Social, Economic, and Policy Implications of Treated Wastewater Reuse

When the Socio-Economic and Policy program of Phase II was mainstreamed into the two thematic programs during the Extension Phase, the weight of its work would apply to Treated Wastewater and Biosolids Re-use program, which related to a number of regulatory issues concerning quality standards. Marginal water sources are used in all five countries that participated in the Dryland Initiative. Jordan reuses 85 percent of the wastewater generated in the country. Israel and Tunisia reuse 67 and 20 percent respectively. Egypt and the Palestinian National Authority reuse smaller proportions. Each of the five countries, however, maintains its own standards and regulations for the use of treated wastewater and other sources of marginal water. These different regulatory environments were compared in a concept note after the Initiative's Granada Workshop in October 2002.

The question of the social acceptability of using treated wastewater in irrigation relates to how receptive farmers and consumers will be to the process and the resulting product quality (Figure 87). Initiative teams conducted surveys to determine this acceptability in the Hebron area in the West Bank and in the Dissa Perimeter in the Gabès region of Tunisia. The results, however, were not made public.

Figure 87: Herbal and medicinal plants irrigation with treated wastewater, Jordan.

Much more was done on the economic front. The reuse of treated wastewater clearly releases pressure on renewable sources of fresh water in MENA and raises productivity thresholds. The question of the economic viability of investments to upgrade wastewater treatment capacity relates to the value of the benefits of this fresh water savings and the increased production it enables relative to the cost of the investment.

The Egyptian team conducted a cost-benefit analysis of advanced methods for preparing fields to be effectively supplemented by marginal water irrigation. The Jordanian team conducted a cost-benefit analysis of growing ryegrass and alfalfa on treated wastewater as compared to cultivation of barley as fodder, usually rain-fed but experimentally receiving supplemental treated wastewater irrigation. The team found that the return per unit area from ryegrass was 10 times greater, and from alfalfa three times greater, than that obtained from irrigating barley with treated wastewater. Water use by ryegrass was found to be twice as efficient as water use by barley. More importantly, the analysis demonstrated that the price of treated wastewater in the analyzed Jordanian Initiative's experiment was almost equivalent to the price paid by the Jordan Valley farmers for high-quality fresh water. A similar cost-benefit analysis of cultivation of herbal and medicinal plants was also conducted, but the analysis omitted the price of water.

The Israeli Treated Wastewater team analyzed the costs of upgrading the quality of treated wastewater in response to a government decision to increase the use of treated wastewater in irrigation – a decision that required new standards for wastewater quality. The standards were established by a government-appointed committee in part based on the findings of a joint Ministry of Agriculture – Israeli Treated Wastewater team survey that tested the effects of various wastewater treatments on crops and soils.

The Israeli treated wastewater Initiative's Team Leader was a member of this committee. The new standard recommended by the committee would entail substantial added cost that would be divided between treated wastewater producers and consumers. The results were expected to determine the relative share in the cost of the elevated standard, as expressed in the Government-pricing of the treated wastewater allocated to the farmers. The Ministry of Agriculture and a farmers' association independently conducted cost-benefit analyses of the recommended standard that generated conflicting findings. Ministry of Agriculture findings suggested that farmers would enjoy stable benefits from the use of the treated wastewater. The farmer association's findings suggested that the benefits enjoyed would vary depending on whether the affected farmers use only freshwater, or if they use secondary-treated water. Farmers who use secondary-treated wastewater to irrigate low-value crops would lose when the price of the treated wastewater increases, according to the farmer association findings. Farmers who currently use only fresh water on the other hand were expected to benefit from the lower price of the treated wastewater relative to that of freshwater. A third category of farmers would lose fertilizer benefits, as the improved wastewater that meets the recommended standard would lose part of its nutrient content. The Israeli Initiative team made a comparative study of the results of the two cost-benefit analyses, based on which it recommended that the government subsidize the costs of complying with the upgraded standard among farmers who grow low-value crops, based in part on the non-market environmental benefits that would accrue from the improved wastewater treatment.

VI. IMPLICATIONS FOR FUTURE TECHNICAL COOPERATION PROGRAMS

The Drylands Initiative was implemented over a ten year period that was characterized by dramatic ups and downs in the Middle East peace process. The experience accumulated over this period and in this context suggests a number of lessons that may inform the planning and design of future programs of technical cooperation that are intended to be instrumental in bringing together parties in conflict. While individual parties are likely to draw additional conclusions, the recommendations presented below are matters of substantial consensus between Initiative participants.

Setting a clear hierarchy of objectives

Having in place a clearer hierarchy of objectives will serve to focus the work program, and to identify and establish the most appropriate institutional structure with which to carry out that work program. A better defined set of objectives and priorities is also far more likely to provide an effective framework for measuring results, identifying bottlenecks, and finding solutions. The Drylands Initiative was intended to serve dual purposes that in the optimism of the mid 1990s were thought to be not only reconcilable, but purposefully complementary. On the one hand the Initiative was intended to support the Middle East Peace Process by fostering mutual understanding—and indeed collegiality—through regional technical exchange and cooperation. On the other hand it was intended to create knowledge through applied research. A stronger focus on either Arab-Israeli cooperation or on knowledge creation would have led its work program in quite different directions, and with different expectations. Making Arab-Israeli cooperation the principal objective would have led to a program focusing primarily on regional communication and consensus building. Making knowledge generation the principal objective would have led to a research program designed to bring together the best minds to tackle technical problems, whether they be identified externally or by program participants – possibly through Competitive Research Grants.

The notion that the technical field work supported by the Initiative was required to generate knowledge and results suitable for regional (Arab-Israeli) exchange and cooperation was flawed in a number of respects. Firstly, the small scope and lack of focus on quality that was characteristic of most Initiative research resulted in minimal—if any—incremental gains in knowledge relative to the existing knowledge base among senior experts in participating countries. Secondly, the technical subjects selected for the field work simply did not require cross-boundary cooperation. Moreover, the technical subjects were not even selected by partner countries but by the country conducting the field work itself. Meaningful regional meetings could therefore be held even in the absence of meaningful technical results, and (national) field work could proceed even in the absence of cross-boundary cooperation.

Identifying technical issues that make cross-boundary cooperation not only desirable but necessary

Technical cooperation that actively aims to find joint solutions to common problems is likely to be a more effective and powerful means of achieving mutual understanding and peace than conference-style regional meetings in which knowledge is simply communicated. In this latter case of “knowledge communication”, consensus building is not required, hence contentious or sensitive issues can easily be avoided, which is less likely to result in lasting and meaningful relationships between the participants. Yet technical cooperation needs to be designed around issues that actually require cross-boundary dialogue and cooperation. Ideally, this cooperation would be based on technical issues which are also addressed in ongoing peace negotiations.

The Dryland Initiative was based on a notion that Israel and her Arab neighbors share common or quite parallel priorities with respect to dryland degradation and poverty reduction – neither of which is a particularly immediate or urgent concern in Israel. These issues therefore provided somewhat limited common ground. A number of trans-boundary environmental issues suggest themselves as more suitable candidates for Arab-Israeli technical cooperation. In fact Arab-Israeli technical cooperation on a number of these issues is already ongoing. Egyptian, Israeli, and Jordanian technical experts already cooperate on pollution management in the Gulf of Aqaba, and Egyptian-Israeli cooperation in Mediterranean oceanography is long standing. Similar work on pollution management and the protection of the marine environments along the Mediterranean coast would provide an area of genuine cooperation between Egypt, Israel, Lebanon, the Gaza Strip, and countries of the Maghreb, as they seek to fulfill their obligations under the Barcelona Convention.

The trans-boundary spread of agricultural pests and zoonotic diseases is another shared issue which continues to bring together Arab and Israeli experts. Arab and Israeli epidemiologists, biologists, wildlife management experts, and other specialists do collaborate on issues like avian flu, foot and mouth disease, and rabies. Trans-boundary biodiversity concerns like alien invasive plant and animal species, endangered species of cross-boundary habitats, and protection of the cross-Middle East Palae-arctic bird migration also represent appropriate candidates for cooperation through the establishment of trans-boundary protected areas and programs to re-introduce species with long-range movement patterns. While water resource management issues carry great technical relevance across borders in the region, their political sensitivity would seriously impinge upon the potential for technical cooperation.

Identifying institutions that have a natural professional interest in the technical issues identified

The Dryland Initiative was carried out by the staff of institutions that had been identified and selected by the politically-minded designers of the Initiative. A pragmatic solution was found which made the start of the implementation of this sensitive program feasible. Yet further outreach to qualified professional institutions in the five countries remained limited—to the extent that it happened at all—throughout the lifetime of the Initiative. This limited involvement of eligible institutions and individuals would limit the relevance and practical application of Initiative-supported technical findings. This was particularly evident in the Initiative's marginal policy impact.

Future programs should cultivate engagement with and involvement by a broad range of institutional partners. Non-governmental organizations are likely to play a vital role in the conduct of future programs, perhaps alongside governmental institutions. Whether or not governmental institutions are involved, individuals who take part in assignments that involve collaborating with counterparts from states in conflict with their own assume personal risk of reprisal from those hostile to the peace process. Donors and implementing agencies need to conscientiously provide for the personal security of participating staff when program details are being negotiated.

Ensuring full institutionalization of the work program and technical cooperation

A number of individuals who were involved in the design and planning of the Initiative's original program would remain involved in the Initiative throughout its ten-year duration. This carried important benefits for the Initiative itself, particularly in terms of continuity and institutional memory, and particularly during periods of intensified conflict between Israelis and Palestinians in the broader context. Over the years however, the program would come to be more and more focused on these individuals, rather than on the institutions in which they served. This "old guard" of original participants who had been present at the creation would in certain respects come to resemble an exclusive clique with a very limited number of members and with very limited connectivity within the host institutions and with other technical institutions. This worked to the detriment of the broader institutionalization of the Initiative program, narrowing it to the discrete, personal relations of a few "insiders."

Future programs should work to minimize the risk of disconnects between the national program management and policy and operational decision-making within the implementing institutions. This offers a number of potential benefits. Involving more specialists is very likely to increase the technical quality of work undertaken. Direct linkages between the technical program and the policy and operational decision-making within the implementing institutions are likely to increase the relevance and practical application of results, including policy impacts. Basing activities on institutions rather than on individuals promises to make cooperation and partnerships more sustainable, both within and between participating countries.

Had the Dryland Initiative not been intended to support the peace process, and had it not been designed with its pre-selected roster of a small number of governmental institutions – it might have pursued the much more modest objective of cross-boundary technical cooperation among scientists similar to programs like MERC. Future program designers will have to weigh the pros and cons of such an approach. MERC-like programs are more likely to establish genuine cross-boundary technical cooperation that is less susceptible to political decisions given that they do not rely on governmental officials who are required to represent official opinions and decisions. On the other hand and for the same reason, such programs do not have the same potential of impacting on political decisions. Technical cooperation established between governmental institutions is more likely to influence political decisions such as those made within the peace process.

Develop future programs using participatory approaches to program design and implementation

Local community participation was not addressed in the Initiative's original program, nor were local communities consulted in the overall planning and design of Initiative programs. Future programs are likely to benefit from incorporating more participatory planning, assuring greater relevance to the needs, priorities, and concerns of local communities, and improve the chances that research undertaken in participating farmers' fields will yield results of greater impact as more neighboring farmers and land users adopt and adapt the techniques developed. Program design should pay careful attention to opportunities to make research and development demand-driven. Farmer participatory research methods have evolved and matured since the mid 1990s when the original Dryland Initiative was being conceived, and future programs should seek to benefit from these developments as much as possible.

Ensuring technical quality of field work through appropriate mechanisms

Assuming that the program involves technical field work, quality assurance is a very important factor to incorporate into program design and planning. A number of factors contribute to the technical quality of research: (i) selection of the most appropriate institutions within countries; (ii) a sound procedure of peer review; (iii) an appropriate incentives framework, for example through competitive research grant mechanisms; (iv) technical assistance through the implementing agency or contracted service providers.

Within the framework of Arab-Israeli collaboration, the only competitive grant scheme compliant with the program's objective would be one which involves research proposals jointly prepared and submitted by Arab-Israeli teams. In the prevailing political context of the Initiative, however, within which the Arab League forbade official Arab cooperation with Israel, joint proposals prepared by governmental entities (which was the structure in the Initiative) would not have been feasible. In addition, an invitation (by governmental to non-governmental entities) could not be made sufficiently public to carry out a successful competitive grant program. Even if competition had been restricted to within-country competition (with fixed budget envelopes for each participating countries and Arab-Israeli collaboration limited to the regional events – as it was actually the case in the Initiative), the program would still have needed to be made public within each participating country. Any future program attempting to use competitive grant mechanisms would have to involve non-governmental entities as implementing agencies or rely on (i.e., wait for) more conducive political circumstances.

Effective regional technical cooperation programs require a broader approach to communication and knowledge sharing

The quality of cross-boundary cooperation of the Dryland Initiative suffered from the fact that technical teams with members from each participating country were never effectively assembled, and as a result cooperation and technical dialogue was limited to periodic communication during workshops and semi-annual events. In-between event communication among participating countries was close to nil, due to the fact that the field work pursued by the Initiative made this dialogue *desirable* but did not *require* it. Future programs should design an appropriate incentives framework for participants to effectively use state-of-the-art communication tools and knowledge-sharing events. Future programs should design an appropriate incentives framework for regular and substantive discussions among participants, effectively using state-of-the-art communication tools and knowledge-sharing events.

The implementing agency selected for a program of regional cooperation must be able to communicate effectively with every participant in this program

This point is self-evident, but the lack of effective communication between the implementing agency and all five partners in the Dryland Initiative emerged as a serious bottleneck for the successful implementation of the work program, due to the fact that ICARDA is based in Syria which has strained relations with Israel. Setting up the Initiative's Facilitation Unit in ICARDA's office in Egypt was an attempt to counter this problem, but the Initiative nevertheless failed to establish functioning cross-boundary technical teams which should have been *facilitated* by the implementing agency.

In conclusion, it is recommended that the objective of any new confidence building program should be to place value on technical cooperation among the parties in areas that *require* this technical cooperation and to view such a goal as an end in itself. Genuine cooperation can be built and bridges of confidence constructed if non-cooperation on the subject matter is likely to create negative effects for both sides. And maybe, this cooperation will also generate personal contacts that will facilitate, in a very modest way, an enhancement of relations between the parties, thus creating one more bridge of confidence towards peace.

ANNEX 1: PROJECT SITES AND AREAS

A. Egypt

Marsa Matrouh Governorate, Watershed Management

The bulk of Egypt's rural population is restricted to the Nile Valley and especially the delta, where the water scarcity of the surrounding desert is overcome by the Nile flow, and where the land is rather flat with no high ground in sight. The Egyptian Watershed Management program targeted the areas outside the Nile Valley, including the Northwestern Coastal Desert and the Sinai Desert, which are mostly hilly, arid watersheds.

Extending south of the 600 kilometer Mediterranean coastline between Alexandria in the East and Sallum in the west, the Northwestern Coastal Desert ranges over 10,000 square kilometers. Only 1,500 square kilometers of the area are cultivated. The Desert consists of a plateau ripped with wadis that generates runoff into hundreds of watersheds traversing lower foothills and reaching the Mediterranean coast, constituting a 20 kilometer south-north, 80-180 millimeter rainfall gradient. Rainfall runoff harvesting using several indigenous methods is practiced by mostly sedentary Bedouin communities with agro-pastoral livelihoods. The major project site is the Wadi Um Ashtan watershed, one of the several watersheds in the Marsa Matruh governorate some 300 kilometers west of Alexandria. This seven and a half kilometer long, 150 square kilometer watershed is a plateau some 115 meters above sea level, and is used mainly as rangeland. Its seaward side is ripped by wide fan of tributaries, initiated by wide "wadi tips" cultivated with figs, olives, cereals (mostly barley), and some vegetables. The watershed accommodates twenty farms owned by 25 families numbering 240 people who together own 770 sheep.

The Wadi Um Ashtan Watershed Management project objective was to demonstrate improved watershed management practices to raise local farmers' income. The demonstration activities covered 4.5 percent of the watershed area, 17 percent of its cereal production area, and just 2 percent of its rangelands – thus involving only 4 percent of its sheep. The project was supported by the nursery facilities at El Qasr Research Station of the Agricultural Research Center at Marsa Matrouh, and in addition to the Wadi Um Ashtan, its activities extended to the adjacent Wadi Medwar, Wadi Halel el Daba, and Wadi Sidi Barani watersheds.

The Sinai Peninsula, Germplasm for Arid Lands

The 61,000 square kilometer Sinai Peninsula is bordered in the west by the Gulf of Suez and the Suez Canal, in the east by the Gulf of Aqaba, the Negev and Gaza Strip, and in the north by the Mediterranean Sea. Its southern point faces the Red Sea. The Peninsula consists mainly of hyper-arid rocky desert, interspersed with sandy areas. Its northern two thirds comprise a limestone plateau traversed by large number of gullies and wide tributaries. Its southern core region is a rugged igneous and metamorphic ridge that peaks at 2,629 meters above sea level.

Vegetation structure and cover in the Sinai are determined by a rainfall gradient from 200 millimeters at the northeastern Mediterranean coast, to 20 millimeters at southern tip facing the Red Sea. In the central southern mountain ridge, this is overlaid by a sharp vertical gradient where mountain tops often exhibit a winter snow cover. The larger part of the peninsula is used as rangeland, with scant, mostly rainfed farming mainly in the northern areas. The relative isolation of the Peninsula explains the high endemism of plant species, 60 of which are endemic to the Sinai. Plant diversity is high (984 species) owing to the diversity of habitats and climates, and to the Peninsula's geographical placement at the eastern Mediterranean edge of the Saharo-Arabian desert areas. The Egyptian Germplasm for Arid Lands program, supported by the Desert Research Center's station in Sheikh Zued in the northeastern Sinai, undertook a survey of vegetation using a network of smaller stations that covered all the habitats found in the Peninsula.

The Nile Delta, Kafr El Sheikh Governorate, Treated Wastewater and Biosolids Re-use

Egyptian Treated Wastewater and Biosolids Re-use project sites were located in the Nile delta, where most of the country's agricultural production and most of its use of marginal water takes place. These project sites were therefore far removed from the Egyptian Watershed Management project sites in the arid northwest, which lack large sources of sewage. Although farming here in the delta area (together with Egypt's major urban centers) enjoys the advantages of Nile river flows, the country's 2.7 percent annual population growth rate has a major impact on water supplies. One way of alleviating the increasing water shortage is the reuse of the irrigation drainage water, which is significantly more saline than the Nile water entering the irrigation system. To reduce salinity, drainage water is blended with freshwater prior to reuse at 20 pumping stations. This preponderance of irrigation drainage water treatment and reuse—between 3 and 8 billion cubic meters annually—distinguishes Egypt from the other four countries in the Initiative, where sewage is the principal source of treated wastewater. Egypt hopes to increase this volume of diluted drainage water further, while at the same time mitigating the mounting problems that drainage water reuse poses to groundwater and soils, and to crops, livestock, and human health.

Activities of the Egyptian Treated Wastewater and Biosolids Re-use program, and the Marginal Waters program that preceded it in the first three years of the Initiative, were carried out in the Kafr el Sheikh governorate in the far north of the middle delta. The governorate is located about 150 kilometers north of Cairo, and is situated between the Nile Rosetta and Damietta branches along the Mediterranean Sea and El Brullos Lake. The Egyptian team selected four demonstration sites within the governorate: Abu Sekeen, Balteem, El-Hamoul and Sidi Salem, where they monitored drainage and well water quality, water table fluctuations inside the wells, soil properties, and crop performance. Lysimeter experiments were used to irrigate selected crops with various qualities of mixed drainage and fresh water.

The Egyptian program's biosolids projects were carried out in the same sites. The increasing health hazards of sewage generated by the rapidly growing population had prompted Egypt to increase the number of wastewater treatment plants with improved capacity to remove solids. The plants generated 10 million tons of treated wastewater per year, which – applied to agricultural production – elevated soil concentrations of potentially toxic elements, increased nitrate pollution of groundwater, and raised the risk of eutrophication in water bodies. In addition, most farmers keep between three and five heads of cattle or buffalo whose manure is added to soils. The Egyptian biosolids project tested treatments of sludge and farm manure using composting and lime applications to reduce the proportion of carbon, and tested the use of the treated sludge and manure as fertilizer and in biogas production. Results were demonstrated to farmers at the Sakha Agricultural Research Station.

B. Israel

The Yatir Watershed, Watershed Management for Afforestation

In Israel runoff harvesting is practiced only in afforestation projects, and hardly if ever in agriculture, which is rain-fed in the least arid drylands and elsewhere mostly pressure-irrigated, including in hyper-arid areas. In order to join efforts with its Initiative partners, the Israeli Watershed Management team was engaged in exploring, improving and developing runoff harvesting practices and techniques for promoting tree growth in arid drylands. These runoff harvesting activities were intended to demonstrate practices for growing trees used for fruit, firewood and fodder production and for soil conservation to farmers and extension agents in the four other countries. The research was also aimed at providing management recommendations to land users in both partner countries and Israel when the runoff practices supported tree-growing projects.

The principal Israeli afforestation project site was in the Yatir watershed, where annual rainfall is about 250 millimeters, placing it in the transition area between the arid and semi-arid regions. Here land use traditionally supported pastoral livelihoods, but during the last five decades a transition from nomadic pastoral to sedentary urban livelihoods has taken place. Livestock grazing continues but the reduced nomadism increases pressure on the range, resulting in severe gully erosion and overgrazed vegetation. Afforestation in the high reaches of the watershed was initiated in 1964 by the Jewish National Fund, motivated by ethos of "making the desert bloom." Because tree life-forms in this dryland area is restricted to channels, maintaining trees on slopes requires runoff harvesting.

The afforestation practice was to manually create a pit for each individual sapling, planted towards the end of the rainy season, when soil moisture is maximal and temperatures are the most favorable. Some saplings received a few irrigation bouts in the first two years after planting. Most saplings were of the circum-Mediterranean *Pinus halepensis*, a pine species not indigenous to the Yatir region. Survival rates were high, and a full forest cover now prevails over the 3,000 hectare "Yatir Forest." Management of the forest is focused on fire prevention, which is pursued through controlled grazing by local Bedouin herds and cutting low branches collected as firewood by local Israeli Bedouins and Palestinians from the adjacent West Bank. The forest also serves a recreational purpose. The local Bedouin community lives within and around Houra township, which only marginally depends on free-ranging livestock.

The Jewish National Fund renewed its afforestation activities in the area in 1977, but at lower reaches of the watershed, using heavy equipment to create contour ditches in which a diversity of trees—mostly indigenous and drought-adapted broad-leave species—were planted at low density. Two decades later, the Israeli Watershed Management team selected demonstration sites in this area and set about installing monitoring devices to collect data for use in the training programs planned under the Initiative. But most attention was directed to research aimed at evaluating the merits of run-off afforestation in an arid dryland, and at improving water-harvesting practices for supporting it.

Avdat and Mashash Experimental Runoff Farms, Watershed Management

The two other Israeli Watershed Management project sites are the Avdat and Mashash experimental runoff farms of the Blaustein Institutes for Desert Research (BIDR). The Avdat farm is located on the ruins of a desert city on an offshoot of the ancient Silk Road, supported by a 15 hectare runoff harvesting farm that operated in the Nabatean and Byzantine periods. The farm was reconstructed in the 1960s as a research and monitoring site in the areas of climate, agriculture and ecology. Olives, pistachios, almonds, grapes and multipurpose fast growing trees are experimentally cultivated on reconstructed terraces, fed by runoff water conveying channels extending from the adjacent slopes. The farm has generated a 35 year database on precipitation, runoff events and water volumes, temperature, and evaporation. During the Initiative the run-off harvesting structures and monitoring infrastructure were maintained and the database was updated. Topsoil is loamy, mean annual precipitation is 85 millimeters, and annual evaporation (Class A Pan) is 2,700-3,200 millimeters, leaving an aridity index of 0.03.

Mashash is a 300 hectare experimental farm in a controlled-grazing rangeland. Its runoff source is two catchments with a combined area of 6,000 hectares. Experiments with olives and intercropped acacia groves under different runoff harvesting methods have been carried out in this farm during the last 15 years. Topsoil texture is sandy loam, mean annual precipitation is 115 millimeters, and annual evaporation (Class A Pan) is 2,500-3,000 millimeters, leaving an aridity index of 0.05.

The Yatir afforestation site has 280 millimeters annual precipitation and from 1,800 to 2,200 millimeters annual evaporation, giving an aridity index of 0.14. The three Israeli Watershed Management sites, Yatir, Mashash, and Avdat, are therefore positioned along a 70 kilometer gradient of decreasing aridity of 0.002 per km. The 0.14 aridity index of the Yatir site is representative of an arid dryland in immediate proximity to a semi-arid zone. The 0.05 aridity index of the Mashash experimental farm places it solidly as arid dryland. The 0.03 aridity index of the Avdat farm is representative of a hyper-arid dryland that is in close proximity to a neighboring arid zone.

Semiarid, Coastal and Valley Agriculture in Israel, Treated Wastewater

The combination of severe water shortages, aquifer contamination, densely populated urban areas, and intensive irrigated agriculture, makes it essential for Israel to put wastewater treatment and use high among its national priorities. In 1999, treated wastewater constituted about 22 percent of the agriculture sector's water supply, by 2005 it accounted for 40 percent, and it is projected to account for 50 percent by 2020. This made the Israeli Treated Wastewater program far more relevant to national priorities than the national Watershed Management program, which conducted research principally for the benefit of Israel's developing partners in the Initiative. The Treated Wastewater project sites were located in the major farming regions of Israel – the coastal plain and the Jezrael Valley in the north. This mostly pressure-irrigated agriculture occupies land stretching about 170 kilometers from north to south, and about 20 kilometers wide. The area corresponds to a south-to-north rainfall gradient of 400 to 600 millimeters, and is characterized by relatively well-developed soils, mainly grumosols and lithosols, in some places mixed with sand. This rectangular area also accounts for most of Israel's urban population, and therefore also generates large volumes of urban and industrial effluents.

Within this area the Israeli Treated Wastewater program compared irrigation using treated wastewater with irrigation using fresh water on some 70 agricultural and experimental plots—most of them owned by cooperative *Moshav* and communal *Kibbutz* farms—between Kibbutz Yassour in the north and Moshav Hammapil in the south. In the rainier segments of the area, mainly in the north, Avocado plantations were the focus of most of the experiments, as well as corn and other field crops in the Jezrael Valley. In the somewhat drier central and southern sections, the effects of different water qualities on citrus orchards were the major concentration. On these sites the Israeli Treated Wastewater team was able to test the effects of treated wastewater on the full range of low altitude, coastal and valley systems that account for the bulk of agricultural production in Israel. The treated wastewater used in the experiments was provided by national and regional wastewater treatment plants located near urban centers in the vicinity of the project areas.

The Northern Negev, Biosolids Re-use

In 2001, sludge production in Israel reached 103,000 tons of dry matter per year. The projection for 2020 is about 250,000 tons. In a very small country like Israel, with very high population density in its major agricultural area giving rise to intense competition for scarce land, using this sludge as composted biosolids is naturally an appealing alternative to incineration or landfills. Much of its agricultural area was identified as being suitable for sludge applications, although the effects of the practice on crops and soils do require further testing and monitoring.

The Israeli Biosolids project sites were located in the Northern Negev, in the somewhat rainier segment of the country's arid area, generally experiencing between 250 and 350 millimeters of rainfall annually. Much of Israel's cereal production takes place here, where production is constrained not only by the naturally low rainfall, but by the low water holding capacity and fertility of local soils. Composted sewage sludge holds considerable promise for reducing these constraints by increasing the volume of rainwater the soil is capable of holding. Field crops like wheat are preferred to orchards in many experiments with the application of biosolids because the fields can be plowed and tilled, allowing more rapid and thorough biosolid incorporation into the soil. Ten project sites between Kibbutz Shuval in the north and Kibbutz Nirim in the south were used to test, monitor, and demonstrate the effects of different qualities and quantities of biosolids applied to soils and crops.

C. Jordan

Watershed Management Project sites

The Jordanian Watershed Management program was active in an area covering much of the country, some 800 square kilometers between Dana in the south and Irbid in the north, and from the upper reaches of Wadi Mujib in the east to the Dead Sea coast in the west. Most project sites were at areas of relatively high elevation along the country's north-south highland range, where annual rainfall is higher than 150-200 millimeters but lower than 300-400 millimeters, and where most communities are rural. The program was not active in arid and hyper-arid areas with less than 50 millimeters of annual rainfall in the east, far south, and in the irrigated Jordan River Valley north of the Dead Sea.

The program's major water harvesting and range rehabilitation projects focused on three project sites. Two of them were located in the central highland range of Jordan: one at the upper reaches of Wadi Mujib on the border between the Karak and Madaba governorates, the other near Faysalyia, in the northern part of the Madaba governorate. The third site, near Sabha, was located off the central highland range though also on relatively high elevation, close to the very arid area in the northeast known as the *Badia*. The local watersheds in these three project sites support pastoral livelihoods, augmented by opportunistic rain fed farming, or by more stable cereal, vegetable, and orchard crops supported by supplemental irrigation. All farming in these sites was supported by runoff harvesting measures. In all three sites, local population increase, land tenure issues, and other expressions of social change was leading to overgrazing, range degradation, the neglect of cisterns and wells, and a growing prevalence of relative poverty.

The Faysaliya region is at the upper catchments of watersheds draining to the Dead Sea, with annual rainfall ranging from 100 to 200 millimeters. The watersheds support rangelands of grass or shrub steppes, depending on elevation. The rangelands are heavily overgrazed and degraded as a result of local overstocking as well as the influx of sheep from eastern Jordan that over-winter near the shores of the Dead Sea. Here, two range reserves, the 1,800 hectare Faysaliya reserve, and the 8,000 hectare Ma'in reserve, were planted with shrubs. Grazing was practiced on a rotational basis, in which up to 25,000 sheep (belonging to 60 families, some 500 persons) were moved through a series of ten unfenced *paddocks*, beginning in the lower elevation, low rainfall range in the early spring, and moving to higher elevations over the course of a 30-90 day period. In these sites, and in the Wadi Mujib upper catchment, several villages and communities were targeted for demonstrating range improvement, livestock grazing management, runoff harvesting structures and cistern rehabilitation.

The Sabha area included two Watershed Management demonstration sites - the Sabha and the Mohareb stations, together covering some 1,050 hectares at altitudes between 746 and 807 meters. The sites receive under 150 millimeters of rain annually. 55 percent of the site area is used as rangeland, and 37 percent is devoted to olive cultivation, irrigated by water from artesian wells. The low precipitation, high temperature, and low soil quality make this region prone to soil erosion. Here range improvement demonstrations focused on planting range and cactus species.

The experimental cultivation of medicinal and herbal plants was carried out in 15 different sites (including several NCARTT research stations) spanning over the whole region from Rabba near Karak in the south to Irbid in the north.

Finally, two project sites, Dana in the south and the lower reaches of Wadi Mukheyres in the west, were used by the Watershed Management team to promote ecotourism as a means of generating income to the local farming communities. At the same time, the team sought to promote nature conservation through grazing control in the Dana site, and vegetation restoration in Wadi Mukheyres. The Dana project was terminated in the early days of the Initiative. The Wadi Mukheyres project only began towards the end of the Initiative.

Treated Wastewater and Biosolids Re-use Sites

Jordan's per capita availability of water is 240 cubic meters per person per year – well beneath the *water poverty level* of 1,000 cubic meters, and water scarcity is intensifying in the face of an annual population growth rate of 3.4 percent. In this circumstance, fresh water supply is inevitably directed to domestic, industrial, and tourist sectors, leaving agriculture proportionately more reliant on marginal water sources – principally treated wastewater. 20 treatment plants currently process only a fraction of the wastewater generated in Jordan. Near the Jordan's major sources of ephemeral running surface water—the King Abdullah Canal in the Jordan Valley, and the Zarqa River in the central highlands—wastewater is diluted using fresh surface water. Elsewhere wastewater treated by regional plants is used for local irrigation. Constraints to this treated wastewater reuse are insufficient transport infrastructure, and the often low quality of the treatment that discourages farmers from using the resource and deters consumers from buying the produce.

The Jordanian Treated Wastewater team therefore limited its projects to the cultivation of crops which are not for direct human consumption, including exotic fodders like ryegrass. Wastewater treated at the Madaba Wastewater Treatment Plant, 30 kilometers south of Amman was used to cultivate volatile oil crops at the El Ramtha Experimental Station. Wastewater treated at the Khirbet As-Samra Treatment Plant, 40 kilometers east of Amman was used to irrigate trees at Hashymiah.

Owing to relatively low rates of investment in wastewater treatment, Jordan does not produce large amounts of sewage sludge. The rural population does however produce large volumes of household sludge, together with plant residues and animal waste. The volume of cow manure produced annually is estimated at half a million tons. Much of this is used, untreated, as fertilizer in orchards and for vegetable production, and with unpleasant environmental consequences. The Jordanian Biosolids team therefore experimented with composting cow manure from the Ministry of Agriculture's Hamodah dairy farm, located in Al-Khaldiah-Mafraq governorate. Jordan's Treated Wastewater and Biosolids sites were all located on the central highland plateau, from 40 kilometers south of Amman to the Syrian border in the north. It shared no sites with the Jordanian Watershed Management program.

D. Palestinian National Authority

Watershed Management sites

Activities of the Palestinian Watershed Management team were carried out in three different areas of the Palestinian Territories. Most of its activities were undertaken in a large number of sites in the Hebron mountains ridge, in the southern part of the West Bank. These sites were located within a northeast-southwest oriented rectangle covering about 30 kilometers between Al Arroub in the north and Dahariyya in the south, and about 15 kilometers between Bani Noem in the east and Doura in the west. The area includes the regional hydrologic divide between the Mediterranean basin in the west and the Rift Valley in the east. The Hebron area is located at the top of the *central mountain plateau* of this rectangle, which has elevations ranging between 600 and 1000 meters above sea level. The *western slopes* descend from 600 to 300 meters above sea level, and contain watersheds that drain toward the Mediterranean. To the east of the plateau, watersheds on the *eastern slope* descend from 600 meters above sea level to *sea level* in the Rift Valley, draining toward the Dead Sea.

The rectangular area in which Palestinian Watershed Management program activities were carried out sees a north-south gradient of increasing aridity superimposed over a west-east aridity gradient in which the regional hydrologic divide is relatively less arid. In the semi-arid north of the rectangle, at Al Arroub, the aridity index is 0.04, with mean annual rainfall of 623 millimeters. In the arid south, at Dahariyya, mean annual rainfall is 348 millimeters, giving an aridity index of 0.18. The mountain plateau and western slope are both semi-arid, with a 0.31 aridity index respectively, and the eastern slope is arid, with a 0.17 aridity index.

These orders of relative aridity dominate biological production in the rectangle, and are key determinants of local rural livelihoods. With increasing aridity, vegetation height and cover decrease, and its composition gradually transforms from Mediterranean to Asian to Saharo-Arabian. Land use and livelihoods gradually change from urban to rural, and from mostly cultivation (mainly orchards), through sylvi-agro-pastoral, to mostly pastoral. Depending on the different climates, vegetation features, and land uses within the rectangle, different degrees of land degradation are evident. The degradation results from overgrazing, firewood collection, deforestation, urban sprawl, and reduced supply and quality of water resources. Yet in many parts farmers employ both traditional runoff harvesting practices and adapt and adopt advanced cultivation and livestock rearing technologies.

The Palestinian Watershed Management team carried out activities to improve range and farming as well as tree cover in both rural and urban areas in scores of sites, as well as conducting extensive surveys of biodiversity and springs, cisterns, and wells. The team used most of the sites for public awareness, demonstration, and dissemination campaigns. In its activities the team was supported by a nursery and botanic gardens it established in the agricultural school of Al Arroub and later at Al Quom. Finally, the team carried out, jointly with owners of twelve farms in the drier, southern part of the rectangle, an experiment to test runoff harvesting techniques supporting olive groves and cereal fields.

Another major site of activity, limited to the first years of the Initiative, was the City of Jericho, where the Watershed Management team established and operated a botanic garden. Jericho is an urban-rural hyper-arid oasis, 250 meters below sea-level, close to the northern end of the Dead Sea. Very hot (49^0C record high) and dry (166 millimeter annual average) climate prevails in this desert area. Yet cultivation of a diversity of crops and advanced and intensive livestock production are practiced, made possible by a local spring that has sustained human habitation in Jericho for several millennia.

The third site was the 25 square kilometer protected area of Wadi Gaza, the only non-urbanized area in the densely populated Gaza Strip. Wadi Gaza is the furthest downstream section of the largest (3,500 square kilometer) watershed in Israel, a wetland that is formed as Israel's Nahal Habesor channel enters the Strip. It has the potential to function as a "green belt" – a sanctuary for coastal, semi-arid aquatic and riparian biodiversity, but it has become a degraded, polluted and littered ecosystem, more of an environmental and health hazard than an environmental asset. The Palestinian Watershed Management team conducted geological, water and biodiversity surveys in this wetland, to be used for supporting management and conservation efforts, which later culminated in restoration efforts to promote the quality of the wetland to the point that it can be granted nature park status.

Treated Wastewater and Biosolids Re-use

Only about one third of the West Bank's population is linked to a sewer system, and there is only one major wastewater treatment plant, in El Bireh, which is not in the Hebron region, where most of the Palestinian Treated Wastewater projects were carried out. Given the severe water shortage in the West Bank, it is not surprising that much of the untreated wastewater is used in peri-urban irrigation. With no stable source of treated wastewater, the Palestinian team could not experiment with irrigation reuse on a large scale, as other Initiative's partners did. The team therefore focused its activity on a small but stable sources of treated wastewater, at the El-Arroub agricultural school 36 kilometers south of Jerusalem. The school's chicken and dairy farms, nursery, greenhouse, orchard, and the school facilities themselves provided sources of waste that could be treated and then used locally for irrigation, composting, and biogas, which was used for cooking in the school. There, the Palestinian Treated Wastewater and Biosolids team was involved in constructing, improving, and operating the local duckweed-supported wastewater treatment plant, a composting facility, and a biogas digester.

The survey of springs, in the central and southern Hebron region, can be regarded as a joint Watershed Management and Treated Wastewater activity, since one of the important outputs of the team was the identification of springs contaminated from wastewater sources, and the characterization of the contamination, both in quality and in quantity.

E. Tunisia

The Zammour Valley and Menzel Habib, Watershed Management

The Tunisian Watershed Management team focused its activities in a relatively small 200 square kilometer area in the southeastern central part of the country, between Gabès in the north and Medenine in the south. The upper reaches of the watershed are at the Matmata Mountains in the west. The watershed's lower reaches form the Hamilet el Babouch plateau, in which the Menzel Habib region is located, draining into the Mediterranean coast in the east. The area is arid, with 150-220 millimeters of annual rainfall in the Matmata project site in the Zammour Valley, and 80-170 millimeters in the Menzel Habib project site. Sylvo-agro-pastoral livelihoods are prevalent in the area around the Matmata project site. At the Menzel Habib project site, steppe shrub and other Saharan-Mediterranean vegetation supports agro-pastoral livelihoods. Olive trees are grown in terraced wadis at the Matmata site, and the slopes of the local Matmata Mountains provide forages. Ecotourism is also promoted in the area. (Some distance south, and closer to the coast, the southern-most olive groves in Tunisia can be found.) This Matmata site was active mainly during the earlier years of the Initiative, when activities focused on improving tree cultivation and the in-situ conservation of local fruit tree varieties.

The 10,000 hectare Menzel Habib project site, 50 to 60 kilometers west of Gabès, is traditionally owned by the Henchir tribe of the Snoussi confederation. The area is about 80 meters above sea level and receives about 170 millimeters of rainfall annually – with a 60 percent coefficient of variation. The soil is sandy and the main land use is livestock grazing and opportunistic barley cultivation by 13,000 agro-pastoralists, with 50,000 livestock heads. During the 1960s much of the land was used by nomadic pastoralists, especially during years with high rainfall. Since the 1970s the population became sedentary, mostly due to governmental encouragement in the form of water and electricity infrastructure development. This social change was accompanied by significant population growth and density (24 persons per square kilometer, compared to 5 at the end of the 19th century), and intensified and expanded cultivation and intensified shrub cutting. These factors led to land degradation and shifting of previously stable sand dunes during 1980s and 1990s, and beginning in the late 1980s, government interventions to stabilize dunes and to replace livestock production with alternative livelihoods.

Tunisian Watershed Management team activities tested and demonstrated a variety of practices to accelerate range rehabilitation and soil conservation in three subsites of the Menzel Habib project site - Henchir Snoussi, Ouled Hfeiyedh, and Qued Zayed. These activities ranged from surveying for economically useful plants species, cultivating cacti, planting shrubs for range rehabilitation and trees for sandy soil fixation, as well as livestock management for range conservation. A nursery was established for these purposes among others at Qued Zayed.

Finally, the activities of the Tunisian Watershed Management team in both the Matmata and the Menzel Habib project sites were supported by nurseries and seed-storage facilities in Gabès and in the IRA research institution in Medenine.

The Dissa Perimeter, Treated Wastewater and Biosolids Re-use

Gabès is situated on the Gulf of Gabès in the Mediterranean Sea, and is the capital of the Gabès governorate which has a population of 350,000 and an area of 7,175 square kilometers. In the drier southern parts of Tunisia, water shortages linked with population increase and the prevalence of low-productivity soils, together with an existing treated wastewater facility that had been built by ONAS, motivated the Treated Wastewater team to experiment with the agricultural use of treated wastewater and treated sewage sludge in the area. The wastewater treatment plant had the capacity to generate 17,000 cubic meters of secondary-treated wastewater per day. When that facility was constructed, a canal was built connecting it to the nearby Dissa Perimeter, 10 kilometers from the plant. There, within the Dissa Perimeter, the Tunisian Marginal Waters and later Treated Wastewater teams would build and operate an experimental infiltration-percolation tertiary-treatment plant and a 50 cubic meter reservoir to receive the secondary-treated wastewater from Gabès. CITET and IRA would use tertiary-treated wastewater from the experimental plant to irrigate a local farmer's vegetable field with encouraging results, though there is no record of further dissemination. Later, the Tunisian Treated Wastewater team would construct a much larger pilot tertiary-treatment plant near the original secondary-treatment facility at Gabès, with a capacity of 150 cubic meters of tertiary-treated wastewater per day. Tertiary-treated wastewater provided by the new pilot plant was used to irrigate sylvo-pastoral and ornamental seedlings in a local nursery, and to water the plant's own garden.

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