**Advance farming in the desert - the Israeli experience**

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## Abstract

Desert constitutes 60% of the total area in Israel. The annual precipitation is 100-200 mm and evaporation reaches 2500 mm. Traditional desert agriculture of growing rainfed wheat and grazing sheep, goat and camels is common. Despite the harsh climate conditions, advance agriculture is concentrated in locations where water resources exist. Mild climate season of winter (October-April) is used for growing vegetables, flowers, herbs and fruits, mostly for export to European countries. The key is sustainable management of the local natural resources. The local research and development system is generating adequate knowledge and technologies. The most important factor is developing water resources, and using them efficiently by drip system and protected agriculture (greenhouses and plastic tunnels). The unfit desert soil is substituted by sand and artificial growing media. For gaining market, botanical species of special flower and vegetable crops, avocado, pitaya, jojoba are introduced. Controlled drip irrigation and drainage helps to solve salinity problems. Integrated Pest Management is used to overcome plant protection issues. Advanced raising of milking cows was developed by using heat stress reduction methods. Raising fish in protected ponds and ostriches were adapted to desert conditions. On the southern Judean hills where precipitation is 250 mm, soil conservation work and rain water harvesting has permitted afforestation, which is changing the desert scenery. Farmers, extension agents and research scientists have all contributed to these developments.

## Introduction

Agricultural production and desert conditions are usually considered to be incompatible. Since the desert is an area with adverse climate and soil conditions, it is unattractive for modern agriculture, even though it also has specific characteristics which could be useful for agricultural development and production. It is necessary to identify the advantages and disadvantages of each of these characteristics and existing natural resources before deciding on large-scale development program. For developing modern agriculture, it is necessary to generate know-how and specific technologies needed for the utilization of desert resources. This can only be done by intensive local research under desert conditions.

The success or failure of desert development depends on the human factor. Exclusively dedicated human resource is needed to settle in desert and be able to use scientific and technologically advanced cultivation methods and apply environment control needed for successful performance under adverse desert conditions. This approach requires abundant economic resources. Applying state-of-the- art technologies in greenhouses, makes it possible to control almost all factors influencing plant growth, such as temperature, humidity, radiation, protection from wind, growth media and plant nutrients.

Israel is a small country in the Middle East with a total land area of about 26,000 km$^2$. Sixty percent of its territory is desert, with rainfall not exceeding 200 mm/year and limited to the five winter months (November to the end of March), which is the only rainy season of the year. Only 7% of the total population of Israel lives in this area. However, the Israeli desert is not

homogenous. It includes the Arava Valley extending from the south of the Dead Sea to the northern part of the Red Sea, and which is part of the Afro-Asian Rift Valley. Part of it is below sea level. Dates, mangos, vegetables, flowers and milk are produced in this valley.

Another part of the desert is the central Negev high plateau of 600 m.a.s.l. This area produces bulbs of flowers such as irises, narcissus and gladioli, as well as olives, grapes, melons and vegetables grown in open fields and in greenhouses. Also Tilapia fish are raised in open ponds and in greenhouses with thermal saline water. The northern Negev desert is flat and hilly, covered by loess soils on which rainfed and irrigated wheat, vegetables, flowers, forage, apple, apricot and citrus (mainly lemons) are produced. The north western Negev desert, near the Mediterranean Sea predominantly consists of sand dunes. These dunes can be easily flattened and cultivated. By using drip irrigation integrated with fertilizer application, Israel's most outstanding agriculture is practiced on these once desolate sand dunes, at present citrus, avocado, mango, vegetables and flowers are grown.

The Israeli Negev desert is characterized by wastelands, low population density, a large number of sunny days with high temperature and radiation levels and scarcity of water. Usually, the few existing limited sweet water resources are only found in oasis. However, like in most deserts of the world, deep saline water aquifers are found that may be utilized when applying specific technological methods. Extreme climatic conditions such as strong winds, sand storms and extreme temperatures frequently occur. One of the characteristics of the desert specific Loess soils is development of superficial crust resulting in low water infiltration rate. The rapid sealing of the surface layer once the soil becomes wet causes immediate water run-off in the form of streams even after a short rainfall. The run-off can be harvested and directed into the fields or reservoirs for later use.

## Methodology

This article is based on the approach of sustainable Agriculture. Under these methods, the regional natural resources are examined in order to take advantages of agricultural production. Natural resources as soil, water, crops, animal husbandry, climate and human resource, are investigated in order to reveal their advantages under the local desert circumstances. Regional agricultural research and development (R&D), is being applied in the Negev region and contributes mostly to solve agricultural production problems and introducing adequate innovations. This R&D system is composed of the cooperation of farmer's representatives, local agricultural researchers; extension services agents and representatives of regional authorities. A local R&D committee is in charge to identify the problems and prepare a short and long term local research and extension programs. The same committee monitors the procedures and is in charge of the application practical results. In this article, we present the local natural resources characteristics and after adaptation, their values, which contribute to turn desert into advanced agriculture area.

## "Desert Agriculture" and "Modern Agriculture In The Desert"

As early as almost 3000 years ago, an ancient agricultural system known as the Nabatean Agriculture was successfully practiced in the desert. This system is based on water harvesting

from nearby bare hill slopes. The run-off water, directed to, and accumulated in cultivated plots located at lower levels, contributed to increase soil moisture. Various vegetables and fruits like olives, almonds, figs and others were successfully grown under this system. This system mainly fits small-scale subsistence farming and is not applicable for more advanced agricultural systems. However, the system has high potential for adoption in the Sahel region of Africa or in other desert areas in Africa, Asia and Latin America. Under this system, Eucalyptus trees can be grown for fire wood, Leucaena trees for fodder for goat and sheep and olive trees for oil production for human consumption.

Another type of traditional agriculture, practiced in the hilly Loess-soil area, where rain-fed wheat cultivation take place during the rainy winter season. Precipitation in this desert area is around 200 mm /year. This amount of rainfall can produce 2 t/h of wheat grain. During summer, sheep and goat herds graze on the wheat stubbles. This is the type of agriculture characteristically practiced by the nomad population of the desert, the Bedouins.

Under the new reality and habits of Israel, modern agriculture is developing and has established itself in the desert. This advanced agriculture can be named "Modern Agriculture in the Desert".

**Water**

Modern agriculture in the desert is firstly based on the availability of water for irrigation. We are distinguishing between external and local water resources. External water resources are transported by the "National Water Carrier" over a distance of more than 300 km from the Sea of Galilee in the north of the country. Another external resource is the recycled sewage water from the central urban area of Tel Aviv and its satellites cities with a total population of 1.4 million located 80 to 100 km to the north of the target area. After secondary biological treatment, the sewage water undergoes further treatment. It is filtered through sand dunes down to a depth of 80 m where it is stored for a prolonged period of time. After reaching a very high quality almost comparable to potable water standard, the water is pumped into the distribution system to be transferred south to the desert. These two water resources from the north are either immediately used by the agricultural sector in the south or stored in very big reservoirs in the target area, some of which may contain up to 1.5 million $m^3$ of water.

One of the local water resources is the saline water stored in 1000m deep aquifers. Water is pumped from 700m deep artesian wells. Salinity ranges from 1000 to 2500 mg Cl/L, and the temperature of the water is about 40$^o$ C. The successful use of this saline water requires specific technology.

An Israeli innovation of the early seventies of the last century, the drip irrigation method, makes it possible to use saline water for crop irrigation. Using this method, the relatively long and frequent irrigation applications at a very low water discharge rate, provide a permanent leaching of salts from the root zone. Compared with other irrigation systems, the salt accumulates around the root system which itself remains with relatively low salt concentration. Next season, before starting a new crop in the fields where saline water was used for irrigation, it is necessary to have fresh water for one time flushing and leaching of the accumulated salts to a depth of 1.2 m below the root zone.

Research carried out in recent years identified a long list of crops which are tolerant or resistant to saline water. Among others, they include asparagus, broccoli, beet-root, celery, cabbage, tomato, melon, lettuce, Bermuda grass, Rhodes grass, wheat, sorghum, sugar-beet, cotton, dates, olive and grapes. These crops provide economic yields under a saline water irrigation regime. In some crops, such as tomatoes, the use of saline water leads to a stress response of increased concentration of sugar in fruits yielding"Sweet desert Tomato". In vineyards, the grapes attain a high level of dry matter resulting in the production of high quality wine. Saline water for irrigating olives also improves oil quality.

By using a special sealed pipe system installed near the plants, the thermal water pumped from the well is used for raising the air temperature in the greenhouse during cold nights. After cooling, the same water is reused for irrigation.The thermal water can also be used for the cultivation of tilapia fish raised in fish ponds protected by greenhouses.

**Introduction of new plant species**

Most of the commercial crops produced by Israel's modern agriculture were developed from species introduced from other parts of the world. As in other agricultural fields, research is continuously searching for new species to be adapted to our desert conditions. In the last years, new crops such Jojoba, Opuntia and Pitaya, were commercially introduced from Mexico on a large scale. The introduction process includes various phases like quarantine, and observations in the demonstration plots, and semi-commercial and commercial plots.

**Harnessing climatic variations**

The desert area of the Arava valley, part of which is below sea level, is known for its warm temperatures and mild climate during the winter season. Precipitation in the valley is low and erratic, usually not exceeding 100mm/year and relative air humidity is also low. During winter, when it is cold and rainy in the north of the country, it is the best time for producing off-season vegetables, flowers and herbs in the Arava valley. These products obtain the highest prices in the market and are mainly destined for export. The limiting climate factors to be dealt with are wind and hail storms, and sometimes extreme temperatures. Growing crops under protection in greenhouses is the best solution to this set of problems. The agriculture growing season in this area lasts from September to May.

**Growth medium**

The growing medium in the greenhouses usually consists of sand brought from a local sand dune resource. Other growing media consist of mixtures of sand, compost, rock wool, peat, vermiculite, etc., used as detached media. Irrigation, integrated with fertilizer application, is fully computer controlled. The amounts of water and fertilizers to be applied as well as irrigation frequency are determined by field tests for meeting water and nutrient demands. Special sensors are installed in the plots and used for monitoring soil moisture content and controlling irrigation. In the sandy desert area near the Mediterranean coast, a very advanced agricultural system of citrus, avocado, mango, flowers and vegetables has been introduced. The sand dunes are leveled and cultivated.

Based on the drip irrigation method, high quality recycled sewage water is used for irrigation. The climate in this area is usually mild and the proximity to the sea prevents the frost hazards.

**Control of other factors**

Under greenhouse conditions, air temperature, humidity, radiation and wind streams can be automatically controlled. Insect-proof nets prevent the penetration of the insect pests that would otherwise transmit virus diseases and in addition to causing physical damage to the plants. The plastic sheets used for covering the greenhouse possess Ultra Violet or Infra Red (IR) characteristics, thereby achieving additional advantages. The greenhouse atmosphere enriched by $CO_{2,}$ induced in early morning hours, improves photosynthesis, resulting in higher yields.

**Plant protection**

Pests and diseases, including nematodes and mites, may inflict heavy damage to the crops and indeed are the most serious limiting factor. Virus diseases, transmitted by vectors such as aphids, mites and white-fly, are capable of completely destroying a crop. The existence of the Mediterranean fruit fly, limits the export of fresh produce to the U.S.A. and Japan. As already mentioned, the protection of greenhouses by insect-proof netting and IR plastics is very useful for controlling insects and strongly diminishing the spread of virus diseases. A specific plant protection project running in the Arava valley aims at controlling pest and disease damages. The project is based on isolating the valley from other agricultural areas and isolating the agricultural plots in the valley itself from each other. The principles of the project are:

- Cultivating in autumn, winter and spring and maintaining zero-cropping during mid summer.
- Removing all crop residues and trash immediately after harvesting.
- Monitoring and applying control treatments based on threshold values.
- Introducing beneficial insects for biological insect control.
- Using environmental friendly, biologically un-harmful pesticides.
- Introducing sterile males for controlling the Mediterranean fruit fly.
- Using soil fumigant treatment for soil disinfection. This method however was replaced by solarization. Solarization is a soil disinfecting method, whereby the soil bed is covered during mid summer with plastic sheets for a period of one month. The plastic cover traps sun radiation and increases soil temperatures to more than $50^{o}$ C over a prolonged period of time, thereby achieving the desired soil disinfection effect.

The project, which has already run for 15 years, succeeded to reduce drastically pest and diseases damages, achieved the eradication of the Mediterranean fruit fly in the whole zone, and resulted in permission for exporting agricultural produce to the U.S.A.

**Reforestation**

The northern desert area includes the southern part of the Judean Hills. In this area, precipitation amounts to 250 mm/year. In the past the hills were completely eroded. By using appropriate soil

conservation methods like terracing, fencing with stones and bushes, rainwater is harvested and soil moisture is increased. Species such as *Eucalyptus occidentalis*, *E. stricklandii*, *E. sarangetii*, *Prosopis alba*, P. Juliflora, *P. nigra, Accacia salicina, A. Raddiana, Tamarix, aphylla, Ceratonia siliqua, Pistacia palestina, Pinus halepensis*, and *Pakinsonia aculeata*, are planted in the area and are slowly turning into forests which are completely changing the landscape.

## Raising Tilapia fish, ostrich and dairy cattle in the desert

### Tilapia fish

The existing deep aquifer in the desert is saline and thermal (40°C). Tilapia easily adapts to this type of water. The optimum temperature for harvesting commercially profitable fish (400g) is 30° C. Under these conditions, the life cycle is short, making it possible to obtain two cycles per year, compared with only one cycle for fish raised at normal water temperatures. Fish raising in ponds located in greenhouses with a forced oxygen environment has the capacity of yielding 15 ton per 1000 $m^2$. This is a very capital intensive but profitable agriculture.

### Ostrich

Ostriches are well adapted to desert conditions and can survive on eroded land of very limited alternative use. They efficiently utilize the scarce natural vegetation produced on the pastureland, but also receive some supplementary feed from other sources. The commercial ostrich products are meat, eggs for ornamental purpose, skin for the leather industry and live animals sold for reproduction purposes. All in all, this is a very profitable agricultural enterprise.

### Dairy cattle raised under heat stress conditions

Under heat stress, cattle waste energy for body cooling instead of producing milk; consequently the milk production decreases. Technological innovations were introduced for overcoming heat stress problems. These include: 1) High and well aerated structures; 2) High-potential ventilators; 3) Sprinklers for spreading water droplets; 4) Frequent wetting of the cattle; and 5) Continuous supply of cool drinking water. All these means help reducing the temperature in the cattle shed and diminish heat stress. Under such circumstances, milk production in the hot desert zones can be increased.

## The human factor

Among all factors and resources influencing agricultural development in the desert, the human factor is the most important one. The farmer who nowadays settles in the desert, is usually of a very dedicated, but also strongly economically oriented type, who attempts to exploit the advantages (while overcoming the disadvantages) of the desert environment and by developing and applying relevant knowledge and technologies needed for this purpose.

Under the prevailing Israeli circumstances, the Regional Agricultural Research and Development (R&D) system has proved to be very effective. The system is based on regional cooperation,

between farmers, researchers, extension workers and local regional authorities. Within the framework of such cooperation, the objectives, working plans and allocation of economic resources, are approved and implemented. The aim of this R&D system is to produce the most relevant, immediately needed solutions and practical knowledge and technologies to be used by the farmers for sophisticated and modern agricultural production.

The development of agriculture in the desert requires relatively high capital investments and additional capital for purchasing sophisticated production inputs. The cost of a 1,000 $m^2$ large greenhouse alone is around 100,000 US dollars. Such high investments are justified due to the intensive, sophisticated and profitable farming developed as the result of the cooperative management and research efforts of all participating parties.

Farming settlements in the desert require a well developed regional infrastructure, resulting from physical and social regional planning and development. This infrastructure includes, among others, access roads, communication systems, access to production inputs, credit and banking services, and supporting systems for grading, packing and cool-storage of produce. Supporting technological systems and agricultural extension and research services are also essential as well as advanced leadership.

The settler in the desert needs living conditions that allow him to overcome the harsh climatic conditions. Nowadays, this can be achieved by technological innovations in desert architecture, air conditioning and other related fields. Number of impressive innovations have been recently achieved. All in all, if intelligently managed by dedicated manpower, the desert has a very high potential for human settlement and food production.

## Conclusion

The Negev desert area of the south of Israel is part of the Sahara desert which extends on all North Africa, Sinai Peninsula and the southern Israeli Negev. The moderate climatic condition in the winter season is the main advantage of the Negev desert area. In open fields and in various types of plastics greenhouses, vegetable, flowers and fruits are grown in winter season and exported to Europe to a high purchase consumer's market. As a result, a very efficient profitable agriculture is created. The Regional Agricultural Research and Development (R&D) system is unique and very efficient in providing practical solutions and introducing innovations to farmers. Efficient use of the saline marginal water resource by using the drip irrigation system, developed in1970 in this region by the local R&D system, has permitted growing high value crops. The local R&D system has also succeeded in overcoming the barrier of desert marginal soils, by introducing the efficient artificial growing media and protected agriculture in plastics greenhouses, to overcome extreme climate events. Despite the hot summer condition, a very efficient dairy system has been developed by the local R&D system by reducing the heat stress in cattle. The local human resource is the key factor of success. Most of the farmers have academic degrees and idealistic motivation. The government policy is to develop an advanced regional infra-structure and support mechanism for regional development. The combination of all these factors is enabling the regional development of desert area through a very advanced rentable agriculture giving high income and high standard of living. This example can serve other desert areas in the world.