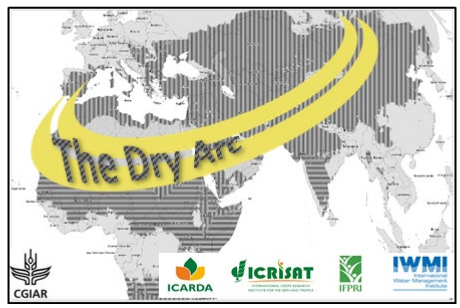
The DryArc Initiative 2019-2021

"Innovations for Sustainable and Resilient Agri-food Systems, Enhanced Food and Nutritional Security, and Employment Generation in Fragile Drylands"

A Proof of Concept for a New CGIAR Interface to support Research and Development Investments in the Drylands

Executive Summary



As the dry areas struggle to adapt to climate change, new research agendas are urgently needed to help strengthen the resilience of rural communities and agricultural food production systems. This Proof of Concept outlines plans for a new research initiative – the DryArc Initiative – which will apply a series of innovations and practical strategies that are designed to raise agricultural productivity, generate new jobs, enhance food and nutrition security, and reduce poverty.

The initiative will utilize a new Interface that harnesses the expertise and knowledge of the CGIAR and its research partners, mobilizing a rich diversity of bio-technical, socio-economic, institutional, and policy innovations tailored to the region's major agro-ecosystems.

By harnessing global research expertise, through a combination of hard system models and institutional reform processes, and by facilitating improved knowledge-sharing on agriculture in the dry areas; the collaboration fostered by the DryArc Initiative will make significant scientific contributions to global agendas such as the Sustainable Development Goals (SDGs). DryArc will also complement the CGIAR Research Programs and Initiatives, and aim to inform and improve the investments and decisions of policy makers, funding agencies, and the private sector.

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

A prototype of the DryArc Interface will be implemented as a pilot phase (2019-2021), during which it will be tested in four distinct Test Cases representing the major agro-ecosystems of the DryArc Region. By the end of 2021, the Interface will have been assessed to identify needs for further improvement, and used to inform, guide, and amplify the impacts of research in the DryArc Region as part of the subsequent 2022-2030 CGIAR Business Plan.

November 29, 2018

1. Why do we need a new CGIAR Interface for the DryArc region?

The dry areas face a daunting combination of challenges, which threaten rural livelihoods and the viability of agricultural production systems. These marginal regions are expected to be among the worst affected by climate change, having to endure significantly hotter and drier conditions, as well as a higher frequency of extreme events such as flooding. The consequences for rural communities in dryland ecologies could be devastating: falling agricultural productivity, increasing poverty, drought-induced displacement, enhanced dependence on costly food imports, and increased competition over scarce resources.

The **DryArc Region** (Figure 1a) extends from Mauritania to China, encompassing a network of major agricultural regions (the Middle East, North Africa, Central Asia, and Sub-Saharan Africa). This Proof of Concept makes the case for an advanced research agenda, led by a science-based alliance and partnership of four CGIAR centers (ICARDA-ICRISAT-IFPRI-IWMI), with support from other CGIAR centers, national agricultural research systems (NARS), advanced research institutes from Europe, China, India, Australia, and the USA, civil society organizations, and the private sector.

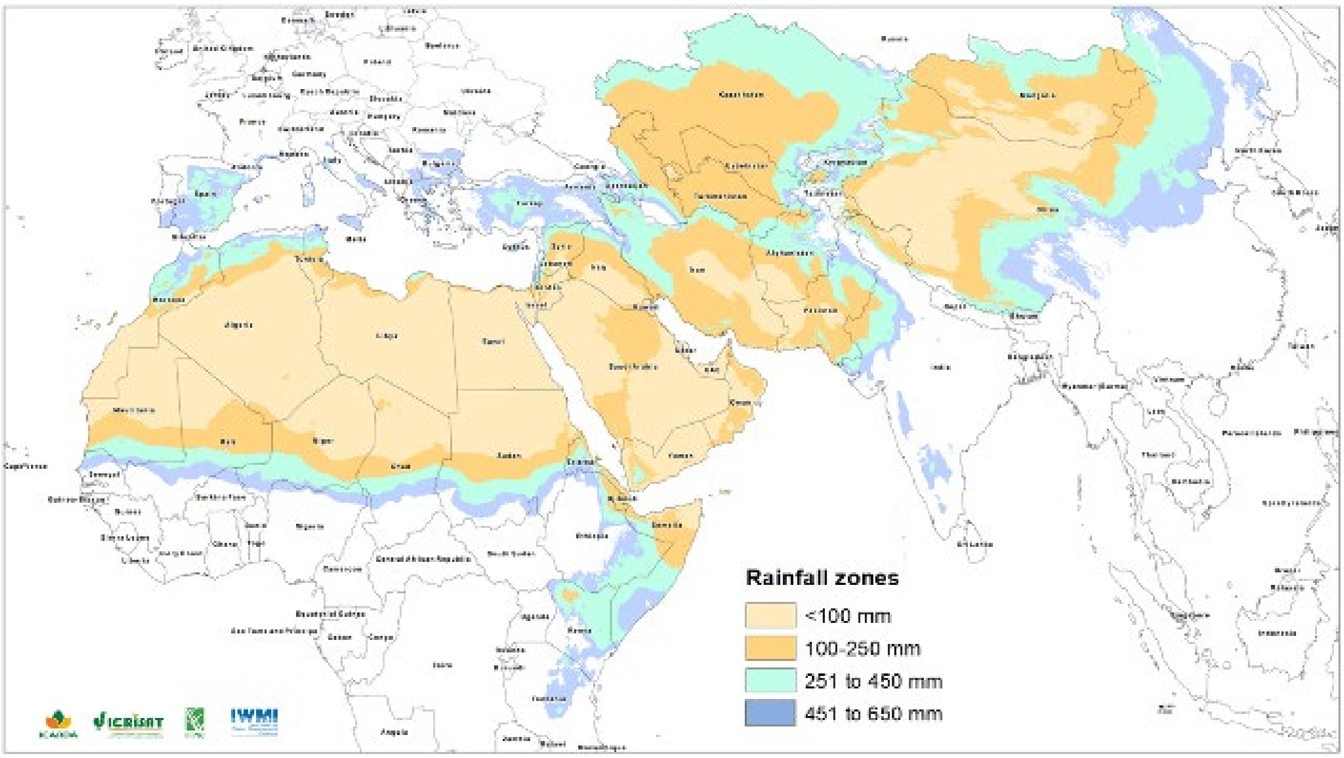


Figure 1a: The DryArc Region and its countries delineated with annual rainfall zones.

The **DryArc Initiative** will strengthen the resilience of rural communities and agricultural food production systems, applying a series of innovations and practical strategies that are designed to raise agricultural productivity, generate new jobs, enhance food and nutrition security, and reduce poverty.

The **DryArc Interface** (Figure 2) will harness the expertise and knowledge of the initiative's research partners, mobilizing a rich diversity of technological, managerial, socio-economic, institutional, and policy innovations tailored to the region's major agro-ecosystems (rainfed, agro-pastoral, and irrigated with green, blue, or grey water) (Figure 1b). By harnessing global research expertise, through a combination of hard system models and institutional reform processes, and by facilitating improved knowledge-sharing on agriculture in the dry areas; the collaborations fostered by the DryArc Initiative will make significant scientific contributions to global agendas such as the Sustainable Development Goals (SDGs) (Figure 3).

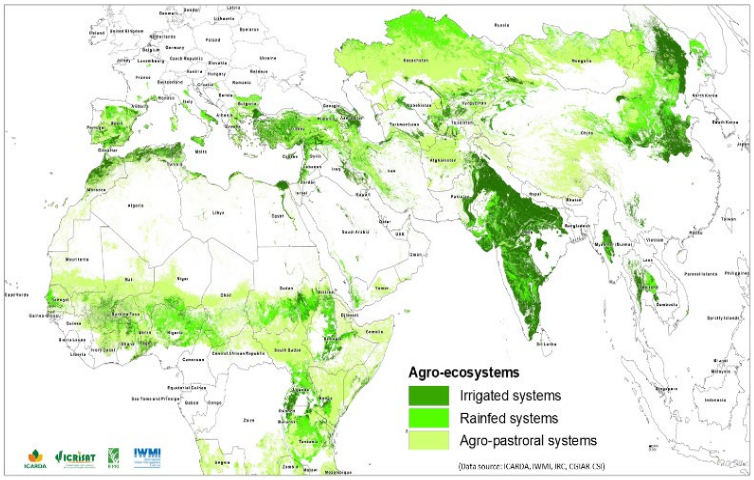


Figure 1b: The three major agro-ecosystems of the DryArc Region.

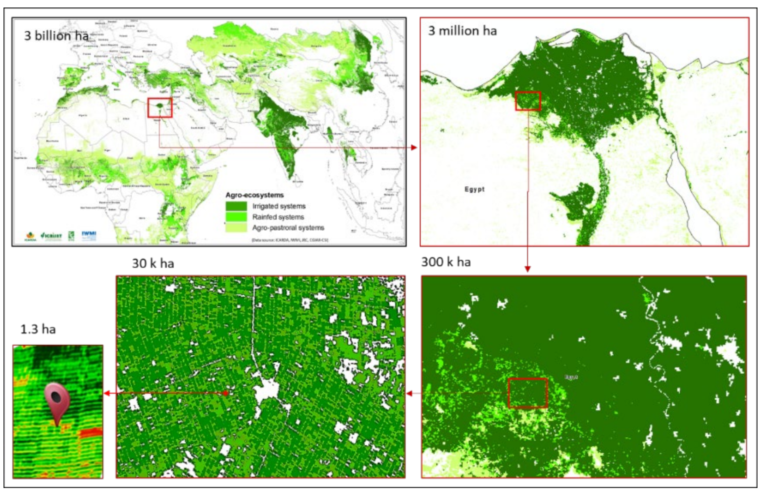


Figure 1c: The fractal delineation of the DryArc Region in the Mapping Tool (MT), based on water availability and at scale, allowing the use of the Integrated Modelling Framework (IMF) of the DryArc Interface.

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

The DryArc **Interface** will use the portfolio of innovations developed for the drylands by CGIAR centers and their public and private sector partners. It is therefore built on and **complements current CGIAR Research Programs (CRPs),** and will add a systemic dimension to other **CGIAR Initiatives** (especially Climate Change) and **platforms** (especially Gender and BigData) in the CGIAR Business Plan (2022-2030).

Compared to ongoing international investments in the drylands, the novelty of the DryArc Initiative lies in the provision of a new interface between research and practice. This interface allows access to existing suites of technological, managerial, socio-economic, institutional, and policy innovations to inform and improve the investments and decisions of policy makers, funding agencies, and the private sector in agri-food systems, thereby generating better livelihoods for the poor. In so doing, the DryArc will support national development strategies and targets that minimize tradeoffs and maximize synergies between several interventions that target SDGs 1, 2, 5, 6, 7, 12, 13, and 15 (Figure 3). The DryArc Interface will therefore help countries enhance their development and attain the 'aspirational' goals of the SDGs, which are often viewed as having targets that go beyond what many countries can realistically achieve.

To this effect, a prototype of the DryArc Interface will be implemented during the 2019-2021 DryArc Project. This Interface will be tested in four distinct Test Cases representing the major agro-ecosystems of the DryArc Region where there is potential for spillovers of integrated packages of bio-technical and socio-economic innovations into neighboring countries where CGIAR is not traditionally present. By the end of 2021, the DryArc Interface will have been assessed to identify needs for further improvements, and used to inform, guide, and amplify the impacts of research in the DryArc Region as part of the subsequent 2022-2030 CGIAR Business Plan.

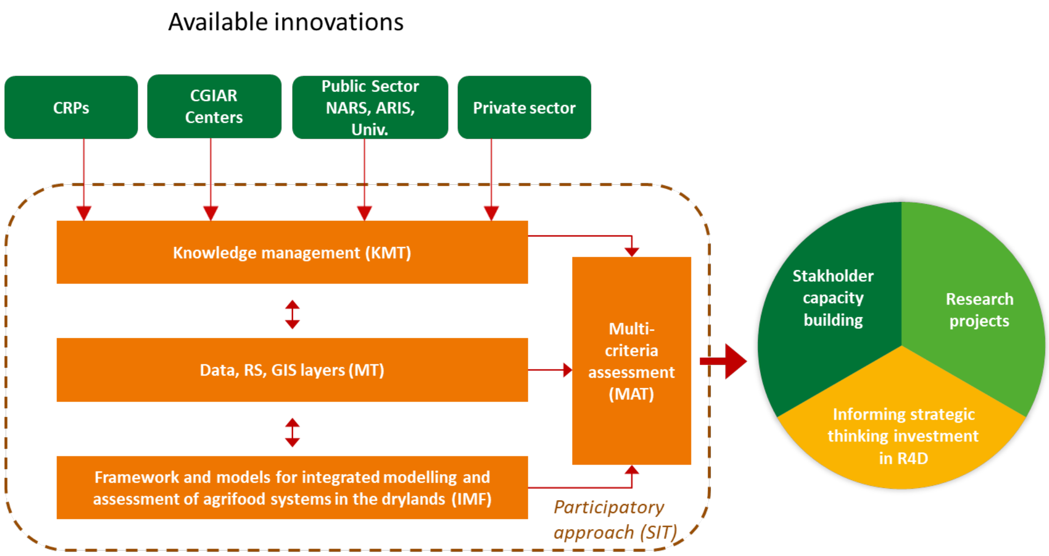


Figure 2: The DryArc Interface and its Five Tools (KMT, MAT, IMF, MT and SIT).

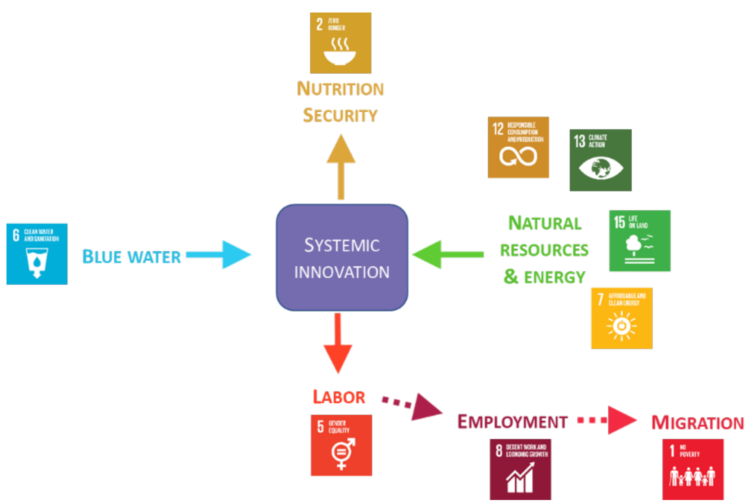


Figure 3: The DryArc Nexus demonstrating how the use of the DryArc Interface to develop Systemic Innovation can minimize tradeoffs and maximize synergies between SDGs.

2. Objectives and the Theory of Change of the DryArc Interface

The DryArc Interface integrates a unique set of evidence and tools supported by four CGIAR centers, which will allow policy makers, funding agencies, and stakeholders of the DryArc region to identify, prioritize, assess, and monitor combinations of proven bio-technical and socio-economic innovations to address SDGs 1, 2, 5, 6, 7, 12, 13 and 15. The interface enables policy makers to assess trade-offs and synergies in agri-food systems across the Drylands, allowing for the prioritization and value for money analysis of public, private, and blended investments in development and R4D projects in the DryArc Region.

The CGIAR has the capacity to develop and test this Interface using a novel combination of five DryArc scientific paradigms:

1. Gap filling research on specific components of agri-food systems in isolation is subordinate to exploring interactions and synergies among crops, trees, soils, and livestock.
2. Trade-offs and synergies in resource use efficiency (especially water, energy, land, and labour) can be quantified at any level of the agri-food system (Figure 1c).
3. Effectively scaling–down climate and economic drivers to the farm level, scaling–out proven technologies to similar ecologies, and scaling–up socio-economic and environmental impacts of innovations in agri-food systems can be achieved with integrated modelling (Figure 2).
4. Plausible and comprehensive trajectories of agri-food systems can be designed and managed to ensure sustainability and trade-off management across SDGs.
5. The likelihood of uptake and impacts of bio-technical innovations in agriculture is increased by the integration of socio-economic innovations (policies, institutions, communities, and markets) during the design process.

The Theory of Change of the DryArc specifies that with this systemic innovation approach (i.e. a combination of several technological innovations, institutional reforms, and an enabling policy and socio-economic environment), it is possible, with existing technologies, knowledge and simulation models, to implement R4D programs in any part of the DryArc Region to improve food and nutrition security, while also reducing the use of fresh water and energy and achieving land degradation neutrality. The impact of these innovations on gender-disaggregated labour requirements and job creation for youth and women needs to be analyzed and quantified at country level, but it is hypothesized that they will be positive - either on farm, or at the regional and supply chain level. The achievement of better trade-offs in this **DryArc Nexus** (Figure 3) is expected to improve livelihoods and resilience in the rural areas of the drylands, thereby reducing displacement and the socio-political fragility of countries in the DryArc Region.

3. The DryArc Interface

As shown in Figure 2, the Dry Arc Interface combines five types of tools and **interact with users** to define problems and describe innovations. It will be developed in 2019 using existing tools and the on-going efforts of the four CGIAR centers. Each Test Case will use, assess, and improve interface components and procedures, and use the Interface to interact with stakeholders and partners. The workflow of the Interface (Figure 2) will allow the Test Cases to start in mid-2019, with problem definitions, the selection of innovations, and a first prototype of the Knowledge Management Tool (KMT).

Knowledge Management Tool (KMT)

The KMT is being designed to describe each innovation, including definitions of the conditions needed for the successful implementation of each innovation at the farm scale (biophysical and socio-economical) and its embedding systems (market, community, policies, and institutions). The development of this tool will make use of existing tools such as GeOC, developed by ICARDA as part of the CRP Dryland Systems. Observed or putative impacts on employment in- and/or off-farm for each innovation by context will be included in the KMT database. A first version of this tool will be produced in June 2019, and an extended version (with enhanced functionalities and a larger number of innovations in the database) will be produced in June 2020.

Multicriteria Assessment Tool (MAT)

The MAT will allow for the qualitative assessment of each innovation by context in the DryArc Nexus (Figure 3), with indicators for food and nutrition security, water use and productivity for each category (blue, green, grey) using the WA+ tool developed by IWMI and water footprints, energy use, and labour requirements disaggregated by gender. In an iterative process, the tool will also allow users to combine several innovations and their enabling contexts to make assessments in the Nexus. The tool will also enable users to make use of other assessment frameworks, such as the Productivity-Stability-Sustainability-Equitability Framework developed by IWMI.

The Integrated Modelling Framework (IMF)

The IMF is a flexible framework that integrates models (of climate, crops, farms, supply-chains, economy) and typologies (groupings of target actors) for multi-scale and multi-criteria impact analysis (using the MAT), cost-benefit analyses, and trade-off analyses that can help assess the impact of innovations on employment and trade-offs related to nutrition and resilience. The on-going work conducted by the four CGIAR centers will enable the development of a first prototype of the IMF, which will be used for the Test Cases in 2020 at one or two of the following levels:

From regional to national and global. Outputs from the local analysis of individual innovations will be used as inputs of more comprehensive economy-wide models. Two of these models are IFPRI's IMPACT (International Model for Policy Analysis of Agricultural Commodities and Trade) and AIDA (Agricultural Investment for Development Analyzer). The IMPACT is an integrated modelling system that links information from climate models, crop simulation models, and water models (such as WA+ from IWMI) linked to a core global, partial equilibrium, multimarket model focused on the agriculture sector. The model supports long-term scenario analysis to assess and compare the potential effects of changes in biophysical systems, socioeconomic trends, technologies, and policies. The new PS-IMPACT (Portable Standard IMPACT Model), recently developed by IFPRI, is a country-level version of the core IMPACT economic model, allowing a more focused and flexible economy-wide analysis of the impact of innovations at the national level. The AIDA, centered on the use of an economy-wide Computable General Equilibrium (CGE) model, links agricultural and rural spending to economic growth, job creation, and household poverty. It considers trade-offs and opportunity costs associated with different investment options, enabling the ranking of possible interventions and allocations of public funds. The KMT database will be used to parameterize these models for each innovation.

From farm to region and supply-chain. The DryArc Initiative will use the rich portfolio of models developed by ICRISAT, ICARDA and their partners: farm modelling (based on multicriteria optimization or decision rules), multi-scale household/farm and community/landscape modelling, and food value chain modelling. Typologies (farms/households, management activities, and regions) will be used to combine models at different scales (e.g. field-farm-landscape). We will also use Group Model Building approaches to develop quantitative value chain models that support community food systems.

This activity will be coordinated by IFPRI for the 'Region to Global' level and by an ICRISAT-ICARDA Community of Practice for the 'Farm to Region/Supply Chain' level, in collaboration with IWMI at each level. Data and expertise generated by the KMT will be used to parameterize and assess these models prior to their use for sensitivity analysis and scenario simulation.

The Mapping Tool (MT)

The MT is a computerized platform that is able to combine geo-referenced data (climate, soil, land use and high resolution remote sensing data, and population) with data produced by the KMT, the MAT, and the IMF in order to support down-scaling, out-scaling, and up-scaling processes in each of the Test Cases. The resolution (or pixel) and extent (area covered by the analysis) is likely to depend on the nature of the innovations (e.g. field level or watershed level), and on the available data for each Test Case. The objective is to go beyond the classical approach of mapping the soil-climate conditions for an innovation, which are only a minor part of the conditions for success. Beyond 2019-2021, the overall objective is to put into synergy the on-going efforts of the four centers (including the Water Portal at IWMI, and GeoAgro at ICARDA), in order to coordinate an international network on agricultural systems and innovations across the various agro-ecosystems (irrigated, rainfed, agro-pastoral) of the DryArc Region, in collaboration with existing national and international networks.

The Stakeholders Integration Tool (SIT)

The SIT is a participatory research methods kit (focus groups, conceptual maps, expert knowledge elicitation) to ensure proper engagement and understanding of the four hardware tools that compose the Interface (KMT, MAT, IMF, MT). The SIT will enable researchers to (1) capture and integrate the objectives, vision and knowledge of stakeholders, policy makers, and NARS; (2) conduct a systemic conceptualization of the issues to be addressed with the Interface tools; and (3) share analyses and communicate the scenarios and indicators produced with these tools.

4. Proof of Concept of the DryArc Interface (2019-2021)

4.1. Objectives and Test Case Selection

The objective is to demonstrate, by the end of the project in 2021, that the DryArc interface has the following six attributes:

- **Relevance** to guide development and R4D investments on interventions in the DryArc Nexus (Nutrition-Water-Natural Resources-Labour) to create employment, improve livelihoods, and reduce displacement;
- **Operationality** to describe, select, assess, and combine innovations produced by the CGIAR, its national partners, and the private sector to improve agri-food systems in the DryArc Nexus;
- **Flexibility** to allow for its potential use in any combination of innovations, agro-ecosystems and countries across the DryArc region;
- **Complementarity** of DryArc with current CRPs and other CGIAR initiatives and genericity of the Interface to guide strategic thinking, prioritization, and investment in agri-food systems R4D in dry areas. The DryArc Interface will also be designed to guide future research activities to regenerate adequate components of the packages developed by the initiative. A key criteria is the potential 'spillover' to countries/regions that are emerging from conflict or opening-up to the international community;
- **Attractiveness** for donors and the private sector so they are encouraged to invest in Drylands R4D in order to support SDG achievements in the region while reducing displacement (within or outside the region);
- **Efficiency** in the use, maintenance, and development of the Interface. Fixed costs will also be limited thanks to its modular design and the fact that it is a collective effort of CGIAR centers.

To achieve these objectives in a limited timeframe (2.5 years), we have selected four Test Cases typical of the DryArc Region to demonstrate that the DryArc Interface complies with the six attributes above, and to guide its future implementation and development in the CGIAR Business Plan, starting in 2022.
Given the budget requirements and to limit the risks of the 2019-2021 DryArc Project underperforming, we have selected, for each Test Case, a principal site and an agro-ecosystem type for which a large portfolio of innovations is available and long-standing partnerships between CGIAR centers and national partners already exist.

4.2. Test Case 1: Sustainable intensification of rainfed cereal-based agri-food systems in the drylands

Test Case 1 targets the "wheat basket" of the MENA region, represented by wheat-based agri-food systems, which are expanding in most countries as a result of population growth, evolution of diets, and dedicated policies to achieve self-sufficiency in wheat (e.g. Morocco, Egypt, Ethiopia, and Sudan).

Wheat expansion to date has been mostly supported by irrigated and intensive wheat crops, which represent approximately 45% of the wheat area in the MENA region. This is often at the expense of other crops (especially pulses and forages), and of sustainable natural resource management (soil, water, and biodiversity). In areas where wheat is grown under rainfed conditions (e.g. Morocco, Ethiopia), crop production is affected by pest/disease build-up and declines in soil fertility due to the predominance of monocropping systems. The lack of rotation options, especially labour saving machine harvestable legume varieties (e.g. lentils, chickpea), is partly the reason for the dominance of wheat-based farming systems. With increased evapotranspiration and rainfall variability, climate change is likely to further undermine the sustainability of these food production systems. This Test Case will focus on rainfed cropping systems to support the sustainable intensification of wheat-based systems where dryland production is constrained by agronomic management, and where there is no opportunity for irrigation. In that sense, this Test Case complements Sub-Theme 2 of the MENA Impact Area of the Climate Change Initiative of the CGIAR, which focuses on irrigated systems.

Wheat-based farming systems are undergoing rapid socio-technical transformation. They are experiencing rising costs for labour, mechanization of land preparation, sowing and harvesting, and the use of herbicides to control weeds. All of these developments are having an impact on employment, and have implications for the employment of youth and women in particular. These trends will reduce on-farm labour requirements, but they could also make farming more attractive to youth, and could increase employment opportunities beyond agriculture (service delivery activities, or value addition), which could also attract youth, and potentially empower rural women.

This Test Case will explore potential combinations of smart bio-technical innovations produced by CGIAR centers over the past 40 years (called innovative systems below) for wheat and barley production under rainfed conditions, so that valuable water can be reallocated for high value uses such as the production of seeds, vegetables, and fruits at the field (with rotation and/or association of rainfed cereals and irrigated crops), farm, and regional levels. We will also explore the socio-economic conditions (at household, community, market, and policy levels) required to support the implementation of these innovative systems at a wider scale (country to region), and to achieve better trade-offs and synergies in the DryArc Nexus.

The hypothesis is that it is possible to sustainably intensify cereal production in the rainfed environments of the DryArc Region, while reducing tradeoffs in the DryArc Nexus, provided that the following measures are introduced and implemented:

- Conservation agriculture, which helps to improve soil health and carbon sequestration, reduce soil erosion, conserve moisture, and reduce labour and energy requirements;
- Diversified rotations, including machine-harvestable pulses (to also contribute to nutrition security) and forages (to leave crop residues for conservation agriculture), which are essential for soil quality, pest and weed control, and water and input use efficiency;
- Closing yield gaps through proven agronomic practices adapted to rainfed production systems;
- Information and decision-support tools are made available and used by farmers and advisors to manage input use (especially N fertilization) and crop rotation under uncertain climate conditions (especially rainfall);
- Supply chain organization (including seed system), credit/insurance mechanisms, and enabling or de-risking policies that help institutions implement systemic combinations and support the positive impacts of innovations in the different agro-ecosystems and farming systems of a country.

Morocco has been chosen as the principal site for this Test Case for the following reasons: (1) rainfed production of cereals and pulses and integration with livestock is one of the priorities of the Green Morocco Plan and only 10% of the country's 3.2 m ha of wheat is irrigated; (2) ICARDA, IWMI and IFPRI have a longstanding collaboration with Moroccan institutions on innovations for this type of agriculture, including a specific program with INRA-ICARDA-CIMMYT on conservation agriculture (under CRP Wheat); and (3) the whole range of rainfall and cereals (bread wheat, durum wheat and barley) of the non-tropical drylands is represented in Morocco, potentially raising the possibility for secondary sites in fragile and post-conflict countries (especially Iraq, Syria, and Afghanistan) where these crops are a food security pillar.

Preliminary discussions will be initiated for this Test Case before the end of 2018 with development agencies and foundations from Europe, Australia, USA and China. Some of the top-level universities and research centers from these countries have already expressed interest in collaboration on this Test Case because of its relevance for their agriculture under climate change, and because of the methodological developments of the DryArc Interface. Preliminary discussions with INRA Morocco generated strong interest, and consultations will be extended to all relevant national institutions (ministries, NARS, Universities) and private companies representing the seed, food and IT sectors.

Test Case 1 will be coordinated by ICARDA. It will involve IFPRI and IWMI for up-scaling activities to region and country levels, including the use of the MAT tool, ICRISAT for the integrated modelling component (IMT) for climate risk and farm-supply chain levels, and CIMMYT for the crop-farm modelling component. Collaboration will be established with CIMMYT and the CRP Wheat, CRP GLDC, and CRP LIVESTOCK to enrich the KMT database with the outcome of these CRPs.

Test Case 1 will assess, in particular, the capacity of the DryArc Interface to describe and combine a large set of bio-technical innovations into innovative cropping systems that can be out-scaled to other regions, assessed in a nexus, and up-scaled for ex ante impact studies on employment at country levels.

4.3. Test Case 2: Information, income shocks and welfare in the irrigated drylands of Central Asia

Test Case 2 targets the drylands of Central Asia, represented by irrigated, diversified agri-food systems, which are expanding towards horticulture products in Uzbekistan, Tajikistan, Kyrgyzstan, and Southern Kazakhstan, as a result of the agricultural diversification policies of national governments, support from development partners (the World Bank, ADB, EU, USAID and others), and growing domestic demand and opportunities in foreign markets.

Despite recent improvements in food security, the diversity of diets in the region remains a challenge, and people continue to face overlapping burdens of malnutrition, together with water scarcity and natural resource degradation. Diversification of agriculture, in this regard, will improve the availability of food legumes, fruits, and vegetables for domestic consumption, and allow farmers to switch to high-value horticulture crops by creating opportunities for productivity and income growth. However, the region's agriculture is highly vulnerable to external economic and weather shocks and long-term climate change. Irrigated crop production is vulnerable to such shocks and changes because intensification of these systems depends on the quality of arable land and the availability of scarce water resources. The irrigated agricultural system in Central Asia has in the past focused primarily on cotton-wheat systems, resulting in low land and water productivity and deterioration in soil health. There is huge scope to improve soil health, increase cropping system intensity, create additional on-farm employment, and improve human nutrition by integrating food and fodder legumes into cotton-wheat systems.

At the same time, the scope for improving irrigated agricultural productivity remains obscure due to a lack of data for timely decision-making and analysis. In this context, there is a critical need for data, models, and knowledge products that provide user-friendly data acquisition and analytical capability for decision-makers, from farm-level decision support to policy decision-makers. The most important limitation to developing these decision-making tools is acquiring timely, site-specific data, and combining it with analytical tools to improve the quality of decision-making from farm to regional and national scales.

The inability to systematically develop and use analytical tools and models has given rise to a situation where policymakers in Central Asia make ad-hoc decisions of which the impacts are, in turn, frequently not evaluated. Working together with partners in the region, we would like to build capacity so they can benefit from the high potential of up-to-date models and tools. This Test Case will link agricultural production and household data with remote sensing data to make evidence-based policy decisions by:

- Explaining spatial patterns of current crop production in the irrigated agricultural landscapes of the region;
- Providing accurate water accounting, which is vital for understanding hydrological processes, managing water flows, and informing dialogues on water. Sound water accounting systems help to improve water management, allocate water equitably between sectors and users, and boost agricultural yields and water productivity;
- Integrating food and fodder legumes in current cotton-wheat cropping system to improve land and water productivity and soil health, increasing cropping system intensity by including cash crops, creating additional

on-farm employment by growing crops during traditional land fallow periods, and improving human nutrition by consuming nutritious food legumes produced by farmers and households;

- Developing flexible, robust, locally accepted, sustainable, and low-cost systems that enable improved production estimates and timely information for enhanced policy decisions and decision making at the farm level, thereby reducing risks and improving technical and economic efficiency in agriculture;
- Analyzing the benefits of timely information on decision making at the household and sectoral level, and understanding how better monitoring of hazardous events can improve the efficiency of water use;
- Examining the effects of adverse income shocks related to weather and market variability in different production systems, and how households are both affected by, and cope with, such shocks;
- Considering the types of policies that can address households' vulnerabilities, including social protection, policies that increase private access to land, and policies that aim to increase both women's and men's aspirations.

Uzbekistan and Tajikistan have been selected as the principal sites for Test Case 2, for the following reasons: (i) diversification of agriculture towards horticulture and more food legumes production is a strategic priority for governments of these countries and supported by large loans from the World Bank and ADB; (ii) IFPRI, IWMI, and ICARDA have a long-standing collaboration with policy and research institutions in these countries, which will help to implement the proposed research and capacity strengthening activities more smoothly; and (iii) the experience obtained from the implementation of the proposed research and capacity strengthening program can be extended to other countries in the region and beyond (for example, the Caucasus).

The potential donors for Test Case 2 are EU, USAID, Germany, JICA, the World Bank, and ADB. These donors are already implementing large projects related to agricultural diversification in these countries. Consultations will also be conducted in Uzbekistan and Tajikistan with national policy and research institutions, and the private sector.

Test Case 2 will be coordinated by IFPRI in close collaboration with IWMI, ICARDA, ICRISAT and regional programs, and will coordinate with WorldVeg, NARS, and the private sector to populate the DryArc KMT database with innovations for the production of horticultural crops adapted to the DryArc region. Outcomes from the CRPs PIM and WLE will also be used to improve the integrated modelling and policy analysis components of the DryArc Interface.

Test Case 2 will assess, in particular, the capacity of the DryArc Interface to manage and analyze a large set of data on agri-food systems to support decision making and policy analysis at the country level. It will also assess the capacity of the KM Tool to describe and assess innovations based on data and IT Technologies to be used across value-chains and markets.

4.4. Test Case 3: Building Resilient Livelihoods in the Dry Lowlands of Ethiopia Through Diversification, Intensification and Natural Resource Management of Crop-Livestock Systems.

The agro-pastoral farming system in East Africa, extending from Tanzania through Kenya, Eritrea and Somaliland is a major agri-food system operating under drought and extremely variable conditions. It features a combination of pastoral and crop production activities at varying levels, depending on the relative suitability, largely dictated by the availability and reliability of rainfall for crop production. In favourable seasons cropping activities tend to dominate the mix in terms of income, whereas the livestock component acts as a source of income security, energy for mechanisation and wealth. The main crops grown in rainfed systems are sorghum, millet, early maturing maize, and beans. Irrigated areas in the lowlands are currently used for cotton production in Ethiopia, but could be diversified by expanding the production frontiers of traditional highland crops.

The low-lying plains in sub-Saharan Africa are commonly drought prone areas, receive limited rainfall, and are exposed to frequent extreme events. Climate variability and associated drought is the most frequently recurring cause of disaster, placing millions of people under extreme risk of food deficit due to crop failures and livestock mortality. The effect is aggravated by the degradation of landscapes and associated poor water holding capacity of soils, poor agronomic practices, and poor water management practices. Even in good years, crop yields rarely exceed 1.5 tones ha^{-1}, which is two to four times less than the achievable yield. This requires an investment in the often untapped potential of upgraded rainfed agriculture.

The risks of recurrent flood and drought in the same location have been aggravating poverty and are the major causes of disaster and displacement. The Ethiopian lowlands often receive a large volume of seasonal floods from neighboring upstream highlands, which causes recurrent population displacements and emergencies every year. It is argued that research has paid little or no attention to the complimentary inputs required to harness the full benefits of water management practices and enabling conditions that are conducive to promote the required investments. ICRISAT and its international partners (e.g GIZ) have already developed strategies and interventions to convert floods into productive uses, for growing food crops and rehabilitating rangelands at scale. This could be implemented at scale through:

- Mapping flood flows, identifying niches and opportunities for intervention, and assessing impacts of flood-based interventions using geospatial tools and models at scale;
- Developing and demonstrating the benefits of integrated flood management programs in improving productivity, incomes and the sustainability of the natural resource base at farm and watershed scales;
- Identifying economic and social constraints to the adoption of rainwater management practices and evaluating new participatory approaches and integrated platforms for increased adoption.

Using rainwater management as an entry point we will use the DryArc KMT and IMT tools to scale-up known technologies and interventions in lowland crop-livestock agro-ecologies in Ethiopia. In an approach similar to Test Case 1 these interventions will combine different bio-technical innovations and socio-institutional innovations, including:

- Making rainfed cereal production (Sorghum, Millets and Teff) more profitable and rewarding through the efficient utilization of crop residues in livestock feeding, product diversification, agri-business incubators and niche-specific rainwater management production systems;
- Promoting specific crop varieties and hybrids that combine adaptation to end-user preferences and to rainfed conditions such as high-biomass, striga resistance, and drought-tolerant or bio-fortified sorghum (Fe, Zn, high lysine);
- Promoting intervention packages for making agro-pastoral sheep and goat production more profitable, combining reproductive, feeding and health management, and marketing strategies;
- Exploring the diversification of cotton-based irrigated schemes in the lowlands by introducing cereals and legumes, and combining heat- and drought-tolerant wheat, barley and chickpea varieties with water use efficient agronomic practices;
- Enhancing the capacity of national stakeholders along the value chain and introducing socio-institutional innovations that encourage commercial agriculture, such as micro-finance, IT-based extension services, and capacity development in systems analysis and modelling.
- Reducing resource conflicts between farmers, agro-pastoralists and pastoralists, especially in areas where feed resources and water are constrained by climate variability.

The agro-pastoral systems and the transition zone of pastoral systems in the lowlands of Ethiopia (potentially extended to Somaliland) have been selected as the principal site of Test Case 3 for the following reasons: (1) with six million people in fragile conditions it can provide a clear demonstration of the capacity of the DryArc Interface to address major challenges in sub-Saharan Africa; (2) many CGIAR centers and CRPs have previously produced crops and livestock bio-technical and socio-institutional innovations adapted to sub-Saharan Africa that can be described and integrated with the DryArc KMT database; and (3) the existence of long-standing partnerships will help facilitate engagement with a large set of partners from public institutions (EIAR, Universities, ATA, and ministries), private sector bodies (agricultural and food companies, farmer's associations), and NGOs (GIZ, Save the Children).

The potential donors for Test Case 3 are BMZ-Germany, which has already invested in similar projects through its development partners, and European Union resilience programs.

Test Case 3 will be coordinated by ICRISAT and will involve ICARDA, IWMI, IFPRI and ILRI to enrich the KMT database and develop the integrated modelling studies. The outcome of CRPs LIVESTOCK, WHEAT, MAIZE, WLE and GLDC will also be integrated in the Test Case.

In terms of the testing opportunity for the DryArc Interface, Test Case 3 will combine the attributes of Test Cases 1 and 2.

4.5. Test Case 4: Sustainable Desert Farming

Test Case 4 targets all forms of agriculture (including horticulture, protected agriculture, livestock, and fish) conducted in sandy soils under a rainfall threshold of 100 mm (Figure1a), which does not allow crop or trees to produce food in rainfed conditions, and in locations where there is no significant water harvesting. This form of desert agriculture therefore requires the use of water for irrigation, which is pumped into aquifers with a more or less saline water, and with no or limited renewability of the water resource.

This desert agriculture is, for many countries in the Drylands (e.g. in the Arabian Peninsula), the only source of food production and employment in agri-food systems. The traditional oasis (e.g. in MENA region), whose sustainability is at threat in many countries, also uses this type of agriculture. In countries like Egypt the expansion of agricultural land and the creation of new employment opportunities and new settlements in response to rapid population growth also relies on this form of agriculture. Opportunities for job creation are noticeable because the development of this agriculture is largely driven by value added and labour intensive horticultural crops and orchards, protected agriculture, and aquaculture. However, the sustainability of this form of agriculture is at threat with low soil fertility, limited availability of water and organic matter, water salinity, wind and high evaporative demand, and isolation from sources of energy (off grid) and markets, all exacerbated by climate change.

The portfolio of technological innovations for desert agriculture is large and diversified, considering the large number of technologies and innovations produced by the public sector (CGIAR centers, ICBA, IWMI, ICRISAT, NARS, and Universities), the private sector (protected agriculture, desalinization of water, solar energy, and treated wastewater), and rural communities in traditional oases and rangelands.

To be sustainable and to have positive impacts in the DryArc Nexus this form of agriculture should be designed and managed as a complex integrated agricultural system (i.e. many components in interaction), with facilitation mechanisms and circular economies among several agricultural activities, depending on the access and quality of water available (fresh, saline, treated waste water). For example, when water is saline the best farming system may involve partial desalinization (with possible aquaculture) to go below a threshold that allows for a larger diversity of crops (including rangeland species and cactus) and trees (including date palm) that could be intercropped for better microclimate conditions and overall tolerance of other crops to heat and drought. Similarly, yield potential, input efficiency, and salinity tolerance of crops may depend, in these sandy soils, on organic matter, itself depending on the integration of livestock and fish supported by forages and crops adapted to these conditions. For example, heat-resistant varieties of millet and barley, together with water saving strategies, could make a substantial contribution to these integrated systems. Also, because desert regions are often off-grid and diesel is required to produce energy for pumping groundwater and desalination, any increase in the price of diesel can make this form of agriculture unsustainable. In response, this Test Case will explore the potential of using solar power for pumping and desalination, informed by a suitability analysis developed by IWMI for solar power and groundwater governance in the MENA region.

The design of these integrated farming systems and their multicriteria assessment under climatic and socio-economic scenarios can be supported by the DryArc Interface and its integrative modelling framework. This would guide public and private investments in large projects for new settlements, as well as in more local development projects to support farming communities in fragile conditions. The KMT-IMT-MAT-MT tool combination will be used to map, design, and assess smart combinations of plant and animal species adapted to desert soil-climate conditions, soil and water management technologies, solar energy, and local transformation methods for high-value products.

The principal site for Test Case 4 will be in the western desert of Egypt in partnership with ministries, NARS (ARC, Desert Center), the El Reef El Masry Company (in charge of the '1.5 million feddans' project), and a renewed partnership between ICARDA, IWMI, IFPRI, ICRISAT, Worldfish, and WorldVeg.

If funding is available, secondary Test Case sites can be established in North Africa (oasis), in the Arabian Peninsula countries, and in India (Rajashtan).

The potential donors for Test Case 4 are countries, international agencies, and the private sector for the large scale farming and settlement projects, and international agencies, NGOs and countries for the traditional oasis systems. Preliminary discussions will be conducted for this Test Case before the end of 2018 with governments, development agencies, and foundations from the Gulf Cooperation Council and its member states. Consultations have already started with Egyptian public and private partners, and will be extended to private companies operating in the region's energy, water, and agricultural sectors.

Building on the comparative advantage and strategic scope of each center, ICARDA and IWMI will co-lead Test Case 4 and will involve ICRISAT, WorldFish, and WorldVeg, as well as national and regional centers specialized in desert agriculture.

Test Case 4 will involve testing the capacity of the DryArc Interface to (1) use the KMT to manage a large set of agro-ecological and technological innovations produced in a dispersed manner by the public and private sector; and (2) use the IMT to design large and small-scale integrated farming systems and assess their sustainability in the DryArc Nexus with MAT.

5. The 2019-2021 DryArc Project

The **DryArc Project** (March 2019-July 2021) aims to develop a prototype of the DryArc Interface, and through the four Test Cases demonstrate its effectiveness in scaling integrated technologies (see part 4.1), in preparation for a full **DryArc Interface** that will contribute to the CGIAR Business Plan (2022-2030). The key milestones and activities of this project are described in Table 1, including the preparation phase (Dec 2018 - Feb 2019) and the assessment phase (Aug.-Dec. 2021). Indications of funding requirements are also given, but they will be fine-tuned during the preparation phase.

We will then describe the output and outcome of the DryArc Project, as well as the foreseen outcomes and impacts of the DryArc Interface beyond 2022.

Table 1: Roadmap of the DryArc Project for proof of concept of the DryArc Interface

Phase	Dec 2018- Feb 2019	March-May 2019	June 2019 - May 2020	June 2020- July 2021	August-December 2021	January 2022-
DryArc Agenda	Preparing the DryArc Project	**DryArc Project**: Proof of Concept of the DryArc Interface			Preparing the full DryArc Implementation	Implementing the **DryArc Interface**
Major Activities	1) Consultations and Project Development 2) POWB of the Interface as a whole and of each Test Case 3) Submission of projects	4) Development of a Prototype of the Interface 5) Populating the KM Tool database with innovations adapted to the 4 Test Cases 6) Development of partnerships with a broad set of stakeholders and donors	7) Test Case implementation	8) Assessing and improving the prototype 9) Presentation and discussion of Test Cases results 10) Marketing of the DryArc Interface with the Output of Test Cases 11) Reporting on the DryArc Project	12) Development of the DryArc Interface POWB and cluster of projects for 2022-2030	13) Implementation of DryArc Interface Projects (2022-2024)
Budget Estimate	US$ 20 to 30 k + Staff Time	US$ 200 to 400 k, including Staff Time	US$ 2 to 3 m per year for each Test case including the implementation/improvement of the Interface + US$ 0.5 m per year for coordination /communication of the Project, with CRPs and others Initiatives, and with potential users of the Interface.		US$ 200 k including Staff Time	US$ 2.0 m per year for maintenance and upgrading of the Interface + US$ 0.5 m per year for coordination/communication specific budgets for applications (US$ 1 to 10 m /year/project)

Outputs of the DryArc Project (2019-2021):

- A prototype of the DryArc Interface and its tools tested and assessed in contrasted situations typical for the DryArc Region, with a roadmap for further improvement and implementation across the whole region.
- Test case results in the form of scenario narratives and recommendations to guide investment, policies, and research prioritization, especially for targeting new non-traditional CGIAR areas.
- Publications, including high impact and integrative scientific papers on Interface methodologies, the DryArc Region, and Test Cases results.
- A new series of high level annual reports, coordinated with international agencies (FAO, UN), with a first issue in 2020 as a baseline analysis of agriculture, water, nutrition, employment, and migration in the DryArc Region.
- A list of potential users and donors with clear commitments to contributing and funding the development of the DryArc Interface under the CGIAR Business Plan (2022-2030).
- A group (10-20) of MSc, PhD, and Post-doc scientists (40% female) involved in the DryArc Project, half of them willing to use and develop the Interface beyond 2022.

Outcomes of the DryArc Project (2019-2021):

- A new way of working across centers is demonstrated, which prioritizes further research for the drylands.
- The scientific approach of the DryArc is reconciled, and operationalized commodity-based and systems-based research in the CGIAR is taken forward by a new generation of researchers (with female scientists equitably represented) embracing this vision.
- The DryArc Interface is recognized by major research and development institutions as the hub for innovation in dryland agri-food systems.
- Increased capacity of regional institutions to define and implement strategies and policies for employment-generating innovations in agri-food systems in each of the Test Cases.
- Each of the four Test Cases is implemented in three other sites in different countries, and ten new Test Cases are identified with a principal site in one of the DryArc countries.

Foreseen Outcomes and Impacts of the DryArc Interface (post 2022) to be Refined with Quantified Targets by 2020, and aligned to the SDGs:

- The agri-food sector in the drylands contributes to sustainably improved food and nutrition security, as well as employment of youth, without further increasing blue water use.
- Reduction in displacement within target regions as a result of resilience in the agricultural sector and enhanced opportunities for livelihoods from agriculture and its aligned sectors.
- Reduction in social conflicts between agro-pastoralists and farmers in target regions, due to employment opportunities in the agri-food systems and to a more equitable and sustainable use of natural resources.
- Investment in R4D for the drylands increases from both public and private sectors.
- Institutions and stakeholder groups (public and private) have the capacity to implement policies and a R4D strategy based on the five paradigms of the DryArc Interface and manage complex interactions and trajectories in the agrifood sector under global change (climate, demography, economy).
- Establishment of major initiatives in higher education institutions of the target regions to train students in integrated and systems approaches for supporting livelihoods in the drylands.