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MODERN IRRIGATIONS, A PREMISE FOR AN EFFICIENT MANAGEMENT OF THE WATER RESOURCES IN ISRAEL

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Abstract

In Israel, water is a very precious environmental factor. Although it is a small country, because of its position at the interference of three distinct geographic regions, according to the quantities of precipitations, Israel is divided as follows: the North (Kinnert and Har Hermon), the coastal region of the Mediterranean Sea and the South (Judea and the Negev Desert). So, to compensate the water deficit in the south, the water resources were reunited in a national network coordinated by Mekorot's National Water Carrier, a system made up of pumping stations, reservoirs, canals and pipes. Thanks to its use, the irrigated land used in agriculture grew from 30,000 ha in 1948 to over 200,000 ha at present. Beside aspersion, advanced water use techniques have been introduced, including dropwise irrigation, which introduces the water directly to the plants' root area, in quantities directed by electronic sensors. They determine the moment when the water reserve drops to values near the critical thresholds of the different cultures, indicating the period and the area in which one needs to take action by supplementary watering. Our researches have approached a few areas by means of case studies, differentiating between the management of the underground water, residual water and desalinated water. So, the results obtained will contribute to a more efficient management of the water resources in this area, assuring the efficiency of the sustainable development programs in Israel.

Keywords: dropwise irrigation, computerised distribution, Negev Desert, Israel,

The total area irrigated worldwide is estimated either at about 250-280 million ha based on the official reports received by FAO and ICID (International Commission on Irrigation and Drainage), or at over 400 million ha (data provided by IWMI (International Water Management Institute). This discrepancy is mainly due to the fact that two states, China and India, which hold over half of the worldwide irrigated surface, practice double cultures on large areas, using surface water sources for 60 % of their irrigated lands and underground water for about 20% of their irrigated lands. Using the FAO data concerning the beginning of this century, the distribution of the irrigated areas on continents is: Asia - 68%, America - 17%, Europe – 9%, Africa -7% and Australia and Oceania – 1%. On hydrographic basins, the largest irrigated areas are situated in the basins of: Ganges-Brahmaputra, Indus, Yangtze, Nile and Mississippi-Missouri.

Compared to these values of the irrigated areas worldwide, the one in Israel is minute, because of the total of 200,000 ha irrigated or watered, proportional to the dimensions of the state of Israel, both as area (20,770 km^2), and as population (estimated to 7,879,500 inhabitants in 2012). 2000 ha use only desalinated or treated waters. Being situated at the interference of three distinct geographic regions from the viewpoint of their water resources: the North (Galilee and Mount Hermon), richer in water resources, the coastal region of the Mediterranean Sea, with satisfactory resources, and the South (Judea and the Negev Desert) with an acute water deficit, for Israel, the water issue is of national interest. This is why, even since 1959 when the water law was adopted, by which the individual or the group ownership over water resources was brought to an end, a new organism was instituted subordinated to the Government: the Water Council, meant to manage the country's water resources. In this way, the state-run company "Mekorot" was constituted, to assure the management of the water resources, which include the underground waters, the residual waters, the desalinated water and a know-how element, the artificial rain. For this reason, the scientific research and the integrated management of the water resources under the limited conditions of the environmental conditions in this area have a special role. The main water sources are: the Jordan River, the Sea of Galilee, a few smaller rivers in the north of the country and the aquiferous structure Jarcou-Rosh Ha'ayin in the central area (Fig.1) accompanied by a few superficial aquiferous structures in the Coastal Plain or the deeper ones from the Negev Desert. On a national level, the annual water renewal capacity is of 1.8 billion m^3, of which over 70% are meant for agriculture, so that the management of the efficient use of the water resources available constitutes a priority in the country's sustainable development programs. Due to the technologies applied, the implementation of the irrigation systems in the arid and semi-arid areas cannot be supported in the long run, as the waters used in this sense contain salts, and the evaporation process in the plant and in the soil concentrates the salts in the vegetal organism. So, the salt needs to be extracted through adequate drainage networks, in order to avoid the salinization of the soil; this method is used in many of the irrigation networks,

yet not in all of them. A major problem in the maintaining of the irrigations is the fact that through the evacuation of the used waters, a phenomenon considered natural until recently, the environment is polluted, as the water in the irrigated fields contains salts, sediments, nutrients and pesticides, all having a negative impact on the ecosystems. The minimization of the pollution through the evacuated waters from the irrigated areas is a challenge for all the nations. The water quantity used for irrigations, its impact on the environment and the importance of the irrigations on the increase of the food production need to be correlated with one another. We need to mention that the level of the productions obtained in the irrigated areas is 2-3 times higher than under natural rain conditions. To conclude, the application of irrigations is essential for the food security of the global population. It is necessary to find solutions so that irrigations may be efficient and sustainable, especially there where the extension of the systems needs to be realized in a controlled way or stopped and where the investments in irrigations and drainage have been declining.

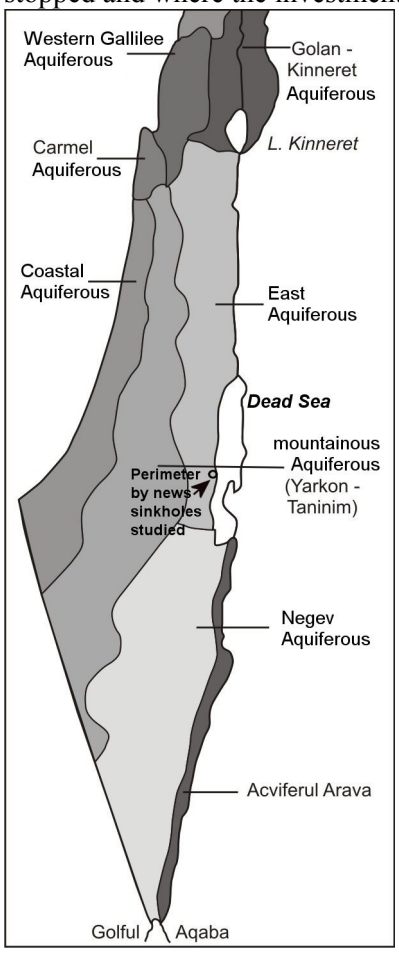

Fig. 1. *Aquiferous structures in Israel* (source: "Mekorot" State-run Company)

Our study has approached as well the examples in which the management of the underground, residual and desalinated waters and, as a know-how element, the irrigations and the artificial rain, is differentiated according to the target of its use. In this way, the results of our research will contribute to a more efficient management of the water resources in this area in the long run, assuring an argument in favour of the sustainable development programs.

Israel, although a small country, due to its position at the interference of three distinct geographic regions that depend on the quantities of precipitations, is divided as follows: the North (Galilee and Mount Hermon), the coastal region of the Mediterranean Sea and the South (Judea and the Negev Desert). So, to compensate the water deficit in the South, between 1950 and 1964, when the National Canal was built, the water resources were reunited in a national network (National Water Carrier), putting together the North with abundant waters and the South lacking water by means of a pumping stations system, reservoirs, canals and pipes. Thanks to the use of this system, the area used in agriculture grew from 30,000 ha in 1948 to over 400,000 ha at present. Nearly half of it is cultivated in irrigated system. Beside the aspersion method, advanced water use techniques have been introduced, including dropwise irrigation, which leads the water directly to the plants' roots. The use of the computerized irrigation system allows for a 50% economy of the used water. The automated irrigations control is realized using complementary electronic sensors, which determine the moment when the water reserve decreases to values that are close to the critical thresholds of the different cultures, deciding the period and area in which action needs to be taken by means of supplementary watering. The automation increases the efficiency of the water application and use, reduces work and economizes the water quantity through recycling. This efficient water management provides great advantages to the agricultural management, yielding very large crops. The irrigation systems in Israel rely on the water sources in the north, the Kineret Lake and the Jordan's basin being the main potable water and irrigation sources. Used waters are also employed, yet only after having passed through several purification systems. Another source is represented by the desalinated waters coming from the Mediterranean Sea (Asdod and Aschelon) and from the Red Sea (Eilat). Although the second water source for irrigations is the coastal aquiferous structure situated along the Mediterranean coast, during the last 150 years, to these one could add a series of depressions in which, due to the circulation of the wet air from the west, a number of 192 swamps had formed, representing 90 % of the wetlands in Israel. The use for irrigations of the waters in these natural basins situated along the coast has resulted in the permanent loss of the water from many marshy basins, only 18 marshy areas surviving so far.

The reasons that determined the loss of the wetlands can be synthesized as follows:

1. Man made, following the excessive urban development and the construction of numerous roads that blocked the drainages of the traditional sources;
2. During the rainy season, the wetlands used to represent 27.6 km^2 by the end of the 19^{th} century, while today, there are just 2.4 km^2 left of them.

3. The sharing of the wetlands into plots of land triggered the isolation of the temporary basins and of the swamps, so that they no longer communicate with one another and are no longer continuous.
4. The wetlands have been polluted through the use of chemical fertilizers in agriculture, the oil dripped on the roads and domestic wastes; these waters then seeped into the soil and then in the water-bearing structures;
5. The intentional drying by man of many of the wetlands, which consequently disappeared especially in the mid-20 century;
6. An example is the huge swamp of the Israel Valley, which was dried to make room for a prosperous agriculture, but also to prevent flooding and diseases such as malaria.
7. The drying of these areas led to a radical change in the sweet waters' ecological system
8. A small part of the swamps present in the past century remained, of which the reserves of HaHula, Ein Afek, the Tamsah.Basin in the Sinai Peninsula or forests on marshy substratum along the Red Sea coast

Alternatives to the water deficit. The water from the springs or from the precipitations, stored in dams or tanks in true "*life reservoirs*" for extended arid areas, has become a main factor concentrating the population in oases, or what we now call a "*polarizing*" human centre. The economic development, along with the blessings it brought to the human society, has also brought different elements degrading the environment (infection of the atmospheric air, of the ground and underground waters, of the soils, residue accumulation, modification of the radiation spectre etc.), which we are now going to present based on the documentation data and following the investigations that we carried out in the field. Among other things, the situation of the used waters has attained, during this last decennium, according to the data of the "Mekorot" company, a state of pollution that has asked for radical decisions from the decisional factors. So, if in 1990, the total used waters in Israel were of 260.5 million m^3 of which 95.5 million m^3 completely untreated, 74 million m^3 treated for the third time, 59 million m^3 treated for the second time and only 24 million m^3 treated just once, in 1995, the treatment capacity assured a 30% increase, so that in 2000, the use potential increased by 60%, but with significant costs. At present, the preservation of these waters' quality has become a vital regional problem for the numerous world states. In our study on the water resources in Israel, we have been preoccupied as well by the future environmental evolution tendency, taking into account as well the impact that the human society here has on itself. Not just in Israel, but also worldwide, the development of the human society and the increase of the population's standard of living has led to important changes in the environmental factors, leading to transformations in the quality of life. First, an evaluation as accurate as possible was made for the water volume available to be used by the economy and by the population, as, considering the need of investments in extracting, treating and directing the water, its price is rising. To these, one can add the costs for the preservation of the environmental factors favourable to human society. This is why we synthesized both the alternatives to the water deficit and the impact of the environmental expenses that society will have to bear under these circumstances:

- taking into account the features of the alternative thermal amplitudes from the arid and semiarid area of Israel (Negev and Judah), an important role goes to the water coming from condensation processes on the soil level, depending on the size and variation of the dew point. A first emergency would be to collect the dew water with adequate technical means, either using captors, adapted to the arid environment, or dew water condensers, regardless of the values of the condensation point;

- also in this context, it is necessary to do the best during the cold semester, which is the rainy season in the case of the arid and semiarid regions in Israel, to collect almost completely the waters coming from the atmospheric precipitations;

- another water category that should be introduced in the irrigation installations systems is the one coming from the desalination of the Mediterranean Sea waters, both the one coming directly from the Israeli coast and the one penetrated in the inner underground waters of the Negev desert (these underground waters may come either from the Mediterranean Sea, or from the Red Sea, or from the Dead Sea), after being extracted through drillings;

- finally, what is needed is a rethinking of the collection, treatment and use of the domestic sewerage from the cities and the rural areas, and of the residual waters after their industrial use, as the new water treatment technologies can bring them back to their superior qualitative parameters; these waters could be used in irrigation by means of canals, sprinklers and dropwise;

- the installation of thermal sensors in the cultivated areas, connected to computerized systems to evaluate the relation between alimentation and evaporation, specific for the different cultivated or decorative plants from the urban or rural area meant to direct the water quantities needed;

- last, but not least, the adaptation of the cultures by means of genetic mutations and the selection of the plant types that can bear different climatic conditions and specific water demands, knowledge that although not being part of our professional specialization, could be transmitted to the decisional factors.

A very large arrangement, which we have presented at the International Symposium of Environmental Geography from Iaşi (October 19-21, 2007) (Cohen, 2007) is the arrangement of the National Canal in Israel, quoted by numerous irrigated agriculture specialists for the economy it brings to the State of Israel. Applying numerous innovations during the years, it managed to increase the production nine times with almost the same water consumption as 40 years ago, due to the National Water Pipe. The idea behind the project is the irrigation of the plants, not of the soil: the plants are watered drop by drop through the soil, as close to the root as possible, taking into account the temperature, the solar radiation, the air humidity and the transpiration of the leaves. The fertilizers are distributed by means of the same system.

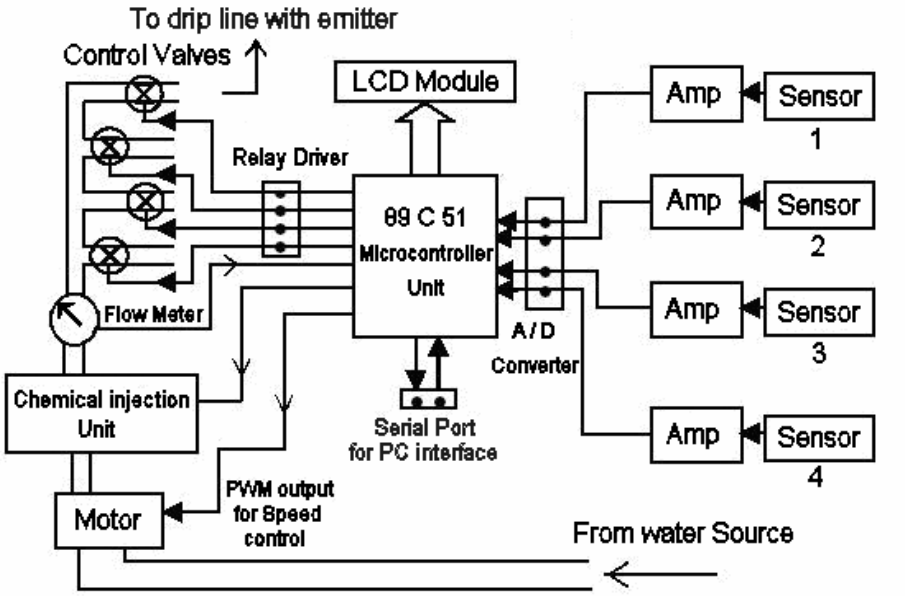

Fig. 2, ***Scheme of a modern coastal irrigation system realized at Ashkelon***
(source: Levin, N., Elron, E. and Gasith, A. 2009)

Integrated water management. Israel can be considered a model of integrated water management model, in the circumstances in which these resources are limited. Only during the last ten years, the water reserves have reached their lowest level. The main sweet water source, the Kineret Lake (Sea of Galilee) has decreased considerably during the last 50 years. The water resources consist in the Jordan River, 13 small hydrographic basins and the Dead Sea. The waters' managerial system includes the underground waters, the residual waters, the desalinated water and a know-how element, the artificial rain. The water law of 1959 put an end to the individual ownership right over the water resources and introduced an allotment administrative mechanism allowing the Israelis to manage the water resources for a long period of time in a beneficial way both for the resource system and for the consumers. The law stipulates that the water resources belong to society and are exclusively designed for it. The volume of the waters is established annually by the Water Authority, yet it depends on the changes in the availability of the water resources and the consumption needs. Two water basin Management Directions administrate the hydrographic basins, so that all the waters remain in the circuit and the treated used waters can be used in dropwise irrigation. In this context, another direction for obtaining water in Israel was the desalination of the underground waters from the Mediterranean Sea. In this way, 4 plants were built to desalinate the waters, and the water obtained was then mixed with the sweet water of the Keneret Lake or the underground water administered by the "Mekarot" state-run company. The water management is the responsibility of the Water Commissary, appointed by the Government, and the designated organism summoning all the parties concerned is the Water Council. At the same time, a special court was created, the Water Tribunal, solving all the litigations between the Government and the water consumers.

Dropwise irrigation. The beginnings of dropwise irrigation can be traced back to the antiquity, when ceramic pots without enamel were used, almost totally buried in the cultivated lands, so that once filled with water, the water seeped through the porosity of the clay and gradually reached the plants. The first modern forms of dropwise irrigation were implemented in Afghanistan, on weakly inclined lands, this time using clay pipes with a significant porosity. Then followed the experiments from the Colorado University,

which concentrated the water infiltration at the roots of some plants, and in the 1920s, in Germany, the irrigation using perforated pipes began to be used. Later on, followed the modifications designed in the USA and Israel, meant to remove the frequent obstruction of the small orifices in the pipes by the particles brought by the unfiltered waters. These modifications included connecting pieces meant to increase the pressure, filters to stop the particles and rubber or plastic pipes that could be removed depending on the characteristics of the cultures (1964). Beginning with this moment, the irrigations on cultivated rows were just one step away; then, in 1989, they were followed by the implementation of the integrated irrigation systems, which, moreover, led to the decrease of the water quantities used for irrigations. Simultaneously to the progresses recorded in the dropwise irrigation technique, in the areas with limited water resources (such as the Negev desert, especially in the south of it) or there where recycled water is used for irrigations, new research directions have emerged. If for the specialists in agriculture the target is the genetic modifications of the cultivated plants, for the geographers, it is the careful study of the lands' topography, of the soils' typology and fertility and of the waters' chemistry that are a must, in order to be able to chose between the different irrigation systems and even to determine the most adequate dropwise irrigation system, depending on the land.

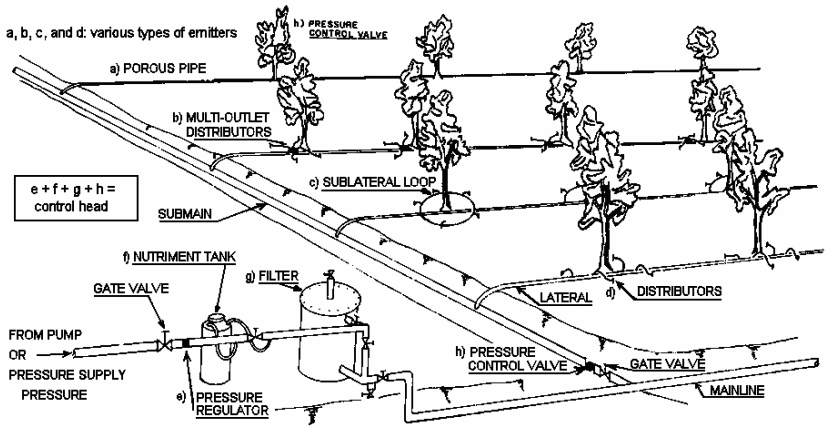

Fig. 3, Scheme of a dropwise irrigation system (source: „Neviot" Company in Negev)

Advantages of the dropwise irrigations systems:

- The quantities of fertilizers and the nutrients loss are reduced by directing the necessary water drops directly to the root of the cultivated plants, without needing a certain frequency, depending on the soil type on which this irrigation system is practiced;
- The levigation of the soils on which dropwise irrigation is practiced is diminished to the maximum and the erosion (both of the area and linear) disappears, while the controlled filtering reduces the risk of obstruction;
- No levelling or geometrization of the land are needed, as dropwise irrigations can be practiced on different land types and regardless of the geodeclivities of the cultivated field;
- Treated and recycled waters enriched with fertilizers, nutrients or herbicides can be used in conditions of maximum security; fighting the weeds is more efficient;
- Humidity in the root area can be maintained at the level that can be supported by the field.
- The water distribution is very uniform, an outlet control being applied for each loop, and the supply variation can be regulated by means of valves and drippers.
- Finally, the use of low pressures compared to other types of irrigation under pressure reduces the energy costs.

Disadvantages of the dropwise irrigation systems:

- The initial costs are much higher than for the suspended irrigations.
- Wastes. The Sun can affect the tubes used for dropwise irrigation, shortening their life. Their longevity is variable.
- Dropwise irrigation pipes demand supplementary expenses for cleaning after picking the crops, so that often they can no longer be used or recycled, which requires new ones.
- These irrigation systems and their components require attentive and permanent studies of all the factors contributing to their installation and use (land topography, soil structure, water chemistry, types of cultures and agro-climatic factors).
- Salinity. Most dropwise irrigation systems are designed for maximum efficiency, which means no leaching, so that the salts in the arid regions may get concentrated at the plants' roots and the soils' impermeability may lead to the appearance of humid areas unfavourable for most cultures.

Perspectives for modern irrigations

Compared to other types of irrigation, the dripwise irrigation uses a smaller quantity of water; evaporation is reduced and the water never reaches a deep drainage, being directed only to the plants' roots. Sure, all these advantages appear only if the installation is correctly designed, installed and managed. Moreover, dropwise irrigations eliminate many diseases transmitted through the contact between leaves and water. In the regions in which the water supply is severely limited, as in the case of Israel, one cannot talk about real water savings but only about a wiser management of this resource. So, using the same water quantity as before, one can obtain significant results in point of the productivity increase. So, in the semiarid and arid areas of Israel, or on sandy lands, the tendency is to use water for irrigation as economically as possible. That is why, in this direction, the most intense efforts are made today to develop new technologies able to assure water for irrigation at very low flows, namely less than 1.0 l / hour. During the last few years, in Israel, such preoccupations have even acquired an international connotation, through the creation of an International Conference[1], an event dedicated to the innovative technologies for water management and control or water treatment. The administration and the management of the water resources has become not just a preoccupation, but also a type of global scientific collaboration as these issues go beyond the boundaries of Israel. The exchange of opinions and knowledge among the specialists plays a major role in finding the best technological or water management solutions. And this, although it is well known, agriculture depends on the climate conditions, even in countries such as the United States and Israel, where the technological level is very advanced. This is the economic sector that depends a lot on the cyclical climatic risks and also on the extreme climatic phenomena. But this does not hinder the specialists from continuing their efforts for the continual improvement of the irrigations systems and from finding solutions to optimize their use, yet without increasing the energy consumption in the efficient water management action. In this context, it is very important to manage the natural environmental factors, which are a chance to assure a sustainable development for society.

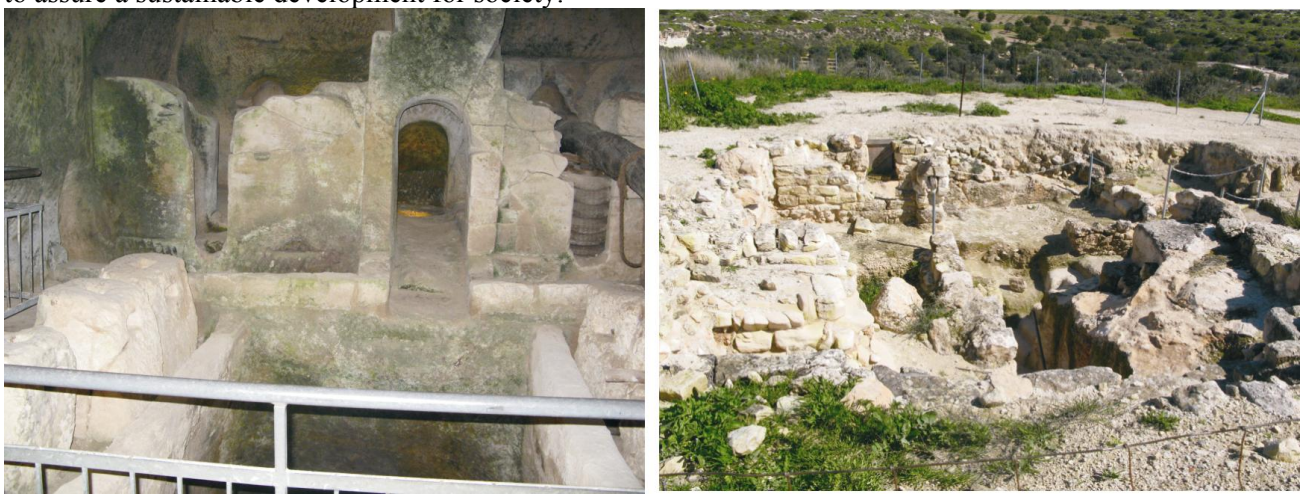

Fig. 4. Underground system water management during the Antiquity at Bet Gouvrin (Judea) photo A; a dropwise irrigation system in Hertzelia (photo B) (source: Adrian Cioacă)

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[1] The latest International Conference of WATEC Israel took place in Tel Aviv, November 15-17, 2011