runoff from local or regional drainage works and their integration into the water supply network.

8. STATISTICS RELATED TO IRRIGATION AND DRAINAGE

A. **Water Balance.**

Table A1 : Water Supply and Demand – Israel 1997-2020 in MCM/year

Supply							
Year	Population (Million)	Water Sources					
		Surface Water	GW	Brackish	Treated Effluents	Desalinat.	Total
1997	5.8	600	1020	125	275	10	2030
2010	7.4	645	1050	165	470	100	2430
2020	8.6	660	1075	180	565	200	2680

Demand						
Year	Urban Sector	Agriculture				Total
		Natural	Brackish	Effluents	Total	
1997	772	880	103	275	1258	1960
2005	980	750	95	380	1250	2220
2010	1060	680		470	1260	2430
2020	1330	600	60	565	1350	2680

Source: Israel Water Commission, 1998

Table A2: National Wastewater Reclamation and Reuse Plan

Year	Population (Million)	Reclamation and Reuse		Sub-Total	Not Reclaimed	Total
		Unrestricted Use	Restricted Use			
1997	5.6	110	160	275	145	420
2025	8.5	200	365	565	135	700

Table A3. Irrigation Water Allocation in drought years (in MCM)

Sources	Average Year	Drought Year	Planned Quantities
Freshwater	860	450	630
Saline & Brackish Water	170	150	200
TWW (Cat. A)	120	120	220
TWW (Cat. B)	100	100	200
Total	1270	820	1250

Cat A – Tertiary treated for non restricted use. Cat B – Secondary treated for restricted use.

B. Irrigation and Agricultural Production

Table B1: Cultivated Area, Major Crops and Irrigation Water Use, Israel 1996's

Major Crops	Cultivated Area (ha 000)		Irrigation Water Use MCM		
	Dry Land	Irrigated Land	Fresh Water	Marginal Sources	Total
Tree Plantation	13	70	490	70	560
Field Crops	141	30	100	110	210
Cotton	---	35	75	95	170
Vegetables	5	45	165	25	190
Fish Ponds	---	3	30	70	100
Fallow	68				
TOTAL	227	183	880	378	1,258

Table B2. Irrigation water demand and Agricultural productivity Index: 1975 -1995 and projection for 2025

Year	Cultivated land (000 ha)	Irrigated land (000 ha)	Irrigation Water (MCM)	Application Rate (cum/ha)	Productivity Index (% of 1986)
1948	222	40			
1956		105			
1959	401				
1966	407	155			
1975	420	184	1325	8700	55
1980	425	203	1210	7560	72
1985		238	1435	7150	95
1990		236	1215	5850	139
1995		235	1210	5500	196
2025					

Source: Ministry of Agriculture, 1997

Figure Table B3: Agricultural sector contribution to the national economy

Year	% of the GDP	% of Employment	% of Export (fresh produce)	% of Production for local Consumption
1952	11.5	17.6	31	56
1962	11	16	23	54
1970	6.3	8.8	17	54
1980	6.1	6.7	12	34
1990	3.4	4.6	5	34
1996	1.9	3.1	4	35
2025				

Source : Ministry of Agriculture, 1997

C. Water Cost and Water Charges

Table C1: Water cost and water tariff for irrigation supplied by Mekorot 1986 - 1997

Year	Cost	Tariff	
	(US C/cum)	(US C/cum)	(% of Cost)
1986	14.3	10	70
1993	36.4	16.1	44
1994	34.4	17.1	50
1995	32.8	19.0	58
1996	30.5	21.1	69
1997	28.2	23.2	82

Source : Mekorot Water Co. Financial Statements, various years.

Table C2. Block Rate Prices for irrigation water supplied by Mekorot, 1995

Water Source	Part of Allocation (%)	Price (US C/cum)
Fresh Water	1 - 50	15
	50 - 80	18
	80 - 100	21
	Average Price	19
Tertiary Effluents	Low Season	14
	High Season	15
Secondary Effluents	Average Price	12

Source : Israel Water Commission, 1996

Table C3: Mekorot water cost and government subsidy 1994 - 1997

Year	Average Water Cost (US C/cum)	Government Support (%)
1993	36.4	40
1994	34.4	35
1995	32.8	26
1996	30.5	23
1997		19

Source : Mekorot Financial Statements, various years.