DESERTIFICATION

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1. Overview

Some 95% of Israel is dry sub-humid, semi-arid, arid or hyper-arid, with 60% of the country's land area is covered by the Negev Desert. Thus Israel is almost entirely comprised of drylands accompanied by the ever-present threats of soil degradation and desertification.

Israel has taken a number of countermeasures during the past several years that strengthen its efforts to address the desertification processes. Most of these activities were part of planning, environmental, and development strategies or policies for the sustainable use of natural resources. The majority were not specifically directed towards implementing a comprehensive national strategy to combat desertification. Nonetheless, they frequently make a significant contribution to Israel's ongoing efforts to reduce erosion, increase the productivity of lands in the semi-arid drylands, ensure agricultural yields in general, and promote afforestation efforts throughout the country.

The following are some of the major programs which have been implemented in each of the country's dryland types:

- **Arid and hyper-arid drylands:** flood control, water harvesting, effluent treatment and reuse of treated wastewater for crop irrigation and landscaping; management of natural vegetation and applied agricultural crops including techniques such as drought and saline-resistant crops and greenhouse agriculture.
- **Semi-arid drylands:** control of free-ranging livestock herds and afforestation to prevent soil erosion, restoration of aquifer recharge, and development of fish farming with saline groundwater as well as establishment of orchards irrigated by treated wastewater transported from densely populated parts of the country.
- **Dry sub-humid drylands:** remediation of salinized agricultural lands and management of water resources to prevent pollution and promote conservation.

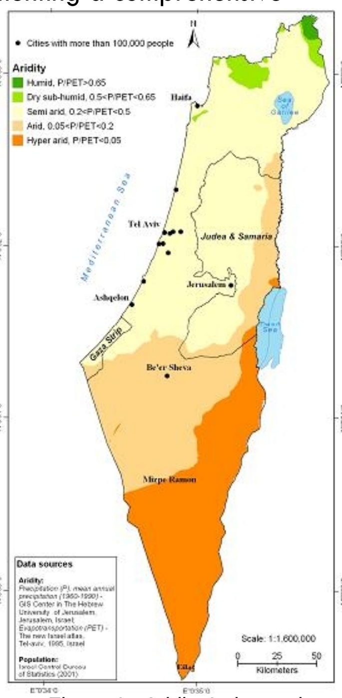

Figure 1: Aridity Index and Classification of lands in Israel. (Source: CLEMDES, 2004)

Dryland productively has largely been achieved through substantial investment in scientific research – in soil, climate, agriculture, forestry and ecological sciences. To a great extent, Israeli's program for combating desertification is based on sustainable agricultural development through centralized national water management that includes: transportation of water from regions of relative water abundance to regions of water shortage; storage during years of abundance for use in years of drought; reuse of treated wastewater for agriculture, cultivation of crops adapted to different water qualities and to the specific local climate and soil conditions. Afforestation of semi-arid lands is another central element in the national strategy. These have been supplemented by water conservation measures based on the implementation of subsurface drip irrigation and fertigation technologies as well as technologies to reduce water loss by evaporation to prevent salt accumulation on the surface and in the root zone of crops.

In light of the fact that less than 50% of the rainwater in the Negev permeates into the underground water table and most flows down gullies into the sea, new methods have been developed for flood prevention as well as water harvesting and conservation. Dams and reservoirs have been constructed to capture runoff water, arrest the velocity and quantities of floodwater, replenish underground aquifers and create tourism and recreation sites.

To overcome the effect of minimal rainfall and extreme temperature variation in the desert, a wide variety of innovative agro-technology systems have been developed. Runoff and rainfall catchment basins have enabled the development of agroforestry in areas with insufficient rainfall. By reducing the evaporation, new subsurface drip irrigation technologies improve the efficiencies and productivity of conventional drip irrigation. Savannization techniques utilize runoff harvest, contour furrows and afforestation to increase productivity and reverse desertification.

Recycled wastewater, which is unusable for irrigating agricultural crops, is utilized to irrigate groves and parks in semi-arid areas, while brackish water is used for salt-tolerant crops and trees in recreation areas. Additional research efforts have led to the identification of crops and technologies that allow agricultural production with water containing up to 4000 ppm salts, thus opening up new horizons for saline water-based agriculture in the desert.

2. Strategic Planning

The most salient new Israeli strategic planning and policies associated with combating desertification can be divided into four general categories as follows:

1. **Development plans –** Approval of the National Master Plan 35 which limits suburban sprawl in the central region and balances and encourages development of the Negev desert region.
2. **Upgraded sustainable water management –** for drylands, based on effluent recycling, desalination, water harvesting techniques and the establishment of watershed management projects.
3. **Afforestation –** adoption of National Master Plan 22 for Forests and Afforestation as a national policy that promotes sustainable forestry through zoning a range of forest types defined by ecological carrying capacity, precipitation levels and landscape values.
4. **Policies to promote sustainable agriculture –** in vulnerable regions based on active erosion control programs, regulation of nomadic grazing, and the promotion of water-saving, salt-tolerant crops with advanced agricultural techniques.

2.1 Afforestation and Drylands Management

The Jewish National Fund is a public corporation responsible for land development, afforestation and water projects on public lands. It recently adopted a broad ecological and environmental program to combat desertification and to upgrade degraded lands by:

- Developing **agroforestry** and properly managing grazing lands by planting rows of individual trees along earthen ridges to capture surface runoff and encourage the growth of savanna-style steppes.
- Promoting **afforestation –** planting “liman” tree clusters (usually comprised of eucalyptus trees) in banked-up water catchment depressions for shade and greenery.

- Fostering **desert agriculture** by providing support for R&D experimental programs to identify and develop new strains of crops suited to semi-arid and arid areas, to control pests and provide solutions to desert soil diseases.
- Building **floodwater control dams** in dry river beds to protect fields from soil erosion and to facilitate the percolation of surface runoff waters harvested from surrounding watersheds to enrich underground aquifers.
- Utilizing **treated wastewater** and collected **surface runoff** to create recreational green belts near towns and rural communities for the benefit of their residents.
- Building **water storage reservoirs** to hold treated wastewater channeled from the Dan Wastewater Treatment Facility in the greater Tel Aviv metropolitan and other urban areas to irrigate farms in Israel's southern expanses.
- Sponsoring **ecological R&D programs** in collaboration with Israeli universities and research institutes to foster desert management programs which enhance productivity and biodiversity, repair damaged arid lands and restore indigenous flora and fauna.
- Collaborating with the **International Arid Lands Consortium** comprised of US Department of Agriculture Forest Service and six American universities in advancing strategies for sustainable development of desert regions.

3. Concrete Actions and Specific Progress

This section considers four different areas that together comprise the heart of Israeli desertification policy:

- General Erosion Laws and Policies
- Afforestation Law and Policy Implementation
- Grazing Statutes and Policy Implementation
- Water Legislation and Management Programs

3.1 Preventing Land Degradation – National Soil Erosion Control

Administrative Framework

The Ministry of Agriculture has a clear mandate to prevent soil erosion with the appropriate legislative, implementation and enforcement mechanisms in place. For example the Ministry can designate areas as special regions and regulate land use, grazing, cultivation and soil conversation in these areas. Coupled with the fact that 92% of the country is designated as public lands, the authorities have considerable tools to prevent land degradation on the one hand and implement erosion control policies on the other. The Ministry's soil erosion departments, stations and hundreds of extension service professionals assist Israel's farmers to facilitate the implementation of standard "best management practices" for controlling soil erosion (conservation tillage, terracing, contour plowing, etc.).

Reducing Runoff on Agricultural Lands

Ideally, all precipitation would be captured on cultivated lands, used by crops or captured in situ for penetration into groundwater. However, achieving this often requires the reduction of physical soil crusts which develop on vegetation-stripped lands in arid regions and encourage desertification.

Physical crusts generally indicate that the amount of organic matter in the soil has decreased and/or erosion has occurred. With expanded surface exposure, the pelting of strong occasional rains breaks down spongy soil-aggregates, which then turn into a dense, particulate crust that retards entry of water into the ground. Downpour runoff increases, producing turbulent flows down any incline that detach loose surface particles, generally the most fertile layer of soil. Thus the land is degraded for natural vegetation as well as for local farmers and pastoralists. Removal of land cover around agricultural plots also increases the velocity of runoff, creating a feedback loop that exacerbates erosion downstream.

The Ministry of Agriculture and Rural Development is active in encouraging farmers to implement erosion control techniques, both through promotional efforts and financial incentive programs. Israeli farmers are generally receptive to the ideas; therefore current strategy for erosion focuses on reducing runoff quantity and velocity particularly on and around farms. One program focuses on best management practices, such as no-till plowing, and soil enhancement techniques, while other programs encourage farmers to shift from field crops such as wheat on steep slopes in hilly areas, to fruit orchards that more effectively reduce soil loss. In addition to control at the micro level of the farm and field, the problem needs to be addressed at the macro watershed level to achieve more effective control the over erosive impacts of runoff.

It is worth noting that most local rangelands are covered with biological crusts, a layer of living community of lichens and cyanobacteria growing on the soil surface and binding it together. Their importance increases as annual precipitation and the potential plant cover decrease. Biological crusts stabilize the soil surface and increase surface roughness. This reduces runoff, thus increasing infiltration and the amount of water stored for plant use. Both physical and biological crusts are susceptible to frequent disturbances; the recovery time for biological crusts in arid zones may take decades.

3.2 Afforestation

Statuary & Regulatory Protection of Forests

During the past 50 years, Israel has planted over 260 million trees, in some 200 areas, covering over 1000 sq. km, largely in areas with semi-arid climates as well as rocky, hilly terrain unsuitable for agriculture and where the risk of land degradation is high. In fact Israel is one of the only nations in the world that has more trees today than it did a hundred years ago.

The objectives of afforestation in Israel are as follows:

- Improving the landscape, biological diversity, natural ecosystems
- Developing parks, recreational, and hiking areas for the public
- Improving the public's connection to forests and participation in planting
- Preservation of Israel's open spaces

Israel is committed to the implementation of international agreements in the sphere of afforestation and environmental protection, such as Agenda 21, as well as the implementation plan pursuant to the afforestation sections of the Johannesburg Declaration, Combating Desertification, the Convention on Biodiversity, and more. During 2007, the JNF hosted an international conference on forestry and desertification which was attended by experts from around the world. In addition, as part of the worldwide UN Plant the Planet: Billion Tree Campaign, Israel has pledged to plant seven million trees in Israel over the next decade (one for each citizen) as part of the worldwide carbon offsetting campaign.

The Jewish National Fund (JNF) is the non-governmental organization responsible for afforestation and land reclamation in Israel. All afforestation areas fall under legislation and strategy is based on the National Master Plan for Forests and Afforestation (NOP 22, 1995), In 2005, the JNF adopted a commitment to "sustainable forestry" involving ecological principles in planting/rehabilitation (and the elimination of pesticides) that define seven different types of forest habitats ranging from "Natural Forests for Preservation" to "Human Planted Existing Forests".

Afforestation Strategy in Drylands

Afforestation plays a significant role in Israel's general strategy to combat desertification. Almost 200,000 hectares – one tenth of the nation's lands are designated as woodlands: 60,000 hectares have already been planted and 30,000 hectares more are planned, most of them in the arid southlands. The remaining 110,000 hectares are to remain as open space with natural woodlands and these have contributed to greater soil fertility in the Negev with its associated benefits such as recreational resources for the public and in many cases sanctuaries for protected wildlife.

Afforestation to Combating Desertification

Considerable tracts of Israeli forests have been planted on lands that were degraded, frequently as a result of historic overgrazing or deforestation. Besides directly contributing to soil conservation, plots used for afforestation have been coordinated with pastoralists' seasonal grazing schedules, thereby reducing grazing pressures. Reduced grazing and the shading effect of the trees promoted the rehabilitation of indigenous vegetation in many places, which further contributed to soil conservation. Afforestation improves the infiltration of precipitation, thus promoting soil moisture and local aquifer recharge. Finally, afforestation has been used in Israel for preventing gully erosion and bank erosion through planting along creeks, for stabilizing sand dunes, for reducing impacts of wind and dust, and especially in recent years, for recreation and leisure activities.

Savannization Technique for Drylands

Israel has developed new afforestation practices for semi-arid and arid regions, the most famous of which is called **savannization**. This technique is based on harvesting of surface run-off through contour furrows hillsides afforested with trees. Savannization has proven to prevent desertification and increase productivity and biodiversity without external resource enrichment. It was demonstrated that savannization reduces flash floods and their consequent soil erosion, and increases the overall productivity of semiarid soils.

Contour furrows are dug on slopes of watersheds with sandy loess soils at vertical distances of several tens of meters. The area between furrows is then covered by an impermeable biogenic soil crust that generates surface runoff; The runoff is collected, infiltrates the soil and is stored in the furrows; trees are planted in the furrows at a density of 100/hectare. During a typical rainy season four to six rainstorms produce surface run-off on the plots, which provide the trees with 6-37% of total annual precipitation, at a storage depth protected from evaporation.

Controlled experiments demonstrated reasonable growth and high survival rates of the trees, increasing productivity of pasture, and enhancing plant biodiversity. By 2006 52 km^2 have been successfully "savannized" while the Master Plan designated additional semiarid areas to be savannized as well. Though the direct effect of savannization on soil erosion and of other semi-arid afforestation practices on the water cycle has not been fully characterized, it is evident that savannization reduces flash floods and their consequent soil erosion, and increases the overall productivity of semi-arid soils. The survival in drought years, of trees watered by surface run-of under this practice, may be much greater than that of trees dependent only on rainfall. A more detailed description of specific dryland forestry techniques (e.g., savannization) appears in case studies at http://desert.bgu.ac.il/desert/EngStart.aspx.

Indicators of Climate Improvement to Combat Desertification

Desertification implies a reduction in dryland productivity due to human impact, as well as climate change. Natural climate change may either cause "natural" desertification, or increase the productivity in semi-arid regions when rainfall increases and/or evapotranspiration are reduced.

However, there are claims that the measures taken to combat desertification in the Israeli semiarid region ameliorated local climate and therefore constitute one of the few cases of “rolling the desert back”. Evidence shows increased overall precipitation in Israel’s semiarid southern coastal area and northern Negev. Research attributes this to the afforestation, intensive agriculture under irrigation, and grazing restrictions that jointly reduced surface albedo and increased convection during daytime, thus enhancing diurnal rains. Though a mathematical model supports this theory, it requires more study (Otterman et al. 1990, Sharon and Angert 1998), (Perlin and Alpert 2000), (Steinberger and Gazit-Yaari 1996).

3.3 Grazing Impacts on Desertification

Statuary & Regulatory Policy

Almost from the country's inception, legislation to control grazing and to combat desertification was a national priority with goats being prohibited from grazing on public rangelands. As the Land Authority manages 92% of Israel's lands, it has the ability to stipulate grazing conditions on most of the lands that are susceptible to degradation. The Minister of Agriculture is also empowered to ban or permit grazing of goats on any lands, backed-up with appropriate statutory penalties and enforcement. A mobile enforcement unit, the Green Patrol, is authorized by law to remove squatters from public lands, confiscate animals and to impose penalties on livestock owners who exceed stock quotas in rangelands.

The Grazing Authority has the responsibility of maintaining the sustainability of some 200,000 hectares of public rangelands, with oversight for 300,000 animals, which are divided into two general groups: grazing by stationary farmers (typically in the Jewish sector) and nomadic herders (typically Bedouin), who migrate with their flocks according to seasonal grazing opportunities. The Authority's extension support focuses on assistance to land owners in the areas of seeding lands, fertilizing rangelands and pruning woodlands to reduce fire hazards and fencing of vulnerable areas in order to control grazing levels. For example, with the closing of several Israeli military training grounds, and the reduction (or cessation) of grazing therein, erosion rates dropped precipitously.

Lessons Learned – Understanding the Role of Goats in Rangeland Management

In recent years, the Grazing Authority has undergone a complete change in orientation with regard to "black goats" or livestock grazing in general. Present thinking at the Ministry of Agriculture and the JNF now holds that during the 1950s there was a fundamental misapprehension about the ecological and practical contribution of goats to rangeland management. Since their phase-out as foragers, forests and woodlands have become overwhelmed with undergrowth making them impassible and a fire hazard. Moreover, the positive contribution of grazing at optimal intensities to biodiversity is now well documented. The Ministry is preparing a new "Grazing Law," which would integrate updated carrying capacity standards of animal numbers according to specific land conditions. Goats have made a modest comeback and are "welcomed guests" by many forest and rangeland managers.

Enforcement of the controlled grazing program is conducted by Israel's Green Patrol, which for 30 years has been active in preserving the integrity of Israel's Nature Reserve System and Israeli forests. In the past, this has created friction with local residents; tensions have emerged with the establishment of several illegal Bedouin settlements in the arid Negev region and attendant uncontrolled grazing that can exceed the capacity of the plants to regenerate. While the Patrol continues to take measures to prevent illegal grazing when it contravenes prescribed limits, tactically, the Patrol's approach has become more conciliatory.

Many Israeli herders operate according to long-term contracts with the Israel Lands Authority and/or seasonal contracts with the forestry department of the Jewish National Fund. For instance, grazing rights to "stubble" to summer are also sold to herders. Typically, a nominal charge is levied as a grazing fee – a couple of pennies per head of livestock per month are paid for grazing rights. These funds are transferred to the Israeli Ministry of Agriculture. In areas where available biomass is insufficient to make grazing a “cost-effective” proposition for herders, the JNF is considering subsidizing their grazing, given its importance in its fire prevention strategy

Notwithstanding the extensive grazing through Israel, a considerable portion of total livestock rely on hay and other fodder during different periods to supplement rangeland grasses. As this increases expenses for livestock farmers, there is a temptation to exceed stipulated foraging limits. When grazing levels violate the stocking limitations stated in the agreements, enforcement can take an iterative series of responses, from the cancellation of subsidies and permits through stock confiscation and criminal prosecution.

Averting Desertification Risks when Transforming Rangeland to Cropland

As part of national soil conservation efforts, the amount of rangelands has been reduced in Israel’s semi-arid regions. Most of the rangelands relieved from grazing pressure have been transformed into irrigated croplands, or to croplands that are rain-fed in winter and irrigated in summer. Transformation of rangeland to cropland, however, is one of the drivers of desertification, especially when there is a total removal of the rangeland vegetation coverage and breakage of the biogenic crust through plowing. When the land is not tilled during the non-rainy season wind and water erosion is imminent, the first winter rains can remove the physical crust with consequent intensified run-off and water erosion.

Yet, in practice, most of these rangelands transformed into cropland in the semiarid region were not rain-fed but irrigated, so that the agricultural practices rarely leave the soil uncovered for a long period. Furthermore, since fields were irrigated with transported water with only marginal dependence on local meager, low-quality resources, enough water could be used for leaching. Therefore, acute soil salinization, linked to irrigation in drylands, did not occur.

Furthermore, practices have been applied to increase infiltration, thus reducing surface run-off and soil erosion on agricultural fields (e.g., mulching, ridges and diked furrows tillage, and the application of chemicals which increase infiltration rate). Thus, at least initially, the transformation of the rangeland to cropland was not associated with intensified desertification. On the contrary – irrigated agriculture of the semiarid region not only averted desertification risks but might have also improved local climate.

3.4 Water Management in Drylands

3.4.1.1 Wastewater Reuse for Dryland Agriculture – Standards and Planning

The utilization of wastewater is a major component of Israel's agricultural infrastructure in the drylands. Indeed, in the semi-arid region, recycled wastewater constitutes the largest single source of irrigation water. In response to three years of consecutive droughts, in 2000 Israel's government formally passed a resolution to increase wastewater reuse to 500 MCM by the year 2010 (total percentage recycled to 74%). In fact progress has been swifter than planned. As of June, 2006, 92% of Israeli sewage is treated and 75% is reused, primarily by the agricultural sector.

Although this strengthens agriculture in the drylands, in order to maximize safety and minimize environmental risk from wastewater reuse new safety standards for use of recycled wastewater have been imposed. The standard is dichotomous with irrigation standards based on considerations of soil, flora, hydrological and public health and stream standards determined by projected in-stream ecological carrying capacity.

Due to the presence of pathogens in the treated wastewater, irrigation is restricted to certain crops (typically disqualifying field vegetables). Such wastewater also poses risks to soils and threatens groundwater sources. High concentrations of salts in treated wastewater (sodium, boron, chlorides) damage crops, salinized soils, and pollute groundwater. Nitrate pollution of groundwater also can often be traced to use of fertilizers by local farmers as well as from irrigation with wastewater, which contains high concentrations of ammonia.

The new improved standards promise to reduce environmental pollution and health risks, as well as eliminate the restrictive list of crops which may be irrigated with wastewater and in this manner conserve fresh water supplies for the growing domestic sector while preserving the extent of crop range currently in cultivation in Israel's drylands. While the old standard for wastewater treatment did not set limits for salinity since salts cannot be removed during the treatment process, the new proposed standard, however, does set sodium, chloride, boron and fluoride limits.

Topsoil Salinization

Some 200 reservoirs that store recycled urban wastewater were created by the JNF over the past twenty years for use in agriculture in drylands. However, farmers found that land adjoining the reservoirs became saline and unusable. Researchers from the Blaustein Institute for Desert Research (BIDR) at Ben-Gurion University showed that the reservoirs partially blocked the normal outflow of the low-lying salt-rich groundwater resulting in low-salt irrigation water mixed with the saline ground water building up close to the soil surface. Evapotranspiration of this water by solar heat left the salts behind, producing saline topsoil unfit for farming and degrading the lands. The discovery of the mechanism of salinization enabled an approach for reversing the soil degradation. Horizontal drains combined with deep vertical shafts were introduced into the partially confined, shallow saline aquifers, releasing the groundwater pressure buildup. This allowed washing, drying and aeration of the topsoil for reintroduction of sustainable, intensive agriculture in the abandoned fields.

Subsurface Drip Irrigation

Water management is undoubtedly the key to much of Israel's success in agriculture in arid, semi-arid and dry sub-humid zones. The most conspicuous technology in this regard is drip irrigation developed in Israel during the 1960. The next generation of irrigation technology involves Subsurface Drip Irrigation (SDI) that provides water and nutrients to plants while maintaining a dry soil surface. SDI Drip emitters are positioned 7-30 cm under the soil to conserve water, control weeds, minimize runoff and evaporation, increase longevity of laterals and emitters, ease use of heavy equipment in the field, and prevent human contact with low-quality water. Additional motivation for SDI comes in the form of savings of the extensive labor involved with seasonal installation and collection of surface drip system laterals.

Utilization of SDI systems is particularly beneficial in effluent irrigation systems, making them relevant to Israeli agriculture in the drylands. Whether for simple soil-based waste disposal or for agricultural utilization, regulated flow and prevention of surfacing are extremely important when irrigation systems rely on treated sewage. SDI is a potential tool for alleviating problems of health hazards, odor, contamination of groundwater, and runoff into surface water. SDI particularly augments opportunities for reclaimed municipal wastewater in landscape and ground cover and in edible crops. SDI presents a unique opportunity to manipulate root distribution and soil conditions in drylands in order to better manage environmental variables including nutrients, salinity, oxygen and temperature.

Desalination

Desalination constitutes the most recently adopted technological component of Israel's water management strategy. New membrane technologies and the reduced energy and economies of scale associated with mass production allow for 1000 liters (1 MCM) of very high quality drinking water to be produced on Israel's Mediterranean coast for a cost of less than sixty cents. The lower cost of desalinated water now makes it economically viable for both commercial and domestic use. The high quality of the water produced by the desalination plant offers new opportunities for desert agriculture with some of the new plants addressing the problem faced by Israeli farmers who reused sewage with high boron levels.

The desalinated seawater's chloride levels are so low (20 mg/l) that, ironically, the desalinated water is actually mixed into the national water grid to dilute the high salinity in the “fresh” water. When the city of Beersheva began using desalinated water in winter 2006, chlorides in the treated wastewater it sent to the farms in the surrounding desert plummeted to 100-150 mg/l, concentrations that even critics of widespread sewage reuse find sustainable. However, Israeli researchers reported that the direct utilization of desalinated water by farmers in Israel’s drylands surprisingly proved problematic, as the total absence of minerals such as calcium and magnesium reduced yields; new standards appropriate for both human health and agriculture were proposed. (Yermiyahu, Tal, et. al., 2007)

4. Best-Practices – Programs for Rehabilitating Degraded Lands

There are a variety of initiatives in which Israel is attempting to restore degraded drylands. The Jewish National Fund has begun a rehabilitation program at the "heads" of ephemeral (seasonal) streams and valleys, especially in the Northern Negev region. A variety of indigenous, arid-land flora has been planted which serve to stabilize the banks. In addition, landscaping to reduce the gradient of steep streambed sections has led to a slowing of runoff during the seasonal floods and reduced erosion.

Stream Restoration of the Besor / Beersheva Streams

A plan that has important regional implications for the semi-arid region in the south of Israel as well as for combating desertification involves the restoration of the Besor/Beersheva Stream. The Besor watershed, Israel’s largest, (3700 sq km) drains a significant percentage of the Israel's northern Negev region, varying spatially in geography, climate, geology, land use, and vegetation.

The "Besor/Beersheva is an ephemeral stream plagued by severe pollution that poses health risks and damages the natural ecosystems. The main source pollutant is the city of Hebron in the Palestinian Authority, which discharges raw sewage into the Hebron stream, along with untreated wastewater from almost 100 industrial facilities. On the Israeli side of the watershed low quality treated effluents are discharged from local Israeli towns; and occasionally treated wastewater accidental discharges from facilities in Beersheva.

Recently, two restoration plans for the Besor and Beersheva streams were approved by the planning authorities under the jurisdiction of a regional River Authority. Included in the plan are stream bank stabilization and other erosion control activities, which will reduce the steady gulley erosion in the watershed. Additional measures include a ban on quarrying near the stream, earthwork to stabilize lands, and a range of plantings to increase groundcover in the affected areas. As desertification in Israel is conspicuous alongside stream banks, the expanded focus of the restoration plan constitutes an important precedent for future activities. A treatment facility is under construction that would capture and treat raw sewage from Hebron before it continues south to Beersheva.

Other management efforts include the harvesting of water runoff upstream to create reservoirs, grazing stands and savanna-like landscapes. These have served to reduce the runoff velocity caused by storm events, which in turn relieves erosive pressures on degraded lands, allowing them improved conditions to regenerate, without periodic damage caused by violent flash floods.

Monitoring Desertification and Carbon Sequestration

As a small country Israel is relatively manageable from the perspective of monitoring drought and desertification patterns. The JNF, for example, has made a substantial investment in monitoring tree plantings, with GPS locations assigned to individual trees for ongoing monitoring.

The replanted Yatir forest, the largest in Israel, is a key factor in preventing desertification processes in the arid region, north-east of Beersheba. Since 2000, the forest has actually been serving as a living laboratory, with a sophisticated Long Term Ecological Research (LTER) monitoring station that checks natural data - precipitation, moisture, growth, the trees' natural development mechanisms, their emission of gases, the air's composition, and other factors. The research at this station is important for afforestation efforts in arid areas, as it is the only monitoring station located in a forest receiving only 200 mm of annual rainfall.

Partial results of the research conducted by the Desert Research Institute of Ben-Gurion University show that the forest's trees have adapted to arid environmental conditions by efficiently utilizing the high level of carbon dioxide in the air. Measurements revealed that, contrary to expectations, the Yatir forest absorbs 2.5 tons per hectare of carbon dioxide just about the same as worldwide averages of 2.6 tons and European averages of 2.7 tons. The assumption is that the rising percentage of carbon dioxide in the atmosphere aids the growth of forests in semi-arid and desert areas. Whereas, the trees can absorb all the carbon dioxide they require without needing to fully open all the stomas (apertures) in their leaves' membranes, this reduces the evaporation of the water from the leaves. The result is that trees can use less water without any damage to their development.

Case Study: Runoff Agro-Forestry to Combat Desertification, Turkana, Kenya

Part of Israel’s contribution to international efforts to combat desertification involves its ambitious scientific program in the field. In order to increase vegetative coverage in arid regions, it is essential to increase the effective supply of water to the degraded land. One approach widely used since ancient times is water harvesting. Here naturally generated runoff from a large watershed area is trapped by ground modifications that bring the flow into a much smaller expanse. Thus the quantity of precipitation concentrated in the receiving area will greatly exceed meteorologically measured rainfall.

In one of dozens of applied research initiatives Blaustein Institute for Desert Research (BIDR) research team adapted this approach for the simultaneous production of firewood and fodder in a system known as runoff agroforestry. Productivity is further increased by planting an “intercrop” between rows of trees. This highly effective technique is extremely suitable for arid environments, and allows farmers to increase their yields of various agricultural products.

The BIDR investigators established a runoff agroforestry system in the dry Turkana district of Northern Kenya. Growing shallow-rooting annuals and deep-rooting perennials, the system takes advantage of blue leaf wattle (*Acacia saligna*) as the tree component, due to its drought resistance, and sorghum (*Sorghum bicolor*) and cowpea (*Vigna unguiculata*) as intercrops. Studies showed that trees grew particularly well, and when the soil was deep enough, large volumes of runoff water could be stored underground, producing high yields of intercrops.

In order to advance use of blue leaf wattle in reversing desertification, the effects of different growing conditions on tree performance were evaluated in Israel’s Negev desert. Flood scheduling, supplemental drip irrigation timing and irrigation water qualities on tree growth were measured. Appropriate conditions for strengthening tree survival were determined. In addition, pollarding of the wattle (cutting low-lying branches down to the trunk) was investigated to increase sunlight entering the forest floor and improving intercrop growth. This procedure was found not to affect root numbers, and after a year of re-growth the development of roots, trunk, branches and the plant’s unusual variety of leaves (phyllodes) was satisfactory, independent of the watering treatment applied. These studies further strengthened the value of blue leaf wattle for runoff agroforestry and fighting desertification.