Chapter 8
Israel

Doron Lavee, Eran Feitelson, and Hadas Joseph-Ezra

Abstract Israel has succeeded in advancing irrigated agriculture on a wide scale on arid and semiarid lands, with an intensive use of technology and capital, and a firm state-led irrigation policy. This chapter describes the evolution of the Israeli irrigation sector since the British Mandate period, distinguishing four distinct eras linked to contrasting political and technological frameworks. It also explores the changes in the institutional framework of the irrigation sector (from the local community level to the state structure). The chapter underscores the critical role of technology in Israeli irrigation, most particularly in the development of micro-irrigation and monitoring systems, and the shift towards desalination and wastewater use for irrigation. Finally, it identifies the major challenges to be overcome, considering water quantity and quality problems, and the impact of climate change, possibly compounded by tensions with neighboring countries.

Keywords Water scarcity · Water policy · Intensive farming · Wastewater recycling · Desalination

8.1 Introduction

8.1.1 Geography, Climate, and Water Resources

Israel is a small country, located at the junction of Europe, Africa, and Asia on the southeastern coastline of the Mediterranean Sea and the northern tip of the Gulf of Eilat/Aqaba. With an area of approximately 20,770 km^2 that includes 445 km^2 of

---

D. Lavee (✉)
Faculty of Social Sciences and Humanities, Tell-Hai College, Qiryat Shemona, Israel
e-mail: doronl@telhai.ac.il

E. Feitelson
Hebrew University of Jerusalem, Jerusalem, Israel

H. Joseph-Ezra
Pareto Group, Natanya, Israel

F. Molle et al. (eds.), *Irrigation in the Mediterranean*, Global Issues in Water Policy 22, https://doi.org/10.1007/978-3-030-03698-0_8

inland water (U.S. Library of Congress 1988),[1] Israel is divided into four main geographical regions: the coastal plain, the central hills, the Jordan Rift Valley, and the Negev Desert. The Jordan River,[2] which terminates in the Dead Sea, flows along the northern part of the Rift Valley. The Sea of Galilee, which is the only lake in the region, serves as Israel's main reservoir. The arid south of Israel is the Negev Desert, covering more than half of the country's total land area.

Israel has two major seasons, summer and winter, with short transition periods. Rainfall occurs during the winter season alone. The difference between the major climatic regions in Israel is very prominent. The northern and coastal regions of Israel are characterized by a Mediterranean climate, with cool, rainy winters (400–1200 mm rain per year) and hot, dry summers, whereas the Negev and Judean deserts are characterized by an arid climate, with very little rainfall (less than 200 mm per year). Between these two areas there is a narrow strip of a hot, dry climate (200–400 mm per year) (Fine et al. 2007).

According to estimates, the total replenishment amounts to 1.9–2 billion m^3 (Kislev 2011; Feitelson et al. 2011). Until the advent of large-scale seawater desalination in 2005, this constituted the total available water supply to households, agriculture, and industry for both Israel and the Palestinians.

Water scarcity is a major concern in Israel. High population growth and rapid economic development, as well as obligations made in water agreements with Jordan and the Palestinians, have placed growing demand on Israel's scant water resources (OECD 2011). Irrigation is essential for intensive farming throughout the year, even in the areas with relatively high rainfall, due to the long and dry summer. Furthermore, the existing inventory of fresh water in Israel cannot satisfy all of the domestic, industrial, and agricultural needs.

The country's water planning, policies, and management are highly challenged by climatic fluctuations and the resulting uncertainty regarding water availability, due to multi-year droughts (Amiran 1994). The main role of the water sector is thus to store water from winter to summer and from rainy years to drought years, utilizing the aquifers (Gvirtzman 2002). Over 40% of the agricultural lands are located in the semi-arid northern Negev, while the highest rainfall occurs in the north. The large-scale water conveyance scheme (the National Water Carrier – NWC) completed in 1964 and extended in 1969 as part of Israel's nation-building effort, allows water to be conveyed from the Sea of Galilee in the north to the densely populated center, and further to the south – where modern agriculture cannot exist without irrigation (Fig. 8.1). Since the late 1980s, Israel has experienced several multi-year droughts, during which water consumption exceeded the natural rate of replenishment. Due to the unsustainable utilization of groundwater, aquifers are threatened with substantial pollution and salinization problems, particularly in the coastal aquifer which has been over-pumped since the 1950s (Furman and Abbo 2013).

---

[1] In discussing Israel in this chapter, we refer only to the area within the pre-1967 Armistice Line and the Golan Heights. We do not discuss the West Bank and Gaza, though we refer to the water relations between the West Bank and Israel wherever necessary to understand the Israeli water situation.

[2] The Jordan River has five riparians: Israel, Lebanon, Jordan, Syria and the Palestinian Authority.

Fig. 8.1 Israel's main freshwater supply resources and National Water Carrier (NWC)

Nonetheless, Israel has succeeded in advancing agriculture on a wide scale also on its dry lands. This was made possible by damming the outlet of the Sea of Galilee,[3] the construction of the NWC, water conservation, crop substitution, and Israel's national water policy. In particular, water supply has been expanded through wide-scale wastewater recycling, making it a world leader in such recycling, and more recently also in large-scale seawater desalination.

Today, Israel's main natural freshwater supply resources are the Sea of Galilee, parts of the Mountain Aquifers, the Coastal Aquifer, and a number of smaller aquifers (50%) (Fig. 8.1). Additional sources of water include treated wastewater, which is largely used for irrigation in the agricultural sector (20%), desalinated seawater (24%), and brackish water (mainly from several small brackish-water aquifers).

8.1.2 Agriculture in Israel: Past and Present

Agriculture occupied a prominent place in the Zionist enterprise and in the early years of the state. During the late Ottoman and early British Mandate period, farming was seen as central to the (re)connection of Jews with the land of Israel, as part of the nation-building efforts. Yet the nature of the Jewish rural settlements changed. While in the initial period, during the late nineteenth century, settlements were mostly on privately owned land, during the British Mandate era (between the two world wars), settlements were mostly cooperative on public land. These collectives were either Kibbutzim (fully collectivized) or Moshavim (where production and consumption are private, but distribution and financing are collective). To provide a "decent" level of living, the settlements were largely based on irrigated agriculture, thereby making water resource development an integral part of the settlement efforts.

Following the Peel Commission[4] of 1936, which suggested a two-state solution in Palestine where the borders between the states would be delineated on the basis of the (largely rural) settlement areas, geo-political factors came to dominate the Zionist rural settlement efforts (Reichman 1979). These continued to be central to rural development in the early state period (Reichman 1990). However, at this time, food security and the settlement of the massive immigration wave that flowed into the country[5] became major factors in agricultural development due to severe food shortages (which led to food-rationing) and the desire to absorb

---

[3] The outlet of the Sea of Galilee, also called Lake Kinneret or Lake Tiberias, was dammed as a side-product of the hydroelectricity project at the confluence of the Jordan and Yarmouk rivers, built in 1931.

[4] The Peel Commission was a Royal Commission of Inquiry established by the UK Government to investigate the causes of unrest in Palestine under the British mandate, following the 6-month-long Arab general strike and to recommend future measure.

[5] Over 700,000 immigrants arrived between 1949 and 1952, severely stressing the country's meagre resources in the early Fifties (Hacohen 1994).

the new immigrants into the economy as quickly as possible (Hacohen 1994). Hence, large-scale water projects were seen as central to nation-building, securing the borders, providing food security, and immigration absorption, thereby making them highly visible in the public agenda, and a priority in development budgets (Feitelson 2013). To advance these goals, irrigation was heavily subsidized. Not only did farmers not pay the capital cost of water supply, they enjoyed subsidized water rates that were much lower than those paid by the urban and industrial sectors.

Since the early 1960s, the relative share of agriculture to the country's economy has declined, due to rapid industrialization followed by a shift to a high-tech and service economy in the late twentieth century. Moreover, farming shifted away from food self-sufficiency goals toward an export-oriented agriculture, not least due to the realization that Israel's water resources could not meet the needs of food self-sufficiency, meaning food supply must be based on imports.[6] Today, agriculture contributes only about 1% of the country's GDP (Central Bureau of Statistics 2016), though it also serves as a beta-site for the agricultural technology industry. Still, until recently, agriculture continued to enjoy lower freshwater rates due to the power of the agricultural lobby in the Knesset (Israel's parliament).

As a result of the economic shifts, the loss of protective tariffs, the elimination of protective practices, and the gradual increase in water rates, there has been a decline in the number of self-employed farmers in Israel. Currently, agriculture is moving towards economies of scale, whereby fewer farmers operate larger farms. The decline in the relative importance of agriculture for the national economy and in the share of agriculture in the workforce has political ramifications, as the power of the agricultural lobby in the Knesset has gradually declined. In recent elections, only a scant number of Knesset members hailed from the rural sector (which was traditionally heavily over-represented).

As a result of the decline in the power of the agricultural lobby, the shift in geopolitical concerns,[7] and the rise of neo-liberal ideologies, the state's support for agriculture has diminished in the last three decades. The previously highly regulated agricultural production, whereby quotas were set for each crop to each farmer, has been largely de-regulated. Water rates have risen gradually and agricultural water subsidies for fresh water have decreased. Whereas farmland protection was a central tenet of land-use regulations, open space considerations, infrastructure, and urban development are now the main factors in planning decisions. Thus, agriculture is largely viewed today as a secondary economic sector, with diminishing political and symbolic capital.

Water is a fundamental factor in agricultural production and constitutes 11% of the average farmer's costs[8] (in the year 2016). Therefore, the change in water pricing is a key element of the change in farmers' decisions, as can be seen in the next paragraphs.

---

[6] From a water perspective this shift implies that Israel increasingly imports 'virtual water', the water embedded in food, thereby alleviating much of its water scarcity (Gilmont 2014).

[7] Following the rise of the Likud to power in 1977, the geo-political concerns shifted to the Occupied West Bank, where most Jewish settlements are not based on agriculture.

[8] www.cbs.gov.il/shnaton68/diag/19_05.pdf

8.2 Historical Development of Irrigation in Israel

Israeli water history can be seen as consisting of four eras (Feitelson 2013) preceded by a pre-state era. The historical development of irrigation can be related to these four eras.

Prior to the establishment of the state, irrigation was largely based on local sources, either surface water (mainly springs) or wells, managed at the village level. Until the 1930s, the wells utilized only shallow aquifers, as the main technology available, the Antilia (animal-driven water wheel), restricted pumping to a depth of 10 m (Avitsur 1991). Surface and shallow well water rights were local.

The latter part of the British Mandate period and the first state period – termed by Feitelson (2013) the hydraulic imperative era – were characterized by the expansion of water conveyance and irrigation systems, from the local to the national level, as part of the nation-building and agricultural development efforts of the time (Feitelson and Fischhendler 2009), as well as by the utilization of deeper aquifers. In the late 1930s, irrigation schemes were planned and built at the regional level, mainly in the northern part of the country, where water was available within the region (Feitelson et al. 2014). Such schemes were built in the Yizrael valley and later in the northern Negev, as part of the pre-state Zionist settlement efforts (Reichman 1979; Seltzer 2010). The Kishon project, supplying the western Yizrael valley, was the first large-scale project built by Mekorot, the national water company of Israel, thereby providing it with the expertise that was later to serve it in its struggle to become the national water company it is today (Seltzer 2010). This was enabled by deeper drilling to groundwater, thereby producing "new" water and circumventing the existing water rights system.

Similar schemes were carried out after the establishment of the state, perhaps most notably in the Beit Shean region (Nir 1989). These were driven in part by geopolitical concerns – particularly the fear that Israel might be forced back to the 1947 UN resolution lines (Reichman 1990). The Beit Shean project, as well as others of its kind, was facilitated by the annulment of local water rights after 1948, a move that was finally formalized in the 1959 Water Law, which nationalized all the water (surface, groundwater, and effluents). This law reflected a shift in attitude toward water resources, from a discourse of plenty to be discovered and utilized, to one of scarcity, to be utilized and managed judiciously (Alatout 2008). More importantly, this law reflected the shift in power from local water associations, controlled by local agricultural interests, to the national level (the newly formed Water Commissioner, Mekorot, and the then-state owned water planning company, Tahal[9]). Opposed by private farmers, this shift was enabled by the collective farming interests' (the moshavim and kibbutzim movements) control over the Ministry of Agriculture and all centralized water bodies. Still, existing regional farmer-controlled water associations continued to supply water to farmers at very low rates. Such associations exist mainly in regions that were settled

---

[9] Tahal was privatized in 1996, as part of the neo-liberalization of the Israeli economy.

by Zionist bodies before the state was formed, that is, in the northern and central parts of the country.

The main purpose of the spatial extension of waterworks was the conveyance of water to the arid northern Negev, which was seen to have the greatest potential for agricultural development once irrigation could be introduced, and hence important from a food-security perspective. Indeed, in this part of the country, the rapid expansion of irrigation could be observed at any point connected to the NWC (Feitelson et al. 2014). To this end, water was first conveyed from the Yarkon River,[10] and later from the Jordan River basin, once the NWC was completed in 1964. These projects had widespread deleterious consequences for both rivers (as well as for the coastal streams that were also captured as part of these projects), since their freshwater flows were replaced by sewage and brackish water. The capture of surface water and the subsequent pollution of rivers and streams (mainly in the coastal plain) reflect the power of the agricultural interests at the time, which largely dominated the main ruling party (Mapai).

The main beneficiaries of the massive water projects in this era were Kibbutzim, followed by the Moshavim. Private farmers and Arab farmers received hardly any additional water (Yunger et al. 1993). This reflects the political power in the irrigation sector at the time. All the water planning and development bodies were controlled by a small elite that was part of the collective agriculture establishment, largely dominated by the kibbutzim. These initial inequities were later institutionalized in the water allocations set under the 1959 Water Law, leaving kibbutzim with more water per dunam than moshavim, and much more than the Arab sector (Kislev 2011).

Once the NWC was completed, all the main streams and rivers were closed (i.e. hardly any water reached the sea). Moreover, the potential for further groundwater utilization was found to be less than originally thought, meaning the ability to further develop new freshwater resources was largely curtailed. The second era of the Israeli water system focused, therefore, on the improved utilization of existing resources (Feitelson 2013). With respect to irrigation, the emphasis shifted from the expansion of irrigation systems to water conservation in irrigation. The development of drip irrigation and its rapid dissemination proved crucial in this respect. Moreover, Israeli agriculture shifted in this period from the self-provision of food to a market orientation, whereby the goal was to derive the maximal income from it. Hence, the emphasis shifted to increasing the product value per unit of water. Figure 8.2 shows the success of this policy, which combined technology (mainly drip irrigation) and crop substitution. It shows that, since the early 1970s, the value of agricultural production was largely decoupled from irrigation (Gilmont 2014), rising faster than the agricultural product, thereby producing substantially higher income per unit of water. These shifts were facilitated by heavy investments in agricultural know-how,

---

[10] The Yarkon River, originating north-east of Tel-Aviv, was captured at the source in 1955 and diverted to the western Negev through the Yarkon-Negev pipeline, which was later incorporated into the NWC.

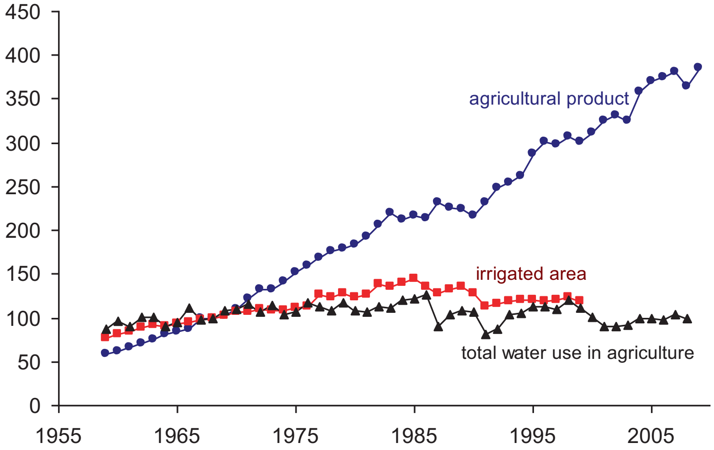

Fig. 8.2 Agricultural product, irrigated area (data on irrigated area were only collected until 1999) and total water use in agriculture (total water use in agriculture includes fresh water, brackish water and recycled wastewater) in Israel 1959–2008 (index: 1968=100). (Source: Central Bureau of Statistics, Annual Yearbooks)

mainly in the state-owned Vulcani Institute and by the ministry's agricultural extension service.

From an institutional-political perspective, this period was marked by the domination of a small, technocratic elite concentrated in the two often-competing national companies – Mekorot and Tahal. These were regulated by the Water Commissioner, who either came from within this technocratic elite or from the agricultural sector, and hence gave precedence to irrigation considerations (Feitelson, Fischhendler, and Kay 2007). Regardless, the Water Commissioner was appointed by the Agriculture Minister who invariably came from the collective agriculture sector (usually the Kibbutzim). Thus, irrigation interests held sway over water policies in Israel throughout this period. This was manifest in the late 1980s, when the Water Commissioner allowed deep drawdowns of the aquifers in order to prevent or reduce the cuts in irrigation quotas.

The brinkmanship policy, whereby excessive abstractions were allowed under the assumption, advanced by water commissioners from the agricultural sector, that a high-rainfall year would replenish both the Sea of Galilee and main aquifers once in a while, combined with several multi-year droughts, led to a series of crises from 1990 to the end of the first decade of the twenty-first century (Feitelson, Fischhendler, and Kay 2007). This is the third era identified by Feitelson (2013). The agricultural sector, and irrigation water in particular, were viewed as a buffer sector. That is, in drought periods, water for irrigation was to be cut and compensation paid to farmers. Such cuts were subject to fierce political struggles between the agricultural lobby and the Water Commissioner, as the agricultural sector utilized the power vested in the Minister of Agriculture to postpone such cuts in lieu of higher compensation (Fischhendler 2008). But, as the urban population grew rapidly in this period,[11] fresh water increasingly had to be shifted from agriculture to the domestic sector. To this end, cheaper recycled wastewater was offered to farmers in lieu of freshwater quotas.[12] This was enabled by the increasing availability of recycled wastewater resulting from the advanced (i.e. secondary+) treatment of wastewater due to pressure from and the increasing power of the Ministry of Environment.

During this third era, a policy impasse ensued, as the agricultural lobby in the Knesset prevented the raising of water tariffs, while the Treasury blocked suggestions to advance desalination, as it viewed higher water tariffs as a crucial instrument to reduce the demand for water, particularly in agriculture (Feitelson 2005). Moreover, as fresh water was increasingly shifted to the domestic sector, and water agreements were signed with the Palestinians and Jordan, resulting in inflexible international obligations for water supply,[13] agriculture's potential as a buffer sector was eroded, forcing the water commissioner to reduce the "red lines" on resource exploitation (Feitelson et al. 2005). To mitigate this impasse and its adverse implications for fresh water for irrigation, a significant effort was made to shift agriculture to recycled water. As discussed below, this had widespread implications for irrigation. Increasingly, farmers rely on recycled water for irrigation, rather than fresh water. To this end, drip irrigation systems had to be adapted to recycled wastewater. This had the additional benefit of largely decoupling irrigation from the vagaries of precipitation (Friedler 2001), and hence could also be viewed as an adaptation measure to climate change. Still, the shift away from freshwater led to several crises in agriculture, as discussed in the next section.

In 2005, the first large-scale seawater desalination plant came on line in Ashkelon, marking the beginning of a new era, the desalination era (Feitelson 2013). Through desalination, the total amount of water available in Israel has risen for the first time since the mid-1960s. Yet, the use of desalinated seawater for irrigation has proved problematic due to the high concentration of Boron, which is toxic to many crops, and the lack of ions that are essential for plant growth (Yermiyahu et al. 2007). Additionally, desalination is associated with several external costs, such as significant energy consumption leading to air pollution and GHG emissions, damage to marine life and resources through the discharge of residual salt to the sea, and the utilization of land along coastal areas. According to a study conducted in Israel, air

---

[11] In 1990 a massive immigration wave from the ex-soviet Union began. As a result of the immigration wave and the high birth rates Israel's population grew from less than 5 million in 1989 to 8.6 million at the end of 2016, a rate of growth unparalleled in any developed country.

[12] Subsidizing wastewater fits well with the government policy in the field of positive externalities. Using treated wastewater is a solution that prevents the disposal of contaminated wastewater into streams and into the Mediterranean. Furthermore, the use of treated wastewater increases the available water sources and therefore reduces the need for desalination of sea water and the negative externalities associated with them.

[13] The current obligations under the two treaties amounts to about 100 Mm^3, out of the 1200 Mm^3 considered safe long-term withdrawals (taking into account climate change projections). However, in the unratified Israeli 2010 draft masterplan the quantity reserved is 143 Mm^3, as it takes into consideration informal obligations and a realization of the amounting needs of both Jordan and the Palestinians.

pollution and GHG emissions resulting from desalination are associated with an external cost of 0.131 NIS/m^3 and the utilization of land is associated with an external cost of 0.135 NIS/m^3 (Lavee et al. 2011). However, desalination also changes the composition of wastewater, as it reduces its average salinity, allowing the wider use of recycled wastewater. Thus, from an irrigation perspective, this era is marked by an increasingly reliable supply of less saline wastewater for irrigation in the central and southern parts of the country. As a result of large quantities of desalinated water becoming available along the Mediterranean coast, the need to convey water from the Jordan River southward through the NWC diminished, leaving more fresh water within the basin. Hence, while irrigation in the central and southern parts of the county increasingly shifted to recycled wastewater, agriculture within the Jordan River basin continues to be irrigated with fresh water. This pattern is further justified when non-market benefits are taken into account (Becker et al. 2012), as it allows more water to be retained for nature.

Due to the increasing price of fresh water for irrigation supplied by Mekorot, the discrepancy in irrigation costs increased between farmers served by water associations and those served through Mekorot. This has a spatial pattern, as the lowest cost accrues to farmers in the north, who are supplied by local water associations from surface sources, while farmers in the south, to whom water must be conveyed inter-regionally, are served through Mekorot and hence pay increasingly higher rates. To address this, a new pricing formula has been advanced that will standardize the rates paid by farmers state-wide. This reform, proposed by the Treasury, is strenuously opposed by the water associations and farmers in the northern part of the country. The Ministry of Agriculture was caught in the cross-fire between the two groups of farmers, leading it to zigzag between antagonistic positions. Although the legislation standardizing water rates was passed, it has not yet been implemented at the time of writing (early 2018), and thus the full implications cannot be assessed at present.

8.3 Agricultural Water Demand

Water has long been the main constraint in Israel's agriculture. Due to the country's Mediterranean and semi-arid climate, all summer crops require irrigation.[14] Thus, irrigation is unequally distributed between the months of the year, with peak demand occurring in the dry summer months. At the beginning of the twentieth century, agricultural water supply was limited to the surroundings of local water sources. As water conveyance widened, irrigation expanded, and the amount of water supplied to agriculture increased. As a result, the extent of irrigated areas grew, until the mid-1980s (Fig. 8.2). By this time, all the available freshwater sources had been utilized. During those years, water for agriculture was mainly provided from natural

---

[14] Agriculture in the southern Negev Desert (mainly the Arava Valley) requires irrigation all year round.

freshwater sources. In 1986, Israel began to cut back on freshwater allocations for agriculture, due to increasing water shortages. The cuts were made mainly in the areas supplied by the NWC (Israel Water Commission 2002). Since the completion, in 1972, of the Shafdan – the wastewater treatment plant of the Tel Aviv metropolitan area (the Dan Region) – the availability of reclaimed wastewater for agriculture rose. By 2010, recycled wastewater made up about 40% of the water used for irrigation, compared to less than 4% 40 years earlier (Fig. 8.3). As can be seen in Fig. 8.2, for the last four decades, the total amount of water used in the agricultural sector (fresh water + recycled wastewater) has remained basically stable, while crop output has risen steadily. Currently, Mekorot provides about 60% of the water consumed in the agricultural sector, while about 40% is supplied by regional and local water associations (Kislev 2013). Since Israel's agriculture is based on kibbutzim and moshavim, they constitute the major water consumers in the agricultural sector.

The increase in the agricultural output (by weight) per unit of water is due to the introduction and widespread adoption of water-saving irrigation technology (fertigation), the substitution of fresh water by recycled wastewater, and a shift to water-efficient crops and to those allowing the use of saline water and recycled wastewater. Saline water, for example, is utilized for the irrigation of salinity-tolerant crops, such as cotton. For a number of crops, such as melons and tomatoes, brackish water improves product quality, although yields are lower (The Israel Export International Cooperation Institute 2013). However, the substitution of basic food crops by export-oriented crops implies that Israel cannot supply all of its food requirements. Since the mid-1960s, it has been realized that the available water in Israel is not sufficient for the production of the country's entire food intake. This

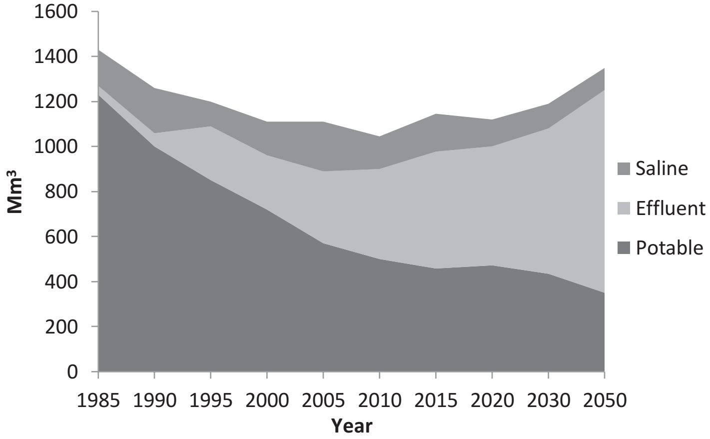

Fig. 8.3 Agricultural water use in Israel by water source, data for 1985–2015 and predictions for 2015–2050. (Source: Data for 1985–2010: Ministry of Agriculture and Rural Development 2010. Data for 2015: Israel Water Authority 2016a. Predictions for 2020–2050: Israel Water Authority 2010)

means that Israel is dependent on the import of water-intensive food, mainly grain and beef (Kislev 2011).

In addition to the transition to water-saving crops and the use of reclaimed wastewater and brackish water, farmers are also required to optimize their operations. Hence, they continually search for cost-effective management and marketing practices in order to reduce their expenditure, and, consequently, agricultural output and the value per unit of production factors, land, water, and labor, have been growing. Today, water-use efficiency in Israeli agriculture is among the highest in the world as a result of research, guidance, and the development of advanced irrigation methods.

According to Israel's national master plan for the water sector (IWA 2012), which constitutes the overall policy framework for water production and use in Israel by 2050, the sector will slightly reduce the amount of water for agriculture in the short term (2020); however, with the growth of desalination for domestic use, the amount of recycled wastewater will increase and thus the constraints on the use of recycled wastewater for agriculture should be alleviated.

In the following sections, we examine in greater detail the issue of agricultural irrigation in Israel under conditions of a water crisis.

8.4 Policy and Practice: Present Situation and Recent Developments

8.4.1 Water Governance and Institutions

Under the 1959 Water Law, all water resources are public property. The law established the office of the Water Commissioner, in order to manage the resources, and provided it with the power to authorize all abstractions and uses of all water resources. This legislation has been complemented by the earlier Supervision of Water Drilling Law (1955), the Water Measurement Law (1955), and the subsequent Water and Sewage Corporation Law (2001), as well as secondary legislation (rules and regulations) intended to regulate the water sector with emphasis on water use and management. Based on these laws, metering is required and applied. The Water Law has been amended over the years.

However, despite the seemingly wide-ranging powers of the Water Commissioner, there was widespread criticism of the management of the water resources, and their systemic over-exploitation, particularly the coastal aquifer (Gvirtzman 2002). As a result, the ability to accommodate multi-year droughts was severely eroded, as became obvious in the 1989–1991 and 1999–2001 droughts (Fischhendler 2008), when the so-called "red lines" in the Sea of Galilee were exceeded. This over-exploitation was the consequence of a 20-year policy impasse between the agricultural lobby, which prevented an increase in water rates for agriculture, and the Treasury, which blocked desalination (Feitelson 2005). This state of affairs led to several government and parliamentary inquiry commissions being set up.[15] Following their recommendations, a major reform was enacted in May 2006, in accordance with which the Water Commissioner was replaced by a Water Authority and the Water Authority Council to provide oversight. Within the authority's purview were placed all government bodies involved in water management, with the aim of creating a professional body with a comprehensive view of the needs of the water and sewage sectors, and the ability to properly manage and supervise all aspects of water and sewage in Israel.

The establishment of the Water Authority, as well as the decision to embark on widespread desalination, resulted from a shift in the position of the Treasury, which sought to reduce the power of Mekorot as part of its drive to introduce competition into the water sector (Feitelson and Rosenthal 2012), and in the power balance between the Treasury and the agricultural lobby (Singer 2011). Today, approximately 35% of the fresh water in Israel is provided by four private desalination plants (out of five in total), (calculated on the basis of data from the Israel Water Authority [2016b]).

Today, several institutions supervise and manage the Israeli water sector (EMWIS 2008; Gelpe 2010; Rejwan 2011). These include:

The Water Authority is responsible for the management, operation, and development of the water sector. It is responsible for the preservation and restoration of natural water resources, the development of new water sources, and the supervision of water consumers and producers. This authority is today within the Ministry of Energy and Water (in contrast to the Water Commissioner, who was originally under the Minister of Agriculture), reflecting the shift in water policy away from irrigation.

The National Water Company "Mekorot", Israel's main water supplier, is a corporate entity, originally established by the Zionist organizations and today a government company. Its main responsibility is to operate and manage the NWC and to supply water. The emergence of desalination somewhat diminished its power; however, it supplies most of the water for irrigation and much of the recycled wastewater. Moreover, it stands to gain from the recent legislation standardizing water rates across water associations.

Water associations are regional cooperatives whose members are kibbutzim and moshavim. Their purpose is to provide water for agricultural needs to members of the associations or to the local authorities in which they operate. They provide much of the water supply in the upper Jordan basin. The water associations are also platforms for political activity, handling negotiations with public officials. The associations' representatives bring their members' requests and needs to the table, giving the organized farmers a collective voice and power. The recent legislation to standardize water rates undermines these associations and severely reduces the voice of farmers in the areas they serve, which explains their strenuous objections.

---

[15] Most notable among them were the Arlosoroff Commission of 1997, and the Magen Commission in 2001.

8.4.2 Water Resource Management Policies

The primary focuses of Israel's water policy are: enhancing water-use efficiency by greater use of economic and market-based instruments, such as raising water prices; enforcing regulatory tools, such as water allocation and quotas; reducing the overall support for water in agriculture; and encouraging the use of non-potable water (effluent or brackish water) for irrigation. In addition, the policy supports research and development, training and technology.

8.4.2.1 Water Rights and Allocations

As mentioned, Israeli law provides that water sources are controlled by the state and are publicly owned. This includes water that may be drawn from wells located at farmers' properties, even if it is intended exclusively for the owner's use. Thus, such water can be drawn only with a water production license. Once allocated, the water is supplied to the farmers mainly by Mekorot and the Agricultural Water Associations.

Since the enactment of the Water Law, the Water Authority issues annual licenses to each of the water producers and suppliers, specifying the amount of water permitted for production, supply, or consumption during that year, as well as production conditions and restrictions.

The main goal of the Water Authority is to ensure water quality and the reliability of supply in the long run. For this purpose, it issues annual extraction licenses that may vary with local conditions. In addition, a levy was set on extractions by water producers, which varies according to region, water quality, use, and source (groundwater or surface water). The purpose of the levy is to reflect water resource scarcity, and thus to internalize externalities, so that, along with production and distribution costs, water prices will reflect more accurately the true value of water. Thus, the extraction levy is intended to encourage water conservation in the agricultural sector as well as to encourage farmers to switch to recycled wastewater, and to provide the Water Authority with an economic instrument to manage water both nationally and regionally (Zaide 2009). Currently, changes are being made to the extraction levy and, under Amendment 27 of the Water Act, a uniform water rate for agriculture was set for each type of water used. This much-contested amendment seeks to standardize water prices between farmers in different parts of the country, since, before the amendment, farmers in the north supplied by water associations enjoyed lower freshwater tariffs than those in the south.

The decisive factors for the allocation of water to various consumers combine political, economic, social, and environmental objectives. Economic efficiency is achieved by maximizing the total economic welfare from water use, whereas environmental efficiency is achieved by allocating water in a manner that will meet environmental objectives. As the vast majority of farmers are connected to water meters, two policy instruments used to achieve these objectives are quotas and pricing. Nonetheless, the issue of water allocation is often strongly linked to internal and external politics, as well as political pressure, rather than to a clear overall policy (Hadas and Gal 2012). Over the years, politicians tended to favor short-term considerations over long-term responsibilities (Feitelson 2005). The reform of 2006 and the creation of the Water Authority were designed, inter alia, to eliminate the political pressure over water allocation (Gilmont 2014). The social objective of the Water Authority is making sure that water is allocated to all Israeli farmers, while an important goal is the allocation of water for agriculture in the peripheral areas (OECD 2010).

Water in Israel is allocated to the various consumers according to type. In the first decades after the establishment of the state, agriculture was the main freshwater consumer. Freshwater allocations to the agricultural sector peaked in the mid-1980s. Over the years, fresh water has been directed toward the urban sector at the expense of the agricultural sector, partly replaced with treated wastewater. Since 1999, following a period of severe drought, major cuts were made in the allocation of fresh water to agriculture. In some cases, the reductions were compensated by payments to farmers; in others, farmers were compensated with treated wastewater as a substitute. The additional water sources (mainly treated wastewater and desalinated seawater) enabled the Water Authority to increase the total allocation of water (fresh water + recycled wastewater) for agriculture in recent years (Israel Water Authority 2016c).

Today, water allocation is made according to the following descending order of priority: domestic consumption, industrial consumption, agricultural consumption, and other needs (including environmental needs). For domestic and municipal uses, only potable water is allocated, while for industrial, natural, and landscape uses, both potable and brackish water are allocated. The agricultural sector receives treated wastewater, brackish water, and potable water (mainly in the eastern part of the country).

The urban sector does not have limits on use. Households are free to use any amount of water but face block-rate tariffs determined by the Water Authority. In the agricultural sector, the initial water allocation is administrative – that is, each consumer has a basic quota, and pays a subsidized tariff. But, due to the technological changes and the dismantling of protective measures, small-scale agriculture faces increasing difficulties. Consequently, farms are consolidated, de-facto, through largely unauthorized lease agreements. Water allocations are also informally leased by farmers who cease to farm their own land to those that farm both their land and that of others.

In Government Decision 828 (dated 01/06/2000), the quota for agriculture was set at roughly 1150 Mm^3 per annum as of 2010, of which approximately 40% (450–530 Mm^3) is fresh water and the remainder is marginal waters – saline water and treated wastewater, unfit for domestic consumption (Israeli Ministry of Agriculture and Rural Development 2013). As can be seen in Fig. 8.3, the use of fresh water is expected to drop to 350 Mm^3, accounting for 25% of the expected total in 2050. The fresh water is mainly designed for livestock farming, crops/areas that are not permitted for irrigation with treated wastewater,[16] or areas with insufficient treated wastewater (mainly in the Jordan basin). Since 2001, the use of fresh water in the urban sector has exceeded that in agriculture (Israel Water Authority 2016d).

8.4.2.2 Water Tariffs and Levies

The Water Authority is responsible for setting tariff levels to recover supply costs and reflect water scarcity. The charges for all water in Israel are determined according to the metered water volume, and municipalities are subject to fines if unbilled water quantities exceed 12% of that supplied by the local authority. Water prices for farmers vary according to the type of water, i.e. fresh water, treated wastewater, and surface or groundwater. The price differences reflect water quality and supply costs, as well as the government's objective to encourage the use of treated wastewater for agriculture.

Following the change in the dominant discourse within Israel, from a statist-socialist to a neo-liberal, market-oriented agenda, the water subsidy policy came to be viewed as a major economic burden. According to this narrative, Israel's water policy guidelines for agriculture were characterized by underpricing, discriminatory and distorted pricing, and misallocation amongst the various water users (Plaut 2000). In 2006, a water agreement was signed with the farmers, according to which the price of water for irrigation was to increase, so as to reflect the average cost of water supply. According to the agreement, new water tariffs would increase gradually, so that, as of 2017, the agricultural sector would pay the full cost of water production, including its share of desalination. As can be seen in Table 8.1, the price of fresh water increased by 111% over a 12-year period, thus achieving the goal. Similarly, increased water rates were expected for brackish water adjacent to fresh water. In addition, although not part of the Water Agreement, the Water Authority increased the tariffs for treated wastewater (Israeli Ministry of Agriculture and Rural Development 2013). As can be seen in Table 8.1, the price of wastewater increased by 56% over a 7-year period. We would expect such an increase to lead to lower levels of water use, but, in practice, farmers did not reduce their use of water (Table 8.1); instead they switched from fresh water to wastewater, the latter being much cheaper (Fig. 8.3).

The price hikes only affect farmers supplied by Mekorot, since water associations are subject to extraction levies, and can shift this cost onto farmers. Although, as farmers control these associations, the cost increase is much lower than for farmers supplied through Mekorot (Kislev 2011). This increasing discrepancy is at the heart of growing discord within the agricultural sector regarding the new legislation proposing to standardize irrigation prices across all farmers (essentially, increasing the cost to farmers supplied by water associations to somewhat reduce the average cost

---

[16] These are areas which are deemed vulnerable according geo-hydrological or health criteria.

Table 8.1 Water tariffs for agriculture use, 2005 until 2017

Year	Fresh water for agriculture (NIS)*	Change in prices (%)	Treated wastewater tariffs	Change in prices (%)	Use of water for agriculture (Mm^3)	Change in land use (%)
2017	2.93	0.0%	1.36	5.1%		
2016	2.93	5.0%	1.33	5.1%		
2015	2.79	9.8%	1.3	10.0%	1096	−0.5%
2014	2.54	11.4%	1.22	11.1%	1102	−6.8%
2013	2.28	9.6%	1.11	9.9%	1183	11.2%
2012	2.08	10.1%	0.98	10.1%	1064	4.1%
2011	1.89	18.9%	0.92	5.7%	1022	−5.2%
2010	1.59	−3.0%	0.87	–	1078	8.2%
2009	1.64	2.5%			996	−9.4%
2008	1.6	7.4%			1099	−5.6%
2007	1.49	0.7%			1164	6.9%
2006	1.48	6.5%			1089	
2005	1.39					
2005–2017		111%		56%		1%

Source: Israel Water Authority (2018)
3.5 NIS = 1$ at December 2017
*Prices do not include VAT

and hence the cost to farmers supplied through Mekorot). As at 2018, this topic was still under discussion, one option being that Mekorot would supply fresh water to all farmers.

Along with the water agreement, farmers were given support to adjust to the new costs. During 2007–2009, farmers in the communities listed in appendix B of the water agreement were given direct refunds, while the rest were required to invest in water use efficiency. Since 2010, all communities have been required to improve their water systems, reducing waste and achieving more efficient water use (Israeli Ministry of Agriculture and Rural Development 2015).

Until recently, an integrated system was practiced for the agricultural sector: each farmer had a basic quota, and the payment for water was determined by block rate pricing – that is, the price rose with the increase in the relative amount of water consumed of the allocation, according to three price levels. An example for Mekorot's former tariffs for fresh water to agriculture, according to block rate prices, is shown in Table 8.2. However, as of January 2014, a uniform tariff was set for each type of water used in agriculture. This is one of several actions promoted recently by the Ministry of Agriculture together with the Water Authority, and compensatory measures include the allocation of fresh water for agriculture for 3 years in advance and a substantial increase in quotas for farmers. For example, the allocation of water from Mekorot to agriculture increased between 2013 and 2016 from 334 to 459 Mm^3 (Israel Water Authority 2013; Israel Water Authority 2016e).

Table 8.2 Mekorot's tariffs for fresh water to agriculture, according to block rate prices (2013)

Price (NIS/m^3)[a]	Present from total quota (%)	Block
2.61	50%	Block I
2.96	30%	Block II
3.66	20%	Block III
2.93 (average)	100%	Total

Source: Israel Water Authority (2018)
[a] Prices do not include VAT

These measures give greater certainty regarding the quantities of fresh water available for use by farmers, allowing them to plan crops in a more optimal and efficient manner. They were made possible by the desalination facilities along with a massive amount of treated wastewater for irrigation.

In practice, most farmers use the first and second blocks. On average, in 2016–2017, farmers used only 70–75% of the quota (compared to 82% in 1999), because of the rise in the average price of fresh water (Mecler 2018).

8.4.2.3 Cross-Subsidization

Cross-subsidization refers to charging one group of consumers higher prices in order to offer lower prices to another. In Israel, domestic and other water consumers in the urban sector cross-subsidize the water prices for agriculture, and farmers near the water sources cross-subsidize farmers in areas where supply costs are high – mainly the south and mountainous areas (Becker and Lavee 2002). The system is heavily criticized by the Treasury and the urban sector, as well as by many economists. This led to the shifts in pricing noted above. Hence, in contrast to the situation in the 1970s, the agricultural sector today covers most of the operating and maintenance costs, as well as the fixed capital costs of water supplies. As mentioned, freshwater prices for agriculture will continue to rise and inter-sectorial cross-subsidies will be reduced (Kislev 2013).

8.4.3 Development of Technologies for Coping with Water Scarcity

The decoupling of agricultural product from total water use since the early 1970s, seen in Fig. 8.2, can be largely attributed to the advent of drip irrigation. While the idea has a long history, the breakthrough was the invention of a new emitter by Simcha Blass in the mid-1960s. As irrigation systems were pressurized to allow sprinkler irrigation, the Blass emitter reduced the velocity to allow timed, low-volume irrigation in the root zone. Blass partnered with Kibbutz Hatzerim to establish Netafim, the leading drip irrigation company, which, in 1970, acquired the rights to the turbulent water passage patent, developed by Rafi Mahoudar to resolve the in-line laminar dripper's clogging problems. Once these were resolved, drip irrigation became available to a wide array of crops, and consequently became one of Israel's best known exports.[17]

Further improvements of the drip-irrigation technology include sub-surface drip irrigation and micro-spray heads. Sub-surface irrigation reduces evaporation and damage to the drip irrigation systems, and allows its use for recycled wastewater. This required further development, in particular, methods for cleaning slime within the tubes. An additional use of drip irrigation is for introducing fertilizers, as liquid fertilizers can be mixed with the irrigation water, thereby allowing more precise fertilization. To allow more precise irrigation, monitoring systems were added. These provide growers with real-time, computerized field display. Based on data collected from an array of sensors, such systems alert the grower to any deficiencies in moisture or nutrients. Further development allows the automatic release of different nutrients into the irrigation water, based on the data collected by the sensors.

While drip irrigation may have reduced the recharge of the coastal aquifer, it has little effect on other sources, as the recharge areas of all other aquifers, as well as the upper Jordan River, are in mountainous areas where there is little drip irrigation. The coastal aquifer has indeed been over-utilized, as seen in the decline in water level and the intrusion of saline water (Gvirtzman 2002). But, as this is also where much of the urban development and heavy pumping for urban consumption took place, it is difficult to identify the marginal contribution of the shift to drip irrigation to this decline.

An additional direction of technological development is the identification and development of salt-tolerant crops that can be grown on brackish, saline, or recycled water (Pasternak et al. 1986). The research and development of such crops is ongoing at present (Ventura et al. 2015, for example).

The advent and widespread adoption of new technologies in Israel can be attributed not only to the high level of research and development, but also to the human capital of farmers. As farming in Israel, for the most part, is not a traditional sector, and much of it was organized in a cooperative manner (whether in fully collectivized Kibbutzim or semi-collective Moshavim), farmers display a high level of education. Moreover, with exposure to world markets, farmers were forced to compete under increasingly challenging circumstances (Kislev 2013),which forced them to innovate. Hence, farmers were willing, and were often instrumental in developing and testing new technologies.

---

[17] For a timeline of Netafim's history and further drip irrigation innovations of the company see www.netafimlegacy.com/timeline.

8.4.4 Transition from Potable Water Irrigation to Treated Wastewater, and the Impact on Israeli Regulation and Water Quality

Until the 1990s, the water used for agriculture was mainly fresh water, with the exception of the western Negev, which was supplied with treated wastewater from the Shafdan, and the western Yizrael valley, which was supplied from the Haifa wastewater treatment plant. Since the 1990s, wastewater recycling for agriculture has greatly expanded. Due to the increasing power of environmental bodies and following the establishment of the Ministry of Environment in 1988, as well as the wider incorporation of environmental considerations into land use planning, any new development must be connected to a wastewater treatment plant (since 1992). These, in turn, face increasingly stringent standards. As a result, the supply of high-quality treated wastewater has increased dramatically.

While wastewater can be reused for urban and industrial uses, stream rehabilitation, and artificial groundwater recharge, most is actually recycled for irrigation. The use of treated wastewater has two main advantages: first, it may be considered a new water resource and substitute for conventional water (potable water) for irrigation and other purposes (Friedler 2001). Second, by switching to recycled wastewater the pressure on conventional water resources is lessened (Lavee 2011). However, the extended use of recycled wastewater has adverse effects on soils and aquifers, particularly the coastal aquifer (Jueschke et al. 2008).

8.4.4.1 Treated Wastewater Quantity

The significant increase in wastewater treatment and use in recent years is shown in Fig. 8.4. As a result of utilizing treated wastewater for irrigation, a considerable reduction in potable water use in agriculture has occurred (Fig. 8.3).

Today, 95% of Israel's domestic wastewater is treated by approximately 135 treatment facilities. Around 86% of the treated wastewater is reused, mostly in agriculture, which receives roughly 520 Mm^3 per year, representing around 45% of its total supply (Israel Water Authority 2015a, 2016a). The remaining treated wastewater is either lost through evaporation or discharged to sea, since some treatment plants lack the infrastructure to convey it to irrigable land. Some treated wastewater is also used for stream rehabilitation projects.

National policy calls for treated wastewater to be eventually fully utilized by agriculture, and it is estimated that, by 2020, virtually all municipal wastewater will be reused, and treated wastewater will provide 50% of Israel's agricultural needs (Brenner 2012; Inbar 2007). This would be accomplished by enlarging the existing wastewater treatment facilities as well as constructing new ones.

The largest player in Israel's treated wastewater industry is Mekorot, as its facility (the Shafdan) provides the largest amount of treated wastewater, approxi-

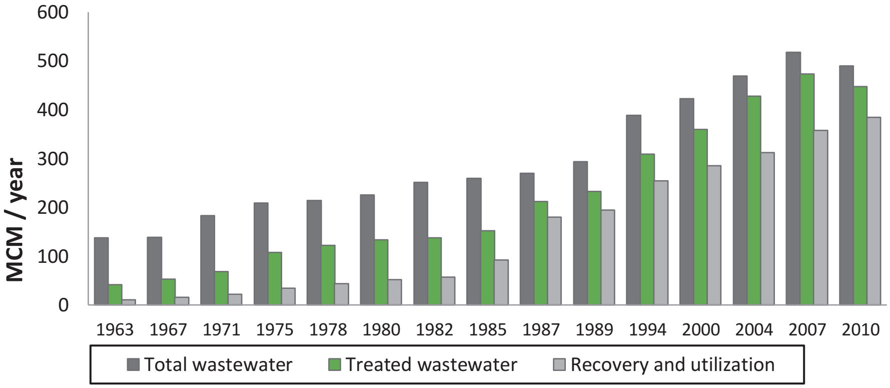

Fig. 8.4 Wastewater treatment, recovery, and utilization in Israel, 1963–2010. (Source: Israel Nature and Parks Authority 2012)

mately 130 Mm^3 per year. The wastewater treated at Shafdan is then conveyed to infiltration fields, where it is recharged into the confined aquifer, thereby further purifying the effluents. This also allows large amounts of water to be stored and made available for irrigation during "dry" seasons. To prevent the leakage of this water into drinking water wells in the area, the treated wastewater is pumped by a peripheral system of 150 recovery wells. Subsequently, the reclaimed wastewater is conveyed for agricultural irrigation in the south by Mekorot through its so-called Third Line. This is separated from the two other lines that convey potable water to the Negev and is intended to provide only treated wastewater for agricultural use.

In addition to the 130 Mm^3 of the Shafdan, through other recovery plants Mekorot provides roughly 63 Mm^3 of treated wastewater (of varying quality) each year. In addition, there are private wastewater treatment facilities, providing approximately 200 Mm^3 per year. By 2050, production is expected to reach approximately 900 Mm^3 per year (Table 8.3).

In 2000, an assistance plan for sewage treatment plants was initiated. Under this plan, financial assistance is granted for converting from the use of potable water to treated wastewater, as well as for improving the quality of effluents to the level required by regulations. The plan provided guidelines for the conveyance of excess wastewater from densely populated areas, which produce high volumes of wastewater but have little agricultural land, to sparsely populated peripheral areas that are based on agriculture and are in need of treated wastewater (Israel Water Authority 2011).

In the next few years, a significant increase in the amount of land irrigated with wastewater is expected, mainly due to reductions in the quotas of fresh water and the many wastewater recycling projects of recent years (Israel Ministry of Health 2011). The increase in total freshwater supply thanks to desalination will also lead to the additional availability of wastewater through recycling.

Table 8.3 National objectives and timeline for improving wastewater use in the agricultural sector

Year	% of irrigation water from effluent	Volume of effluent per year (Mm^3)
2010	38	400
2015	43	464
2020	51	587
2050	67	900

Source: Israel Water Authority (2011)

8.4.4.2 Treated Wastewater Quality and Regulations

Irrigation with treated wastewater may cause various environmental and sanitary hazards, such as water and soil pollution, as well as a decline in crop yields (Lavee 2011). These risks are largely a function of wastewater quality. Therefore, it is necessary to set standards and requirements for wastewater treatment and use.

Initially aimed at preventing health risks, a regulatory framework began to evolve alongside the development of wastewater reuse. Water quality standards for irrigation were set in 1977 by the Shelef Commission (Sagi and Shisha 1999). Subsequently, in 1981, wastewater irrigation was limited to crops specified by the Public Health Law, and permits were required for all wastewater reuse projects. In 1992, a secondary standard was set by the Ministry of Health in response to demands for the improvement of wastewater quality for irrigation and the prevention of the pollution of streams and further environmental risks (State Commission of Inquiry on water management in Israel 2010). While this standard reduced the environmental and health impacts arising from the use of wastewater, treatment plants in Israel continued to discharge effluents containing various pollutants and high levels of salt, raising various issues (Israel Ministry of environmental protection 2005; Lavee 2010).

Consequently, a special committee (Inbar Committee) was established in the year 2000 in order to set new standards for wastewater quality. The committee's objectives were to address various aspects of health, soil, plants, and hydrology, so that wastewater use would not constitute a hazard, on the one hand, and would be economically viable on the other (Pareto Engineering Ltd. 2003). On the basis of a cost-benefit analysis, the committee advanced a tertiary standard, to allow the use of treated wastewater for unlimited irrigation and improve the quality of wastewater released into the sea (Inbar 2007). The recommendations were approved in 2005 and took effect on 7/25/2010. Currently, most (59%) of the treated wastewater used for irrigation is of high quality and can be used to irrigate specific crops (Israel Ministry of Health 2011).

8.5 Future Challenges

8.5.1 Water Supply

Over the past three decades, water supply to Israel's agriculture has been characterized by climate vagaries, leading to uncertainty in the agricultural sector. Following the advent of seawater desalination, the increased use of treated wastewater, and the higher quality of this wastewater, it appears that the supply of water for agriculture in forthcoming years will be sustained and even increased. This is true, however, only for the central and southern parts of the country. Irrigation in the northeast, largely within the Jordan River basin, still depends on precipitation patterns. Due to increasing competition from tourism, the worrying situation in Jordan, and a series of below-average rainfall years, the future of irrigation in this part of the country remains uncertain.

Irrigation, particularly with treated wastewater, may cause changes in the irrigated soil properties and its environment due to high salt concentrations. In addition, recently, there has been increased awareness of the presence of organic pollutants, such as pharmaceuticals, cosmetics, and hormones, in treated wastewater and their effect on the environment and agricultural crops. Organic pollutants and salinity may affect the food chain and water resources, although these effects are not yet sufficiently known (Shaviv et al. 2011). Therefore, it will be necessary to address these impacts.

8.5.2 Climate Change

Despite the greater certainty of the water supply in the coming years, due to the combination of desalination and wastewater recycling, there are concerns that climate change may affect the water sector.

In the last few decades, a warming trend has been observed in the Middle East. While the trends in precipitation are ambiguous, scenario analyses have suggested that levels may decrease and the incidence of droughts will increase (Alpert et al. 2008). According to the A1B scenario of the IPCC, a rise of 1.5 °C in Israel's average temperature is expected by 2020 compared to 1960–1990. According to IPCC scenarios A2 and B2, between the years 2071 and 2100, average temperatures are expected to rise by up to 5 °C by the end of the century compared to 1960–1990. Furthermore, by 2020, a 10% decrease in precipitation is projected in Israel, and expected to reach a 20% decrease by 2050 (Israel Ministry of Environmental Protection 2010). The rising sea level is likely to lead to further intrusion of sea water into the coastal aquifer. Melloul and Collins (2006) estimate that the storage capacity of this aquifer will diminish by 16.3 Mm^3 per 1 km of coast for each 50 cm rise in sea level, thereby reducing the available fresh water.

According to the OECD (2010), by 2020, climate change will benefit agriculture in Israel, thanks to its ability to meet the demand of international markets earlier in the season. However, in the long term, Israel will need to supply the expected increase in total water consumption due to population growth and higher evapotranspiration rates, while the availability of freshwater resources is expected to be reduced due to the higher frequency and severity of extreme events (particularly droughts) and the rising sea level (Alpert et al. 2008). This will adversely affect rain-fed agriculture, thereby requiring additional irrigation.

To address this challenge, Israel will need to continually improve water savings, inter alia by using more efficient irrigation methods, expanding the use of water-saving crops, and increasing the use of brackish water and treated wastewater, whose availability will continue to rise as additional desalinated seawater is used. However, these measures will not be available in some parts of the country, mainly the northeastern part, where there are few sources of wastewater. Moreover, these measures will not be available to Israel's eastern neighbors, Jordan and the Palestinians. Hence, if additional water will be conveyed to these water-stressed neighbors, Israel will have to do with less fresh water, thereby furthering its reliance on desalination and wastewater recycling.

8.6 Summary and Conclusions

Irrigation enjoyed wide public and political support in the early years of the state, as it was deemed essential for state-building, food security, and immigration absorption. The agricultural lobby was closely connected to the centers of power. Consequently, major water infrastructure was built, at substantial cost, creating a national-level water system. One result of this, as well as of the trans-regional conveyance of recycled wastewater, is a spatial discrepancy between the sources of water and the areas irrigated. As the collective farming sector controlled the Ministry of Agriculture and the bodies that planned and implemented these water development projects, it was also the main beneficiary of these investments. Moreover, the control of the collective farming sector by the Ministry of Agriculture enabled the state to nationalize all water resources and form a centralized water management structure, as the management was entrusted to the ministry. The Water Commissioners that came from the agricultural sector prioritized irrigation, allowing groundwater levels to decline in order to increase the water supply to agriculture and reduce allocation cuts in drought years.

After almost 20 years of relatively abundant precipitation levels, a series of drought years began in the late 1980s. Due to the unsustainable utilization of water, mainly for irrigation, that preceded these droughts, Israel experienced severe water crises in the 25 years that followed. These were exacerbated by a combination of rapid urban population growth, rising standards of living, and new obligations under water agreements between Israel and its neighbors. This led to increasing pressure on the scant water resources, in terms of both quantity and quality.

Due to the technological and economic shifts in agriculture, the number of farmers declined dramatically, as did the status of the Ministry of Agriculture within the governmental system. As a result of these trends, and the Likkud party coming to power, the influence of the agricultural lobby declined. Along with the rise of neoliberal ideology and the increasing power of the Treasury within the governmental system, cuts were made to freshwater allocations and subsidies for irrigation, thereby raising the cost of fresh water for farmers. Moreover, with the marketization of agriculture and the decline of the central institutions that underlay the agricultural lobby, the previously unitary voice of the agricultural sector fragmented, further weakening the political power of irrigation interests.

The ability of the Israeli agricultural sector to withstand these adverse trends can be largely attributed to the high human capital in the Israeli agricultural sector, as well as to improvements in technology and the management of water resources. In particular, the substitution of fresh water by treated wastewater allowed irrigation to retain much of its water allocation, despite the sharp decrease in freshwater allocations, with the prospect of even increasing it in coming years. The availability of high-quality treated wastewater can be attributed to the growing power of environmental interests, which led to the enactment of more stringent standards for wastewater treatment, the demand by planning authorities that all new residential developments be connected to treatment plants, and the advent of seawater desalination that led to increasing quantities of higher quality (i.e. fresher) water flowing through urban systems. The increasing use of both treated wastewater and desalinated water has relieved much of the pressure on freshwater resources, thereby reducing the need for further cuts in the total water allocated for irrigation.

A second factor that allowed Israeli agriculture to continuously increase productivity without increasing the total water use (and decreasing freshwater allocations) is the development and application of advanced water-saving technologies, most notably drip irrigation. Thanks to these technological developments, Israel became a lead exporter of water-saving irrigation technology. Within Israel, drip irrigation has been central to improving irrigation efficiency, i.e. increasing the amount of agricultural production per unit volume of water consumed. Water conservation, along with crop-substitution and the substitution of fresh water by recycled water, allowed Israel to largely decouple agricultural output from (fresh) water. Indeed, since the 1950s, Israel's agricultural output has grown tenfold (volume), while the amount of freshwater for agricultural use has decreased significantly.

But Israel's water policy reforms were not only driven by technology. Rather, they resulted from the decline in support for the subsidized supply of water for agriculture, due to the shifting power balance between the agricultural lobby and the Treasury. This resulted in the introduction of real water prices for farmers, giving them an incentive to increase the efficiency of water use in agriculture, and to substitute fresh water with treated wastewater. The technological improvements allowed them to do so while increasing the agricultural output. Nonetheless, the falling profit from agriculture, not least due to the increase in water prices, has led most of the young generation of farmers to abandon agriculture. This is manifest in the rising median age of active farmers. Hence, the future of Israeli agriculture is uncertain. This may lead to a decline in the demand for recycled wastewater. Israel may face, therefore, an excess in treated wastewater, particularly in its northwestern parts. The widespread recycling of wastewater might have adverse effects on soils, the extent of which requires further study. Therefore, the success of Israel's irrigation systems may be more tenuous than they seem from past trajectories.

References

Alatout, S. (2008). States of scarcity: Water space and identity politics in Israel 1948–59. *Environment and Politics D, 26*, 959–982.

Alpert, P., Krichak, S. O., Shafir, H., Haim, D., & Osetinsky, I. (2008). Climatic trends to extremes employing regional modeling and statistical interpretation over the E. Mediterranean. *Global and Planetary Change, 63*, 163–170.

Amiran, D. (1994). *Rainfall and water policy in Israel*. The Jerusalem Institute for Israel Studies, No. 55 (Hebrew).

Avitsur, S. (1991). Water of affliction. In J. Aviram & A. Shachar (Eds.), *David Amiran volume, Eretz-Israel: Archeological, historical and geographical studies* (Vol. 22). Jerusalem: Israel Exploration Society (Hebrew).

Becker, N., & Lavee, D. (2002). The effect and reform of water pricing: The Israeli experience. *International Journal of Water Resources Development, 18*(2), 353–366.

Becker, N., Lavee, D., & Tavor, T. (2012). Desalinate or divert? Coastal non-market values as a decision tool for an integrated water management policy: The case of the Jordan River basin. *Ocean and Coastal Management, 64*, 27–36.

Brenner, A. (2012). Limitations and challenges of wastewater reuse in Israel. In *Clean soil and safe water* (NATO science for peace and security series C: Environmental security, pp. 3–9). Dordrecht: Springer.

Central Bureau of Statistics. (2016). www.cbs.gov.il

EMWIS (2008). Water resources management – institutions. Israeli EMWIS Focal Point. www.emwis-il.org/en/Water_legislation/legislation_06.htm

Feitelson, E. (2005). Political economy of groundwater exploitation: The Israeli case. *International Journal of Water Resources Development, 21*, 41–423.

Feitelson, E. (2013). The four eras of Israeli water policies. In N. Becker (Ed.), *Water policy in Israel: Context, issues and options* (pp. 15–32). Berlin: Springer.

Feitelson, E., & Fischhendler, I. (2009). Spaces of water governance: The case of Israel and its neighbors. *Annals of the Association of American Geographers, 99*, 728–745.

Feitelson, E., & Rosenthal, G. (2012). Desalination space and power: The ramifications of Israel's changing water geography. *Geoforum, 43*, 272–284.

Feitelson, E., Gazit, T., & Fischhendler, I. (2005). *The role of "red lines" in safeguarding the Sea of Galilee (Lake Kinneret)*. The Jerusalem Institute for Israel Studies (Hebrew).

Feitelson, E., Fischhendler, I., & Kay, P. (2007). The role of a central administrator in managing water resources: The case of the Israeli water commissioner. *Water Resources Research, 43*(11), 1–11.

Feitelson, E., Tamimi, A., Bein, A., Laster, R., Marei, A., Rosenthal, G., & Salahout, S. (2011). *Defining water needs for fully exploited resources: A necessary step for Israeli-Palestinian reconciliation*. Jerusalem: The Jerusalem Institute for Israel Studies, Green Cross International and Peres Institute for Peace.

Feitelson, E., Seltzer, A., & Almog, R. (2014). Water history facets of landscape change in Israel/Palestine 1920–1970: A question of scale and periodization. *Water History, 6*, 265–288.

Fine, T., Segev, S., Lavie, R. (2007). *Precipitation and climatic zones in Israel*. CET: Center for Educational Technology (Hebrew). http://lib.cet.ac.il/pages/item.asp?item=9591

Fischhendler, I. (2008). Institutional conditions for IWRM: The Israeli case. *Ground Water, 46*(1), 91–102.

Friedler, E. (2001). Water reuse – An integral part of water resources management: Israel as a case study. *Water Policy, 3*, 29–39.

Furman, A., & Abbo, H. (2013). Groundwater management in Israel. In N. Becker (Ed.), *Water policy in Israel: Context, issues and options* (pp. 125–136). Dordrecht: Springer.

Gelpe, M. (2010). Legal framework for allocation of water and for protection of water quality in Israel. In A. Tal & A. A. Rabbo (Eds.), *Water wisdom: Preparing the groundwork for cooperative and sustainable water management in the Middle East*. New Brunswick: Rutgers University Press.

Gilmont, M. (2014). Decoupling dependence on natural water: Reflexivity in the regulation and allocation of water in Israel. *Water Policy, 16*, 79–101.

Gvirtzman, H. (2002). *Water resources in Israel*. Jerusalem: Yad Izhak Ben Zvi.

Hacohen, D. (1994). *Immigrants in Turmoil: The great wave of immigration to Israel and its absorption 1948–1953*. Jerusalem: Yad Izhak Ben-Zvi.

Hadas, E., & Gal, Y. (2012). Inter-sector water allocation in Israel, 2011–2050: Urban consumption versus farm usage. *Water Environment Journal, 28*, 63–71.

Inbar, Y. (2007). New standards for treated wastewater reuse in Israel. In M. K. Zaidi (Ed.), *Wastewater reuse—Risk assessment, decision-making and environmental security* (pp. 291–296). Dordrecht: Springer.

Israel Ministry of Environmental Protection. (2005). *Effluent quality standards – Inbar Committee* (Hebrew). http://old.sviva.gov.il/bin/en.jsp?enPage=BlankPage&enDisplay=view&enDispWhat=Object&enDispWho=Articals%5El3576&enZone=vaadot_tkina

Israel Ministry of Environmental Protection. (2010). *Israel's second national communication on climate change*. Submitted under the United Nations Framework Convention on Climate Change.

Israel Ministry of Health. (2011). *Final activity report for 2010*. Israel Nature and Parks Authority, environmental unit, the water quality domain (Hebrew).

Israel Nature and Parks Authority. (2012). *Wastewater collection and treatment and effluent utilization for agricultural irrigation – A national survey – 2010*. Prepared for the Water Authority, May 2012 (Hebrew). www.water.gov.il/Hebrew/ProfessionalInfoAndData/Water-Quality/DocLib1/seker-kolhin-2010.pdf

Israel Water Authority. (2010). *A long-term master plan for the water sector – Policy document of the State of Israel*. Ministry of National Infrastructures, Water Authority, Planning Department.

Israel Water Authority. (2011). *The state of Israel: National water efficiency report*. Planning Department of the Israeli Water Authority, April 2011.

Israel Water Authority. (2012). *Master plan for the National Water Sector – Policy document of the State of Israel*. Ministry of National Infrastructures, Water Authority, Planning Department. www.water.gov.il/Hebrew/.../09-Israel-Water-Sector-Master-Plan-2050.pdf

Israel Water Authority. (2013). *Water allocations for 2016*. Water division regulation, licensing department. www.water.gov.il/Hebrew/ProfessionalInfoAndData/Allocation-Consumption-and-production/20131/water-quantity-2013.pdf

Israel Water Authority. (2015a). *Book of water and sewage rates – Rates for water and sewage consumers*. Economics Division. www.water.gov.il/Hebrew/Rates/DocLib1/water-prices-book-1.1.15.pdf

Israel Water Authority. (2016a). *Water consumption by purpose, 1998–2015*. http://water.gov.il/Hebrew/ProfessionalInfoAndData/Allocation-Consumption-and-production/Pages/Consumer-survey.aspx

Israel Water Authority. (2016b). *Desalination plants in Israel*. www.water.gov.il/Hebrew/Planning-and-Development/Desalination/Pages/desalination-%20stractures.aspx

Israel Water Authority. (2016c). *Annual report for the year 2015*. The Government Water and Sewage Authority.

Israel Water Authority. (2016d). *Water consumption for 2014 summary report*. http://water.gov.il/Hebrew/ProfessionalInfoAndData/Allocation-Consumption-and-production/20143/hakdama.pdf

Israel Water Authority. (2016e). *Water allocations for 2016*. Water division regulation, licensing department. www.water.gov.il/Hebrew/ProfessionalInfoAndData/Allocation-Consumption-and-production/20162/water-allocations-end-of-2016.pdf

Israel Water Authority. (2018). *The government water and sewage authority* (Hebrew). www.water.gov.il/Hebrew/Rates/Pages/prices-archive.aspx

Israel Water Commission. (2002). *Water in Israel – Consumption and production 2001*. State of Israel, Ministry of National Infrastructures, Water Commission, Demand Management Division, December 2002. http://gwri-ic.technion.ac.il/pdf/wcom/demand.pdf

Israeli Ministry of Agriculture and Rural Development. (2010). *Irrigated agriculture – The Israeli experience*. www.water.gov.il/Hebrew/ProfessionalInfoAndData/2012/13_Israel_Water_Sector-Water_and_Agriculture.pdf

Israeli Ministry of Agriculture and Rural Development. (2013). *Agriculture in Israel – Term summary* (Hebrew). www.moag.gov.il/NR/rdonlyres/0917C695-A29C-41A5-9CB3-5662E6C7B2B0/0/shulhan_mankal_23.pdf

Israeli Ministry of Agriculture and Rural Development. (2015). *Special agreements and administrative benefits of the development policy*. Agricultural Investment Administration (Hebrew). https://bit.ly/2GbevxL

Jueschke, E., Marschner, B., Tarchitzky, J., & Chen, Y. (2008). Effects of treated wastewater on the dissolved and soil organic carbon in Israeli soils. *Water Science and Technology, 57*, 727–733.

Kislev, Y. (2011). *The water economy of Israel* (Policy Paper No. 2011.15). Taub Center for Social Policy Studies in Israel. http://taubcenter.org.il/wp-content/files_mf/thewatereconomyofisrael.pdf

Kislev, Y. (2013). Water in agriculture. In N. Becker (Ed.), *Water policy in Israel: Context, issues and options* (pp. 51–64). Dordrecht: Springer.

Lavee, D. (2010). The effect of water supply uncertainty on farmers' choice of crop portfolio. *Agricultural Water Management, 97*(11), 1847–1854.

Lavee, D. (2011). Cost-benefit analysis of alternative wastewater treatment standards: A case study in Israel. *Water Environment Journal, 25*(4), 504–512.

Lavee, D., Ritov, M., & Becker, N. (2011). Is desalination the most sustainable alternative for water-shortage mitigation in Israel? *International Journal of Sustainable Economy, 3*(4), 410–424. https://doi.org/10.1504/IJSE.2011.042796.

Mecler, B. (2018). *Water allocation for agriculture*. www.mekler.co.il/hozrim/item/3602-%D7%94%D7%A7%D7 %A6%D7%90%D7%AA-%D7%9E%D7%99%D7%9D-%D7%9C%D7%97%D7%A7%D7%9C%D7%90%D7%95%D7%AA-2016-2018.html

Melloul, A., & Collins, M. L. (2006). Hydrological changes in coastal aquifers due to sea level rise. *Ocean and Coastal Management, 23*, 2015–2029.

Nir, D. (1989). *Beth-Shean Valley: The region and its challenges on the fringe of the desert* (3rd ed.). Tel Aviv: Hakibbutz Hameucahd (Hebrew).

OECD. (2010). *OECD review of agricultural policies: Israel 2010*. OECD Publishing. ISBN:978-92-64-07934-2.

OECD. (2011). *OECD environmental performance reviews: Israel 2011*. OECD Publishing. https://doi.org/10.1787/9789264117563-en.

Pareto Engineering Ltd. (2003). *Final report of the committee for establishing wastewater treatment standards* (Inbar Committee) (Hebrew). http://www.sviva.gov.il/InfoServices/ReservoirInfo/DocLib2/Publications/P0301-P0400/P0321.pdf

Pasternak, D., Aronson, J. A., Ben Dov, J., Forti, M., Mendliger, S., Nerd, A., & Sitton, D. (1986). Development of new arid zone crops for the Negev desert of Israel. *Journal of Arid Environments, 11*, 37–59.

Plaut, S. (2000). *Water policy in Israel*. Institute for Advanced Strategic and Political Studies, Policy Studies, 47.

Reichman, S. (1979). *From foothold to settled territory, 1918–1948*. Jerusalem: Yad Itzhak Ben-Zvi.

Reichman, S. (1990). Partition and transfer: Crystallization of the settlement map of Israel following the war of independence 1948–1950. In R. Kark (Ed.), *The land that became Israel*. New Haven/Jerusalem: Yale University Press/Magnes Press.

Rejwan, A. (2011). *The state of Israel: National water efficiency report*. Prepared by the Planning Department of the Israeli Water Authority. www.water.gov.il/Hebrew/ProfessionalInfoAndData/2012/04-The-State-of-Israel-National-Water-Efficiency-Report.pdf

Sagi, G., & Shisha, A. (1999). Advanced wastewater treatment, in modular field systems, for unrestricted irrigation. *Water and Irrigation, 390*, 11–13 (Hebrew).

Seltzer, A. (2010). *Mekorot: The story of the Israel national water company – The first 75 years*. Jerusalem: Yad Ben-Zvi.

Shaviv, A., Zaida, M., Tarchitzky, J., & Goldratt, T. (2011). *Water and agriculture: Summary and recommendations of the discussion forum water, no. 2*. Haifa: The Samuel Neaman Institute (Hebrew).

Singer, G. (2011). *Over troubled water: The establishment of the water authority as a case of implementation of government decisions in Israel*. Unpublished MA Thesis, School of Public Policy, The Hebrew University of Jerusalem (Hebrew).

State Commission of Inquiry on water management in Israel. (2010). *Committee Report* (Hebrew). http://elyon1.court.gov.il/heb/mayim/doc/sofi.pdf

The Israel Export International Cooperation Institute. (2013). *Israel's agriculture*. www.moag.gov.il/agri/files/Israel's_Agriculture_Booklet.pdf

U.S. Library of Congress. (1988). *Israel: A country study*. Washington, DC: GPO for the Library of Congress.

Ventura, Y., Eshel, A., Pasternak, D., & Sagi, M. (2015). The development of halophyte-based agriculture: Past and present. *Annals of Botany, 115*, 529–540.

Yermiyahu, U., Tal, A., Ben-Gal, A., Bar-Tal, A., Tarchintzky, J., & Lahav, O. (2007). Rethinking desalinated water quality and agriculture. *Science, 318*, 920–921.

Yunger, M., Carmon, N., & Shamir, U. (1993). *Who benefits from Israel's water resources?* Haifa: Technion, Center for Urban and Regional Studies (Hebrew).

Zaide, M. (2009). *Drought and arid land water management*. United Nations Commission on Sustainable Development (CSD)-16/17 National Report Israel.