ICARDA Caravan

Issue No. 11 Summer/Autumn 1999

Review of agriculture in the dry areas

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From the Director General

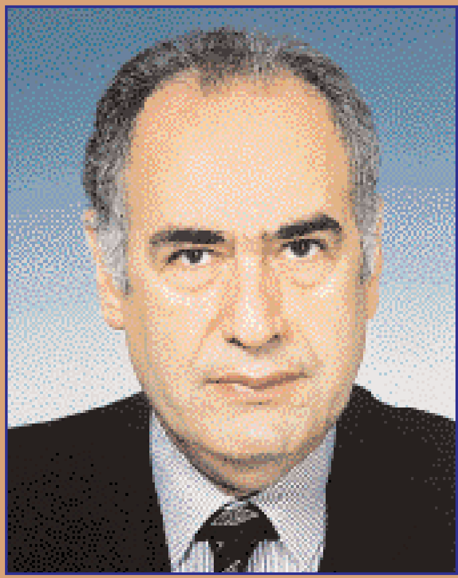
The challenges in the dry areas are many and varied in their intensity to constrain agriculture for the resource-poor farmer.

Underlying these challenges is, however, a common factor—water, or at least scarcity of this precious commodity. It is now generally accepted that allocation of water for agricultural production will come under increasing pressure from competing industrial and domestic demand in all countries.

And the impact of this will nowhere be greater than in the dry areas of the developing world, which are witnessing increasing population growth and urbanization. The freshwater currently available per capita in the West Asia and North Africa region is only 1045 cubic meters as against 3568 cu m in Western Europe and 9529 cu m in North America. Expanding populations in WANA will cause extra pressure on available supplies.

ICARDA has devoted considerable attention to developing improved water-harvesting systems. There were many ancient systems that well served the needs of days gone by. Modern techniques, including GIS, satellite positioning systems, computerized mapping and modeling techniques, allow today's hydrologists to plan water catchment schemes close to a peak of efficiency undreamed of by the original designers of such systems.

Technical specialists at ICARDA are working to safeguard supplies of water for both domestic and agricultural uses through better collection or 'harvesting' and conservation. The importance of water in the dry areas means this issue of *Caravan* is almost entirely devoted to water issues. It reports on a new ICARDA project in a resource-poor village where the only water supply comes via a 1500-year-old *qanat,* now in danger of drying up due to lack of maintenance. This project will show how low-cost, proven methods of water collection and distribution can be used effectively to enhance quality of life, provided local people are fully involved as stakeholders in projects.



Non-conventional sources of water will have to be tapped to meet the needs of agriculture in dry areas. Hence developing and refining management techniques that allow the use of marginal-quality water, such as that from municipal wastes, brackish water from drainage schemes, etc., will be important. Increased knowledge of plant tolerances to toxic chemicals contained in these waters could help in their safe use. ICARDA is researching in this area, together with national partners.

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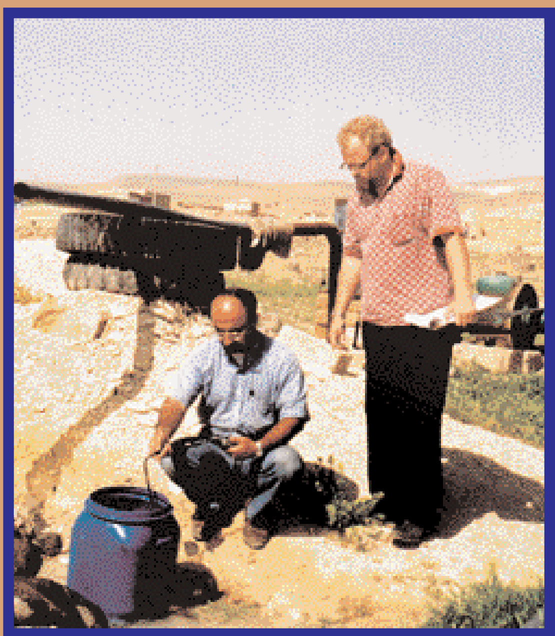
***Cover*: This is the only freshwater source in the Shallalah Saghira village near Aleppo in Syria. If this 1500-year-old *qanat* is not renovated soon, these women and their families will be forced to abandon their homes and move elsewhere.**

WATER SPECIAL

Supplemental irrigation can greatly increase the productivity of rainfed crops by dint of management techniques designed to maximize return per unit of water. For example, applying a small amount of additional water at critical times before a wheat crop comes under stress, can increase the water-use efficiency (WUE) of such crops to 2.5 kg of grain per cubic meter of water used. This is well above the 1 kg of grain per cu m obtained in the best-managed rainfed systems without irrigation.

There is a need for increasing adoption of this technique by farmers in the dry areas, and ICARDA has been working with national institutions to demonstrate and adapt this technology for different cropping systems. ICARDA has shown that good management can introduce a new stability at farm level into crop yields. It continues to work closely with national programs to build expertise in water management. By directing the latest technology into the safe and efficient use of non-conventional water sources, the sustainable use of other water sources is enhanced. Lack of water will always be the scourge of the dry areas but it will not be permitted to destroy them.

Prof. Dr Adel El-Beltagy
Director General



Excessive use of irrigation is harming prospects for farming by allowing salt into water. **See page 16.**

About ICARDA and the CGIAR

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is governed by an independent Board of Trustees. Based at Aleppo, Syria, it is one of 16 centers supported by the Consultative Group on International Agricultural Research (CGIAR).

ICARDA serves the entire developing world for the improvement of lentil, barley and faba bean; all dry-area developing countries for the improvement of on-farm water-use efficiency, rangeland and small-ruminant production; and the West and Central Asia and North Africa region for the improvement of bread and durum wheats, chickpea, and farming systems. ICARDA's research provides global benefits of poverty alleviation through productivity improvements integrated with sustainable natural-resource management practices. ICARDA meets this challenge through research, training, and dissemination of information in partnership with the national agricultural research and development systems.

The results of research are transferred through ICARDA's cooperation with national and regional research institutions, with universities and ministries of agriculture, and through the technical assistance and training that the Center provides. A range of training programs is offered extending from residential courses for groups to advanced research opportunities for individuals. These efforts are supported by seminars, publications, and specialized information services.

The CGIAR is an international group of representatives of donor agencies, eminent agricultural scientists, and institutional administrators from developed and developing countries who guide and support its work. The CGIAR receives support from a wide variety of country and institutional members worldwide. Since its foundation in 1971, it has brought together many of the world's leading scientists and agricultural researchers in a unique South-North partnership to reduce poverty and hunger.

The mission of the CGIAR is to promote sustainable agriculture to alleviate poverty and hunger and achieve food security in developing countries. The CGIAR conducts strategic and applied research, with its products being international public goods, and focuses its research agenda on problem-solving through interdisciplinary programs implemented by one or more of its international centers, in collaboration with a full range of partners. Such programs concentrate on increasing productivity, protecting the environment, saving biodiversity, improving policies, and contributing to strengthening agricultural research in developing countries.

The World Bank, the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP) are cosponsors of the CGIAR. The World Bank provides the CGIAR System with a Secretariat in Washington, DC. A Technical Advisory Committee, with its Secretariat at FAO in Rome, assists the System in the development of its research program.

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ICARDA takes off into 2000

"A Center transformed and ready to 'take-off' into 2000 and beyond at a time when the high quality of its science is still very much needed in the region it serves." That's how Dr Don Plucknett, Chairman of the Fourth External Program and Management Review, summed up the Review Panel's assessment of ICARDA.

Presenting the Panel's findings to ICARDA staff, Dr Plucknett said the Center had been transformed over the last five years by the new committed leadership of the Board of Trustees, by a new Director General with new ideas and a drive to achieve excellence, and by a new management team.

Dr Plucknett said the Panel had been struck by the enormity of water problems, particularly in WANA, which had been identified by international authorities as the most water scarce region in the world in terms of per capita supplies. "The Panel believes water will always be the single most important factor to consider in the Center's work in crop improvement and natural resource management."

Now enjoying the respect of more than 40 countries in its mandate region, ICARDA was being increasingly asked to take on new responsibilities by the countries themselves as well as by others. The Panel agreed with ICARDA's move into Central Asia and the Caucasus where crop improvement and natural-resource management problems are similar to those in the WANA region.

EPMR Chairman Dr Donald Plucknett praised ICARDA as a much-needed Center for its role in serving the poor people of the CWANA region.

"The Panel concluded that ICARDA has made major efforts to achieve the objectives of its founders, and that the need for ICARDA is just as great now as it was in 1977."

Turning to the review period from 1993-1999, Dr Plucknett said it spanned a time of great change, not least in unrestricted core funding which fell from 80% in 1993 to 31% in 1999. Nevertheless, the total ICARDA budget had grown by $4 million over the five years—a "tremendous accomplishment" when unrestricted core funding was falling and the Center was also adapting to new external and internal needs as set out in its new Strategic Plan.

He welcomed the new model of research collaboration with NARS and other partners which fitted in well with ICARDA's move to decentralize research in the regions.

Looking ahead, Dr Plucknett said the fruits of the last five busy years were a much-improved institution with most of its house in order. "The Panel believes the time has come at ICARDA for a kind of 'dynamic consolidation' in which some of the matters that still need attention can be dealt with."

ICARDA was entering the new millennium with world class research or research-related capacity in genetic resources conservation and use; as well as in genetic enhancement of barley, grain legumes and durum wheat. It had in place a regional structure that allowed a continuum of research from headquarters to NARS, including NARS/NARS relationships, and it had learned how to conduct research in its mandate region in a decentralized manner.

The Panel believed ICARDA should aspire, after its period of con-

Tribute Presentation

The new Chairman of the ICARDA Board of Trustees, Mr Robert Havener (right), paid tribute to the wisdom, courage, dedication and devotion to duty of his predecessor Dr Alfred Bronnimann at a special presentation evening in Aleppo. He presented Dr Bronnimann with an engraved silver plate on behalf of the Board and staff of ICARDA to mark his retirement. ICARDA Director General Prof. Dr Adel El-Beltagy (center) added his thanks and good wishes during the special event.

solidation, to gain new positions in science, including recognition as the lead center for integrated on-farm water management for the dry areas, and to become known as the scientific center of excellence serving as the regional node for a consortium of international efforts.

"Donors who wish to see their resources used to help the poor are urged to support ICARDA in its research efforts in the harsh, water-scarce environments of the dry areas. ICARDA is worthy of their support," said Dr Plucknett. ■

During their preliminary visit to ICARDA, members of the fourth EPMR attended Annual Presentation Day (pictures right) at Tel Hadya where an extensive 'menu' of laboratory and field trips was available. For first-time visitors, a general tour of the laboratory facilities and the farm was provided. Those guests wishing more in-depth insight into specific areas of ICARDA research were given the options of finding out about livestock productivity improvement, integrated natural resource management and land use, participatory research approaches, and integrated gene management.

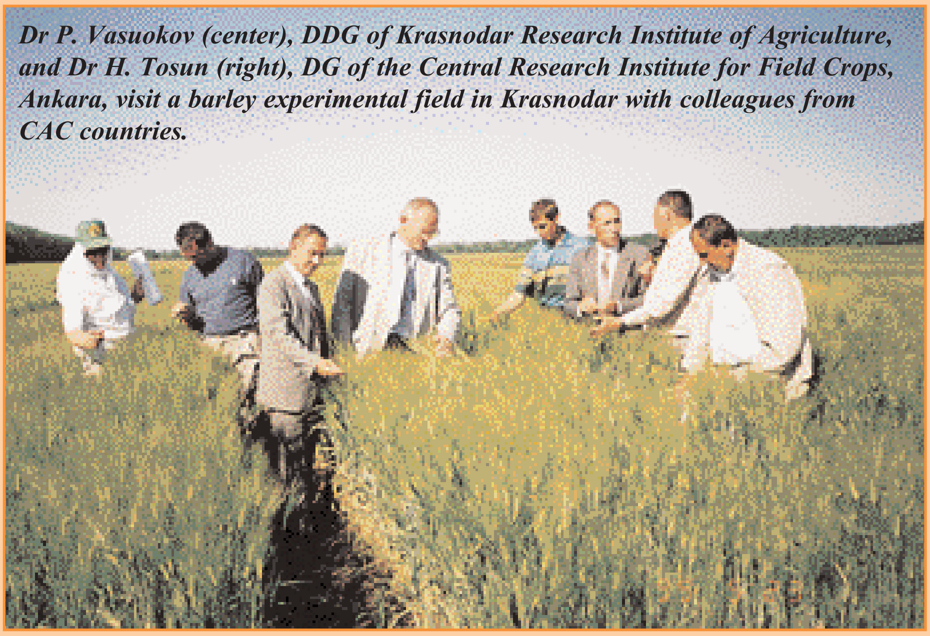
Breeders Bid for Better Barley

A wealth of scientific talent for the improvement of the barley crop in Central Asia and the Caucasus (CAC) came together in a three-center traveling workshop which highlighted potential new varieties and methods for streamlining development of new lines.

From ICARDA's Tel Hadya and Breda stations in Syria, the workshop moved on to look at barley nurseries in Turkey, and then to the Krasnodar Research Institute of Agriculture in Russia, which has been responsible for many decades for breeding the majority of spring and winter barley varieties grown in Russia and neighboring countries.

Taking part were Drs Baribay Sariev (Kazakstan) and Tamara Bessonova (Kyrgyzstan), both of whom have worked with barley for more than 30 years and have developed the varieties grown on many millions of hectares in Central Asia. Other barley specialists were Dr Gudrat Orudjov (Azerbaijan), Dr Huseiyn Tosun, former barley breeder with, and now Director General of, the Central Research Institute of Field Crops in Turkey, and Dr Armen Petrosian, Head of the Department of Science in Armenia's Ministry of Agriculture, and a former Director General of the Research Institute of Agriculture in Echmiadzin. They were joined in Syria by Drs B Dzumahanov (Uzbekistan) and O Kovaleva (Russia), who spent several months working in ICARDA's Genetic Resources Unit.

In the nurseries at Tel Hadya, a number of potential new varieties from Central Asia, and from joint projects with ICARDA, were inspected. Among them were new lines that show even better performance than the spring variety 'Mamluk,' previously developed through cooperation between ICARDA and the Krasnodar Research Institute. 'Mamluk' is also producing impressive yields in official trials in Armenia, reported Dr Petrosian. After two years of testing, average yield increase over current varieties in rainfed systems is 15-18%; extra yield can rise to 22-25% in more favorable conditions.



Dr P. Vasuokov (center), DDG of Krasnodar Research Institute of Agriculture, and Dr H. Tosun (right), DG of the Central Research Institute for Field Crops, Ankara, visit a barley experimental field in Krasnodar with colleagues from CAC countries.

In the quarantine nurseries, the breeders were able to see for themselves how their own fledgling lines were performing under Syrian conditions. Some of these lines, developed in dry environments, were showing excellent promise, especially the mutant line, Donetskiy 8-1 from Kazakstan, which is rather tall but resistant to lodging, and has a large grain size.

The results of the first steps taken by ICARDA and the CAC countries in barley germplasm improvement were seen in the Crossing Block in the Tel Hadya fields. These preliminary crosses include some special hybrid combinations using existing varieties and lines from CAC countries. Two varieties, 'Dostan' (Uzbekistan) and 'Arna' (Kazakstan) have been treated with a chemical mutagen intended to induce genetic variability in barley germplasm suitable for the driest environments.

Workshop members were enthusiastic about a number of the varieties and new lines seen during their visit to ICARDA, and they requested seed samples of both existing varieties and early-generation material. Differences in preference were expressed; Turkey's Dr Tosun preferring barley with two-rows in the ears while six-row lines were the favored choice of the Azerbaijani specialist.

While visiting the Central Research Institute for Field Crops near Ankara, Turkey, the group examined barley nurseries from the national program, as well as large nurseries containing material obtained from ICARDA, including winter barley advanced and preliminary yield trials, and segregating populations. The Turkish researchers, who were particularly impressed by the cold tolerance of ICARDA lines, also asked for sets of further ICARDA material for testing.

On arrival at the Krasnodar Research Institute of Agriculture in Russia, the major role of this breeding center became clear to the workshop members. In the last 30 years, 26 varieties of winter and spring barley have been released by the Institute, with about half of them owing their development to chemical mutagenesis. The winter barleys, 'Debut' and 'Secret,' and the spring barleys, 'Temp' and 'Mamluk,' were multiplied directly from induced mutants, while a number of others had mutants in their parentage.

The workshop was introduced to the Institute by its Deputy Director General Dr P Vasukov, the head of the barley breeding department Dr U Gruntsev, and barley breeders Drs N Serkin, T Tikhomirova, A Salphetnikov, and O Kremzina. All were in agreement that the use of ICARDA material had helped in developing new two-row germplasm with improved cold tolerance.

Very strong links with farmers are a feature of both the wheat and barley breeding teams at the Krasnodar Research Institute. Farmers are involved in preliminary yield evaluation of the most promising new lines and their testing in targeted environments. The barley breeding department also has contracts with 33 large farm businesses, each growing from 500 to 2,000 hectares of barley each year. New lines, including those going into official state trials, are tried out by farmers.

By the time a new variety completes its third year of official trials when it is eligible for official recognition, seed production may already be underway on up to 100,000 ha. This is in addition to seed being produced on the Institute's own seed producing farms.

ICARDA barley breeder Dr Victor Shevtsov, who led this first traveling workshop for the Central Asia and Caucasus countries, said feedback from the various national programs was positive. Cooperation between ICARDA and the countries taking part was now being stepped up as a direct result. Targeted crosses of barley are to be produced at ICARDA's principal research station at Tel Hadya for national programs in Kyrgyzstan, Armenia and Azerbaijan, and further two-way exchanges of material with the Central Asia and Caucasus countries are planned.■

Disney Helps Tell the ICARDA Story

Only a handful of brandnames are recognized in every country of the world. One of them is that of the Disney Corporation which has helped ICARDA and other CGIAR Centers publicize their work.

Nabil Trabulsi, from ICARDA's Aleppo headquarters, took the Disney University communications course in Florida, prior to representing ICARDA at the annual EPCOT International Flower and Garden Festival at Walt Disney World.

A staff member of the Government Liaison Unit at ICARDA, Nabil stayed for three months in the USA for the Festival where the educational exhibit, Gardening for Food Around the World, is jointly sponsored by the World Bank, the CGIAR and the Rodale Institute.

Twelve international communicators, including several from the CGIAR, staffed the exhibit for nine hours each day. As well as a working model of a traditional waterwheel (*noria*), Nabil used a number of ICARDA posters in his presentation to illustrate the shortage of water for agriculture in the dry areas, and how both traditional and modern high-tech methods were being used to increase food production and alleviate poverty. He found a high level of appreciation among the visitors to EPCOT for the work being carried out by ICARDA to feed people while protecting the environment.

A total of 165,000 people visited the exhibit, of which 30,000 attended the four daily formal presentations and the remainder took part in informal exchanges with Nabil and the other international communicators. Among the visitors were several official groups from the World Bank, and the CGIAR.

ICARDA has again agreed to send a communicator to EPCOT in 2000. Ali Shehadeh, from the Genetic Resources Unit, has accepted the challenge of meeting thousands of visitors to the Flower and Garden Festival which will be held in Florida in April.■

Nabil Trabulsi (left) from ICARDA and a participant from IRRI exhibiting posters at the EPCOT International Flower and Garden Festival in Florida, highlighting the importance of land and water conservation for agriculture in the dry areas.

When Water Lights the Fire

Diamonds, gold, oil, land, even spices, have all led to conflict of one kind or another. Yet a simple molecular combination—H_2O—may provide the new century with its most persistent source of cross-border disagreement.

Disagreement over water could stoke the fires of conflict unless nation resource sharing agreements which help everyone in the dry areas enj

It's not just that most of our body comprises water and we each need a vital daily intake. For more than 5,000 years water has been managed to maximize its role in agriculture; many of those techniques were adopted and spread usefully in Europe, West Asia and North Africa (WANA), thanks to the influence of Imperial Rome.

Even if the Romans weren't the first plumbers, they were certainly instrumental in introducing civic baths, central heating, drains and rudimentary water closets to European, African and West Asian countries within their control. Their enduring legacy is a priority allocation of water for urban use and a decline in its availability for agriculture.

The rapid expansion of population in many already-stressed developing countries is generating yet more demand for fresh drinking water. World Bank estimates (1996) suggest that by 2025 around 3 billion people in 52 countries will face either periodic shortages of water or a chronic scarcity.

The historians of two millennia ago record that much of what is today regarded as arid land in ICARDA's mandate region flourished with field crops and productive orchards. It is likely that the Mesopotamians were the first engineers to harness the waters of the major rivers—in their case, the Tigris and Euphrates—for grand agricultural irrigation schemes.

However, water engineering on a grand scale always seems to turn up victims – human or environmental – as well as beneficiaries. Few individuals fully welcome being shifted permanently from homes and land in favor of dam and other storage projects, however great the advantages these schemes bring on a wider scale.

No clear international law exists to govern cross-border disputes over water flow. The World Water Convention, coordinated by the World Water Council, is keen to develop a statement for each of the different regions of the world. This will be based on how countries in those regions see water issues developing over the next 25 years. From the information to be collected it will be possible to develop advance warning scenarios for crisis management and for sustainability.

The United Nations Environment Programme (UNEP) has already come up with a 'water exploitation index' to measure the amount of water used by a country as a percentage of its renewable water resources such as rainfall and river flows. By this measurement, an index of more than 50% indicates potential future difficulties. Tunisia, Egypt, and Libya, for example, all far exceed 50%, and Morocco and Algeria are expected to follow suit as they increase water use to supply their rapidly expanding populations.

For the moment, only a few riparian neighbors have been able to settle differences on water extraction. India and Bangladesh argue over the Ganges while Iraq, Syria and Turkey discuss the Euphrates but have no formal treaty arrangement on either the volume or quality of water leaving Turkey for its more southerly downstream neighbors.

There are exceptions. Sudan and Egypt now have an agreement on the level of extraction each may make from the Nile.

Working with the Syrian national program, ICARDA has been able to more than double wheat yields in Syria by improved irrigation management. Despite this and other advances in water use efficiency, Dr Theib Oweis, who is a water management and supplemental irrigation specialist at ICARDA, sees the potential for disagreement between upstream and downstream countries in providing water to their burgeoning populations. "Some countries are starting to feel they can't manage their agriculture and food security programs, and provide enough water for drinking with the supply they have available," he says.

"These countries may then start to look at shared water resources such as the major rivers that extend beyond their borders."

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Water quality in turn becomes an issue when technically-proficient farmers in the upstream country install extra irrigation to improve crop yields. Most open systems suffer from evapotranspiration leaving a steadily increasing legacy of salt which enters the soil profile before being leached out. The resulting saline drainage waters may have to be pumped back into the river supply to further fuel discontent among downstream users. Egypt is able to dump unwanted high saline drainage water in the sea but this is not an option for countries bordering the Tigris and Euphrates.

The cards remain stacked, therefore, in favor of the upstream countries. Like their neighbors they face competing demands from indigenous industry, agriculture and urban development. In theory, surplus water that Turkey now dumps in the Mediterranean could be diverted to cater for the needs of agriculture and urban areas over much of the Middle East.

Dr Oweis believes countries will eventually be forced to sit around the conference table as water becomes scarcer. He points to Jordan's plan to pump ground aquifer water 350 km from the south of the country to Amman. With an elevation difference of 1,000 meters between source and destination, this will be a remarkable feat of engineering at an estimated cost of around $1 per cu meter. Source water from elsewhere at 50 cents per cu meter and you have a worthwhile alternative. Provided, that is, society accepts the premise that some subsidy will continue to be needed for sectors such as agriculture.

It is a brave government indeed that proposes putting anything like a real monetary value on the cost of water. In many countries with a significant dry area, water is regarded as a gift from God. Few governments charge consumers for little beyond the cost of operating the system that delivers water for domestic or agricultural consumption. Persuading society that it should be paying to subsidize vital food production requires a major change in collective thinking.

There is, however, much that is being done to make best use of water at present levels of supply and demand. Agriculture may still take 75% of available water in the Middle East and North Africa but it is steadily losing out to domestic requirements. Scientists such as Dr Oweis and his ICARDA colleagues are working to ensure the efficiency of water use for food production is kept high in many ingenious ways, particularly in those dry regions around the Mediterranean.

Where rain does fall erratically, it is frequently spread so thinly it either evaporates or is of little lasting benefit for crops and vegetation. Water harvesting concentrates rain water from very localized areas or up to several hundred square kilometers by building barriers and channels to guide runoff into ponds, reservoirs or lakes. In essence, an achievement not all that different from the Romans and their predecessors who likewise collected rainfall and stream water for use where it does the most good.

Rainfed wheat yield in the WANA region averages about 1 tonne/ha, in a range from 0.5-2 t/ha depending on rainfall pattern as well as fertility and crop variety, but always well short of the potential of 5-6 t/ha achievable from well-watered sites. In the dry areas, farm production performance is now evaluated in terms of water-use efficiency (WUE), not yield per unit area, since it is now clear that water is the greatest limiting factor.

By this reckoning, the average output of wheat in WANA is about 0.35 kg grain per cu meter of rain. Good management and enough seasonal rain at the right time takes this up to 1 kg/cu m. Supplemental irrigation using harvested rainwater or surface water can dramatically increase WUE by more than 2.5 kg/cu m over rainfed production. This is done by ensuring that extra—albeit limited—water is available to alleviate severe moisture stress when the wheat plants reach their most critical growth and ear filling stages.

This supplemental irrigation (see p14) makes considerably more efficient use of water than in fully irrigated areas where the rainfall contribution is so exceeded as to have little effect on yield.

Quite simply, many farmers currently use too much scarce water, and that applies both to full irrigation and supplemental management systems needing a third to two-thirds less, says Dr Oweis. It comes back, in part at least, to that low cost of water. Where there is a charge imposed it is often just a few cents per hectare,

Continued on page 21

Dams like this allow the distribution of vital irrigation water for agriculture but some environmentalists fear that even larger schemes now being planned may result in harmful effects on ecologies and the environment that outweigh the expected benefits.

Winning Ways with Water

Flooding on a semi-arid steppe? It's just one of the irregular forces of nature that ICARDA scientists are seeking to manage for the benefit of a hard-pressed rural population.

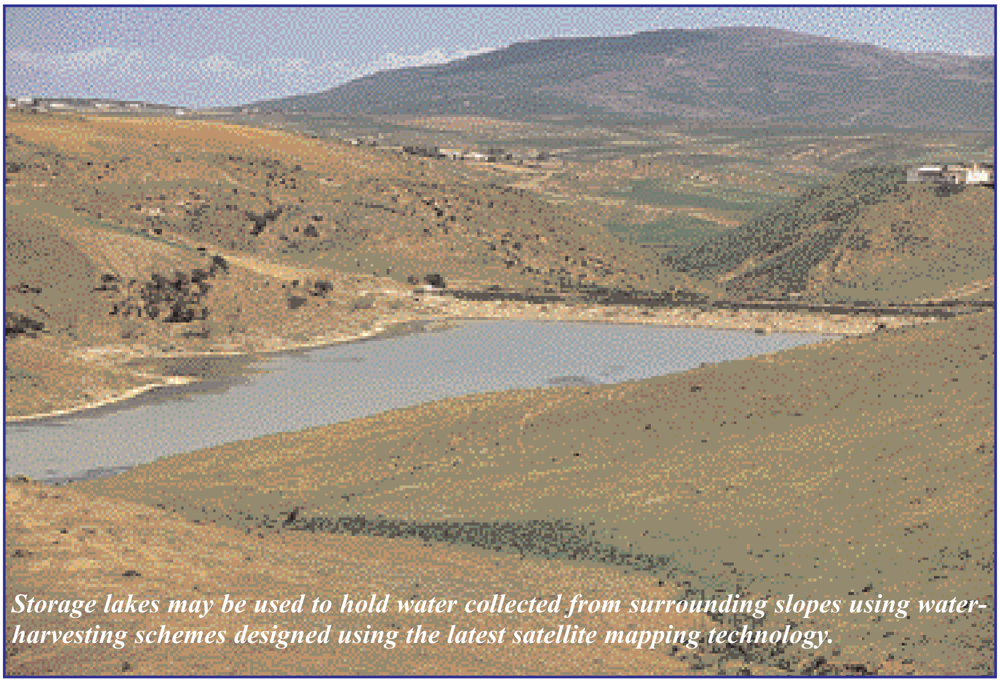
By Theib Oweis

Dry areas are the focus of ICARDA's research and development programs but work on water-use efficiency has its application well beyond most people's vision of a 'dry area.'

Three major environments come within the scope of ICARDA's water specialists—drier environments such as steppe or *badia*, rainfed cropping environments and fully irrigated agricultural areas. Shortage of 'sweet' water is common to all such areas but the pressures and solutions have to be tailored to the immediate environment to obtain the highest crop yields from the most effective use of life-enhancing water.

That's why it is vital to appreciate that the semi-arid steppe which suffers long periods of zero rainfall can be harmed irretrievably when scarce rainfall is so intensive that it leads to flash flooding and erosion of already-fragile soil. Invariably, however, it is more likely the case that the meager seasonal rainfall is so widespread that it is of little or no benefit to plants before it is lost through evaporation or simply dissipated uselessly in the soil.

ICARDA is engaged in a number of projects relating to water harvesting in environments with either too little water or where it is uneconomic to grow crops with imported irrigation water. The underlying principle is the concentration of water from a large area on to a smaller area of land where the precious moisture can do the most good in nurturing either arable crops or trees. In fact, water harvesting isn't new. Systems based on technology devised several thousand years ago are still in use, and ICARDA is compiling details of indigenous systems in each of the countries where it operates.



Storage lakes may be used to hold water collected from surrounding slopes using water-harvesting schemes designed using the latest satellite mapping technology.

A major trans-national project in on-farm water husbandry takes in research projects in eight countries: Egypt, Iraq, Jordan, Libya, Morocco, Pakistan, Syria and Tunisia.

Within the CGIAR System-wide Water Resources Management Program, ICARDA leads this ecoregional program in 'On-farm Water Husbandry in West Asia and North Africa' that links national program researchers in WANA. The research program addresses four main themes:

- Description and analysis of indigenous systems, with particular focus on the human dimension;
- Development of methods for appraisal of sites for water harvesting potential;
- Optimizing the utilization of harvested water through devising proper methods and techniques; and
- Disseminating new technologies to land users.

Some of the richest experience gained so far has come from the Matrouh Resource Management Project centered on the town of Marsa Matrouh in northwest Egypt. ICARDA provides technical assistance for implementing this project within the Egyptian national program on "Research for Development." It has been financed since 1994 by the World Bank and the International Development Association. ICARDA is promoting the integration of water harvesting into watershed development plans appropriate for various ecosystems.

Various techniques for water harvesting have been introduced or improved. Macrocatchment systems enable the concentration of water from large areas from which it can be stored in small reservoirs or in the soil for agricultural use. For water harvesting in *wadi* beds in Matrouh, stone walls are appropriately located and designed to cross the *wadis*, harnessing sufficient water to grow figs, olives and melons. Cisterns (large underground tanks) are also examples of macrocatchment and have been the only source of water for human and livestock consumption in this area for thousands of years. Many thousands of new cisterns are being constructed by the project to help farmers.

ICARDA is working with the project on improving the efficiency of this indigenous system. The overall efficiency of these cisterns can be improved by firstly increasing collection efficiency and, subsequently, storage and utilization efficiency.

In Tunisia, other types of water harvesting are used, including mountain lakes constructed to supply supplemental irrigation water for crops much lower down. The famous *jessour* and *misqat* systems have supported figs and olives for hundreds of years in drier environments.

At another extreme, microcatchment is proving exceptionally useful for small-scale agriculture—down to perhaps just one tree in some circumstances. The principle is the same as for some macrocatchment techniques—storing moisture in the soil. The catchment area may, however, be just 50 sq m, and the semi-circular bunds just a few meters long.

Contour ridges created on the slopes are being used successfully in a number of countries to concentrate water in the required place particularly for improving shrubs and grasses for livestock. ICARDA has adopted simple methods to help farmers properly locate a contour ridging system. Using transparent plastic tubes filled with water and marked off for level, the task can be carried out quickly by just two people. In Pakistan, a father and son working together planned 5 km of contours in one day using the tubes at 15 m spacing.

Other microcatchment techniques found by ICARDA to be superior in the dry areas are the runoff strips for field crops such as barley, and small basins such as semicircular bunds and negarim (individual small basins) for shrubs and trees. A further alternative, particularly suitable for steppe areas where growing any crop is difficult for lack of moisture, is to alternate cultivated strips with bare water collection strips. Small gullies or depressions can be placed laterally in the crop rows to distribute water more evenly. Such a technique is useful for wheat, barley, lentil, chickpea and other field crops. It will not appeal to farmers who get sufficient rainfall to grow some sort of crop on all their land, but could make the difference between some crop production and none at all in more water-scarce areas.

Plowing in strips separated by natural catchment areas supplies more water to barley which would normally suffer stress, and the technique substantially increases yield and reduces risk of crop failure. ICARDA has developed technologies to overcome the uniformity problems associated with this technique. ICARDA is also adapting a special ridger that can be towed by a normal tractor for large-scale mechanical implementation of the semicircular bunds. With this technology, shrub survival rate in the Syrian steppe pilot project was increased from 10% to 90%.

Increasingly, remote sensing by satellite or other aerial photography, and geographical information systems (GIS), are being used to help determine suitable sites for water harvesting. For example, the Landsat system will give a 30 m by 30 m definition with which ICARDA scientists can plot areas with high potential for water harvesting. Once the site has been identified, fieldwork then takes place to determine factors such as run-off so the expected amount of water from the site can be estimated.

Any of these techniques is useable in the drier environments where rainfall is not enough to support crops. It has to be remembered that while 100-250 mm of annual rainfall is very little indeed on an individual field or farm, it represents a great deal of water when spread over the vast extent of the dry areas. About 95% of that rainfall is lost through evaporation without any benefit. However, we can still make use of this rainfall by harvesting even where there are no rivers and no groundwater.

Nor is it simply a case of producing more food by harnessing this moisture. Desertification is halted, wind and water erosion is prevented, and the environment maintained. By improving the potential returns from farming, male migration in search of city work is cut back.■

Dr Theib Oweis is Water Management/Supplemental Irrigation Specialist at ICARDA.

Above: A technique in use for many hundreds of years but updated versions of the* jessour *can still play a valuable role in making efficient use of scarce rainfall in the dry areas.
Left: The unplanted strips in the field provide a catchment area for water which nurtures the crop plants alongside to give better results than from planting the whole field with crop.

Tunneling for Survival

A small and poor village faces the grim prospect of being abandoned if neglect and lack of money is allowed to destroy a 1500-year old water supply system which is its lifeline. ICARDA is monitoring how the experiences of the villagers of Shallalah Saghirah can be used to help other communities to manage their fragile water supplies sustainably.

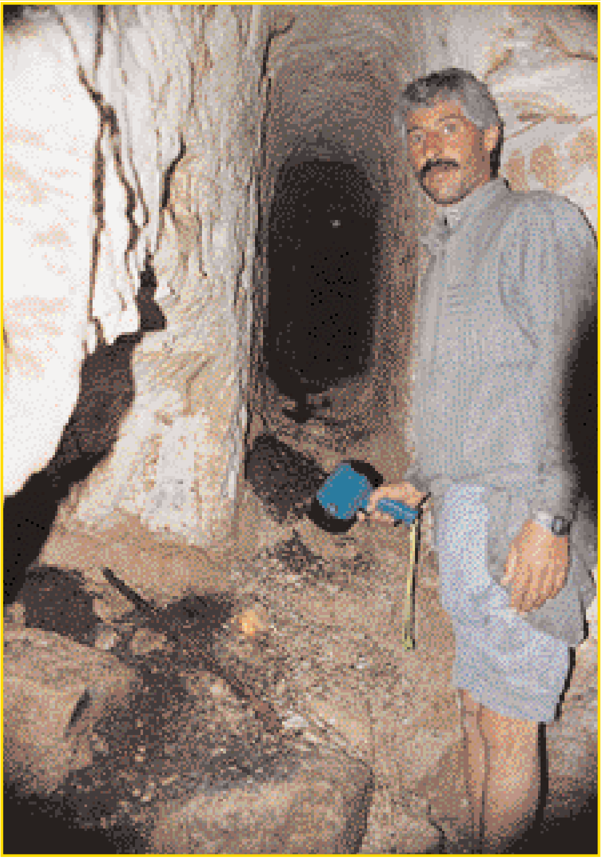
By Joshka Wessels

Shallalah Saghirah ("little waterfall") is a small village of about 20 households located in the Khanasser valley, in northern Syria. The village has no electricity and still uses an ancient '*qanat*' system as its main source of water.

In Syria many ancient *qanat*/irrigation systems have been abandoned due to falling water tables caused mainly by the increased use of modern electric- and diesel-pumped wells. Hydrological research shows the diesel-pumped wells located in the Khanasser valley do not affect Shallalah Saghirah yet, but many shafts and water collection points of the *qanat* system are filled with debris that has accumulated over the years. Due to lack of maintenance the water flow has reduced considerably.

Urgent renovation is necessary so the village doesn't lose its main source of water. Some elderly residents, who are experts on the *qanat* system, and their sons have expressed willingness to spend time and use their expertise and labor in the renovation of the *qanat*. However, the villagers are resource-poor and must seek outside help for the estimated renovation costs of $10,000 for the low-cost material to restore the *qanat* system which was originally constructed in the late Roman or early Byzantine period.

This renovation of the 520-metres *qanat* is part of applied anthropological action research being implemented by ICARDA at village level. Through intensive fieldwork and scrutiny of earlier studies—a similar exercise was carried out in Oman—methods of renovating these ancient systems using low-cost modern technologies are being investigated. Renovation and cleaning of the *qanat* will not only be based on specialized knowledge on *qanat* systems but also on the local expertise and direct needs and priorities of the villagers. Their active involvement and responsibility in planning, implementation and utilization are integral parts of the action research project.



This part of the* qanat *is tall enough for Mohammed Khair Ismail, one of the villagers working with ICARDA, to stand upright. Blockages mean it is completely dry at this point.

The small irrigated area (center) at Shallalah Saghirah provides a vital supplement to the incomes of villagers. On the slopes to the left are the remains of Roman-era terracing where the water supply has been allowed to dry up.

Left: Direct involvement of villagers in the renovation project is essential to making it and the system of water allocation work. Here, villagers work on a sketch plan of the qanat *to be renovated.*
Below: A village elder opens up the birkeh, *or reservoir, from which certain households in Shallalah Saghirah are allowed to draw irrigation water for a set period each day.*

Qanat Facts

A *qanat* is a tunnel, perhaps many kilometers long, which taps water where it concentrates in the ground and leads it to the surface. The tunnel gradient must be less than that of either the water table below ground, or the ground's surface. The design of the tunnels therefore has to be very precise, and they require regular maintenance. But they operate without any mechanical device.

Qanats are thought to have originated in the area that is now northern Iran but the technology was later carried as far afield as western China, to Spain where they are known as *galerias*, and subsequently to South America by the Spanish. Iran has by far the greatest number of working *qanats*—in excess of 20,000—and was building new *qanats* until relatively recently. However, with the exception of Oman, in particular, *qanats* have largely fallen into disuse in most Arab countries.

Ultimately the project aims to generate more agricultural income at village level and also enhance the efficient use of water for agriculture. Moreover it will directly save water costs for the village if, through the renovation effort, more water is harvested. Shallalah Saghirah is not primarily an agricultural village, although many villagers do grow barley, vegetables and fruit trees to supplement income from outside jobs.

Renovation of the *qanat* may increase water discharge from one liter per second to 1.5-2 liters/sec, thereby securing domestic supplies for 150 people but also potentially allowing more water to be used for crop irrigation. ICARDA scientists are carefully documenting the existing system of water allocation and rights so this can be continued and conflict avoided when the additional water becomes available.

Next to its importance for the ongoing anthropological research, which will monitor the value and use of the *qanat* in a modern environment, the actual renovation is a contribution to the cultural heritage of Syria in terms of developing the sustainable use of ancient irrigation systems for agriculture. There are perhaps 250 *qanat* systems remaining in Syria, none of which is in full working order. Syrian experts, as well as scientists from a number of US, Middle Eastern and French universities, are assisting with the project. ■

Ms Joshka Wessels is an Associate Expert - Applied Anthropology with ICARDA's Natural Resource Management Program.

A Little Goes a Long W

It's the hardest task of all for the farmer anxious to grow a successful crop. To determine how much irrigation water to apply, and when, to get the optimum benefit from this scarce resource in the dry areas, ICARDA is experimenting on spreading the same amount of water widely for maximum returns.

By getting extra water to his crops at critical growth stages befor from drought stress, this farmer can increase his overall yields. S allows farmers to make the most efficient use of scarce water by two-thirds of the full irrigation requirement at the best timings.

By Theib Oweis

Go to any country in the world – dry or humid, developed or developing, rich or poor – and there will always be farmers accused of over-irrigation. For these growers, the temptation of having even limited supplies of water to hand proves too great and they must use it to gain, as they see it, the greatest guarantee of a high-yielding crop.

Only gradually is it becoming accepted that the gains from over-irrigating can be less than from using the same amount of water to under-irrigate a wider crop area. By skillful management of supplemental irrigation in rainfed areas, water-use efficiency can be greatly increased to the benefit of the crop and the farmer.

In water-scarce areas, the goal should no longer be to get the greatest yield per hectare or to satisfy the crop's full water requirement. ICARDA has found that supplementing only 50% of a wheat crop's irrigation requirement reduces the grain yield by only 10-20% relative to full irrigation. By using the saved 50% to irrigate an equal crop area, total production is greatly increased.

Harvested yield across a greater area of land is much improved by using supplemental irrigation in conjunction with appropriate varieties and a good fertilizer program.

Supplemental irrigation (SI) trials were carried out at the ICARDA research station in northern Syria. Water-use efficiency in SI is a function of the amount of irrigation water applied. It was found that the maximum water-use efficiency is reached when one- to two-thirds of the full irrigation water is applied. Given that many farmers over-irrigate, at least one-third of the full irrigation requirement can be saved without significant losses in productivity.

The actual amount of water that should be applied will vary according to the actual rainfall in the rainfed areas. Research in the eastern Mediterranean region has shown that the amount of rain falling before the end of March is a good indicator of what will happen later in most years. One to three supplemental irrigations between late March and early May

Way

re they start to suffer Supplemental irrigation using between one- to

are usually enough for a wheat crop.

It is important to remember that the crop will normally produce some yield without irrigation because of the influence of even limited seasonal rainfall. These rainfed crops should not, therefore, be irrigated at times when rain is already catering for their immediate needs, or irrigated in an attempt to provide moisture-stress-free conditions throughout the growing season. The prime aim should be to ensure there is a sufficient amount of water available during critical stages of crop growth to permit optimal instead of maximum yield.

In the Mediterranean-type climate, moisture is usually short in the spring when crops need it for accelerated growth. Evapotranspiration rates are higher and soil moisture in the root zone is depleted as plants increase their uptake. Before long, in the absence of rain, moisture stress begins and can continue until the end of the season with severe effects on final yield. Wheat may have a yield potential in West Asia and North Africa of more than 5-6 tonnes/hectare but the average yield of rainfed wheat is only about 1 t/ha, although it can range from 0.5 to 2 t/ha, depending on rainfall, soil fertility, management and crop variety.

The average water-use efficiency (WUE) of rain in producing wheat in the dry areas of WANA is about 0.35 kg grain/m^3, although this can be increased to 1 kg grain/m^3 with good management and favorable rainfall. Water used for supplemental irrigation can be much more efficient.

ICARDA research has demonstrated that a cubic meter of water applied at the right time when the crop is suffering from moisture stress, and combined with good management, is more than twice as water-efficient than rainfed production (Fig 1). Why is the water-use efficiency so high? It can be attributed mainly to the effectiveness of applying even a small amount of water to alleviate severe moisture stress during the most sensitive stages of crop growth and seed-filling. Applying the additional water before stress reaches a peak will allow the plants to reach their high yield potential.

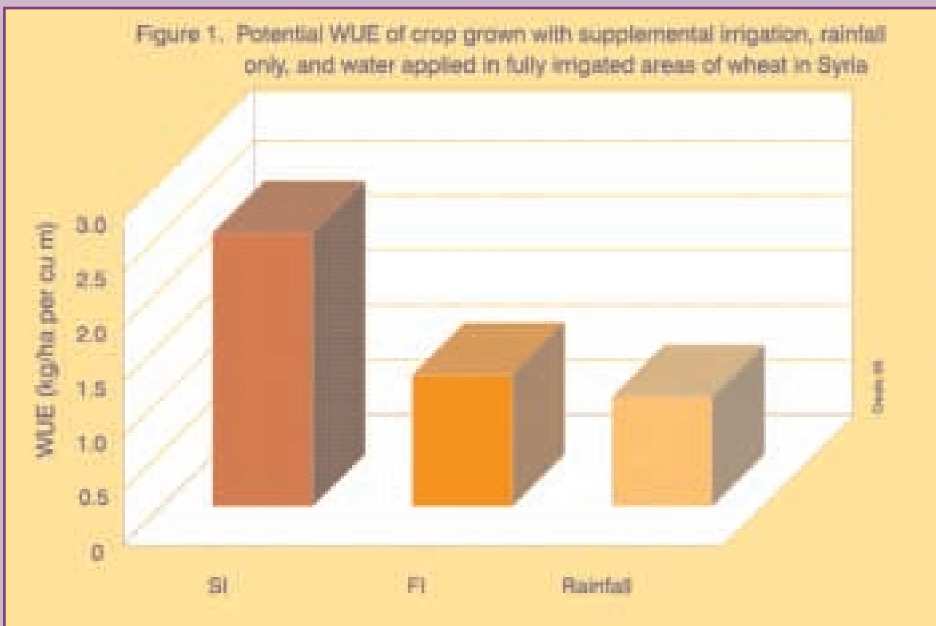
Does supplemental irrigation really outperform full irrigation in its water-use efficiency? Again, the results tell the story. In fully irrigated areas with good management, wheat grain yield could reach 6 t/ha when using about 800mm of water. That gives a WUE of about 0.75 kg grain/m^3—one third of that under supplemental irrigation.

However, it remains the case that most farmers irrigate earlier than they need to, and then apply too much water for an individual crop's needs. In part, this is because the cost of irrigation water is low and there is little incentive for the farmer to use less. ICARDA is investigating various ways of helping the farmer make better judgments about issues such as timing, either by recording rainfall and linking it to soil and crop conditions, or by using 'indicator' plots containing other water-sensitive crops to give early warning of impending stress.

Farmers are also reminded of the importance of other farm management practices in getting best crop performances in rainfed systems. These include variety choice and planting date. Lack of nitrogen is a common problem that can lead to lower yields and poor water-use efficiency. Other nutrient deficiencies will also hamper crop response to nitrogen and to water if they are left uncorrected.

The aim of the ICARDA research is to produce a package of measures and recommendations that will help as many growers as possible to gain the maximum benefit from available water. It is water, not land, that is the limiting factor in the dry areas. Any improvement in water-use efficiency is reflected across the whole agricultural sector.■

Dr Theib Oweis is Water Management/Supplemental Irrigation Specialist at ICARDA.



Full irrigation (FI) has potential to increase wheat yield per hectare to a creditable 6 t/ha but at the expense of applying 800 mm of water. The water-use efficiency in producing this grain is much less than that of supplemental irrigation (SI) which spreads the water over a wider crop area before critical periods of moisture stress.

Intervention to Stop Sweet Water Irrigation Turning Sour

The lessons of introducing technology without considering its potential effects on fragile resources such as underground aquifers in the dry areas are beginning to show in a valley where excessive use of irrigation is harming future prospects for agriculture. 'Sweet' water is starting to give way to brackish water from a nearby salt lake. ICARDA is formulating solutions which will be applicable in similar situations elsewhere.

The salt content of water pumped for irrigation is measured by ICARDA scientists who are monitoring salt intrusion in the Khanasser Valley.

It's a recurring dilemma for many farmers eager to expand their production. They need to invest in irrigation equipment to drive up their incomes, but the side effects of using that very machinery could make their land unproductive.

The reason is that good water available for volume irrigation in dry areas is inevitably very limited. Once an aquifer in a low-rainfall area has given up its stored content of sweet water, there is a risk of it being replenished from less palatable sources. This is exactly what is happening in Syria's Khanasser Valley.

Irrigation is boosting crop yields for now in Khanasser but those growers, who have so far installed pumping equipment, are also condemning their land to a gradual decrease in productivity unless they act now to forestall disaster. The lessons being learnt there from an ICARDA project with local growers will have applications in many similar areas where farmers, who have not traditionally irrigated, also want to increase their yields.

Irrigation brought higher crop yields to the Khanasser Valley at first, but now the groundwater resources have deteriorated both in quantity and quality. Large parts of the valley could be rendered unproductive due to salinity.

Pressure on land resources due to increasing population leads to degradation if the carrying capacity of land is exceeded. Without the development of appropriate land-use practices, long-term overuse of land may irreversibly destroy its potential for production.

By Robert Hoogeveen

However, this does not mean that intensification cannot be used as an alternative way to accommodate increased pressure on the land resources. With this approach, a smaller amount of land is used more intensively, but it is also cared for more intensively. Investments are made to enhance its productivity.

In dry areas, soil moisture is usually the most limiting production factor. Intensification therefore tends to be based on moisture conservation and irrigation. If the water quality is unsuitable for irrigation, salinization processes are accelerated and can render the land useless for any cultivation after relatively short periods.

In the Khanasser Valley, about 70 km southeast of the city of Aleppo, farmers are investing in irrigation to maximize returns from their land in the semi-arid area at the fringe of the Syrian Steppe. They use the groundwater from the shallow unconfined aquifer for irrigation. This aquifer is recharged by local rainfall but this is irregular and only between 200-250 mm each year, mostly in the winter months. Excessive pumping can lower the groundwater table significantly, especially at peak irrigation periods. Since the groundwater system in the Khanasser Valley is linked to the Jabul Salt Lake, prolonged lowering of the groundwater table causes salt water from the salt lake to enter the sweet-water aquifer.

Most households in the valley practice a combination of crop production and livestock rearing. Rainfed farming, with barley as the dominant crop, occupies most of the arable land. However, irrigation farming has developed rapidly over the past 10 years on the most fertile soils in the middle of the valley. Most irrigating farmers practice a rotation with cotton and wheat, and sometimes fallow. The hill slopes and the eastern plateau are used exclusively for grazing.

Typical wells in Khanasser are a combination of a tube well and a traditional Arab well. The typical Arab well has a diameter of 1.25 m and is dug to 5 - 10 m below the groundwater level. At the bottom of the well, a 3 m-high chamber with a 3 m diameter is excavated to serve as a reservoir. Several horizontal channels (*daharas*) are drilled radially from the storage chamber to increase the rate and amount of water flowing to the well. These *daharas,* with a diameter of 2.5 – 5.0 cm, can be up to 250 m long. About one meter away from the Arab well, a tube well is drilled. The chamber of the Arab well is then connected to the tube well by a horizontal hole. The pump is located at the bottom of the tube-well. With this system, farmers can pump continuously for about three hours before the collection chamber is empty. It means most farmers can irrigate for up to three hours in the morning and then for another two to three hours in the evening.

The first irrigation wells were drilled in the Khanasser valley in 1975, but rapid development of wells began around 1990 so that by 1998, 154 wells were being used for irrigating wheat, barley and cotton from the unconfined aquifer. The main driving force for the rapid increase was that farmers wanted to share in the very evident success of the first few farmers to irrigate. Now, these first irrigators complain they can only pump water for about 5 hours a day until the wells run dry, instead of 24 hours as before.

Pumping capacity in the valley could irrigate about 450 ha, but only around 150 ha was being irrigated in 1998 because farmers could not obtain sufficient groundwater for all the fields they had hoped to irrigate. Even now, more farmers want to sink wells and construct *daharas*, because the returns from irrigated crops are still, they claim, significantly more attractive than from rainfed barley growing.

Basin flooding is the only irrigation method used. From the well survey, total water extraction was estimated at approximately 7.7 million cubic meters for the entire valley. During this survey, groundwater levels were measured throughout the valley. (Fig. 1). The water level of the Salt Lake was 314 m above sea level. Valley groundwater levels generally follow the topography.

Figure 1: An ICARDA survey found that the water level of the salt lake was 314 m above sea level. Water levels in many parts of the valley were already close to this. Rapidly-increased extraction for irrigation has lowered the groundwater level in several areas, causing water from the lake to flow towards nearby wells.

Irrigating farmers empty the collection chamber of their Arab wells twice a day on average. This means that a ‘draw-down’ cone develops around the well that lasts until the well is refilled. This cone is enlarged because of the horizontal holes (*daharas*) drilled around the collection chamber. As some of these holes are 250 m long, the wells are effectively closer to each other than might at first appear, and the draw-down cones overlap, especially in the central northern part of the valley.

This causes a regional lowering of the groundwater level, that can be observed clearly in the area between Shallaleh Kbireh and At Shaneh where the water level was below that of the Salt Lake. This low water level causes water from the lake to flow towards the nearby wells. Near the village of Al Hawwaz where cotton is irrigated, the groundwater table is lowered during pumping, but no draw-down was observed. However, during the summer months it is likely that groundwater levels will drop periodically so that water from the Salt Lake can reach the unconfined aquifer. When this saline water reaches the village of Al Hawwaz, it may then flow to the south of the valley towards the lower groundwater levels in Qorbatieh.

The effect of this salt-water intrusion on the salinity of the valley’s water can be measured in electrical conductivity (EC) of the groundwater. An electroconductivity of 1 dS/cm means that about 0.64 g/l salt is dissolved in the water. In the Salt Lake itself, water reached up to 43 dS/cm at the beginning of summer 1998 and the salinity was of the sodium chloride (Na^+Cl^-) type. Irrigation with water this saline can degrade the soil irreversibly.

Continued on page 21

High-tech Tools Reveal the Secrets of Dry Area Watersheds

Sustaining viable traditional agricultural communities in the world's driest areas requires the application of some very non-traditional, high-tech tools and technologies. ICARDA is ideally placed with the necessary expertise.

Cloudless skies, empty plains, a scattering of dusty salt bushes, rock outcrops jutting from the shallow soil, a flock of sheep, some small boys, and a donkey slowly moving in the distance. A universal and seemingly timeless picture of the dry areas, etched in the minds of ICARDA's natural resource management scientists.

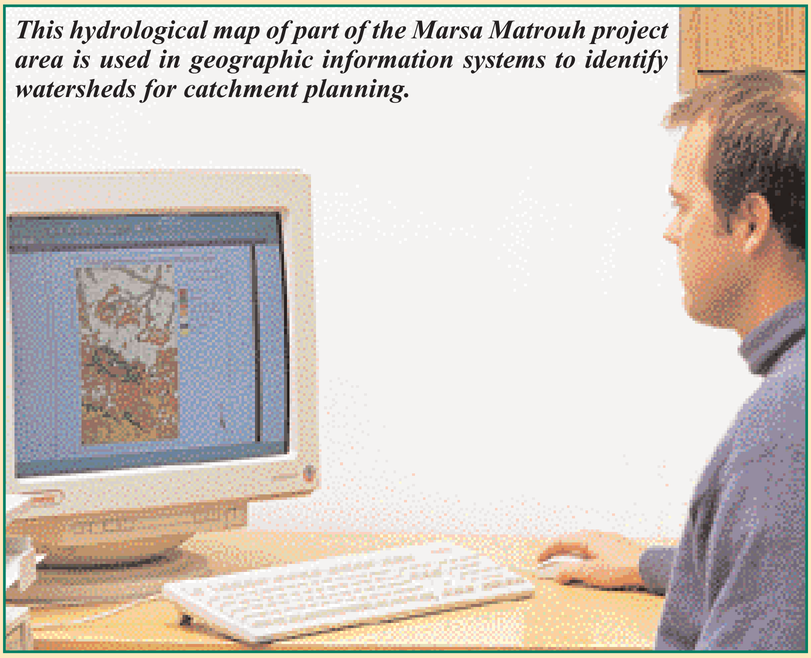
It is an image that disguises to some extent the continuing ecosystem based on seasonal rainfall that allows the dry areas to support flocks of sheep and food crops. The picture may, however, have to be re-drawn without those visible signs of sustained life unless the latest technological aids are focused on dry area management.

Ever-increasing human demands seem to have exceeded the carrying capacity of our natural resources. Sustainable management practices that will reduce the pressure on these natural resources are urgently needed. A participatory, problem-solving approach, involving the rural population, planners, scientists, and policy makers from all levels and disciplines is essential to the successful implementation of natural resource management programs.

To conduct such effective natural resource management, geographic areas should be delineated by their natural boundaries. Watersheds or catchments are hydrologically-defined areas that drain into a stream or surface water body. The flow of water, sediments, and nutrients through watersheds connects the up- and downstream users of these natural resources. By operating and coordinating programs on a watershed basis, stakeholders can better understand the cumulative impacts of various activities and determine the most critical problems within each watershed.

In areas where renewable groundwater resources are available and of good quality, the judicious use of this resource for household activities, watering of animals, or supplemental irrigation is an extremely valuable, stabilizing factor for the livelihoods of the rural population. Hidden groundwater divides, which separate aquifers or groundwater basins, do not always coincide with the topographic surface water divides. However, due to the relatively fast nature of surface water processes, as compared to groundwater processes, a watershed approach helps us to focus our attention on capturing this resource, before it disappears into salt sinks, or evaporates into the atmosphere.

Traditional agricultural research conducted in laboratories, pots, and plots has increased our understanding of small-scale processes, but is still not enough to explain the interdependency of these processes at the watershed scale. The characterization of the spatially- and temporally-variable water, soils, and vegetation, and the effects of natural and human activities on this system is an almost impossible task. However, techniques such as remote sensing, GPS (global positioning systems), automated monitoring equipment, digital elevation models, GIS (geographic information systems), and computer-based mathematical models have increased our capability to measure, analyze, and synthesize the spatially-distributed and time-variable interaction of a broad spectrum of our natural resources. ICARDA is currently testing and evaluating these technologies for their application throughout the Central and West Asia and North Africa region.


This hydrological map of part of the Marsa Matrouh project area is used in geographic information systems to identify watersheds for catchment planning.

By Adriana Bruggeman, Aden Aw-Hassan, Nicholas Thomas and Sobhi El-Naggar

More information is needed on the long-term effects of different land uses and management practices on the natural resource base of spatially-variable watersheds. Simulation models allow us to extend our knowledge of the current system to predict future effects. ICARDA is focusing on the state of the art in watershed modeling, integrating simulation techniques directly with GIS to provide scientists and planners with maps, graphs, and numbers for natural resource impact analyses of different development scenarios. Daily rainfall and temperature data, soil and land management data are collected from meteorological databases, soil maps, satellite imagery, and field surveys to serve as input to the model. Surface flow processes, erosion, nutrient transport, grazing effects, and crop yield are predicted throughout the watershed.

However, to make the best possible use of available natural resources, it is necessary to go beyond the biophysical constraints to consider socioeconomic effects. Whereas the physical, chemical, and biological processes in the watershed can be reasonably well described, the institutional arrangements that affect the activities in the watershed are often less obvious. To determine optimal land use practices, the watershed simulation modeling will be integrated with a socioeconomic component for assessing the financial and environmental costs, the benefits of alternative practices, and the willingness and ability of land users to invest in different land management alternatives. The challenge is to design, implement, and evaluate watershed systems that are environmentally sustainable, economically efficient, and socially acceptable, based on full participation by all stakeholders.■

Dr Adriana Bruggeman is Agricultural Hydrology Specialist; Dr Aden Aw-Hassan, Agricultural Economist; Mr Nicholas Thomas, GIS Analyst at ICARDA; and Dr Sobhi El-Naggar is Deputy Director General of the Matrouh Resource Management Project, Marsa Matrouh, Egypt.

Shake that Salt Right Out of the Soil System

Blending allows saline waters to be used productively in agriculture without harming sensitive crops.

Water may be a life-giving restorative for plants and humans alike, but dealing with it once it has been used either in agriculture or in cities is often nearly as big a problem as acquiring it in the first place.

By Fawzi Karajeh

Check out your garden in the next prolonged dry spell. After a few days of regular watering the soil crust will probably take on a grey-white tinge. It is a sign that chemicals—mostly salt—even in the water from a domestic tap are accumulating on the surface. Consider then what this means for irrigated agriculture in the world's driest and arid areas where water application beyond the actual needs of the crop is a must to compensate for evapotranspiration. Every time irrigation water goes on a field it adds salt to the root zone but this salt concentration has to be kept within acceptable levels or yield and quality may suffer.

It is no mean task for farmers in the dry areas who are pleased to apply any irrigation water at all. If the salinity of good quality irrigation water is 500 mg/liter TDS (total dissolved solids), every 10,000 cu m of water contains 5,000 kg of salts. But that's not all. Additional salt comes from naturally-occurring salt in the soil structure, and from consumptive use of capillary ground water.

In an experiment in Syria conducted by ICARDA, in collaboration with Aleppo University and funded by the Canadian International Development Research Center (IDRC), preliminary results show that bread wheat irrigated by saline groundwater of about 5 dS/m (1dS/m = 650 mg/l or 650 parts per million total dissolved solids) produced 1 kg of grain per cubic meter of water. The same crop irrigated with water of double the salinity produced just 0.3 kg grain/cu m of water.

In Egypt, where about a third of the 2.7 million hectares irrigated land in the early 1970s was salt-affected, reported results show salinity reducing yields from conventional agriculture by 30%. An intensive program was started to improve sub-surface drainage on at least two million hectares by 2000.

More than half of the 2.32 million hectares of irrigated land in Uzbekistan is salt-affected, and the build-up of salinity is seriously threatening productivity. ICARDA, with national scientists, has established a research site near the Arys-Turkestan Canal in Kazakstan.

The research there aims to improve irrigation efficiency with attention to leaching; to improving drainage in order to reduce soil salinity; to irrigation regime; to crop rotation, and other experimental treatments. An important component of the project is building awareness among farmers of the importance of drainage and that better management can lead to higher yield with less water used and better soil quality. Early results from 1999 look very promising, having produced significantly more cotton yield with about 40% less applied irrigation water.

Where natural drainage is insufficient to leach accumulated salts below or out of the root zone, artificial drains must be installed.

To avoid upward movement of saline water from the shallow groundwater table, drains need to be dug deeper in irrigated, arid land than is generally necessary in humid climates. These drains are needed to remove excess water and salt from the soil at a rate that will permit normal plant growth.

Adequate drainage is an important agricultural practice, particularly in arid and semi-arid regions to prevent soil salinization and waterlogging-related problems. Traditionally, collected drainage water is disposed of to sea, in a river, lake, or drainage reservoir. When drainage water contains naturally-occurring and potentially toxic trace elements such as selenium and boron, or pesticide residues which impact negatively on the environment at high concentrations, new drainage disposal strategies have to be developed.

The logical thing to do in areas such as West, Central, and North Africa, among other dry areas of the world where water is scarce, is to develop strategies to use such water and other wastewaters in agricultural production. It all depends on the salinity and other chemical concentration levels in the drainage. This water can be used for conventional agriculture under good and modified water management practices or it can be used for non-conventional agriculture, such as the production of halophytic forage or industrial plants.

Yields of up to double the usual forage output in 1999 have given ICARDA's Central Asia Soil and Water Project a very promising start to the use of treated wastewater for irrigation. In the Sorbulak area, north of Almaty, Kazakstan, the project is developing a sustainable agronomic system which safely utilizes treated wastewater to produce various forage and industrial crops. At least 40,000,000 cubic meters of treated wastewater from the Almaty area is potentially available each year for agricultural use, enough for 10,000 hectares of land designated to produce forage crops under irrigation.

The city wastewater travels a 100-km-long canal to Sorbulak, passing through a series of ponds and mechanical and biological treatments on the way, which are designed to remove solids and restore the oxygen content. Instead of then being discharged into a river as in the past, it is now of sufficient quality to be applied to crops. ICARDA is assessing the benefit to the crops of the nutrients in the wastewater which has a high nitrogen content.

Egypt is also trying to benefit from drainage to improve not only the quality of its natural resource and its sustainability but to expand agriculture production horizontally, based partly on drainage water as a source for irrigation. The officially-reused drainage water increased from 2.6 billion cu m per year in the 1980s to about 4.2 billion cu m per year in the early 1990s. Two projects, the El Ummum drain and the Salam Canal, coming on stream will bring the total reused drainage water in the Nile Delta to about 7.2 billion cubic meters per year.

Irrigation water guidelines indicate that waters of salinity below 0.7 dS/m can be used for agriculture without restriction. If salinity is between 0.7 to 3.0 dS/m, slight restriction on use is warranted, and if the salinity of waters is greater than 3 dS/m then some salinity problems and perhaps a reduction in crop yield should be expected.

In the Jordan Valley, 98% of the total irrigated area of 24,300 ha is being irrigated with irrigation water of salinity between 0.7 and 3 dS/m. This is possible because of the active drainage systems permitting sustainability of this land for conventional agriculture production.

A similar approach could be adopted elsewhere in the dry areas to help solve drainage-induced environmental concerns or potential problems. By treating the drainage as a 'resource' rather than as a waste, it is possible to help the growers, as well as to contribute to the sustainability of agricultural systems.■

Dr Fawzi Karajeh is Marginal-Water Management Specialist at ICARDA.

Above: Cereal plants struggle to survive when treated with saline water. Left: Forage crops in Kazakstan thrive after treated wastewater is applied.

Intervention to Stop Sweet Water Irrigation Turning Sour

Continued from page 17

Surveys reveal the tongue of salt water that is being pumped into the valley and used by farmers for irrigation. More tellingly, a farmer near the village of Shreema stopped irrigating his cotton because it would not grow any more.

Irrigated soils are showing levels of soil salinity, which are at the limit of the salt tolerance of most crops. A 1999 survey by ICARDA showed that the highest accumulation of salts was at 40-60 cm depth, i.e. within the root zone of most irrigated crops. The differences between rainfed fields and irrigated fields are striking, considering that irrigation has only been practiced for a relatively short period.

The expected potential reduction of crop yields for barley, wheat and cotton, due to salt accumulation in the soil were determined. The figures show that the irrigated soils in the valley are approaching the limits of salt tolerance of the crops grown in the area.

To protect the quality of the groundwater less water should be pumped in the valley. At the moment work is being done on a groundwater balance of the valley. This will show the amount of groundwater that can be pumped from the aquifer in a sustainable way without encouraging the intrusion of saline water.

Farmers in the valley are also being encouraged through experimental work to introduce what for them are new crops that consume less amounts of water. These include olive trees and other fruit trees. Furthermore, shrubs that can be used for sheep fodder are being planted to demonstrate how the income from rainfed farming can be increased.

It is all an integral part of ICARDA's bid to ensure that sustainable food production can thrive in such areas where resources are under threat from the poor management practices of the past.■

Robert Hoogeveen is a Consultant Hydrologist with ICARDA.

When Water Lights the Fire

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irrespective of how much water is actually used. This encourages unsupervised over-extraction. The energy cost of pumping is usually then the only constraint on enthusiastic farmers.

Dr Oweis estimates at least one-third of the full irrigation requirement could be saved without any loss in wheat productivity. ICARDA has developed recommendations for farmers to determine the correct level of supplemental irrigation for given rainfall zones, seasons and level of inputs such as nitrogen fertilizer.

This is also giving plant breeders more work. They have had considerable success in transferring genes which confer drought stress resistance from wild species into cultivated varieties of wheat and barley. Now they are selecting varieties, which can also show the greatest response to additional water.

Water-use efficiency can also be stepped up for crops other than wheat both through improved management and plant breeding. Biotechnology tools have allowed ICARDA scientists to identify genes for cold tolerance as well as drought resistance. As a result, varieties of lentil and chickpea—both traditional spring crops—are being developed for winter sowing when the newly established plant will have the advantage of a ready supply of moisture.

Many farmers mistakenly apply too much irrigation water which is lost to evaporation or drains away without benefit to the crop.

Less dramatically, bringing planting date forward by a week or two can be enough to increase plant survival. Tillage practices that conserve soil moisture are often overlooked by growers with a fixed management approach until the effects of extra yield are physically demonstrated.

On both micro- and macro-scales, there are improvements in water use to be gained from blending water of varying qualities to produce a standard acceptable to individual crops. This can be done at farm level with mixtures of surface and borehole water or on a national scale as in Egypt. The Al Salam Canal will take 10-15 cu m a second of mostly drainage water from the Nile Valley under the Suez Canal to Sinai for blending with groundwater.

Super-efficient trickle irrigation is now being used extensively, particularly in water-hungry Jordan, but it is only economic when used on higher value cash crops such as vegetables. The cost of installation is currently too high to make it worthwhile even for major strategic crops such as cereals and other small grains, which have a much lower cash value.

All this successful application of science and technology is aimed at releasing more water for agricultural production, says Dr Oweis. "By releasing this additional water, we reduce the level of scarcity, and indirectly reduce the potential for conflict."■

Making Every Drop Count: the OSWU Approach

As if severe drought was not enough, what little water is available for crops in the world's driest areas is being badly managed, turning a serious difficulty into a desperate problem. Many solutions to the chal-lenge of getting more pro-duction per unit of water are being explored and found, but sharing ideas through colla-boration is essential to get success in farmers' fields.

Water-use efficiency in cereal growing systems can be improved markedly by replacing traditional fallows with legumes, including vetches. These make better use of the scarce available water and provide ideal grazing for livestock. There are further benefits for the soil in improved nitrogen and organic matter content.

By Christoph Studer, Mustafa Pala and Niek van Duivenbooden

For millions of resource-poor dryland farmers in sub-Saharan Africa (SSA) and Central and West Asia and North Africa (CWANA), small total rainfall and its erratic, unreliable distribution constrain the achievement of stable, sustainable production systems which would provide them with satisfactory, low-risk livelihoods.

High population growth rates in arid and semi-arid regions increase the demand for food, feed, and other agricultural products.

At the same time, production increases from fertile lands are known to be declining, forcing people to use also marginal lands. Thus, both marginal and fertile lands are currently suffering from various forms of degradation, including nutrient depletion, soil acidification, soil erosion, and reduced soil water retention.

Effective soil, water, and nutrient management requires actions not only at the farm level, but also at community, regional, and national levels. The agricultural priority across all dry-area farming systems in sub-Saharan Africa and CWANA is to increase biological and economic yield per unit of water.

OSWU Consortium

One of ICARDA's activities directed at improving the productivity of water use in dry areas taps into knowledge and expertise from countries as far apart as Iran and South Africa, despite distinct differences, among other things, in rainfall distribution.

ICARDA is, together with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the national research organization of South Africa (ARC-SCW), co-convener of the Optimizing Soil Water-use (OSWU) Consortium. This is a constituent of the CGIAR System-wide Soil, Water, and Nutrient Management Program (SWNMP). The overall goal of the consortium is sustainable and profitable agricultural production in dry areas, based upon the optimal use of the available water.

It brings together two international agricultural research centers (IARC) and 12 national agricultural research and extension systems (NARES) in Burkina Faso, Egypt, Iran, Jordan, Kenya, Mali, Morocco, Niger, South Africa, Syria, Turkey, and Zimbabwe. By bringing together researchers and farmers from different environments, the OSWU Consortium promotes fruitful exchange of ideas, experience and, most important, practical techniques to combat the effects of water scarcity, and to sustainably improve production, security, and livelihood of the farmers in dry areas of WANA and SSA.

An important achievement is a compendium of the state-of-the-art of research in the 12 member countries. Future outputs include generic tools that can be used by the other consortia and relevant eco-regional programs as well. It is OSWU's strategy to build on existing scientific knowledge and indigenous practices of soil and water conservation.

Exchange of scientific and indigenous knowledge and technologies between countries and regions is a key element in the Consortium's approach. Therefore, linkages among and partnerships with NARES, international agricultural research centers, advanced research organizations, non-governmental organizations, and local farming communities play key roles in OSWU's strategy. These linkages increase and facilitate the spread of knowledge about the very specific techniques required to boost agricultural production in the varying ecosystems found in dry areas. In rainfed fields, improvement is possible only by conserving rainfall water in the root zone of crops (including shrubs and trees), and by managing the field and the crops to use this water more efficiently.

However, actual water-use efficiency in current farming systems in the drought-prone countries of CWANA and SSA is often very low, and a surprisingly small proportion of the available water is actually transpired by the crop. The water losses at the field-level include surface runoff, percolation below the rooting zone, evaporation from the soil surface, seepage in deep cracks, and transpiration by weeds, but vary according to site- and situation-specific conditions and are often not well quantified.

Viable farm-level techniques, such as those developed by ICARDA and ICRISAT for their mandate areas, are applicable in many other dry countries to reduce these losses and to increase the capture and retention of incoming water as well as maximize the proportion of water that is productively transpired by the crop. The development of water-efficient cultivars is one way to achieve this. Such new varieties, which are often developed by national programs from ICARDA-sourced germplasm, usually require improved soil, crop and cropping system management.

Improving productivity

Recent agricultural research by ICARDA and other international and national centers has enabled farmers to overcome many of the constraints previously limiting their crop yields. However, in most rainfed farming systems, the major constraint that farmers cannot influence remains low and erratic rainfall. The technologies required to increase outputs and input-use efficiencies (e.g. water- and nutrient-use efficiencies), must fit the land-use system of resource-poor farmers, and must conserve the natural resource base.

The main agronomic strategies to intensify crop production systems are *(i)* soil and water management, and *(ii)* cropping system management, with strong emphasis on soil fertility management. Soil and water management recommendations to improve the productivity of scarce and erratic rainfall can be grouped under three main headings: improved tillage practices, different water harvesting techniques, and erosion control measures. Cropping systems management to improve water productivity is first concerned with the type and sequence of crops grown. The choice of appropriate rotations, intercropping or relay cropping determines to a great extent the productivity of rainfed farming systems.

In CWANA, introducing legume crops in place of a fallow period can increase a production system's water-use efficiency considerably in many dry areas. A number of national programs have taken pasture and forage legume germplasm from ICARDA to develop appropriate varieties of vetch, chicklings or medics.

About 30 million hectares of land is left fallow in CWANA every year. If only 70% of this land could be sown to forage legumes, it would produce enough feed for 80 million sheep. Moreover, there would be an influx of 1.4 million tonnes of nitrogen from symbiotic nitrogen fixation per year.

Use of medic and vetches in the cereal-based rotation over a period of 10 years in ICARDA trials showed a significant increase in total nitrogen and organic matter in the soil, when compared with cereal monocropping or cereal/fallow rotations. These changes improved soil physical properties and fertility, thereby increasing the productivity of cereals following legumes. These rotations also broke the disease and insect pest cycles that had built up in monocropping.

Of course, identifying appropriate crop varieties with optimum physiology, morphology, and phenology to match local environmental conditions and, especially, the pattern of water availability is one of the important areas of research within cropping systems management for improved water-use efficiency.

ICARDA's recent success in rainfed areas has been with 'Arta,' an improved barley landrace developed by the center from germplasm collected in Syria. Compared with most local landraces, 'Arta' averaged about 70% greater yield on-farm. Further drought-tolerant barley and wheat cultivars have been selected and are being tested under stress conditions in a number of CWANA and SSA countries.

Lentil varieties better adapted to low rainfall areas were adopted by farmers in Egypt where the lentil area declined steadily in the 1980s and 1990s until ICARDA developed new lines able to withstand drought stress more readily. In another collaboration with ICRISAT, ICARDA produced the first drought-tolerant kabuli chickpea lines for a Mediterranean environment.

When these and other lines emerge as varieties suitable for planting by farmers in combination with the various improved technologies to optimize soil water use, the scope for improving the livelihood of the farmers will be greatly increased.■

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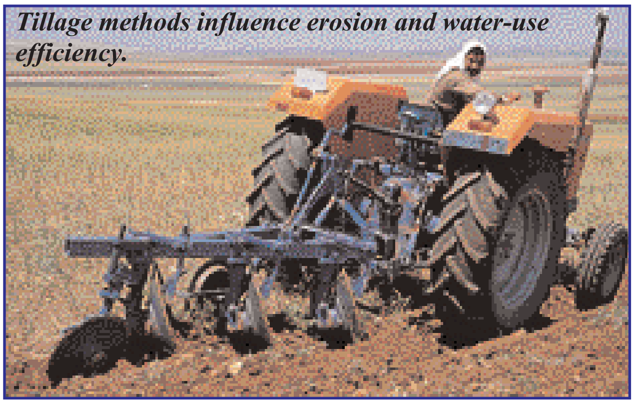
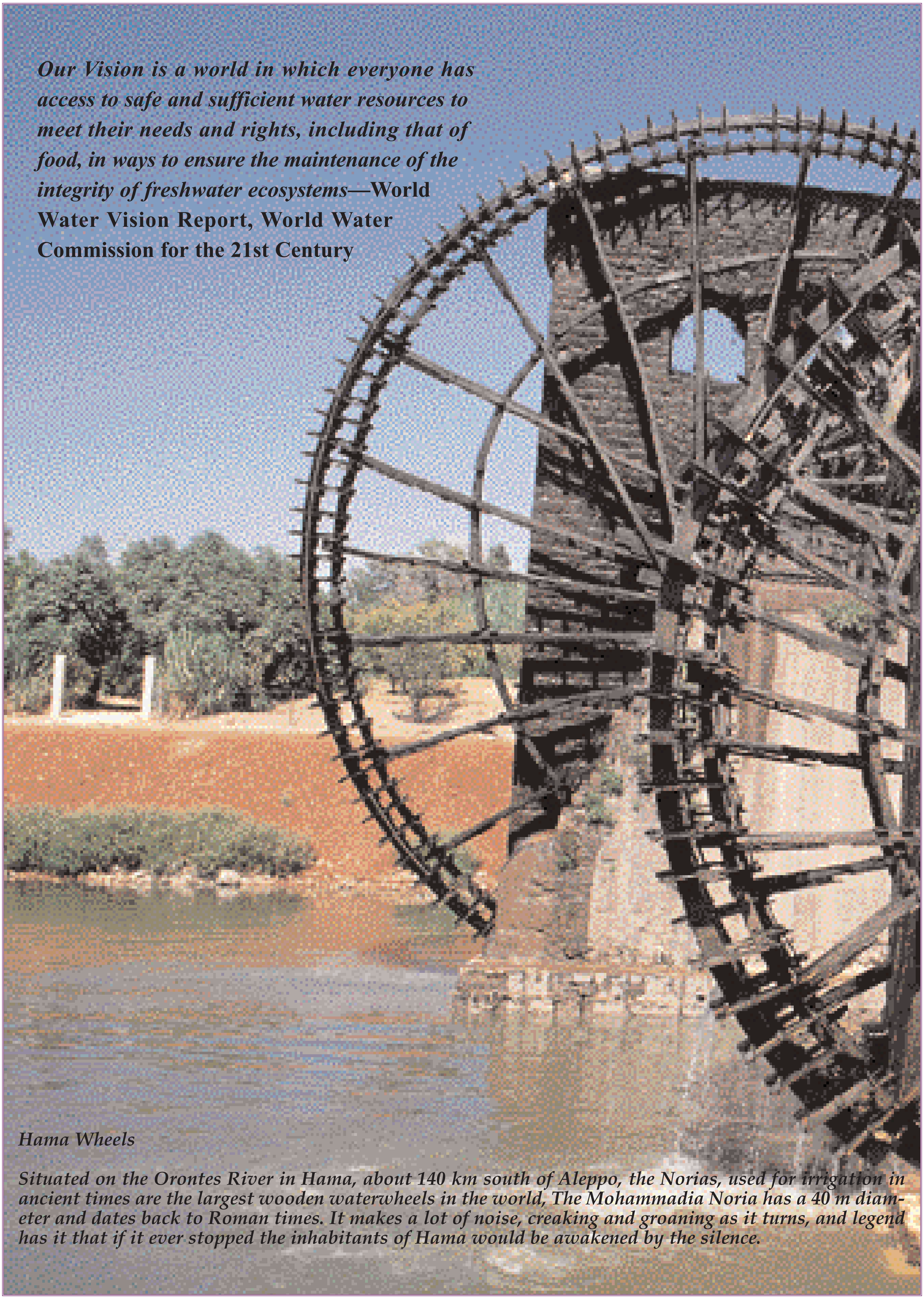
Tillage methods influence erosion and water-use efficiency.





***Our Vision is a world in which everyone has access to safe and sufficient water resources to meet their needs and rights, including that of food, in ways to ensure the maintenance of the integrity of freshwater ecosystems*—World Water Vision Report, World Water Commission for the 21st Century**

Hama Wheels

Situated on the Orontes River in Hama, about 140 km south of Aleppo, the Norias, used for irrigation in ancient times are the largest wooden waterwheels in the world, The Mohammadia Noria has a 40 m diameter and dates back to Roman times. It makes a lot of noise, creaking and groaning as it turns, and legend has it that if it ever stopped the inhabitants of Hama would be awakened by the silence.