



ICARDA

International Center
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Review of agriculture in the dry areas **Caravan**

Research integration in practice

A second Green Revolution?

Good research, poor adoption

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Foreword

Few regions present bigger development challenges than the dry areas – home to 2.5 billion people and the vast majority of the world's rural poor. Dryland agricultural systems are limited by a range of factors: biophysical, socio-economic and policy-related. And many of the biggest challenges – poverty, drought, land degradation, water scarcity, food insecurity – will be exacerbated by climate change.

Despite these challenges, dryland agriculture holds the key to food security in many developing countries, and must therefore be a priority not only for researchers, but also for policy makers and development investors.

This year saw the launching of the CGIAR Research Program (CRP) on **Dryland Systems** – a global initiative targeting farming systems in dry areas. The program (CRP1.1, *Integrated and sustainable agricultural production systems for improved food security and livelihoods in dry areas*) is led by ICARDA, and implemented in partnership with more than 80 institutions worldwide. The program was designed jointly by nine international research centers, eight regional and international fora, and national research organizations from 28 countries.

What makes this new program different from previous research is the shift in emphasis from components of the farming system to the system as a whole. Dryland agro-ecosystems are complex and diverse, with dynamic interactions between many different components – crops, livestock, rangeland, trees. We now understand the components well enough to move to a more holistic approach to better understand interactions between components, and exploit synergies (e.g. between crops and livestock) to increase system output and productivity.

The CRP on Dryland Systems is all about integration: between different research disciplines, between biophysical and socio-economic factors, between crop farming and pastoralism, between research and development. The program aims to develop new technologies, new livelihood opportunities, stronger local institutions, enabling policies to support technology adoption, and ultimately higher incomes and better lives for the poorest and most vulnerable households.

This issue of *Caravan* describes the new program, and some of the research innovations it will build on. The issue begins with two 'opinion pieces' by scientists from partner organizations in the CRP. They share lessons learnt



from past successes (and failures), and ideas that could be applied to dryland systems worldwide. Other articles present examples of the integrated, multi-disciplinary approach that is central to the CRP on Dryland Systems – farming systems research, water-saving irrigation methods, salinity management, conservation agriculture, rangelands, feed and fodder, animal breeding and horticulture. We look at new approaches for selecting research sites, and an innovative project that helps women access high-value export markets.

These articles provide food for thought. They also provide convincing evidence that good research and strong partnerships can transform livelihoods even in the most difficult dryland environments.

Mahmoud Solh
Director General, ICARDA

A Second Green Revolution?



Ram Badan Singh

India's 2010-11 harvest was its largest ever, more than 240 million tons.

The next harvest is expected to be even bigger. The government recently announced its target for year 2020: 400 million tons. Is this realistic? What changes would it require, in technology, policies and approach? And could these ideas be applied in other developing countries?

To answer these questions, we first look at the Green Revolution of the 1960s and '70s, which transformed a chronically food-deficient country into the world's second largest agricultural producer. Between the mid '60s and the mid '90s, food production more than doubled, while the intensity of hunger and poverty was cut by half.

The Green Revolution was driven by greater use of inputs – irrigation, fertilizer, and high-yielding photoperiod-insensitive 'dwarf' varieties of wheat and rice. But what set it apart from similar but less successful efforts in other countries was the integrated approach, combining research, education, policy, institutions and services, backed by strong political will.

THE LIMITS OF SUCCESS

The Green Revolution has now waned. India's agricultural sector is growing, but much slower than the rest of the economy. Total factor productivity growth has leveled off or even declined. The income gap between farmers and non-farmers is widening.

Although largely self sufficient in food production, India still needs to import some commodities in some years, and pulses (the major source of dietary protein) every year. Nearly half the edible oil is imported. Adoption of modern varieties has been restricted mainly to cereal and horticultural crops. And the Green Revolution has yet to reach large parts of the country – especially dryland areas, where poverty incidence and farming risk tend to be highest.

The Green Revolution also involved environmental costs: unsustainable groundwater extraction, fertilizer run-off, pesticide residues, salinization. In the '60s and '70s the priority was to resolve food shortages, and environmental issues were poorly understood. Today we have a

clearer understanding of how to monitor, control – even reverse – land and water degradation. We also have technologies that can increase yields without damaging the environment. These technologies are the key to a second Green Revolution.

INTEGRATED TECHNOLOGIES

A second Green Revolution, like the first (but even more so), must be based on integrated approaches. It must focus on the entire farming system: crops, livestock, water, soil, and income opportunities from agriculture.

Ultimately, we need to create a single chain linking every step from inputs and farm equipment to production to food processing and retail. We also need to link research and extension into this chain. This will require integration at multiple levels.

Research integration. The emphasis must shift from commodity-oriented or disciplinary research to multi-disciplinary, farming-systems-based programs. We need not only new varieties and crop management methods but also innovations for crop planning, warehousing and food processing. Researchers must not only resolve current problems, but also anticipate and forestall future ones such as the impacts of climate change on dryland agriculture.

Private investment. Greater private investment is essential. The government's role would be to facilitate such investment, and also to provide oversight to ensure fairness and transparency. Research centers and universities must work with agribusiness to develop products for specific markets. We also need greater integration between agriculture and industry, e.g. establishing food processing plants near production areas, linking farmers directly to buyers, reducing the role of middlemen — in short, creating an efficient value chain.

Policies. The country must move from consumption subsidies to capital subsidies to encourage farmers to invest in new technologies and equipment. Subsidies on water, electricity and fertilizer were crucial to the Green Revolution, but led to severe environmental consequences. These subsidies must be phased out, and replaced with targeted subsidies to encourage the adoption of new technologies that use resources more efficiently.

FOCUSING ON DRYLANDS

The first Green Revolution targeted irrigated areas. The second must focus on rainfed (unirrigated) areas, which cover 60% of India's farmland, and support the vast majority of its rural poor. Drylands produce half the country's cereals, 77% of its oilseeds and 85% of its pulses.

Private investors will naturally focus on profitable crops, relatively wealthy farmers and favorable environments. For resource-poor farmers in dryland areas, the public sector must continue to play the key role. Policies and investments must be targeted at improving input and output markets, providing credit, and helping farmers manage risk through crop and livestock insurance and other tools.

The technology focus must be on new water-efficient irrigation methods, small-scale irrigation schemes, and watershed management to reduce erosion, better match water availability to crop needs, and maintain vegetation cover in catchment areas.

India currently spends about 0.6 per cent of its agricultural GDP on agricultural research and development. This needs to be doubled or tripled by 2020.

Dr Manmohan Singh,
Prime Minister of India

IS A SECOND GREEN REVOLUTION POSSIBLE?

The signs are encouraging. Gross capital formation in agriculture, as a percentage of agricultural GDP, increased from 12% in 2004-05 to 22% in 2010-11. Investment in agriculture has increased by 30% in recent years. Advances in biotechnology have stimulated private sector interest in a range of commodities. Farm cooperatives are becoming larger and more effective.



The new mantra: dryland agriculture, crop-livestock integration.

The use of contract arrangements (where buyers offer farmers a guaranteed market in exchange for volume and quality commitments) has increased several-fold in recent years.

Research and extension agencies are now focusing on bridging the yield gaps – the huge differences between actual and potential yields – in rainfed areas. Food production is expected to grow at 4-4.5% per year as a result of massive investments under the XII Five-Year Plan (2012-2017). The government has launched several country-wide programs: the National Agricultural Development Scheme, Food Security Mission, Horticulture Mission, National Rainfed Area Authority and others, each with a specific mandate.

For example, the National Initiative on Climate Resilient Agriculture has a mandate for research to minimize the impacts of climate change (e.g. lower rainfall, land degradation, loss of biodiversity) in dryland areas. New legislation, being debated by Parliament or recently enacted, will encourage agro-processing and marketing, improve seed availability, and stimulate investment in tribal areas.

The Second Green Revolution is still a few years away. But with the elements in place, most experts are optimistic that the next quantum leap in Indian agriculture is only a matter of time.

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Good Research, Poor Adoption

Promoting new technologies more effectively

Aden Aw-Hassan and Abdelali Laamari

New technologies can help farmers increase productivity and income without compromising natural resources. A major problem in developing countries is that many proven, cost-effective agricultural technologies lie unused. Traditional extension methods have rarely been effective in promoting new technologies to small-scale farmers in dryland areas. Do we need a new approach?

Any new approach must overcome two big challenges: geography and credit. In many dryland regions, smallholder fields are small and widely scattered, while roads and communications are poor. It's expensive for government agencies or the private sector to service these communities, or for the communities to access markets, so technological

change is slow. Farmers remain poor and vulnerable – and being poor, find it hard to invest in a new technology even if they are convinced of its benefits.

Credit is either unavailable or too expensive, because lending agencies require collateral. Land is the preferred collateral, but many small-scale farmers do not have secure land tenure. Their fields may be common property (individuals have user rights but not ownership) or leased government land; or title deeds may not be available.

Even if collateral can be found, the transaction costs of borrowing from formal systems is often extremely high: borrowers must travel, fill numerous forms, convince friends or relatives to sign as guarantors. The terms may be

inflexible, with high penalties for delayed payments. This forces small-scale farmers to borrow from the 'informal' sector – traders or money lenders who charge high interest rates. Often, the interest rate is not explicit, but hidden as a price differential. For example, the trader may sell fertilizer (on credit) at inflated prices; or buy back produce after the harvest, at well-below-market prices.

Unless these issues are addressed, technology adoption by small-scale farmers will remain limited. Governments and external donors will have to invest in roads, communications and other infrastructure, and perhaps offer incentives to the private sector (especially small-scale rural entrepreneurs) to provide services in remote areas. Policy makers will need to modify land tenure laws to



incentives, particularly for resource management technologies, where the benefits (e.g. improved soil structure, better water-holding capacity, higher organic matter content) are gradual, long-term and not easy to see.

The cost of these incentives will have to be borne by governments or donors, but the benefits – higher adoption, higher yields, more sustainable farming systems – are many times higher than the costs. International centers, working with scientists in each country, could provide

common market outlet. A cooperative can also act as a channel for the flow of credit (lending to a cooperative is usually less risky than lending to an individual), new technologies and training programs.

In practice, however, many cooperatives have been unsuccessful for one reason or another. In any case, small-scale farmers usually need external help (awareness, legal advice, logistic support) to form a cooperative. National agencies and NGOs in most countries lack the capacity to provide such support. And



New technologies will not spread unless farmers and researchers work closely together.

encourage private ownership, which not only improves credit access but also encourages investment in long-term land management and more sustainable use of resources.

In addition, other measures are needed to create a 'development package' that will improve small-farm profitability and rural livelihoods. We discuss two areas where international research centers can play a role.

ADOPTION INCENTIVES

In many cases, the benefits from new technologies, although considerable, are still not enough to convince small-scale farmers to invest. Convenient, affordable financing is necessary – but not sufficient. Farmers need additional financial

hard data to policy makers. These studies could help identify the specific incentives needed for a particular technology, and measure the potential costs and benefits.

FARM COOPERATIVES

Smallholder farmers cannot generate the economies of scale needed to compete with large-scale producers. Cooperatives can help overcome this challenge. A group of farmers, acting together, can negotiate better prices for inputs as well as outputs, and improve market access, for example by sharing transport costs or creating a

in some countries, the government may discourage the formation of civil society organizations.

International research centers, because of their global experience, their apolitical credentials and their extensive partnerships with other institutions, could develop guidelines for developing small-scale producer cooperatives. They could also help establish, monitor and evaluate pilot cooperatives in carefully selected areas, as a model for larger-scale efforts by governments, international NGOs or other partners.

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Dryland Systems: Research with a Difference

The first global-scale application of integrated approaches, focusing on the entire system rather than individual components.



Dry areas cover 41% of the world's land surface. They support one-third of the global population and a majority of the rural poor. In most developing countries, food security and economic growth will depend on our ability to increase agricultural output and productivity in these areas.

In 2012, the CGIAR launched a new research program, led by ICARDA and implemented jointly with more than 80 partners worldwide. It's called CGIAR Research Program 1.1, *Integrated and sustainable agricultural production systems for improved food security and livelihoods in dry areas*. In short, CRP1.1 — Dryland Systems. The program is the first ever application, at a global scale, of integrated, agro-ecosystem approaches to dryland farming systems research.

MULTIPLE PARTNERS, MULTIPLE COMPONENTS

Dryland systems are diverse and complex, with interactions between multiple

components. For many years, researchers tended to focus on the individual components, not the system as a whole. CRP1.1 uses a more holistic approach, aiming to understand these interactions, and identify the key factors that drive system-level processes or constrain productivity growth. This knowledge will be vital for developing new farming technologies, research tools and policy options to improve rural livelihoods.

This holistic approach will help avoid the pitfalls of studying system components in isolation: technologies that may be ineffective in the 'real world', development programs designed without a clear understanding of trade-offs, poor adoption of new technologies, lack of change in policies and institutions — all adding up to limited impact on the ground.

The program is ambitious, involving not only a fundamental paradigm shift, but also an unparalleled breadth of partners — nine CGIAR centers, a dozen other

international research organizations, several regional and international forums, and national research agencies in 28 countries.

RESEARCH THEMES

CRP1.1 includes four research themes. One theme looks at innovation: models for strengthening innovation, building stakeholder capacity, and linking research findings to policy action. Another covers impact assessment and cross-regional syntheses, to evaluate the impact of the program and provide lessons for future work. Two other themes focus on two kinds of dryland environments: highly vulnerable, poverty-endemic areas, where the aim is to reduce risk and vulnerability; and higher-potential areas, where the program will help farmers intensify production, diversify the farming system, and connect to profitable markets.

Research will cover crops, livestock, natural resources (water, soil, rangeland, biodiversity) and socio-economics.



All work will be multi-disciplinary. For example, developing a new variety – or more typically, a 'basket' of varieties of different crops, for a farming system – will require plant breeders, agronomists, physiologists, soil scientists, water management experts and socio-economists, working with farmers and extension specialists.

Developing new technologies is a key objective; but a large share of project resources will also be used to fine-tune currently available technologies to suit different agro-ecologies, and to build the capacity of farming communities to use these technologies.

TARGET SITES

Research will cover five target regions: (1) the Sahel and dry savannas of West Africa, (2) East and Southern Africa, (3) North Africa and West Asia, (4) Central Asia, and (5) South Asia.

Each of these regions has areas with high levels of food insecurity, poverty and natural resource degradation, but also considerable potential for poverty reduction. Research in each target region will cover two types of areas – vulnerable, high-poverty environments and more favorable ones.

Given the size and diversity of the target regions, proper selection of research sites is crucial. These sites must necessarily be limited in number, for budget and logistical reasons, but must still be representative of ecological conditions over a large area, so that results can be scaled out widely. Sites were selected through a combination of literature reviews, surveys, consultation with other experts, and GIS analysis.

Each target region will have two kinds of sites: 'action sites' where much of the work will be concentrated, and complementary 'satellite sites' that capture more diversity. For example, a satellite site may have soils and rainfall similar to the action site, but much better (or much worse) roads and communications.

WHO BENEFITS, AND HOW

What outcomes can we expect? Higher productivity of crops and livestock. More diverse farming systems. More sustainable use of land and water resources, through new resource-efficient technologies supported by appropriate policies and institutions. New sources of income for poor households: for example, sale of value-added farm products. Households and farming systems that are more resilient, and less vulnerable to drought and climate change.

These outcomes relate to farm communities, the primary beneficiaries of CRP1.1. The program also aims to bring about change at institutional level. R&D organizations will benefit from innovations developed by the program. The global science community will have new insights on how dryland systems work. Policy makers will have data to help inform investment decisions, and to target limited funds more effectively. NGOs will have field-tested products that can be scaled out through their own development programs, far beyond CRP1.1 research sites. Investors will have better evidence of the impacts generated by the projects they fund – and the incentive to increase funding, to enable dryland farmers to grow their way out of poverty.

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A Mediterranean mosaic. Crops, trees, livestock.... and the synergies between them.

Making Money from Mohair

Empowerment! Women in remote steppe communities produce wool products for high-end markets.

The rural poor can increase their incomes substantially by producing value-added goods for market. But what if the market is 12,000 kilometers away?

ICARDA and its partners are showing how the challenges of distance can be overcome with an integrated research-for-development approach. The project, supported by the International Fund for Agricultural Development, aimed to improve women's welfare in remote communities in the steppes of Tajikistan. These communities depend on livestock, and mohair-spinning is a traditional skill. Most households keep Angora goats – which produce mohair, a luxury fiber prized for its luster, softness and strength. Value-added mohair products were an obvious entry point for the project.

COMPETING IN GLOBAL MARKETS

Communities in remote areas are cut off from global markets not only by their isolation but also because they lack access to livestock services, suitable processing techniques, or information on markets and prices. To produce the raw material for spinners to spin quality yarn, for example, farmers need well fed, healthy animals with superior fleeces. Spinners and knitters need to know what products fetch the highest prices, and how to make them. They need to know how to advertise, fulfill orders, and ship what they've made. They need to move from producing low-quality, low-price products to high quality goods that fetch premium prices in the United States and Europe.

In northern Tajikistan, this transformation is just beginning. Government breeding programs for Tajik Angora goats collapsed at the end of the Soviet period. Trade continues, but little attention is paid to breed quality or extension support for producers. Mohair and knitted products are mainly exported to Russia and China at low prices. These markets pay fair prices for coarse mohair (which makes up the bulk of exports), but do not offer premiums for high-quality fine mohair.



To help producers go up-market, the project integrated different components: breeding and management of Angora goats, processing techniques, marketing, training, equipment... The women were already skilled in spinning coarse mohair with spindles, and knitting intricately patterned traditional socks and mittens. Now they were introduced to spinning wheels (much faster than traditional

spindles) and contemporary designs that would appeal to Western buyers.

The women make up to ten times more money spinning fine yarn for the US market, rather than coarse yarn for Russia. This difference is a reflection of retail prices. A pair of ordinary knitted mittens costs \$2 in Russia; high quality mohair knits cost upwards of \$150 in the US.

QUALITY AND PRICE

Quality and profits can be raised even further with improvements at both ends of the value chain: breeding Angora goats for fine fleeces, and making the process of booking orders and shipping more efficient.



Livestock scientists worked with farmers to create nuclei of breeding goats selected for fleece quality, i.e. finer mohair with less kemp. (Kemp fibers are coarse, stiff, and make the finished garment feel scratchy.) In October 2011, 230 nucleus females were inseminated with imported frozen semen from Texas Angora bucks. The first offspring were born in spring 2011.

Farmers learnt how to manage their nucleus flocks, and how to improve feeding and healthcare.

Women were trained on how to choose good fiber, clean it of kemp, and prepare it for spinning. They can now spin raw mohair into quality yarn that meets



The project's integrated approach – spanning the complete chain from breeding to marketing – has transformed incomes and livelihoods in poor, remote communities.



This kid born, in spring 2012, was sired by a Texas Angora buck. The new generation is being bred for finer, kemp-free mohair.

international standards. Learning took time and persistence but, throughout the process, professional knitters in the USA tested samples of the yarn and provided feedback to the project. Although quality yarn takes longer to produce, it fetches many times the price of coarse yarn. The Tajik mohair yarn was successfully test-marketed at US\$140 per kilogram, the same price as Australian mohair. To

add even more value, the women – who had never seen high quality yarn or luxury goods before – were taught how to knit the yarn into shawls, sweaters, scarves and other products.

These products require the finest yarn, spun from kid mohair. For coarser (but still

good quality) adult mohair, carpets are one option. The project, with support from FAO, provided training and equipment; and helped link women's groups in Tajikistan to 'mentors' in Afghanistan.

MORE SPINOFFS

The leaders of Tajik women's groups are now training more women to spin to the same high standards. The next stage, after further training, is to help these groups set up their own businesses. Project partners (or other organizations that are coming on board) will help link women's groups with buyers in the USA and Europe, and set up ordering and shipping systems.

Can this success be replicated? The project is testing the same approach at other sites in Tajikistan, Kyrgyzstan and Iran, with cashgora, Merino wool and cashmere. Poor, remote communities are building on traditional skills to compete in the global market for handmade natural products.

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Building on Biodiversity: Highland Farming Systems in Eritrea

Researchers tap indigenous biodiversity to increase yields and reduce the risk of crop failure.

Eritrea is a small but remarkably diverse country, with dozens of ethnic groups, languages and agro-ecologies. Altitude ranges from 110 meters *below* sea level to over 3000 meters. Ecosystems include arid plains, escarpments, forest areas and desert; highly saline areas with unique plant communities; a highland plateau with up to 900 millimeters of rainfall; some 350 islands in the Red Sea; and seven volcanoes (two active, five probably extinct).

Researchers are using this diversity – in environmental conditions, crops, and varieties of crops – as the starting point for agricultural development.

NEW GENES FOR TRADITIONAL VARIETIES

ICARDA and its partners launched a project in 2004, targeting the highlands of the Atbara Basin, a region with high poverty rates but considerable potential for increasing food production. The

project, funded by the CGIAR Challenge Program on Water and Food, aimed to tap this potential using an integrated approach — farmer-participatory breeding of new crop varieties; introducing low-cost production technologies; and establishing village-based cooperatives to produce high-quality seed at low prices.

The huge genetic diversity in Eritrean barley, and strong local preferences for specific varieties, encouraged project scientists to use the indigenous gene pool

to develop new genotypes. Three barley varieties were developed that gave yields 20% to 100% higher than local varieties. The new lines were also crossed with traditional 'landraces' to develop disease-resistant, early-maturing genotypes with high water productivity.

CROPS, WATER, PRODUCTION METHODS

Early maturity is important because rainfall is concentrated in July and August, leaving crops struggling for moisture during the crucial grain-filling stage two or three months later. The new wheat and faba bean varieties provide high yields, while minimizing (by maturing earlier) the risk of crop failure caused by late-season drought.

Experiments on soil water balance showed how farmers could benefit by planting their crops earlier. Planting dates can be advanced by 2-3 weeks in many areas, 'lengthening' the growing season and making better use of rainfall and nutrients. Improved tillage methods (conservation agriculture) were introduced to replace traditional ox-drawn plows, which cause soil erosion and water runoff while doing little to improve moisture infiltration, and tractor-drawn disc plows, which aggravate waterlogging – a common problem in highland soils.

Wheat is one crop where the Eritrean gene pool is fairly limited, so the project introduced breeding materials from ICARDA to improve resistance to drought and to rust diseases. Many farmers sow a mixed crop called *hanfets*, jumbling varieties of barley and wheat to hedge against drought spells or pest and disease outbreaks. Researchers compared a range of wheat-barley combinations and mixture ratios, and found that most types of *hanfets* give significantly higher yields than wheat or barley alone.

Legume crops – chickpea, faba bean and lentil – are the main source of protein for most rural families, but domestic production is insufficient. Substantial quantities must be imported each year. The project has developed new high-yielding varieties of all three crops, using a combination of indigenous and 'exotic' breeding lines. Consider chickpea, for example, where production is declining because of widespread pod borer infestations. New pest-resistant varieties were bred from traditional Eritrean varieties, other local genetic resources



The highlands, which cover nearly one-fifth of Eritrea, offer the best potential for sustainably increasing food production.

and improved parent material from ICARDA and its sister center ICRISAT. The project also set up large-scale field demonstrations to encourage farmers to adopt row planting, which facilitates weeding and slows the spread of leaf diseases.



Farmers and researchers jointly evaluate new barley lines, ensuring that every new variety meets local needs and preferences.

Legumes produce not only grain but also natural fertilizer, by converting nitrogen into nutrients. The project found, however, that the potential benefits were limited by the traditional system, under which land is rotated among farmers every seven years. Many farmers are reluctant to plant legumes in the last two years of the cycle because they will not benefit from the improved soil fertility. Solving this problem will not be easy; but data from the project will help design alternative land use options.

Other project studies focused on agronomy. A three-year experiment measured the effect of different crop management practices, individually and in combination. It found, for example, that farmers could maximize rainwater productivity (highest yield and economic returns) by using a specific combination of phosphorus and nitrogen fertilizer. Another study demonstrated how wild oats in barley could be controlled using affordable herbicides.

SCALING OUT SEED PRODUCTION

The project has laid the foundation for Eritrea's first formal seed-delivery system. It set up pilot village-based cooperatives, where a group of farmers receives initial seed, training, equipment and some financial support, and then produces seed for sale to the community. The pilot scheme is now being used as a model for a country-wide project supported by the International Fund for Agricultural Development.

Nearly 80% of Eritreans depend on rainfed agriculture. The typical farmer may own three or four scattered plots of land totaling about one hectare. Rural poverty is widespread. Despite these challenges – and the lingering effects of decades of war – the project has generated substantial benefits. It has also demonstrated an integrated research model that can be used in developing countries worldwide.

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Watershed Research in Iran

Community-led research to improve farm livelihoods, combat degradation, and protect water resources.

The Karkheh river basin in Iran is a good example of the problems affecting large watersheds in dry areas – and the solutions that can be developed through integrated, multi-disciplinary research.

The basin, located in the Zagros mountains, is a largely agricultural region, but only 10% is fully irrigated. Most farmers in basin rely on low and erratic rainfall. Crop yields are declining as a result of soil degradation and other factors; and could decline further due to climate change. Water productivity is low in both irrigated and rainfed areas.

THE KARKHEH PROJECTS

Two four-year projects implemented jointly by ICARDA, Iranian research centers and other partners have shown that these problems are not

insurmountable. The projects, supported by the CGIAR Challenge Program for Water and Food, used community-led approaches to promote new technologies to improve livelihood resilience and water productivity.

Researchers worked with farm communities in two watersheds (Merek and Honam, covering about cover 380 square kilometers) in the upper reaches of the basin. This work covered soil and water management, erosion control, vegetation assessment, livelihood and gender studies, and policy analyses. Research at two other sites in the lower basin (the Sorkheh and Azadegan plains) focused on water productivity. This helped test low-cost methods to increase water use efficiency at farm and basin levels, and identify the policy and institutional reforms needed to encourage adoption of these technologies.

Scientists also conducted a GIS-based 'similarity analysis' to identify areas (in Iran and several other countries) that are ecologically similar to the project sites. This is the first step to scaling out project findings to dryland farming systems far beyond the Karkheh basin.

PUTTING FARMERS FIRST

A 30-member team of researchers and extension experts worked with 140 families in eight communities in the upper basin. The emphasis was on participatory technology development – driven by community needs, combining new crop varieties, watershed development, crop and resource management, and new livelihood options.

Sixteen different land and water management technologies (micro-catchment water harvesting,

supplemental irrigation, erosion control structures, among others) were selected by the communities and tested jointly by farmers and project staff. Each of these technologies was low-cost and easy to use; several were targeted specifically at women farmers.

Iran's Agricultural Research, Education and Extension Organization has launched a new government-funded project based on this model. Technical and educational material produced by the project – including an extension booklet on watershed management – are now being used by national agencies as well as NGOs.

MORE CROP PER DROP

Following assessments of on-farm water productivity, the project team worked with farmers to set up field trials to test a 'package' of technologies: new crop varieties, supplemental irrigation in rainfed areas, optimal planting dates, and more efficient irrigation methods. Farmers using these technologies have increased crop yields and water productivity by up to 100%.

Another project component mapped the potential of supplemental irrigation in the upper basin, providing policy makers with data to aid decision-making. One common worry is that upstream interventions may negatively affect downstream users. Project studies showed that for supplemental irrigation, there is no cause for concern. Analyses of the quantity and quality of downstream

flows showed that even if all potential upstream areas were developed for supplemental irrigation, downstream areas would not suffer. Flow reduction would be 15% at most, and there would be no significant impact on water quality.



Traditional tillage methods accelerate erosion. The project offers more sustainable alternatives.

MONITORING EROSION

Changes in land use can have major long-term implications, but analyses of such trends are often lacking. Project scientists compared satellite images taken in 1975 and 2002, showing that large forest areas in the upper basin had been cleared for cultivation. Spatial erosion modeling was used to examine the trade-offs: environmental benefits provided by



Rapid industrial growth means less water available for irrigation. The only solution: higher water-use efficiency in agriculture.

WHY WORK TOGETHER?

Scientists develop new technologies, farmers adopt them without question... this approach has never worked. Instead, ICARDA and its partners focus on participatory technology development, where researchers and extension staff work closely with the community.

Farmers are presented with a 'basket' of technologies. They choose the ones best suited to local conditions, and test them themselves, with technical support and advice from researchers. This approach allows joint learning. Farmers become familiar with new technologies, researchers better understand the dynamics of the farming system, and extension agents can refine dissemination methods.

The Karkheh project illustrates the importance of solutions tailored to local conditions, identified by the local community. Eight villages came up with 16 different options for improving livelihoods and natural resource management. The options ranged from introducing potato as a substitute for sugarbeet to making shallot cultivation legal – this commonly used vegetable is grown illegally on rangelands.

In each village, the community determines which technologies would be tested. Farmers are free to adopt fully or partially, or to modify the technologies presented by the project. And every technology has to meet several criteria: simple to understand, requiring no major changes in current practice, minimal external inputs, and minimal extra labor.

forests versus additional food produced on newly created cropland. Even on shallow slopes (10%), this conversion of forest to cultivation in the Honam watershed tripled water erosion and increased tillage erosion by 40%. More food is welcome – but at what cost? The project findings are helping development planners to understand the long term impacts of changes to the ecosystem.

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More Fodder for Livestock

Low-cost technologies boost fodder production and encourage small-scale owners to produce for the market.

Livestock are a vital component of dryland farming systems worldwide, from South Asia and the Middle East to North Africa to the steppes of Central Asia. Sheep and goats (collectively known as small ruminants) are a vital source of income, providing meat, milk, and other products including cheese and yogurt, leather and wool. But small-scale livestock owners must constantly battle against shortages of livestock feed. Multi-disciplinary research – plant breeding, range management, livestock husbandry – is helping to provide solutions.

BRIDGING THE SUPPLY-DEMAND GAP

Rapid growth in small ruminant numbers has altered traditional production systems. A generation ago, rangelands provided three-fourths of total feed requirements. Today they provide less than one-fourth. The rest comes from straw, crop stubble (grazing left-over biomass from harvested fields), barley grain and other purchased feeds.

Feed scarcity is most severe during the winter and early spring when peak demand coincides with a period of low supply. This is the season when lambs



Peak-demand and low-supply usually coincide, leading to severe fodder shortages.

and lactating ewes need high quality feed; but supply is low because both natural vegetation and crop residues are scarce. Range quality and productivity are also declining due to overgrazing, loss of vegetative cover, erosion, fuelwood collection, and conversion of range to cropland.

ICARDA and its partners have developed a number of low-cost options to improve fodder availability and reduce feed costs. They've shown how fodder shortages can be resolved even in very dry environments like the Arabian Peninsula, using a

combination of strategies depending on local conditions. Researchers are working on several fronts: developing improved varieties of traditional forage crops, identifying little-known alternative crops, and promoting the conservation and use of indigenous grass species.

NON-TRADITIONAL FODDER CROPS

More than 400 farmers in Syria are involved in research supported by the International Fund for Agricultural Development. The project is developing

alternatives to the traditional practice of planting barley monoculture for forage. Four alternative crops (common vetch, narbon vetch, oats and Triticale) were tested, individually and in different combinations, in large-scale field trials.



nummularia). Both species are well adapted to hot, dry areas. They have been tested extensively by ICARDA projects in Tunisia and Morocco, and are now being studied in Libya. Researchers tested 43 cactus genotypes, mostly originating from Sardinia and Sicily, and found that most were well adapted to Libyan conditions. One genotype produced 26 'pads' only seven months after being established from a single 'pad'.

NEW FODDER VARIETIES

Fodder is traditionally grown without irrigation, and with minimal inputs. But high-input irrigated production is sometimes the better option. ICARDA scientists, working with the Agricultural Research Centre (ARC) in Libya, identified fifteen genotypes well suited to intensive production on irrigated farms.

Six new oat lines, introduced from ICARDA, yielded more than 12 tons of dry

can provide forage for livestock and simultaneously rehabilitate degraded soils. They're working with government research and extension agencies to promote indigenous buffel grass (*Cenchrus ciliaris*) to replace the exotic Rhodes grass (*Chloris gayana*), which despite its high water requirements is widely grown in this very dry environment. Buffel grass is nutritious, palatable, and highly water-efficient. Under drip irrigation it gives yields similar to Rhodes grass (20 tons of dry matter per hectare), but uses only half the quantity of water.

As a result of the ICARDA project, drip-irrigated buffel grass has now replaced other forage grasses on more than 60 large-scale farms in the United Arab Emirates. Twenty demonstration plots have been established in six other countries. To ensure that enough high quality seed is available, ICARDA has helped set up seed multiplication fields and seed technology units in Oman, Saudi



Protein supplements for sheep. New forage legume varieties in a field trial at ICARDA.

The trials compared not only crop yields but also the performance of animals under different diets. Lambs grazing oat fields grew 60% faster than those grazing barley. Lambs grazing oat-vetch mixtures grew 38% faster than those grazing barley-vetch. The new crops (especially vetch, which provides high-protein feed as well as soil fertility benefits) have simultaneously improved animal nutrition, farm profits and soil health.

Two other non-conventional feed sources are spineless cactus (prickly pear, *Opuntia ficus-indica*) and saltbush (*Atriplex*

matter per hectare, many times higher than traditional practice. New forage legume varieties (vetch and grasspea) gave 6 to 10 tons per hectare. Although forage legumes give lower yields than oats, they contain more protein, and are a good complement to the low-protein diet obtained from rangeland grazing.

RE-INTRODUCING INDIGENOUS SPECIES

In the arid Arabian Peninsula, ICARDA scientists are testing native grasses that

Arabia and the UAE. Four more seed units will soon be operational in other countries in the region.

In summary: new technologies, effective dissemination, better nutrition for livestock, and bigger profits for their owners.

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Indigenous Breeds, International Partnerships



Small-scale sheep owners in Ethiopia improve their flocks affordably, effectively and sustainably.

For centuries, dryland farmers have practiced crop-livestock integration, where each component of the system provides benefits for the other. Small ruminants (sheep and goats) graze farmland between cropping periods, and also harvest biomass from land that is unsuitable for planting. The animals improve nutrient cycling, provide meat, milk and other products for home consumption and sale, and reduce farming risk by providing an alternative source of income.

Many developing countries have tried – unsuccessfully – to boost sheep and goat productivity by replacing indigenous breeds with ‘improved’ ones. With a few notable exceptions, centralized breeding programs that import live animals, embryos or semen have proved not only expensive but also damaging, eroding the genomes of the indigenous breeds they hoped to upgrade.

Climate change (higher temperatures, more frequent droughts) will further

reduce the options for using exotic breeds for productivity improvement.

An ICARDA-led project in Ethiopia used a different approach – a community based program focusing on four indigenous sheep breeds: Afar, Bonga, Horro and Menz. The project, funded by the Austrian Development Agency and implemented with local partners, aimed to make these breeds more productive and profitable without undermining their hardiness or their genetic integrity.

TRADITIONAL BUT DIFFERENT

Livestock breeding programs typically yield results only in the long term, but this project has made measurable progress in four years.

Two problems were common: high-quality breeding rams were scarce, and flocks were too small for effective genetic improvement. Researchers overcame both problems by selecting superior ram lambs twice a year in each community, to be used as a freely shared community resource.

Sheep owners were educated on the value of retaining especially fast-growing ram lambs for breeding, rather than selling them young for slaughter and early profit. As a result, lamb sales have increased as animals are born in larger numbers, grow more quickly and, with improved healthcare and feeding, suffer lower mortality rates.

The project involves over 500 households (and 8000 sheep) at four locations, with different environmental conditions and different breeds. Researchers first characterized the main breed at each location. They then worked with the community to understand their breeding goals and selection criteria, and design strategies to meet these goals more effectively.

This joint learning provided new insights. For example, qualitative traits that do not necessarily contribute to productivity, such as coat color, the presence or absence of horns, and horn orientation, can strongly determine the market value of sheep and therefore must be considered in selection decisions.

EMPOWERMENT THROUGH INFORMATION

Communities evaluated various breeding options: for example, what traits to select for, what percentage of rams to select, how many seasons to use them for breeding. Project scientists ran simulations to predict the likely genetic and economic gains from each option, helping owners make informed decisions on which breeding plan to choose.

The project also initiated a recording system to monitor animal performance, operated by community-based extension workers. For the first time, owners in



Researchers work with the community to select breeding rams – a crucial step in improving breed performance.



Community service awards. His animals were the best in the village, and will now service the community flock.

these remote communities are recording birth dates, litter sizes and the live weight of individual animals, which are identified and tracked using ear tags.

Training programs – basic training for owners, more specialized training for community-based animal health workers

– helped promote simple but effective technologies for nutrition and disease control. To improve fodder supplies, new forage crops were introduced at two sites, and the communities taught how to produce seeds on their own. The project hired and trained ten post-graduate students, who are now putting their skills to good use in other development programs.

INTERNATIONAL PUBLIC GOODS

This project builds on similar work by ICARDA and its partners in Latin America and Central Asia. The benefits potentially extend far beyond the four communities in Ethiopia, because we now have a better understanding of how to design and implement community-based breeding programs, what constraints limit market access, and what institutional support livestock owners need. The findings were used by the project team to develop guidelines for similar programs elsewhere.

The breeds may be indigenous or localized – but the research findings are international, applicable in developing countries worldwide.

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Re-Greening the Rangelands

Field genebanks protect biodiversity, rehabilitate degraded rangelands, and create new opportunities for pastoralists.

Rangelands are among the most important – and almost certainly the most neglected – agro-ecosystem component in dry areas. They are the largest land-use category, home to the poorest section of the population, and crucial for millions of small-scale livestock producers. They also provide vital ecological services such as nutrient cycling and pollution filtration. But in developing countries worldwide, rangelands are being rapidly degraded. Overgrazing, harvesting of fuelwood and encroachment of cultivation have accelerated erosion and devastated native plant species; climate change will accelerate this decline.

Innovations developed by ICARDA and its partners are helping to reverse this trend. New reseeding techniques are increasing success rates and reducing the cost of rangeland rehabilitation programs. Low-cost methods such as surface preparation (scarification, pitting), direct seeding and seed treatments have improved plant germination and viability. Native and introduced species adapted to different agro-ecologies have been identified.

BIODIVERSITY CONSERVATION: A NEW APPROACH

The biggest threat to rangeland biodiversity? Overgrazing, which accelerates the spread of hardy but non-palatable species. A recent study in Syria showed that protected areas had 77 species of native plants, compared to only 23 in continuously grazed areas. The most heavily grazed (most palatable) species have nearly vanished. Clearly, fodder production must be a key element in any rangeland conservation program.

The traditional approach is to collect threatened species from the field and preserve them in refrigerated genebanks. ICARDA is helping to pioneer the use of 'in-situ' conservation to complement traditional methods. We're working with national research agencies in Libya, Morocco and Syria to establish pastoretums or field genebanks of rangeland species.

ICARDA provides training and technical advice to develop herbaria (dried specimens for reference), pastoretums and seed banks. National agencies set up nurseries to multiply and distribute seed. And finally, government agencies, farmers' groups and NGOs plant these seeds in degraded rangelands. In Libya seed multiplication has been partly contracted out to private firms, with very successful results.

Using the new approach, native biodiversity can be conserved and community support built up, with limited staff and budgets. Community involvement is crucial, because strict protection (e.g. fences) of large areas is neither possible nor necessary. Instead, the aim is to encourage rangeland users to manage their resources sustainably. Healthy, biodiverse rangelands provide more fodder, directly benefiting



Private seedling nursery in Syria: the private sector works with government agencies to multiply and distribute rangeland species.

livestock owners. They also create new opportunities, such as the cultivation or wild harvesting of medicinal or aromatic plants.

THE LIBYAN EXAMPLE

A collaborative project with the Agricultural Research Center in Libya illustrates how this approach works. In 2009 and 2010, researchers traveled to 64 sites across the country, 'sampling' seven geomorphological zones – rangelands, valleys, salt lakes, sand dunes, forests, coastal areas and roadsides. They collected seeds of 115 species and specimens of 215 plants, focusing on species with economic value and particularly on palatable rangeland species.

The seeds were planted in two newly-created nurseries, with a duplicate set stored in the national genebank in Tripoli. A variety of techniques (seed priming, fungicide treatment, scarification etc) was used to ensure good germination and healthy seedlings. In February 2010 the seedlings were transplanted from the nurseries to two new pastoretums, Al Hira in western Libya and Al Fatayeh in the east. Both pastoretums contain species not only from Libya, but also from 15 other countries, sourced from ICARDA's collections.

The project team identified twelve species of trees, shrubs, herbs and grasses that will form the core of rangeland rehabilitation programs in Libya: *Atriplex nummularia*, *Atriplex halimus*, *Salsola vermiculata*, *Acacia victoriae*, *Acacia tortilis*, *Pistacia atlantica*, *Periploca*

angustifolia, *Oryzopsis miliacea*, *Dactylis hispanica*, *Phalaris truncata*, *Rhus tripartita*, and *Retama raetam*.

Many are indigenous to Libya; some are exotic, but well adapted to Libyan conditions. The two species of *Atriplex* (saltbush) are hardy, drought-tolerant fodder shrubs; *nummularia* is highly palatable to livestock, *halimus* can thrive in degraded saline soils. Both *Acacia* species are leguminous trees (they enrich the soil by fixing atmospheric nitrogen) adapted to hot, dry areas. *Acacia victoriae*, native to Australia, is a fast-growing tree widely used for afforestation and stabilization of sand dunes; parts of the tree are also used in soap production. *Acacia tortilis* is slower-growing but provides high quality timber; the pods, bark and roots are used in the tanning industry. *Rhus tripartita* is a perennial shrub with multiple uses: animal fodder, human food, industry, aromatic use, and in local (traditional) medicine.

SCALING OUT

In 2009, a similar project was launched in Morocco, with the Institut National de la Recherche Agronomique, using 106 indigenous and exotic species. Eleven indigenous species were from the national collection; the remaining 95 (mostly fodder species) were supplied by ICARDA, originating from different countries, but all adapted to Moroccan environments.

In 2010, Syria's General Commission for Rangeland Development worked with ICARDA to establish the country's first pastoretum of fodder, medicinal and aromatic plants. As in Morocco, both indigenous (78, from the national collection) and adapted exotics (51, from ICARDA) were used. Chemical analyses and feeding trials are under way, to measure the nutritional potential (e.g. palatability, digestibility, energy content) of these species.

Degradation cannot be reversed overnight. But this new multi-disciplinary approach provides a model for rangeland conservation. It's working well in three countries, and could be applied, with minor modifications, to developing countries worldwide.

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Research Locations: Choosing the Right Site

A new GIS-based approach helps select benchmark watersheds and research sites faster and more accurately.

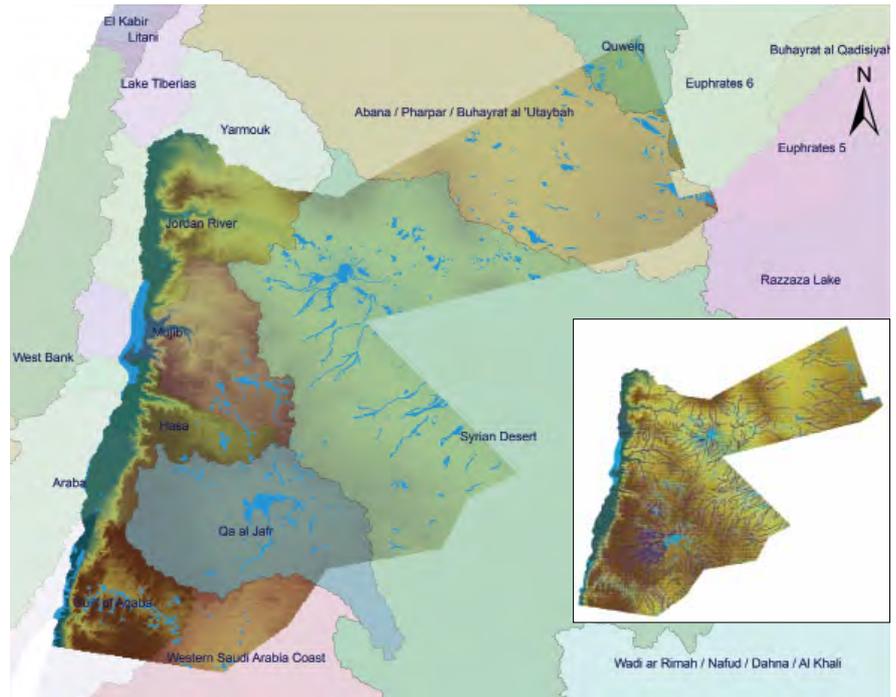


The productivity and sustainability of any farming system depend on the performance of, and interactions between, its different components – crops, soil, water, livestock, farming methods, animal husbandry practices. These interactions generally operate at the scale of the watershed – the area over which water is captured, added to groundwater reserves or used. Watersheds range in size from a few hectares to thousands of square kilometers.

Researchers must therefore focus not on the farm, farming system or administrative district, but on the natural ecological unit, the watershed. This is especially true in dry areas, where water scarcity is usually the main constraint. With the watershed as the primary 'research unit', the next question is: in which particular watershed, or which site within a large watershed, should research be conducted?

SELECTING RESEARCH SITES

Selecting the right site is easier said than done. The ideal site must represent conditions over the entire watershed, so that results from the site can be scaled out to larger areas. But accurate data on soils, hydrology, topography and other factors – all crucial in the selection process – are often lacking. Field surveys are slow and expensive. ICARDA scientists, working with partners in different countries,



GIS maps, produced from satellite images, help zoom in from large areas to particular watersheds.

MODELING THE WATERSHED

Site selection is done in three stages: analysis using geographic information systems (GIS), surveys, and rapid rural appraisal. Having determined the parameters for selection, researchers scanned large areas — 13,000 square kilometers in Jordan and 97,000 sq km in Libya — using coarse data on watershed area, rainfall, population distribution, topography, land use and other factors.

Next, they visited candidate watersheds to better understand factors that could not be read from data alone, choosing benchmark watersheds on the basis of accessibility; existing and potential cropping systems; microclimates; water resources; soil type, depth and slope; and community characteristics. Using this information, they created detailed models to understand local hydrology and analyze land suitability. This narrowed down the hundreds of potential locations to a manageable number of sites in each watershed.

Finally, the team visited each of these sites, using rapid rural appraisal techniques to collect biophysical and socioeconomic data, including land ownership and farmers' willingness to cooperate. Results from the three-stage

process fed into detailed environmental and socioeconomic analyses to select the final project sites.

The selection process must be flexible and multidisciplinary to accommodate the complexity of dryland systems. Flexible, because interactions with the community often provide new information that is critical to the decision process. Multidisciplinary, to better understand the interactions between diverse system components.

After multiple iterations, researchers zero in on ideal sites and appropriate technology packages for each site. Data gaps are filled using local knowledge gathered from farmers, extension experts, community organizations and the local administration. Crucially, this approach can be used in dryland systems worldwide, with modifications to suit local circumstances.

devised an alternative method that is quick, accurate and cost-effective.

The new method was developed in 2005, to select sites for a research project in Jordan. The nature of the project, integrating crop, water management and rangeland components, meant that proper site selection was critical. The method was refined in 2010 for another integrated project in Libya, which combined water harvesting, livestock production, new crop varieties and new cropping systems.

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Mountains of the Maghreb

North African communities build on the comparative advantages offered by mountain ecologies.

Happy families are all alike; every unhappy family is unhappy in its own way."

The opening sentence of Tolstoy's *Anna Karenina* is one of the most famous in literature. Does it suggest a parallel in agriculture? Agriculture in fertile lowlands can be happily uniform over large areas. But in mountainous, low-rainfall regions, each community faces its own set of problems.

North Africa's mountain regions are as important as they are vulnerable. They contain 30% of all arable land in Morocco, 13% in Algeria and 10% in Tunisia. They also contain 65% of Morocco's forests, 31% in Algeria and 60% in Tunisia. They are vital sources of freshwater, and the main reservoir of biodiversity.

But most mountain communities in North Africa are poor, highly dependent on

agriculture, and vulnerable to weather and market fluctuations.

In the past, agricultural development programs in these areas often sought to adapt technologies originally designed for lowland ecologies. This usually failed, because topographically complex environments are also highly diverse; areas just a few kilometers apart may require very different technology solutions.

INTEGRATED APPROACHES

ICARDA led a three-year project in Algeria, Morocco and Tunisia, funded by the Swiss Agency for Development and Cooperation. The project looked at ways to reduce poverty in mountain communities while conserving forest, soil and water resources. It began with

the clear understanding that simply raising subsistence crop yields wasn't enough. Instead, researchers worked with communities to first understand the different factors (environmental, social, financial) that affected local livelihoods, and then to identify and test 'best-bet' technologies tailored to local conditions.

Extensive training programs helped ensure that innovations were effectively disseminated and used. Research and extension staff were trained on different technologies, particularly natural resource management.

Farmers received hands-on, practical training that would allow them to create or expand income generating enterprises: bee-keeping and goat milk processing (Tunisia), growing and processing red peppers, carpet weaving (Algeria), apple production, irrigation methods, sheep and goat husbandry (Morocco). Members of



Kabylie mountains, Algeria. Farmers install a low-cost irrigation system with rock and straw beds to increase water use efficiency.



Women farmers now process farm-grown peppers for sale to town markets, instead of selling raw produce locally.



High and dry. Traditional rock and mud structures in Tunisia harvest rainwater and reduce erosion on mountain slopes.

farm cooperatives in all three countries were trained on basic accounting and business practices.

PUTTING KNOWLEDGE TO USE

Given the short duration of the project, the emphasis was on limited testing of the most promising technologies, and on assembling data that could help design future interventions. The technologies included a package combining crop nutrition, pest and disease control, pruning techniques and micro-irrigation for fruit production, that improved yield and fruit quality while reducing irrigation requirements.

Researchers created 'data banks' on soil and water resources, farm system dynamics, and biodiversity and habitat status of forest plants. Other key areas were diversification and value addition: production of fresh vegetables, potatoes and other high-value crops, dairy processing, cultivation of herbal and medicinal plants, and the production and sale of woolen handicrafts.

The project included a large socio-economics component looking at local marketing chains; institutional or policy constraints; the roles of governments, community groups and NGOs; micro-credit schemes; and infrastructure requirements.

A TALE OF TWO VALLEYS

Taddarine and Anougal are both valleys in the High Atlas of Morocco, ecologically similar but economically different. Taddarine has a paved road and electricity, Anougal has neither. Yet, poverty is much lower in Anougal, 57% versus 70%. The key difference was in the strength of local institutions: Anougal's farmers are organized in a dairy cooperative, which links them to a reliable market.

But the research also showed that market relationships are not always straightforward. Taddarine's paved road allows easy access to traders, who send large trucks to buy apples directly from individual farmers. The farmers benefit from trader competition – but usually sell their harvest months before picking time, receiving early payment based on traders' estimates of harvest size and quality. In contrast, Anougal has poor road access and a much smaller harvest. But farmers in Anougal store their best apples for months before selling them for 4-5 times what they received for lower-quality fruit sold locally. They can afford to delay selling their most valuable produce because the local cooperative gives them credit on friendly terms.

The lesson? Farm cooperatives are a powerful development tool. Helping small-scale producers to organize themselves into cooperatives enables them to become part of the market economy, negotiate premium prices for high-quality products, and lift themselves out of poverty.

The pilot program has shown how technology 'packages' can be tailored to local conditions even in highly diverse environments. Equally important, it has shown how integrated approaches can help unlock the potential of small-scale mountain farming systems, in North Africa and far beyond.

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Conservation Agriculture: the Bottom Line

Conservation agriculture provides immediate economic gains as well as long-term environmental benefits.

Conservation agriculture is a combination of minimal tillage and other practices that delivers a range of environmental benefits that make dryland farming more sustainable. Plowing is eliminated, minimizing soil disturbance and thereby improving soil structure, water infiltration rates and water use efficiency. Residues left behind from the previous crop reduce evaporative water loss, and also protect the soil from wind and water erosion. Nutrients drawn from crop residues and manure (from animals grazing these residues) improve nutrient cycling. Conservation agriculture reduces greenhouse gas emissions in various ways: by reducing fuel consumption (less plowing, less tractor

time), by sequestering carbon in the soil through an increase in organic matter content, and by more efficient nutrient cycling, which reduces the amount of nitrogen fertilizer needed. Air and surface water quality also improve because burning (a traditional method of stubble control), soil drift and chemical runoff are reduced.

These environmental benefits are long-term. They materialize slowly, and only when conservation agriculture is used over large areas. For this to happen, the technology must be attractive, offering immediate, visible benefits – which is precisely what conservation agriculture does.

LOWER COSTS, HIGHER PROFITS

By eliminating or minimizing tillage, farmers save time, fuel and labor. The specially designed seeding equipment used for zero-till planting also helps optimize seeding rate, allowing farmers to reduce seed costs by up to two-thirds. This, along with earlier planting, better nutrient cycling (lower fertilizer costs), improved water use efficiency, all lead to higher yields and profit for the farmer. The water factor is particularly important in dry areas; greater efficiency minimizes the risk of low yield or crop failure under drought, and in irrigated crops, reduces the cost of pumping water.



Research trials at ICARDA helped optimize crop management practices to get the best possible returns from conservation agriculture.

ICARDA and its partners have calculated the increases in revenues and profits from conservation agriculture trials in Syria and Iraq. In Syria, eliminating two plowings saved \$40 per hectare. Lower seeding rate (reduced from 300 to 100 kg/ha) saved \$80/ha, and a 25% increase in wheat yield (250 kg/ha, \$100/ha) increased profits by \$220/ha. In all, profits were 50% higher compared to conventionally tilled fields.

In Iraq, where wheat prices are higher (\$700/ton), the higher yield brought in an additional \$175/ha. This, combined with savings from optimal seeding (\$140/ha) and reduced plowing (\$40/ha), increased farmers' returns by \$355/ha.

POLICY SUPPORT

ICARDA and its partners are working with farmers in Syria and Iraq to tailor conservation agriculture methods to local conditions. The project is funded by the Australian Centre for International Agricultural Research and AusAID.

In the past five years, adoption of conservation agriculture in Iraq and Syria has increased from near-zero to over 28,000 hectares. One reason is that the biggest bottleneck – lack of affordable machinery – has been largely resolved. Locally manufactured zero-tillage seeders are now available. They offer the same performance as imported equipment, for one-tenth the cost.

Adoption could grow even faster with more policy support. Syria, for example, has launched a micro-credit scheme to help farmers finance the purchase of seeders. If half of Syria's 3 million hectares of wheat and barley were grown under conservation agriculture (up from 15,000 ha today) and if yields increased by 25% (as consistently observed in field trials), the national cereal harvest would grow by 12% — bolstering national food security while saving fuel, water and other resources.

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Fighting Salinity in Central Asia

Innovations in Central Asia – new crops, soil amendments, biodrainage – help rehabilitate salt-degraded farmland.

Rusted ships lie abandoned on desert sands that were once covered by the Aral Sea... just one example of the damage caused by runaway irrigation on the steppes of Central Asia. But this is only the most visible symptom of a wider problem: widespread, irrigation-induced degradation of some of the most fertile farmland in the region.

In the past 60 years the Aral Sea has shrunk to one-tenth of its former volume, largely because water from the Amu Darya and Syr Darya rivers that fed the Aral Sea was diverted to irrigate cotton fields. The impacts of this Soviet-era policy are being felt by farmers in Kazakhstan, Turkmenistan and Uzbekistan, through which these rivers flow. More than half the irrigated land in these countries (and at least 20% globally) is degraded by waterlogging or by toxic concentrations of salt left behind when irrigation water evaporates.

ICARDA and its partners — the International Water Management Institute, the Center for Development Research (ZEF) and others — have tested

a number of interventions that could slow down or even reverse soil degradation, and restore the productivity of farming systems in Central Asia.

SALT SOLUTIONS

One good option is to use crops or trees for phytoremediation. Field trials in Uzbekistan tested the cultivation of licorice (a salt-tolerant legume) on highly salt-affected land. Within four years, the water table had been controlled, salt content in the root zone had dropped, and soil organic carbon content had increased substantially. New crops planted on this land gave much higher yields compared to an adjacent 'control' plot where no licorice had been grown — wheat yields tripled, cotton yields increased six-fold.

Another option is to use abandoned salt-affected land and saline water to grow bioenergy crops such as jatropha, toothbrush tree, Russian olive and sweet-stem sorghum. These species can thrive in 'wastelands', providing renewable energy (and cash) without displacing food crops or invading natural ecosystems.

Yet another option is, surprisingly, rice cultivation. Some rice varieties can yield 4-5 tons per hectare even on saline soil. Fields used for winter wheat require leaching to counteract the capillary rise of saline groundwater. This is normally done by flooding fields during the summer fallow period. By planting rice in the flooded fields instead of leaving them fallow, farmers can harvest an extra cash crop while accomplishing leaching. Water requirements can be reduced by 20-25% by using early-maturing rice varieties and slightly delaying transplanting.

Some technologies such as fertilizer and mulching, designed primarily to improve yields and soil health, also help control salinity. A three-year experiment in Uzbekistan studied the effects of mulching: placing wheat straw in the furrows of cotton fields to capture surface runoff, reduce evaporative losses and improve water infiltration. Mulching not only increases yield and water use efficiency, but also reduces soil salinization in the root zone. The benefits are significant even when only every second furrow is mulched — which



DRAINING UP

Most irrigated areas in the Aral Sea basin suffer from a high groundwater table and high salinity levels. Natural drainage is limited by topography and soil properties. Artificial drainage systems are poorly maintained. And the combination of excessive irrigation and high evaporation rates is pushing salinity levels even higher.

One possible solution: plant trees to serve as biological pumps. Trees suck up water through their roots and transpire it out through their crowns. This lowers the water table, alleviates waterlogging, and gradually reduces salt levels in the crop root zone. Trees also shade the ground and reduce evaporation from the surface, thus slowing down salinity build-up.

If the right tree species are selected, biodrainage plantations can help rehabilitate farmland that has been abandoned due to salinity. The species must have specific characteristics (e.g. high leaf transpiration rate) that increase water 'throughput'. In addition, they must be salt-tolerant, with a deep, extensive root system.

Scientists tested various tree species in the Khorezm region in the Aral basin. The best option? Russian olive, which is native to the region, and provides multiple benefits: biodrainage, nutritious fodder for livestock, fuelwood, and also improves soil fertility through biological nitrogen fixation. Siberian elm and two species of poplar were also found suitable.

means farmers have enough straw for mulching and for animal fodder. Almost 90% of farmland in the Syr Darya basin is planted with cotton in summer, so mulching could generate huge economic and environmental benefits.

Research in Kazakhstan has found that applying nitrogen fertilizer above recommended rates offsets the effects of salinity, improving crop establishment and yields. The more saline the irrigation water, the greater the difference between generously fertilized and normally fertilized crops.

In large parts of Kazakhstan, soils contain high levels of magnesium, which reduces infiltration rate and hydraulic conductivity. ICARDA researchers found a relatively simple cure: the addition of calcium-rich phosphogypsum, which is affordable and locally available. Phosphogypsum improves the ionic balance between calcium and magnesium, improving water infiltration into the root zone – in effect, making existing soil moisture more available to plants. Field experiments helped establish optimal application rates

(4-8 tons per hectare), enabling farmers to significantly increase cotton yields.

REVERSING DEGRADATION

The challenges are complex: poor irrigation practices, scarcity of freshwater, and soils prone to salinization. Given the



Excess magnesium increases clod formation and reduces yields and water productivity.

scale of degradation, rehabilitation of salt-affected farmland will require both local and landscape-scale efforts, including policy support in each country and much greater cross-border cooperation. Scientists, NGOs and governments must work together to develop water management plans that minimize salt loads and improve irrigation drainage at basin scale, across the region. Without this, Central Asia's huge farming potential will remain just that – potential.

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Dates with Destiny

Research in the Gulf, the home of the date palm, creates new opportunities for producers and industry.

The Palm Islands, a man-made archipelago off the Dubai seashore, celebrate the Gulf's iconic tree: the date palm, cultivated for at least 6000 years.

Today dates are a major food and cash crop in the Gulf. The trees are exquisitely adapted to desert soils and climates. In addition to their fruit – nutritious, high-energy, consumed fresh, dried and in various processed forms – they provide animal feed, fuelwood and construction materials, and also protect understory crops from sun and wind.

Date production in the Middle East is increasing rapidly, but several problems remain. These include diseases and insect pests that affect yield and quality, slow adoption of modern techniques for propagation and orchard management, and a limited product range.

ICARDA's date palm research covers seven countries. In 2004, the Gulf Cooperation Council provided funding for a collaborative project in Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. In 2010, the International Fund for Agricultural Development began supporting similar work in Iraq – the probable home of the date palm.

YIELD, QUALITY, MARKETABILITY

Research findings extend from propagation to packaging. Liquid pollination, in which female flowers are sprayed with a pollen solution, was found to be easier, faster and cheaper than other techniques; and equally effective. It was scaled out to growers last year, through a government program with technical support from the project.

Two other technologies – fruit-thinning and bubbler irrigation – are also being scaled out, and users report significant improvements in yield and fruit quality. Surveys of diseases and insect pests identified more than 300 species, as well as 17 natural predators to help control the most serious ones. Project scientists have identified two effective and environmentally friendly biopesticides against the lesser date moth. Research trials in Iraq, now in their second year, are showing promising results on control of the Dubas bug using three biopesticides: neem oil, summer oil and a local strain of the soil fungus *Beauveria bassiana*.



Dubas bug infestation: biopesticides could be the answer.

Experiments on fruit maturity and harvesting showed that sun-drying fruit under glass or polycarbonate sheets shortens the process from 12 days to 5 days and significantly improves quality. Other studies identified ways to profitably use unmarketable low-quality dates and the by-products of date processing: for example syrup, liquid sugar, citric acid, medical ethanol, vinegar and baker's yeast. For high-quality but surplus fruits the options include paste, date bars, breakfast cereal and pastries.

BIOTECHNOLOGY AND GENOMICS

Complementing this adaptive research is a cutting-edge biotechnology program. ICARDA scientists, working with researchers from Iraq, Morocco, Qatar and Syria, have developed more than 1000 microsatellite markers for date palm. These are chromosome segments, or pieces of DNA, containing a recognizable sequence of base pairs. Markers are a powerful tool for gene tagging, genetic diversity analysis, marker-assisted breeding and other studies.

This research won ICARDA the 4th Khalifa International Date Palm Award (instituted by the UAE government), in the 'Distinguished Research' category. These kinds of studies will help create 'next generation' palm trees, as modern as the Palm Islands of Dubai.

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The halophytic flora of Syria. Mohammed Al-Oudat and Manzoor Qadir

The first comprehensive list of indigenous halophytes (salt-tolerant plants) in Syria. Photographs, description, habitat, conservation status and uses for more than 110 species - including six species reported from Syria for the first time.

Also discusses halophyte biology and adaptive traits, their role in maintaining ecological stability, and potential for use in rehabilitating degraded saline soils.



Assessment of wheat yield gap in the Mediterranean: case studies from Morocco, Syria and Turkey. Mustafa Pala et al.

Analyzes differences between potential and actual wheat yield in three countries over a 10-year period, showing that yields can be increased 1.6-2.5 fold in Morocco, 1.7-2 fold in Syria and 1.5-3 fold in Turkey

using currently available technologies. Outlines specific measures to bridge the yield gap, and research priorities for the future.



Animal nutrition and product quality laboratory manual. Monika Zaklouta et al.

Describes laboratory protocols for various kinds of analyses: quality and nutritional value of feed products and silage, milk quality, assays to determine udder health, diagnosis of mastitis, and blood analysis (use of ELISA to evaluate progesterone

levels in sheep). Designed as a training aid, and a reference for developing-country laboratories seeking to establish their own standards and protocols.



Water, land and livelihoods: an overview of ICARDA's research. Theib Oweis.

Describes ICARDA's research portfolio in natural resources management. Thumbnail descriptions of 32 ongoing or recently completed projects, training programs, and laboratory diagnostic services offered to our partners in developing countries. The book also describes the 'benchmark site' approach pioneered by ICARDA, and now used in several countries.



Land degradation in Jordan: review of knowledge resources. Esmat Al-Karadsheh, Samia Akroush and Safa Mazareh.

A review of the literature on causes, processes and extent of land degradation. Includes analysis of legislation, land-use policy, institutional support, and development programs to promote sustainable agricultural practices. Identifies indicators, data sources and analytical tools to improve the measurement and monitoring of land degradation. Part of a four-volume series covering Jordan, Morocco, Pakistan and Yemen.



The International Center for Agricultural Research in the Dry Areas (ICARDA) was established in 1977. It is one of 15 centers supported by the CGIAR. ICARDA's mission is to help fight hunger and poverty through research and training to increase the production, productivity and sustainability of farming systems in dry areas. Our research covers vital food crops — barley, bread and durum wheat, lentil, faba bean, chickpea — as well as pasture and forage legumes, water and land management, rangelands, and small-ruminant production. All our work is conducted in partnership with national research centers, universities, NGOs, the private sector and others.



CGIAR is a global research partnership that unites organizations engaged in research for sustainable development. CGIAR research is dedicated to reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring more sustainable management of natural resources. It is carried out by the 15 centers who are members of the CGIAR Consortium in close collaboration with hundreds of partner organizations, including national and regional research institutes, civil society organizations, academia, and the private sector.

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