Sustainable Agriculture Methods to Combat Desertification

The Israeli Experience

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Abstract

Traditional desert nomad agriculture in Israel is based upon growing wheat under rain fed conditions and sheep grazing on harvested wheat fields, as well as growing fruit trees in oasis. What characterize the desert are low precipitation, high evaporation, diverse and extreme climatic conditions, intensive solar radiation and vast land areas. Israeli arid land is composed of five distinguished regions, each with specific characteristics, resulting in few types of modern agriculture. Advanced agriculture in the desert takes advantage of producing off-season vegetables, as well as flowers, fruits, mostly palm dates for local and export markets and fodder for animal husbandry.

Cultivation of tilapia fish is also practiced widely, as is the raising of ostriches. Greenhouses, in which growing conditions are fully controlled, are very common. Water is the most limiting factor. Water resources include: conducting water from out-region resource, the use of saline and thermal water, the harvesting of rainwater, the recycling of sewage water and desalinized sea water. Drip irrigation to economize the use of water and using saline water, are the dominant systems. Reforestation based upon soil conservation-works and rainwater harvesting is applied.

The main reasons for success in agricultural production under arid conditions, is the skilled and knowledgeable human resource.

Introduction

Agricultural production and desert conditions are usually considered to be antagonistic or at the best incompatible. Since the desert is an area with adverse climate and soil conditions regarding as a marginal natural resource, 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.

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 heavily investing in local research under desert conditions. The success or failure of desert development depends on the human factor. There is need for dedicated manpower ready to settle in the desert and capable to use scientific and technologically advanced cultivation and environment control methods needed for successfully performing under adverse desert conditions. For developing and applying these technologies, abundant economic resources are required.

The 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, in most deserts of the world exists deep saline water aquifers that may be utilized when applying specific technological methods. Frequently occurring excessive climate phenomena, such as strong winds, sand storms and extreme temperatures dominate the desert climate.

Modern agricultural production methods, particularly for crops grown under protection in greenhouses which are specifically developed for utilizing the favourable properties of the desert, such as high temperatures and intense sun
radiation, for achieving high production of biomass. Local saline water resources are advantageously used for crop irrigation. 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.

One of the characteristics of the desert specific loess soils is their very low infiltration rate, resulting in rapid sealing of the surface layer once the soil becomes wet and causing almost immediate water run-off in the form of streams and flooding even after a short rainfall. These run-off waters can be harvested or captured and directed into reservoirs for later use.

Israel is a small country in the Middle East with a total land area of about 26,000 km². Sixty percent of its territory is desert, with rainfall not exceeding 200 mm/annum and limited to the five winter months to the end of March, which is the only rainy season of the year. Only 10% of the total population of Israel lives in this area. However, the Israeli desert is not a homogenous complex. 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. Dates, mangoes, vegetables, flowers and milk are produced in this valley, part of which is below sea level.

Another part of the desert is a high plateau of 600-800 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 greenhouses in thermal saline water.

Similarly another part of the desert are the flat and hilly areas covered by loess soils on which rain fed and irrigated wheat, vegetables, flowers, forage, apple, apricot and citrus, mainly lemons, are produced.

The part of the 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 looking sand dunes: citrus, avocado, mango, vegetables, flowers.

Desert Agriculture or 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 slopes. The run-off water, directed to, and accumulated in cultivated plots located at lower levels, is used for increasing soil humidity. 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 practically 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, is rain-fed wheat cultivation during the rainy winter season. Precipitation in this desert area is around 200 mm per annum. This amount of rainfall can produce 2 tonnes/ha of wheat grain. During summer, sheep and goatherds graze on the wheat trash. 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, which the present article is dealing with, may be named “Agriculture in the Desert”.

Water Resources

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 1.2 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.

These two water sources 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 one million m$^3$ of water.

One of the local water sources is the saline water stored in 1000 m deep aquifers. Water is pumped from 700 m deep artesian wells. Salinity ranges from 1000 to 2500 mg/Cl/l, and the thermal temperature of the water is about 40°C. The successful use of saline water requires knowledge and specific technology.

An Israeli innovation of the early seventies, the drip irrigation method, makes it possible to use saline water for crop irrigation. Using this method, the comparatively long and frequent irrigation applications at a very low water discharge rate provide for the permanent leaching of salts from the zone of the plants’ root system. Compared with other irrigation systems, the salt content accumulating around the root system remains relatively low. Before starting a new crop in fields where saline water is used for irrigation, it is also necessary to make an alternative, sweet water system available for flushing and leaching the accumulated salts deep below the crops’ root zones.

Research carried out in recent years, provided a long list of crops, which are tolerant and 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 and cotton. These crops yield commercial yields under a saline water irrigation regime. In some crops, as in tomatoes, the use of saline water for irrigation results in increased concentration of sugar in the fruits. In wine grapes, the grapes attain a high level of dry matter resulting in the production of high quality wine. Using saline water for irrigating olives also improves their 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.

Climate

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/annum and relative air humidity is also low. During winter, when it is cold and rainy in the north of the country, is the best time for producing off-season vegetables, flowers and herbs. These products obtain the highest prices on the market and are mainly destined for export. The limiting factors to be dealt with are wind and hail storms, and some times extreme temperatures. Crops grown under protection in greenhouses are the best solution to this set of problems. The agriculture growing season in this area lasts from September to May.

Soils

The growing media in the greenhouses usually consists of sand which is especially brought from often far away dunes, or special prepared material consisting of mixtures of sand, compost, peat, vermiculite, etc., used as detached media. Rock wool, an artificial product, is also in common use. 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 establishing water and nutrition demands. Special sensors, such as tensiometers and extractors are installed on the plots and used for monitoring soil humidity and controlling irrigation. In the sandy desert area near the Mediterranean coast, exist today a very advanced agricultural system of citrus, avocado, mango, flowers and vegetables. The sandy dunes can be easily 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 vicinity of the sea limits frost hazards.

Plant Protection

Pests and diseases, including nematodes and mites, may inflict heavy damage to the crops and indeed are the most 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 Fly limits the export of fresh produce to the USA and Japan. As already mentioned, the protection of greenhouses by insect-proof netting and IR plastics is very useful for controlling insects and thereby the spreading of virus diseases. A plant protection specific project running in the Arava valley is aimed at controlling pest and disease damages. The project is based on the assumption that the valley is isolated from other agricultural areas and that the agricultural plots in the valley itself are also isolated from each other. The main activities involved 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 methyl bromide for soil disinfecting; this method however is now replaced by solarization.
- Solarization is a soil disinfecting method, whereby the prepared 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°C over a prolonged period of time, thereby achieving the desired soil disinfecting effect.

The project, which already runs for 5 years, succeeded to reduce drastically pest and diseases damages, achieved the eradication of the Mediterranean Fruit Fly in the whole zone, and resulted in the granting of permission for exporting agricultural produce to the USA.

**Control of other factors**

Under greenhouse conditions air temperature, humidity, radiation and wind storms can also be automatically controlled. Furthermore, the greenhouse is protected by insect-proof nets for preventing the penetration of insects, many of which serve as vectors transmitting virus diseases in addition to causing physical damage to the plants. The plastic sheets used for covering the greenhouse possess UV (Ultra Violet) or IR (Infra Red) characteristics, thereby achieving additional advantages. The greenhouse atmosphere, enriched by CO₂, facilitates improved photosynthesis resulting in higher yields.

**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. In the last years, new crops such as Jojoba, Opuntia and Pitaya, were commercially introduced on a large scale. The introduction process includes various phases like observation, demonstration, semi-commercial and commercial plots.

**Reforestation**

The northern desert area includes the southern part of the Judean Hills. In this area, precipitation amounts to 250 mm/annum. During previous generations the hills were completely eroded. By using appropriate soil conservation methods like terracing, fencing with stones and bushes, rain harvesting is obtained and soil humidity is increased. Species such as *Eucalyptus occidentalis* Endl., *E. stricklandii* Maiden, *E. sargentii* Maiden, *Prosopis alba* Griseb., *P. juliflora* DC., *P. nigra* Griseb. ex Hieron., *Acacia salicina* Lindl., *A. raddiana* Savi, *Tamarix aphylla* (Linn.) Karst., *Ceratonia siliqua* Linn., *Pistacia palestina* Boiss., *Pinus halepensis* Mill., *Parkinsonia aculeata* Linn., are planted in the area and are slowly turning into forests which are completely changing the landscape.
Raising animals under heat stress conditions

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 raised on ponds locating in greenhouses with a forced oxygen environment, has the capacity of yielding 15 tonnes per 1000 m². This is a very capital intensive but profitable agricultural branch.

Ostriches

Ostriches are well adapted to desert conditions and can survive on eroded land of very limited alternative use. They are efficiently utilizing the scarce natural vegetation produced on the pastureland, but also receive some supplementary food 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

Under heat stress, cattle are wasting energy for body cooling instead of producing milk and the resulting milk production decreases. Technological innovations were introduced for overcoming heat stress problems. These include:

- High and well aerated structures
- High-potential ventilators
- Sprinklers for spreading water droplets
- Frequent wetting of the cattle
- 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.

Conclusion

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 to develop and apply 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 and extension workers. 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 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 the purchasing of highly sophisticated production inputs. The cost of a 1,000 m² large greenhouse alone is within a range of 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. 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 climate conditions. Now-a-days, this can be achieved by technological innovations in desert architecture, air conditioning and other related fields. An impressive number of such 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.

**Feature**

### For Further Reading


Water resources and irrigation methods to achieve advanced agriculture in arid land

In most of the globe’s arid zones, serious scarcity of water occurs. People’s food security is often connected with opportunities for applying irrigation techniques. Most of human kind’s non-nourished communities are located in arid zones. Arid zones are determined as vulnerable to severe water shortage and other ecological factors.

Almost half of the world’s arable soils are located in arid and semi arid areas. Arid areas are characterized by low precipitation rate, high rates of evapo transpiration, extreme climatic conditions, high salinity, intensive solar radiation, vast land areas and low population pressure.

Arid land could be environmentally remediate provided the developing of water resources and introducing of advanced irrigation methods. This could dramatically improve food production and security, farmer’s income and rural-society level of living.

About 60% of global water consumption involves with agriculture. Humanity, facing water scarcity, has to introduce water-saving irrigation methods to achieve a higher water irrigation efficiency rate.

Developing water resources in arid zones include the conveying water remotely from an out-region resource; using saline and thermal water; rain-water harvesting through soil conservation methods to increase soil moisture; building dams and reservoirs, lakes and rivers resources; recycling sewage water and desalinization of brackish and sea water.

To achieve a higher efficiency of irrigation water use, it is necessary to limit the use of traditional methods such as furrow and flood irrigation, which is considered as water-wasting irrigation systems. Sprinkler irrigation is also considered as a waste system due to the high evaporation rate. More recommendable is the enhanced use of drip and mini sprinklers, which are more precise and accurate. Water-monitoring control devices are essential in order to achieve more precision and accuracy in field-water application. Field methods are used to measure the daily water evaporation rate; reducing of soil moisture capacity and plant censors apparatus which measure directly the plant water needs.

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