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Enhancing resilience: helping dryland communities to thrive

ICARDA

Science for Better Livelihoods in Dry Areas

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FOREWORD

Enhancing resilience: helping dryland communities to thrive

Joint message from the Director General and the Board Chair

2016 was the hottest year on record – the third consecutive record-breaking year. It was a sign that we have to act fast to enhance the resilience of dryland farmers, who not only have to contend with more extreme temperatures but also face rapidly depleting water resources and the destructive effects of new pests and disease.

Farmers are on the frontline in the fight against climate change. Many are already struggling to produce sufficient food, particularly in the dry areas of the developing world, where shifting weather patterns are generating immense challenges and food import burdens continue to grow, exposing ordinary people to the vagaries of global commodity markets.

Delivering practical solutions that farmers can utilize to raise their productivity is therefore critical: improved climate-resilient crops, sustainable land and water management practices, enhanced livestock productivity, and value-added production are key to effective climate change adaptation. Each forms an integral part of **ICARDA's new Research Strategy (2017–2026)**, which supports the Center's vision of thriving and resilient livelihoods.

In 2016, we continued to deliver solutions despite significant institutional change. We welcomed a new Director General and said farewell to our former Director General, Dr. Mahmoud Solh, who provided strong leadership during his ten-year tenure and successfully guided the Center through an extremely difficult period following our relocation from Aleppo.

We also consolidated the Center's new decentralized research infrastructure. A response to current circumstances, decentralization is enhancing ICARDA's efficiency, improving the delivery of new technologies, and strengthening our response to the global challenges facing the dry areas.

The completion of a new genebank in Lebanon and state-of-the-art field and laboratory facilities in Morocco form part of a new global genebank architecture, providing additional safekeeping and enhanced access to ICARDA's unique globally-important collection of plant genetic resources.

Decentralization is also helping to initiate new partnerships and strengthen existing ones. In 2016, our collaborations with partner countries continued to generate impressive results. One initiative – Enhancing Food Security in Arab Countries – raised wheat yields by an average 23% across ten participating countries. Our Capacity Development Unit provided trainings and workshops in over 50 countries and targeted the next generation of agricultural researchers – providing training opportunities for some 295 scientists under the age of 35.

Additional partnerships brought the construction of a rust research center in Turkey – to strengthen resistance to wheat rust diseases; the release of improved climate-smart crop varieties – including 16 bread wheat varieties, five new barley cultivars, and 13 varieties of food legumes; and the initiation of a new Food Legume Research Platform in India – to support efforts to raise food legume productivity across South Asia and countries worldwide.

Last year, ICARDA also amplified its voice on the world stage, attending strategic events to address

the challenges facing agriculture in the dry areas, and calling for more investments in agricultural research for development. In November, the Center co-organized or led six sessions at COP22 where we demonstrated the impacts of our scientific research on farmers' lives and engaged with high-profile donors and decision makers.

In March, ICARDA also helped organize the 2016 International Conference on Pulses for Health, Nutrition, and Sustainable Agriculture in Drylands. This event brought together some 350 experts from 35 countries to discuss policy frameworks capable of raising pulse production and maximizing the development impacts of these climate-smart resources.

ICARDA's 2016 Annual Report – *Enhancing resilience: helping dryland communities to thrive* – demonstrates the successes and impacts of our innovative science and research for development initiatives, made possible with the continuing support of donors, international partners, and NARS collaborators.

Mr. Aly Abousabaa

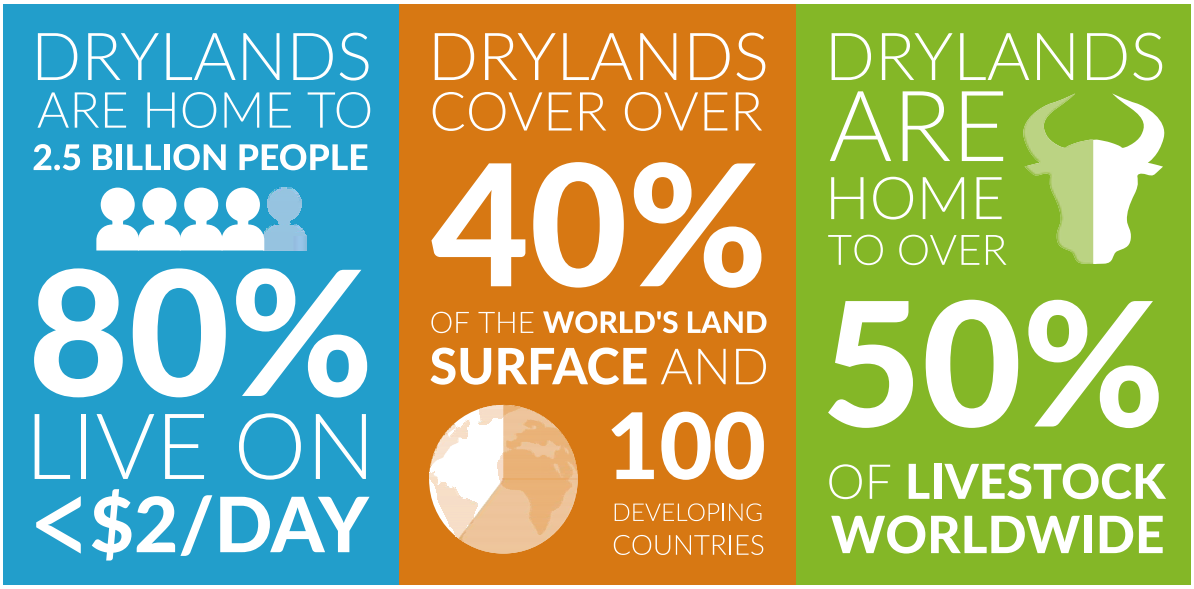
ICARDA Director General

Dr. Margret Thalwitz

ICARDA Board Chair

Agriculture and climate change: how can we strengthen resilience and raise productivity?

The dry areas are highly vulnerable to the impacts of climate change. Rising temperatures and increasing water scarcity – already bad – are expected to get significantly worse. Failure to invest in agricultural research for development will affect our ability to address food insecurity and instability in these fragile regions.



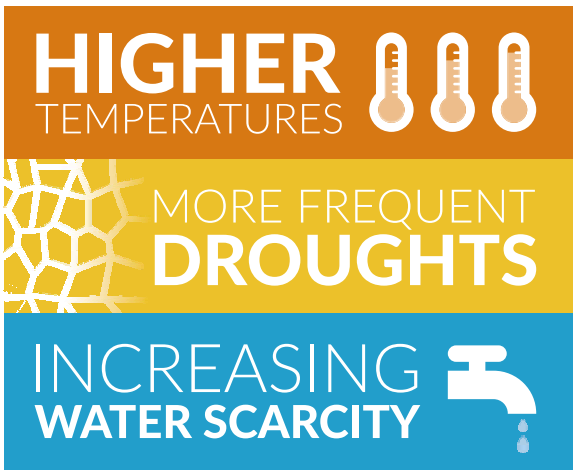
The dry areas are fragile regions highly vulnerable to the effects of climate change. The Intergovernmental Panel on Climate Change (IPCC) predicts that over the coming decades these marginal areas will experience higher temperatures, more frequent droughts, and increasing water scarcity. In the Middle East and North Africa, for instance, climate change will exacerbate pressures on the region's dwindling water supplies – per capita renewable water resources are predicted to drop from 1100 m^3 per year to 550 m^3 per year by 2050.[1]

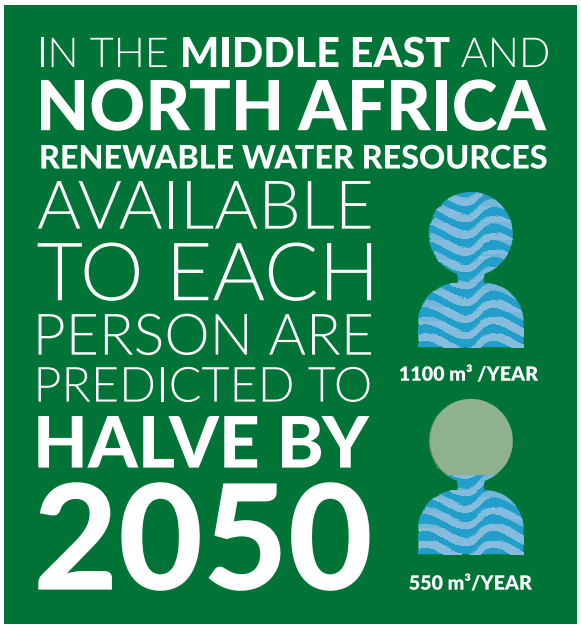
Declining productivity

What does this mean for agriculture and food production? In short, declining productivity, shorter growing seasons, and less cultivable land. If temperatures rise by 4˚C, as some models predict, vast swathes of the dry areas would see their growing seasons cut by more than 20%.[2]

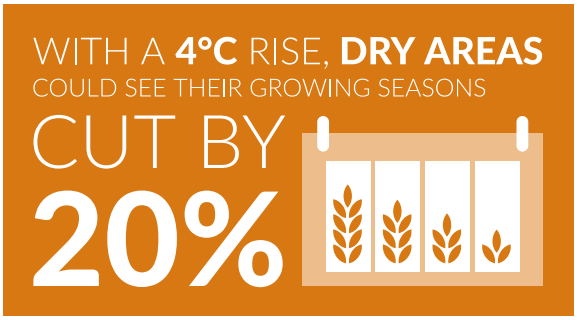
In North Africa, depending on the model used, rising temperatures and increasing water scarcity could cause rain-fed cereal production to decline by as much as 6.5%, and production from the region's grasslands by 49–33%. In West Asia, predictions suggest that cereal production could decline by 3%, and production from the region's woodlands by 14–15%.[3]

A reduced production capacity could exacerbate import dependence – already a growing problem across the dry areas. The Near East and North Africa, for instance, is the world's highest food deficit region. The Middle East currently imports approximately USD 35 billion of food annually, and this looks set to rise to USD 70 billion over the next two decades as climate change impacts crop yields and the region's population rises.[4] Dependence is also a growing issue in other regions with vast arid and semi-arid areas, such as Sub-Saharan Africa.





[1] IPCC, 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R. K. Pachauri and L. A. Meyer (eds.)]. IPCC, Geneva, Switzerland.
[2] Solh, M. and M.C. Saxena (eds). 2011. Food security and climate change in dry areas: proceedings of an International Conference, 1-4 February 2010, Amman, Jordan: International Center for Agricultural Research in the Dry Areas (ICARDA).
[3] Solh, M. and M.C. Saxena (eds). 2011. Food security and climate change in dry areas: proceedings of an International Conference, 1-4 February 2010, Amman, Jordan: International Center for Agricultural Research in the Dry Areas (ICARDA).
[4] Arsenault, C. (2015). How can the Middle East meet its food needs? Thomson Reuters Foundation.



The threat of instability

These trends threaten to substantially increase food insecurity. The dry areas worldwide are home to some 2.5 billion people – 80% of whom struggle to get by on less than USD 2 per day – and continued dependence on costly food imports will expose ordinary people, particularly the poor, to the vagaries of global commodity markets.

The risk is a repeat of the food crisis of 2007-2008 when the international food price index rose from 140 points in March 2007 to 220 points in March 2008. For major cereals during this same period the rise was even steeper - from 151 to 284 points.[5] The immediate impacts of the crisis were riots and widespread instability as people protested their inability to afford basic foods.

Failure to raise productivity could also undermine efforts to stem the flow of migrants risking their lives to reach Europe. While this mass movement has a multitude of causes, it is hard to ignore rising food insecurity, drought, the depletion of natural resources, and low productivity as important 'push' factors.

Investments to enhance resilience

For over four decades ICARDA has been at the forefront of developing practical solutions to help rural communities thrive, and a new decentralized strategy is enhancing the Center's responsiveness to the challenges that communities now face. Strengthening resilience in dry areas requires enhanced investment in agriculture research that combines modern science and technology with traditional knowledge.

Greater investments will help ICARDA and its national and international partners enhance the development and promotion of proven technologies and practices, including: new climate-resilient crop varieties that help farmers cope with drought, extreme heat, pests, disease, and other stresses; water-saving technologies and more efficient irrigation regimes that enhance water productivity and guarantee 'more crop per drop'; and agronomic practices that promote the sustainable management of natural resources.

Climate change presents a significant risk to the survival of production systems across the dry areas. Last year was the hottest year on record – the third consecutive record-breaking year – and renewable water resources are replenishing at ever-lower rates. The dry areas desperately need solutions, and fast.

[5] Food and Agriculture Organization (FAO). 2008. Crop Prospects and Food Situation. FAO, Rome, Italy.

HIGHLIGHTS 2016

130 ISI JOURNAL ARTICLES PUBLISHED

712 TRAINEES BENEFITED FROM **TRAINING** COURSES

828 PUBLICATIONS AND **DATASETS** PRODUCED

736491748
53062837
83613740

124 **RESEARCH** PROJECTS IMPLEMENTED IN **45 COUNTRIES**

177 **PARTNERSHIP AGREEMENTS** SIGNED OR RENEWED

32,252 **PLANT ACCESSIONS** REGENERATED

35 **ICARDA CROP VARIETIES** RELEASED BY NATIONAL PARTNERS

2,490 **BREEDING LINES** DISTRIBUTED TO PARTNERS IN **50 COUNTRIES**

50

HIGHLIGHTS

Conserving precious seed: In 2016 ICARDA implemented a new decentralized genebank architecture, offering enhanced safety, improved access, and more efficient seed distribution.

ICARDA safely duplicated its globally-important seed collection in the Svalbard Seed Vault, with help from the Crop Trust.

After ICARDA became the first organization to withdraw seeds from the Svalbard Seed Vault in October 2015, it invested significant efforts in reconstituting its collection in new locations.

Last year saw the Center make significant strides in its mission of conserving and distributing plant genetic resources after the upheavals of the past few years: developing and expanding new facilities and laboratories in Morocco and Lebanon, including a new genebank at Lebanon's Terbol Research Station, part of a 30-year partnership with the Lebanese Agricultural Research Institute (LARI).

A vital resource for global food security

ICARDA holds in trust one of the world's largest and most unique collections of landraces and wild relatives, with a total of 154,000 different samples of major winter-sown cereals, food legumes, forage, and rangeland species. Many were collected from the Fertile Crescent in West Asia, the Abyssinian Highlands in Ethiopia, and Central Asia where the earliest crop domestication and development practices were first recorded.

Many of these plants are now threatened and their conservation is a matter of crucial importance for humanity and global food security. After the threat of conflict in Aleppo and the subsequent duplication of the Center's seed collection in Svalbard, a new genebank architecture provides additional safekeeping. In addition to samples in Svalbard and the genebanks of international partners, there are now some 35,000 stored in newly established genebanks in Morocco and Lebanon.

Enhanced seed delivery

The new infrastructure enhances access to these international public goods, providing the genetic material that national and international partners need to develop improved climate-resilient crop varieties, our best chance of dealing with the adverse impacts of climate change, including drought, extreme temperatures, and the emergence of new pests and disease.

A decentralized approach also improves the efficiency of the Center's seed distribution, potentially increasing the 25,000 samples that are already sent to requesters each year. It also complements ICARDA's ongoing organizational restructure which followed its departure from Aleppo in 2012, involving the relocation of staff and resources to regional offices in North Africa, Central Asia, the wider Middle East, and Sub-Saharan Africa.

The construction of ICARDA's new genebank facilities in Lebanon was supported by the Arab Fund for Economic and Social Development (AFESD).

From adversity, opportunity

While ICARDA's decentralized strategy has posed many challenges, the progress made demonstrates that the Center's seed conservation and distribution services are resilient and that this core activity is secure.

"ICARDA was the first organization to retrieve seed from the Svalbard Vault," says the Center's Director General, Mr. Aly Abousabaa. "But, we are also the first organization to demonstrate that material stored in the Vault can be returned and regenerated safely. This is a huge achievement and a model for other centers facing adverse circumstances."

"This is a huge achievement and a model for other centers facing adverse circumstances."

Mr. Aly Abousabaa, ICARDA Director General

HIGHLIGHTS

Promoting solutions and innovations at COP22: ICARDA strategically engaged with decision makers and other key players at COP22. The Center used this major international meeting to promote the role of science in climate change adaptation.

ICARDA Director General, Mr. Aly Abousabaa (third from left), listens as the Center's Board Chair, Dr. Margret Thalwitz, addresses the audience at a COP22 side-event.

COP22 offered an opportunity for the international community to demonstrate progress towards implementing the Paris Agreement. ICARDA used the meeting as a platform to promote the solutions it has developed with partners through years of scientific exploration and practical on-farm experience, and to engage with policy makers, donors, and the private sector.

The Center organized or played a leading role in six sessions and used these fora to communicate several key messages related to dryland agriculture: tried and tested technologies are available and have a proven ability to raise production, and improve livelihoods and nutritional security; enabling policies are needed to bridge the gap between science and implementation; and diversification can build resilience and support climate change adaptation.

A diverse agenda

During a packed agenda, ICARDA representatives contributed to discussions around a genetic resource strategy for the Middle East and North Africa (MENA)

region; resilient soil management strategies to enhance agriculture in Africa; the role science and technology can play in climate change adaptation; and the potential for date palm production to strengthen resilience.

ICARDA contributions at one event exploring practical ways of reviving Africa's soils informed the development of a new initiative – Adaptation of African Agriculture to Climate Change – which provides a concrete framework that will be applied across the continent to guide climate action for all African countries.

Climate change adaptation across the MENA region

At another session, ICARDA responded to two major questions confronting the agricultural sector in the MENA region: with a rapidly growing population to feed, can the region produce enough food to reduce its increasing reliance on imports? And, is the region prepared to address the threat posed by climate change to its food and nutritional security?

The Center's Director General, Mr. Aly Abousabaa, part of a panel of science and policy experts, stressed the need for greater investment in the agricultural sector to improve water-use efficiency, support the expansion of irrigation, and develop new infrastructure.

In addition, the panel called for policy reform: the removal of subsidies that encourage the over-use and waste of already scarce water, and the removal of obstacles that prevent the release of new improved cultivars and technologies. Diversification, according to Mr. Abousabaa, is also a key farming strategy, and strengthens the resilience of dryland communities in the face of rapid climate change.

Promoting sustainable solutions

Discussions provided an opportunity to promote the results of ICARDA's research over the past four decades to an engaged and highly influential audience. The solutions relevant to the discussions at COP22 included: heat-tolerant wheat varieties that are capable of enhancing food security under new climate change scenarios; Orobanche-resistant faba bean varieties which are reviving production in Egypt; raised-bed planting which has helped to enhance water productivity; conservation agriculture; and diversified barley–livestock production linked to dairy and meat value chains.

HIGHLIGHTS

Tackling the threat of rust diseases: The completion of a new research facility will help countries fight wheat rust diseases and the threat they pose to wheat yields and food security.

A laboratory inside the Regional Cereal Rust Research Center.

Completion of the Regional Cereal Rust Research Center (RCRRC) marked a significant milestone in global efforts to contain the threat of rust diseases. Supported by Turkey's Ministry of Food, Agriculture and Livestock, the facility offers enhanced support to breeding programs, regional cooperation on rust monitoring systems, and capacity-building opportunities.

Although wheat rusts are well known, the situation and threat are fundamentally different today. Changes in temperature and rainfall patterns have promoted the emergence of new races of rust that are increasingly overcoming the defenses of rust-resistant wheat varieties.

The possibility of a serious stripe rust pandemic that devastates millions of hectares of wheat production is therefore more than a 'scenario' – it is a looming possibility. The disease may be widespread and dispersed in large wheat growing regions, and it poses a big threat for crop researchers and agricultural planners.

The Rust Research Center provides an important addition to ICARDA's ongoing efforts to combat the spread of rust diseases, which includes strategic advice, scientific support for decision making, and the fast-track development of improved rust-resistant wheat varieties.

Wide-ranging support

The new Center offers rust-vulnerable countries scientific expertise and services to identify and track wheat rust diseases: screening crop varieties for resistance to rust and providing advice on crop varieties that are rust-resistant in specific agro-climatic conditions. In the future it is hoped that the Center will also be able to analyze rust samples sent by affected countries to identify specific rust races and virulence to specific crop varieties.

Researchers can also assist in the utilization of molecular markers for the development of rust-resistant cultivars, and help improve understanding of the pathogenic variability of races. A bio-safety facility ensures that the Center can safely receive plant and disease materials for screening and evaluation. There are also new sophisticated planters that can facilitate and expand the precise planting of large numbers of wheat genotypes for field assessments.

A strategic location

The Center is conveniently located in Izmir, Turkey, at the center of the 'Wheat Belt' linking Southern, East, and North Africa with West, Central, and South Asia. The 'Wheat Belt' provides more than 30% of the world's wheat. In addition, Turkey's Mediterranean climate provides optimal conditions for the evaluation of regional and international plant genetic material for both winter and spring wheat against rust diseases.

"As the threat of rust diseases grow, the Center has come at an opportune time," says Mesut Keser, ICARDA's Country Manager for Turkey. "It combines strategic advice, monitoring systems, and evaluations that are vital to the development of rust-resistant varieties – a robust and practical defense for farmers exposed to the threat of rust diseases."

With climate change, the threat posed by wheat rust diseases is growing.

"As the threat of rust diseases grow, the [Rust Research] Center has come at an opportune time."

Mesut Keser, ICARDA Country Manager for Turkey

HIGHLIGHTS

Enhancing pulse production – for people and the environment: ICARDA co-organized an international conference in Morocco, leading a gathering of over 350 participants from 35 countries, to raise the profile of pulses and their multiple benefits.

ICARDA Board Chair, Dr. Margret Thalwitz, addresses participants at the opening session of the International Conference on Pulses.

The 2016 International Conference on Pulses, held in Marrakesh from April 18 to 20, promoted the environmental, economic and health benefits of pulses. Contributing to the International Year of Pulses, organized by the Food and Agriculture Organization (FAO) of the United Nations, the conference was a global effort to raise public awareness about the role that pulse production can play in sustainable production systems and food and nutrition security. Its international participants included leading researchers, donors, farmers, policy makers, and private sector representatives.

Under the auspices of the Ministry of Agriculture and Fisheries of the Kingdom of Morocco, ICARDA organized the Conference in collaboration with the Institut National de la Recherche Agronomique (INRA-Morocco), OCP Foundation-Morocco, the International Fund for Agricultural Development (IFAD), FAO, and the CGIAR Research Program on Grain Legumes.

Strengthening food and nutrition security

The event's main focus was understanding how pulse production could be improved to deliver nutritional gains to the estimated two billion people in developing countries who do not have access to sufficient food to meet their basic nutritional needs.

Pulses are widely recognized as having significant development potential: they are a good source of protein, fiber, and essential nutrients; they are a staple food in many dryland countries, particularly in poor households; they require fewer inputs such as water; and can improve soil health by fixing nitrogen.

A wide range of issues were discussed and participants explored ways of raising production and securing benefits for farmers and poor communities: improving farming systems and access to markets; enhancing policy frameworks to enable targeted pulse research, soil health and increased nitrogen fixation; and environment management. The health benefits of pulses were also raised.

A new framework to raise pulse production

The Conference concluded with a declaration that provided a framework to capitalize on the growing interest in pulse production and secure its benefits for sustainable food production, health, and development.

The 'Morocco Declaration on Pulses as Solutions to Food and Nutrition Security, Agricultural Sustainability and Climate Change Adaptation' called for a 20% increase in pulse production by 2030 which could be achieved by closing yield gaps, expanding the land devoted to pulse production, and intensifying rice fallows with pulses; raising the profile of pulses so more people were aware of their benefits; reviewing policies related to pulse production and consumption; and increasing investments in pulse research and development.

"The Conference brought together significant global expertise to discuss the practical ways we can maximize the many benefits of pulse production," says ICARDA's Director General, Mr. Aly Abousabaa. "We now have a global agenda that we can carry forward and implement, generating significant benefits for the environment and rural communities."

ICARDA's Dr. Kamel Shideed presenting an award to Rachid Dahan, Deputy Director of INRA Morocco, acknowledging the role of his organization in the dissemination of improved pulse varieties.

"We now have a global agenda that we can carry forward and implement, generating significant benefits for the environment and rural communities."

Mr. Aly Abousabaa, ICARDA Director General

Easing dependence on imported wheat:

An ICARDA-led initiative continued to strengthen wheat production across the Arab Region – testing, validating, and disseminating new technologies with the potential to boost yields and ease the region's growing import dependence.

Participating farmers have enjoyed higher wheat yields since the initiation of 'Enhancing Food Security in Arab Countries' in 2011.

Farmers across the Arab region face multiple production constraints: a degraded natural resource base, chronic water scarcity, variable weather patterns, and a range of pests and diseases which severely affect the production of staple crops – especially wheat. The result is a large and growing import burden that undermines national food security in the Arab region and exposes ordinary people to the vagaries of global commodity markets.

A regional integrated approach

The 'Enhancing Food Security in Arab Countries' initiative, led by ICARDA, works with national partners to improve the performance of regional wheat production across 10 countries: Algeria, Egypt, Iraq, Jordan, Morocco, Palestine, Sudan, Syria, Tunisia, and Yemen.

Launched in 2011, the program adopts an integrated approach to raising productivity: disseminating validated technologies – including improved climate-resilient crop varieties; undertaking adaptive research under farmer conditions to fine-tune new technologies; assessing the impact of disseminated technology; and offering capacity strengthening opportunities to farmers, researchers, and extension staff.

Raising wheat production

The initiative achieved a number of notable successes in 2016. The dissemination of improved technologies at demonstration plots installed in farmers' fields resulted in significant increases in wheat yields: on average, yields were up by 23% and maximum yields increased by an average of 62%.

In Egypt's El-Sharkia province, mechanized raised-bed technologies continued to be adopted by farmers. This technology, which raises yields while improving water-use efficiency, is now applied across 38,000 hectares (ha) – up from only 2000 ha in 2011.

The initiative also embraced modern technologies, using cell phone SMS and WhatsApp applications to deliver practical technical advice to wheat farmers in Tunisia and Sudan. Tunisian farmers who used SMS technology to irrigate wheat saw an average 51% increase in wheat yields, compared to farmers who did not embrace this technology.

Investing in the future

Capacity strengthening also enhanced the knowledge and skills of beneficiaries. More than 15,500 participants benefited from capacity development activities, which included Farmer Fields Schools and Field Days. Farmers and extension staff represented 72% and 17% respectively of all beneficiaries who attended the 393 events organized last year.

A key focus of the initiative is advancing the capacity of young researchers, thereby helping to achieve long-term impact. Last year, the project's Young Agricultural Scientists Program (YASP) allowed eight young researchers from across the region to train in various areas and topics related to wheat-based production systems; each returning to their countries to strengthen and consolidate their respective national research programs.

"Year on year we have witnessed the growing potential of the Arab region's wheat sector," says Project Leader Dr. Habib Halila. "2016 was no exception and as we see wider dissemination and increasing interest by wheat producers in improved production technologies, we can look forward to rising wheat yields and declining import dependence."

Enhancing Food Security in Arab Countries is funded by: the Arab Fund for Economic and Social Development (Phase I and II), the Kuwait Fund for Arab Economic Development (Phase I and II), the Islamic Development Bank (Phase I), the OPEC Fund for International Development (OFID) (Phase I and II), and the Bill and Melinda Gates Foundation (Phase II).

Field days help promote improved varieties and new production technologies.

"Year on year we have witnessed the growing potential of the Arab region's wheat sector."

Dr. Habib Halila, Project Leader

HIGHLIGHTS

Vital seed health testing continues in ICARDA laboratories: ICARDA plays a crucial role in conserving genetic resources and developing high-quality germplasm of its mandated crops – barley, chickpea, faba bean, grasspea, lentil, bread wheat, and durum wheat. Following the relocation of the Center's genetic resources conservation and crop improvement research, it continued to ensure effective seed health testing in 2016.

An ICARDA scientist performs seed characterization in a new lab supported by AFESD.

Following relocation of the Center's crop improvement research, continued activities were facilitated by the Moroccan government, which provided experimental fields at Marchouch station and facilities at Rabat, and the Arab Fund for Economic and Social Development (AFESD), whose financial support helped renovate and equip the new facilities. In 2016, genebank facilities were also established in Morocco and Lebanon through the support of the Genebank CRP and the Global Crop Diversity Trust. This allowed the resumption of core genebank activities, including the reconstruction of active and base collections and the distribution of genetic resources to requesters around the world.

Seed health testing is vital to core genebank and crop improvement activities, and ensures the safe movement of incoming and outgoing seed samples. Under best practices, all incoming and outgoing seed samples, from genebanks or breeding programs, are tested for diseases and pests. Any infected seeds are either destroyed or disinfected. The facilities in Lebanon and Morocco therefore inspect seed multiplication fields and test the seed after harvesting for the presence of seed-borne pests, fungal, bacterial, and viral diseases.

Seed Health Laboratories (SHLs) collaborate with the quarantine services of host countries where ICARDA has breeding and genetic resource conservation activities, to ensure safe movement of seeds and avoid any breaches of host- and receiving-country quarantine protocols. To safeguard countries from phytosanitary risks associated with the movement of germplasm, ICARDA follows a regulatory and quarantine program working in close collaboration with institutions where ICARDA has platforms for developing germplasm.

There are different methods available for seed health testing, depending on the nature and location of the pathogen in or on the seed. These methods are recommended by the International Seed Testing Association (ISTA) or developed at ICARDA SHLs. These methods have been successfully used at ICARDA for several years for detection of seed-borne fungi, bacteria, viruses, nematodes, and parasitic weeds.

During 2015–2017, around 20,000 samples of genebank accessions were tested by SHLs in Morocco and Lebanon before being processed into storage in active and base collections, and for distribution. More than 35,000 seed samples of genebank accessions and breeding germplasm – incoming and outgoing materials – were tested for major quarantine diseases. In addition, about 12,000 plots were inspected at Marchouch, which serves as the quarantine area in Morocco. During the 2016/2017 growing season, 15,160 genebank accessions were tested at SHLs in Morocco and Lebanon, and shipped to Svalbard.

Implementing ICARDA's decentralization strategy

2016 was the year that ICARDA consolidated its decentralized research infrastructure. The result: more efficiency, improved delivery of scientific innovations, and enhanced relevance and proximity to partner countries.

In 2012, as the conflict in Syria escalated, ICARDA was forced to redeploy staff and resources away from its home in Aleppo, and upgrade field, laboratory, and office facilities at existing and new sites in Central Asia, North Africa, Sub-Saharan Africa, South Asia, and the wider Middle East.

From adversity, opportunity

Over the course of the next few years, a new decentralized research infrastructure took shape. Existing facilities were expanded in Lebanon, Turkey, and Jordan, and new research platforms were established in several new locations: a research platform in Morocco supported rain-fed cereal and legume production; integrated crop–livestock systems were the focus of a platform in Ethiopia; a research platform in India targeted food legume production; and a West Asia Thematic Research Location based in Jordan focused on strengthening resilience on marginal lands through integrated crop–rangeland systems and water management.

Additional research locations were also established: in Egypt, to cover intensification under irrigated conditions; in Sudan, to

ICARDA staff now operate in a decentralized research architecture across the dry areas.

investigate cereal and legume heat tolerance; and in Turkey, to focus on improved winter wheat and barley varieties and wheat rust diseases.

The Center is already experiencing the advantages of its new decentralized research infrastructure: closer proximity to partner countries and farmers, greater flexibility and responsiveness to global challenges, and the improved delivery of new innovations and technologies. From a situation of adversity, the Center has embraced the opportunity to become more efficient, effective, and relevant.

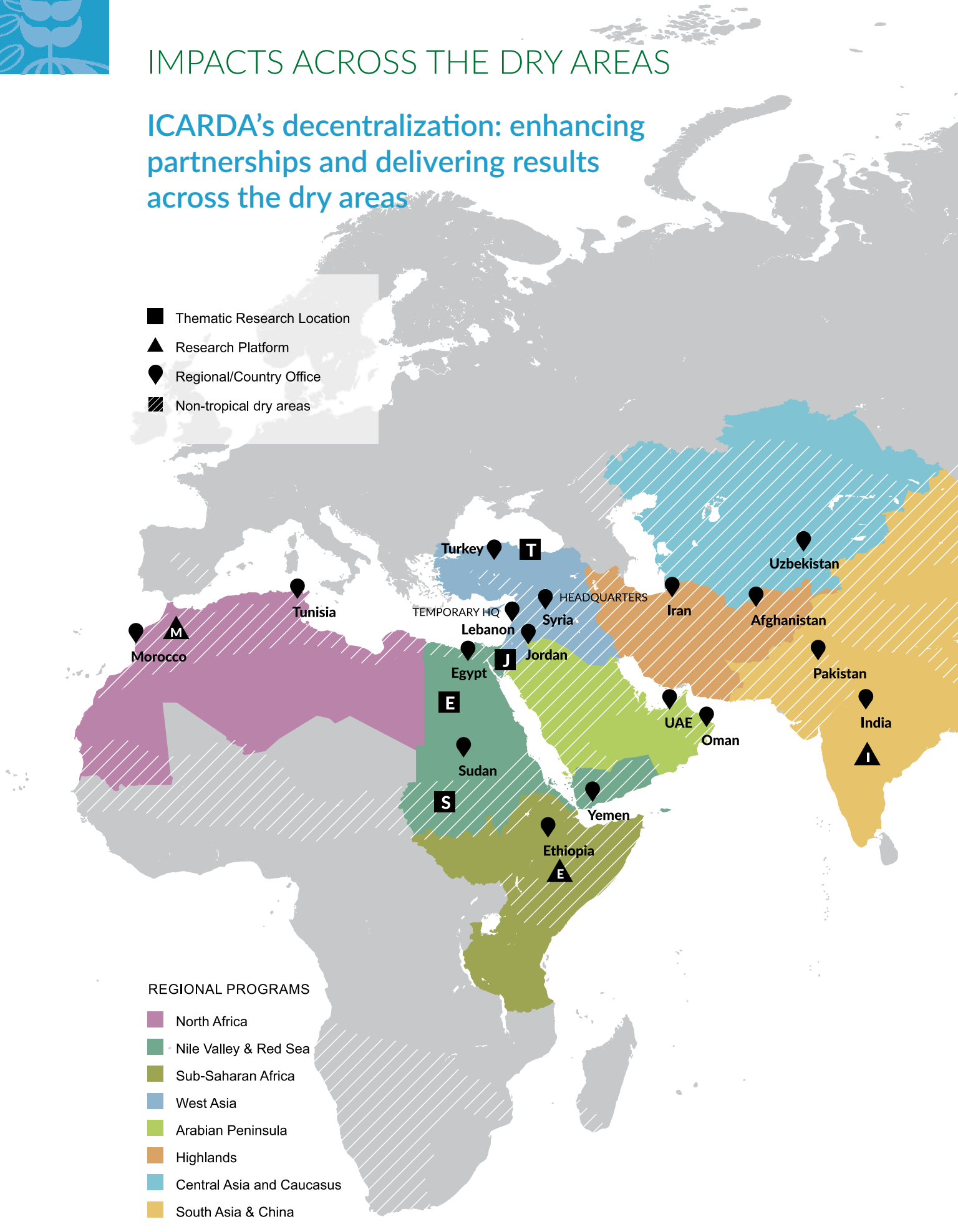
A new genebank architecture

A new decentralized genebank architecture also emerged. When ICARDA became the first organization in history to withdraw seeds from the Svalbard Global Seed Vault in 2015, it subsequently reconstituted seed in Morocco and Lebanon and constructed state-of-the-art facilities in both countries, including a new genebank at Lebanon's Terbol Research Station. The new architecture provides additional safekeeping and enhanced access to the Center's unique and globally-important collection of plant genetic resources.

The following sections demonstrate the impacts of decentralization in each of the regions where ICARDA is working to raise farmer productivity and strengthen climate change adaptation.

IMPACTS ACROSS THE DRY AREAS

ICARDA's decentralization: enhancing partnerships and delivering results across the dry areas



M **North Africa Platform:** Based in Morocco and working on sustainable intensification and diversification of rain-fed cereal-based production systems.

E **Egypt Thematic Research Location:** Focused on high-input irrigated agricultural systems.

E **Sub-Saharan Africa Platform:** Based in Ethiopia and concentrating on integrated crop–livestock systems.

T **Turkey Thematic Research Location:** Focused on winter wheat and barley and wheat rust diseases.

S **Sudan Thematic Research Location:** Specializing in heat-tolerant wheat and food legumes.

I **South Asia Platform:** Based in India and strengthening food legume systems.

J **West Asia Thematic Research Location:** Based in Jordan and focused on building resilience on marginal lands through integrated crop–rangeland systems and water management.

IMPACTS ACROSS THE DRY AREAS

North Africa Regional Program

Manual cactus cutters, supported by the German Federal Ministry for Economic Cooperation and Development, enhance access to fodder and reduce workloads.

Creating and developing sustainable production means for small landholders in North Africa is key to creating stable livelihoods in the region. To that end, ICARDA and its partners are promoting interventions throughout the area: introducing cactus choppers to reduce women's labor in producing food sources for ruminants; and introducing hardier barley cultivars, for example. New technology in geospatial sciences is also making it possible to create maps that can compare areas in terms of soil quality, growth and yield potential, and other factors. All of these projects ultimately seek to make the area more resilient to the food security issues the region currently faces and will face as climate change effects become more devastating.

'Cactus Choppers' – another step to attaining sustainable livelihoods

An ICARDA project in Tunisia seeks to maximize feed resources for small ruminants, cut down labor time and injuries, and promote usage of a readily available and climate-resistant crop.

Cactus plants are widespread in Tunisia, able to withstand harsh dry climates, and are packed with energy-providing sugars. While only 10% of a cactus cladode is made up of nutrients, the rest is water. As such, they can provide an essential part of the daily water needs of ruminants that call such an arid area home.

ICARDA's 'red meat value chain' project, funded by the German Federal Ministry for Economic Cooperation and Development (BMZ), aims to provide rural regions with a more readily available feed resource for small livestock. The latter can't be let free to graze the landscape, however, as such practices can effectively destroy a harvest of spineless cacti and harm an already vulnerable landscape.

Cactus farming in Tunisia comprises over 600,000 ha, and its harvesting and processing requires labor-intensive cutting and chopping by knife in order to make it a better feed for ruminants. The labor is most often undertaken by women, who already have significant workloads.

Undertaken with the National Agricultural Research and Extension Services (NARES), the project distributed 29 locally-manufactured cactus choppers to local farmers and farmer associations, and an additional one to NARES partners for demonstration purposes. The choppers are powered by hand and more efficiently cut the cactus for ruminant consumption. Additionally, the machines are of relatively low cost (USD 326) and can be shared among small farmer households.

The project is estimated to reach about 1,540 families, adding a total of 2,500 working days per year based on labor hours saved. When surveyed about what they intended to do with the time, 95% of the farmers noted that they would intensify their agricultural activities. This is particularly important in Tunisia, where labor is in short supply.

Chopped cactus can also be sold at local markets at higher prices than non-chopped cactus and can thus provide an additional source of income for farmers with surplus product.

Malika and Jannet Saabil were both beneficiaries of the chopper provided to their village in Kasserine: "We use cactus leaves to feed our sheep and goats [in] years when feed is scarce," says Malika. "Usually we use knives to cut them into pieces. The spines and use of knives always cause wounds on our hands and make the work really exhausting. Thanks to the chopper we don't cut our fingers anymore and have more time to spend on farming and other activities."

"Thanks to the chopper we don't cut our fingers anymore and have more time to spend on farming and other activities."

Malika Saabil, farmer in Kasserine, Tunisia

Naked barley minimizes grain loss and maximizes productivity

With funding from the CGIAR Research Program on Dryland Cereals, two husk-less food barley cultivars developed from germplasm supplied by ICARDA were released in Morocco in 2016. The varieties, dubbed 'naked barley,' maximize the amount of product available for local consumptions and distribution.

Barley is an integral part of Morocco's economy, with more than two million ha sown annually. The nation is responsible for most of the worldwide human consumption of the grain, with an average of 28 kg consumed per inhabitant every year. Due to a very dry season in 2016, however, Moroccan barley production fell to 700,000 tons, raising prices substantially.

A hardy cereal that can grow in harsh environments, barley requires little labor and promotes generally stable yields. It provides food, forage, and livestock feed for the region, and is a regional cultural touchpoint – its harvesting and

use date back thousands of years in Africa and the Middle East.

Increasing yields, disease resistance, and food security

ICARDA works with its partner Institut National de la Recherche Agronomique (INRA) to support the 'Green Morocco Plan.' A multi-billion dollar country-wide initiative, Green Morocco aims to restructure the agricultural sector to stand as a bulwark against climate change by creating more resilient crops, implementing sustainable agricultural methods and technologies, and providing effective marketing strategies for its harvests.

ICARDA's role is to provide improved germplasm to create varieties that have a higher grain yield with higher nutritional content (fiber, zinc, iron, and beta glucan). The two new varieties – CHIFAA (INRA 1791) and ASSIYA (INRA1793) – produce naked grains. That is, the varieties are essentially husk-less, thus eliminating the need to pearl the husks mechanically. Additionally, they are resistant to net blotch, powdery mildew, and lodging, wherein plants are bent low at the stem, making them difficult to harvest and potentially causing yield losses.

Only 1% of the available certified seeds are used, however, and the projections aim to increase use to 22% by 2020.

ICARDA's Barley Team in Morocco. In front of the team, genetically variable barley, which ICARDA's barley program can provide to meet global needs.

Using similarity maps to promote conservation agriculture

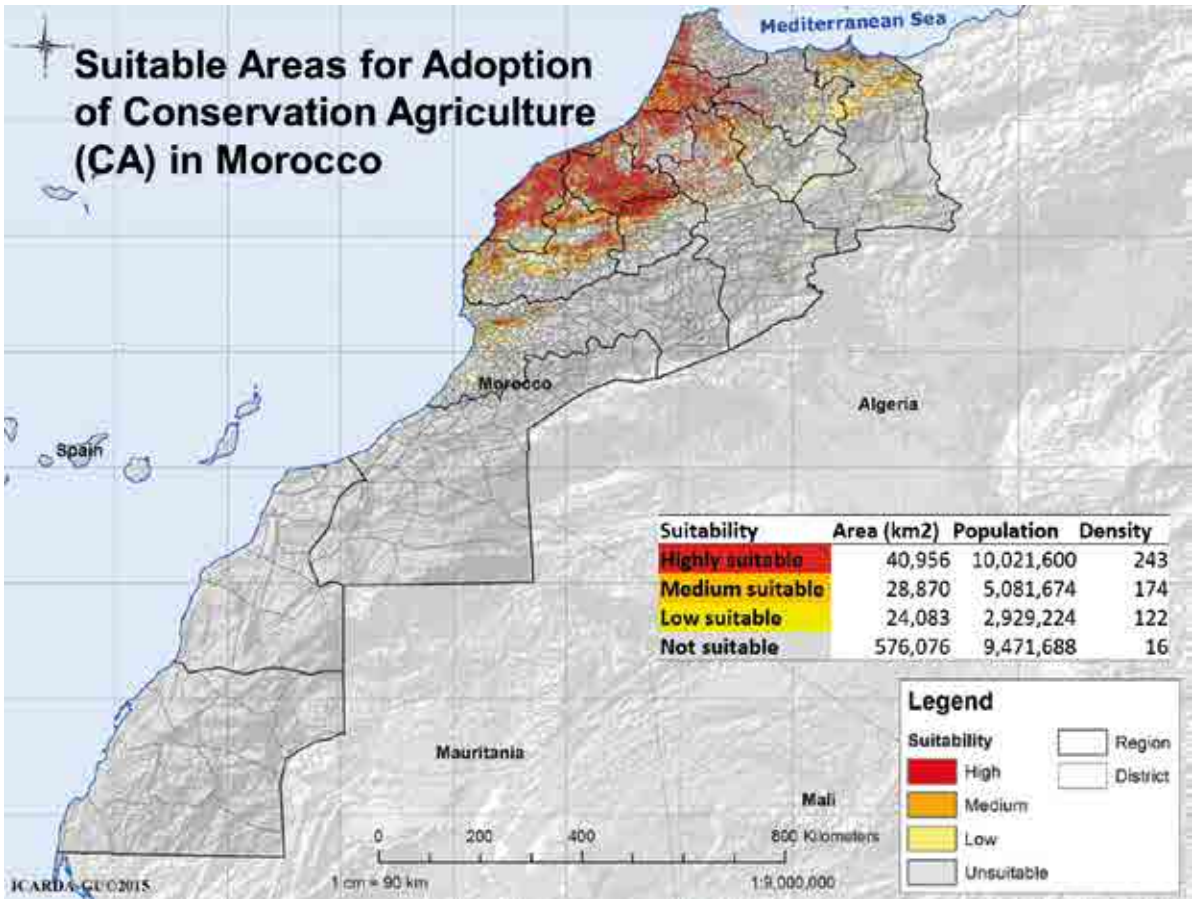
Conservation agriculture (CA) is key to creating and maintaining food and environmental security practices that can provide sustainable livelihoods in dry and arid regions. To make it work, it is crucial to have better data and information on agricultural land and its potential.

ICARDA launched a two-pronged Geospatial Science, Technology and Applications (GeSTA) pilot study using a 'target' area and 'match' location to better assess which areas in North Africa could be optimized for CA.[1] Land similarity and other factors, including edaphic variations, regional climate, and bio-physical land features are compared and analyzed in the process.

The 'match' location in this case was Morocco. Its location in the northwestern region of the larger study encompasses the country's most populous areas, along with a wide range of agro-climactic zones (including a Mediterranean clime), making it an ideal location. Additionally, while Morocco has been an early CA innovator (since the 1990s) – implementing field demonstrations that have reduced soil erosion, improved soil quality and yielded stable and higher crop yields – Moroccan farmers have yet to adopt these practices at large. It is therefore important that such suitability and similarity maps also include a socio-economic component.

Because CA practices are increasingly information-driven and address a complex set of issues, decision makers must have up-to-date information on a variety of factors. The pilot study seeks to develop spatial information to provide such key 'decision-guiding' informatics. To date, poor imaging (low-resolution), the lack of open-access data and information, and varied methods of data collection, if any, often mar the process.

[1] Boughlala and Dahan, 2011, and Moussadek et al., 2014, in 'Adapting CA for rapid adoption by smallholder farmers in North Africa: Mapping Similarity and Suitability.' Beirut, Lebanon: ICARDA, 2014-2015.



According to similarity map analysis, 45% of total arable land in Morocco is highly suitable for the adoption of Conservation Agriculture, which could benefit nearly 10 million people.

Thus the program objectives were to:

1. Develop regional level similarity maps for out-scaling based on the matching of bio-physical similarities identified from the pilot sites;
2. Develop suitability maps to identify ideal areas for CA adoption in Morocco.

To create comprehensive data for CA implementation the project would answer questions like:

- What is the spatial extent of area (in ha) suitable for CA?
- How many farmers live in potentially suitable areas?
- What are the agro- and socio-economic characteristics of the CA area?

Additional data, including, for example, the number of farmers and households in a region, machinery available, etc., and other factors could make the technology an excellent tool in facilitating greater CA adoption in the region.

The pilot study was funded through the Conservation Agriculture for North Africa (CANA) Project, Australian Centre for International Agricultural Research (ACIAR) and the Multi-National Geospatial Co-Production Program III-International Resource Management (INRM).

IMPACTS ACROSS THE DRY AREAS

Nile Valley and Red Sea Regional Program

Supported by the Government of Sudan, ICARDA is enhancing water harvesting to boost the production of staple crops like sorghum.

The drylands face a constant barrage of challenges, including water scarcity and rapid climate change. To make the Nile Valley and Red Sea region more resilient to its ongoing and coming challenges, ICARDA has launched several initiatives in the area, including: repurposing wastewater in the Nile Delta; creating water points in Sudan to maximize water access; and studying the genetic traits of indigenous ruminants to determine what makes some better suited to surviving and thriving in harsh climates.

Water harvesting in Sudan

Water access in Sudan is key to the livelihood of the country's farming communities. With financial support from the Government of Sudan, ICARDA is working on the ground in Kordofan to maximize the productivity of the area's crop–range–livestock systems by developing and implementing water-harvesting interventions.

Sudan is already facing the frontline consequences of climate change, its arid and semi-arid systems affected by increases in temperature, erratic rainfall, and drought. Yet, farming is critical to its economy, with many agro-pastoralists raising livestock while also raising crops, primarily millet and sorghum. Because most of the livestock feed on range grasses, however, overgrazing and water scarcity keep the region's inhabitants in a cycle of hardscrabble subsistence farming. Additionally, arable land can go underutilized due to a lack of water points.

To address such challenges, ICARDA and the Sudanese Agricultural Research Corporation (ARC) implemented a set of crop–range–livestock system interventions across an area of 250 km^2 in the semi-arid zone of North Kordofan, around the village of Faris. Key to the project was creating water conservation structures, in this case a water pond, to supplement irrigation to usually rain-dependent

crops. The latter include sorghum, fodder, Arabic gum trees, and sunflowers and maize. Already, sorghum yields have risen significantly, with an increase to 1,317 kg/ha from a base average yield of 475 kg/ha.

Improved water utilization has increased productivity and improved food security, raising food and feed crop yields. And it has sparked interest from neighboring communities and further interest by the government to expand the intervention to other parts of the country.

The project seeks to impact around 500 resource-poor farmers by 2019. Additionally, the project aims to incorporate better monitoring to improve data collection and produce more scientific studies, both particularly important as the climate continues to change rapidly, creating shifting circumstances on the ground.

The construction of a water pond will enable farmers in Kordofan to use supplemental irrigation on their crops.

Repurposing wastewater to combat water scarcity

Wastewater offers an alternative and readily available, though unconventional, source of water for irrigation in Egypt. In collaboration with national partners, and with funding from the CGIAR Research Program on Water, Land and Ecosystems (WLE), ICARDA investigated the potential use of wastewater in the Nile Delta as the area faces severe water scarcity, which only promises to worsen with climate change.

Using wastewater – whether treated, partially so, or untreated – is a common practice throughout the world. In Egypt, agricultural drainage creates the largest amount of wastewater, much of which is untreated or only partially treated as it comes from industry sources or even wastewater treatment plants. All of this then mixes into drain water, which gets pumped back into irrigation canals and creates potentially harmful conditions for humans and the environment alike.

Treated wastewater, however, is considered an undervalued and underused resource for the region. Egypt creates about 5 billion m^3 of raw sewage annually, thus creating a readily available supply that can be treated and used for groundwater recharges of aquifers, and agricultural irrigation. However, implementation of the technology faces both economic and cultural barriers. The technology is impossibly expensive for the average rural household or small farmer. Additionally, uptake of the idea has been difficult because communities can be wary of health and sanitation concerns.

Because women and children take on the duties that most closely put them in contact with wastewater, the study incorporated gender-disaggregated data that parsed out perceptions of using wastewater for agricultural and non-agricultural purposes, and the actual use of such water. The project also sought to improve awareness for stakeholders, including farmers and other decision makers, about using untreated wastewater, how to manage its use, and discuss re-use options and investment decisions.

IMPACTS ACROSS THE DRY AREAS

Resilient livestock production in a changing climate

With funding from the Government of Egypt, ICARDA's Small Ruminant Genetics and Genomics team, the Animal Production Research Institute (APRI), and Iowa State University launched an analysis on the genetics of sheep and goats indigenous to the drylands to determine how their genetic "fingerprints" best suit them to be resilient in the face of climate change.

The drylands face a constant barrage of challenges: climate change is exacerbating extreme weather patterns that include droughts, heat waves, and water shortages. And the worldwide increasing demand for animal products means that small-scale farming and livestock-producing households will depend on the income and food security that these animals provide.

As such, understanding the genetic basis of how desert sheep and goats adapt to biotic and abiotic stresses is crucial. The analysis undertaken compared desert-adapted Barki sheep and goats in the Coastal Zone of the Western Desert in Egypt to various breeds of sheep and goats raised and bred in temperate environments. The study found significant genetic differentiation and divergence between the livestock bred and raised in desert zones versus those in temperate zones.

The analysis also indicated that adaptation was influenced by a complex network of interacting genes rather than a single gene influencing one particular characteristic. The genes that make Barki sheep and goats more adaptable to hot arid climes include those that affect muscle function, metabolism, the development and function of the nervous and endocrine systems, thermo-tolerance, body size and development, and autoimmune and inflammatory response and regulation.

The study was a promising step towards mining the genetic potential of adaptable indigenous livestock to provide the foundation to breed appropriate small ruminant genetic resources to mitigate against food insecurity and instability in increasingly volatile climate events. Additionally, it creates a foundation for exploring the evolution and genomics of different species co-existing in common environments.

With support from the Government of Egypt, ICARDA is working with the Animal Production Research Institute (APRI) and Iowa State University to mine the genetic potential of climate-resilient small ruminants.

Sub-Saharan Africa Regional Program

Thanks to USAID support, barley farmers like Gosaye Degefa have achieved significantly higher incomes.

ICARDA works with its partners in Sub-Saharan Africa to alleviate poverty, improve water productivity, and strengthen the capacity of NARES. In 2016, the Center's regional priorities included the development of improved climate-resilient crop varieties, such as heat-tolerant wheat that has the potential to reduce the region's rising wheat import dependence, and a community-based livestock breeding program adapted to the resource-constraints of rural communities.

A boost to crop production in Ethiopia

From its research hub in Ethiopia, ICARDA's cereal and legume improvement program is overhauling the productivity of the region's strategic crops.

Working with national partner the Ethiopian Institute for Agricultural Research (EIAR), and supported by the United States Agency for International Development (USAID), the crop improvement program combines the development and/or testing of high-yielding climate-resilient crop varieties with capacity development and efforts to strengthen seed systems, ensuring that farmers have timely access to quality seed.

In 2016, with ICARDA support, Ethiopia released three malt barley cultivars with higher grain yields and malting quality, making them an ideal raw material for Ethiopia's growing malt beverage sector. They included the variety 'Singitan,' which is higher-yielding – generating up to 4.1 tons per hectare (t/ha) – and resistant to shoot fly, a major pest which can cause crop losses of up to 100% during shorter rainy seasons.

The benefits of improved malt barley varieties are acknowledged by farmers. Gosaye Degefa, a smallholder farmer from Ethiopia's Oromia region, comments: "I have benefited a lot from

barley production. We didn't have money to spend before, but we are now saving more money and are able to send our children to school."

ICARDA is also strengthening seed systems to ensure that quality seed gets into the hands of farmers – ineffective seed systems in developing countries can be a major obstacle to higher productivity. In the absence of a strong formal public or private sector, the key to enhanced adoption and diffusion of the newly improved varieties is mobilizing and engaging farmers in local seed entrepreneurship.

Approximately 893 tons of chickpea, faba bean and malt barley seed were distributed, and the program anticipates that an additional 3,489 tons of quality seed will be produced by farmers and seed producer cooperatives in 2017 – enough to cover a land area of approximately 30,651 ha, benefiting some 157,500 farmers.

Heat-tolerant wheat thrives in Sub-Saharan Africa

In 2016 the performance of improved heat-tolerant wheat varieties continued to impress policymakers in Sub-Saharan Africa. The varieties offer a solution to the region's rising dependence on costly wheat imports, which currently account for 80% of its needs.

The climate-resilient wheat varieties were disseminated as part of a multi-national CGIAR-led project funded by the African Development Bank – Support to Agricultural Research for Development of Strategic Crops in Africa (SARD-SC). ICARDA leads the initiative's wheat component, working with national partners across 12 countries in Sub-Saharan Africa to boost production, enhance food and nutrition security, and reduce poverty.

SARD-SC combines the dissemination of improved wheat varieties with an integrated package of interventions: fast-track seed multiplication programs; the dissemination of proven technologies and farming practices; and value chain approaches to support domestic producers. The testing, validation, and promotion of proven technologies is first initiated in three 'hub' countries – Ethiopia, Nigeria, and Sudan – and then applied in other participating countries.

With funding from the African Development Bank, SARD-SC has raised the wheat production of farmers in Kano, Nigeria.

In 2016, some varieties yielded up to 4–6 t/ha, a significant improvement on the average 1–2 t/ha generated by existing commercial varieties. Average yields were also higher among participating farmers: 2.5 t/ha in Nigeria, 3.39 t/ha in Sudan, and 2.54 t/ha in Ethiopia.

In all three countries the land devoted to wheat expanded: reaching 1.6 million ha in Ethiopia, 230,000 ha in Sudan, and 100,000 ha in Nigeria. There were also increases in the amount of wheat produced: 787,000 metric tons in Sudan, 4.23 million in Ethiopia, and 250,000 in Nigeria.

These successes have translated into policy impact. There have been national commitments to raise production, Nigeria and Sudan have guaranteed minimum price guarantees for wheat farmers, and Sudan and Ethiopia have adopted the SARD-SC extension model to enhance technology transfer.

Livestock improvement delivers for dryland communities

Livestock are a mainstay of dryland communities, providing much-needed income and a crucial source of food and nutrition. ICARDA works alongside communities to develop practical, cost-effective strategies to raise livestock productivity and profitability, helping households to get the most from these vital resources.

In 2016, the Center's Sub-Saharan Regional Program promoted community-based sheep and goat breeding programs, field solutions for cost-effective estrus synchronization and artificial insemination, and food-feed crop varieties.

Community-based breeding programs (CBBPs) are adapted to the resource-constraints of smallholder farmers and designed to raise the productivity of indigenous breeds without undermining their adaptation to harsh environments. This unique approach involves: farmer participation to organize selection schemes; pooling individual flocks to create larger community gene pools; improving farmer–scientist interactions to inform better decision making; and establishing recording systems to monitor and assess performance and bring continuous genetic improvement.

CBBPs were acknowledged by the Ethiopian government in 2015 when the Ethiopia Livestock Master Plan was developed and CBBPs were identified as one of the strategies for small ruminant genetic improvement. Ethiopian regional government authorities in Southern Nations and Amhara are also investing money in the approach's regional expansion. The new World Bank-funded national livestock program that will start in January 2018 will implement CBBPs for small ruminants.

There have also been improvements in field solutions for synchronization and artificial insemination in sheep. The tested synchronization protocol, which involved two injections of prostaglandin analog 11 days apart, reduced costs from an estimated USD 8.5 to a mere USD 1.3 per treatment.

Optimal feed options were also explored to enhance animal nutrition and health. In Ethiopia, where crop residue comprises an estimated 70–100% of feed resources in mixed crop–livestock farming systems, ICARDA identified genotypes that combine superior grain yield and straw traits in lentil, chickpea, field pea, and faba bean.

ICARDA's community-based breeding programs will be included in a World Bank-funded national livestock plan.

IMPACTS ACROSS THE DRY AREAS

West Asia Regional Program

ICARDA works with communities across West Asia to enhance the productivity of rangelands.

ICARDA worked on the ground to promote sustainable rangeland restoration and development, and better production systems for farmers and their commodities. As West Asia faces increasing desertification, water scarcity and degradation, ICARDA and its partners worked on methods to restore the Badia (steppes), better adapt the eroded area to climate change, and develop more sustainable livelihoods for local farmers and others by creating a better managed agro-ecosystem.

Jordan's watershed restoration program

Involving several partner organizations, ICARDA worked in the Jordan Badia to restore and re-vegetate overgrazed and eroded areas by implementing Vallerani water-harvesting techniques. The watershed management project aims to reverse land degradation, reduce fodder shortages, and improve the area's economic viability.

The Jordan Badia is a vulnerable region that has suffered from a combination of land mismanagement, overgrazing, and aggravated droughts and erratic rainfalls due to climate change. The latter, and the resulting erosion and run-off, have also affected the livestock and farming practices of the area's native Bedouin and thus the area's food security.

With financial support from the United States Forest Service, ICARDA worked with the Service's SEED project and Jordan's National Center for Agricultural Research and Extension (NCARE) to counter the increasingly poor outputs of the area – both in terms of the goods and services provided by the degradation of the area and the poverty of its citizenry.

Agency scientists coordinated with local groups, which included young men from the local Majidyya community – who engaged in the out-planting fieldwork – and a women's collective from Mafraq, whose nursery provided the

seedling shrubs. A 25 ha watershed was targeted, with 3,500 native shrub seedlings. The latter form the base of 'vegetation islands' of native shrub species that can better sustain not only animal fodder but also increase biodiversity and provide local herbs used by the local population.

Sustainable agro-economic methods

The Vallerani system uses a special plow that breaks up crusted soil layers to create 'micro-catchments' that harvest water run-off and protect shrub seedlings. The method's water retention benefits also lessen potential drought damage during the initial planting period.

Oversight of the fields and their security continued after project implementation, undertaken by young men from Majidyya. In conjunction with other partners, ICARDA continues to investigate the long-term benefits of such ecosystem restoration and sustainability projects: it is jointly conducting a photogrammetry study with Utrecht University to observe Vallerani structure development over time; and conducting a Rangeland Hydrology and Erosion Model (RHEM) study with scientists from the University of Nevada and the ARS Great Basin Rangelands Research Unit. Both aim to continue discussions with local governments and communities to ensure that the Badia sustains an ecologically viable agro-economic system for the land and its inhabitants.

A Vallerani water harvesting pit during the rainy season.

Promoting sustainable rangeland management

A sustainable rangeland management initiative – including planning, improved seeding, and periodic resting – illustrated how such projects can improve both the agricultural landscape and the economic outlook of its inhabitants.

Suffering from a 'crisis of the commons,' rangelands across the dry areas have been overgrazed by ill-managed livestock breeding and land management schemes. Overgrazing has often led to erosion, further soil degradation, and to poorer livelihoods for pastoralists and agro-pastoralists.

In an effort to ensure long-term agricultural viability for Bedouin inhabitants, ICARDA and its partners used data gathered from pre-conflict Syria to evaluate the adoption of sustainable rangeland management practices (SRMPs) targeting pastoral lowlands (landscape depressions), with an emphasis on providing better technical interventions and incentives that would allow for long-term restoration of the land. Three SRMPs were recommended as optional management alternatives to the current system:

- **Periodic resting.** Creating a protected area for two years, so that natural vegetation can recover.
- **Direct seeding or broadcasting.** Planting hardy shrubs best suited to agro-ecological climes with zero-tillage methods to decrease erosion.
- **Shrub transplantation.** While highest in cost, this method involves planting already-nurtured seedlings in order to promote faster biomass creation in a shorter amount of time.

IMPACTS ACROSS THE DRY AREAS

The authors* of 'Financial incentives: Possible options for sustainable rangeland management?' postulated in their study that a combination of the methods above would lead to increased shrub areas and better grazing and agro-economic opportunities for the Bedouin communities.

However, they found that without attractive financial incentives for what is, in essence, a long-term investment with long-term pay-offs, communities – which without incentives were likely to prefer drought- and erosion-vulnerable barley crops – would be unlikely to implement such changes. However, as the study notes, SRMPs could lead to carbon sequestration, flood erosion control, conservation of native biodiversity, and better economic results for inhabitants. The study has implications for rangeland communities throughout West Asia and beyond.

Funding was provided by the CGIAR Research Program on Livestock Agri-Food Systems and OPEC Fund for International Development.

Digging a water harvesting pit in the Jordanian 'Badia.'

Partnered with the National Center for Agricultural Research and Extension and the United States Forest Service, ICARDA has constructed 'vegetation islands' to sustain animal fodder and increase biodiversity.

* Mounir Louhaichi, Yigezu A. Yigezu, Jutta Werner (ICARDA Jordan); Lojoo Dashtseren, Tamer El-Shater (ICARDA, Syria); and Mohamed Ahmed (Food and Agriculture Organization of the United Nations, FAO).

Arabian Peninsula Regional Program

In Oman, as in the rest of the Arabian Peninsula, ICARDA scientists are working to improve greenhouse management techniques.

ICARDA's Arabian Peninsula Regional Program (APRP) works with local organizations in Bahrain, Kuwait, Qatar, Saudi Arabia, Oman, United Arab Emirates (UAE), and Yemen. The region faces multiple challenges: water scarcity, harsh climate conditions, increasing food insecurity – all exacerbated by climate change.

Currently, the emphasis in the region is on the development of sustainable rangelands, water efficiency, reduction of harmful pesticides and chemicals, protected agriculture, and capacity development to ensure that improved varieties of crops and more efficient agro-cultural-technologies are implemented and disseminated.

Protected agriculture: increasing yields and reducing chemical and water use

To address the challenges of protected agriculture, a leading method of agricultural production in the Arabian Peninsula, ICARDA developed and implemented the Integrated Production and Protection Management (IPPM) program to maximize its benefits and increase product yield and quality.

Greenhouses have intrinsic challenges, including soil disease, insect infestation, over-use of chemicals, and inefficient water use. Therefore, in collaboration with NARES in Arabian Peninsula countries, ICARDA developed IPPMs to institute improved greenhouse management techniques to minimize the use of chemical pesticides, increase plant growth, and decrease the spread of fungal infection and other diseases.

In Yemen, IPPM methods included soil solarization, soil mulching, mechanical removal of infested plants, yellow sticky traps for insects, bio-insecticides, insect-proof netting on openings and cooling pads, as well as insect-proof nets over greenhouses. The implementation of the latter methods reduced the number of chemical sprays needed for the

plants (number of sprays decreased by 38%, from two sprays compared with 18–22 sprays without IPPMs). Downy mildew also decreased, as did nematode infestation (down to 26% from the control of 47%).

In Kuwait, soil solarization alone, under drip irrigation, provided effective weed and nematode control while increasing tomato yields by 50%.

Soilless production

Because water scarcity in the Arabian Peninsula makes it impossible to have enough water for high-yield high-value crops even in optimal conditions, ICARDA has also worked to research and implement soilless techniques. Vertical cultivation for high-value produce (including herbs, green vegetables, or fruit) involves using a tower of interlocking stackable Styrofoam pots with drainage holes. Hydroponics of tomato plants in the United Arab Emirates (UAE), for example, showed that 120 m^3 of water were saved for each ton of tomato compared to conventional soil systems.

Additionally, upgrading a hydroponics system by adding an automatic controller for nutrient solutions increased yield and water productivity by 11% to 50% in the UAE and Oman.

Cooling systems challenges

Studies in Qatar, Oman, and UAE showed that water for cooling exceeded water for crop production anywhere from two to six times (the range gap due to the growing season). For example, for tomato crops grown in Ras Al-Khaimah Station (UAE) during the 2014/2015 season, the cooling system consumed over 200% of the water needed by the tomato crops themselves. To address such discrepancies and increase water-use efficiency, ICARDA introduced two approaches: net houses and the use of solar energy to enhance cooling system efficiency. Net houses generated similar yields to their cool greenhouse counterparts, even though the former were in production for 8 months of the year compared to the year-round "season" of conventionally cooled greenhouses.

To minimize insecticide use, maximize water efficiency, and produce high-quality yields, IPPM offers a way forward for creating productive protective agricultural environments that can better provide food and income security in the Arabian Peninsula.

Adoption of feed production using manual machines in Yemen

With funding from AFESD and IFAD, ICARDA feed block technology offers a practical and cost-effective solution to feed shortages and low livestock productivity.

Agriculture is a major sector of the national economy of Yemen, where livestock is estimated to contribute about 20% to agricultural GDP. Water scarcity and feed shortage can limit livestock production, however, so ICARDA and NARES in Yemen have collaborated to promote feed block technology. A cost-efficient method to take agricultural by-products and crop residue to make feed blocks, they are easily made with basic training and can be done by family farm labor.

Feed blocks made in this manner conserve water resources because they reduce crop waste, provide a balanced diet for the animals which can be further supplemented by added nutrients if necessary, and have a long shelf-life, which is useful in case of extended famine or other adverse conditions. Another advantage is that the machine developed for this project is simple compared to its electric expensive counterparts. The basic feed block machine can therefore be created and distributed locally.

Because of Yemen's civil war, training has taken place in Qatar and in Oman, so that the technology can be taught and disseminated in Yemen's rural areas. Those farmers already reached by the project have given positive

feedback on the technology, particularly since it supplies a ready source of food for their ruminants and other livestock in a time of crisis.

Development and expansion of sustainable date palm production systems

An ICARDA-led research project funded by the Gulf Cooperation Council (GCC) improves date palm crop management, creates and transfers best-practice technologies, conserves and further develops date palm germplasm, and reinforces the capacities of national researchers and farmers.

A key commodity throughout the Arabian Peninsula, date palm is an important agricultural staple, a source of feed and fuel, and a building material. To increase its productivity in the Arabian Peninsula, ICARDA worked to improve production methods, including the following:

- Implementing and expanding liquid pollination. By-hand pollination of date palms has traditionally been expensive, time-consuming, and labor intensive. Spraying palm trees with a pollen solution via hose, by contrast, is a cheaper and equally effective method compared to conventional pollination methods. In fact, because production costs decreased significantly, the value of production per ha increased by almost 50% in some cases.
- Introducing subsurface irrigation maximized date palm production. In a well-implemented system, subsurface irrigation reduces water loss and run-off while providing weed control. The precise and uniform delivery of water also improves crop yield.
- Decreasing drying times in polycarbonate chambers (by typically 4–5 days) reduced labor costs and the amount of dust in storage chambers, providing cleaner fruit.
- Promoting integrated pest management (IPM) as an alternative to chemical pesticides which cause damage to the local environment and its human, flora, and fauna populations. ICARDA promoted the use of bio-pesticides and other more natural options. The organic pesticide, Coragen, gave promising results, as did three bio-pesticides employed in Saudi Arabia: matrin (0.5% solution); paraffin oil; and abamectin with sulfur (1.8%). The use of trichogramma – a miniscule predatory wasp that can feed on over 200 insectisoids – is also being explored as an option.

As the project moves on to the next stage of development (2018–2022), ICARDA and its partners hope to work on further management organization, water efficiency, and IPM options, particularly combating red palm weevil proliferation.

ICARDA is working with national partners to raise the productivity of date palm.

IMPACTS ACROSS THE DRY AREAS

Highlands Regional Program

With Afghanistan's Ministry of Agriculture, Irrigation and Livestock, ICARDA is promoting village-based seed enterprises for rural women.

Optimizing a region's existing strengths and resources is part of what ICARDA does best. In Afghanistan, a village-based seed enterprise provided the means for women – often marginalized in rural farming areas – to contribute to their communities, take on leadership roles, and learn about sustainable agriculture practices. Bayesian analysis in the region provided an evidence-based analysis for better understanding the seed variety preferences and needs of local farmers. Finally, to meet food security needs in Iran, ICARDA set up demonstration areas throughout local farm regions to promote and disseminate conservation agriculture techniques and technologies.

Empowering women to enhance agricultural productivity

Village-based Seed Enterprises (VBSEs) are a means for women – often marginalized in rural farming communities – to contribute to their communities, take on leadership roles, learn about improved agricultural methods, and perhaps most importantly, feel the satisfaction of empowerment.

While women make up over half of the agricultural workforce in Afghanistan, they are nevertheless marginalized by the confines of the deeply patriarchal cultural system. These strictures make it difficult, if not impossible, for them to gain access to land, credit, or other opportunities. As one of those agricultural domains, seed production is considered a male role, thus exacerbating the persistent and concerning gap between the demand and supply of improved seed varieties in Afghanistan.

Recognizing the missed opportunity in potential income, increased productivity, and food security, ICARDA and the Afghanistan Ministry of Agriculture, Irrigation and Livestock (MAIL), launched VBSE development programs to engage women in farming activities and improve the cultivation of certified seeds.

The initiative included capacity-building programs, engaging both men and women, and training in business administration and management as well as the day-to-day production aspects of seed production, including cleaning, chemical treatments, labeling

and storage, and quality testing. Training also included courses on land preparation, optimal planting dates, seeding rates, fertilizer application, pest and disease management, irrigation, and seed certification and marketing.

Machinery – and training on it – was also provided to ensure successful seed production and included tractors, threshers, seed processing units, and seed drills. The program has been a success: by using the same resources, certified seed production by women-led VBSEs increased by 50% compared to men-led VBSEs in 2016.

Bayesian analysis improved legume varieties

Bayesian analysis is a systematic statistical means that can harness the data of previous on-farm trials to better understand how to make the genetic selection process more efficient in creating improved crop varieties.

While legumes are vital to meeting the nutritional needs of Afghanistan's population, their uptake as an agricultural product and their harvest yields remain low under farmers' conditions. As a result, ICARDA and Afghanistan's Ministry of Agriculture, Irrigation, and Livestock (MAIL) collaborated on a series of demonstration on-farm trials in 2009–2012 throughout three provinces to showcase improved seed varieties and best agronomic practices. Using that data to refine the means by which improved varieties are created, the method provides an empirical and evidence-based path towards agricultural breeding.

Up until recently, the data from such trials would be largely underutilized, if not entirely ignored. Much like designing a new drug and not using any clinical trials data that came beforehand, such an approach neglects to build on previous successes and failures. Thus, because farmers' preferences heavily influence what they plant and how they approach agro-technology methods – thus throwing more random variables into the process – the Bayesian approach seemed a more appropriate way to analyze the data.

The yields of the demonstrations were compared with the yields of farmers growing local varieties with local agronomic practices. The datasets for 2012 were evaluated to compare the seeding and agro-technologies employed for productivity and risk, while the data from 2009 to 2011 were used to establish variance parameters for the analysis.[2]

In this case, Bayesian analysis was used to calculate the probability distribution of various parameters to refine and identify accessions' potentials and to predict the genetic gain from crossing particular genotypes to achieve desired traits – for example, high-yielding wheat with drought tolerance.

Using empirical evidence to inform the iterative process of breeding selection further validates the evidence-based grounding of crop breeding and builds on the breeding successes (or failures) to improve uptake and productivity.

Promoting Conservation Agriculture to enhance mung bean production in Afghanistan.

[2] Singh, M. (2017). "Increasing yields from improved chickpea and mung bean varieties in Afghanistan." Retrieved from www.icarda.org/dryWire/increasing-yields-improved-chickpea-and-mung-bean-varieties-afghanistan

IMPACTS ACROSS THE DRY AREAS

Tackling food and nutrition security head-on in Iran

The Government of Iran is funding and collaborating with ICARDA on a new initiative to increase the country's rain-fed wheat, barley, and chickpea production by over 25% during the next five years.

Food insecurity currently affects 49% of households in Iran, including 67% of children, and 65% of the elderly, according to a recent study by the Ilam University of Medical Sciences.

Additionally, harsh farming terrains – made only more so by the effects of increasing climate change – and low productivity in the agricultural sector have exacerbated the problem. While the country's rural areas depend heavily on the agricultural sector, the latter's share of GDP has decreased significantly in the last two decades.[3] According to FAO, the country's food security challenges include low self-sufficiency in major staple crops and poor access to food in rural communities.[4]

During the 2016–2017 growing season, the collaboration established 10 innovation/demonstration platforms over 4,800 ha. These 'dissemination farms' were created across four agro-ecological zones, including cold, moderate, and warm climes (in East Azerbaijan, Kurdistan, Kermanshah, and Lorestan).

The platforms are agro-eco specific to each region and aim to demonstrate improved seed varieties and agro-technology systems that will promote conservation agriculture. The approaches include exploring seed planting depth, zero-tillage methods, crop rotation, integrated pest management, effective fertilizing/nutrition, weed and disease management, and improved cultivation and harvesting methods.

Increasing farmers' access to, and knowledge of, high-quality varieties of wheat, barley, and chickpea that can thrive in heat, frost, and drought, and are resistant to diseases, is vital for sustainable agriculture in Iran and the wider region.

ICARDA has partnered with the Government of Iran to raise the productivity of chickpea to strengthen national food security.

[3] ICARDA. (2016). "ICARDA and Iran to boost food and nutrition security." Press release, retrieved from www.icarda.org/sites/default/files/PressRelease-Iran-Agreement.pdf
[4] FAO, Iran, www.fao.org/iran/en/

Central Asia and Caucasus Regional Program

The CACILM II Knowledge Management initiative, funded by IFAD, holds a field day in southern Kazakhstan to promote the direct sowing of winter wheat.

The Central Asia and Caucasus (CAC) face multiple challenges: the increasing effects of climate change to a region that already receives sporadic rainfall; overexploited landscapes and depleted soil; low agricultural productivity; and food insecurity.

ICARDA is working throughout the CAC to disseminate improved wheat varieties, as well as developing sustainable practices that will optimize the region's agricultural strengths. Closing the yield gap, increasing sustainable land management practices, and improving cultivar adoption and dissemination will further food and economic security throughout the area.

Developing resilient crop varieties

Yellow rust fungus, also called stripe rust, is an incredibly destructive crop disease in the CAC region that can substantially devastate the harvests of susceptible wheat crops. ICARDA and its partner organizations have worked to distribute resilient varieties of winter wheat, among other crops, to increase the productivity of the region's agricultural systems.

Farmers in the CAC face challenges from multiple fronts: increasing effects of climate change to a region that already faces sporadic rainfall; depleted soil; low agricultural productivity; food insecurity; wheat disease variants that have adapted to higher temperatures; and a bottleneck in distribution that has stymied the dispersal of yellow rust-resistant varieties.

Fighting yellow rust in Uzbekistan and Tajikistan

With funding from the Russian Federation and CGIAR Research Programs 'WHEAT' and 'Dryland Systems,' ICARDA worked with local partners to accelerate the adoption of yellow rust-resistant winter wheat in Uzbekistan and Tajikistan. Planting resistant crops is significantly more cost-effective than the use of fungicides, which are prohibitively expensive for smallholders and can often have unforeseen ecological effects.

The national institutions promoting the work are the Kashkadarya Research Institute of Breeding and Seed Production of Grain and Leguminous Crops, the Uzbek Research Institute of Plant

IMPACTS ACROSS THE DRY AREAS

A training on wheat improvement in Qarshi, Uzbekistan.

Industry in Uzbekistan, the Tajik Academy of Agricultural Sciences, and the Administration of Bobojon Gafurov district in Tajikistan.

Over 30 winter wheat varieties originating from improved germplasm provided by the International Winter Wheat Improvement Program (a Turkey–CIMMYT–ICARDA joint collaboration) have been released in the region. In recent years, adoption of yellow rust-resistant varieties has significantly increased, with Uzbekistan in particular increasing its rust-resistant wheat production, reaching 40% cultivation of its total wheat area.

Stress tolerant varieties of cereals and legumes in Tajikistan and Uzbekistan

In collaboration with farmers in the Aral Sea Action Site in Karakalpakstan and Khorezm provinces in Uzbekistan, and with financial support from the Russian Federation and 'WHEAT' and 'Dryland Systems,' ICARDA's teams evaluated 150 wheat genotypes at 2 and 4 cm seeding depths respectively. The seeding at 4 cm yielded higher harvests as the depth protected crops from frost damage.

Crops – including winter wheat, spring wheat, chickpea, and mungbean – were also evaluated for tolerance to frost, heat, and salinity in CRP Dryland Systems action sites. Winter wheat–mungbean and winter wheat–potato crops were successfully implemented in the Aral Sea Region, as well as the Fergana Valley in Uzbekistan and the Sugd province of Tajikistan. Over 100 farmers were impacted favorably by the cultivars and improved practices, increasing soil health, family nutrition, and income production potential.

Addressing wheat yield gaps

With financial support from the Russian Federation, ICARDA analyzed 18 sites in Central Asia – encompassing the full range of agro-ecological zones – to determine how to address the gap between the area's potential wheat yield and its low productivity.

Despite the large growth potential in agriculture characterized by high crop diversity and farming traditions, productivity in Central Asia is low. A variety of reasons explain the latter: land erosion; overgrazing; over-irrigation leading to increased soil salinity; increasing global climate change effects that exacerbate droughts, frosts, and high temperatures; and poor land management. Closing the yield gap is key to addressing regional food and economic insecurity.

Throughout 18 sites of CAC – in Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan – crop growth parameters and actual yields in farmer and experimental fields were collected. CROPSYST modeling analysis for each of these 18 sites identified potential interventions for the best use of a location's agro-ecological characteristics to achieve highest yields:

One of the innovations ICARDA is promoting to raise wheat production in Central Asia is raised-bed planting.

- In the case of early sowing, pre-sowing irrigation and nitrogen-level management interventions would be applied to the rain-fed (spring) wheat production in Kazakhstan and Tajikistan – CROPSYST model results demonstrated an increase of 158% in farmers' harvests while the experimental stations' performance improvement ranged from 16% to 110%.
- In irrigated sites, salinity management, optimum irrigation, and nitrogen management could potentially increase farmers' yields from 36% to 182% under model-based interventions, with experimental station yields potentially improving by 5% to 47%.

As water scarcity is an ongoing reality in the region, the analysis also determined that targeted crop breeding, crop rotation with alfalfa, irrigation, and nitrogen management, and improved seed varieties that are drought and heat resistant could further lower the yield gap.

Combating land degradation

The Knowledge Management in Central Asian Countries Initiative for Land Management (CACILM), funded by IFAD, was launched by ICARDA and its partners to develop and out-scale sustainable practices capable of optimizing productivity in the region's varied agro-ecosystems. The project successfully completed in 2016.

Four agro-ecosystems make up the agricultural landscape of the CAC region: irrigated, which covers a relatively small area (8 million ha) but nevertheless provides the region's highest agricultural output; mountain, covering 90% of Kyrgyzstan and Tajikistan; rangelands, which cover most of the land resources of Kazakhstan, Turkmenistan, and Uzbekistan; and rain-fed.

Land degradation and climate change are two of the region's most significant challenges. The former is a result of a complex set of factors,

IMPACTS ACROSS THE DRY AREAS

but can be attributed to the overexploitation of the land, unsustainable and inappropriate agricultural practices that are remnants of top-down farming strategies implemented during the Soviet era, deforestation, poor watershed management, the environmental effects of mining, forest degradation, and natural disasters.

These in turn have created erosion, salinization, and water-logging, which combined with the aggravated effects of climate change – including hotter summers and colder winters with erratic precipitation, and increasing desertification – have led to decreased agricultural productivity. It's estimated that agricultural yields have declined by 20% to 30% in the last two decades, with soil salinization alone accounting for USD 2 billion in losses.[5]

CACILM set up demonstration sites across the four regions of the five nations in the CAC to test selected sustainable land management (SLM) techniques applicable to the respective four main agro-ecological systems of the region. The project's mission was not only to demonstrate these techniques but to promote them region-wide to decision makers, local farmers and authorities, and the media. Over 90 SLM practices were synthesized from available resources, including research institutions and farmers' knowledge – with 2–3 demonstration sites maintained in each of the five countries – creating a clearinghouse of resource and knowledge to be shared and scaled-out for further implementation.

The second phase of the project, CACILM II, seeks to build on the accomplishments of phase I by enhancing rural livelihoods, restoring land productivity, and delivering solutions to make the CAC region more resilient to climate change.

Similarity maps, which ICARDA has undertaken in other regions, have also been developed to identify where selected agricultural interventions could be potentially implemented and serve as targeted investment and out-scaling areas to increase productivity and improve livelihoods.

Gullies caused by water and wind erosion in Tashkent Province, Uzbekistan.

[5] ICARDA. (2016). "CACILM II Sustainable Land Management Practices in Central Asia." www.cacilm.org

South Asia and China Regional Program

With NARES partners throughout South Asia, ICARDA is promoting nutritious and climate resilient pulses to rural communities.

Pulses are versatile crops that are a crucial staple in South Asia. Yet, India, Bangladesh, and Nepal all run a deficit in providing them for their populations. A nutritious pulse, grasspea, has not been widely cultivated because traditional varieties have had high levels of toxicity. To address these problems, ICARDA and NARES have worked to increase lentil production – using otherwise fallow rice fields; released new, less toxic varieties of grasspea varieties; and embarked on a study to examine the release and uptake of improved cultivars of lentils. In addition to addressing the ongoing need for more resilient harvests, the study also sought to understand the reasons for uptake, or lack thereof.

The adoption and impacts of new lentil varieties in South Asia

With partners in South Asia, ICARDA has continued its research in improved lentil varieties, of which three new genotypes were released in 2016 by Bangladesh, India, and Nepal.

Lentil is the single most important pulse crop in South Asia. Considered the 'poor man's meat' because it has high protein concentrations, as well as high levels of vitamins and macro- and micro-nutrients, it is crucial to the staple diet of the poorer segments of Bangladeshi, Indian, and Nepalese societies.

IMPACTS ACROSS THE DRY AREAS

Bangladesh, India, and Nepal have released a number of varieties from ICARDA's genebanks, some of which are particularly rich in iron and zinc. These have been particularly important, as insufficient nutrition and iron deficiencies are responsible for 'hidden hunger' in these communities, which lead to underweight and anemic pregnant women, and growth impairment and stunting in young children.

In conjunction with Virginia Tech University (USA), and Bangladesh Agricultural University, ICARDA carried out a study examining the introduction, adoption, and diffusion of lentils throughout the country since the first released variety in 1991.

The study was carried out using a combination of expert opinion, household surveys, and DNA fingerprinting. The DNA fingerprinting showed that improved varieties now cover 99.37% of the total lentil growing area in the country, with 45.4% showing varieties released after 2005. Since 1991, 15 improved lentil varieties have been released in Bangladesh, of which eight varieties (which cover 98.24% of the cultivation area) contain genetic material that originated from ICARDA's cultivars.

An Indian woman grinding grasspea. In collaboration with national partners like ICAR, ICARDA is developing low toxin grasspea varieties.

A slower uptake and diffusion of post-2005 varieties was blamed on consumer-related preferences (taste). Interestingly, breeders focused primarily on yield and agronomic advantages when choosing varieties, while farmers focused on the cooking and consumption qualities of the lentil types.

Regardless, the adoption of improved lentil varieties has brought greater overall production in the country and helped Bangladesh to achieve higher yields and household incomes, saving an estimated USD 25.8 million in foreign exchange per year, due to a decrease in foreign imports necessary to fill the demand deficit.

This initiative was funded by ACIAR, OFID and Harvest Plus.

Decreasing grasspea toxicity and increasing its agricultural uptake

A versatile crop that can withstand extreme heat, drought, and is resistant to insect infestations, grasspea has nevertheless been discouraged as a cultivation crop throughout South Asia because its long-term consumption can be dangerous for human health. Improved cultivars are making this hardy pulse an increasingly viable option.

Grasspea is a vital subsistence crop for resource-poor farmers in much of South Asia. A versatile pulse, it's often planted as a relay crop, can be used for human food, animal feed, and can enrich soil health by re-balancing nitrogen and carbon. Additionally, it is a source of protein and one of the cheapest pulses on the market, making it more accessible to low-income consumers.

Widely grown throughout Bangladesh (covering over 300,000 ha), and in over five states in India (in about 650,000 ha), it nevertheless faces reluctant uptake by farmers and landowners. This is primarily because its long-term consumption (as in the case of famine), can

lead to brain damage and paralysis, due to the presence of the neuro-toxin ODAP in traditional grasspea varieties.

In collaboration with the Indian Council of Agricultural Research (ICAR), and funding from India's National Food Security Mission (NFSM), the OCP-Foundation and Harvest Plus, ICARDA has developed and begun to distribute low-toxin or toxin-free grasspea varieties, which have also increased harvest yields (up to 43% from traditional varieties).

Bangladesh recently released four grasspea varieties, two of which were supplied by ICARDA's genebanks (Barikhesari-3 and Barikhesari-4). In India, improved varieties have been distributed to 13,000 farmers in 868 villages in five states. A total of 19,000 farmers including 4,867 women farmers, were trained in improved production and detoxification practices, storage, and other value-added methods.

It is hoped that all of these interventions will further encourage the uptake of this hardy crop and provide increased stability to the food security of India, Bangladesh, and their South Asian neighbors.

Farming fallow land with improved agro-technologies

Cultivating land left fallow after the rice season is boosting lentil production across South Asia – helping to reduce import dependence, strengthen food and nutrition security, and increase farmer incomes.

Pulses make up a crucial part of the diets of the people of India, Bangladesh, and Nepal, yet all three countries run a deficit in providing them to their populations. For example, while India alone consumes one-third of the global output of pulses, and is also its largest producer, the country is also the world's largest importer of the product. The dilemma hits at the core of one of South Asia's food security challenges: housing

Farmers who cultivated lentil on land left fallow after rice production have seen an increase in their income.

the world's most densely populated area while having only one-twentieth of the world's land.

To address the problem, ICARDA and NARES partners in India worked to cultivate the fallow fields that follow a rice harvest and leave so much land – over 14.3 million ha in South Asia – empty after the rice season. By using improved relay cropping techniques, as well as developing early-maturing, high-yielding, and disease-resistant varieties, lentil production increased significantly throughout the area.

Improved agro-technologies included the application of lime and boron in acidic soils, a higher seeding rate (50 kg/ha), rhizobia and fungicide seed treatments, pre-planting watering, and applications of insecticides and fertilizers. Additionally, the project included capacity building for farmers, extension personnel, and regional scientists to ensure successful technology transfers and large-scale training for lentil and seed production in order to improve uptake of the techniques.

Lentil production increased significantly, improving food sources for rural farm families as well as providing additional income. ICARDA continues to work with the ICAR, the Bangladesh Agricultural Research Institute, and the Nepal Agricultural Research Council to promote further uptake of effective relay cropping.

Financial support is provided by NFSM, OCP-Foundation, and IFAD.

CAPACITY DEVELOPMENT

A core strength: as the organization adjusts to the challenges and opportunities presented by decentralization, ICARDA has continued to carry out one of its core missions.

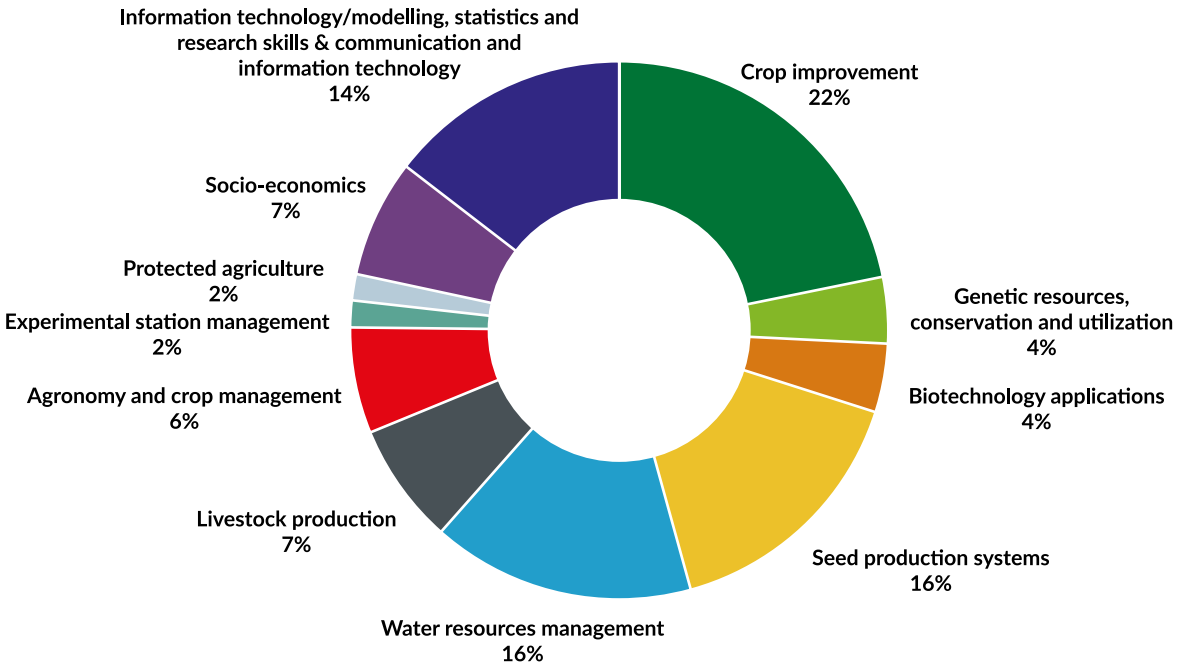
ICARDA researchers and scientists work closely with NARES and local research institutions and universities to ensure that trainings are ongoing and reach over 50 countries.

From its founding in 1978, ICARDA has consistently engaged in capacity development throughout its partner countries. As illustrated in the pie chart below, its trainings have covered a wide range of topics. However, crop improvement (22%), seed production systems (16%), and water resource management (16%) continue to dominate the organization's thematic development areas.

In 2016, some 712 trainees benefited from training courses that took place throughout the dry areas, including in Morocco, Tunisia, Lebanon, Turkey, Jordan, and Egypt. ICARDA also provided training for 37 MSc and PhD students and individual non-degree training for seven researchers.

A two-week course in Amman, Jordan, for example, was conducted by ICARDA and made possible by funding from the Arab Fund for Economic and Social Development (AFESD) and the Islamic Development Bank (IDB),

ICARDA Capacity Development Activities by Thematic Research Areas 1978 to 30 April 2017



in collaboration with the National Center for Agriculture Research and Extension (NCARE). Attendees participated in an extensive agenda that covered sustainable livestock management in the rangelands and dryland systems, addressing practical and theoretical aspects.

ICARDA also organized two courses on 'Field Inspection Methodologies and its Application' and 'Seed Quality Testing' for participants from the National Seed Administration (NSA) of Sudan. The course was organized in collaboration with the Central Administration for Seed Certification and Testing (CASC) in Cairo, Egypt, and offered an extensive program on seed quality control – from production to procession, distribution to marketing – a crucial part of successful sustainable agriculture.

Under Japan's International Cooperation Agency (JICA) Iraq Program, ICARDA coordinated a range of courses in Amman, Jordan: Geographic Information Systems; Water management for water used efficiency; Supplemental irrigation; Adoption and impact assessment of water policies; and Statistics design, data analysis and biometrical techniques in agricultural research.

Under the JICA Afghanistan Program ICARDA carried out the following courses: Soil analysis, Soil chemistry, Soil physics, and Soil fertility in Amman, Jordan; Seed processing and storage in Terbol, Lebanon; Genebank and germplasm in Beirut, Lebanon; Cereal crops breeding in Terbol, Lebanon; Seed health testing, also in Terbol; Extension methods (contemporary approaches to extension) in Cairo, Egypt; and Seed production, in Terbol.

Other capacity building programs presented throughout ICARDA's partner countries, included:

- 'Biometrics,' in Rabat, Morocco
- 'On farm water management,' in Terbol, Lebanon
- 'Crop protection and agricultural statistics,' in Oman
- 'Salinity management,' in Cairo, Egypt
- 'Ensuring the continuum between conservation and utilization through strengthening pre-breeding activities,' in Rabat, Morocco.

COMMUNICATIONS

Communicating for development

Communication is an integral part of ICARDA's research for development agenda: it highlights evidence and impact; promotes the Center's mission, solutions, and technologies; and encourages political and financial stakeholders to invest in agricultural research. Last year, ICARDA's Communication, Documentation and Information Services (CODIS) utilized multiple platforms to strategically communicate with target audiences.

Website and social media presence

ICARDA's website was continually enhanced, including new responsive versions that allow access via multiple devices (laptop, tablet, mobile phones). New visuals, more attractive layouts, and over 110 articles were also continually uploaded. Last year saw growing interest in ICARDA's online platforms: the organization's website received over 10,000 unique visits per month, its Twitter followers number over 11,000, and it now has over 15,000 followers on Facebook.

Publications

ICARDA produced a broad range of scientific and corporate publications, including two editions of Science Impacts, a research synthesis series that highlights the impacts of ICARDA's research on the ground in rural communities; brochures that highlighted rewarding partnerships with major donors like the Asian Development Bank; and in-depth scientific reports on subjects ranging from conservation agriculture to crop variety release and seed markets. In total some 46 publications were produced in 2016. They can be found online at www.icarda.org/publications-resources

Media coverage

ICARDA research activities and impacts were covered in over 100 reputable international, regional, and local media, including Voice of America, Nature, and Reuters.

Support at international events

Communication activities in 2016 also included communication support at major international events to capture new learning and rapidly disseminate information to global audiences, including at COP22 (see page 12) and the International Conference on Pulses (see page 16).

E-newsletters

ICARDA continued to keep partners and target audiences regularly informed about new developments at the Center and the progress of its research projects and initiatives. In addition to its monthly news digest 'What's New at ICARDA,' CODIS disseminated two editions of 'DryWire,' a newsletter that summarizes and synthesizes ICARDA research results.

Financial information

Statement of Activity (US$ x 1000)

REVENUES	2016	2015
Grants (core and restricted)	40,149	52,141
Other revenues and gains	865	597
Total revenues and gains	**41,014**	**52,738**
EXPENSES AND LOSSES		
Program related expenses	39,635	52,332
Management and general expenses	4,746	5,216
Other losses and expenses	-	-
Total expenses and losses	44,381	57,548
Indirect costs recovery	(3,420)	(4,380)
Net expenses and losses	**40,961**	**53,168**
Net surplus/(Deficit)	53	(430)
Overall surplus/(Deficit)	53	(430)

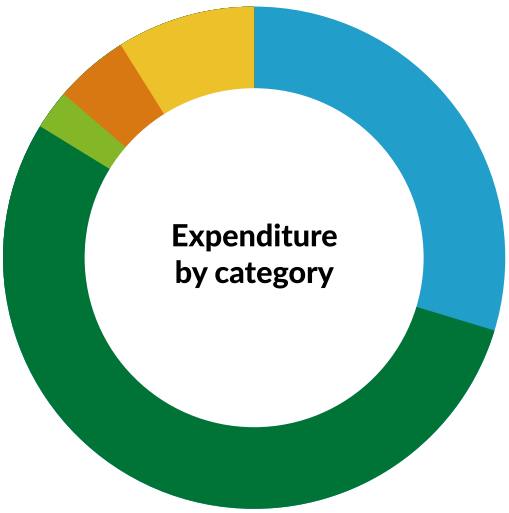
Statement of Financial Position (US$ x 1000)

ASSETS	2016	2015
Current assets	26,660	32,882
Property & equipment	2,231	2,733
Other assets	-	-
Total assets	**28,891**	**35,615**
LIABILITIES AND ASSETS		
Current liabilities	20,307	27,084
Long term liabilities	-	-
Total liabilities	20,307	27,084
Net assets = Reserves	8,584	8,531
Total liabilities and net assets	**28,891**	**35,615**

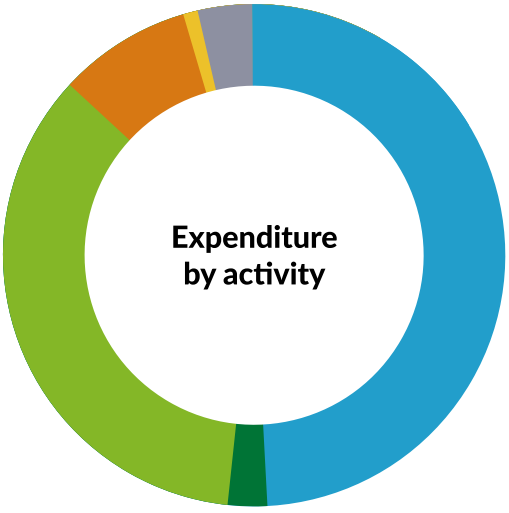
Statement of Grant Revenues (US$ x 1000)

DONORS	2016
Abu Dhabi Food Control Authority (ADFCA)	431
Afghanistan Ministry of Agriculture, Irrigation, and Livestock (MAIL)	1,334
African Development Bank through IITA	3,437
Arab Fund for Economic and Social Development (AFESD)	5,400
Australian Centre for International Agricultural Research (ACIAR)	1,420
Austrian Development Agency	211
Bill and Melinda Gates Foundation	214
CGIAR Fund	2,795
Eurasian Center for Food Security at Moscow State University (ECFS)	1,175
European Commission	943
Food and Agriculture Organization (FAO)	537
Germany	1,535
Global Crop Diversity Trust (GCDT)	3,154
Grains Development and Research Corporation (GRDC)	543
Gulf Cooperation Council (GCC)	575
HarvestPlus	208
India	1,036
International Crop Research Institute for Semi-Arid Tropics (ICRISAT)	1,325
International Food Policy Research Institute (IFPRI)	318
International Fund for Agricultural Development (IFAD)	1,144
International Livestock Research Institute (ILRI)	986
International Maize and Wheat Improvement Center (CIMMYT)	2,550
International Water Management Institute (IWMI)	526
Iran	390
Japan	508
Kuwait Fund for Arab Economic Development (Kuwait Fund)	513
Libya – Agricultural Research Center	800
OCP Foundation	581
Sudan	564
Syrian Arab Republic	268
United States Agency for International Development (USAID)	1,731
United States Department of Agriculture (USDA)	1,479
Miscellaneous	1,518
TOTAL	**40,149**

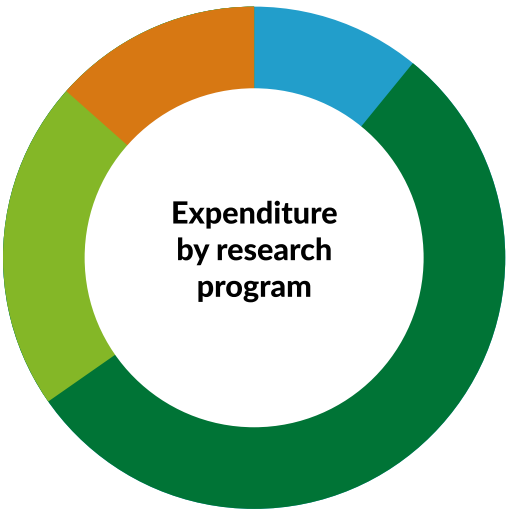
FINANCIAL INFORMATION



- Personnel Cost **29.66%**
- Collaborators, Supplies and Services **54.42%**
- Collaborators – CGIAR Centers **2.29%**
- Travel **4.74%**
- Depreciation **8.89%**



- Research Programs **49.11%**
- Research Support **2.61%**
- International Cooperation and Communication **35.28%**
- Corporate Services **8.69%**
- Decentralization Funding **0.78%**
- Management **3.53%**



- Integrated Water and Land Management Program (IWLMP) **10.88%**
- Biodiversity and Integrated Gene Management Program (BIGMP) **54.35%**
- Sustainable Intensification and Resilient Production System (SIRPS) **21.19%**
- CGIAR Research Programs Dryland Systems (CRP1.1) **13.58%**

Awards and honors

Dr. Mahmoud Solh (Center) receiving the FAO 70th Anniversary Commemorative Medal.

In 2016, ICARDA received several prestigious honors, including the **Khalifa International Award for Date Palm and Agricultural Innovation**, in Abu Dhabi, United Arab Emirates (UAE). The award highlights the importance of the date as a crucial regional commodity and as an example of sustainable agriculture going forward. The award was created by Sheikh Khalifa Bin Zayed Al Nahyan, president of the UAE.

ICARDA's former Director General, Dr. Mahmoud Solh, was awarded the **FAO 70th Anniversary Commemorative Medal**. Awarded by the UN's Food and Agriculture Organization, it recognizes the achievements of key stakeholders throughout the world who have helped FAO achieve its mission during the past 70 years. The honor recognized Dr. Solh's contributions to global food security, the alleviation of hunger and malnutrition, and the sustainable management of natural resources, all key to FAO's mission.

During the **10th Annual International Rangeland Congress (IRC)**, which took place in Saskatoon, Canada, in the summer of 2016, Dr. Mounir Louhaichi – a principal scientist specializing in range ecology and management research at ICARDA – was elected to the vice presidency of the organization. The IRC promotes the interchange of scientific and technical research on all aspects of the rangelands involving research, planning, development, management, education, and training.

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ICARDA varieties released

List of varieties released by NARS partners in 2016

CROP	VARIETY	PEDIGREE AND SELECTION HISTORY	COUNTRY	ADAPTATION AND KEY TRAITS
Durum wheat	Miki 3	Stojocri3//Bicre/Lukos4 ICD94-0994-C-10AP-0AP-2AP-0AP-9AP-0TR	Iraq	Resistant to LR, YR, and SR (except Ethiopian strains) and tan spot
Winter wheat	Altuğ	JAGGER/ITIJ -21LE-0LE-7LE-0LE -1E-0E 0P	Turkey	High yielding; yellow rust resistance
	Yuksel	OK81306/STAR CMS92W M00167S -17WM-05WM-015WM-010WM-3WM-0WM	Turkey	High yielding; good grain quality; yellow rust resistance
	Agruni1	TAST/SPRW//BLL/3/NWT/4/3013 TCI-02-440:-0AP-0AP-5AP-0AP-3AP-0AP	Georgia	High yielding, good quality and resistant to yellow rust and leaf rust
	Shumon	CADET/6/YUMAI13/5/NAI60/3/14.53/ODIN// CI13441/CANON TCI-02-417 -0AP-0AP-1AP-0AP-5A-0AP	Tajikistan	High yielding; satisfactory grain quality; resistant to yellow rust
	Gozgon	AGRI/BJY/VEE/AKLUA/4/3013 TCI-1972515: -0SE-0YC-0YE-20YE-0YE-1YE-0YE	Uzbekistan	
Barley	HB1963	PFC9215/ZHEDAR#1/SHYR1//OLMO/4/SCARLETT (ENSMEX 1 CEB 09-607)	Ethiopia	High yield, hectoliter weight, TSW, and extract; and low screening loss and acceptable protein content
	HB1964	RECLA 78//SHYRI/ GRIT/3/ATAH92/GOB	Ethiopia	High yield, hectoliter weight, TSW, and extract; and low screening loss and acceptable protein content
	Singitan (IB-ON-MRA08/09-26)	Carina/Moroc 9-75	Ethiopia	High yield; resistance to rust and net blotch, shoot fly resistance and low screening loss and acceptable protein content
	Assyia (INRA1793)	Alanda//Lignee527/Arar/3/Asal/4/AwBlack/Aths// Rhn-08/7/Man/4/Bal16/Pro//Apm/DwII-1Y/3/Api/ CM67/5/Gas/OreS/6/Atahualpa	Morocco	Naked barley; high yielding; moderately resistant to lodging; resistance to barley diseases; nutrient dense (high Fe and beta glucan)
	Chiffa (INRA1791)	LIGNEE527/GERBEL/3/BOY-B*2/SURB// CI12225.2D/4/BBSC/CONGONA	Morocco	Naked barley; high yielding; moderately resistant to lodging; resistance to barley diseases. Nutrient dense (high Fe and beta glucan; good for human consumption)
Chickpea	BRS Aleppo	FLIP02-23C (X99TH54: FLIP91-14C/FLIP90-27C)	Brazil	High yielding (≤3.5 ton/ha); good grain quality; field tolerance to *Fusarium* sp.; winter type; adapted to dry area
	Dhera	FLIP01-63C (X98TH30: FLIP93-55C/596231)	Ethiopia	High yielding; mechanical harvesting; tolerant to wilt–root rot complex and resistant to Ascochyta blight
	Hora	FLIP04-9C (X00TH50: FLIP98-52C/FLIP98-12C)	Ethiopia	High yielding; resistance to wilt–root rot complex and Ascochyta blight
	Merowe 2016 (Sheihk Mohamed)	FLIP03-50C (X99TH62: FLIP93-2C/FLIP94-115C)	Sudan	High seed yield and favorable environment; large seed weight; earliness
	Hudeiba 2016	FLIP03-59C (X99TH62: FLIP93-2C/FLIP94-115C)	Sudan	High and stable seed yield; large seed weight; earliness; *Fusarium* resistance
Lentil	Binamasur-10	ILL 7656	Bangladesh	Early maturing, drought tolerant
	Pusa Ageti Masoor (L4741)	ILL7617 x 91516	India	High yield (>14%); extra early (<100 days); biofortified with high iron (Fe) and zinc (Zn) content; resistance to powdery mildew and moderately resistance to Ascochyta and wilt
	RL4	ILL6037 x ILL8007	Nepal	High yield; biofortified with high Fe and Zn

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ACRONYMS AND ABBREVIATIONS

Acronyms and abbreviations

ACIAR	Australian Centre for International Agricultural Research
AFESD	Arab Fund for Economic and Social Development
APRI	Animal Production Research Institute
APRP	Arabian Peninsula Regional Program
ARC	Agricultural Research Corporation
BIGM	Biodiversity and Integrated Gene Management
CA	Conservation agriculture
CAC	Central Asia and Caucasus
CACILM	Central Asian Countries Initiative for Land Management
CANA	Conservation Agriculture for North Africa
CASC	Central Administration for Seed Certification and Testing
CCAFS	Climate Change, Agriculture and Food Security
CIMMYT	International Maize and Wheat Improvement Center
CODIS	Communication, Documentation and Information Services
CRP	CGIAR Research Program
CWANA	Central and West Asia and North Africa
EIAR	Ethiopian Institute for Agricultural Research
FAO	Food and Agriculture Organization
GDP	Gross domestic product
GeSTA	Geospatial Science, Technology and Applications
HR	Human resources
ICAR	Indian Council of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
IDB	Islamic Development Bank
INRA	Institut National de la Recherche Agronomique
INRM	International Resource Management
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated pest management
IPPM	Integrated Production and Protection Management
IRC	International Rangeland Congress
ISTA	International Seed Testing Association
IT	Information technology
IWLMEP	Integrated Water and Land Management and Ecosystems Program
JICA	Japan's International Cooperation Agency
LARI	Lebanese Agricultural Research Institute
MAIL	Ministry of Agriculture, Irrigation and Livestock
MENA	Middle East and North Africa
NARES	National Agricultural Research and Extension Services
NARS	National agricultural research systems
NCARE	National Center for Agricultural Research and Extension
NFSM	National Food Security Mission
NSA	National Seed Administration
NVRSP	Nile Valley and Red Sea
ODAP	Oxalydiaminopropionic acid
OFID	OPEC Fund for International Development
OPEC	Organization of the Petroleum Exporting Countries
RHEM	Rangeland Hydrology and Erosion Model
SAARC	South Asian Association for Regional Cooperation (SAARC)
SAC	SAARC Agriculture Centre
SIRPSP	Sustainable Intensification and Resilient Production Systems Program
SLM	Sustainable land management
TSW	Thousand seed weight
UAE	United Arab Emirates
USAID	United States Agency for International Development
VBSE	Village-based Seed Enterprises
WHEAT	CGIAR Research Program on Wheat
YASP	Young Agricultural Scientists Program

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Established in 1977, ICARDA is one of the 15 centers supported by the CGIAR. ICARDA's mission is to improve the livelihoods of the resource poor in dry areas through research and partnerships dedicated to achieving sustainable increases in agricultural productivity and income, while ensuring efficient and more equitable use and conservation of natural resources. ICARDA has a global mandate for the improvement of barley, lentil and faba bean, and serves the non-tropical dry areas for the improvement of on-farm water use efficiency, rangeland and small ruminant production. In Central Asia, West Asia, South Asia, and North Africa regions, ICARDA contributes to the improvement of bread and durum wheats, kabuli chickpea, pasture and forage legumes, and associated farming systems. It also works on improved land management, diversification of production systems, and value-added crop and livestock products. Social, economic and policy research is an integral component of ICARDA's research to better target poverty and to enhance the uptake and maximize impact of research outputs.
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