Seeds of Life

How wastelands become fertile fields

Virtually barren land can spring to life through a new approach to farming that soil scientists call "biosaline agriculture." Applying isotopic tools, countries are showing the way. One IAEA interregional project is spreading the news – one hectare at a time.

by Bill Wallin & Jorge Morales Pedraza

Although water covers the majority of our planet, it is a cruel irony that most of it is saline rather than fresh. Plants, animals and microbes that have evolved under freshwater conditions are unable to use seawater for survival. Furthermore, freshwater for farming is scarce in many of the world's countries and potentially productive lands remain barren. But an innovative technique, known as "biosaline agriculture," is bringing life to these dormant lands by cultivating salt-tolerant crops, trees and fodder grass that are nourished by saline water.

Approximately two-thirds of rain water and snow falling on land flows into the sea leaving only one-third of the non-saline water available to support terrestrial life. Moreover, the water retained is unevenly distributed geographically, creating ever-shifting patterns of wet, dry and arid areas that develop as climate evolves under natural and anthropogenic forces. Naturally, as the human population expands, the need for freshwater grows and today freshwater demand has surpassed supply.

Since humans domesticated wild plants during a time when water was plentiful, they selected and bred species that depended on freshwater to flourish. Consequently, as pressure developed to move agricultural production into drier areas, freshwater irrigation systems became necessary.

Many techniques for distributing water to plants are inefficient and expensive. Yet initially agricultural output significantly increased. However, improper irrigation practices using irrigation water containing salt has resulted in "salinization" and continues to occur causing an accumulation of salts in the soils. As a result of evapo-transpiration capillary action and water movement within the soil, the salts are concentrated and redistributed.

Engineering solutions to salinization, including drainage and leaching, may be necessary in fertile irrigated areas. But at present several problems are beyond the economic and technical capability of many countries. Furthermore, they ignore very large saline arid and semi-arid areas that have saline groundwater that could be used for growing salt-tolerant plant species. Despite these problems, pressure continues to expand agriculture into marginal lands to meet the needs of a growing population.

In addition to agricultural ecosystems, there is also an increasing water demand for other human needs and other ecosystems in the landscape. Further expansion of

morocco: demonstration sites involved local farmers and communities. During 2002, the government approved the Strategic Document containing actions to ensure the sustainability of the project. The aim is to expand into new regions.

algeria: three sites have been selected, 10 hectares each, to reflect different ecological zones. The sites were characterized, prepared and planted in early 2002. Four farmers are working with the project and a Strategic Document is expected during 2003.

tunisia: the technology is rapidly spreading to more sites in the region. In addition to the introduction of salt-tolerant plants, neutron and gamma measurements have supported studies of groundwater with reference to salinity sources and irrigation management. After the success on five demonstration sites covering 32 hectares, it was proposed to start new demonstration sites in several other provinces affected by aridity and salinity. A national strategy for the use of saline water and wastelands is being formulated. The demand for seeds of salt-tolerant species has increased and a number of farmers have been contacted to apply biosaline agriculture techniques as a good option for their farms.

egypt: two 25-hectare demonstration sites are established. One is located on a farmer's field in the Sinai. Several hundred variations of salt-tolerant plants are performing well on this farm. A 10 hectare area has now been acquired to establish a Biosaline Agriculture Station. Egypt's Atomic Energy Authority and Ministry of Agriculture have approved the project's expansion.

agriculture into marginal lands, not previously used for agriculture using freshwater irrigation, is not possible in many countries due to their limited freshwater resources.

In many dry, arid areas soils and groundwater are saline and traditional crops cannot be cultivated on such lands. Fortunately, during the course of evolution of land plants at the sea margins and in the saline deserts, a few hundred species have developed that, in some cases, grow vigorously when irrigated even with high-salinity water.

These plants, called Halophytes, represent a wide range of plant families and forms including grasses, shrubs and trees — many of which have great development potential. Over the past thirty years, as the freshwater shortage has become apparent, interest in their domestication as crop plants has increased. Several hundred species of halophytes have been evaluated for economic potential as food, forage, fuel, manure or as industrial feedstock.

In addition, scientists are making efforts to induce salt tolerance into cultivated crop species. Over the past several decades, the biosaline agriculture concept has been gaining in understanding. Although technical progress has been made in the use of saline ground and surface water for agricultural production of salt-tolerant plants, the translation from science to larger scale practice still remains to be done. Biosaline technology transfer to agriculture has had some success where it has been demonstrated under farm and local conditions. Local authorities, agricultural agents and farmers have seen useful products grown for their direct use or sale.

The salinity problem

Nearly 10% of the world's total land surface is covered with different types of salt-affected soils and no continent is unaffected. Salt-affected soils are all soil formations in which water soluble salts exceed a certain limit, consequently adversely influencing physical, chemical and biological soil properties. As a result, this type of soil has a decreased productivity.

Salinization is a growing concern. Improper use of irrigated areas, deforestation, over-grazing and other anthropogenic measures result in so-called "secondary salinization," — particularly in arid and semi-arid regions mainly in the developing countries of Asia, Africa and Latin America.

According to estimates of the Food and Agriculture Organisation (FAO), 77 million hectares of land are affected by human-induced salinization. Out of these areas, 45 million hectares are in irrigated areas and 32 million hectares in non-irrigated areas.

Country Cultivation

jordan: two demonstration sites were selected encompassing a total area of approximately 8 hectares involving 17 different salt-tolerant plant species. The Ministry of Agriculture and Jordan Valley Authority support the project, and a National Committee has set a series of strategies for the utilization of saline groundwater and wastelands. A Strategic Document to expand to new regions was approved.

syria: two sites demonstrate the feasibility of biosaline agriculture and farmers have shown an interest in planting salt-tolerant plants, mainly through work at Deir Ezzor. (See box: Syria's Saltwater Crews.)

iran: the demonstration site covers over 30 hectares and has enough seeds to extend it further. Fifteen farmers in different areas are already practicing the technology and growing several species, including pistachio plants. The newly re-named "Salinity Research Centre" in Yazd is an institution that deals with soil and water and is cooperating with the Atomic Energy Organization. The government approved expanding the work to other areas in the country. To support the project's first phase, US $300,000 has been allocated to the expansion of the projects to three provinces covering 8,000 hectares.

united arab emirates: the feasibility of using high-salinity irrigation water is demonstrated in establishing 16 salt-tolerant forage and tree species. A 35 hectare site at the experimental station at the International Centre for Biosaline Agriculture (ICBA), which was designated by UAE as the representative in the project, has been allocated for carrying out demonstration, research and development activities. Groundwater monitoring was also initiated during 2002. The Ministry of Agriculture, in collaboration with ICBA, has identified farmers' fields and a preliminary survey has been done for forthcoming field activities.

pakistan: around 200 farmers — the largest group of participants among the project — are now growing a few salt-tolerant species. In 2002, the government approved expanding project results and approved the next phase. It will encompass an area of over 30,000 hectares with a possible increase to about 480,600 hectares. The resources allocated for this phase are US $3 million over five years. (See box: From the Salt of the Earth.)

Most efforts to control salinity have been made by using an engineering-based drainage concept. This is most useful where freshwater is available. But what about the arid and semi-arid lands where the only source of water is saline groundwater? A different approach is required for such areas and the IAEA had taken the lead in promoting the search for sustainable solutions.

Isotope applications to manage salt in agricultural water

Nuclear techniques play a critical role in determining the long-term effects and sustainability of proposed approaches. Introduction of plants require that irrigation be managed to suit the plants' needs to avoid accumulation of salts in the upper soil. Several nuclear techniques are used in this approach:

- The soil moisture neutron probe has been developed for field management of water balance. It is used through access tubes that are permanently installed in the 2-meter upper layer of soil. Soil moisture profiles are established every 7-10 days. The date of soil profiles gives information on evapo-transpiration, amount of irrigation water infiltrating the soil, and amounts of water and salts leached below the root zone. These criteria are essential for good monitoring of soil water storage and, subsequently, soil irrigation scheduling.
- Water, soil and plant interaction can be studied with isotope techniques. The dynamics of salt movement in soil and its uptake and distribution in the plants can be better tracked using isotopes as tracers.
- Movement of soil bulk density by gamma-ray back-scattering is important in field monitoring. The probe involved is equipped with an encapsulated caesium source. It is used through the same access tubes as the neutron probe and allows non-destructive measurements of the soil bulk density versus depth. The soil porosity is calculated from these values. On poor structured salt-affected soils, the impact of the salt-tolerant plant root growth can be correctly determined.
- The characterization of aquifers, in terms of water quality, storage capacity, amount and origin of the recharge, and dynamic proprieties, may be evaluated with environmental isotopes. For this purposes, the analysis of deuterium, oxygen-18, tritium, carbon-13 and carbon-14 in ground, rain and surface waters can contribute to the aquifer's management.

From results, information on groundwater origin and recharge can be inferred. In cases where the sampling network allows for gathering all necessary information, the water balance can be calculated. Tritium is of special value in detecting recent recharges. Its short half-life allows this isotope to be detected only in waters a few decades old. Carbon-14 is also widely used for dating older groundwater.

In summary, isotopes provide a tool for the characterization of the condition and the dynamics of groundwater systems. Specific isotope techniques provide more robust results and they have been widely incorporated in multidisciplinary investigations of groundwater systems. Furthermore, isotopes provide unique information in, for example, age distribution of water in aquifer systems, labelling of water origin and as an evaluation tool for conceptual and numerical models which can act as an "early warning system" indicator before quantity or quality is irreversibly damaged. *(See box: Great Lakes Beneath Their Feet, page 36.)* This is very important, since long-term use of saline water for irrigation may, under certain conditions, cause serious salt accumulation in the soil.

Sowing the seeds: Interregional efforts

In 1997, the IAEA launched the interregional project "Sustainable Utilization of Saline Groundwater and Wastelands for Plant Production" in six countries: Egypt, Iran, Morocco, Pakistan, Syria and Tunisia. Three more countries — Algeria, Jordan and United Arab Emirates (UAE) — were incorporated into the project at a later stage increasing the number of participating countries to nine.

The main project objectives were to:

- Introduce known salt-tolerant plants (halophytes) on a 10 hectares demonstration site irrigated with saline groundwater and subsequent selection of plants that have a comparative advantage in terms of survival and economics;
- Use nuclear and other techniques to manage irrigation to reduce salt accumulation on the soil surface;
- Monitor groundwater dynamics through chemical and isotopic analysis to estimate the quality, and possibly quantity, of recharge; and
- Transfer the technology to the end-users for economic benefit.

The project was implemented in two phases. Phase I, covering a two-year period, involved a limited number of farmers and established demonstration sites showing the potential of the technology and approach. In 2002, at the end of phase II, most of the participating countries had at least one demonstration site of 10 hectares or more establishing that it was economically possible to grow useful salt-tolerant plants using saline groundwater in wastelands. In all participating countries, about 63 plant species were grown in the established demonstration sites.

Reaping the benefits

Plant species were primarily chosen for their forage and food value and for their usefulness as soil stabilizers and organic matter for improving the soil and the environment. Most of these species are native to the participating countries and thus well-adapted to local conditions. However, if not irrigated, they barely survive. By applying water, even though saline, the same species start to thrive and produce much more biomass.

In most cases it was sufficient to plant the species and irrigate with saline groundwater without any other inputs, including fertilizer, since most of the woody species chosen are nitrogen-fixing plants. The initial feasibility and low cost of the technology has been established. Reliance on the vast capabilities of plant species, and their optimum exploitation, has been a key element of project activities. Efforts can now be made to increase per hectare yields through applications of organic matter produced on-site and other measures.

So far, the project's overall results show that:

- In all participating countries, economically useful plant species can be cultivated on wastelands using saline groundwater.
- Increased awareness has been created among the scientific community, government officials and end-users to the potential of biosaline agriculture as a feasible and low-cost option for specific arid areas with saline groundwater and wastelands.
- Almost all countries are considering expanding the results within the project to other regions through the preparation of a national project or expansion of the scope of the interregional project. Pakistan is the first country to make this decision and Iran has agreed to do the same. Egypt, Jordan and UAE are following these examples.
- In total, twenty demonstration sites have been established covering 441 hectares of wastelands and 251 farmers are working with the project using the technology on 582 hectares of their own land.
- Regular monitoring (chemical and isotopic analyses) in a two to 10 kilometre radius of the demonstration sites has provided important information on groundwater dynamics with respect to quality, quantity, and sustainability. This

information will be very useful to support future activities related to the economic development of these areas.

- Strategic documents on future steps have been prepared following IAEA missions during 2001 and 2002. The following countries have approved them: Egypt, Iran, Jordan, Morocco, Tunisia, and UAE. Syria has a strategic document under consideration.
- Staff and field workers in all participant countries have been trained.
- The IAEA has supplied basic equipment and other materials to most participant countries, according to their needs and the availability of funds.
- The IAEA has provided resources for establishing plant nurseries in participant countries. It has also arranged transfer of seeds from one cooperating country to another. This has helped in the introduction of these species in other countries and promoted technical cooperation among developing countries.

Taking root

Over time, more arid lands may flourish with the help of nuclear techniques and good cooperation. To date, at least five countries are preparing a national project as part of the project's next expansion phase. These national projects should cover thousands of hectares of land on which to apply biosaline technology.

Using the results already gained as a starting point, the IAEA approved for the cycle 2003-2004 a new interregional project to support the efforts in ten countries in Asia, Africa and Latin America. They are searching for new varieties of crops that are salt-tolerant and can grow in extremely severe conditions with high yield.

Agricultural development is a central component of the IAEA's technical cooperation programme, which is taking a lead in demonstrating innovative solutions for conservation and agricultural production of marginal lands. By overcoming agricultural challenges with nuclear techniques, the IAEA, and its partners, envisage a greener and more productive landscape.

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Pakistan: From the Salt of the Earth

"The potential to benefit lives and land is great"

"Initially it is impossible to believe that anything could grow in such wasteland, " says Mr. Jorge Morales, IAEA Interregional Projects Manager. "Not surprisingly the locals - who have been farming the land for hundreds of years - don't believe it at first either." Their awe stems from witnessing the transformation of parched pastures into thriving and lush farmland. Using the techniques of "biosaline agriculture," over one million acres of Pakistani wasteland is targeted to become farmland.

Water for farming is scarce in this arid country and every day nearly 2,000 square meters of farmland in Pakistan becomes desert — exacerbating large-scale poverty — as people lose the land they once farmed to erosion. But innovative use of nuclear science and technology is turning that around. Through biosaline agriculture, isotopic techniques help to cultivate salt-tolerant crops, trees and fodder grass that are nourished by brackish water. Essentially it transforms abandoned land into economically valuable land.

Demonstration farm sites that grow the salt-tolerant species take the mystery out of the process. "When they see the results, the neighbouring farmers soon begin planting these seeds," Mr. Morales said. The programme has now been extended to eight districts in four provinces.

Hundreds of Pakistani farmers are already reaping the benefits. "It gives the local people an income," says Mr. Morales. "They are now able to grow crops or grass to feed their livestock. In some cases plants are grown to stop erosion," he said.

The commitment by the Pakistan Government is part of an IAEA programme that supports nine countries to grow economically useful plants in rugged terrain using saline groundwater and salt-tolerant plants. IAEA assistance ranges from locating and tapping the salty water sources used to irrigate the plants, to advising on what species to grow in the area and helping to cultivate and supply the seed.

Barley, wild olive and wheat are among the salt resistant crops being grown. "Only two percent of the many salt-tolerant species we know about are being used. The potential to benefit lives and land is great," Mr. Morales said. Already the living conditions of many local farmers and their families have improved due to this low-cost technology.

— based on a report by Kirstie Hansen, IAEA Division of Public Information, that first appeared on the IAEA's website at www.iaea.org.

Syria's

Teamwork & Nuclear Science Help Bring Wastelands to Life

Looking through the window into Deir Ezzor's farmhouse, Jamal Al-Howeish (center) and other members of the saltwater crew stand before their fields of green.

Syria's economy is rooted in agricultural fields, like those near the ancient oasis city of Palmyra and along the banks of the Euphrates river.

The land is dry and hot, the farmers determined and proud. They come on foot, by bicycle, by motorbike, by mule to farm once abandoned fields and bring them back to life. They're succeeding a crop at a time, with the help of nuclear science and technology. Syria's saltwater crews near Deir Ezzor are showing other farmers that wastelands, if farmed in the right way, can bring productive harvests to communities. Their toil is helping to shape the country's agricultural future.

From Damascus to Deir Ezzor and beyond, Syria's 15 million people depend on farmers working the irrigated valleys of the Euphrates river, the country's lifeline. But most of the land can't be used for food crops because the soils contain too much salt. Problems trace back to the 1960s, when cotton was introduced as a bumper crop, without measures to control soil salinity. Today, the cotton fields are gone, but the salt remains as a legacy blocking agricultural development. About 40% of all arable land is too saline to sustain plant growth, and thousands of hectares are still lost to salinity each year.

Conditions are changing. With IAEA support through an interregional technical cooperation project, Syria's Atomic Energy Commission (AECS) is working with the country's Ministry of Irrigation and other bodies to help farmers reclaim dry and dusty saltlands. They are working together at home, and with counterparts in other countries engaged in the IAEA project where people face similar agricultural problems. The focus is on growing crops that tolerate saline soils and water, and in many cases, can thrive if farmed and managed correctly.

"Countries like ours need to follow this path," says Dr. Khalaf Haji Khleifeh, an AECS scientist helping to coordinate Syria's participation in the interregional project. "Scarcity of water and the spread of saline soils are considered the main impediments to agricultural development."

Syria's main demonstration site is at the 800-hectare "7th of April" Farm on the outskirts of Deir-Ezzor, a city on the Euphrates about 500 kilometres from Damascus. There, Mr. Farhan Habbas and his 12-member crew farm about 15 hectares of saline land. The fields were once so salt-crusted and barren they looked to be covered with snow, he recalls.

Today, water lines linked to a new pump and well snake through rows of green fields. Crops are fed by saline water from groundwater basins mixed with river water drawn from nearby irrigation canals of the Euphrates. Nuclear-based techniques add to the ecological equation. Isotopes used as tracers help characterize water sources, for example, and instruments called neutron probes help scientists monitor soil moisture and crop conditions. They provide valuable feedback data to optimise irrigation and drainage so that salt leaches away rather than settles near roots to thwart or stunt plant growth.

Findings guide the field work of the saltwater crew. By hand and machine, they sow the seeds, till the irrigation channels, and harvest crops, including barley, Eucalyptus trees, acacia bushes, and forage plants such as Kallar grass, atriplex, and Sesbania for feeding sheep, goats, and mules. For the next growing season, new lines of wheat brought from Pakistan are going to be sown and tested.

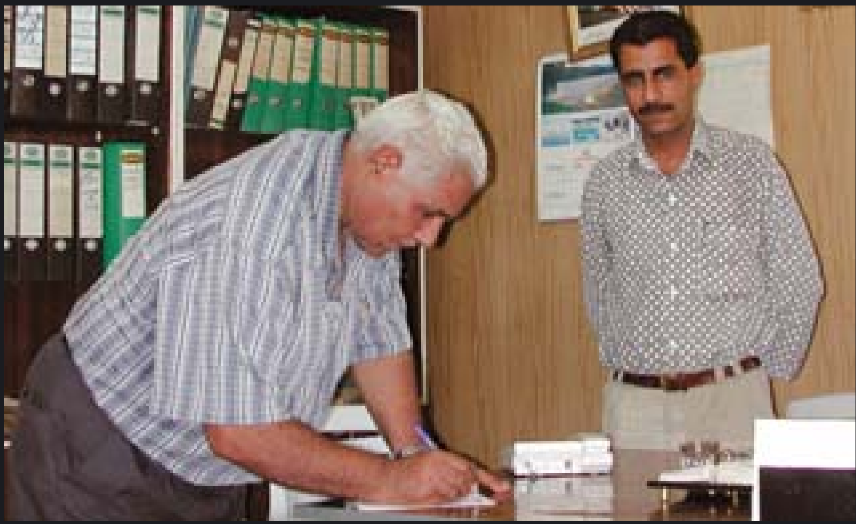
"The farmers smile, especially for barley," says Dr. Khalaf. The barley's mainly used as animal feed, he points out, and by a local brewery.

The work at Deir Ezzor points the way toward a better farming - and environmental - future. Already the site has become a training hub for local farmers and technicians - as well as a new sanctuary attracting long-lost wildlife, from birds and snakes to rabbits and foxes. They offer another visible sign of real and potential benefits to local communities from expanding this new approach to agricultural development.

Plans now call for a bigger investment to develop a National Biosaline Agriculture Center at Deir Ezzor. Based on an IAEA-proposed strategy, the center would support government aims to reclaim wastelands in other regions of the country - a sign that more smiles could be on the way for the nation's millions of farming families.

—Lothar Wedekind, IAEA Division of Public Information. (Photos Credit: Wedekind/IAEA)

More information about the IAEA interregional project – known as INT/5/144 "Sustainable Utilization of Saline Groundwater and Wastelands for Plant Production" – is available through the IAEA Department of Technical Cooperation.



Engineer Radad Al-Oweid, manager of the 7th of April Farm where the demonstration site is located, meets with Dr. Khalaf.

Dr. Khalaf and Mr. Farhan Habbas check water irrigation lines feeding rows of salt-tolerant plants.

Surveying the fruits of labour at Deir Ezzor, where fields once lay barren and crusted with salt.