

# ANNUAL REPORT 2018



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2018 Annual Report Production

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# ANNUAL REPORT

2018



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# FOREWORD

*Joint message from the Director General and the Board Chair*

## The critical importance of agricultural research for development

The Intergovernmental Panel on Climate Change (IPCC) released a sobering report last year on the consequences of a 1.5 °C rise in global temperatures. It warned of long-lasting and irreversible impacts on health, livelihoods, food security, water supplies, and economic growth. After decades of progress, the report cautioned, we risk backsliding on many development gains, threatening the world's ability to deliver the UN's Sustainable Development Goals (SDGs).

The impact of this rise in global temperatures in the non-tropical drylands, where ICARDA operates, is predicted to be particularly severe. Agricultural research for development in these fragile environments offers a critical defense against the negative effects of climate change—it is an essential prerequisite to enhance the agricultural sector's resilience. Agriculture will continue to be a key driver of socio-economic conditions in the dry areas, and farmers—particularly smallholder farmers—will need support to help them cope with future climate challenges. Without this support the sector's ability to produce sufficient income, employment, and food and nutrition cannot be guaranteed. Given the multiplier effects a productive agricultural sector can generate, agricultural research for development may also help to address the increasing [threat of climate-induced migration](#).

Our new Deputy Director General for Research leads a highly motivated and experienced team of scientists intimately familiar with dry area farming systems and the challenges they face—from North Africa and

the Middle East to Central Asia and India. With vast expertise accumulated over several decades, Dr. Jacques Wery and his team will set priorities, strengthen planning, and implement and monitor a cohesive research agenda tailored to rapidly changing conditions.

In 2018 this expertise informed the planning of a new research-for-development program. In cooperation with several CGIAR Centers, this program takes a comprehensive, cross-sectoral systems approach to the challenges facing agricultural sectors in the dry areas. DryArc will draw on the collective knowledge of the CGIAR to mobilize a rich diversity of technological, managerial, socioeconomic, institutional, and policy innovations tailored to major agroecosystems. It will build upon ICARDA's core scientific and collaborative programs, and benefit from our extensive cooperation with national agricultural research systems (NARS).

In 2018 these programs and collaborations continued to deliver for smallholder farmers. Activities included distributing 1,521 breeding lines of wheat, barley, faba bean, chickpea, lentil, and grass pea to some 135 collaborators in 44 countries; collaborating with Iraq on its national strategic review of food security and nutrition; pioneering mechanized chickpea production in Ethiopia; exploring the safe and productive use of waste water in Egypt; identifying the first cactus ecotypes resistant to wild cochineal in Morocco—and promoting this climate-smart plant as an alternative fodder in India; initiating a water supply and management project in Lebanon to help host communities cope with the

influx of Syrian refugees; and working with our national partners in Tunisia to draw up a new pastoral code that will facilitate a more sustainable governance regime, providing an important framework for other countries.

ICARDA also co-organized several conferences, notably the Seventh International Food Legumes Research Conference (IFLRC-VII) in Marrakesh, Morocco, which brought together over 300 legume experts. During the Conference of the Parties to the Convention on Biological Diversity, we shared the results of a farming with alternative pollinators (FAP) initiative, which the *Guardian* newspaper described as a blueprint to [save bees and enrich farmers](#). Demonstrating the importance we place on advancing and sharing new research and knowledge, our scientists contributed to over 150 scientific publications. Our work was also featured in major international media outlets, including Reuters and the [TV channel ARTE](#), which showcased the critical work of our gene bank.

These activities were all made possible by the generous support of our donors and the tireless work of our national and international partners. We acknowledge their commitment and look forward to further collaborations in the future as we continue to explore, develop, and scale up the innovations that rural communities in the dry areas need to thrive.



**Aly Abousabaa,**

*ICARDA Director General*



**Margret Thalwitz,**

*ICARDA Board Chair*

# RESEARCH HIGHLIGHTS



**155 partnership agreements**  
signed or renewed



**135 research projects**  
implemented  
in **46 countries**

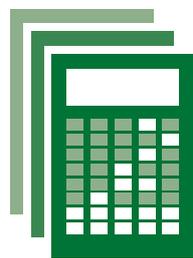


**1,521 breeding lines** distributed  
to partners in  
**44 countries**

**37 ICARDA crop varieties**  
released by national partners



**33,000 plant accessions**  
regenerated



**627 publications**  
and **datasets**  
produced



**>650 people** benefited from  
**capacity development** opportunities

# IN BRIEF

## Developing and disseminating climate-resilient crop varieties

ICARDA continued to play a critical role in the development, improvement, and dissemination of climate-resilient crop varieties last year. The varieties strengthened food and nutritional security and provided a critical defense against extreme temperatures, water scarcity, and the emergence of new pests and diseases. During 2018, some 1,521 sets of international nurseries of wheat, barley, faba bean, chickpea, lentil, and grass pea were distributed to 135 collaborators in 44 countries. ICARDA, through its collaborative partnerships with NARS also released 37 improved varieties of wheat, barley, chickpea, and lentil in 11 countries.



## Strategic review targets zero hunger in Iraq



ICARDA contributed to a national strategic review of food security and nutrition in Iraq—an effort to transform the country’s agricultural sector and address worrying levels of food insecurity and malnutrition. We worked on behalf of the World Food Programme, which delegated responsibility to ICARDA because of its intimate knowledge of Iraq’s agricultural sector and close partnerships with Iraqi officials and researchers. The Center contributed a set of policies, institutional changes, and investments designed to support implementation of SDG 2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture).

The [\*National Strategic Review of Food Security and Nutrition in Iraq\*](#) is the first assessment of its kind in Iraq to comprehensively discuss, synthesize, and prioritize actions to accelerate progress toward SDG 2 targets. The Review adopts an integrated approach that goes beyond a single focus on agriculture to also consider health, education, and social development. Its priorities include improving safety-net instruments, addressing the burden of poor nutrition, increasing employment, enhancing sustainable agricultural production, and reforming marketing, trade, and pricing policies.

## Piloting mechanized chickpea production

An initiative in the Ethiopian Highlands piloted mechanized chickpea production last year, laying the foundations of a lucrative export-oriented farming system. Previously neglected because of the crop's dependence on traditional farming practices and high labor costs, new higher-yielding and machine-harvestable varieties are now contributing to the crop's increasing popularity. The erect and early-maturing chickpea plants were developed and piloted with support from the United States Agency for International Development (USAID) and the Debre Zeit Agricultural Research Center.

A positive performance led to demonstration trials, and with private-sector support—including the dissemination of improved seed and the supply of inputs and services such as planting, spraying, and training—farmers were able to produce some 602 tons of chickpea by February, an average of 3.5 tons per hectare. The harvested crop was delivered to exporters at a negotiated price, providing an assured market for farmers. Bale Green, the private state farm, is expected to increase the area of chickpea production through contract farming with smallholder farmers.



## Enhancing food security in Arab countries

The Enhancing Food Security in Arab Countries initiative, which works across 10 Arab countries to raise wheat production and address the region's growing dependence on costly wheat imports, entered its third phase with funding from the Arab Fund for Economic & Social Development.

The action plan for phase three, building on previous phases, will prioritize:

- verifying and fine tuning recommended technology 'packages' (including wheat and food legume cultivars and improved agronomic and water management techniques);
- expanding the number of pilot sites to other agroecologies (thereby out-scaling the technologies and making them available to more beneficiaries);
- exploring enabling policy environments; and
- strengthening the capacity of national research and extension systems to promote technologies for wider adoption throughout the Arab region.

## A new pastoral code for Tunisia

In Tunisia, ICARDA contributed to a new pastoral code, a response to the severe economic, social, and environmental costs of degradation across the country's rangeland areas. Working with the General Directorate of Forestry, the code is designed to deliver a more sustainable governance regime that also protects the livelihoods of pastoral communities. Inclusive and practical, the code offers a framework for other countries experiencing degradation in rangeland areas.

Although rangelands are a critically important resource in Tunisia, they have become seriously degraded in recent years due to a combination of overgrazing, crop encroachment, and complex land tenure systems, which complicate the application of regulations and protections. Government efforts to reverse degradation have also been held back by a lack of coordination between different agencies, limited human resource capacity, and insufficient access to relevant research and data to inform decision-making processes. Finally, rangelands now have to contend with the adverse impacts of climate change—North Africa is becoming a hotspot for prolonged drought, placing these marginal areas under additional strain.

Legally, the protection of rangeland areas in Tunisia was insufficiently covered by the country's forest code. Of the code's 232 articles, only 6 referred to pastoralism, requiring a separate code that specifically targeted pastoral activities. The resulting code covers:

- institutional governance (including the creation of a central coordinating body to oversee rangeland governance);
- sustainable management and land tenure reforms that involve pastoralists and rural communities (such as designated resting areas and a ban on land privatization);
- measures to manage herd mobility; payments for environmental services; and
- climate-change adaptation/mitigation measures.



## Improving the livelihoods of farmers and refugees in Lebanon

ICARDA, in collaboration with the Lebanese Agricultural Research Institute (LARI) and the United Nations Development Programme (UNDP), implemented an irrigation water supply and management project in Lebanon's Beqaa Valley, designed to support host communities struggling to accommodate refugees from Syria. In response to the region's severe water scarcity—compounded by climate change, rising food demands, and inefficient irrigation systems—the initiative targets more sustainable practices for cereal-based farming systems, drip-irrigation systems, and the lining of earth canals.

More than 1,000 Lebanese farmers and 5,000 Syrian casual agricultural workers in the Beqaa Valley benefited from the enhanced efficiency and productivity of irrigated farmlands, the introduction of improved seed varieties, and new agricultural practices suitable for cereal-based systems. With a population of around 4.5 million people, Lebanon is currently home to nearly [1.5 million](#) registered refugees from Syria and an estimated [450,000 refugees](#) from Palestine.



## Community-based livestock breeding delivers for Ethiopian farmers



A community-based small ruminant breeding program, first introduced to Ethiopia by ICARDA and its partners in 2009, was included in the country's Livestock Master Plan and national Growth and Transformation Plan II. The approach combines farmer training to improve selection methods; pooling community flocks to create a large gene pool from which breeding rams can be selected; farmer–scientist interactions to evaluate different breeding options; and setting up recording systems to monitor the performance of individual animals, leading to continuous genetic improvement.

The Ethiopian government's decision follows a sustained research program that has demonstrated the approach to smallholder farmers over several years. To date, the program has directly benefited more than 3,200 households in 40 villages—with an average income increase of 20 percent. Farmers have also created some 35 breeder cooperatives. Given the program's continuous success in Ethiopia, the community-based small ruminant breeding model is now being replicated in other countries, including Malawi, South Africa, Sudan, Tanzania, and Uganda.



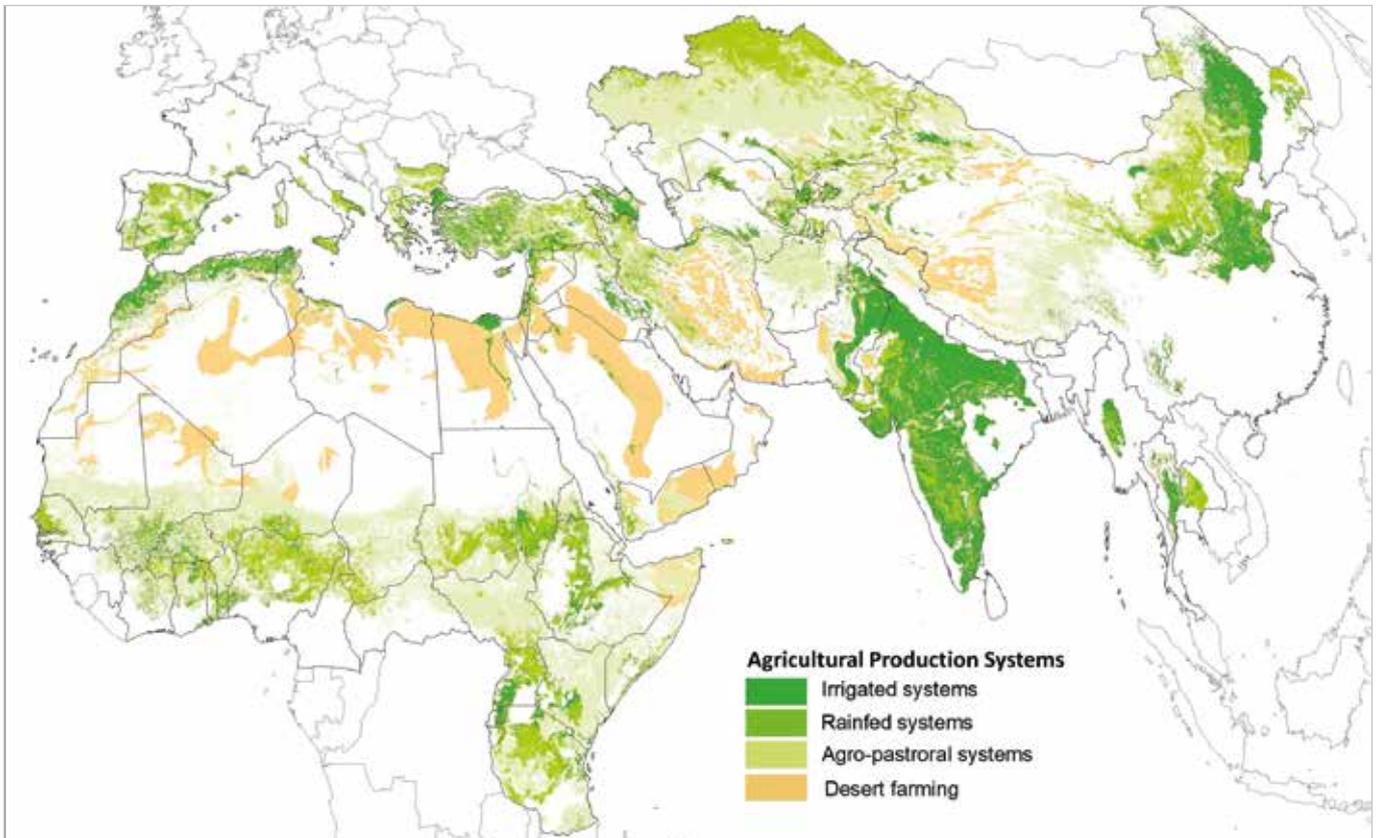
## Promoting the climate-smart benefits of food legumes

The Seventh International Food Legumes Research Conference, co-hosted by ICARDA in Marrakesh, Morocco, brought together over 300 legume experts to explore ways of promoting the multiple benefits of these climate-smart crops. The Conference demonstrated the huge strides advanced crop science had made in recent years to develop varieties that are high yielding, disease resistant, and heat and drought tolerant.

Discussions focused on advances made in genomics and genetics, including gene identification in faba bean, new opportunities for chickpea improvement, and the diversity, characterization, intergene pool hybridization, and breeding of bean varieties. The conversation also moved beyond yield and performance to adoption constraints, options to strengthen seed systems, value chains, and the ecosystem services that legumes provide.

Finally, the conference considered the potential role of Big Data and the CGIAR's Big Data platform, which offers a holistic insight into the conditions, constraints, and opportunities that production systems face. This powerful new tool offers legume research a transformative pathway—away from a narrow focus on performance toward a systems approach that considers the full range of factors determining the uptake and success of legume production.

# IN FOCUS



## DryArc: Strengthening the resilience of dryland agriculture

A new research-for-development partnership—DryArc—was initiated in 2018 by ICARDA and four other CGIAR Centers: ICRISAT, IFPRI, IWMI, and WorldFish. The initiative will identify and promote proven technologies and strategies to address critical challenges facing agrifood systems across the 80 dryland countries in Africa and Asia most impacted by climate change.

The initiative harnesses the knowledge, expertise and comparative advantages of CGIAR centers and their research partners to mobilize a rich diversity of technological, managerial, socioeconomic, institutional, and policy innovations tailored to major dryland agroecosystems.

DryArc poses research questions that reflect the complex challenges facing rural communities across the dry areas. For example:

- Can intensification of rainfed cereal-based agrifood systems in North Africa and the Sahel also increase youth employment?
- Can irrigated crop production in Central Asia be intensified without exposure to income shocks?
- How can the full potential of the dryland crop–livestock systems of sub-Saharan Africa be realized?
- Can desert farming be expanded without compromising sustainability?

Working with governments, public bodies, and the private sector, this research partnership will streamline existing knowledge, develop new research, and apply this learning in four major agroecologies—rainfed, agro-pastoral, irrigated, and desert farming—to enhance the testing and dissemination of promising innovations and catalyze systemic innovation and change.

The innovations target a complex series of challenges, including water scarcity, land degradation, drought, and temperature extremes, which threaten rural livelihoods and the viability of agriculture. They will also aim to alleviate some of the underlying causes of human displacement and the sociopolitical fragility that affects many dryland countries.

Innovations and strategies will be evaluated according to the following criteria: (1) their ability to foster climate-change adaptation and sustainable intensification; (2) their ability to generate new employment opportunities for the rural poor; (3) their affordability and context specificity; and (4) their potential to reduce conflict and displacement. Impacts on nutrition, women and youth will also be closely monitored.

The initiative applies a participatory approach to generate concrete recommendations to guide investment, policies, and research prioritization for the transformation of agricultural production systems. The initiative is now approaching donors and partners to support its plan, requesting problem-solving cases that will be incorporated into proof-of-concept test cases. It is also asking for assistance in developing knowledge-sharing and implementation systems for the transformation of dryland agrifood systems.

## MEL online platform expands reach

The Monitoring, Evaluation and Learning (MEL) online platform offers one organized space to plan, manage, monitor, evaluate, report, and share program and project activities. It saves time and resources and allows for faster and more-informed decision-making—both inside an institution and across project or program partners. It is also flexible, allowing organizations and projects to customize the platform to more adequately meet their needs.



In 2018, MEL provided an online space for a growing number of programs and projects across the CGIAR and worldwide. Over 700 CGIAR and partner projects have now been mapped onto the platform. Additional improvements last year mean the platform is now fully interoperable with a range of systems and repositories relevant to agricultural research for development, including Marlo, Dataverse, EPrints, CGSpace, WorldFish, DSpace, ORCID, GitHub, and Open Data Kits (ODKs).

The knowledge contained in MEL is FAIR (findable, accessible, interoperable, and reusable). It is available through the open access and open data (OA-OD) compliant MELSpace repository and, visually, through the Agricultural Research e-Seeker (AReS). The publishing rights of the information products and datasets within MEL are ensured through the platform's integration with a variety of reputable web services, such as SHERPA/RoMEO and InCites JRC. Additional integration with AGROVOC, Altmetric, Creative Commons, Flickr, Twitter, and YouTube also ensures data quality, eases knowledge sharing, provides correct attribution, and clarifies the correct use of copyrighted knowledge.

MEL is hosted by ICARDA and has been continuously enhanced since 2016 by MEL partners, namely ICARDA, the International Potato Center, World Agroforestry (since 2016), the International Institute of Tropical Agriculture (since 2017), WorldFish, and ICRISAT (since 2018). All of this takes place within the frameworks of the CGIAR Research Program on Dryland Systems (closed), the CGIAR Research

Program on Roots, Tubers, and Bananas, the CGIAR Research Program on Grain Legumes and Dryland Cereals, and the CGIAR Research Program on Fish Agri-Food Systems.

In recognition of the continued efforts of its implementers and partners, MEL won the [Silver Prize at the 2018 Enterprise Business Collaboration Award in Berlin](#). The award positions MEL and its development team as global leaders in the field of knowledge management and enterprise collaboration. The event brought together over 150 industry professionals and 78 corporations to discuss the most pressing challenges, solutions, technologies, and best practices for scaling up in collaborative programs, communities, and platforms.

## Protecting rich pollinator diversity

[Conservation of pollinator diversity for enhanced climate-change resilience](#) is a project that assesses the impact of habitat enhancement on the abundance and diversity of insects—pollinators, natural enemies, and pests—and farmers' net incomes. Funded by the Federal German Ministry for the Environment, Nature Conservation and Nuclear Safety, its results are used to mainstream pollinator protection through policies. Fields

that adopt the Farming with Alternative Pollinators (FAP) approach generate higher incomes because a higher diversity of pollinators improves the quantity and quality of crops, and the habitat enhancement plants are all marketable. The approach, developed by ICARDA scientist Stefanie Christmann, also reduces the need for chemicals, and it is cost effective since nesting support is built using local waste materials.

Wild pollinators are threatened worldwide by the increasing use of chemicals, monoculture farming, habitat fragmentation, and tillage practices. Yet they are critical for agriculture, biodiversity, the functioning of ecosystems, and human well-being. In the dry areas, in particular, they support climate-change adaptation. Two of the seven countries participating in the FAP project—Morocco and Turkey—are hotspots of pollinator diversity, both in the Mediterranean Basin and globally.

The FAP approach uses around 25 percent of every field for habitat enhancement—strips of marketable plants such as oil seeds, spices or food crops that attract a higher diversity of pollinators. These enhance the productivity of the main crops and attract natural enemies, reducing the abundance of pests. In 2018, on-farm trials in approximately 120 farmer fields were held across four agroecological zones in Morocco—mountainous, semiarid, oasis, and adequate rainfall/



coastal areas. Around 1,500 questionnaires were used to assess current knowledge and threats to pollinator protection, helping to tailor information to farmers and other stakeholders in the form of [instructional videos](#) and PDFs distributed via smartphones.

The five-year project promotes cross-sectoral policies, targeting cost-effective pollinator protection in low- and middle-income countries. In Morocco, working with national partners, it will develop a practical model for pollinator protection that can subsequently be applied in Algeria, Egypt, Jordan, Palestine, Tunisia, Turkey, and beyond. The model will also be shared with the [Coalition of the Willing on Pollinators](#), an international group of forerunner countries committed to pollinator protection.

Other objectives are an international stewardship for pollinator-protecting agriculture, the first inventory of pollinators for West Asia and North Africa, an assessment of the economic value of pollinators for Moroccan agriculture, and collaboration with the Moroccan extension service, the Office National du Conseil Agricole.

## Biofortification research fights hidden hunger

ICARDA has continued to work with national partners in Bangladesh, India and Nepal to enhance iron and zinc levels in lentil. This is to address the fact that a majority of the population in each country, particularly pregnant women and preschool children, suffer from micronutrient deficiency. This form of hidden hunger weakens immune systems and causes serious health problems such as anemia, blindness, stunting, learning difficulties, and even premature death. Rice-lentil dishes are the predominant food eaten in eastern Bangladesh, India, and Nepal, and there is significant scope to develop high iron and zinc content cultivars using the significant variability present in germplasm reserves.

In the past year research partnerships have helped identify 18 new parental lines with high iron and zinc content that can be used in cross-breeding programs. Newly developed genetic stocks have been shared with national partners through an international nursery



network, and several biofortified varieties have been released for commercial cultivation, including Barimasur-9 in Bangladesh, IPL\_220 in India, and Khajurah-4 in Nepal.

To ensure the new varieties are delivered to farmers, ICARDA researchers, in partnership with national programs, also strengthened the region's food legumes research-development continuum. In India, for instance, ICARDA's Food Legumes Research Platform in Madhya Pradesh State continued to offer research and training facilities for researchers and farmers, with support from the Indian Agricultural Research Institute, the Indian Institute of Pulses Research, and Bidhan Chandra Agricultural University. In Bangladesh, the Bangladesh Agricultural Research Institute promoted the varieties Barimasur-7, Barimasur-8, and Barimasur-9. In Nepal, the National Grain Legume Improvement Research Program disseminated the varieties Khajurah-4, Sisir, and Simal through its research partnership with ICARDA.

## Taking mechanized raised-bed planters to scale

With Egyptian partners over the past decade, ICARDA researchers have developed, tested, and modified mechanized raised-bed planters. Now a component of Egypt's national wheat campaign, estimates suggest that by 2023 approximately 800,000 hectares of wheat will be planted in this way. This practical technology, designed for smallholder conditions, has demonstrated a range of positive benefits, including higher yields, reduced costs, and enhanced water productivity. A paper published last year also estimated the economic benefits, predicting that over a 15-year project horizon the benefits would exceed US\$4 billion, with most accruing to more than one million Egyptian wheat producers.

Researchers also explored supply constraints and the factors affecting adoption by studying the technology delivery mechanisms of different providers—public, private, and civil-society groups—to inform the development of policies that can take the raised-bed planters to scale. Interviews were held with key

informants, including farmer agricultural cooperatives, water user associations (WUAs), private machinery and input suppliers, and government extension agents in Assiut and Sharkia governorates, where the technology was extensively demonstrated.

The interviews revealed several advantages and limitations of the different delivery systems. For instance, quality control of key inputs such as fertilizer and seeds remained a challenge in private-sector systems, and required urgent attention. Making mechanized raised-bed planters available to farmers for free, through donor- or publicly funded initiatives, was not sustainable, researchers argued, and represented an inefficient strategy for the technology's wider dissemination. Large-scale manufacturing and renting of the machines based on market forces were preferable, and would ensure their more equitable distribution. In a separate study, researchers offered several other complementary recommendations, including enhanced farmer access to credit and finance, increased cooperation between the private sector, machinery traders, and users, and the provision of more extension officers and pilot plots.



# RESEARCH TO IMPACT

## Collecting, conserving, and using agricultural biodiversity



Conserving dry-area agrobiodiversity is critical to securing genetic gains, strengthening adaptation to climate change, and addressing market-related challenges. ICARDA gene banks are unique and globally significant—our collections now exceed 156,900 plant accessions and 1,380 strains of rhizobia (nitrogen-fixing bacteria in legume roots), collected predominantly from the Mediterranean, Central Asia, West Asia, and Abyssinia.

In 2018 we continued our intensive regeneration efforts to reconstruct ICARDA's active and base collections, and duplicated these accessions at secure storage facilities,

including the Svalbard Global Seed Vault. A total of 33,300 accessions were regenerated and characterized (19,278 in Morocco and 14,022 in Lebanon).

ICARDA researchers also focused on phenotyping and genotyping plant genetic resources, identifying critical resistance traits that can be used in breeding programs. They also undertook prebreeding initiatives to introgress adaptive traits from wild relatives and landraces into elite germplasm. Sources of low-ODAP neurotoxins and resistance to *Orobanche* parasitic weeds, for instance, were identified in wild species of *Lathyrus*, and high sources of beta-glucans were identified in

wild progenitors of barley. Efforts were undertaken to introgress these valuable traits into grass pea and barley, in close collaboration with our Moroccan partner, the National Institute for Agricultural Research (INRA).

## Chickpea resistance to aphid-borne yellow virus

In the first-ever study to investigate the [effects of aphid-borne yellow virus on chickpea in Sudan](#), ICARDA researchers examined the exact identity of the viruses attacking crops to inform breeding programs and strengthen resistance to this debilitating disease. Chickpea is an economically important crop in many countries of the world—but its yields in some regions are often devastated by the aphid-borne yellow virus, which can cause stunting, yellowing, and tip wilting.

Some 204 chickpea samples displaying symptoms typical of viral infestation were collected from chickpea fields and tested against a battery of legume virus antibodies. A positive reaction confirmed that luteoviruses had affected some 41 chickpea samples. Further confirmation was sought using reverse transcription polymerase chain reaction with luteovirus primers, a laboratory technique used to amplify virus sequences. Direct sequencing then confirmed that 12 chickpea samples, which all displayed common symptoms, including leaf yellowing and stunting, were susceptible.

## Limiting the destructive effects of net blotch

Net form net blotch (NFNB) is considered to be one of the major constraints affecting barley production worldwide. The disease, which appears as elongated lesions with dark-brown blotches and striations with a net-like appearance, can cause yield losses of up to 40 percent on susceptible cultivars if the disease occurs under favorable environmental conditions. The malting and feed quality of barley can also be negatively affected.

While chemical control, cultural practices, and host resistance are commonly used to manage net blotch,

the most cost-effective and environmentally friendly way to control the disease is the development and dissemination of resistant cultivars. Last year, ICARDA researchers [evaluated resistance to NFNB in a barley collection of 336 genotypes](#) at both seedling and adult stages. The panel was genotyped with 9K single nucleotide polymorphic (SNP) markers (genetic variations). Genome-wide association studies, a method that searches genomes for small variations, were carried out using mixed linear models, accounting for population structure and kinship as covariates.

Four genotypes showed an average infection response to both isolates at the seedling stage; 30 genotypes showed resistance in the field; and 3 genotypes exhibited the highest resistance at both stages. The genome-wide association studies identified 31 distinct quantitative trait loci (QTL)—DNA that correlates with variations of a particular trait—on all 7 barley chromosomes. Of these, 8 QTLs were resistant at the seedling stage; 21 were associated with resistance at the adult stage; and 2 conferred resistance at both stages. Of the 31 resistant QTLs reported in the study, 10 coincided with previously mapped QTLs, while 21 were novel, validating the genome-wide association study approach.

## Developing salt-tolerant wheat varieties

Research efforts to [identify the genetic and molecular components of salt stress response](#) facilitated the development of gene-specific markers to improve salinity tolerance in wheat. Salinization of arable land poses a significant threat to global wheat production, affecting over 6 percent of the world's total land area and causing losses worth an estimated US\$12 billion. High salt concentrations in soils reduce plant growth, damage a plant's photosynthetic apparatus, reduce seedling growth and survival rates, and adversely affect grain quality.

Developing salt-tolerant crops through a combination of large-scale plant phenotyping and genome sequencing offers a practical and cost-effective defense. In order to dissect the genetic and molecular components of salt stress response and enhance breeding strategies to improve salt tolerance in wheat crops, ICARDA



scientists conducted a genome-wide association study to identify SNP loci associated with salt stress response in wheat. Of these, 14 SNP loci were identified that controlled multiple independent salinity tolerance traits, such as sodium ion uptake, potassium ion/sodium ion ratio, and specific energy fluxes for the absorption and dissipation of salt. Breeding strategies that target sodium exclusion or accumulation in the cell vacuole are often used to increase salt tolerance in plants.

Further analysis of the SNP markers revealed that they were descended from genes involved in photosynthesis and salt stress response. The subsequent application of a real-time polymerase chain reaction quantification strategy—a laboratory technique that is widely used in molecular biology and makes copies of a specific DNA segment—confirmed gene expression and indicated that the genes were more active in salt-tolerant genotypes and less active in salt-sensitive genotypes.

# Developing climate-adapted crops and livestock



In response to rapidly changing climatic conditions across the dry areas, ICARDA applies conventional and molecular breeding strategies to develop highly adapted crops and livestock with resistance or tolerance to major biotic and abiotic constraints.

Our ability to develop climate-resilient crops, sheep and goats is dependent on ICARDA's continued efforts to widen the Center's genetic base, building the Center's collection of genetic resources and enhancing the methods that support precision breeding and accelerate genetic gains. Last year, ICARDA's unique and globally important genetic resources collection was used to develop dual-purpose barley and legumes that provide nutritious feed for livestock and grain; barley with superior malting quality; and small ruminants that have been bred with specific traits to help farmers cope with climate change.

Additionally, we played an important role in the surveillance, identification, and characterization of wheat stripe disease. We also enhanced seed delivery

systems—through increased private-sector participation and institutional and policy reforms—to improve farmer access to improved crop varieties.

## Improving breeding efficiency in spring bread wheat

Association mapping identifies marker–trait associations, facilitates the use of diverse sets of germplasm (landraces, cultivars, elite breeding lines), and exploits high marker coverage and higher resolutions of new genotyping technologies. All this can be done without the time and efforts needed to develop biparental mapping populations.

An ICARDA study last year [determined the genetic variability of spring bread wheat genotypes](#) for yield and other agronomic traits under heat-stressed environments in Sudan and high-yielding environments in Egypt, using SNP markers through association

mapping. A heat-association panel of 197 spring wheat genotypes was evaluated for yield and agronomic traits. Some 111 marker–trait associations were detected.

The top 20 high-yielding and heat-tolerant genotypes identified in the study have now been distributed to the national research systems of Central and West Asia, North Africa, and sub-Saharan Africa for potential direct release and/or use as parents after local adaptation trials.

## Evaluating pastoral plant species in saline conditions

As the vegetation and biomass production of rangeland ecosystems decreases at an alarming rate, irrigating pastoral salt-tolerant plants on salt-affected soils is considered to be one of the most valuable tools to increase production.

Research by ICARDA last year [studied the ability of four plant species](#)—*Atriplex halimus*, *A. mollis*, *Lotus creticus*, and *Cenchrus ciliaris*—to grow in both low-salinity and high-salinity plots, analyzing canopy cover, dry biomass, and chemical content (ash, nitrogen, and polyphenol). *A. halimus* performed the best in both plots: Its canopy cover was significantly larger than the other plant species.

An examination of alternative attributes, however, also suggested the suitability of other crops and their potential role as part of a targeted strategy to rehabilitate saline soils. For instance, *A. mollis* retained the highest dry matter in both low- and high-salinity plots, and *L. creticus* and *A. halimus* showed the highest total nitrogen content in low-salinity plots.

## Tailoring modern genomic approaches to small ruminant breeding

A review of evidence on [genomic selection and other molecular-based methods in the improvement of small ruminants](#) was also undertaken by ICARDA scientists, evaluating their potential and feasibility for smallholder

production systems in developing countries. Although molecular information has enhanced breeding accuracy and helped to identify QTLs for economically important traits, the basic building blocks to support conventional small ruminant breeding programs are absent in most developing countries.

The review, however, suggests that the unique genotypes of goat and sheep breeds in developing countries, and especially in Africa, provide a good opportunity for understanding genetic diversity, structure, and adaptation. The review also found that next-generation molecular tools were already prompting investigations into genome-wide signatures of selection for adaptive and reproduction traits in several developing countries.

The available evidence led the research team to conclude that genomic selection cannot be a 'one size fits all' strategy, and will depend on the type of production system. Classic genomic selection is feasible, the study contends, in breeds with some degree of conventional genetic improvement already in place. It suggests that community-based breeding programs, pioneered by ICARDA in Ethiopia, can offer an effective framework and testing infrastructure to guide implementation of genomic selection in small ruminants that are adapted to their production environments.



# Toward climate-resilient, integrated crop–livestock farming systems



Crop–livestock production systems are the nexus of smallholder farming in marginal areas; they are critical for natural resource and rangeland management, food production, and the value chains that sustain rural communities.

ICARDA’s crop–livestock research program aims to better understand these interactions, specifically in the context of managing and mitigating risks caused by climate change and making innovative use of these production systems for local job creation.

Among the solutions researched and validated last year were improved agronomic practices to reduce yield gaps in rainfed systems, including the wider promotion of conservation agriculture. Smallholder farmers also worked with ICARDA scientists to improve optimal approaches for livestock feeding, community-based livestock breeding, and their integration into local food production systems.

## Dual-purpose crops offer climate-smart strategy for livestock and crop production

Stable access to forage crops is the lifeblood of a robust crop–livestock food production system. This is especially true in dryland farming, where the risk of forage deficit is severe and made more uncertain by changing climate patterns. A dual-purpose cropping strategy with cereal crops offers an innovative solution: Where livestock is allowed to graze on grain crops at their vegetative stage and the plants then continue growing to produce grain.

This practice holds promise and is applied in many dryland locations. But there is currently little information on which cereal species and management practices are optimal for providing forage and grain production. To deepen evidence on this question, the ICARDA crop–livestock research team [assessed the](#)

[potential of dual-purpose cropping](#) in dry highland environments in Turkey's Central Anatolian plateau. The research examined the effect of spring defoliation of barley, triticale and wheat varieties at the tillering and stem-elongation stages. It also assessed the effect of a no-cut grain-based system under low- and high-input management on yield and quality of forage, straw, and grain.

The findings suggest there is a compelling case for the dual-purpose management of cereal forage for improved efficiency in crop-livestock farming in low- and high-input systems. These systems are vulnerable to erratic climatic events and frequent droughts that happen in roughly 2 of every 10 years in the region. Barley was shown to be the crop that was most productive and most resilient to defoliation. The advantage of barley over wheat and triticale was only apparent during a better growing season, not a dry year. Triticale was the least productive of the three cereals, but it showed similar recovery after defoliation to the other two.

## Helping chickpea farmers strengthen their resilience to insect damage

Chickpea is Morocco's second-most important grain legume crop, grown on some 72,564 hectares. However, its productivity is hampered by insects, diseases, and weeds that reduce yields and depreciate its quality. A recent survey of insect pests showed that the leaf miner is the country's major pest. To better understand potential solutions that farmers can apply to [reduce this risk and improve their yields](#), ICARDA researchers assessed prevention strategies using insecticides and environmentally friendly integrated pest management approaches. The study looked at the effect of combining early or late cropping dates, four improved disease-resistant chickpea varieties, and the responsible use of insecticides.

Farmers typically plant chickpea in the spring in rainfed areas, on deep soils with a high capacity for water retention. The team assessed yield losses caused by the leaf miner on four improved kabuli chickpea varieties, comparing winter and spring planting dates and the use of insecticide treatment. Study results indicated that the

time of sowing strongly affected grain yield, with winter planting maximizing chickpea yield: Grain yield losses averaged 20 percent for winter planting and 42 percent for spring planting.

Leaf-miner infestation was logged at 25 percent for untreated winter planting, 43 percent for untreated spring planting, and 3 percent for treated plots. The percentage infestation by leaf miner was therefore significantly lower in winter-sown than spring-sown chickpea. The insecticide deltamethrin was an effective control to reduce infestation for both planting times.

## Spineless cactus: A highly palatable and productive fodder for livestock

On the arid and semiarid lands of South Asia, and worldwide, livestock production is an integral part of rural livelihoods and local income. For rural communities in these areas, livestock production is limited by several factors, and difficult access to animal feed and nutrition are among the most significant. Smallholder farmers living in these harsh environments have limited resources to improve their supply of animal feed.

To ensure resilience to climate shocks for local food and nutrition security, new options for livestock feed are needed. This means identifying well-adapted and highly



palatable and productive fodder that thrives on marginal lands. Spineless cactus, also called cactus pear, is being adopted by farmers in a number of dryland regions, but many farmers remain skeptical or uninformed about the benefits that this alternative fodder can bring. To [identify challenges and opportunities for more widespread adoption](#), the ICARDA range and forage research team studied social and agroecological factors related to the plant. Their studies found a general acceptance of the spineless cactus in the communities surveyed in India and Pakistan. A considerable number of farmers polled said that spineless cactus can provide a source of livestock feed and contribute to reducing rangeland degradation.

However, the research team also reported that more effort is needed to increase farmers' awareness of the socioeconomic and environmental value of this plant. More effort on spreading knowhow was highlighted. A large number of farmers mentioned they do not have the technical information or the financial means to cultivate spineless cactus. This suggests a need to promote the added-value that it provides to decision makers and



investors. The unique characteristics of spineless cactus, if they are more widely appreciated, can be a real game changer for communities living on semiarid marginal lands in South Asia. The plant can grow dependably in areas with low and erratic rainfall, low-nutrient soils, and high temperatures—where typical livestock forage performs badly, season after season.

## Promoting a better understanding of the benefits of shared rangeland management

Rangelands provide a number of valuable ecosystem goods and services to the population of Baluchistan, Pakistan: Food, forage, medicine, and wood. But poorly managed livestock grazing practices in recent years have negatively affected this ecosystem, damaging vegetation biomass and plant species diversity.

ICARDA rangeland scientists assessed the current situation in the region to [identify options for improving rangeland management and reversing current trends of rangeland degradation](#). The study concludes that it is possible to bring these lands back to their original condition, but a serious awareness effort is needed. Local herders are a key stakeholder group to be targeted. They need to be convinced of the importance of this fragile ecosystem and how they can contribute to its regeneration.

The study found that initially, grazing pressure needs to be significantly reduced. At a later stage, moderate grazing using low stocking rates can be applied to maintain rangeland productivity. Grazing management needs to consider the physiological stage of vegetation, so as to avoid early grazing and overgrazing. Future grazing schemes also need to fully involve local communities, with a view to promoting a mutual understanding of the character and benefits of a sustainable rangeland-based livestock production system. Finally, the research team suggested action points for the government of Baluchistan, which can support local herders and help them to withstand the region's harsh environment of swings in rainfall variability and the consequent fluctuations in livestock productivity caused by extreme droughts.

## Sustainable value chains, supportive policies, and viable off-farm activities



Although agriculture has the potential to generate income and provide financial stability for poor households, this potential is often not realized because food production systems are not fully developed, and targeted investments—in new technologies, infrastructure, and markets—are low. ICARDA supports countries in the dry areas to reverse this situation, and in 2018 worked with a range of partners to build resilient and vibrant farming systems that deliver for rural communities.

Our researchers assessed and evaluated value chains for major dryland crops and commodities such as durum wheat, barley, legumes, and small ruminants; developed effective monitoring, evaluation, and learning systems for investment programs; and supported the creation of decent and attractive employment opportunities, with a specific focus on women and youth.

### Enhancing the market responsiveness of goat producers

A study in Ethiopia identified the factors that determine the market price of goats, [offering valuable information to help farmers become more market responsive](#), develop effective marketing strategies, and take advantage of seasonal and spatial price changes. Although goats are a valuable commodity for many households, farmers and pastoralists often buy or sell at inopportune times, limiting their income potential.

Researchers gathered data from 357 farm households, and the records of 2,103 goat transactions were also collected from 3 major goat markets in the lowlands of Ethiopia. Hedonic price models adjusted for heteroscedasticity were used to analyze the price data—an

important analytical framework to help identify the factors that determine price formulation and variability. The model revealed that attributes associated with higher prices included age, sex, live weight, body condition, and the presence of horns. The type of buyer, the market outlet targeted, and the time of selling, particularly festive periods, were also found to be important.

With this information, researchers were able to identify several interventions with the potential to enhance the market responsiveness of farmers: Systematic community-based selection schemes targeting traits demanded by the market; improved linkages to markets; easy access to market information; and creating incentive mechanisms and a conducive environment that enhanced the farmers' ability to take advantage of seasonal and spatial price changes. In addition, given the production constraints that smallholders face, the study recommended that kidding periods be planned using simple synchronization methods, and that farmers adopt alternative feed resources to overcome shortages and enhance feeding efficiency.

## Transforming Ethiopia's barley sector

Barley is a major crop in Ethiopia, where it is grown by approximately 4.1 million smallholder farmers on close to 1 million hectares. Yet, despite a favorable biophysical



environment, conventional varieties tend to be low yielding and susceptible to pests and diseases. The country's growing brewery industry offers an excellent opportunity to improve the production and productivity of malt barley. In addition to improving the livelihoods of farmers, improved production would also reduce the growing demand for costly imports: Barley imports grew from 5,509 tons in 2002 to 46,437 tons in 2016, which represents an increase of US\$2.5 million to US\$50 million over this same period.

In order to reverse this situation, ICARDA and its national partners have initiated a new collaboration to transform Ethiopia's barley sector, shifting it from subsistence production to commercialization. In addition to higher-yielding, resilient barley varieties, the initiative involves the development of alternative seed delivery systems with seed producer cooperatives because formal seed supply through the public or private sector is limited and unable to satisfy demand. Partnerships are also critical: Breweries and malting companies provide financial support for NARS to develop the improved varieties, seed suppliers produce quality seed, and the Bureau of Agriculture provides technical support for farmers. Finally, the Ethiopian government provides an enabling environment through various incentives, including an assured market for malt barley producers by linking them with the malters and breweries.

Some 400,000 hectares and close to 1.8 million smallholder farmers accessed improved malt barley varieties in 2018. The initiative also supported entrepreneurial activities: 24 seed producer cooperatives, 4 multi-purpose primary cooperatives, and 5 unions with a combined membership of over 3,700 members, 12 percent of them female, were engaged in the development of local seed businesses. As the initiative develops, ICARDA's barley improvement researchers see the potential for a lucrative export-led business model in the years ahead.

# Supporting the sustainable use and management of scarce water and land resources



Without adequate water, dryland economies will grind to a halt. Nowhere is water scarcity a more direct threat to the lives of millions of people. The situation is well known, as are many of the solutions:

- deficit and supplemental irrigation;
- strategies for water harvesting and storage;
- rangeland regeneration and replanting of indigenous forage crops, shrubs and trees; or
- identifying micro-catchments in remote communities to help them to capture as much water as possible.

Research by ICARDA's Water, Land & Ecosystems Research Program last year assessed these and other interventions. Policy makers and research colleagues agreed that adopting these solutions and other approaches makes good sense. But none of this becomes reality without the buy-in and assessment of farmers and communities. They need to be convinced

to change their current practices and adopt new ones. This is why an important component of this research program is focused on better understanding the factors that influence people's perceptions of issues such as technology adoption.

## Rangeland rehabilitation through micro water harvesting

The Badia, rangelands with low rainfall and scarce water resources, sustain the livelihoods of millions of settled and nomadic communities across the Middle East and North Africa. These fragile areas are under increasing strain as a result of rapid population growth, political conflicts, overgrazing, mechanization and improper management, and increasingly unpredictable climate patterns. The severe degradation of these natural

areas threatens critical ecosystem services and the communities that make their livelihoods there.

The native vegetation—both in terms of biomass and biodiversity—is being severely degraded. In addition to reducing the ability of indigenous plants to thrive, this shift has enabled the invasion of unpalatable and partially toxic plants, which has progressively altered the livestock feed system across the region. In the Jordanian Badia, ICARDA's long-term research is testing approaches to regenerating these natural areas using innovative monitoring, modeling, and technical interventions. The lessons learnt here can help decision makers and planners bring rangelands across the region back to life.

The research team is testing a number of restoration approaches, including the creation of micro rainwater basins using contour plowing, and combining micro-catchment water harvesting with the planting of native shrub seedlings in the basins. These approaches are becoming widely used, but the implications for the drylands' soil water dynamics are complex. So the research team is working to better understand these interactions. The research focuses on the relation between local rainfall characteristics, soil moisture dynamics, and planted shrub seedlings (such as *A. halimus*) on the hill-slope scale, and how these actions are influenced by the presence or absence of contour-plowed micro-catchment rainwater harvesting basins.



The land-rehabilitation techniques evaluated include:

- laser-guided tractor-plow calibration to facilitate rapid and affordable creation of contours;
- deep ripping of degraded soil to encourage deep water infiltration during rains;
- the creation of water-harvesting pits to collect, in addition to water, sediments and seeds that boost the creation of vegetation patches; and
- mechanized micro-catchment water harvesting.

The studies also assessed water modeling approaches, such as the Rangeland Hydrology and Erosion Model, the Soil & Water Assessment Tool, and the Hydrus model, to help planners explore the implication of water and soil fluxes on different rangeland states.

The research concluded that the enhancement of soil moisture provided by micro-catchment water harvesting supported the development of out-planted shrubs, increasing their survival probability during their first years of growth (when they are most vulnerable), and provided favorable conditions for the habitat to flourish, thereby enhancing biodiversity. The research team is now pursuing follow-up monitoring to assess the potential for long-term rangeland rehabilitation and transition toward a healthy rangeland status for the beneficial and sustainable use of Badia ecosystem services.

## Dynamic program modeling to track weather events

Crop models commonly use annual soil, weather, and growth data to analyze experiments and support decisions for the coming cropping season. The reality for farmers, however, is that they face many weather events within a cropping season that affect their food production. These are not taken into account in the classic annual modeling and planning view. Most applications in the literature base their analysis on annual time steps with fixed strategies within the year, not taking into account the need to respond to events that occur during the year.

In an effort to provide more precise modeling frameworks that capture intra-seasonal decisions and

responses to weather conditions as they happen, the ICARDA bioeconomic modeling team is studying [how dynamic programming for planning and modeling can improve long-term crop management](#). Research in 2018 found that agricultural producers' conditional responses during the growing season are important adaptations to weather and other randomly occurring events. It indicated that a failure to recognize these responses overstates the risks that producers face and understates their ability to respond to adverse circumstances and develop alternative solutions.

The research suggested an alternative approach that captures the strategic responses to random weather variables as they happen within a cropping season, reflecting farmers' ability to adapt to weather events. The approach was tested on a typical cereal farm in Karak, Jordan. The results showed that including conditional within-year responses to weather reduces the frequency of fallowing by 23 percent and increases expected income by 9 percent. The findings highlight the importance of modeling conditional responses to random variable outcomes during the year. These responses lead to differences in profit, average soil-attribute levels, and planting rotations relative to models without conditional responses.

## Enhancing the adoption of soil- and water-conservation techniques

Soil- and water-conservation technologies are an important strategy for countries to ensure the stability of agricultural production systems on rangelands and semiarid areas. The current situation faced by many dryland countries—declining soil health, increasing erosion, and moisture stress—has implications for agricultural livelihoods, national food security, and the well-being of rural communities and the national economy. Last year ICARDA researchers focused on the use of soil- and water-conservation technologies in Tunisia, a leader in applying these approaches but curiously a country where uptake by farmers has been lower than planned. The research [identified and analyzed factors that affect adoption](#) in Sidi Bouzid governorate—a region representative of resource-poor environments across the country.



The research team found that among farmers surveyed, the probability of adopting crop-water conservation innovations depended on a combination of factors, such as socioeconomic conditions, livestock holdings, institutional issues, and other biophysical conditions. Adoption was positively influenced by farmers' experience and their membership of community-based organizations, but negatively influenced by attendance at training meetings or if farmers had livestock holdings. Researchers suggest that these counterintuitive findings indicate that conventional processes for knowledge transfer and dissemination are in need of reform. Other counterintuitive findings were the fact that the farmers' age, education level, household size, contact with extension systems, land tenure, family labor force, access to credit, and land fragmentation were not statistically significant in influencing the adoption of soil and water conservation practices.

The results suggest that the solution to changing perceptions lies not only in the promotion of more cooperation between farmers who may lack resources to put water conservation technologies in place, but also in encouraging a learning loop, where experience is continually transferred from farmers with the knowhow to those who are not informed. Furthermore, a 'one size fits all' strategy is unlikely to be successful, and planners need to consider interhousehold and interplot variations as well as different biophysical factors. Finally, the research argues, there is no escaping the need for finance—working capital, credit lines, and crop and livestock insurance will be required to encourage adoption.

# Scaling up proven technological packages



Taking technological innovations to scale can only be achieved through cooperation and strategic partnerships with key stakeholders and actors. In 2018 ICARDA continued to grow its partnership base, working strategically with advanced research institutions, NARS in partner countries, development agencies, nongovernmental organizations (NGOs), and the private sector.

These partnerships delivered decision support systems, comprehensive assessments to inform the development of viable value chains, effective outreach activities, and capacity development opportunities for researchers, farmers, and entrepreneurs. ICARDA also supported the development of public-private partnerships, prioritized innovative and cost-effective scaling approaches using social media and information and communication technologies, and engaged more effectively with decision makers through dialogue, advocacy, and regional forums.

Finally, we continued to refine innovation platforms, enhancing their ability to act as a conduit for getting research outputs into farmer fields; developed new and innovative business models to ensure the delivery of superior genetic resources to farmers; and strengthened seed production and seed delivery systems.

## Modeling land-use decisions in multi-crop production systems

In Ethiopia, researchers investigated farmer land-use decisions in production systems with multiple crops—an attempt to [identify the factors that influence technology adoption and help improve extension policies and strategies](#). Applying a fractional response model to a representative sample of 1,469 households dependent on barley and potato production, the study demonstrated that farmer decision-making was infinitely more complex

than previous studies had suggested, involving multiple trade-offs and complementarities across several crops and varieties.

In a further departure from previous research, the study found that cultivation history, the relative importance of each crop in a farmer's portfolio, and rotation requirements were more important determinants of land-use decisions than traditional variables such as soil fertility, sex, age, and education. Interestingly, the frequency of extension visits did not appear to affect land allocation; given the high density of extension personnel in Ethiopia, this indicates the poor performance of the country's extension service delivery system.

The findings suggest it is unwise to view a crop variety in isolation from others, and that agricultural technology adoption predictions and technology targeting efforts need to consider all major crops in a farmer's portfolio. Finally, the poor performance of Ethiopia's extension system requires immediate reform, researchers argue, warning that unless there is an overhaul, agricultural development in the country will remain a far-off dream.

## Promoting wheat production in sub-Saharan Africa

Another study, which [reviewed the performance of wheat production across sub-Saharan Africa](#), provided valuable insights to boost the productivity of this strategic crop. Although the demand for wheat is increasing, driven by rapidly growing populations and shifts in food consumption habits, production is hampered by a range of constraints, including drought, heat, pests and disease, and low investments, which weaken extension systems and fail to improve basic infrastructure. This results in dependence on costly wheat imports, exposing ordinary Africans to the vagaries of global commodity markets.

Boosting production in sub-Saharan Africa, the study contends, is dependent on the development and adoption of climate-smart technologies, encompassing resilient varieties of wheat, drip irrigation, modernized water harvesting, and sustainable agronomic practices. The increased threat of pests and disease as a result

of climate change, especially in the highlands of eastern Africa, also requires a combination of resistant wheat varieties with integrated pest management and the application of chemical, physical, and biological tools in a way that minimizes economic, health, and environmental risks.

Getting improved varieties into the hands of farmers will be dependent on more efficient and effective seed delivery systems, but this needs to be supported by effective policy and regulatory frameworks, adequate institutional frameworks, and capacity strengthening. Additional measures should target enhanced government subsidies for agricultural inputs such as improved seed, irrigation water, and chemicals. Targets should also include the strengthening of research networks and public-private partnerships to develop and promote improved wheat varieties and associated technologies and practices.



## Scaling up the production of improved cash crops

When scaling up improved crop varieties and associated technologies, experience tells us that the demonstration and popularization of innovations needs to be combined with seed multiplication to enhance farmer access, widen adoption, and generate impact at scale. In Ethiopia, ICARDA has been adopting this approach to enhance malt barley, faba bean, and chickpea production—all important cash crops for Ethiopia's smallholder farmers. With USAID support, ICARDA has boosted the dissemination of these strategic crops (malt barley and faba bean in 76 districts and chickpea in 52 districts) across 4 major crop production regions:



Amhara, Oromia, the Southern Nations, Nationalities, and People's Region, and Tigray.

On-farm demonstrations were conducted by NARS on the fields of 573 farmers, including 46 women farmers. District-level field days, organized by NARS and the Office of Agriculture, reached an additional 31,563 participants, of whom 6,399 were women. Attendees included farmers (80 percent of the total), other key stakeholders, and policy makers from partner institutions. In addition to demonstrations, farmer-based seed production and marketing was initiated through partnerships with 36 cooperatives and their 15,000 members. To ensure wide dissemination, national agricultural research partners were engaged in early seed production and supply to enhance access to good-quality seed for further multiplication. In all, 353.98 tons of malt barley seed, 177.9 tons of faba bean seed, and 377.51 tons of chickpea seed were produced on an estimated 1,112.97 hectares of research farms and farmer fields.

This basic seed was then further multiplied and converted to certified or quality-declared seed. Some 5,653.3 tons of malt barley, 2,038.8 tons of faba bean, and 2,914.5 tons of chickpea were produced, enough to plant an estimated 49,159 hectares of malt barley, 10,194 hectares of faba bean, and 23,316 hectares of chickpea, benefiting some 415,265 farmers. To enhance the productivity of the crops, the initiative also worked with private-sector companies to distribute biofertilizers, and strengthened the capacity of farmers and extension agents by providing practical hands-on training. In total some 24,412 farmers, development agents and junior technical staff—including 3,834 women—benefited from the trainings.

## Challenging gender inequities



Although women play a critical role in dryland agriculture, they face significant financial, cultural, and legal constraints that limit their access to new knowledge, innovations, resources, finance, and markets. Addressing gender gaps is a critical priority, and our research efforts in 2018 explored the transformative strategies needed to enhance women's food production, strengthen their food security, increase their income-generating potential, and improve working conditions in the agricultural wage sector, which is largely dependent on their labor.

ICARDA studies also identified promising formal and informal institutional arrangements that strengthen women's voices and power in dry-area communities, empowering them to make positive changes in their lives and communities. We supported women to engage in more lucrative economic activities—through agricultural diversification, intensification, and value addition.

### Understanding gendered patterns of asset ownership and control

In recognition of the extremely small number of women who own land in the Middle East and North Africa, research in Egypt last year [explored the barriers preventing women from owning property and other assets](#). While the study found that land ownership was higher than previously thought, it was still limited and significantly lower than for men, posing worrying implications for women's security and well-being, particularly for those women who experience divorce, separation, abandonment, or the death of their spouse.

Researchers attributed the low levels of land ownership and asset control to gender norms prevalent in rural communities. They found that women and men were socialized to believe that land, agricultural equipment,

and vehicles were male assets—and men tended to own and control the sales and profits of these assets exclusively. Women who owned land through state-led land distribution schemes or inheritance tended to hand control to their husbands, and land mostly went to sons and not daughters upon inheritance, despite the fact that women viewed housing and land as the most valuable assets in their communities. Women controlled non-commercial activities that were supportive of—but not independent of—their husband's breadwinning activities.

Addressing biases in norms and strengthening women's security through their access to landed property, in particular, will only be partially accomplished through legal measures and economic interventions, regardless of how well-intentioned and progressive they may be. Consciousness-raising initiatives will be crucial, the research concluded, as will strengthening and validating women's roles in agriculture, given that they tend to be perceived as helpers rather than farmers.

## Women, irrigation, and challenging social norms

Another study in Egypt revealed that although women play a far more active role in irrigation than was previously thought, [their contributions continue to be undervalued](#), limiting their access to new technologies and restricting their participation in water governance. The study identified several factors—including land ownership, educational attainment, and institutional support—that could enhance women's visibility and increase the benefits they receive from irrigation.

A survey and in-depth interviews provided an overview of the role women play in irrigation, their adoption of irrigation technologies and techniques, and the constraints and opportunities they face in Egypt's Old and New Lands. The former are more traditional areas which have been cultivated for centuries, and the latter are desert areas that were reclaimed and cultivated after the construction of the Aswan Dam. The two differ in terms of gender norms, irrigation technologies, and land ownership dynamics.

Analysis revealed that women participated in irrigation activities in 78 percent of the households surveyed, and while their contributions were undervalued and they faced discrimination in both locations, their experiences varied according to geography. Women in the New Lands were provided with land ownership rights (20 percent of distributed land was given to women graduates of technical schools and universities); they tended to be better educated; they faced fewer restrictions in their day-to-day lives; and they were also perceived more favorably. However, while involvement in water governance in the New Lands was also more common—mainly due to institutional support and pressure from international development organizations such as the World Food Programme—it was still limited.

Given that participation in irrigation, and the benefits that accrue from this participation, are influenced by prevailing social, economic, and political norms in rural communities, researchers found that in addition to land ownership, educational attainment, and institutional support, it was critical to address gender inequalities at multiple levels. In particular, introducing policy reforms (such as quotas in WUAs and other governance bodies); facilitating organizational support to substantiate the role of WUAs; and developing awareness-raising campaigns to promote gender equality and challenge societal norms.

## Women, work, and wage equity

Research in Morocco [documented the wages and working conditions of landless female and male agricultural laborers](#) in the country's Saiss region. The study revealed that higher-paid and equipment-intensive tasks were predominantly assigned to men, whereas women often performed lower-paid and time-intensive tasks. In addition they were systematically paid less than men, even when they performed the same tasks. The study also looked at how age and gender interact to shape the experiences of young workers. Findings reveal that young men were particularly vulnerable to entering the workforce at too young an age and young women were more likely to experience sexual harassment.



Enforcing existing legislation in Morocco to ensure equal pay was an essential first step identified by researchers. Policy makers were encouraged to not only create more agricultural employment through export- and commercially led agriculture, but also to pay close attention to issues of equity in wages and working conditions. These are stipulated in the decent work guidelines of the International Labour Organization, to which Morocco is a signatory. Enforcing legislation that already exists in Morocco to ensure equal pay, zero tolerance for sexual harassment, and better working conditions for women were also encouraged, as was strengthening social protection, given that employment is often precarious in rural areas. This precariousness, the study argues, also necessitated skills training for wage earners displaced by mechanization.

Beyond legislation, as in Egypt, efforts are also needed to challenge pervasive gender stereotypes, which are often the major causes of discrimination faced by women. Training women for higher-paying jobs is key to breaking these stereotypes. Finally, the findings suggest that a deeper structural revaluation of the importance and necessity of the agricultural sector in Morocco, the Arab States, and around the world is required so that agricultural labor is not perceived as an occupation of last resort.

# Strengthening capacities across the dry areas



Capacity development is core to ICARDA's mission and an essential element in the delivery of quality research and sustainable-development impact. We prioritize the dissemination of new knowledge and expertise related to a wide range of challenges and issues, including crop improvement, water and land management, integrated crop–livestock–rangeland management, and climate-change adaptation.

Last year ICARDA continued to build its extensive network of partners (including universities, advanced research institutions, and farmers), thereby strengthening an effective and efficient ecosystem of science and research with a focus on building capacities at the individual, institutional, and community levels. Our approach to capacity development also addressed broader questions of empowerment, leadership, institutional change, and greater public–private collaboration, partly through the fostering of South–South partnerships.

We continued to adopt a mix of training approaches, including group courses and individual short- and long-term courses. We also assisted in the upgrading of the skills of scientists, research associates, and assistants in our partner countries. In total, we provided capacity-strengthening opportunities to over 650 individuals in 2018, including 191 women, some 29 percent of the total number of beneficiaries. Among interns and individual

degree and non-degree trainees, the proportion of women was 54 percent. In addition to increasing the pool of trained personnel, these activities helped to build strong bonds to facilitate continuous research collaboration and the sharing of knowledge and experience.

## Support to rehabilitate Syria's agricultural sector

In an effort to support the rebuilding of Syria's agricultural sector, devastated by years of conflict, ICARDA, with support from the UNDP and LARI, held two workshops in 2018 for Syrian technical agricultural staff. The workshops, held in Lebanon and Syria, provided hands-on practical sessions on natural resource management, introducing key principles associated with sustainable agriculture such as integrated land management, climate-smart agriculture, and climate-change adaptation.

Over 50 participants, including staff from the Agricultural Engineers Syndicate and UNDP Syria, received instruction on a broad range of subjects critical to reversing the country's low productivity and supporting agricultural livelihoods, including soil reclamation, water management, seed preservation and multiplication, and crop–livestock integration. Trainees were also introduced to quick

survey techniques to help identify additional needs in Syria's recovery phase and options for sustainable development.

## Raising the capacity of early-career researchers

Investments in early-career researchers will deliver impacts for decades to come, ensuring that countries and institutions have the right combination of skills and knowledge to meet future challenges. Given that many of the best-qualified agricultural researchers in the dry areas are nearing retirement, early-career researchers will provide a critical level of support when older generations are no longer active.

Last year ICARDA provided supervision and research and training opportunities for some 49 MSc and PhD researchers, who were nominated by their institutions and then selected on a competitive basis. In a two-way relationship, the students benefited from the support of the Center's scientists and the Center benefited from the knowledge and expertise of students who contributed new ideas and perspectives to on-going research efforts. Research themes covered by the early-career program last year included:

- the evaluation of genetic resources and their use in breeding and prebreeding;
- the use of genotyping and precision phenotyping to efficiently select elite germplasm;
- assessments of the quality and nutritional attributes of cereals and legumes;
- assessments of biodiversity and the uses of native pollinators;
- improved cropping systems;
- conservation agriculture; and
- data management and modeling.

## Introducing Open Data Kits to improve animal health surveys

OPKs are a practical and cost-effective tool for mobile data collection. These open data platforms

can easily manage a large volume of data and can be adapted wherever mobile networks are present. They are becoming increasingly popular around the world and are now being used extensively by public-health organizations, including the World Health Organization and Centers for Disease Control and Prevention.

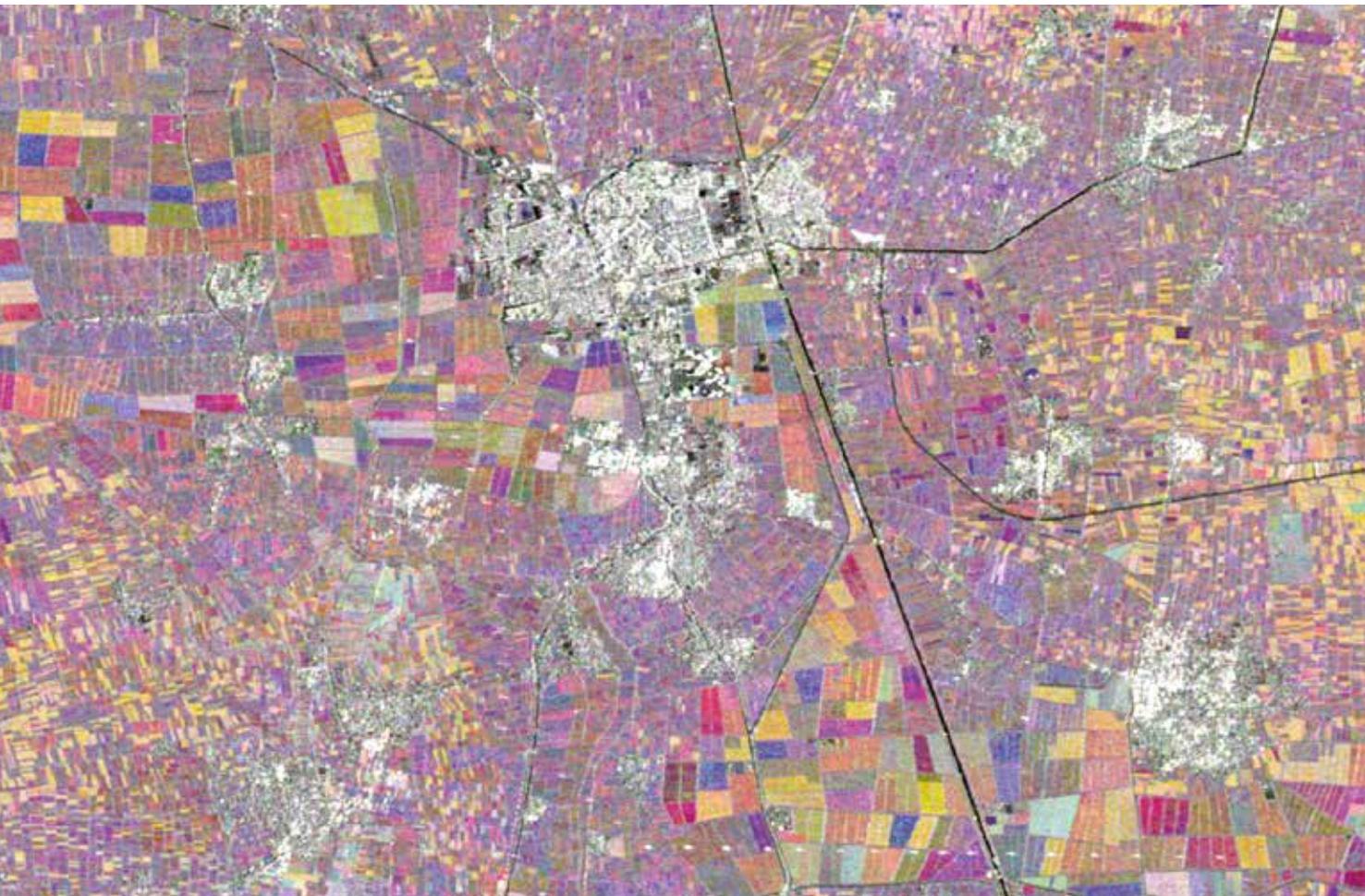
Last year ICARDA provided a course for veterinary epidemiologists and agronomic engineers working in animal health to equip them with the knowledge and expertise to create and use questionnaires, and collect animal and herd data. The participants, from institutions in Algeria and Tunisia, were given a full range of practical instructions, including the adaptation of OPKs for tablets and smartphones, questionnaire design, and data recuperation. Since the course's conclusion, a learning network has been established by the trainees to share knowledge and support continued innovation in the use of OPKs.

## Building capacity on wheat improvement

Some 25 scientists from Central and West Asia, North Africa and sub-Saharan Africa, of which 5 were women, participated in ICARDA's annual training on wheat improvement in March 2018. This annual course, held in Morocco, is an integral part of the Center's strategy to build the capacity of students and scientists involved in wheat farming. The training targeted classical and emerging molecular techniques of wheat breeding and aimed to strengthen collaboration between participating scientists, thus enhancing a global research network that is integral to the development, release, and promotion of improved wheat varieties.

The three-week training was built around both theoretical and practical sessions covering wheat-breeding approaches and strategies, marker-assisted selection, doubled haploid, and speed-breeding techniques. It also dealt with quality analysis, integrated pest management approaches, genetic resources conservation, and biometrics.

# Harnessing the power of Big Data and analytics



Big Data and analytics are a game changer for research and innovation. They bring us a wealth of tools and expertise, such as artificial intelligence and machine learning, geo-informatics, and the ability to mine data rapidly and precisely. These techniques improve the quality and relevance of all our research at a pace that did not exist even five years ago.

ICARDA's Geoinformatics Unit provides expertise to all research teams, helping to boost their insight and productivity. Their activities in 2018 helped gain a more precise insight into land degradation, used radio frequency to investigate soil for salinity mapping, and provided rapid scans to identify the most suitable locations for specific crops.

## Mapping grassland degradation and desertification in Central Asia

The grasslands and rangelands of Central Asia have been degrading, with some movement toward desertification, for three decades since the fall of the Soviet Union. Cropping patterns have changed or ceased in many locations, and land-use changes such as land abandonment, increased human activity, and the unregulated use of livestock have changed their character. Changes in climate patterns in recent years have further complicated the picture. If degradation progresses past a certain point to desertification, the process will be irreversible, with no option to return these lands to productive use.

ICARDA's land and water research team worked with Big Data scientists [to deepen knowledge of grassland degradation and desertification](#) against a background of global climate change. Knowing the details of the desertification process is essential for planning and taking action to prevent increased desertification in Central Asia. The study used satellite data analysis to build a comprehensive picture of grassland degradation and desertification in Central Asia from 2000 to 2014, improving understanding of the drivers of grassland degradation and helping to inform the actions needed to stop or reverse it.

Three key learning points emerged from the research: (1) grassland degradation increased from 2000 to 2014, and desertification is gradually expanding northward; (2) sensitive and fragile regions have been clearly identified (one is in southern Kazakhstan, with more sparsely vegetated land, and the other is in the persistent grassland of northern Kazakhstan); and (3) grassland degradation and desertification were largely linked with persistent droughts. Identifying these hotspots helps decision makers to effectively mitigate desertification in the region. These data can guide grazing activities, water extraction, and other types of human activity. The grassland degradation strategy based on the classification of desertification zones that was used in this research can be used to detect grassland degradation and desertification in other dryland regions.

## Predicting soil salinity and mapping in Iraq

Soil salinity in agricultural land causes declines in vast areas of crop production in the Middle East and other dryland regions, with countries such as Iraq being severely affected. In some areas of Mesopotamia, for example, production has declined by 30–60 percent in comparison with land not affected by salinity. To combat this crisis, agricultural planners and policy makers need a clearer picture of the scope and severity of soil salinity in space and time, to inform effective decisions that mitigate food security issues in salt-affected countries.

Mapping the spatial distribution of salinity has traditionally been done by satellite remote sensing.

There have been some attempts at radar-based measurements, but these were not extensive. ICARDA researchers therefore [tested radar-based methods for salinity mapping and prediction](#) using machine learning algorithms, to measure its potential efficacy and precision against traditional remote sensing. The research team reported that the detection of soil salinity by microwave radar data had the advantage of measuring salinity independent of weather conditions. It is also possible, they argue, to use microwave signals to remotely penetrate through the surface, reaching subsoil to a depth of 1.50 m or more, depending on the frequency of the waves and soil moisture.

The study applied machine learning algorithms to soil salinity prediction and mapping by combining an optical–radar dataset and field measurements. The results showed this approach was practical as it used biophysical indicators from both optical and radar data for mapping. Removing the impact of vegetation on the radar substantially increased the predictability of radar data.

## Finding a suitable niche for cultivating spineless cactus in the dryland agroecosystems of India

Spineless cactus is a highly versatile crop that has the potential to boost livelihoods for dryland communities in South Asia. As climate change threatens agroecosystems, especially in the dry areas, bringing abrupt precipitation changes and frequent drought, spineless cactus is an ideal crop. It is tolerant to high temperatures and low soil-moisture levels, and is highly resilient. Policy makers are now asking where the best growing locations in India are.

To bring more precision to this question, the ICARDA Big Data team partnered with crop scientists and agronomists to develop a spatial suitability map to guide decision makers to the best locations. The team used an analytical hierarchical process to match nine essential growth factors to locations across the subcontinent. The study shows that 32 percent of the country is in the 'highly to moderately suitable' category for developing the crop; some 46



percent is in the 'marginally suitable' category; and 22 percent is in the 'low to very low suitability' category.

The 'highly to moderately suitable' category is mostly located in the western and east-central regions of India. Study results also suggest that the drier croplands, barren lands, and wastelands of Chhattisgarh, Odisha, and Rajasthan, are 'highly to moderately suitable' for cactus cultivation. Dryland agricultural farming systems cover a significant extent of these areas, where cultivation is heavily dependent on the certainty of rainfall. Integrating spineless cactus as a crop in dryland farming areas and rangelands can be one of the most useful solutions for fighting changing climate events. It can be a critical factor to build resilient agroecosystems, provide food and fodder, and improve ecosystem services as the environment changes.

## Annual cropland mapping using reference Landsat time series

Maps of the dynamics of croplands are an important tool to aid effective monitoring of agricultural production performance, managing land and water resources, and understanding the environmental impacts of agriculture. This is typically done by analyzing archives of satellite

Earth observations to obtain a picture of the situation over time. Existing maps of annual cropland have a low spatial resolution, and existing high-resolution maps, such as Landsat 30 m, are not provided frequently due to a lack of in-situ reference data, irregular timing of the satellite image time series, the huge amount of data to process, and the need to have a regionally or globally consistent methodology.

To sharpen this focus, the ICARDA Big Data research team [developed a method for time-series mapping](#) and created binary cropland versus non-cropland maps using irregular Landsat time series and the reference time-series based method (RBM). As a test case, the team created and evaluated annual cropland maps at 30 m in agricultural landscapes in Xinjiang, China, and the Aral Sea Basin. The results revealed that in this test RBM identified cropland at accuracies of more than 85 percent. RBM cropland maps were significantly more accurate than two commonly used mapping products.

Dependable spatial information gives decision makers and planners a clear picture of land-use intensity or agricultural-land abandonment. A specific challenge in locations such as Central Asia, where effective monitoring is critical for effective future planning, is that agricultural statistics are outdated, of variable quality, or absent. As a result, the current state of cropping systems in this region is likely to be quite different from what the available data show. Agricultural production has experienced unprecedented expansion and there is widespread degradation of croplands and rangelands. Today, with growing aridity and a growing population, there is a risk of potential conflicts over shared scarce resources. Faced with this situation, policy makers will greatly benefit from mapping tools like the one tested. It is an efficient way of updating their view and knowledge of the actual state of their rangelands and food production systems.

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## IN MEMORIAM

# Dr. Mohamed Badraoui

ICARDA was saddened by the loss of our Board Member, Dr. Mohamed Badraoui, who passed away on April 5, 2019. Dr. Badraoui was an invaluable member of ICARDA's Board, and brought with him a deep understanding of agricultural science and sustainable development. He served as the Board's Vice Chair for many years, relinquishing that role at the end of 2018. When unrest in Syria made it necessary for ICARDA to relocate in 2012, Dr. Badraoui played an essential role in facilitating the support of the Government of Morocco so that ICARDA could continue a large part of its research there.

Dr. Badraoui held a doctorate in agronomic sciences from the Hassan II Institute of Agronomy and Veterinary Sciences (IAV) in Morocco, and received his second doctorate in soil chemistry, mineralogy, and fertility from the University of Minnesota in the USA. From 2008 onwards, Dr. Badraoui served as the Director General of INRA in Morocco under the Ministry of Agriculture and Fisheries, Rural Development, Water and Forests.

Prior to that he was director of combating desertification and nature protection with the High Commission for Water and Forests and the Fight against Desertification in Morocco. He was also professor of soil science and land management at the Hassan II IAV. From 2002 to 2007, he served on the Committee of Science and Technology of the UN Convention to Combat Desertification.

ICARDA will be forever indebted to Dr. Badraoui for his leadership and support.

# FINANCIAL INFORMATION

## Statement of activity (in thousands of US Dollars)

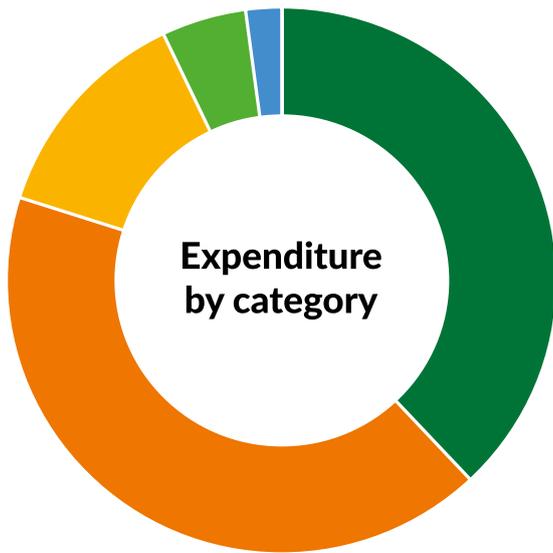
REVENUE	2018	2017
Grants	31,680	35,225
Other revenues and gains	460	258
<b>Total revenue</b>	<b>32,140</b>	<b>35,483</b>
<b>EXPENSES AND LOSSES</b>		
Program-related expenses	31,466	34,993
Management and general expenses	4,406	4,675
Non-operating expenses	1,104	–
Adjustment due to International Financial Reporting Standards (IFRS) adoption	1,057	2,230
Total expenses and losses	38,033	41,898
Indirect costs recovery	(3,279)	(3,366)
<b>Total expenses</b>	<b>34,754</b>	<b>38,532</b>
Net surplus/(deficit)	(2,614)	(3,049)

## Statement of financial position (in thousands of US dollars)

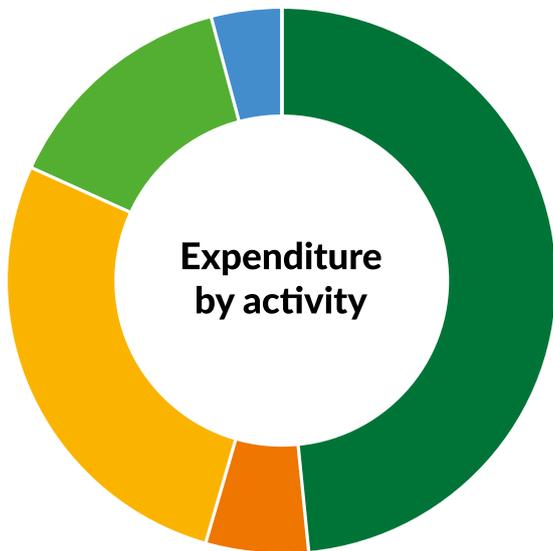
ASSETS	2018	2017
Current assets	19,841	23,644
Property and equipment	2,203	3,355
<b>Total assets</b>	<b>22,044</b>	<b>26,999</b>
<b>LIABILITIES AND ASSETS</b>		
Current liabilities	12,413	15,365
Long-term liabilities	2,864	2,253
Total liabilities	15,277	17,618
Net assets	6,767	9,381
<b>Total liabilities and net assets</b>	<b>22,044</b>	<b>26,999</b>

## Grant revenue by donor (in thousands of US dollars)

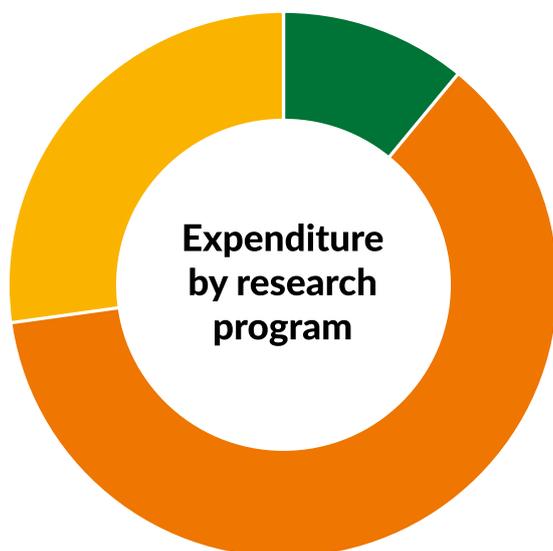
DONORS	
African Development Bank (AfDB)	515
Agricultural Research, Education and Extension Organization (AREEO), Iran	912
Arab Fund for Economic & Social Development (AFESD)	5,059
Australia	756
Australian Centre for International Agricultural Research (ACIAR)	818
Austrian Development Agency (ADA)	187
Bill & Melinda Gates Foundation (BMGF)	538
European Commission (EC)	1,006
Federal Ministry of Agriculture and Rural Development (Nigeria)	162
Food and Agriculture Organization of the United Nations (FAO)	355
General Directorate of Agricultural Research and Policies (GDAR), Turkey	220
Germany	1,466
Global Crop Diversity Trust (GCDDT)	3,003
Gulf Cooperation Council (GCC)	495
India	1,327
Indian Council of Agricultural Research (ICAR)	809
International Center for Tropical Agriculture (CIAT)	236
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	735
International Food Policy Research Institute (IFPRI)	572
International Fund for Agricultural Development (IFAD)	1,670
International Labour Organization (ILO)	153
International Livestock Research Institute (ILRI)	1,808
International Maize and Wheat Improvement Center (CIMMYT)	2,808
Kuwait Fund for Arab Economic Development (KFAED)	243
Ministry of Agriculture and Agrarian Reform (Syria)	345
Ministry of Agriculture, Irrigation and Livestock, Afghanistan	785
OCP Foundation	191
OPEC Fund for International Development (OFID)	308
United Nations Development Programme (UNDP)	199
United States Agency for International Development (USAID)	1,299
United States Department of Agriculture (USDA)	941
World Food Programme (WFP)	150
Miscellaneous (less than 150,000)	1,609
<b>Total</b>	<b>31,680</b>



■ Personnel cost	38%
■ Supplies and services	42%
■ Collaborators—CGIAR Centers	0%
■ Collaborators—partners	13%
■ Travel	5%
■ Depreciation	2%



■ Research programs	49%
■ Research support	6%
■ Resource mobilization and project office	27%
■ Corporate services	14%
■ Management	4%



■ Water, Land & Ecosystems	11%
■ Biodiversity & Crop Improvement	62%
■ Resilient Agricultural Livelihood Systems	27%

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Cornell University  
Curtin University  
Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ)  
Durham University  
European Commission (EC)  
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Federal Ministry of Agriculture and Rural Development, Nigeria  
Food and Agriculture Organization of the United Nations (FAO)  
Global Crop Diversity Trust (GCDDT)  
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