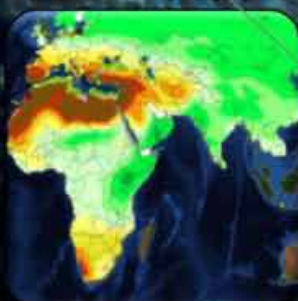


Review of agriculture in the dry areas
Caravan

**Coping with climate
change in dry areas**
Improved land management and
resilient production systems





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(Photo credit: Claudio Zucca)

Contributing to climate resilient agriculture in dryland agroecosystems

At the United Nations Climate Change Conference at Paris in December 2015, serious implication of climate change on food security, particularly in dry areas, was emphasized. Linkages between climate change, agriculture and food security were also discussed. These highlight the need for climate resilient agricultural systems, particularly in dryland areas, which make up 41% of the earth's surface and where more than 2 billion people live. An integrated approach is essential to sustainably increase agricultural productivity, reduce greenhouse gas emissions from agriculture, and build resilient production systems to improve livelihoods and protect natural resources. As estimated by the United Nation's Food and Agriculture Organization (FAO), food production must increase by at least 60 percent by 2050 to respond to the demand of the 9 billion people who are expected to inhabit the planet. Feeding these people amidst rapidly increasing temperatures, increased frequency and intensity of drought, erratic rainfall, floods, higher sea levels and the emergence of new pests and diseases pose a daunting challenge.

Reducing climate risks require changes in both agricultural technologies and approaches. Through its longstanding research and scientific innovations in dryland agriculture, ICARDA, along with its National Agricultural Research System (NARS) partners, has consistently developed knowledge and techniques for sustainably increasing agricultural productivity which are climate-resilient. When ICARDA started in 1977, its research focus was on climate variability in rainfed agriculture before climate change implications became apparent. These techniques provide practical solutions to protect rural communities from the serious climate change implications in dry areas. However, there is under-investment in agricultural research and development in rainfed agriculture. This needs to change and strategies for combating climate change implications in dryland agriculture need to be scaled-up.

This issue of *Caravan* showcases some of ICARDA's efforts of coping with climate change in dry areas with improved water land management and resilient production systems. These include initiatives in conservation agriculture which provide sustained production levels while conserving the ecosystems on which our entire food system is dependent upon. ICARDA continues to make significant contributions in the promotion of sustainable water land management approaches and technologies devised by researchers and farmers. Research studies have quantified the impacts of climate change on farm income and analyzed the risk minimization potential of weather-related index-based insurances. It is hoped that these research results will increase the confidence of agriculturists and inform their investment decisions in agriculture. They will also encourage evidence-based policy frameworks that will be supportive of both agricultural research and development.

ICARDA's GeneBanks play a crucial role in conserving and distributing genetic resources of cereals, food and feed legumes and pastoral species adapted to dry areas. Our Focused Identification of Germplasm Strategy (FIGS) program uses applied mathematics to address region-specific challenges and opportunities for maintaining genetic resources for sustainable agricultural productivity. ICARDA's innovations include developing improved crop varieties that are resistant/tolerant to climatic stresses. These contribute to improving food security and livelihoods of rural poor communities and reduce rural to urban migration.

Through these concerted efforts, ICARDA continues to promote and champion climate resilient agriculture in dryland agroecosystems to sustainably increase agricultural productivity, farmers' incomes, and enhance food and nutritional security.



*Mahmoud Solh
Director General, ICARDA*



Adaptation to climate change in the Ethiopian highlands: A holistic research approach to watershed development

Gondar in the Amhara region of Ethiopia during rainy season

(Photo credit: Claudio Zucca)

Climate change and land degradation are intricately interlinked. Addressing land degradation enhances farmers' ability to adapt to climate change.

During the peak of the rainy season, the landscapes of Gondar in the Amhara region of Ethiopia are covered with lush green vegetation making it too idyllic to imagine that there could be anything amiss. However, such conceptions quickly change upon meeting the local farmers and learning of their everyday challenges to live off agriculture. Land degradation and moisture stress have become major threats to their livelihoods. Their land is no longer as productive as it used to be; rainfall is neither predictable nor sufficient; and access to alternative sources of water, while improving, is still limited. These, combined with other challenges including access to sufficient credit and agricultural inputs have resulted in reducing household income in the area.

The Gumara-Maksegnit watershed, located 35 km south-east of Gondar, serves as the main research site for the Austrian Development Agency (ADA) funded ICARDA-ARARI (Amhara Regional Agricultural Research Institute) project on reducing land degradation and farmers' vulnerability to climate change in the highland dry areas of north-western Ethiopia. The project operates on the premise that rural communities depend on a variety of livelihood strategies to meet their basic needs - these include growing crops, raising livestock, and a pursuit of alternative income generating opportunities. Adopting a holistic approach (as detailed in Figure 1) allows the project to appreciate the complexity of the challenges and seek solutions through multiple interventions. The approach in combination with watershed level assessment and modelling of natural resources provides a comprehensive environment to undertake Research for Development (R4D) activities.

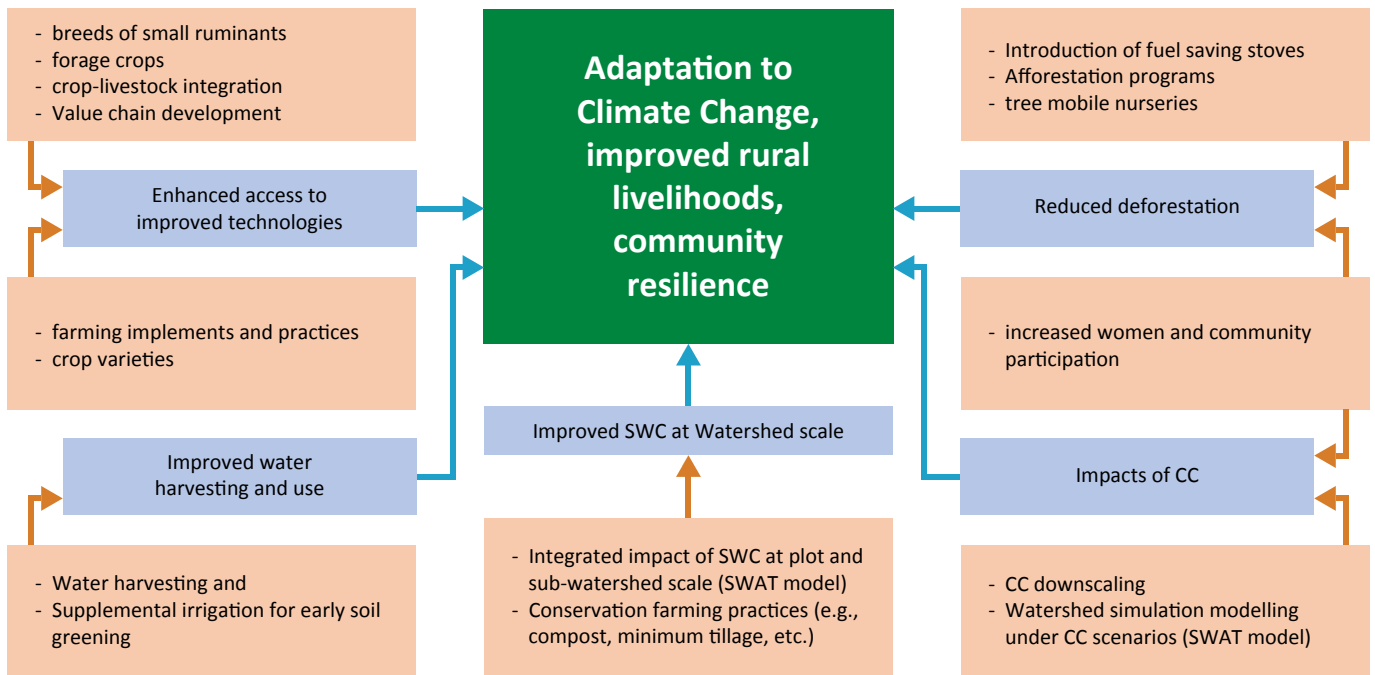


Figure 1: A holistic approach for adaptation to climate change. Ziadat F., Bayu W. (Eds), 2015. "Mitigating Land Degradation and Improving Livelihoods: An Integrated Watershed Approach". Routledge. Taylor & Francis Group. 262 pp.

Soil loss measurements ring alarm bells

Participatory surveys conducted in the area indicate that farmers point to deforestation as a major driver of land degradation. Their observations are validated by ICARDA's remote-sensing based studies, which showed that around 30 percent of watershed forests were lost between 1986 and 2007. Major parts of the forests were replaced by crops (mostly teff, sorghum, chickpea, faba bean, and others) and pastures. The remaining ones are increasingly under pressure as a source of firewood. Deforestation, however, is not the only cause of land degradation in the area. A combination of bio-physical and socio-economic challenges including inappropriate farming practices, unsustainable grazing management, inefficient rainwater management, climate variability - particularly increased frequency of extreme events, and lack of alternative income generating opportunities also contribute to the current state of degradation.

Extensive soil erosion is by far the greatest manifestation of land degradation in the area. Even on moderate slope conditions the annual soil loss during the rainy season exceeds 10 t/ha, and often is as high as 20 t/ha or more. This is equivalent to throwing away about two shovelfuls of fertile topsoil per square meter, every year. The deleterious effects of climate change and land degradation on the sustainability, viability and resilience of livestock and cropping systems and thus on people's livelihoods would be immense if strategies to adapt to climate change and halt land degradation are not put in place.



Photo 1: Measurement infrastructure to quantify and monitor the impact of soil conservation structures (stone bunds) on soil erosion (Photo credit: Claudio Zucca)

Developing improved management options at the watershed scale

In line with the holistic approach the project introduced a number of out-scalable adaptation strategies in the watershed during both the first (2009-2012) and second (2013-2016) phases of the project to reduce farmers' vulnerability to climate shocks. With additional support from CGIAR Research Program on Water Land and Ecosystems (2012-2016) the project is currently using hydrological and bio-economic models to assess the impact of climate and land use change on watershed processes, as well as strategies to improve women's livelihoods.



Photo 2: Several improved crop varieties and farming practices are being tested and demonstrated to farmers (Photo credit: Claudio Zucca)

During the first phase of the project, resources and factors constraining livelihoods were appraised, erosion hotspots were mapped, along with land cover changes and deforestation dynamics, and participatory processes were launched to prioritize research activities and to promote action to mitigate soil erosion. As an immediate result of this, technical interventions (stone bunds, terracing, permanent grass vegetation strips, and afforestation) were implemented by the community in collaboration with scientists.

During the second phase the performance of several practices was evaluated and their degree of adaptation to the site conditions tested, with the aim of designing technical packages accepted by the farmers and applicable in different environmental conditions within the watershed (from upstream to downstream). Experimental activities addressed the following four priority areas:

- Assessing the actual impact of the soil conservation measures (stone bunds) commonly adopted in the region on runoff and erosion, by means of a cutting-edge measurement infrastructure at both plot and sub-watershed level (Photos 1 & 3);
- Developing water harvesting and supplemental irrigation techniques to increase farmers' resilience to climate variability;
- Enhancing land productivity through improved crop varieties and farming practices, including conservation agriculture (Photo 2);
- Enhancing livestock productivity through improved management, better crop-livestock integration, and value chain development.



Photo 3: Automatic equipment to measure soil and nutrient losses located at the outlets of treated and untreated sub-watershed (Photo credit: Claudio Zucca)

This field work was supported by a thorough participatory research conducted to identify farmers' perception about their vulnerability to climate variability, and their willingness to adopt improved management options.

Mainstreaming gender considerations

All the researchers engaged in the project were trained and equipped with essential tools to mainstream the key component of gender in all their activities. Hence due attention is given to equitable participation of women in all activities in the watershed. In addition, the project has introduced fuel-saving stoves commonly referred to as the “Mirt” stove (Photo 4). Widespread use of these stoves is primarily expected to reduce the fuel demand and hence reduce pressure on the watershed forests. The stove also reduces women’s drudgery, improves women’s health by reducing their exposure to open smoke while also providing young unemployed women with opportunities to generate income by producing and marketing it. To this effect, the project designed and implemented a stove-for-work program through which about 40,000 trees were planted in the watershed.



Photo 4: Energy efficient mirt stoves help reducing pressure on the watershed forests. (Photo credit: Claudio Zucca)

Towards integrated management and up-scaling

The unique dataset generated by the project, which includes 5-year long runoff, sediment yield, and nutrient loss series, along with socio-economic baseline data collected at household level, is being used to develop and calibrate hydrological and bio-economic models. Global climate change scenarios are also being downscaled and analyzed. These models will be used to analyze system dynamics, productivity and constraints at the watershed scale, and to simulate the hydrological and socio-economic impacts determined by varying climate and land use scenarios. The models’ results will show how different spatial arrangement of the soil conservation measures and improved management options may generate different hydrological and economic impacts. This will indicate how a more integrated watershed management can be achieved, and will create a sound basis to draft recommendations for up-scaling.

The outcome of the research will empower the stakeholders, particularly the communities, enabling them to manage and use their resources more effectively and sustainably, and to reduce their vulnerability to climate change (Photo 5). As a result of these holistic adaptation and mitigation strategies there will be reduced soil erosion, improved soil health, better crop and livestock productivity, improved vegetation cover, and reduced deforestation. The technologies promoted by the joint ICARDA/ARARI research will have a positive effect in livelihood improvement of over 4,000 people residing in the watershed. Once these technologies are out-scaled to other similar watersheds, the livelihoods of tens of thousands of farmers in the Amhara region will be improved.



Photo 5: Empowering the communities to manage and use their resources more effectively and sustainably (Photo credit: Claudio Zucca)

The project will also enhance the capacity of institutions in management and rehabilitation of natural resources while also enhancing livelihoods in rainfed systems. Communities will also benefit from empowerment in decision-making and participation in research and communal resource management. Final technical and policy recommendations will provide the basis for improved regulation of natural resources for sustainable development.

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Packing durum wheat seed with tolerance to climatic stresses



ICARDA's durum wheat team

Resilient crop varieties provide a strategic mechanism for coping with the vagaries of climate. Scientists at ICARDA have applied breeding technologies to introduce new target traits in durum wheat for resistance to climate induced stresses.

The adverse effects of changing climate are already taking a heavy toll on farmers world over. Various aspects of climate change, such as higher atmospheric CO₂ concentration, increased temperature and changed rainfall have different effects on plant production and crop yields.

Durum wheat (*Triticum durum* L.), regarded as one of the 'drought tolerant' cereal crops, is often cultivated on marginal lands with poor soil and reduced water availability. Unfortunately, it gets negatively affected by high temperatures and frequent droughts occurring during the crop's growth cycle. This is particularly true for farmers in the south shore of the Mediterranean basin, where durum is often cultivated as staple food for self-consumption. Smallholder farmers do not have the capacity to adapt to environmental constrains through the application of expensive technologies, such as supplemental irrigation, and are therefore exposed to negative consequences.

Some of the adaptation strategies that are being considered in this region include the development of drought and heat resistant crop varieties, in combination with improved agronomic practices. ICARDA's breeders and agronomists work side by side to identify and accumulate useful genes for tolerance to climate change adversities into the DNA of each seed. All this is being done under the CGIAR Research Program on Wheat, with support from U-Forsk 2014 and the University of Agriculture of Malmo (Swedish University of Agricultural Sciences).

Dealing with climate induced stress on crops

Due to the changing climate, crops are exposed to the following types of stress:

- more damaging pests,
- fungal diseases that spread beyond their typical areas or season,
- frequent temperature extremes, and
- changes in the normal rain patterns.

Scientists at ICARDA are carefully targeting each of these issues to deliver climate-ready varieties.

Combating the menace of pests and diseases

Pests and diseases are common in the region where ICARDA operates. In fact, some of the most virulent species and races can be found here. As part of ICARDA's breeding program, top-yielding elites are extensively combined with primitive wheats and landraces, which are unique types of germplasm that have co-evolved with the pests developing special genes for protection (Photos 1, 2 & 3).



Photo 1. Heavy infection of leaf rust in Morocco that helped identify resistant genotypes (first and second leaves)



Photo 2: Yellow rust wiped out old varieties (center forward and back), but varieties developed by ICARDA breeders flourished (green plots)



Photo 3: Hessian fly completely destroyed varieties on the right, while ICARDA's resistant varieties grew untouched (left)

This 'broad' germplasm is then exposed to several environments, each presenting a different set of pathogens species and races. The levels of resistance are recorded at the various sites by pathologists and entomologists. Gathering of all these data from many races allows discriminating the different combinations of genes that exist within the breeding material.

These major and minor genes can then be combined into varieties to ensure durable resistance and ultimately reduce the need for fungicides and pesticides. For instance, a recent QTL (Quantitative Trait Locus) study of the ICARDA variety 'Sebatel' revealed that its resistance against leaf (Morocco), stem (Ethiopia), and stripe (Warrior race) rusts is due to three major and five minor genes combined. Similarly, the use of alleles from *Triticum araraticum* has led to the development of some of the first Hessian fly resistant durum varieties to ever reach the farmers' fields.

Building resilience to water scarcity

The same broad germplasm used to identify resistances to pests and diseases is also exposed to environments with variable levels of drought (Box 1). This challenging strategy is deployed, thanks to the help and support of scientists at different testing sites, in several countries. Testing at these locations (Table 1) allows selecting candidate varieties capable of maximizing the water productivity (i.e. water use efficiency).

Through this selection for drought tolerance (water use efficiency), disease resistance, and good end-use quality, in 2015, an ICARDA cross (*Amedakul/T. dicoccoides/Loukus*), was submitted to the variety catalog in Morocco. In the past three years, this variety has consistently out-yielded the best commercial variety by at least 1 t/ha, even under the most severe drought conditions (Photos 5 & 6).

Table 1: Testing sites for developing drought resistant varieties

Location	Rainfall	Average yield
Melk Zehr, Morocco	650 mm	>8.5 t/ha
Sids, Egypt	550 mm	>7.5 t/ha
Terbol, Lebanon	500 mm	>6 t/ha
Marchouch, Morocco	400 mm	>5 t/ha
Sidi el Aidi, Morocco	350 mm	>3 t/ha
Kfardan, Lebanon	250 mm	>1 t/ha

Box 1: Experiment to study the behavior of roots under well-watered and dry conditions

Scientists at ICARDA utilize several advanced physiological tools to study the behavior of the roots under well-watered and dry conditions. In an interesting experiment, several genotypes are grown side by side in sandy soils inside pasta strainers (Photo 4). At flowering only some of the replications are watered, while others are left completely dry until maturity. During the harvest, the pasta strainers are carefully removed from the soil and the roots are scored. The measurements that better correlate to true field conditions are the percentage of superficial vs deep roots and the total root biomass inside the strainer. These results have shown to be highly heritable and that only few genotypes change their root behavior under different water regimes. The next step is to compare this behavior with the different types of drought, and ultimately identify the best root system for the best environment.



Photo 4: An experiment to determine root behavior in the soil



Photo 5: Two candidate varieties in Morocco that yielded 6.8 t/ha with just 400 mm of rain



Photo 6: Durum wheat grains with good yellow pigment harvested from an ICARDA candidate variety in Morocco

Coping with temperature extremes

The occurrence of heat or freeze shocks at the time of flowering is one of the most damaging events to plant productivity. To tackle this issue, ICARDA scientists initially studied the ability of different varieties to tolerate heat shocks by delaying the sowing until January, and therefore exposing the flowers to the heat conditions of May. However, that approach tended to change the normal phenology of the plant and the germplasm that flowered earlier was able to escape the worst part of the heat.

So a system was developed to identify 'true heat tolerance' independent of flowering time (Photo 7). In this system, the same genotype was planted twice in small experimental plots. At the time of flowering, one of the two replicate was placed under a plastic tunnel. In Morocco, the plastic tunnel increased the average temperature by 4°C during the day and 2°C during the night. It also increased the max temperature by 6°C. These temperature stresses were sufficient to cause a reduction in the total productivity of over 2 t/ha, mainly due to seed abortion.

An experiment was conducted to compare late and early flowering varieties both under plastic tunnels and late planting. Interestingly, the results were opposite in the two conditions, with the late planting method favoring the early variety, while the tunnel revealed better performances for the late flowering variety. This further confirmed that heat-tolerance can be identified also in late flowering varieties, once the confounding effects of phenology are controlled.

A final step in this strategy was the use of two field stations in Senegal and Mauritania, where, the minimum temperature never goes below 16°C and the daily maximum temperature is often well above 38°C. Under these conditions, the best varieties reached maturity in just 90 days, and still obtained yields well above 5 t/ha, mainly due to the large size of the grains and fertility of the ears.

Empowering farmers

The final goal is to introgress all these traits into superior varieties of durum wheat seed that are climate resilient and to deliver them freely to farmers worldwide. The road ahead is challenging, but the use of the phenotyping methodologies described here will enable breeders to truly pyramid useful alleles and reach the ultimate goal, slowly, one selection cycle after the other. This will go a long way in empowering farmers in adapting to climate variability.



Photo 7: (Top) Two polytunnels are applied on the candidate varieties. (Bottom) The effect of applying heat stress (right) vs. normal conditions (left)

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Measuring climate change impacts on farm income in Central Asia

Farmers in Central Asia are trying hard to cope with the increasing climate variabilities

To provide insights and rationally convince policy makers about the impacts of climate change on agricultural economy and elicit adaptive measures, a study was conducted to measure climate change impacts on farm income in Central Asia.

Impacts of climate change on agricultural economy are being closely experienced by agriculturists around the world. However, the question being currently debated is how big will be the overall effect of climate change on the agricultural economy? The increasing interest in climate change heightens the need for an agro-economic model to analyze climate change impacts on farmers' incomes.

Despite serious influences of climate change on food security and farm income, there is insufficient research in Central Asia on the impact of climate change on agro-ecosystems, farm incomes, and analysis of adaptation strategies. There is also a limited use of integrated assessments critical for analyzing environmental, economic and social trade-offs in adaptation options.

To fill this knowledge gap and convincingly elicit policy measures, a study was undertaken by ICARDA* in cooperation with the International Food Policy Research Institute (IFPRI) and funded by the Asian Development Bank and later expanded with the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). The goal of this study was to assess the impacts of climate change at the farm level in Central Asia with focus on three main crops (cotton, potatoes, and wheat) which are crucial for the rural economies and food security in Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan (Fig 1).

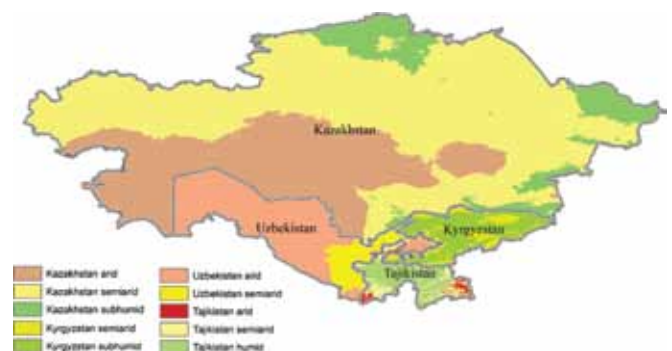


Fig. 1: The farming systems of Central Asia

* For details of this research see I. Bobojonov and A. Aw-Hassan (2014). Impacts of climate change on farm income security in Central Asia: An integrated modeling approach. Agriculture, Ecosystems and Environment 188 (2014) 245–255.

Analyzing the climate change scenarios for representative farming systems

A bio-economic farm model was adopted for this study. This model is capable of simultaneous consideration of biophysical changes and management decisions in different farming systems, and is suitable for analyzing the impacts of climate change on whole farm or sector.

Climate change scenarios were spatially downscaled to the local levels. The crop simulation models then used these downscaled scenarios. This combination allowed the consideration of impacts of climate change on the productivity of different crops. These crop simulation models were calibrated with the crop experiment data as well as actual farm management practices collected from farm surveys. The results of the crop simulation models (yields) were then used to identify the climate change impact of farm income volatility and potential of different management options to improve farm income.

For this study ten representative farms were identified according to agro-ecological and socio-ecological diversity of the regions in Central Asia (Kazakhstan, Uzbekistan, Tajikistan and Kyrgyzstan). Water availability is the main climatic factor constraining crop growth in Central Asia and aridity zones are considered one of the main factors characterizing agro-ecological diversity within the country according to farming system and bio-economic modeling studies.



Photo 1: Scientists and farmers engaged in a discussion to assess farm incomes

The study yielded results close to the observed situation, even in areas with complex topography, and directly generated climate surfaces. The downscaling method provided absolute deviation of monthly temperature and relative deviation of monthly sum of precipitation from historic data for two future periods (2010–2040 and 2070–2100) (Fig. 2).

CropSyst and DSSAT models were used to assess the impact of climate change on crop yields. Data on crop experiments conducted by national research institutes in Central Asia was obtained in order to calibrate the crop simulation models. The results of the crop simulation models (yield impacts) were then used in the economic impact assessment component of the integrated modeling. In this study, the expected value-variance (EV) framework approach was used to analyze risks associated with different agricultural decisions such as crop allocation and input use levels.

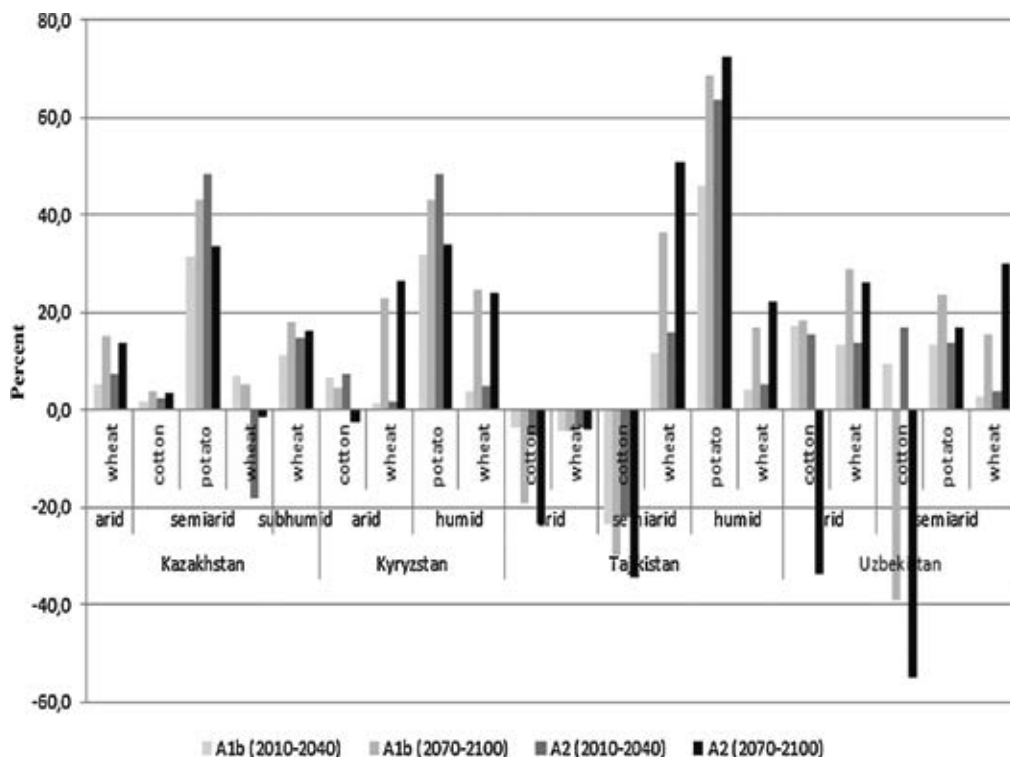


Fig. 2: Crop yield changes under average input use levels compared to the baseline scenario

Gains and losses in the near and far future

Discussing the results of this study, Dr. Aden Aw-Hassan, Director, Socio Economic Research Program, ICARDA, said, "It's interesting to note that some countries may gain from the impacts of climate change in the near future. Like, the mean yields of wheat and potatoes in semiarid Uzbekistan will increase under all management options. However, climate change might reduce expected utility by more than 30% in the late future in the arid zones. This is mainly due to expected decline of yields of all crops in the arid zones of Tajikistan."

The main finding of this study was that climate change impacts on agricultural systems in Central Asia differ depending on agro-ecological zones and socio-economic aspects. Farmers in Uzbekistan will benefit from climate change due to more favorable weather conditions for crop growth in the near future (2010–2040). However, their revenues are expected to decline in the late future (2070–2100) due to increasing temperatures and increasing risk of water deficit, especially if availability of irrigation water declines.

There might be a slight increase in expected revenues in semi-arid zones of Kazakhstan. Some increase in revenues is also expected in arid areas of Kazakhstan which will not increase the farmers' utility due to expectation of higher variances in crop yields associated with climate uncertainties.

In contrast, farmers in sub-humid zones are expected to benefit from increasing temperature and precipitation. Impact of climate change on income of Kyrgyz farmers in semi-arid zones will be neutral in the near future, but is expected to be positive in the late future. Farmers in sub-humid zones of Kyrgyzstan will probably have higher expected income under all emission scenarios in near and late future years. However, this might not increase their utilities since additional gain is prone to increased risk associated with weather extremes. In Tajikistan, impact of climate change is crop specific. Wheat revenues may not change in the future, but income from cotton will decline due to a drop in yields if current levels of management are maintained. Potato farmers may receive higher revenues in the future as yields are expected to increase.

Overall, the impact of climate change is positive in semiarid and humid zones of Tajikistan, but producers in arid regions may suffer from losses under climate change scenarios. Scenario simulations with the condition of market liberalization show great potential for policies to enable producers to mitigate negative consequences of climate change, especially in Tajikistan and Uzbekistan.

Box 1: Further risks of climate change

Climate change and variability affect agriculture in many different ways. The effects of changes in temperature and precipitation as well as potential changes in irrigation water are analyzed in this study. Results show that some locations will benefit from longer and warmer growing season while others will lose due to water deficits. But this analysis does not account for unpredictable severe weather events of heat, drought, frost and floods that may result in significant losses. Climate change may increase such events and associated risks. These risks make insurance an important adaptation strategy for climate change. Adoption of improved land management practices will reduce risks and increase farm income.

(Read stories on 'Weather index-based insurance for climate risk management and rural development' – pg. 25 and 'Adaptation to climate change through integrated watershed management in Ethiopian highlands' – pg. 2)

A further finding of this study was that more open economic policies and less rigid trade policies can be effective adaptation strategies as trade barriers may limit farmers to shift to export crops or require production of uncompetitive crops even if they are more affected by climate change.

These changes in farm incomes, as reflected in the findings of this study, will go a long way in helping policy makers take decisions that can provide adaptation measures. A long term view can give insights into cultivation and marketing policies that will benefit farming communities and safeguard their interests.

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Effective mining and use of genetic resources to cope with climate change

ICARDA's Genebanks hold unique accessions and distribute them to crop breeding scientists around the world

Different innovative approaches are being applied to mining agricultural genebanks for the discovery of climate change adaptive traits. This will improve the effectiveness of breeding programs to produce crop varieties that are resistant to a wide variety of pests, diseases, and bio-physical constraints. It will contribute to ensuring food security for dry areas.

Crop improvement and use of adapted germplasm can be the key components in any climate change adaptation strategy. Research shows that because of their intrinsic genetic adaptation and untapped sources of germplasm, landraces of crops and their wild relatives, native pastoral, range and forest species, are likely to make a significant contribution to food security and sustainable agriculture in the face of climate change. However, efficient targeting of valuable traits within the *ex situ* collections (outside of their natural habitat) and *in situ* habitats (where they naturally occur) is a pre-requisite for selecting the appropriate germplasm to be used as a parental germplasm in breeding programs or in the rehabilitation and restoration of degraded ecosystems.

Box 1: Vavilov Center of Diversity

A Vavilovian Center of Diversity is a region of the world which is an original center for the domestication of plants. Russian botanist, Dr. Nikolai Ivanovich Vavilov (1887-1943), developed a theory on the centers of origin of cultivated plants which stated that plants were not domesticated somewhere in the world at random but there are regions where the domestication started. These centers of origin are regions where a high diversity of crop wild relatives can be found, representing the natural relatives of domesticated crop plants.

ICARDA's genebanks in Syria, Lebanon and Morocco hold more than 147,000 accessions 'in-trust' which are available as global public goods for distribution to partners around the world (Table 1). Since they are held 'in trust' for the international community under the terms of International Treaty on Plant Genetic Resources for Food and Agriculture, ICARDA manages these resources with a high degree of professionalism and in a sustainable manner. These collections are unique because of their richness in landraces, wild relatives and native species, mainly collected from the major Vavilovian centers of diversity (see Box 1).

Table 1: composition of the 'in-trust' collections held at ICARDA genebanks as of December 2014

Species	Number of accessions	Species	Number of accessions
<i>Aegilops</i>	4267	Forage and range	6167
Barley	29703	<i>Pisum</i>	6107
Bread wheat	14552	<i>Trifolium</i>	4937
Durum wheat	19790	<i>Vicia</i>	6155
Primitive wheat	913	Faba bean	10029
Wild <i>Hordeum</i>	2058	Chickpea	15046
Wild <i>Triticum</i>	1584	Lentil	11876
<i>Lathyrus</i>	4180	Wild <i>Cicer</i>	270
<i>Medicago</i> annual	8569	Wild <i>Lens</i>	587
Not mandate cereals	175	Others	130
Total			147,095

Mining of genetic resources for climate change adaptive traits

These valuable collections are used by ICARDA to fulfil requests for crop diversity from breeders, researchers and farmers around the world, so they can develop and test new strains to cope with new diseases and extreme climate. Since it involves complex traits and rare alleles, the following new strategies are adopted by ICARDA to collect, conserve, identify and use accessions with the desired traits:

- **Promoting *in situ* conservation** is needed to allow dynamic conservation of broader genetic base and larger species richness. DIVA-GIS software, a computer program for mapping and geographic data analysis, is used to identify natural habitats and traditional farming systems for community-based management and establishment of protected areas for the needed diversity to cope with climate change.
- **Collecting missions:** Gap analysis done using DIVA-GIS tools allows to enrich the genebank holdings with new accessions from non-sampled areas and can also be used to target accessions with climate change adaptive traits. Following this, collecting missions are carried out to gather these accessions with adaptive traits. In the case of wheat, some species found in very dry areas (such as *Aegilops kotchyii*, *Ae. searsii* and *Ae. vavilovii*) and others on the sea shores with high salt concentration (like *Ae. bicornis*) can be use as sources for heat, drought and salinity tolerances (Fig. 1).
- **Use of Focused Identification of Germplasm Strategy:** The Focused Identification of Germplasm Strategy (FIGS, explained in Box 2) approach is being used by ICARDA to search genetic resources for climate change related traits. Genetic resources have been reported as valuable resources to address climate change by the recent 2014 Norway international conference on genetic resources under changing climate conditions. The approach was conceived to develop subsets with reduced size of accessions that are likely to contain the desired traits like heat and drought resistance. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) has validated this approach for the successful identification of these climate change adaptive traits. Reports on the international media, like BBC have also widely discussed the far reaching potential of this approach.

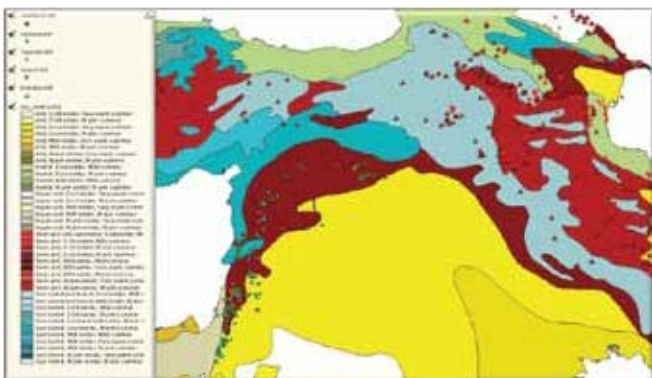


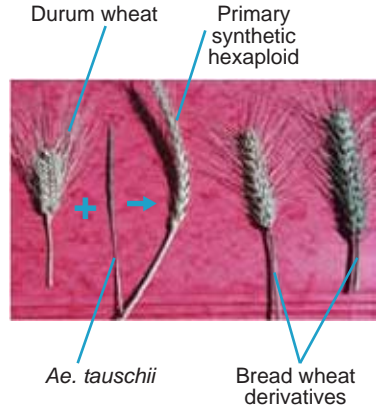
Fig. 1: Distribution of drought and heat tolerant *Aegilops* species along the aridity gradient

Box 2: What is FIGS?

FIGS - or Focused Identification of Germplasm Strategy - is a new technique for searching agricultural genebanks for useful traits based on relationships between environmental factors and the sought-after traits. This approach helps genebank managers, crop breeders, development agencies and donors to improve the effectiveness of crop improvement programs. ICARDA's FIGS program uses applied mathematics to address region-specific challenges and opportunities for maintaining genetic resources for sustainable agricultural productivity under changing climatic conditions in the dry areas.

- Direct use of genetic resources for rehabilitation of degraded systems:** The rangelands are under severe degradation due to overexploitation and frequent droughts. For the rehabilitation and restoration of these fragile systems it is helpful to use native adapted species provided that the reseeded is followed by appropriate management of flocks and grazing. In the case of dryland forests, afforestation and reforestation efforts with native and diverse species combined with water harvesting have found to be relevant in several countries in West Asia.
- Hybridization of adaptive genes from landraces and wild relatives:** In plant genetics, genetic recombination through crosses allows to extend the genetic base of crops and overcome any breeding constraint. The diversity of crop wild relatives (CWR) can be further tapped to overcome major environmental challenges. Studies have estimated the economic value of CWRs to exceed 10 billion US\$ annually and have concluded that this would significantly increase when dealing with adaptation to climate change. Therefore, a strong pre-breeding effort is needed to mobilize additional useful diversity from the crop wild relatives. In the case of wheat and barley breeding at ICARDA, the wide crosses using wild relatives (*Aegilops*, wild *Triticum*, wild *Hordeum*) have resulted in elite germplasm with improved yield potential and grain quality, drought tolerance, heat tolerance, salt tolerance and resistance to major diseases and insects.
- Finding resistance to abiotic and biotic stresses through bread wheat improvement:** Synthetic Hexaploid Wheat (SHW) has contributed to broaden the genetic base of cultivated bread wheat, and the derived lines have proven to be valuable donors of improved tolerance to a range of abiotic and biotic stresses. These include resistance to major diseases and insects, tolerance to drought, heat and salt and improvement of end-use quality attributes (as shown in Table 2). More than 30% the elite germplasm generated by the International Maize and Wheat Improvement Center (CIMMYT) and ICARDA breeding programs are derived from crosses with the synthetic hexaploid parents. ICARDA is involved in the development of new SHW using accessions of *Ae. tauschii* (the D donor of bread wheat) collected from the dry areas as a way to overcome drought, heat and salinity stresses, tightly associated with climate change.

Table 2: Development of Synthetic Hexaploid Wheat and traits derived in the germplasm

Development of Synthetic Hexaploid Wheat	Traits derived in the germplasm
 <p>Durum wheat + <i>Ae. tauschii</i> → Primary synthetic hexaploid → Bread wheat derivatives</p>	<p>Resistance insects: Hessian fly, Russian wheat Aphid, Sunn pest, aphids</p> <p>Resistance major diseases: rusts, Septoria blight, tan spot, root rots, Powdery mildew.</p> <p>Tolerance to abiotic stresses: drought, salt and heat, cold</p> <p>Agronomic traits: earliness, lodging resistance, yield potential,</p> <p>Good quality attributes: higher proteins, resistance to sprouting</p>

Moving forward

To effectively combat the complex challenges caused by climate variability and new virulences of diseases and pests and to ensure sustainable yield gains, more concerted efforts are needed to:

- Ensure effective conservation of threatened genetic resources using the complementary approaches of ex situ and in situ conservation including climate change adaptive traits collection;
- Fine tuning of FIGS approach for identifying novel diversity by combining environmental, phenotypic and genotypic data;
- Strengthen pre-breeding activities to take advantage of all species in the crop gene pools; and
- Use molecular techniques for mining genetic resources for novel allelic variation and efficient introgression of desired genes.

In September 2015, ICARDA retrieved part of its genebank collection that has been safely duplicated and stored in the Svalbard Seed Vault in Norway, to fulfil requests for crop diversity from breeders, researchers and farmers around the world, so they can develop and test new strains to cope with a changing climate and new diseases. Each sample will be planted and grown to multiply the seeds and re-establish ICARDA's active collection so it can continue distributing germplasm to crop breeding scientists the world over and also return a portion back to the Seed Vault for safekeeping.

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Enhancing production with drought and heat tolerant bread wheat varieties

ICARDA's bread wheat yield trials at Merchouch station, Morocco, 2014/15

Despite its large wheat production area, the Central and West Asia and North Africa (CWANA) region struggles to adequately meet the regional demand for wheat. With growing climate variability, increased temperatures and less precipitation, wheat production is further getting impacted. ICARDA breeders have developed drought and heat tolerant wheat varieties to achieve enhanced wheat production.

Demand for wheat in the developing world is projected to increase 60 percent by 2050. However, climate-change-induced temperature increases are likely to reduce wheat production by 20-30 percent. Wheat is produced on more than 50 million hectares annually in Central and West Asia and North Africa (CWANA) region, which is nearly 50% of the wheat production area in the developing world. This accounts for an annual wheat production of around 126 million tons. However, it is not sufficient to meet the regional demand of about 164 million tons. Such imbalance between demand and production has led to the import of 44 million tons of wheat at a cost of 15 billion dollars during the 2011 season alone.

Wheat production in the CWANA region is predominantly done under rainfed system. Since it depends on the amount and distribution of rainfall, the total annual wheat production is highly variable. Drought is a major limiting factor in this region.

Even in areas where wheat production depends on the use of supplementary irrigation, water is becoming scarce. This is further accentuated by the increasing incidence of climate change, characterized by rising temperature (heat), less and erratic rainfall (drought) or sometimes excessive rainfall (flooding), and emergence of new pests and diseases, making agricultural productivity less predictable in the CWANA region. Wheat productivity in this region is already very low, 2 t/ha as compared to the 3 t/ha world average. Climate change also affects the quality of wheat as increased heat results in early ageing with shriveled wheat grain and protein degradation. Therefore, it is critically important to develop climate smart wheat varieties with resistance to major abiotic (drought and heat) and biotic stresses (diseases and insect pests), and enhanced productivity and water-use-efficiency.

Breeding approaches

ICARDA's wheat breeding program, in collaboration with the International Wheat and Maize Improvement Center (CIMMYT), and national partners through the support of CGIAR Research Program WHEAT and bilateral funding, are developing climate smart wheat technologies with high yield and heat and drought resistance to combat the effects of climate change. National Agricultural Research Systems (NARS) and other Advanced Research Institutes (ARIs) are also collaborating in these efforts.

Drought and heat tolerances may be considered complex traits and difficult to improve, but ICARDA breeders and agronomists have been breeding improved cultivars for high and stable yield in heat and moisture stressed environments. They use diverse sources of germplasm and precise phenotyping approaches. ICARDA's bread wheat breeding uses both conventional and molecular techniques in an inter-country shuttle and key location yield testing approaches (Fig. 1).

Germplasm generations are shuttled between Terbol station in Lebanon and Kulumsa station in Ethiopia. This is followed by key location testing at Terbol and Kheferdan (Lebanon), Marchouch and Jammashaim (Morocco), Sids (Egypt), Wadmedani (Sudan) and Izmir (Turkey) and Kulumsa (Ethiopia). It enables to combine yield potential and wide adaptation with resistance to biotic and abiotic stresses.

On an annual basis, the bread wheat program composes and distributes more than 250 elite sets of these genotypes through international nurseries and yield trials to countries in the CWANA region and beyond upon request for potential direct release/or parentage purposes. Bread wheat germplasm have been also evaluated across Australia under the CIMMYT-Australia-ICARDA Germplasm Evaluation (CAIGE) project. Outstanding germplasm were observed from both the breeding programs across different locations in Australia (caigeproject.org.au) indicating the potential of the CGIAR germplasm for Australian wheat breeding programs as well.

Marchouch + Jemaat Shaim: Yellow rust, Septoria, drought tolerance, HF resistance

Sids: Yield potential

Izmir: Screening for rusts (Lab +field)

Kulumsa /Dz: Stem rust, yellow rust, septoria, fusarium

Wadmedani: Heat tolerance

Terbol: CB, adaptation, yield potential, rusts, cold, drought (at Kheferdan)



Fig. 1: Key locations for ICARDA's wheat breeding tests

Making inroads with improved cultivars

ICARDA-origin wheat cultivars are widely and increasingly grown in thousands of hectares by smallholder farmers in Ethiopia, Egypt, Sudan, Iran, Afghanistan, Syria, Lebanon, Nigeria and other countries. Recently, the wheat breeding program at ICARDA in partnership with CIMMYT, NARS and other ARIs, has developed high yielding wheat genotypes with increased water-use efficiency, heat tolerance and resistance to major diseases and pests. Some of these genotypes yield up to 11 t/ha in Egypt under optimum conditions (Photo 1).



Photo 1: Performance of wheat genotypes at Sids station, Egypt, in 2014

The performance of the best genotype at Merchouch, Morocco, reached up to 7.5 t/ha under rainfed condition which is a dramatic gain as compared to the 3.4 t/ha yield level of the commonly grown cultivar, Arrehane (Photo 2). Under drought conditions (250 mm rainfall), the yield level of some of these genotypes reached up to 2.5 t/ha (Photo 3). Pedigree analysis showed that most of them contain synthetic hexaploid wheats (SHWs) while others possess *T. dicoccoides* in their background. Some of these genotypes have deep green leaves with early vigour and 'stay green' characters.



Photo 2: Evaluation of bread wheat genotypes at Marchouch research station, Morocco



Photo 3: Drought and heat tolerant high yielding lines at early (left) and maturity stages (right)

Table 1 shows the performance of top ten bread wheat genotypes at Merchouch compared to Arrehane, the commonly grown cultivar. The three best performing genotypes are being considered for registration by INRA (Institut National de la Recherche Agronomique), Morocco. The release of these varieties would boost wheat productivity in Morocco enormously as the currently grown cultivars such as Achar, Arrehane, Amal and Mahadia are all susceptible to yellow rust.

ICARDA has distributed the currently available elite genotypes to the respective NARS in CWANA countries through international nursery system for potential direct release and/or parentage purposes. Rapid deployment of such wheat varieties with improved crop management technologies, such as conservation agriculture, water harvesting, drip irrigation, site-specific nutrient management and integrated pest management (IPM) will further enhance sustainable wheat production across the CWANA region.

Table 1: Performance of the top 10 bread wheat genotypes at Merchouch compared to Arrehane

Var. No.	Pedigree	Yield (T/ha)	Yield in % of Arrehane
1004	KAUZ/MON/CROW/S/3/SHUHA-4/NS732/HER/4/MILAN/PASTOR	7.5	195.8
1038	JAWAHIR-1/GIRWILL-5	6.16	160.8
1002	SHUHA-4/NS732/HER/3/MILAN/DUCULA	6.12	159.8
1027	SERI.1B*2/3/KAUZ*2/BOW//KAUZ/4/TRA P#1/BOW//PFAU/3/MILAN	5.71	149
1013	FLAG-3/ICARDA-SRRL-5	5.62	146.7
1028	KAUZ//ALTAR 84/AOS/3/MILAN/DUCULA	5.58	145.6
1014	ATTILA 50Y//ATTILA/BCN/3/PFAU/MILAN	5.56	145.2
1015	KAUZ/MON/CROW?S2/3/VEE/PJN/2*KAUZ	5.52	144.1
1037	SERI.1B//KAUZ/HEVO/3/AMAD/4/FLAG-2	5.42	141.4
1001	SERI.1B//KAUZ/HEVO/3/AMAD/4/FLAG-2	5.16	134.6
1016	SERI.1B//KAUZ/HEVO/3/AMAD/4/ATTILA//PSN/BOW/3/ATTILA/5/KAUZ'S/SHUHA-15	5.15	134.4
1040	ARREHANE	3.83	100

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Conservation agriculture for building climate change resilient farming systems

Cactus-barley alley cropping under conservation farming is being tested through CRP DS in Zoghmar community in Sidi Bouzid (Tunisia)

Conservation agriculture, which is based on enhancing natural biological processes above and below the ground for resource-saving agricultural crop production, provides sustained production levels while concurrently conserving the environment. It has successfully emerged as a climate change resilient farming system.

“We were expecting a bumper crop this year,” said Mohamad Qatawneh in Karak governorate in Jordan. However, unexpected freezing temperatures during late April shattered all his hopes. The barley crop was badly affected. Mohamad could harvest very little grain. He sat despondently staring at his nearly empty barn.

Similar devastation was seen in Tunisia. But that was caused by an excessive heat wave last April. Taoufik Ben Amr, a community leader in Chouarnia, Siliana (Tunisia), seems to have identified the real cause. “Climate has become the biggest risk factor for us”, he complained. Yields of wheat and barley in Tunisia and Jordan were lower than the long term averages despite good rains.

Climate is changing globally, but dry areas of the world are worst affected by the erratic climate events. Scientists predict that droughts and heat waves will become more common in dry areas and will significantly reduce already lower crop yield, livestock productivity and overall farming system performances.

Climate change resilient farming systems

ICARDA scientists have been investigating climate change resilient farming systems for two decades. Conservation Agriculture (CA) has been found to be one of the key tools for combating climate change. ICARDA's investigations into CA started in 2000 first in Central Asia, and then extended to North Africa, West Asia and South Asia. CA is based on three main principles; i) no or minimum soil disturbance, ii) organic soil cover and iii) diversified crop rotation.

CA practices have a direct influence on climate regulation through carbon sequestration and greenhouse gas emissions, and regulation and provision of water through soil physical, chemical and biological properties. Perhaps the most important benefits of CA for the dry areas are related to better soil and water retention and storage as compared to conventional agriculture. Soils under CA have very high water infiltration capacities reducing surface runoff and thus soil erosion significantly. This improves the quality of surface water reducing pollution from soil erosion, and enhances groundwater resources. Stored soil water is very helpful during spells of drought (Photo 1).

Undisturbed soil and soil cover serve multiple purposes. Some of the benefits can be obtained in the short term while others take longer time to realize. An immediate benefit of CA is the reduction in the use of fossil fuels and greenhouse gas emissions associated with ploughing or cultivation of soils. Since crops are directly seeded without tilling the ground, farmers save fuel and reduce gas emissions (Photo 2). No till fields act as a sink for CO₂. If conservation farming is applied on a global scale, it could provide a major contribution to control air pollution in general and global warming in particular. Farmers applying this practice could eventually be rewarded with carbon credits.



Photo 1: Water infiltration and storage of soil water is much greater in the case of CA (left) as compared to conventional field (right), which benefits during prolonged drought periods.

Box 1: Benefits of Conservation Agriculture

In the short-term:

1. Reduced wind and water induced soil erosion
2. Increased rain water capture and retention
3. Improved water infiltration into soil
4. Reduced evaporation and water loss
5. Creation of microclimate for the emerging crops.

In the long-term:

1. Increased organic matter and fertility of soils
2. Improved soil structure
3. Protection and improvement of soil biological activity
4. Reduced input requirements (fertilizers and pesticides)
5. Suppressed annual weeds.



Photo 2: Eliminating tillage helps in the reduction of soil erosion and fuel consumption, one of the many benefits of CA.

Alley Cropping

While conservation farming is a promising option to grow field crops under semiarid conditions, alley cropping with rows of cactus and barley growing in the inter-rows, is another option to tackle the same objective. Cactus is a drought-tolerant range species having high water use efficiency. The rows of cactus create micro-environment enhancing water availability for barley. Combining cactus-barley alley cropping and zero-till is a cost-effective and an environmental friendly option improving food-feed production while saving water.



Photo 3: A farmer settled in Zoghmar community in Sidi Bouzid (Tunisia) experiencing the benefits of zero-tillage farming in dry areas with minimum inputs

Cactus-barley alley cropping under conservation farming is being tested by ICARDA through CGIAR Research Program on Dryland Systems (CRP DS) in Zoghmar community in Sidi Bouzid (Tunisia). Alley cropping shrubs and cactus with barley, oats, feed legumes or native vegetation, and dual-purpose barley varieties have significantly reduced the cost of feeding livestock and reduced farmers' dependence on rangelands. Farmers who were initially unsure about the benefits of conservation farming can now see the results for themselves. 'I had heard that zero-tillage holds promise to produce in dry areas with minimum inputs. Now I'm testing this and feel convinced,' said a farmer settled in Zoghmar community in Sidi Bouzid, Tunisia (Photo 3).

Crop livestock integration under CA

Livestock are also adversely impacted by climate change. Heat stress tends to increase disease incidences, reduce fertility, and reduce milk production for livestock. Droughts reduce pasture and rangeland productivity, reducing the access to quality feed resources.

The third principle of CA, diversified crop rotation, encourages farmers to plant food and forage legumes or other crops instead of continuous cropping of wheat or barley. It also allows them to diversify their operations and increase the resilience of their system to external shocks such as extreme climate events.

Livestock is one of the best insurance for farmers in dry areas and most of them own it. However, under continuous cereal production systems farmers cannot produce high quality nutritious forage and are forced to rely on expensive external sources. Through an IFAD funded "Crop-livestock integration under conservation agriculture" project ICARDA has been looking at ways to design climate resilient diverse farms in dry areas. ICARDA is the only international center working on such integrated systems in the dry areas.

With these climate resilient diverse farms in dry areas, ICARDA hopes to enhance agricultural resiliency to climate change. These farms will also improve prospects for community empowerment and self-reliance in the face of climatic variability.



Photo 4: Crop livestock integration under Conservation Agriculture (Photo courtesy: Dryland Systems)

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Sustainable land management under climate change in Central Asia



ICARDA's Central Asian Countries Initiative for Land Management Project team at Kamashi demo plot in Uzbekistan

Efforts to combat land degradation in the five Central Asian countries of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan have received a new impetus with the establishment of a platform to consolidate knowledge and promote sustainable land management approaches and technologies that have been devised by researchers as well as farmers.

Climate change poses serious threats to Central Asia's environment, ecological and socio-economic systems, particularly because of the arid nature of the region. Land degradation in Central Asian countries is a big problem, particularly considering the sizeable share of agriculture in their GDP. Causes of land degradation are not limited to the current irresponsible use of water resources; unfortunately, there is a legacy of pre-independence land management system when maintenance of soil health was not duly considered. Among different types of degradation, soil salinization, erosion and desertification are prevalent in the region because of high water losses from irrigation networks and overgrazing.

With support from IFAD and CGIAR Research Program on Dryland Systems, ICARDA-led Knowledge Management project, 'Central Asian Countries Initiative for Land Management' (CACILM), initiated in 2013, has been contributing to building a knowledge platform in the region to consolidate knowledge created for up-scaling and out-scaling sustainable land management (SLM) interventions. Project's demonstration sites include four main target agro-ecosystems: (i) irrigated agriculture, covering about 8 million hectares; (ii) mountain ecosystems, constituting over 90 percent of the area of Kyrgyzstan and Tajikistan; (iii) rangelands, occupying a large portion of land in Kazakhstan, Turkmenistan and Uzbekistan; and, (iv) rainfed cropland. These demonstration sites are used to channel the selected SLM technology packages to farmer communities.

Some of the SLM technology packages that have been successfully implemented by local farming communities are given below.

Establishing pistachio plantations in arid lands of Kyrgyzstan

Pistachio, with its strong root system, is known for its soil and water protection role in the arid foothills and low hills of the Central Asia region. Kyrgyzstan shares 33 percent of the biggest wild pistachio forest which covers an area of 300,000 hectares. The tract of Achy in Kyrgyzstan has more than 600 hectares of grazing land.

In 2009, Rasuljan Khaitov, a local farmer began subduing 5 hectares of land by planting 7,600 seedlings of Akbari variety pistachio, almond and peach, and fenced the territory using 6 km of barbed wire. It usually takes six years before the pistachio tree gives its first yield. For cost recovery Rasuljan sowed wheat, barley, peas, tomatoes and melons between the rows with an initial investment of 391 USD. To overcome his irrigation related difficulties, last year Rasuljan began developing drip irrigation system to save water and schedule watering. For this he received assistance from CACILM project (Photo 1).



Photo 1: CACILM project scientists at Rasuljan Khaitov's pistachio plantation

In 2015, Rasuljan implemented drip irrigation on a part of his garden. A well was drilled to water melons, vegetables and trees. From intercropped wheat Rasuljan gained 106 USD per ha. His profitability rate reached 22 percent. Within four years there was total cost recovery. Rasuljan's Akbari variety plantation, fixed by a 4x8 scheme, is expected to provide approximately 6240 kg of harvest per ha worth approximately 40,000 USD income by 2019. Rasuljan now wants to spread his experience among farmers of Southern Kyrgyzstan. Within CACILM project, Rasuljan Khaitov's experiences have been published in Uzbek and Russian languages and distributed among farmers on field day workshops.

The technology of drip irrigation is still new in the arid locations of Kyrgyzstan. But it is steadily expanding. In 2014, drip irrigation systems covered 140 hectares in Kyrgyzstan. In 2015, this area is expected to reach 1,000 hectares.

Efficient fodder production in the rangelands of Uzbekistan

Households in Uzbekistan are increasingly investing in livestock as a secure way of savings. However, this puts much pressure on the existing rangeland resources. Degradation in the infrastructure of watering points in remote areas leads to overgrazing. Limited flock mobility adds to the difficulties due to overuse of natural resources. This is reflected in the decrease of herbaceous forage cover, changes in the composition of biodiversity, reforestation and reduced soil fertility which leads to desertification, changes in hydrological regime, and soil erosion and landslides in the foothills of mountain zones. About 40 percent of desert rangelands in Uzbekistan are degraded to varying degrees, and their average yield in recent years has decreased by more than 20 percent.

Due to rangeland forage deficit, procurement of forage and feeds adds to 45-50% of the total cost, bringing down the profitability rate. The live weight loss per sheep amounts to a 12-15% less meat and 8-10% less wool produced. Reliable food supply and sustainable use of fodder resources is very important for improving the livelihoods of local people because they directly affect animal productivity and production of Karakul (Astrakhan sheep).

CACILM project works toward improving the nutritional value of feed that is available as one way of coping with increased pressure on pastures (Photo 2). Preparation of forage for feeding improves taste, palatability and enhances the absorption of nutrients. Simple mechanical methods like milling, wetting, steaming and self-heating can improve the taste and increase palatability by 50 percent.



Photo 2: A field day for fodder production in Farish, Uzbekistan

Biological treatment methods are based on roughage enrichment with yeast and application of enzyme preparations. These are efficient ways that significantly increase the performance of digestible protein, fiber and all the organic matter. Chemical treatment of coarse forage (as explained in Box 1) also increases its digestibility and nutritional value.

Box 1. Chemical treatment of coarse forage

Addition of:

- 1.5-2% caustic soda solution
- 5% soda ash
- 1.5-2% quick lime

Benefits:

- 20-25% improvement in nutritional value of rough pasture feed
- 25-30% weight gain in sheep fed on treated forage
- 18-25% reduction in feed consumption per kg of weight gain

Rural advisory and extension services in Central Asia

Transition to market economy after the break-up of the Soviet Union has brought about many changes. Agricultural production in Central Asia occupies a leading place in the region's economy and reflects its economic potential. The demand from agricultural producers for information on latest research and advanced experience, marketing, business planning and taxation has grown.

There is a need for rural advisory service (RAS) which would not only ensure timely delivery of scientific, market and technological information to agricultural producers, but also assist them in mastering innovative developments and best practices. An effectively operating rural advisory service would combine functions of education, knowledge dissemination and consulting.

To address challenges like changing climate and land degradation, CACILM project works on exploring and developing the best ways to channel and out-scale the agricultural innovations to farming community. The project conducted surveys among advisory service providers in the four countries of the region (Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan) to identify problems hindering their development.

Data collected from 90 organizations, which included NGOs, state and private institutions revealed specific reasons for the poor performance of rural advisory services (for details see Box 2). However, there is a general consensus that the quality of rural advisory services has improved as compared to those during the former Soviet Union. It has become more farmer-oriented and better adapted to new agricultural technologies.

According to the survey findings, the reach of public extension service providers in some countries is wider in comparison to the private RAS. These networks (e.g. Kazagroinnovation and Kazagromarketing in Kazakhstan and Rural Advisory Services in Kyrgyzstan) can be used for broader dissemination of promising SLM interventions.

Taking into account the different capacities of public extension systems and donor-funded rural advisory services in each Central Asian country, the project is preparing recommendations for the best technology transfer scheme to ensure wider coverage of farmers.

Box 2. Reasons for the poor performance of rural advisory services (RAS)

Kazakhstan

- single-mission (non-repeated) advisory service provision
- lack of transport

Kyrgyzstan

- low knowledge level of farmers
- lack of large farms
- limited funding

Tajikistan

- low paying capacity of farmers
- shortage of funds
- lack of qualified consultants and technical equipment

Uzbekistan

- insufficient funding
- weak communication channels with farmers
- limited knowledge on agricultural innovations

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Weather index-based insurance for climate risk management and rural development

Unpredictable weather patterns have left farmers and traders bewildered

To secure food production, it is important to encourage farmers to invest in production enhancement, despite climate related risks. An analysis of the risk minimization potential of index-based insurance shows that the adoption of risk management tools by farmers may significantly contribute to maintaining food security at national as well as household levels.

Aziz, in his mid-forties, has long been contemplating investing money into buying some agricultural equipment that can enhance production. But he is still reeling under the shock of unexpected crop failure due to last year's drought. The weather has been unpredictable for past many years now, something which Aziz finds difficult to comprehend. With the weather, his agricultural yield has also become unreliable. This makes it difficult for him to take any investment related decisions. What if he loses it all?

Aziz, like most smallholder farmers in any developing country, is risk averse. However, he is surprised to see the confidence and relaxed demeanor of his friend Atef, who doesn't seem to be perturbed by the growing weather uncertainties. From the time Atef has received the assurance of drought insurance program based on rainfall index, he is more confident about making strategic investments. He has bought the same agricultural equipment which Aziz couldn't venture investing in. As a result, Atef's production has increased.

Importance of weather index-based insurance

Smallholder farmers in developing countries are vulnerable to weather risks related to climate variability. This can trap their households in poverty. It also limits their willingness to invest in measures that might increase their productivity and improve their economic situation.



Photo 1: Weather index-based insurance schemes help small farmers tide over growing climate variabilities and escape the debt trap.

Studies have shown that agricultural insurances against yield loss allow risk to be transferred to agricultural insurance markets and thus increase the confidence of farmers and facilitate their investment in agricultural production in general. Insurance products have been developed that can allow weather-related risk to be insured in developing countries where traditional agricultural insurance may not always be feasible.

These weather-related index-insurance schemes differ from traditional indemnity coverage in that they are based on factors such as rainfall rather than actual measured loss, and kick in the moment a threshold fixed in advance is breached. Because the transaction costs are lower, index-based insurance becomes financially viable for private-sector insurers and affordable to small farmers. Weather index-based insurance schemes drastically cuts costs for farmers, giving them more spare cash for fertilizers and seeds and help them avoid distress sale of assets to escape the debt trap. They even provide opportunities to farmers to improve their productivity by investing in climate-smart technologies, thereby helping to secure the world's food supply.

Risk minimization potential of index-based insurance in Syria

With a view of improving the adaptive capacity of rural producers in Syria to climate and weather risks, a study was conducted by ICARDA in collaboration with the CGIAR Research Programs on Climate Change, Agriculture and Food Security (CCAFS) and Dryland Systems (DS)*. The risk minimization potential of index-based insurance was examined in the case of winter wheat production in northern Syria, which is very significant for food security.

Winter wheat, as well as all other major winter crops in northern Syria, are mainly cropped under rainfed conditions. Winter wheat is usually planted in November–December at the onset of the (winter) rainy season and harvested by the end of May, beginning of June.

This research analyzed the agro-ecological, economic and social benefits and the institutional challenges of establishing index-based insurance markets to catalyze rural development in Syria. The potential of three index insurance schemes were examined for minimizing risk: (1) a statistical index, (2) an index based on agro-meteorological approach and (3) a remote sensing-based index. It also explored how index-based insurance markets contribute to rural development in scenarios of increasing climate risks, as in the conditions of northern Syria.

A Rainfall Deficit Index was used for this study. Some modifications were made to improve the joint dependency of index and yield. The Rainfall Deficit Index was estimated for whole vegetation period (November–June months) from the ICARDA research station data in Aleppo in northern Syria and correlated with the case study farm yields. The CropSyst crop simulation model was also used.

Benefits of index-based insurances and the potential of scaling out

The study results hold much hope for smallholder rural farmers like Aziz. Research findings show that risk associated with drought can be effectively reduced with index-based insurances. Especially, the agrometeorological and Normalized Difference Vegetation Index (NDVI)-based alternative indexes have a very good potential to be implemented under limited data conditions. The analysis of yield dependencies between different regions of Syria reveal low correlation between the regions. That may provide a unique opportunity of pooling systemic risk between

* For details of this research see I. Bobojonov, A. Aw-Hassan and R. Sommer (2014). Index-based insurance for climate risk management and rural development in Syria. *Climate and Development* 6 (2): 166-178.

different regions and providing insurance with affordable prices. Establishing insurance markets will not only help farmers reduce income risks, but also support productivity improvements. Farmers will have a guaranteed income even under drought conditions, which will allow them to purchase inputs in the ensuing growing seasons and thus reduce spillover effects of droughts.

“Climate related factors make dryland farming riskier. Fearing the risks, smallholder farmers do not invest in production capital and technology adoption. Weather-based index insurance helps smallholder farmers in dry areas gain confidence in investing and adopting new technologies”

- Dr. Aden Aw-Hassan

Adoption of risk management tools by farmers may significantly contribute to ensuring food security at national as well as household levels in dry areas. Existence of efficient insurance markets could help smooth consumption and attract more investment in agriculture. Therefore, an index insurance has positive effects beyond merely securing farmers' income.

Lack of insurance companies and current political uncertainty are the main challenges hindering the establishment of index insurance markets in Syria. However, there are also some positive signals that may create a favourable institutional environment for launching index insurance projects in the country. Availability of state funds for disaster aids and the positive perceptions of rural households about the risk-sharing schemes could be useful to support an insurance culture and, therefore, insurance uptake. These novel indices considered for the conditions of Syria could be potentially used for other countries with similar agro-ecological environments.

Global efforts in index-based insurance

There are global efforts to support developing countries to apply index-based insurance. One such example is the World Bank-run Global Index Insurance Facility (GIIF), which is a multi-donor trust fund supporting the development and growth of local markets for weather and disaster index-based insurance in developing countries, primarily Sub-Saharan Africa, Latin America and the Caribbean and Asia Pacific. In Kenya and Rwanda, 230,000 farmers and maize, sorghum, coffee and wheat cultivators have taken advantage of the scheme to protect themselves against drought, excessive rain and storms. According to GIIF analyses, on an average, such farmers have been able to invest 19 per cent more in their farms and earned 16 per cent more than those who did not enjoy such insurance cover.

These observations further validate the significance of the index-based insurance schemes that were examined in the ICARDA-led study for minimizing risks, and provide confidence to smallholder farmers like Aziz.



Photo 2: Risk management tools like the weather index-based insurance will contribute to ensuring food security at the national and household levels in dry areas

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Review of reproductive performances of sheep breeds in Ethiopia

Mourad Rekik, Aynalem Haile, Zeleke Mekuriaw, Ayele Abiebie, Barbara Rischkowsky and Imene Ben Salem

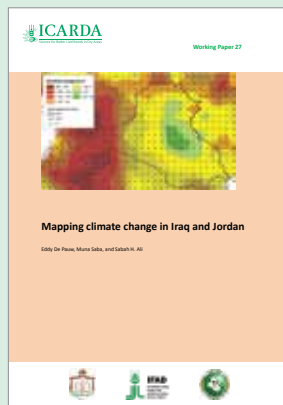
This working paper reviews the current state of knowledge related to the reproductive performances and characteristics of Ethiopian sheep. This information serves as a resource material for scientists actively performing research within Ethiopia. It allows researchers to identify gaps in the current knowledge and determine future research priorities. It also hopes to influence policymakers.



Conservation Agriculture in Irrigated Areas of Azerbaijan, Kazakhstan and Uzbekistan

Aziz Nurbekov, Asad Musaev, Dossymbek Sydyk, Zokhidjon Ziyadullaev and Jozef Turok

This working paper provides convincing evidence for farmers and policymakers to adopt conservation agriculture (CA) in Central Asia. Among the many conclusions and recommendations stemming from this project, the most important was that the governments of Central Asian countries need to be assisted in the formulation and implementation of national strategies for the adoption and promotion of CA.



Mapping climate change in Iraq and Jordan

Eddy De Pauw, Muna Saba, and Sabah H. Ali

This working paper provides a synthesis of the climate change assessment studies undertaken in Iraq and Jordan in the context of the IFAD-funded and ICARDA-implemented Project 'Improving food security and climate change adaptability of livestock producers using the rainfed barley-based system in Iraq and Jordan', leading to the production of Climate Change Atlases for both the countries.



Rangelands for better livelihoods

Mounir Louhaichi

This manual is intended to add a wider dimension to the understanding most people have about rangelands resources. A major shift in rangeland science needs to occur, from considering their main function as grazing lands with a specific focus on livestock production to a much broader concept of ecosystem services management.



New winter wheat varieties for improving productivity on saline fields in Central Asia

Michael Baum and Ram Chandra Sharma

This newly launched series, 'Science Matters', explain how ICARDA's science innovation is leading to measurable results. 'Davlatle' is among the superior winter wheat varieties identified by wheat researchers in Central Asia with the potential to improve food security by producing more wheat on saline fields.



Heat-tolerant wheat transforms food production and policy for Sudan

Solomon Gizaw Assefa

This publication in the 'Science Impact' series talks about an integrated wheat package that has introduced heat-tolerant wheat varieties able to withstand temperatures greater than 38°C. This is transforming farmer fields in Sudan and showing policy-makers a new road to food security.



Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is one of 15 centers supported by CGIAR. ICARDA's mission is to contribute to the improvement of livelihoods of the resource poor in dry areas by enhancing food security and alleviating poverty through research and partnerships to achieve sustainable increases in agricultural productivity and income, while ensuring the 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 the Central and West Asia and North Africa region, 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. www.icarda.org



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