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# Management of Scarce Water Resources and Mitigation of Drought in Dry Areas (MegaProject 1)

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## Introduction

Water is the scarcest natural resource in the dry areas. It is the most limiting factor for agricultural development. In the dry areas the demand for food is increasing while the amount of water allocated to agriculture is declining due to allocation to higher priority sectors. Furthermore, groundwater resources are being overexploited and both surface and groundwater resources are affected by quality degradation. MegaProject 1 responds to this situation and to the needs of the poor communities in the region by promoting the capture of undeveloped and underutilized water resources, the improvement of agricultural water use efficiency and the sustainability of the production base. Sustainable production of more food with less water to improve the livelihoods of poor communities is the ultimate goal of this Project. This is in line with ICARDA's mandate and mission for promoting productive agriculture while preserving and enhancing the resource base and with the CGIAR vision developed at Lucerne and TAC's 1995 "Priorities and Strategies for Soil and Water Aspects of Natural Resource Management Research in the CGIAR." The greater emphasis of the Center on natural resource management called on by previous EPMR and endorsed by TAC through the MTP 1998-2000 and the emphasis on producing international public goods was largely materialized through adopting themes designed to address these issues. The program addresses one of the most important CGIAR priorities developed by the SC and adopted recently.

As a result of global and regional physical and socio-economic changes particularly regarding water scarcity and food security and priority settings of ICARDA's NARS, the water program at ICARDA has continued to evolve in response to these changes. The restructuring of ICARDA research programs in 2005 further emphasized water through creating MegaProject 1 (MP1). The new water program (MP1) continues to research the strategic issue of sustainable increase of water productivity with linked on-farm water research to that at the basin level. A strategic partnership with IWMI, IRRI and CIAT is established to achieve this linkage. Emphasis is being laid on the assessment of scarce water resources in CWANA and on sustainable allocations to various uses including fresh and marginal-quality water. Drought, before 2005, was only tackled by developing germplasm for drought tolerance. Preparedness and mitigation of drought through integrated management of water resources and appropriate cropping patterns is now initiated. A new emphasis is started on researching water policies and institutional setups to support adoption of appropriate technological options to improve water productivity. More emphasis is being placed on the research for dissemination and adop-

tion of improved options through participatory research at community level in an integrated and multidisciplinary manner. The major themes and outputs of the Project are summarized as follows:

- 1) assessment of precipitation, surface water, groundwater and marginal water resources and the productivity, benefits and costs of their use in agriculture at different scales (plant, field, farm, watershed, and basin),
- 2) options for improved productivity (economic, social and environmental) of rain-water, irrigation and marginal-quality water in rainfed and irrigated systems through water harvesting, supplemental irrigation, agro management, and improved germplasm and cropping systems,
- 3) methods, options and strategies for drought characterization, preparedness and mitigation in the dry areas,
- 4) technical, institutional and policy options for improved water use and irrigation demand management, and
- 5) enhanced human capacity to improve water use in agriculture in dry areas.

## Achievements

- **Green (rain) and blue (fresh) water productivity was improved through supplemental irrigation:** The Project characterized physical, environmental and management factors that control the productivity and sustainability of rainfed production systems in the region, and introduced technical and socio-economic options to improved water productivity or water use efficiency. Research conducted in collaboration with NARS in Syria, Turkey, Iran, Morocco and Tunisia led to the development of supplemental irrigation options that increased wheat yields on farmers' field.
- **Water productivity was improved through deficit irrigation:** ICARDA's research demonstrated that deficit irrigation of winter and summer crops has a greater potential to improve water productivity and resource sustainability than full irrigation. ICARDA research showed that as the amount of irrigation water decreased below full crop water use, productivity per unit land decreased, however productivity per unit water increased. Thus, more food could be produced from the available water by irrigating new lands, allocating water to high value crops, or to supplemental irrigation of rainfed winter crops. Optimal strategies for practicing deficit irrigation under various conditions are being tested in collaboration with NARS at various benchmark sites in Iran, Egypt, and Morocco.
- **Rangelands productivity was improved and land degradation was reduced through water harvesting:** The Project researched options for promoting the capture, storage and the efficient utilization of the limited rainfall for agricultural production and environmental protection within the eco-regional initiative on 'On-farm

water Husbandry in WANA' in 8 countries. Indigenous water harvesting systems in the region were studied, packages for optimizing the use of water were developed with NARS and advanced institutions, and a methodology for proper selection of water harvesting sites and methods using GIS and remote sensing was developed. Awareness of the potential of water harvesting in improving agricultural production and combating desertification was enhanced and the use of the technology promoted.

- **On-farm water use efficiency in irrigated areas was improved:** A state-of-the-art document on techniques for improved water use efficiency was produced and published within the System Wide Initiative on Water Management (SWIM). Options for optimizing WUE in supplemental irrigation were also developed.
- **Increased awareness for the use of marginal-quality water resources:** Research was initiated on the use of saline water for supplemental irrigation in Syria, wastewater production and its agricultural use in Syria, the use of treated sewage effluent for restricted agriculture in Jordan, the use of agricultural drainage water in Egypt, and the use of marginal-quality waters and salt-affected soils for crop production systems in Central Asia and the Caucasus (CAC). ICARDA participated in the development of guidelines for the use of treated effluent in agriculture. In collaboration with CIHEAM and INRA, ICARDA characterized the tolerances of its cereal and legume crops to salinity. A joint appointment of ICARDA-IWMI Marginal Water Management Scientist has further strengthened work in this area.
- **Methodology for assessing water resources and productivity developed:** A low-cost method for assessing groundwater resources in dry areas, based on the chloride mass balance method, surveying and mapping of the groundwater flow system, and estimation of the irrigated area by satellite analysis was developed and applied in the 1550-km<sup>2</sup> Jabal Al-Hass-Aleppo basin in northern Syria. In addition, a framework for a more comprehensive assessment of water resources in marginal dryland areas (100-1000 km<sup>2</sup>) was developed in cooperation with NARS and ARI partners and applied to a dry valley in northern Syria. Water use options for the valley were discussed in a multi-stakeholder workshop and policy meeting.
- **GIS- and remote sensing-based methodologies developed to assess the potential for water harvesting and supplemental irrigation:** GIS and remote-sensing based methodologies to assess the potential for water harvesting and supplemental irrigation at the country level were developed and applied in cooperation with the GIS Unit (GISU) of ICARDA and Tunisian NARS. A GIS-based watershed model (Soil Water Assessment Tool) was modified to simulate crop and management practices that are typical for arid Mediterranean environments and was used to assess the effect of different water harvesting at the watershed level. A method to evaluate the structural functioning of three Tunisian water harvesting systems (*jessour*, *tabias*, check dams) was developed and tested in cooperation with Tunisian NARS and Purdue University.

- **GIS-based methodology developed to assess and map the suitability of different water harvesting practices:** A GIS-based method for assessing and mapping the suitability of different water-harvesting practices at the watershed-level was developed in cooperation with NARS partners in Jordan and used to select water-harvesting techniques in the badia watershed benchmark site in Jordan. A hydrological assessment methodology for the design of macro-catchments water harvesting systems in dry, data-scarce environments was also developed and applied for the Badia Benchmark watershed in Jordan.
- **Promoted partnerships for drought mitigation and contributed to global water issues:** A network for drought mitigation called NEMEDCA DroughtNet, covering Central Asia, West Asia, the Middle East and South Europe, was established in collaboration with FAO and CIHEAM. The Project collaborated with CIHEAM-Zaragoza to strengthen NARS capacity on drought mitigation under an EU-funded project (MEDROPLAN), and assisted in the implementation of the EU-INCO-DC project on the development of a decision support system for mitigation of drought impacts in the Mediterranean region.
- **Strengthened capacity of NARS:** Short-term (1-9 weeks) training courses and on-the-job training on water harvesting, watershed management, supplemental irrigation, water use efficiency and non-conventional water resources were organized. Training materials were developed for the courses and numerous graduate and intern students from WANA and Europe were trained.

## Current activities

The current activities are implemented under several special projects in partnership with NARS at benchmark sites that represent the major rain-fed and irrigated farming systems in the dry areas. The benchmark sites are complemented by smaller satellite sites established to tackle issues of particular interest relevant to low water productivity. Research results obtained at benchmarks are out-scaled to other areas of similar conditions. The majority of the water activities are multi-disciplinary and community-based with full participation of farmers, community leaders, local institutions and policy makers; only 10% of the activities are implemented on-station. Socioeconomics forms an integral part of each project in addition to technical components to ensure a problem-solving approach and a high adoption rate. Outline of the projects and activities are given below.

- Water Benchmarks of CWANA project “Community-Based Optimization of the Management of Scarce Water Resources in Agriculture in West Asia and North Africa”: This project is funded by the AFESD, IFAD and OPEC Fund for International Development and is implemented at three benchmark sites: a) rainfed benchmark in Morocco with satellite sites in Algeria, Tunisia and Syria for research

on improving the productivity of rain-water and limited supplemental irrigation water; b) irrigated benchmark site in Egypt with satellites in Sudan and Iraq for research on improving blue water productivity and sustainability, and c) badia or steppe benchmark in Jordan with satellite sites in Saudi Arabia and Libya to address rangeland improvement to reduce degradation of the environment and desertification in dry areas. The project aims at understanding constraints to adoption of improved water management by working with all stakeholders and to develop and test packages for sustainable and efficient use of water, higher productivity and improved livelihoods.

- **Improving On-farm Agricultural Water Productivity in the Karkheh River Basin (KRB):** This project is funded by the CGIAR Challenge Program on Water and Food. It aims at improving water productivity at farm and basin levels. Benchmark sites were selected in representative watersheds for rainfed and irrigated conditions. The work at the Karkheh basin is linked to two other basins - the Euphrates in West Asia and Amudarya in Central Asia. It addresses sustainable improvement of water productivity and looks into environmental consequences of interventions as well as policy and institutions.
- **Improving Rural Livelihoods through Efficient On-Farm Water and Soil Fertility Management in Central Asia:** This is an ADB-funded project aiming at dissemination of soil and water management options among farmers in Central Asian countries. Verification of water saving and marginal-quality water use technologies as well as socio-economic assessment of the developed technologies are also under investigation.
- **Communal Management and Optimization of Mechanized Microcatchment Water Harvesting for Combating Desertification in East Mediterranean (The Vallerani project):** Funded by SDC and implemented by NARS of Syria and Jordan, is a community-based project on using mechanized water harvesting system “Vallerani” in the marginal lands for improving rangeland productivity and reduce desertification. The project looks into options for communal management of the machinery to implement water harvesting at large scale in the steppe. Options are related to land tenure policies and other socioeconomic factors influencing communities’ attitude towards utilizing public and private lands.
- **Assessment of Water Harvesting and Supplemental Irrigation Potential in Arid and Semi-Arid Areas of West Asia and North Africa:** Funded by the CGIAR System-wide Initiative on Water Management led by IWMI, this project aims at developing methodologies for assessing the potential and the consequences of implementing water harvesting and supplemental irrigation at the pilot site and country level with out-scaling to the WANA region. It is implemented in Tunisia, Syria and Turkey; and modeling, GIS and remote sensing are used for out-scaling purposes.

- **Bright Spots for Salinity Management in Central Asia:** Funded by ADB (in partnership with IWMI and ICBA), the project is implemented in three CA countries and attempts to identify 'Bright Spots' of salinity management as well as on-farm studies addressing sustainable management of salt-prone land and water resources. The project aims at out-scaling the promising technologies to similar environments in CA. The partnership with IWMI and ICBA adds to the strength of the project and links on-farm work to watershed and basin scales.
- **Field Crops Response to Salinity and Drought Stresses (with CIHEAM, Bari & INRA, France):** The first phase of the project was concluded in 2005 and studied the tolerance of ICARDA cereal and legume crops varieties to different levels of salinity. The second phase started in late 2005 to study the combined response of ICARDA mandate crops to both salinity and water stresses. Collaboration with CIHEAM-Bari allows involvement of their students in the project and INRA-France and other European institutions participate in the project.
- **Improving Water Productivity of Cereal, Legume and Alternative Crops (Cotton and Maize):** This project is implemented at ICARDA research station and studies water productivity of crops which are not in the traditional crop improvement mandate of ICARDA but are part of the systems in which the mandated crops are used. The project should provide information to develop efficient options for crop selection and water allocation to supplemental irrigation of winter and full/deficit irrigation of summer crops. It also provides data for the modeling and economical analysis of various allocation alternatives.
- **Crop Water Stress Indices:** This project is funded by the core with pending grant proposals to advance ICARDA's research program in soil-crop water relations, particularly crop water stress quantification and management. Crop measurements, including porometry, leaf water potential, and infrared thermometry are being used to quantify the state of crop water stress and develop stress indices for the strategic crops of wheat and legumes and alternate summer crops. This research should have utility in advancing ICARDA's programs in drought tolerance breeding, drought mitigation, and optimization of production with limited water resources.
- **Pilot Project for Combating Desertification in West Asia (SRAP-WA):** This project is implemented with ACSAD in Syria, Jordan, Yemen and Lebanon and financed by OPEC Fund and Global Mechanism of the UNCCD. Improved technologies for mountainous and degraded rangelands have been developed and implemented in cooperation with communities. This is a model to involve local communities in combating desertification with focus on using limited water resources in water harvesting and supplemental irrigation.

The above activities are implemented in partnership with NARS and with linkages to other MegaProjects and ICARDA Units and external research institutes, as given below:

**MPs:** MP2 - Drought work and water use efficiency work; MP3 - Participatory, community analysis and INRM approach to improving adoption of proven technologies in Karkheh CPWF, Water Benchmark, and SRAP WA projects; MP4 - Agronomic work in Karkheh, Water Benchmark, Alternative crops, Comprehensive assessment projects; MP5 - Policies, institutional and economic aspects of Water Benchmark project and Karkheh CPWF project and Vallerani project; MP6 - Dissemination and packaging of produced options for the Water Benchmark, Karkheh and Vallerani projects.

**Units:** GISU - Comprehensive assessment and Karkheh CP; CBSU - Water benchmarks, Karkheh CPWF and alternative crops; CODIS - Publications.

**External:** IWMI - on Karkheh CPWF, CA bright spots, Comprehensive assessment, and marginal quality water (joint appointment); IRRI - on rice-wheat in CA, CPWF at Karkheh and the CA; ICBA - Salinity bright spots in CA, Inventory of low quality water and capacity building in CA and Afghanistan; FAO - Drought network, capacity building, CA and water productivity; CIHEAM - Drought, response to salinity and drought, and capacity building; UC Davis - Karkheh basin project and the CA; INRA France - response to salinity and drought and alternative crops; CPWF - Karkheh and Nile basin; USDA/ARS - Tunisia GIS project; Utah State University - New capacity building initiative; SEI - CA (Stockholm Environment Institute Comprehensive Assessment) and capacity building.

## Future Plans

- Further assessment of precipitation, surface water, groundwater and marginal water resources and the productivity, benefits, and costs of their use in agriculture at different scales (plant, field, farm, watershed, and basin).
- Options for improved productivity (economic, social and environmental) of rainwater, irrigation and marginal-quality water in rainfed and irrigated systems through water harvesting, supplemental and deficit irrigation, agro management, and improved germplasm and cropping systems.
- Development of methods, options and strategies for drought characterization, preparedness, and mitigation in the dry areas.
- Exploring technical, institutional and policy options for improved water use and irrigation demand management.
- Improvement of human capacity to enhance water use in agriculture in dry areas through partnerships with NARS and advanced research institutes, and linkages with other ICARDA MegaProjects and regional and international research and development institutions.
- Development of an inventory on the production and use of marginal-quality waters in CWANA –extent of use in agriculture in terms of volume and area under irrigation; and quality evaluation against commonly used standards.
- Improvement of the long-term sustainable and economic use of groundwater

resources, with increased attention to local options for artificial recharge and water level response management, and national-level policy and regulatory frameworks that address the comprehensive management of this complex and dynamic resource.

- Development of crop, irrigation, and soil management strategies of using marginal-quality waters and salt-affected soils for sustainable crop production systems that maximize farm profit and minimize adverse health and environmental impacts.
- Development of policy interventions to capture opportunities for risk management associated with the use of marginal-quality water resources.
- Development of simple tools and methods such as the use of infrared thermometry to develop and quantify crop water stress, its impact on final yield, and the advancement of the concept of stress management in crop production in dry areas in close cooperation with crop physiologists and plant breeders in MP2, MP4 and advanced NARS.
- Strengthen the team capacity on drought and risk management and develop a proposal on drought mitigation by hiring a new scientist. The Drought Net will be strengthened in collaboration with FAO and CIHEAM and a framework for drought mitigation integrating technical, socio-economic and policy issues developed.
- Development of a framework for water and land policy options and their implementation in consultation with policy makers. A policy forum will be organized with emphasis on the role of Water Use Authority in irrigation water management.