# Advanced Agriculture as a Tool Against Desertification

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October 2000

## Introduction

Desertification affects arid regions throughout the world, inflicting destitution on the populations of vast areas and threatening them with famine. Reversing the process by which the desert invades arable land and turns it into a desolate waste is one of the most crucial challenges facing the communities and nations of arid regions.

Confronting the problems caused by desertification requires tremendous efforts. An essential prerequisite for success is a dedicated leadership aware of the problems, willing to allocate adequate financial resources and to introduce effective agrotechnological methods - and endowed with perseverance.

From the very inception of modern Israel, settling the desert and turning it into farming land was considered a matter of national priority. First by trial and error and later on through research and development, agricultural know-how was incorporated into practice and became a highly useful tool for turning the desert into productive and habitable land.

The major transition from traditional to modern agriculture was based, from the very beginning, on changing attitudes with regard to the supply of water to the arid regions, combined with suitable adaptation and implementation of advanced agricultural methods and accumulated experience.

The pivotal role of water supply for agricultural purposes in the arid and semiarid regions of Israel will be discussed in detail.

## Background

Although the State of Israel borders the Mediterranean Sea, its climate is profoundly affected by the proximity of vast tracts of desert to the south and east. Precipitation is limited to the winter season, which extends essentially from November to March. Annual rainfall averages between 400 and 800 mm. in the north and west of the country and declines sharply toward the south and east, dropping almost to zero. Thus, most of the area of Israel is characterized by semiarid and arid conditions. About 60% of the country is classed as arid and needs to be irrigated all year round to sustain agriculture, and even where precipitation is relatively high - in the northern and western parts - summer crops require irrigation between April and October. The more aridic areas are characterized by stronger solar radiation and higher levels of water evaporation from the ground surface.

All over the country, but much more so in the southern and eastern regions, the annual precipitation varies considerably from one year to the next. Under such climatic conditions the water supply picture is one of a fragile balance between supply and demand.

## Agriculture under arid conditions - An historical perspective

### The Negev before 1948

Until 1948, the year of the establishment of the State of Israel, the southern part of the country, called the Negev, was inhabited mainly by nomadic Bedouin tribes. The Bedouin - who numbered some 65,000 at that time and were spread out over an area of about 10,000 sq. km. - subsisted principally on sheep, goat and camel herding. The Bedouin tribes moved around periodically in search of pasture and water. Being wholly dependent on erratic seasonal rains and floods, they were often short of food for themselves and for their flocks.

In certain areas - mainly the northern and western Negev - semi-nomadic Bedouin practiced a subsistence agriculture which relied wholly on the erratic rainfall. The crops grown were mainly barley and wheat, and farming was restricted to winter and early spring crops. Drought and crop failure were frequent events.

An additional type of farming practiced on a very small scale by the Bedouin was based on the stone dams erected by the ancient Nabateans and Byzantines. Such dams, supplemented by simple barriers made of dirt, were used to collect floodwaters and promote deep wetting of the ground. Under such conditions they were able to plant a small number of fruit trees, such as grape, almond and pomegranate and to cultivate vegetables during the summer.

### First Modern Agricultural Settlements in the Negev

The officials of the ottoman Empire who ruled Palestine until 1917, and later the British Mandatory authorities, saw the Negev as uninhabitable territory whose main importance was strategic and political. Therefore, little effort was invested in developing the region and improving the standard of living of its inhabitants.

The Jewish community, on the other hand, showed particular interest in the vast uninhabited tracts of the Negev from the very inception of the agricultural settlement drive at the end of the l9th century. A small number of studies and surveys were carried out in the 1920s. These pointed to a pessimistic conclusion - namely that scanty rains, lack of local sources of water and infertile soils precluded successful farming. Furthermore, the agrotechnologies available at the time did not offer ways of overcoming local environmental limitations. There is no doubt that the early surveyors were influenced by the meager, rain-fed agriculture practiced by the Bedouin.

At a later date, it was realized that the establishment of small communities to explore local conditions was essential to planning future settlement in the Negev. In 1943 three experimental settlements were established in the Negev, each roughly 30 km. distant from the others. The main aim was to explore soil conditions, availability of water (including data on annual precipitation), and the kind of crops that could be cultivated under the prevailing conditions. Another eleven settlements were founded in the Negev in 1946, equipped and financed by Jewish national institutions, and a further five settlements in 1947.

From the very beginning of this pioneering endeavor, it was apparent that the main limiting factor from the standpoint of agriculture was the scarcity of water. The recognition that the establishment of a modern and economically viable agriculture hinged on irrigation, which in turn called for a reliable supply of water, led to the launching of a series of exploratory studies. These included meteorological, geological and hydrological surveys. Attempts were made to drill wells and draw underground water; however, the quantities obtained were quite small, and the salinity of the water was often too high for agricultural use. Attempts to build dams and reservoirs to collect seasonal floodwaters failed because of the large fluctuations from year to year in quantity and intensity of the floods, as well as technical difficulties. Eventually it was concluded that the only way of securing a dependable and sufficiently large supply of water for agriculture was to transport fresh water from northern sources via pipes.

The first pipeline, installed in 1947, assured a reliable but limited supply of water to most of the settlements of the Negev - although several of them still needed to rely on local wells. This pipeline transported water from wells in the northern Negev. The first stage, installed and functioning in 1947, consisted of l90 km. of 6"-diameter pipelines supplying one million m3 (MCM) annually. Later on this line was converted to a 20" pipeline supplying 30 MCM annually. This pioneering endeavor was followed by two large-scale projects which will be described below. The significance of this pioneering pipeline was that the concept of transporting water from the north to sustain the southern arid section of the country had become firmly established.

**Agricultural Settlements in the Negev after 1949**

Shortly after the establishment of the state of Israel in 1948 a large influx of immigrants took place. A relatively large proportion of the new immigrants were directed to new settlements, many of them in the southern region of the country. Proper supply of water was a precondition for inhabiting a region which lacked sufficient local resources of water for farming and domestic use. A comprehensive system for supplying water was therefore called for.

The first large-scale project constructed to provide the new settlers with an adequate water supply system was a 66"-diameter pipeline drawing water from the Yarkon River to the Negev over a distance of 130 km. The annual output of this line was about 100 MCM.

The second large-scale project was the National Water Carrier, the most ambitious water supply project to date, designed mainly to convey water to the southern region of the country from the Kinneret (Sea of Galilee) in the north. The plans were approved in l956, and the carrier was completed and functioning by 1964. The carrier is a combination of underground pipelines, open canals, interim reservoirs and tunnels supplying about 400 MCM annually. Water from the Sea of Galilee, located about 220 m. below sea level, is pumped to an elevation of about 152 m. above sea level. From this height the water flows by gravitation to the coastal region, whence it is pumped to the Negev. In addition to water from the Sea of Galilee, the NWC is supllied by two large aquifers, the Mountain Aquifer and the Coastal Aquifer, The National Water Carrier functions not only as the main supplier of water, but also as an outlet for surplus water from the north in winter and early spring and a source of recharge to the underground aquifers in the coastal region.

## Israel's water resources and supply: Policy and management

As mentioned earlier, the problem of an adequate water supply for agriculture began to preoccupy the leadership of the Jewish community long before the State of Israel was founded. Soon after the state's establishment in 1948, the issue of water was assigned top priority. Urgency was seen not only in planning and carrying out projects and securing funds, but also in consolidating a legal framework which would regulate all the elements pertinent to the matter of water supply. Accordingly, in l959 the comprehensive Water Law was passed in the Knesset. The Water Law states that all sources of water in the state are public property, subject to the control of the state and dedicated to the needs of its inhabitants and the development of the country. Each person is entitled to obtain water and to use it, subject to the provisions of the Law. Three central institutions created by the Law - the water council, the water commission and the court for water matters - are charged with carrying out a comprehensive and balanced policy of water production and supply on the national level.

### Management of Water Resources in Israel

Total available water in Israel averages about 2,000 MCM annually. The main consumers are the agricultural, domestic and industrial sectors, with agriculture accounting for 60 - 72% of total water consumption.

About 90% of the fresh water resources have been incorporated into a single system that enables implementation of a uniform national policy of water production and regular supply to the different sectors of consumers (agriculture, domestic and industry). To conserve and protect Israel's water resources, currently exploited almost to the limit, several measures have been taken by the Water Commision:

1. Allocation of water quotas. Each sector is assigned an annual quota of water. The policy of allocation depends on the water balance, which may vary from one year to the next.
2. Institution of sliding price scales varying according to sector. The individual consumer, be he farmer or city dweller, pays a higher price for water consumed beyond the allocated quantity.
3. Recycling of sewage water. Increasing quantities of sewage water have been finding their way into the environment and endangering groundwater and other sources of fresh water. The pressing need to find alternate sources of water supply, together with the critical condition of the environment, led the authorities to set up the Shafdan plant, a large-scale project for processing sewage to produce purified water. The process allows the same water to be used twice.

   The treated water is recharged to a nearby aquifer. Two major benefits result: a) percolation of the water through the soil layers provides an additional cleaning phase, and b) the aquifer serves as an underground reservoir for the recharged water, preventing loss by evaporation. Water is pumped off when needed, i.e., mainly in summer. About 100 MCM of this purified water is transported annually via a separate pipeline called the "Third Negev Pipeline" to the western Negev for irrigation. Due to the high degree of purity of the treated water, it can be used for all crops without any health risk.

Additional plants for processing sewage water for irrigation are under construction or on the planning boards. It is expected that most of the water allocated for agriculture will eventually consist of purified effluents.

Smaller-scale plants in the Negev provide treated sewage water for irrigation of fields located a short distance from the source of the effluent. This water is of inferior quality because of minimal treatment, and use is restricted to irrigation of crops such as cotton in the summer. Small projects of this type are reported to be highly cost-effective.

While the benefits of recycling treated sewage water are indisputable - contributing to the water reserves by providing a substitute for the use of fresh water in agriculture and reducing pollution - there is one drawback which must be considered: domestic and industrial effluents are saltier than the fresh water supplied (due to detergents and salt in dishwashers and salt and other chemicals used by industry). As a result, the concentration in salts in recycled water is about twice that in fresh water, and irrigation with recycled water causes a gradual salination of the soil.

The problem of soil salination can be overcome by regularly monitoring salt concentrations and by flushing out accumulating salts downwards from the soil layer where the roots are active. The option of desalinating treated effluents will have to be given serious consideration in the future.

4. Exploitation of saline (brackish) water. Hydrogeological surveys have revealed that the Negev and the Arava valley possess considerable reserves of saline underground water with a variable concentration of salts. Many studies have been carried out to investigate whether this water can be used for irrigation. It was found that certain crops, such as cotton, tomato and melon, readily tolerate saline water (up to 7-8 dS/m electric conductivity, equivalent to salinity of 0.41-0.47% NaCl). For certain crops, there is no doubt that saline water can be used for irrigation in place of fresh water. However, to minimize accumulation of salts around plant roots and facilitate leaching away of salts that do accumulate, it is essential a) to use drip delivery systems and b) to cultivate the plants in soil-less medium or light soils (sandy or loamy-sandy soil).

**Advanced Methods of Irrigation**

One of the principles of good agricultural practice is to provide developing plants with an adequate water supply - i.e., to avoid excess standing water and to prevent exposure to water shortage. Excessive amounts of water can cause poor aeration of the root system leading to inhibition of plant development, or wasteful percolation through the soil beyond the volume of the root system, or both. A water deficit places the plant under stress and interferes with its normal development. Avoiding water stress is particularly important in arid regions, where high solar radiation and low humidity enhance evapotranspiration (the process of loss of water from the ground surface and plant canopy).

Efficient use of water is crucially dependent on advanced irrigation technologies, and nowhere more so than in arid-land farming. Until about 50 years ago, crops in this country were irrigated by surface (flood and furrow) irrigation. Surface irrigation is possible only when the ground is leveled and the soil type enables slow or moderate percolation of the water. Under arid conditions, surface methods of irrigation lead to severe loss of water by evaporation and by percolation beyond the developed root system, especially in the stages of germination and early development; moreover, between irrigation sessions the plants are exposed to stress. Another negative aspect of surface irrigation under arid and semiarid conditions is the process of soil salinization. The prevailing high temperatures and low humidity cause intense evaporation from the ground accompanied by accumulation of salts in the upper layers of the soil. The soil gradually becomes unfit for cultivation, both because of the destruction of the soil and due to the direct effect of the high concentration of salt on the plants. Vast areas in arid and semiarid regions of many countries affected by salinization have indeed had to be abandoned.

Pressurized irrigation with sprinklers, introduced about 50 years ago, contributed much to modernizing agriculture and increasing water use efficiency. However, from the standpoint of agriculture in arid and semiarid regions, the most important development has been the introduction of drip irrigation. Drip irrigation was developed in Israel and introduced into Israeli agriculture less than 35 years ago. Since then it has been disseminated all over the world with great success.

Drip irrigation has many advantages over other irrigation methods:

- Water is discharged uniformly along the lateral (pipe fitted with drippers) even on moderately sloping terrain. The invention of compensated drippers enables uniform irrigation of steeper slopes and long distances.
- Fertilizers can be supplied to the plant via the drippers together with the water (fertigation).
- Water and fertilizers are delivered directly to the root system rather than to the total area of the field, thereby economizing on both water and fertilizers.
- The quantity of water delivered can be optimized to fit different soil types, avoiding percolation of water beyond the root zone.
- The emergence of weeds is minimized.
- Exploitation of poor quality water (saline water or effluents) is made possible.
- Drippers with a given discharge of water (liters per hour) can be installed at any spacing to accommodate the needs of any crop.
- Drip irrigation is the most efficient method as regards water saving. Since the drippers emit the water directly to the soil adjacent to the root system, which absorbs the water immediately, evaporation to the air is minimal. This effect is especially important under the conditions prevailing in arid zones.
- In irrigation by sprinklers or by surface methods, evaporation is enhanced by winds; by comparison, in drip irrigation the impact of winds is minimal.
- Drip irrigation, unlike sprinkler irrigation, makes it possible to utilize saline water by eliminating direct contact between the water and the leaves, thus avoiding burns.

- Drip irrigation causes salts to be continuously washed away from the root system, avoiding salt accumulation in the immediate vicinity of the roots when irrigating salinized soils or irrigating with saline water.
- Drip irrigation allows the use of sewage water because the water is delivered directly to the ground, minimizing health risks.
- High-quality drip irrigation equipment can last for fifteen to twenty years if handled properly.

A new, modified drip irrigation system has recently been developed for small-time farmers. Known as the "family drip system" or the "gravitation drip system", it is designed for use where both the water supply and the financial means are very limited. A simple container - such as a barrel or a hand-built container coated with a plastic layer - is filled with water and positioned about one meter above the ground. By opening a valve, the water flows by gravitation into the drip system. The container can be refilled using a manual pump, and fertilizer may be added to the water, as in the conventional drip system.

- Water use efficiency (WUE), is the ratio between the amount of water taken up by the plant and the total amount of water applied. studies show that while WUE is about 45% in surface irrigation and 75% in sprinkler irrigation, in drip irrigation it is about 95%. Consequently, it may be concluded that drip irrigation has many advantages over other methods of irrigation and that it is significantly superior to surface and sprinkler irrigation in regard to water saving, especially under conditions of limited water supply.

- Cultivated Land (square meters per person) (graph)
- Water for Irrigation as Percentage of Total Supply (graph)

**The Role of Research in Arid Zones**

From the very early exploratory agricultural communities in the arid regions of Israel to the large settlement projects and all the way to the present, there has been a continuous and fruitful interaction between farmers and scientists. Many problems deriving from the conditions specific to arid regions have been studied by researchers, leading to successful solutions and innovative discoveries. Among many others are the development of methods for bettering salinated soils, the use of saline water for irrigation, the development and breeding of new varieties of vegetables and other crops, and the methodology for incorporating fertilizers in irrigation water by means of drip systems.

The extension services offered to farmers by the Ministry of Agriculture have been instrumental in the introduction to the farmers of advanced agrotechnologies, new varieties and proper agricultural management. The existing close cooperation between farmers, extension officers and researchers is the main factor contributing to the success of farming in the arid Negev.

In the light of the review presented here, it is suggested that Israel can serve as an effective model for many regions afflicted by similar arid conditions.

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